M.O. 393 **FOR OFFICIAL USE ONLY**

AIR MINISTRY

METEOROLOGICAL OFFICE

REPORT OF THE CONFERENCE OF EMPIRE METEOROLOGISTS

LONDON

August 12—21, 1935

Published by the Authority of the Meteorological Committee

LONDON:
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
1936

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Frontispiece.

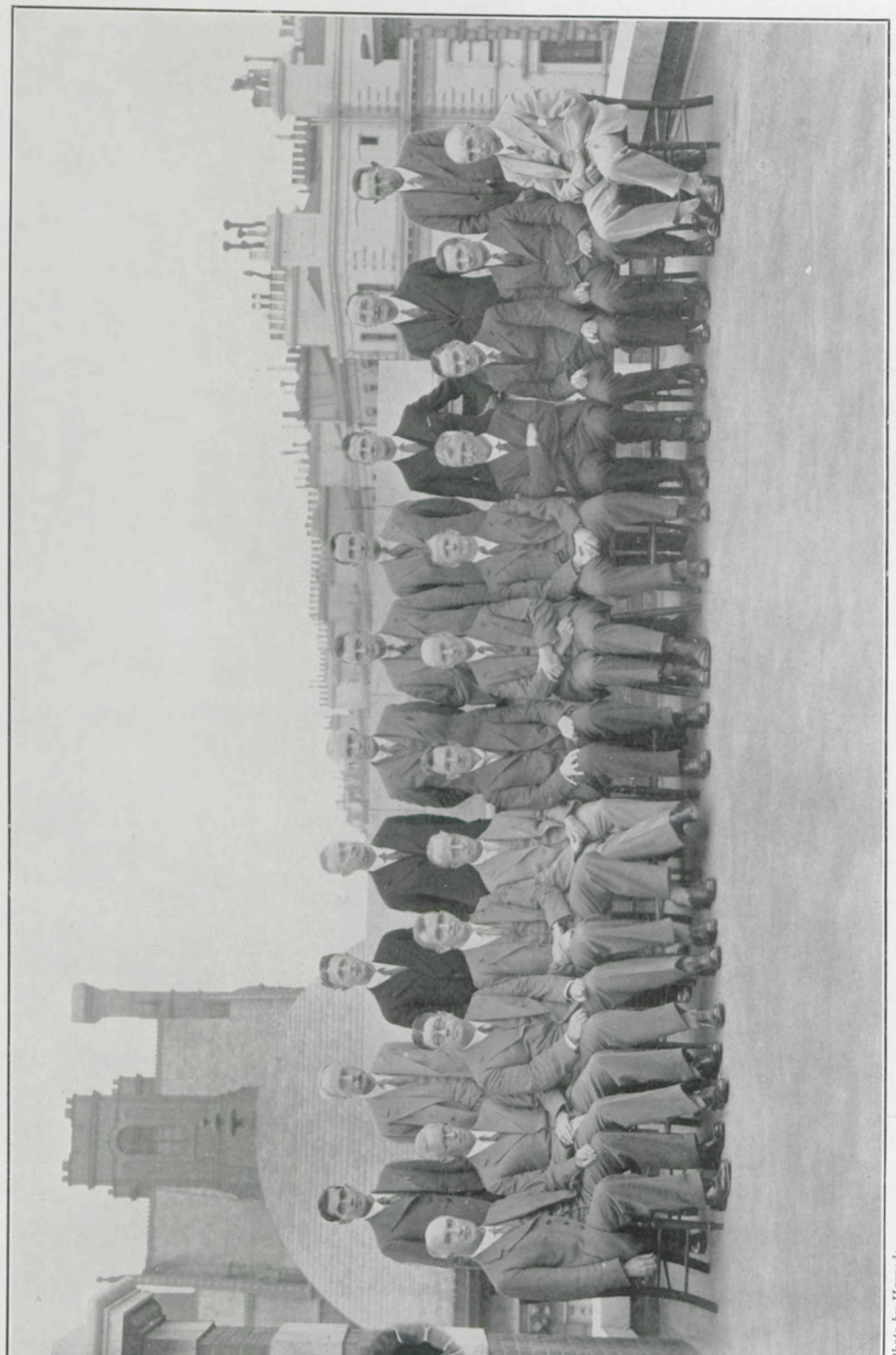

Photo by Harrods.

The photograph reproduced above, in which the majority of the members of the Conference appear, was taken at the Meteorological Office, South Kensington, after the Friday morning meeting. The names reading from left to right, are:—Seated: Dr. F. J. W. Whipple, Great Britain; Mr. N. R. McCurdy, Mauritius; Mr. C. W. Jeffries, Hong Kong; Dr. T. Schumann, South Africa; Dr. E. Kidson, New Zealand; Sir George Simpson, Great Britain; Mr. J. Patterson, Canada; Dr. C. W. B. Normand, India; Mr. W. S. Watt, Australia; Mr. C. D. Stewart, Malaya; Mr. A. Walter, East Africa; Mr. G. K. Thornhill, Ceylon. Standing: Mr. R. D. Kreltszheim, Ceylon; Mr. R. G. K. Lempfert, Great Britain; Cmdr. G.S. Ridgway, R. N. (retd.), Bermuda; Mr. G. W. Grabham, A.E. Sudan; Mr. D. W. Gumbley, Palestine; Capt. A. Bertram Smith, R.N.R., Trinidad; Mr. J. H. Churchill, Nigeria; Lt.-Cmdr. S. H. Butler, R.N.R., Nigeria; Mr. L. J. Sutton, Egypt; Lt.-Col. E. Gold, Great Britain.

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LIST OF DELEGATES

A. E. Sudan (unofficial observer).	Mr. G. W. Grabham	Geological Adviser to the Sudan Government.
Australia	Mr. W. S. Watt	Commonwealth Meteorologist.
Bermuda	Cmdr. G. S. Ridgway, R.N. (retd.)	Member of the Board of Trade.
Canada	Mr. J. Patterson	Director, Canadian Meteorological Service.
Ceylon	Mr. G. K. Thornhill	Surveyor General.
	Mr. R. D. Kreltszheim ..	Junior Technical Assistant, Colombo Observatory.
Cyprus	Mr. D. L. Blunt..	Director of Agriculture.
East African Group (Kenya, Northern Rhodesia, Tanganyika, Uganda, Zanzibar).	Mr. A. Walter	Director, British East African Meteorological Service.
Egypt (unofficial observers)	Dr. L. Balls	Chief Specialist to Cotton Research Council.
	Mr. L. J. Sutton	Director, Meteorological Service, Physical Department.
Gambia	Mr. F. W. Hall	Senior Agricultural Superintendent.
Gold Coast	Mr. W. H. Beckett	Superintendent of Agriculture.
Great Britain	Sir George Simpson	Director, Meteorological Office.
Hong Kong	Mr. C. W. Jeffries	Director, Royal Observatory.
India	Dr. C. W. B. Normand	Director-General of Observatories.
Malaya	Mr. C. D. Stewart	Superintendent, Meteorological Service.
Mauritius	Mr. N. R. McCurdy	Director, Royal Alfred Observatory.
New Zealand	Dr. E. Kidson	Director, Dominion Meteorological Service.
Nigeria	Mr. J. H. Churchill	Surveyor.
	Lt. Cmdr. S. H. Butler, R.N.R.	Marine Department.
Palestine	Mr. D. W. Gumbley	Director of Civil Aviation.
Seychelles	Mr. F. L. Squibbs	Director of Agriculture.
South Africa	Dr. T. Schumann	Chief Meteorologist.
Southern Rhodesia ..	Mr. N. P. Sellick	Government Meteorologist.
Tanganyika	Mr. P. E. L. Gethin	Director of Civil Aviation.
Trinidad	Capt. A. Bertram Smith, R.N.R.	Harbour Master.
Uganda	Mr. G. W. Nye	Senior Botanist.
Zanzibar (in unofficial capacity).	Capt. C. J. Charlewood ..	Port Officer.

PROGRAMME

The meetings were held at the Meteorological Office, Exhibition Road, South Kensington.

MONDAY, AUGUST 12

Opening Meeting

11 a.m.—Reception of delegates by Col. SIR HENRY LYONS, Vice-Chairman of the Meteorological Committee.
Election of President.
Presidential Address.
Arrangement of Programme.

8.30 p.m.—Reception by SIR GEORGE and LADY SIMPSON at the Meteorological Office, South Kensington.

TUESDAY, AUGUST 13

Aviation Meteorology

11 a.m.—Meteorological organization along Empire Air Routes.

3 p.m.—Preparation of upper wind and visibility data for aviation purposes.
Ice-accretion on aircraft.
Meteorological aid required for blind-flying.
Standard of knowledge in meteorology required for candidates for " B " flying licences.

WEDNESDAY, AUGUST 14

Synoptic Meteorology

11 a.m.—Methods of forecasting from synoptic charts.
Methods of plotting data on synoptic charts.

3 p.m.—Methods of plotting data (*continued*).
Scales, projections, relief, etc., shown on synoptic charts.
Collection of information ; International code 1929.

THURSDAY, AUGUST 15

Synoptic Meteorology (continued) and General

11 a.m.—Value for forecasting of observations from ships and of upper air data.
Organization of synoptic messages in south-east Asia.
Dissemination of information to the public, seamen, airmen, farmers, etc.
The use made of the collective message issued from Rugby.
Inter-Empire organization : Exchange and facilities for training of meteorologists within the Empire.

General

3 p.m.—Meteorology and military operations.
Meteorology for the Navy.
Instruments—
Barometers suitable for use in tropical highlands.
Standardization of meteorological instruments.

FRIDAY, AUGUST 16

General and Marine Meteorology

11 a.m.—Instruments (*continued*).
Methods of generating hydrogen.
Method of making pilot-balloon observations including methods of computation.
Marine meteorology. The working of the scheme for wireless reports from ships.

Marine Sub-Committee

3 p.m.—The working of the scheme for wireless reports from ships (*continued*).
Synoptic meteorological code for ships.
Preparation of ocean charts : work by London Meteorological Office.
Exchange of data between London and the Dominions.
Collection of rainfall data at sea.
Storm-signals.

8 p.m.—Government dinner at Lancaster House, St. James's.

SATURDAY, AUGUST 17

General

11 a.m.—Reports of Sub-Committees.
Meteorological organization for aviation along the Persian Gulf.
Meteorological organization required for the Khartoum–West Africa Air Service.
Symbols for plotting data on synoptic charts. (First meeting).
Meteorology in Africa.
Classification of meteorological literature.
Organized research in meteorology.
The responsibility of meteorological services for geophysics.
The proposed establishment of stations at Tristan da Cunha and Chesterfield Inlet.

3.30 p.m.—Garden Party at Kew Observatory, Old Deer Park, Richmond, Surrey.

PROGRAMME—*continued*

MONDAY, AUGUST 19

Climatology and Agriculture

11 a.m.—Micro-climatology: the measurement of soil-temperature and soil moisture.
Uniformity in climatological observations.
The form of publication for climatological observations.

3 p.m.—Time-units for climatological purposes.
The form to be used for expressing the water-vapour content of the atmosphere.
Soil-temperatures. The depth at which observations should be taken and the hours of observation.

TUESDAY, AUGUST 20

Climatology and Agriculture (continued)

11 a.m.—Air masses as units in climatology.
Broadcast of climatological data.
Computation of meteorological averages.

3 p.m.—Correlation of general crop-observations with meteorological data.
Seasonal forecasting.

WEDNESDAY, AUGUST 21

Climatology and Agriculture (continued) and General

11 a.m.—Measurements of evaporation with special reference to (*a*) water-supply and (*b*) agriculture.
Construction of rainfall maps.
Methods of measuring snowfall.
Methods of obtaining measurements of sunshine in high latitudes with the Campbell-Stokes sunshine recorder.
Representation of Empire meteorologists at International Conferences.

General

3 p.m.—Proposal of the Italian Air Ministry with regard to amendment of the Statutes of the International Meteorological Organization.
The responsibility of meteorological services for the study of micro-climatology.
Reports of Sub-Committees.
Minutes.
Votes of thanks.

SUB-COMMITTEES

Note.—The meeting of the Marine Sub-Committee at 3 p.m. on Friday, August 16, is included in the programme of the main Conference.

Wednesday, August 14

9.30 a.m.—Meteorological organization required for the Khartoum–West Africa Air Service.

Thursday, August 15

10 a.m.—Meteorological organization for aviation along the Persian Gulf.

Friday, August 16 and Saturday, August 17

10 a.m.—Symbols and codes for synoptic meteorology.

Monday, August 19

2 p.m.—Organization of meteorology in Africa.

Tuesday, August 20

Synoptic issues in the Far East.

10 a.m.—War organization of Fleet meteorology.

5 p.m.—Meteorological arrangements for experimental flights by Imperial Airways, Ltd., between Penang and Hong Kong.

REPORT OF THE MEETINGS OF THE CONFERENCE

MINUTES No. 1.

Opening Meeting, Monday, August 12, 1935, 11 a.m.

The meeting was held at the Meteorological Office, South Kensington.

The following delegates were present:—Mr. W. H. Beckett (Gold Coast), Lt.-Cmdr. S. H. Butler, R.N.R. (Nigeria), Capt. C. J. Charlewood (Zanzibar), Mr. J. H. Churchill (Nigeria), Mr. P. E. L. Gethin (Tanganyika), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. F. W. Hall (Gambia), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Mr. G. W. Nye (Uganda), Mr. J. Patterson (Canada), Cmdr. G. S. Ridgway, R.N. retd. (Bermuda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Capt. A. Bertram Smith, R.N.R. (Trinidad), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present:—Prof. D. Brunt and the following members of the staff of the Meteorological Office:—Mr. R. G. K. Lempfert (Assistant Director), Mr. E. G. Bilham (British Climatology), Capt. L. A. Brooke-Smith, R.N.R. retd. (Marine Meteorology), Dr. C. E. P. Brooks (General Climatology), Mr. R. Corless (Forecast and Aviation Services), Mr. J. S. Dines (Instruments), Mr. F. Entwistle (Empire Air Routes), Cmdr. L. G. Garbett, R.N. retd. (Navy Services).

Copies of the agenda, the list of delegates, memoranda (with three exceptions) and list of memoranda, were circulated.

1. Address by Col. Sir Henry Lyons.—COL. SIR HENRY LYONS, Vice-chairman of the Meteorological Committee, welcomed the delegates on behalf of the Secretary of State for Air.

I am desired by the Secretary of State for Air to express to you his deep regret that he is unavoidably prevented from being here this morning to offer a hearty welcome on behalf of His Majesty's Government to the delegates who are attending this Conference. It has devolved upon me to take his place, and I therefore offer to you the welcome that he would have offered on behalf of His Majesty's Government, and I hope that you will have not only a successful but an extremely pleasant time at your Conference.

I feel it a great honour to be asked to do this thing because it is really a Conference of exceptional importance, and, moreover, it is very pleasant to meet more than I expected of those whom I have met before and with whom I have worked in earlier times.

This, the third Conference, has followed two earlier ones: one in 1919 and the other in 1929, both of which, I think, were held in these rooms.

Twenty years ago the Meteorological Office was feverishly organising, developing and getting together what was needed by the Fighting Services at the beginning of the war. At that time new problems were coming up for the meteorologist every day, first for the Royal Flying Corps and then for Gas Warfare. The meteorologist found himself facing problems many of which were more or less new to him; the Fighting Services had different wants which they could not yet formulate, and were asking questions of which they had no idea of the answers nor indeed whether they were answerable at all. A great deal has happened since then. The meteorologist has gone a long way. The Fighting Services have for some time known that a competent meteorologist is absolutely essential as an adviser, and now it seems to me that the difficulty is that they are demanding more and more day by day, and demanding almost more than the most competent meteorological service can supply. There is no doubt that the great importance of meteorology as a science, and as an applied science has now been fully realised. This is shown by the steady increase in the importance of such conferences as this. I believe we have here to-day some 25 countries represented by about 30 delegates, and to them all, this Conference will be looking for advice and for the results of their experience drawn from almost every quarter of the globe.

Meteorology, like most of the geophysical sciences, is world-wide in its sources of information and has to be world-wide in its investigations. At such a conference as this not only is there a pooling of information and experience from all quarters, but there is the invaluable opportunity of personal contact between workers in various fields in the various parts of the Empire, which not only makes for a readier solution of problems but also greatly facilitates communication in the intervals between the conferences.

This Conference, it seems to me, is going to be more than merely a dress rehearsal for the International Conference at Warsaw, because so wide an area and so many different conditions are represented by the delegates here that it will be almost an international conference in itself in the width of its outlook and in the varied character of the material that you are able to bring together. But I am sure, and I know Sir George Simpson has many times emphasised this, that there is no idea of there being a British *bloc* which enforces its views on the international gathering at Warsaw. It is merely that the advantage of a widespread Empire enables our delegates here to bring together so varied a fund of information that many of the problems that must inevitably be examined at the international gathering will, in fact, have been gone over and considered by the delegates of this Conference; and in many cases that should make for a readier solution and increase the thoroughness of the study that can be given to them.

Of course, when we look at these very voluminous sheets of agenda, which are to be your task for the next week, aviation naturally takes a big share, and that is reasonable and inevitable. The increasing activities of aviation both military and civil must, of course, throw an increasing burden and greater responsibilities on the meteorologist and on the meteorological services to which you belong; the variety of the problems that arise, the importance of the issues and the serious results of failure, must make this a very responsible and a very important portion of the work of meteorological services. The Services also, I believe, as they appreciate more what meteorology can do, are increasing their demands, and the special problems which they present are by no means any simpler than they used to be. With the air becoming the third arm in the military services and also an important factor in world transport, there is no likelihood that there will be any lack of questions for the meteorologist to solve in the near, or even in the more remote, future.

But this, as your agenda indicate, is by no means the only field you are called upon to study. The sea, which gives you a certain amount of information, is also asking for more and more in return. Agriculture, public health and industry—all these are insistently demanding more attention. And not a few demand prompt answers to questions which inevitably require a long series of past observations which do not exist; but the meteorologist is expected to produce them whether he can or whether he cannot. In this country, the shortage of rainfall during the last two years has brought that side of the question very prominently to the public notice; but that a series of observations relating to the water resources of this country should have been provided seems to have entirely escaped public notice.

I am sure that you will agree with me that it is the scientific basis of meteorology which is all-important for the advance of meteorological science. In each service there is no doubt, or should not be, that some of its members should have had a sound training in physics and mathematics sufficient to enable them to push forward the progress of meteorology on a scientific basis and to contribute to the setting out of those new principles and new generalisations on which the advance of the applied science wholly depends. The well-known instance of a country that during the late war was cut off from its supply of daily observations and turned to an intensive study of its own conditions, and out of that produced much that was really valuable to meteorologists, is an encouraging example.

Turning to the literature of the subject: it is voluminous, but it is not getting any easier. It is very technical and also in part highly mathematical, but that is unavoidable and there will have to be a certain number of those who can devote themselves to the consideration, the criticism and the study of the latest pronouncements in meteorological science and if need be make the results available for practical application.

Here, as well as at the International Conference at Warsaw, you are largely limited to the practical applications of meteorological science mainly, I expect, because the amount of material which must be discussed does not leave a great deal of time for the discussion of purely scientific aspects of the matter. The more scientific problems may on these occasions have to give way and be dealt with at other opportunities.

At this point may I direct your attention to another international organization which enters the field of meteorology from a slightly different angle. At the beginning of this century there was an international association of the scientific and literary academies of most nations which acted very efficiently in initiating international scientific work until the war came, and then it ceased to exist. Towards the end of the war several of the neutral nations realised that the lack of such an organization was seriously hindering science, and there was a movement to restart it. At the end of 1918 the Royal Society called a meeting of such academies as could be approached at that time, that is of the allied nations, and out of that meeting grew the International Research Council in 1919. From then onwards the Council and the unions related to it, notably the Astronomical Union, the Geophysical Union and the Union of Scientific Radio, which were established either then or in 1922 and are of a world-wide type, have taken a leading part in the promotion of international science in their own spheres. The Union of Geodesy and Geophysics is the best known to meteorologists. It is concerned with terrestrial magnetism, meteorology, and physical oceanography, and so touches upon the same field as the International Meteorological Committee and its conferences. The question soon came up as to their respective fields of activity, and questions relating to the meteorological services and to the practical application of meteorological science were held to fall entirely within the scope of the Meteorological Committee and its conferences, while the more purely scientific investigations in the meteorological field were rather a part of the section of the Union which is now called the Association of Meteorology. It has been well understood throughout that there is no hard and fast line between the subjects dealt with by the two organizations, and on the whole I think that this arrangement has worked well.

One point in which the Association of Meteorology is at a disadvantage is that it does not at the present time include all nations in its membership. There is nothing to prevent any nation from joining but all have not yet joined.

The report of the meeting of the International Council of Scientific Unions in July last contains a report on the recent activities of the Meteorological Association under the presidency of the late

Dr. Wallén of Stockholm. From that report it will be seen that the Meteorological Association has done a great deal of useful work without trenching on the fields of the International Committee and its conferences.

The Union of Geodesy and Geophysics is holding its meeting next summer in this country in Edinburgh, and though it is primarily attended by delegates of the countries belonging to the Union, there are always a considerable number of visitors, and I am sure that, if any man of science from any part of the Empire overseas wished to attend, it would be easy to arrange that he should be invited to do so.

I am sure that there is room in meteorological science for the work of both organizations.

It only remains now for me to offer you a hearty welcome to the third Conference, and to leave you to the discussion of your lengthy agenda, confident that your deliberations must have most valuable results. Before sitting down I would like to congratulate Sir George Simpson on the attendance that there is here to-day, and on the fact that so large a number of meteorologists of the Empire have found it possible to meet at this third Conference in London.

2. Election of President of the Conference.—Sir George Simpson proposed that Mr. Patterson, Director of the Meteorological Service of Canada, be elected President of the Conference; the proposal was seconded by Dr. C. W. B. Normand and unanimously approved. Mr. Patterson then took the chair.

3. President's Address :—

Sir Henry Lyons and Members of the Conference, I wish to thank you for the very high honour that you have conferred upon me by electing me President.

On behalf of the Conference I desire to extend to you, Sir Henry, our very warmest thanks for the most cordial welcome that you have extended to the delegates from overseas. May I assure you that we are always glad to get back to the heart of the Empire. At the same time we wish to thank you for the hospitality that has always been shown to us and for the arrangements that have been made for this meeting.

Many members of the Conference know that Sir Henry Lyons, as Director of the Survey in Egypt, found time to investigate very thoroughly the physiography of the Nile Basin and collected all available data on the Nile floods. During the war he was Commandant of the Meteorological Services in the European area and for a time Director of the London Meteorological Office while Sir Napier Shaw was on special duty. He then became Director of the Science Museum in South Kensington, and its present commanding position is due to his organizing and creative ability. In the midst of all his many duties he has always taken an active interest in meteorology and has been the representative of the Royal Society on the Meteorological Committee and is its vice-chairman. He also spent very much time on the publication of the observations of Scott's last Antarctic Expedition, and has followed very carefully meteorological progress; we owe very much to the encouragement that he has given us.

We are very grateful to His Majesty's Government for having delegated Sir Henry to open this Conference, and I wish to congratulate him most heartily on the very able review that he has given of our problem. We hope that he may long be vice-chairman of the Meteorological Committee.

It gives me very great pleasure on behalf of the Conference to extend to the Director of the London Meteorological Office our most sincere congratulations on the very great honour conferred upon him by His Majesty the King. It is a very fitting recognition of the valuable service that he has rendered to meteorology and I know that all members of the Conference join in best wishes and congratulations to Sir George.

This is the third Conference, as Sir Henry has said, and although the first Conference in 1919 was comparatively small, it formed the basis for the convening of the larger Conference six years ago; time, however, has wrought many changes, and of the 25 members who were present six years ago, only six are here to-day—Sir George Simpson (Great Britain), Dr. Normand (India), Mr. Walter (East Africa), Mr. Sutton (Egypt), Capt. Bertram Smith (Trinidad), and myself from Canada. We welcome to this Conference for the first time, Mr. Watt, Dr. Kidson, Dr. Schumann, Mr. Jeffries, Mr. Stewart, and Mr. Sellick. In addition we have representatives of various parts of the Empire where there is no organized meteorological service, but who carry on the meteorological work of their country in addition to their other duties. To all, we extend a most cordial welcome, and invite you to take your full share in the deliberations of this Conference.

At the last Conference we were very greatly assisted by members of the London Meteorological Office. They contributed very materially to its success, and we are very pleased to welcome most of them to this Conference, knowing that we will receive the same help from them as we did at the last. We are very pleased to have Miss Austin, who acted so efficiently as Secretary of the last Conference, with us again, and Miss Chambers and her staff who were responsible for the many details of the Conference, preparing the reports, etc., thus expediting its work. We do not always realize how much work the Conference entails on them, not only during the sessions but between sessions in preparation for the next. Their presence is an assurance that their part of the work will be well done.

Since the last Conference there have been four new services organized within the Empire: East Africa, Southern Rhodesia, Malaya, and Bermuda. Messrs. Walter, Sellick, and Stewart, the Directors of the first three services are with us, and it is a source of great gratification to the Empire that they have with their limited means and under great difficulties built up exceptionally fine meteorological services.

In order that we may get the proper background for the Conference, I propose to review briefly the work done at the last Conference, the accomplishments in the interval, and the problems that we have now to consider. In this connexion it may be said that when the Conference ended six years ago it is most probable that no one realized that the world had come to the end of a prosperous era and was to be plunged into the most severe economic depression that has occurred in recent times, so that whatever the Meteorological Services have been able to do in the various countries has been done under great economic and financial handicaps.

One of the most important problems considered at the last Conference was in connexion with marine meteorology. It had so overgrown the organization then existing that something else had to be devised to take its place if it was to survive. All nations were demanding more and more ship observations in their own form and at hours most suitable for them, with the result that the additional work imposed on the officers of the Mercantile Marine made it practically impossible to perform it without neglecting their own duties. The multiplicity of messages was also becoming a very severe strain on the Wireless Companies; consequently the Conference had to face the situation and see what could be done to put it on a proper basis. Two problems were involved, an international organization for marine meteorology and an international code. These subjects were very carefully considered at the Conference with representatives of the London office. The British proposed that there should be a list of selected ships sufficient to meet meteorological requirements, and an international code. Both these proposals were adopted with only minor changes at the International Conference at Copenhagen. It is very gratifying to report that these have been put into operation and are proving on the whole most satisfactory, but there are naturally some difficulties connected therewith and these will be discussed at our Conference.

Closely associated with the Mercantile Marine is the Navy. Naturally, with the development of aviation the Navy requires very much more information than was necessary hitherto. Cmdr. Garbett gave us an illuminating account of this work and of the proposed organization. Conferences were held in Malta with the Commander-in-Chief of that station in 1928; in the East Indies and the China Station in 1929 and 1930; at the end of 1930 in Bermuda, for the West Indies and Canada, and in 1932 in South Africa. As a result of this work there is now a Fleet synoptic message uniform at all stations, and each region has a very complete meteorological organization. I may say that one of the results of his visit to Bermuda was the establishment by the Government of Bermuda of a meteorological service of its own, in place of the part time station that has been maintained by the Canadian office. It is much to be regretted that Cmdr. Moorhead, the first Director of the Service, could not be present at this Conference. I can assure you that he is doing excellent work.

Synoptic meteorology was also faced with the problem of obtaining a suitable code for land stations as well as for the ships. Hitherto this affected Europe more than other countries, but with the developments taking place in the air every country was confronted with this same problem. It was considered carefully in 1929 and the basis for an international land code was laid down. This, I may say, was finally adopted in a modified form at the Conference at Copenhagen; and in this connexion I should like to refer to the work of the President of the Synoptic Commission, Col. Gold, who had the formidable task of getting many nations with different codes to agree on a single code. I was present at the discussions, and time and again when agreement seemed almost hopeless, Col. Gold saved the situation and at last succeeded in getting a code acceptable to all. That was a very great achievement and I understand it has been just as great a success.

Charts had also to be considered for they are closely associated with synoptic meteorology. When nations were more or less independent of each other meteorologically it did not matter very much what kind of charts were used, but with the developments in aviation it is most desirable that there should be uniformity. They should be constructed to the same scales and projections and kept uniform as nearly as possible. They were discussed at length last time, and we await with much interest the report of the services which have introduced new charts.

One problem leads to another, and having obtained a code there has arisen the question of symbols. How are you going to represent the different meteorological elements on the weather charts? Each country has its own method but it is again very desirable that the same symbols should be used in all countries, especially throughout the Empire. It is all the more necessary that careful consideration should be given to this question because it is to be one of the very important subjects for discussion at the international Conference to be held at Warsaw.

As a result of the last international Conference four major broadcasts of synoptic data in the European area were recommended. We are especially interested in the world broadcast by Great Britain from Rugby giving data over Europe, Siberia and in the eastern part of the Atlantic. How far has that broadcast been successful? How far is it meeting the situation? We will have reports from the various countries that are especially interested in it.

Synoptic weather information, charts and symbols, are preliminary and necessary for one of the main functions of the Meteorological Service, namely, forecasting. At the time of the last Conference, the Norwegian methods had not been or were just being introduced into Empire services. In the interval there has been a very intensive study of them, and the session which is to be directed to the discussion of this subject should be of absorbing interest.

One of the most important subjects considered at the last Conference was aviation meteorology, and it is again probably the most important, not so much from the internal organization for each country, but from the Empire standpoint, because after all it is this aspect which unites all the Services. At the last Conference the minds of navigators were strongly turned to navigation by airships, and naturally airship meteorology played a very great part in our deliberations. However, owing to the tragedy of the R101, it is unnecessary to dwell on this aspect of the subject, except to say that in Mr. Giblett, who in the performance of his duties went down with the airship, meteorology has lost an able investigator and organizer. His work at Cardington on wind structure of the atmosphere and his organization of the Empire air routes will ever remain a monument to his ability as an investigator and organizer. Owing to this disaster, interest has turned from the airship to the aeroplane. It is never wise to limit the possibilities of new discoveries, and very few if any realized in those days that the aeroplane could undergo such tremendous development as has occurred in the last six years. At this Conference the important problem is the organization of air routes from the Empire standpoint

for aeroplanes. The importance is so great that Mr. Self of the Air Ministry will be here to-morrow morning to give a full account to the Conference of the problem as they see it, after which we will discuss and consider the meteorological problems associated therewith. In addition there are many very difficult problems calling for consideration, of which two only need be mentioned, blind flying and ice-accretion on aeroplanes. Both create great risks to aeroplanes and we will have to review the situation and see what steps it may be possible to take to give the necessary meteorological information connected with them, and any suggestions from members of the Conference will be welcome.

Another division of our programme has to deal with agriculture and climatology. At the last Conference there were meetings for two days with representatives of the agricultural interests, with papers on climate and agriculture. This time there is only to be one paper on the correlation of agriculture and climatology. We feel we are here to discuss ways and means to harmonize methods and procedures and organize the work rather than listen to papers on particular subjects (information the members may desire can be obtained by personal discussion rather than in conference). There are several very important problems about which agreement should be obtained if possible. One is the broadcast of climatological information at the close of each month; as this is a subject for discussion at Warsaw all information that can be obtained will be most helpful. Another important question that has to be decided at Warsaw is time units. It is much to be desired that a decision for a system of practical time units should be obtained.

Seasonal forecasting is now demanding serious consideration. Owing to the conditions experienced in Canada for the last four years the demand for seasonal forecasting has become an important question, and the public are wanting to know why we cannot issue forecasts as other persons very frequently do. A discussion of this problem will be very timely. It is most difficult but at the same time we must face it and consider the best means by which it may be attained. We have a very excellent memorandum on the subject by Dr. Brooks, and a report or statement from the Conference as to what it is possible to do will be very timely.

The rapidly increasing demands on meteorology make it very important that the training of the meteorologist should be considered, and owing to the Empire and international aspect of the subject the possibility of arranging for an exchange of technical officers for a year or so was raised at the last Conference and is again to the fore. There is no doubt but that it would be of great advantage to each service if a member of its staff were thoroughly familiar with the working of other Empire services. It would be a most valuable contribution if we could succeed in formulating some plans in that respect.

The classification of meteorological literature was briefly discussed in 1929 and a committee has been working on it in the interval. The literature has now become so voluminous that a proper system of classification is necessary. A report of the work of the sub-committee will be submitted for our consideration.

Another subject not coming up at this Conference but which I should like to mention is the International Polar Year 1932–3. In 1929 at Copenhagen, it was decided to organize what is now known as the Second International Polar Year for 1932–3. In spite of all the financial difficulties and the economic crisis at that time, that year was carried to a successful conclusion in August, 1933. The British Empire had a very important part in the undertaking, and we may congratulate ourselves on the results achieved. It is hoped that one of the many results will be the establishment of a permanent magnetic and geophysical observatory at Chesterfield Inlet. This station is unique in that it is close to the magnetic pole and within the zone of maximum auroral activity. When fully established it will be possible to undertake magnetic and geophysical investigations that can only be made at a station so uniquely situated.

This brief review indicates that the work of the last Conference and the projects initiated at that Conference have been remarkably successful so that with this as a background we may go forward to the work of this Conference confident of success.

4. **Arrangement of Programme.**—The President called on Sir George Simpson to put forward his proposals for the agenda.

Sir George Simpson thanked the President and through him the Conference for their congratulations on the honour recently conferred upon him. Though he felt proud of the honour personally, he valued it especially as a recognition of the important part which meteorology was now playing in public life in all countries. From being a somewhat despised science, it was now an important Government department and an indispensable part of public service.

With regard to the social functions Sir George said that these had been reduced to a minimum. They were three in number: an informal soirée at the Meteorological Office in the evening of the opening day; a dinner at Lancaster House on Friday the 16th, when the Secretary of State for Air, Sir Philip Cunliffe Lister, would complete the welcome already conveyed by Sir Henry Lyons, and a meeting at Kew Observatory on Saturday the 17th, when delegates and their friends would have an opportunity of meeting the members of the professional staff of the Meteorological Office in London. A special circular with particulars of arrangements for that meeting was issued.

Times of Meeting.—It was suggested that the meetings of the full Conference should be held each day at 11 a.m. and 3 p.m. in order to allow time for meetings of Sub-Committees before the morning meetings. The proposal was unanimously approved.

Visit to Croydon aerodrome.—At the previous Conference an organized expedition was made to Croydon Aerodrome. Sir George said that he would be very glad on this occasion also for delegates to visit the aerodrome, and suggested that members who wished to do so should send in their names and Mr. Corless would then make the necessary arrangements.

Revised Programme.—Sir George then proceeded to the details of the programme. He said that in view of the importance of the Empire Air Mail Scheme he proposed that this subject should be the first item on the agenda for Tuesday morning and he had invited Mr. Self of the Air Ministry to come to that meeting to explain the Government's policy with regard to it.

Mr. Entwistle had recently been appointed on special duty in the Meteorological Office for the scheme and would be glad to answer questions in relation to its bearings on the various parts of the Empire.

The general programme of the meeting and the various memoranda dealing with each item were enumerated. Sir George said that with three or four exceptions the memoranda had all been circulated and he proposed that they should be taken as read. The following revised programme was approved :—

Tuesday, August 13, 11 a.m. and 3 p.m.	Aviation Meteorology.
Wednesday, August 14, 11 a.m. and 3 p.m. and Thursday, August 15, 11 a.m.	Synoptic Meteorology.
Thursday, August 15, 3 p.m.	Meteorology for the Army. Meteorology for the Navy. Instruments. Pilot-balloon observations.
Friday, August 16, 11 a.m. and 3 p.m...	Marine Meteorology.
Saturday, August 17, 11 a.m.	Classification of Meteorological literature. Organized research in Geophysics.
Monday and Tuesday, August 19 and 20, 11 a.m. and 3 p.m.	Climatology and Agriculture with seasonal forecasting.
Wednesday, August 21, 11 a.m. ..	Organization of Empire and International Meteorology. Exchange and facilities for training of Meteorologists within the Empire.
Wednesday, August 21, 3 p.m... ..	Closing meeting.

Sir George reported that he had recently received notice that the Italian Government had put forward a proposal to change the constitution of the International Meteorological Organization with a suggestion for a new set of statutes. He hoped to speak about this suggestion at the meeting on Wednesday morning, August 21, if time were available.

At the suggestion of Dr. Schumann the President agreed that in view of its importance for the Dominions the question of the exchange and facilities for training of meteorologists within the Empire should, if possible, be considered at one of the earlier meetings.

The President then thanked Sir George Simpson for his setting out of the programme, and said that in some cases he thought it would be advisable to appoint Sub-Committees to draw up recommendations for the consideration of the Conference.

The last Conference depended almost entirely on the work of the London Office, but he was glad to see that on this occasion many countries had contributed to the Agenda.

He further thanked Sir George for the arrangements made for the social functions at which he felt sure the delegates would endeavour to be present.

The meeting adjourned at 12.50 p.m.

(Signed) J. Patterson.

MINUTES No. II

Second Meeting, Tuesday, August 13, 1935, 11 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Mr. W. H. Beckett (Gold Coast), Lt.-Cmdr. S. H. Butler (Nigeria), Capt. C. J. Charlewood (Zanzibar), Mr. J. H. Churchill (Nigeria), Mr. P. E. L. Gethin (Tanganyika), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Cmdr. G. S. Ridgway (Bermuda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Capt A. Bertram Smith, (Trinidad), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Mr. A. H. Self (Air Ministry), Dr. M. A. F. Barnett, Prof. D. Brunt and the following members of the staff of the Meteorological Office :—Lt.-Col. E. Gold, Mr. R. G. K. Lempfert, Dr. F. J. W. Whipple, Mr. H. W. L. Absalom, Mr. E. G. Bilham, Capt. L. A. Brooke-Smith, Dr. C. E. P. Brooks, Mr. R. Corless, Mr. J. S. Dines, Mr. F. Entwistle, Cmdr. L. G. Garbett.

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1. **Documents circulated.**—The revised programme of the meeting was circulated. The Chairman drew the attention of delegates to certain changes that had been made, especially the provision for the consideration of Reports of Sub-Committees on Saturday morning, and for the question of the exchange and facilities for training of meteorologists in the Empire which would be considered on Thursday morning.

2. **Meteorological organization along Empire Air Routes.**—The President expressed the gratification of the Conference that Mr. Self had come from the Air Ministry to give an account of the problems facing the Air Ministry in connexion with Empire Air Mails, and called upon Mr. Self to address the delegates.

Mr. Self gave a brief account of the Empire Air Mail Scheme which he said was concerned with three basic problems—the first was that of getting an adequate nucleus load, the second was concerned with the question of the speed at which the service should be worked, and it was with this that meteorology was most closely concerned, and the third was the problem of subsidising the service. He gave an outline, of the various routes which it was proposed should be operated, of the approximate dates when they would be initiated, and of the type of service that was contemplated. The programme was dependent on their being able to rely on regularity of operation, and for this they must depend to a large extent on meteorological information which the several Governments would be asked to provide.

A discussion followed in which the following took part :—Mr. Patterson, Capt. Brooke-Smith, Dr. Normand, Mr. Stewart, Mr. Jeffries, Dr. Schumann, Mr. Walter, Mr. Gethin, Mr. Sellick, Dr. Kidson, Mr. Entwistle, Col. Gold, Mr. Churchill and Mr. Thornhill. Various delegates asked for information which would assist them in making arrangements for the meteorological services that would be required. With regard to flying heights it was noted that for commercial planes the height was not likely to exceed 12,000 feet as a general rule, and that for long distances 4,000 or 5,000 feet was preferable.

Sir George Simpson thanked Mr. Self for his remarkably clear account of the scheme. He emphasized that much fundamental meteorological research would be required to provide the information that would be necessary, especially as many of the routes would be over country where at present not even a rainfall station existed. He asked that delegates requiring further information would get into touch with Mr. Entwistle, who would give them all the assistance in his power with regard to details of technical points.

Mr. Entwistle then gave the following account of the meteorological aspects of the scheme.

He referred to the memorandum on Meteorology and Aviation in the British Empire which he had submitted at the last Conference of Empire Meteorologists held in London in August, 1929. That Conference had been held at an opportune moment, for the inauguration of the main Empire air routes had then been under consideration. The first section of the England–India route between Cairo and Basra had already been established in January, 1927, and the extensions in both directions to England and India completed in April, 1929, just prior to the Conference. It had been possible, thus, to discuss the meteorological arrangements along the routes, including the Cairo–Cape Town route which had been established subsequently in February, 1931, as far south as central Africa, the extension to Cape Town having been completed in January, 1932. Subsequent extension of the India route to Singapore had been carried out in December, 1933, and to Australia a year later. In December, 1933, the weekly service to South Africa had been duplicated, while, in December, 1934, a bi-weekly service between England and Calcutta had also been established.

The meteorological arrangements which had been made along the main Empire Air Routes had been in accordance with the accepted principles enunciated in the memorandum, but Mr. Entwistle thought that the members of the Conference would agree that the organization was, in the main, below the minimum required for the safe and regular operation of a commercial air route. The speeding up of the air services and the introduction of regular night flying, which were involved in the Empire Air Mail Scheme, would necessitate the provision of more adequate meteorological facilities along all sections of the routes.

Mr. Entwistle then gave an account of the provisional arrangements for meteorological services, which had been made during the visit of an Air Ministry Mission to Iraq, Palestine, Egypt, the Sudan and British East Africa in May and June of the present year in connexion with the introduction of the Empire Air Mail Scheme. He recalled that, as civil aviation had gradually developed, the London Meteorological Office staffs attached to the Royal Air Force in the Middle East and Iraq had undertaken the work of providing the meteorological information required for civil aviation in those countries in addition to their normal duties. It was felt, however, that with the development of air services now in contemplation the time had come when the countries concerned should accept full responsibility for the provision of the necessary meteorological organization in their own territories. He was glad to be able to report that this principle had been accepted by the Governments concerned. The Iraq Government had agreed to establish a meteorological service as from January 1, 1936, with headquarters at Baghdad and a subsidiary forecast centre to serve the Persian Gulf at Basra. It was anticipated also that Palestine would establish a meteorological service with headquarters at Lydda, and that a service would be established in the Sudan with headquarters at Khartoum and subsidiary forecast centres at Wadi Halfa and Juba. In Egypt, the Meteorological Service of the Egyptian Physical Department was contemplating the establishment of an Aviation Section with an adequate network of forecasting stations. In British East Africa, the extension of the existing meteorological service which was necessary for the air routes had been agreed with Mr. Walter and proposals submitted to the Government.

Mr. Entwistle expressed the hope that time would be found during the Conference to discuss the proposed extensions of the meteorological services along the remaining sections of the routes. He noted that there were three areas where the co-operation of foreign meteorological services would be required, viz., the Mediterranean, the Dutch East Indies and Portuguese East Africa.

Finally, reference was made to the projected air service between Khartoum and Kano, which it was intended to establish on an experimental basis in October, 1935. It was hoped that by 1936 a full service would be established between Khartoum and Lagos with an extension to Takoradi. Mr. Entwistle proposed that provisional meteorological arrangements for the experimental service to start in October should be discussed by a sub-committee of representatives of the interested services.

In reply to a question by Mr. Sutton, Mr. Entwistle said that as a general rule the forecasts from any aerodrome were expected to extend as far as the next aerodrome where forecasts would be made.

With regard to a question by Mr. Sellick as to who was to make the arrangements that would be necessary to get reports from Portuguese East Africa, Mr. Entwistle said that such arrangements would concern South Africa, Southern Rhodesia and East Africa, but that as the scheme was initiated by the Government of Great Britain, that Government would be prepared to facilitate the arrangements with foreign countries.

CAPT. BROOKE-SMITH asked what was the minimum information that would be required from ships in areas where air routes crossed the sea, and in particular what wireless range would be required. In reply, Mr. ENTWISTLE said that the main help that ships could give would be in providing as many regular reports as possible at the standard hours for forecasting purposes. Except in the Mediterranean and the Far East the main flying would be over land, but all land services depended to a greater or less extent on observations from the sea. The question as to how many observations were required was for each country to decide.

Mr. THORNHILL (Ceylon) reported that Ceylon had no difficulty in getting sufficient messages from ships. He thought that the provision of additional messages by ships would be ultimately to their own advantage as they would get the benefit of improved broadcast messages.

Sir GEORGE SIMPSON said that the details of the scheme were not yet worked out, but what was contemplated was that there should be a central forecasting station which should be in touch with aircraft, and that ships should transmit their observations to this central station and not to individual aeroplanes. The means and organisation necessary to get observations well distributed in time and space was a matter necessitating close co-operation between the meteorological services and the ships' owners, and this would come up for consideration in the discussions on Marine Meteorology.

On Mr. Entwistle's recommendation a Sub-Committee was appointed to consult with regard to the service from Khartoum to West Africa, with the following members :—Mr. Entwistle, Mr. Grabham (A.E. Sudan), Mr. Churchill (Nigeria), Lt.-Cmdr. Butler (Nigeria), Mr. Beckett (Gold Coast) and Mr. Sutton (Egypt).

The Sub-Committee would be convened by Mr. Entwistle and would report to the Conference on Saturday.

Dr. NORMAND (India) said he hoped to be able to consult with Mr. Entwistle regarding questions of the Persian Gulf, and it might be desirable for the result of the discussions to be regarded as the findings of a Sub-Committee.

The PRESIDENT said that so far no mention had been made in the discussion of a scheme for the western routes. In Canada an Air Mail Service had been put in operation in 1930 from Winnipeg to Edmonton, but had been discontinued in 1932 on account of finance. At present landing grounds were being prepared under an unemployment scheme. A skeleton meteorological organization had been mapped out to provide the information necessary for a daily air mail service from Halifax to Vancouver, but had so far not been put into active preparation.

The meeting adjourned at 12.55 p.m.

(Signed) J. PATTERSON.

MINUTES No. III

Third Meeting, Tuesday, August 13, 1935, 3 p.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Mr. W. H. Beckett (Gold Coast), Lt.-Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. P. E. L. Gethin (Tanganyika), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Mr. G. W. Nye (Uganda), Cmdr. G. S. Ridgway (Bermuda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Mr. F. L. Squibbs (Seychelles), Capt. A. Bertram Smith (Trinidad), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Dr. M. A. F. Barnett and the following members of the staff of the Meteorological Office : Mr. H. W. L. Absalom, Dr. C. E. P. Brooks, Mr. R. Corless, Mr. F. Entwistle, Cmdr. L. G. Garbett.

1. Preparation of upper wind and visibility data for aviation purposes.—(Reports on the Meteorological Organization for Aviation in Canada and in Southern Rhodesia are given in Appendix I.) Mr. CORLESS (Forecast and Aviation Services in the Meteorological Office, London) gave a brief description of a chart designed to represent the normal surface and upper winds in any month over a wide area. Copies of a specimen chart for January covering a large part of Europe, the Mediterranean and north Africa were circulated. Mr. Corless said that the chart was based on a system devised by Sir Napier Shaw and Cmdr. Garbett, which had been described originally in the *Quarterly Journal of the Royal Meteorological Society* for 1933. The method was designed to show in a single rose for any one level the frequency and strength of winds in the 12 months of the year, but it had been adapted for aviation purposes to show on one chart the winds for all levels in one month instead of those for one level in the 12 months. In the chart submitted the heights were: Surface, 500m. above surface, 1,000m., 2,000m., and 3,000m. above mean sea level. To give a complete statistical representation of the winds in all months at the 5 selected levels, 12 charts would be sufficient instead of 60 required if the ordinary type of wind-rose were used.

Visibility data have up to the present been published only in the form of tables with no graphical representation.

Mr. Corless than gave a brief survey of aviation meteorology since the last Conference in 1929. He said that the general position had not changed much from that set out in Mr. Entwistle's Memorandum on page 78 of the Report of that Conference. Some changes in detail might be noted. In the first place a change had occurred in the work at Croydon resulting from the fact that aeroplanes now fly direct to their destination instead of passing over Lympne. The importance of Lympne from a meteorological point of view had therefore decreased, though it still took a large part in radio direction finding. A rearrangement of the auxiliary stations in south-east England had resulted. The work at Croydon had been increased by the spread of internal air lines.

A system had been started at Croydon known as the Q.B.I. system. Q.B.I. was a code signal sent out when visibility was less than 1,000 yards or cloud below 1,000 feet. When such conditions occurred an additional wireless operator was put on duty at Croydon working on a different wave length; weather reports were broadcast as required and the Control Officer was responsible for getting the accurate position of machines and guiding them to Croydon.

Internal air lines were not much required in a country so small as the British Isles but they were rapidly increasing especially for flights over sea, for example to Jersey, the Isle of Wight, Ireland and the Isle of Man, and to Orkney and Shetland. The principle on which they were managed was that the local authorities were responsible for the aerodromes and buildings while the Government was responsible for the wireless telegraphy and meteorological services, subject to the provision that not less than 10 per cent of the maintenance cost was recoverable.

A civil meteorological station for forecasting had been established at Manchester linked by teleprinter with Liverpool. And in addition there were R.A.F. stations at Aldergrove and Abbotsinch which were occupied with work for Civil Aviation as well as for the R.A.F. Other civil stations which might have to be provided with forecasting staff were Liverpool, Bristol, Birmingham and Aberdeen.

Auxiliary meteorological stations were usually established at aerodromes and these stations made reports to the nearest forecasting station two or three times a day using the first three groups of the international message. A number of other stations were gradually being established in places where conditions were known to be bad for civil aviation. At auxiliary stations observations were made of the height of cloud (for which small balloons were issued), weather and visibility. The stations were also called upon to report certain sudden changes of weather, as follows:—(1) When cloud previously above 1,000 feet fell below that level over a period of at least 10 minutes and conversely; (2) when visibility above 1,000 yards fell below that limit and conversely; and (3) sudden squalls and thunderstorms.

In connexion with civil aviation teleprinters had been installed between Manchester and Liverpool as already stated, between Manchester and Heston, and between Heston and Croydon; it was hoped to instal them also between Croydon and Shoreham-on-Sea and between Bristol and Cardiff.

The scheme for radio broadcasting of weather reports described in a recent "Notice to Airmen" was not yet fully established. A broadcasting cabinet was in the forecasting room connected with a transmitting station in Northamptonshire and the messages could be received by loud speaker over most of England and by telephone in Scotland. The broadcasting starts at about 7h. and continues to about 20h. The main synoptic reports at 7h., 13h. and 18h. were broadcast,

with intermediate reports at 10h. and 16h., and also reports of sudden changes. The scheme had been started originally at Heston, but had now been transferred to the Air Ministry and was at present working in shortened form; it was hoped that the full scheme would be in operation in two months.

With regard to the diagram on page 80 of the Report of the Conference in 1929, Mr. Corless said that recent decisions of the International Aeronautical Conference had caused certain modifications in the diagram.

Form of Chart.—A discussion followed with regard to the specimen form of chart. Sir George Simpson explained that the chart had been designed originally for use in the choice of air routes, but its main purpose was to put the observations in the hand of the meteorologist to be used by him for whatever purposes they might be required. He referred to a series of wind roses submitted to him by Cmdr. Ridgway, which had been prepared in Bermuda giving a separate rose for each month and for each level.

Sir George emphasised the great importance to airmen of an adequate representation of upper winds and urged the necessity of analysing the results of pilot balloon observations on a uniform plan, in order that data for the world might be comparable.

The wind rose represented on the chart was based on the Baillie wind rose which had been used on ocean charts for many years. The light winds were represented on the inside of the rose with gales on the outside. The steps of velocity and the levels selected were those recommended by the International Commission for Aerial Navigation (cf. Conference Report, 1929, Annex A, facing page 88).

The chart now submitted to the Conference was to be discussed at Warsaw and if approved would be adopted for the future.*

In reply to a question by Dr. Kidson (New Zealand) as to whether the chart had been found acceptable in practice and whether it was possible to appreciate so large a number of data on a single sheet, Mr. Entwistle said that the question of the most suitable rose had been considered very thoroughly before adopting the present scheme and that the new form was much less cumbersome than using individual charts for each month and level. It was especially useful in deciding for a single flight or for an air route what was the best height for flying between different points. It has been found that familiarily with the charts made it very simple to pick out whatever information was required. The scheme was, however, still only in the experimental stage.

Mr. C. D. Stewart (Malaya) welcomed the introduction of the new rose which he regarded as a notable advance on previous methods.

The President also expressed his appreciation of the new form. He said that in Canada they had been asked to give information about the frequency of the wind components both along the air route and at right angles to it.

Additions to the Chart.—Dr. Schumann (South Africa) suggested that the figures on which the roses were based should be published on the back of the chart in a form similar to that shown for Sealand. It was agreed that this suggestion should be considered in future issues.

Mr. Patterson (Canada) pointed out that in the case of high level stations "500m. above surface" might be about the same as "1,000m. above M.S.L.". It was agreed that the height of the station should, if possible, be entered on the wind-rose.

Mr. Sutton (Egypt) pointed out a discrepancy between the heights used for the charts and for the table. The charts gave values for "500m. above surface" and the table for "500m. above M.S.L." It was agreed that the latter was the modern practice.

The form and frequency of publication of upper wind summaries.—A discussion followed as to what information it was necessary to publish; various delegates asked for information on the subject and explained their present practice.

Mr. C. D. Stewart (Malaya) said that pilot-balloon data had been available in Malaya for some years; for 1932 and 1933 roses only had been published, but these differed in several details from international practice. After correspondence with Col. Gold, it had been decided that in future frequency tables of standard

* The wind rose was approved at Warsaw with a slight modification suggested by Mr. W. R. Gregg, Chief of the United States Weather Bureau, Washington.

form should be published instead of roses, and the first volume of data for the year 1934 was in the press. It would be possible to supply data for earlier years in similar form if they were required in the London Office though there might be some delay.

Dr. NORMAND (India) stated that India published data of pilot-balloon ascents day by day in a publication of *Upper Air Data*. A summary of frequency data in international form was prepared month by month, but was neither printed nor circulated. At the end of a period of years averages were worked out for the several stations and these were brought up to date from time to time.

Mr. SELLICK (Southern Rhodesia) stated that summaries over a 5-year period had already been published for Southern Rhodesia, and it would be difficult on account of the expense to publish summaries month by month.

Dr. SCHUMANN (South Africa) said that in South Africa, in order to get a general survey of the wind distribution over a wide area, stations had in some cases been established for a period of a year or 18 months. In sparsely populated districts it was not always possible to maintain the station over a longer period, and the publication of 5-year summaries was therefore not feasible. South Africa had already published summaries of the data available over varying periods.

Sir GEORGE SIMPSON reported that data for about 10 stations for a period of about 10 years were available in Great Britain and normals for that period were being prepared.

It was generally agreed that it was desirable in view of international agreement that monthly frequency summaries in standard form should be published where possible, either as a monthly or an annual issue, and that such publication should extend over a period of at least 5 years. As soon as 5 years' data became available summaries for that period should be issued, and these summaries should be brought up to date at the end of successive 5-year periods. Sir George emphasized the great use that had been made of the summaries already published. Mr. Corless suggested that it would be desirable to use the same 5-year period in all cases.

Mr. ENTWISTLE said that in producing the original chart all available data had been used and the roses were not all for the same period. In the case of Loanda the original sheets had been obtained from the Director of the Service and the summary had been compiled in the London Office. If the monthly frequencies could in the first instance be published monthly or annually they could be used at once even for a period of 1 or 2 years until a 5-year normal became available.

Units for height and velocity.—Dr. NORMAND raised the question of the units to be employed. Mr. CORLESS reported that at one time both Km/hr. and m.p.h. were in use on continental routes, but that the present practice was to give Km/hr. on continental routes and m.p.h. on inland routes.

Mr. STEWART reported that Malaya also had changed from m.p.h. to Km/hr. Heights were given in code and could be interpreted in either miles or kilometres.

It was generally agreed that for publication the practice of the International Meteorological Organization should be followed.

Frequency or percentage frequency.—Mr. SELLICK asked whether it was desirable to publish the summaries for individual months as the number of occasions of wind of given direction and strength or as the percentage frequency. He pointed out that, if the data were to be combined to form a summary over a period of several years, data of the number of occasions were more easily summarised than data of percentage frequency.

Sir GEORGE SIMPSON explained that it was desirable that data for individual months should be in the form of the number of occasions, but that for summaries over a period of years they should be expressed as percentage frequencies so that data for all stations should be comparable.

Time of observation.—Mr. SELLICK pointed out that noon was specified as the time for the observations on which the summaries were to be based. In his opinion that hour was unsuitable in tropical countries because convection was then in full force and the winds derived from the observations would bear little relation to the general circulation. Observations in Southern Rhodesia were usually made between 8h. and 9h. The tail method was not in use.

Mr. PATTERSON said that in Canada also observations were usually made at 8h. so that the results might be available for synoptic meteorology. Special observations were made as required for special flights. In the United States, observations of pilot balloons were made at about 6h. and aeroplane observations between 5h. and 5h. 30m. (75th meridian time).

Mr. STEWART said that in Malaya observations were made between 7h. and 8h. and at 12h. using the tail method, and consistent results had been obtained. Observations at 18h. were also being started.

Visibility.—Mr. PATTERSON referred to a book on " Visibility in Meteorology " recently published by Mr. W. E. K. Middleton of the Toronto Office. He said that the subject had recently been investigated with the object of devising a simple instrument for observations by night as well as by day. An effort was being made to get a visibility-meter by using a wedge method of observing a standard lamp, and some progress had been achieved. Pilots making aeroplane flights were trying to get observations of vertical and also of oblique visibility. (Appendix I(*a*).) It had been suggested by some workers that " visual range " would be a more satisfactory term to use than " visibility ".

Sir GEORGE SIMPSON said that for some years a special scientist had been working in the London Office trying to devise a method of getting a scale of visibility suitable for day and night. The problem was exceptionally intricate. The aviator requiring information with regard to visibility at night wished apparently to be told what the visibility would be in similar conditions if it were day. Experiments had been made by watching lights during the transition period between day and night, but so far the problem of getting a satisfactory estimate had proved insoluble. He did not think the Conference could do anything with regard to technical details, but it would be of interest to learn what their experience was.

2. **Ice accretion on aircraft.** (Appendix II.)—The experience of delegates was asked with regard to the problem of ice-accretion on aircraft.

Dr. NORMAND said that the problem had up to the present not arisen in India.

Mr. STEWART said that in Malaya also the problem did not arise as freezing temperatures were not reached below about 17,000 feet.

Mr. PATTERSON reported that ice-accretion was common both in Canada and the United States at certain times, but forecasts of its occurrence had not so far been required in Canada. In the United States it was at times a serious problem for air-mail services. Experience had shown that ice formed at temperatures down almost as low as 0° F., but was most common between 0 and 5° F. below the freezing-point. The formation was often very rapid and was chiefly on the forward edge of the plane. He understood that attempts had been made to overcome it by having a rubber shield fitted along this edge through which air could be forced to expand the rubber and thus break the ice.

Dr. KIDSON said that the one occasion of ice-accretion that had come to his notice was that during the first crossing of the Tasman Sea by Sir Charles Kingsford-Smith. This presumably occurred in a frontal region during a thunderstorm. In New Zealand the problem hardly arose because temperatures near the surface were usually above 40° F. and the danger could be overcome by flying at low levels. The danger would probably become serious if blind flying were undertaken over mountains in New Zealand.

Mr. ENTWISTLE asked Dr. Schumann if there had been any investigation of the conditions on June 10 last when a pilot had been forced down in the neighbourhood of Beaufort West. Dr. Schumann said that no report had been received.

3. **Meteorological aid required for blind flying.** (Appendix III.)—Sir GEORGE SIMPSON said that the modern tendency in all Air Forces was to fly in cloud and to use clouds for tactical purposes. The memorandum which had been prepared set out the problem which would have to be faced by meteorologists when they were asked for the meteorological data necessary to enable blind flying to be carried out. The problem would have to be faced in the near future. Information with regard to different types of bumpiness, and to denseness and thickness of the cloud was likely to be specially required, and also as to what was the best estimate of wind direction above a cloud layer, and what discontinuity in wind would be encountered above the cloud. The problem was important for civil aviation as well as for the R.A.F. because in recent years aeroplanes were accustomed to fly by compass direct to their objective and not to keep within sight of the ground. The introduction of radio-direction flying had considerably increased the importance of studying the problems of blind flying.

Mr. PATTERSON said that he did not know to what extent blind flying was practised in Canada but asked for the experience of other delegates and for suggestions for attacking the problem.

Mr. WALTER (East Africa) gave an instance of a flight near Abercorn when the aeroplane entered a rain cloud and was carried up 2,000 feet in two minutes.

Mr. SELLICK said that local pilots in Southern Rhodesia would not fly above a complete cloud layer because the change in wind direction above the cloud might make them lose their way. Even with cloud amount of 8 tenths a change of wind direction through 30° or 40° was quite common.

Mr. PATTERSON said that in the United States a simple radio instrument had been designed to give the velocity of wind in and above cloud by means of a signal followed by direction finding apparatus. He had seen no report as to the success attained by the method.

4. **Standard of knowledge in meteorology required for candidates for "B" Flying Licences.** (Appendix IV.)—Sir GEORGE SIMPSON explained that the question had arisen in the first instance out of a request from one of the British stations in Egypt as to whether the questions asked in the examinations should be taken direct from the specimen set out in the British instructions or adapted to local conditions.

Mr. PATTERSON said that in Canada the British book of instructions was used as standard.

Dr. NORMAND said that in India the British book was also used as standard but the questions were adapted to apply especially to India and tropical countries. The practice had been submitted to the London Office before adoption. The examination was partly oral and partly written.

Mr. ENTWISTLE stated that it was necessary for any pilot carrying passengers for hire or reward to hold a "B" licence. The licence was only actually valid for the country in which it was issued but was frequently accepted also in other countries and this was especially so in British colonies. It was desirable therefore that the standard should be uniform.

Dr. KIDSON said that in New Zealand the British Air Force syllabus was used without reference to the local meteorological office, but the meteorological knowledge required was small.

Cmdr. BERTRAM SMITH (Trinidad) said that he believed all colonies were obliged to accept a British "B" licence as valid. He understood that in America a pilot flying over a new route always made his early flights as a co-pilot. His licence was then endorsed for that route. He thought pilots' licences might be endorsed for routes as was done for types of planes.

Mr. STEWART said that at present Malaya had no examining body but the Government were considering the appointment of a Director of Civil Aviation and might soon have to provide an examination and a syllabus. In his opinion it was inevitable that "B" licences should be regarded as interchangeable and it was therefore desirable that the test should contain questions of general principle as well as of local knowledge.

Mr. GETHIN said that in Tanganyika the papers for "B" licence were sent out by the Air Ministry and were returned there for examination. There was no oral test.

Mr. PATTERSON reported that the aviation authorities in Canada had not referred the question to the Meteorological Office.

Mr. SELLICK said that in Southern Rhodesia when an examination was held some years ago the questions were sent from South Africa and were obviously adapted to local conditions.

Cmdr. RIDGWAY (Bermuda) said that for the examination of navigators at sea a knowledge of the general principles of navigation was required and information of local conditions was supplied in Sailing Directions. A pilot could obviously not be required to have a knowledge of all localities but this might be supplied in Flying Directions.

Mr. CORLESS said that the "Air Pilot" contained references to meteorology but they required amplification.

Mr. GUMBLEY (Palestine) said that the general practice in Great Britain was to demand higher qualifications of their pilots than those required internationally.

Mr. ENTWISTLE said there were three classes of licence for which an examination in meteorology had to be taken; the "B" Pilot's licence, the 2nd Class Navigator's licence and the 1st Class Navigator's licence. In the case of the first two licences, only an elementary knowledge of meteorology was required, sufficient to ensure that the pilot could make an intelligent use of the meteorological service and understand the information provided. There was no attempt to make these pilots meteorologists. The examination for the "B" pilot's licence was the most elementary, and questions were limited mainly to conditions obtaining in the candidate's own country. In the case of the 2nd Class Navigator's licence which most air transport companies insisted on for their air line pilots, the candidates had to draw a simple synoptic chart and questions were asked relating to meteorological conditions and organization in those parts of the world where they were likely to be called upon to fly. The examination for 1st Class Navigator's licence which, incidentally, was held by very few pilots, was much more comprehensive. The intention here was that the holder of the licence should be in a position to act, if necessary, as a meteorological officer even to the extent of drawing and interpreting synoptic charts.

It was generally agreed that a knowledge of general principles should be required for the licence with possibly a knowledge of the local conditions of the country issuing the licence but that a pilot holding a "B" licence could not be required to have a very high standard of meteorological knowledge.

The meeting adjourned at 5.5 p.m.

(Signed) J. PATTERSON.

MINUTES No. IV

Fourth Meeting, Wednesday, August 14, 1935, 11 a.m.

The following delegates were present:—Mr. J. Patterson (Canada), *President*, in the Chair, Lt.-Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. P. E. L. Gethin (Tanganyika), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Cmdr. G. S. Ridgway (Bermuda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Capt. A. Bertram Smith (Trinidad), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present:—Dr. M. A. F. Barnett and the following members of the staff of the Meteorological Office:—Lt.-Col. E. Gold, Mr. H. W. L. Absalom, Dr. C. E. P. Brooks, Mr. E. G. Bilham, Mr. R. Corless, Mr. J. S. Dines, Mr. F. Entwistle.

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1. **Visit to Library of Meteorological Office.**—The President announced that if there were any delegates who wished to see the library of the Meteorological Office, and the methods adopted for cataloguing, etc., Dr. C. E. P. Brooks would be glad to show them at any time that might prove convenient. A list was circulated and ten delegates expressed their wish to join the party.

2. **Minutes.**—The PRESIDENT reported that it was hoped to circulate at the afternoon meeting the Minutes of the first two meetings of the Conference. Delegates were asked to give to Miss Austin any additions or corrections they wished to make and the Minutes so amended would be approved at the Final meeting of the Conference on Wednesday afternoon, August 21.

3. **Methods of forecasting from synoptic charts.**—Reference was made to a memorandum prepared by Mr. Corless (Appendix V(*a*)) which outlined the methods of forecasting from synoptic charts practised in Great Britain.

The PRESIDENT said that it would be of interest to learn the experience of delegates with regard to the Bergen methods of air mass analysis which had been extensively developed in recent years. In *Canada* an intensive study of the method had been made during the last two or three years and the United States Weather Bureau were also making a thorough investigation of its possibilities. Considerable difficulties were, however, being experienced. Canada was generally under the influence of polar air, and it was only seldom that there was an inflow of true Gulf air. During the summer it sometimes happened that there was an inflow of polar air which on its journey southward became warmer and moister and then, after a sojourn of a few days over the southern States, turned northward over southern Canada as a very hot current, carrying at times temperatures of 100° F. or even more. In such cases it was very difficult to identify the fronts. In the winter the air masses were fairly well defined, but on account of the low temperatures in the upper air humidity observations were not reliable. The problem, however, was different from that in Europe in that the air masses arriving in Europe were almost without exception of maritime origin and occlusions were the rule. In America, however, the polar air masses were most frequently of continental origin and occlusions were not the rule. Good progress was being made in the study.

At the present time information of upper air temperatures up to heights of about 17,000 feet was being received from about 20 stations in the United States, and the problem of how best to plot and use these observations was being investigated.

Dr. C. W. B. Normand said that *India* might perhaps be regarded as the first country to use air mass nomenclature. No doubt Mr. Patterson himself when forecasting in India some 30 years ago had spoken about the advance of the monsoon. That was, however, a very different stage from the modern one which attempted to obtain a clear and definite identification of the different air masses.

In Poona it was difficult to apply the Bergen methods because only one chart a day was prepared. He could best summarise the situation by saying that they had found that on certain days and in certain types of weather the Bergen methods could be applied. For example, in the case of cold-weather depressions which crossed north India from west to east a forecast was made from the oncoming of the cold mass from Persia and Baluchistan. In the case also of storms at sea, particularly the post-monsoon storms of November, the equatorial current was well-marked; it was found that after the storm had been in existence for a short time a front began to appear. The recurving of tropical storms might indeed be taken as an indication that the warm equatorial air had advanced as far as it could, a front then formed and the depression moved off to the north-east along the front.

It was usually difficult to identify fronts in the early stages of a tropical storm. On a map extending over a wide area there might be moist equatorial air over one region and air of more northerly origin over another, but up to the present it had not been possible to get a clear idea of the structure of the boundary between the two. Indian forecasters believed that, however ill-defined the boundary might be, storms always formed on such a boundary; if in the early stages it was not sharply defined it often became so at a later stage.

There was often considerable difficulty in identifying air masses from surface observations and pilot-balloon data had proved useful. As an example Dr. Normand referred to the fact that it had been found that rain occasionally occurred over the Central Provinces in March without any marked indications of its oncoming from the surface observations. Pilot-balloon data revealed the fact that such rain was preceded by southerly winds in the upper air. Maps were now prepared every morning for the heights of 0·2, 0·5, 1, 1·5, 2, 3, 4 and 6 Km., and on these charts pilot-balloon observations were plotted. Isobars were drawn on the charts for the levels of 1 and 2 Km. based partly on the pilot-balloon observations and partly on the pressures at mountain stations, reduced to the standard levels. The drawing of these upper air charts had meant a considerable advance in forecasting technique.

Mr. Stewart said that much of the experience described by Dr. Normand was common also to *Malaya*. There had been considerable difficulty in attempting to forecast in the equatorial regions and the technique had been evolved largely from the drawing of charts for earlier years based on those obtained from India and Hong Kong.

Mr. Stewart referred to his memorandum (Appendix V(*b*)) and said that the charts there reproduced represented types of pressure distribution which when once established usually persisted for 3 or 4 days. In Malaya the same pressure and wind distribution was always accompanied by the same weather.

Persistent types, however, did not always occur and the method of forecasting from the analysis of air masses had been tried. He was not sure that polar air had ever been identified at the equator but the air certainly came from different sources. One mass might be brought by a SE. wind from the equator and another by a NW. wind, and the boundary between the two oscillated from about 1° N. to 3° or 4° N.; the distribution of rain depended on the position of the boundary and this could be located. The NE. monsoon between November and February, was usually accompanied by heavy rain, on one occasion 48 inches were measured in 3 days, but in the southern part of the peninsula it appeared that the rain was brought by a SE. wind and fell through the NE. current.

In the middle of the year when there was an extensive low in the north the isobars sometimes formed a V over the south of Malaya. The winds on the east side would follow the isobars, while those on the west moved from high pressure to low. The boundary between the two, the point of the V, might oscillate east and west carrying its weather with it. It was not a front in the accepted sense of one air mass rising over another but rather a boundary between air masses.

In the case of Sumatra squalls which occurred sometimes in the afternoon but mostly at night and were accompanied by all the phenomena of a line squall, a block of cold air certainly existed but its origin was quite unknown. Its low temperature had been attributed to the cooling effect of the rain, but it was difficult in that way to account for a fall of temperature of as much as 14° F. in 10 minutes. It was not yet possible to forecast the arrival of a cold mass of that type, partly owing to the lack of observations west of Malaya. On one occasion it had been possible to withdraw a warning of the occurrence of a Sumatra squall on a given night because the existing pressure distribution was reversed during the day.

In the equinoctial seasons when the air was stagnant and there was no definite supply of air from outside, the forecasting of rain and cloud in conditions of instability must depend on upper air observations. Forecasts had been made also with some success from the differences of temperature between hill and valley stations. There were many days with no persistent type and when no difference of air mass was discernible and on such occasions a forecast was hazardous.

Mr. Stewart emphasized the fact that observations of surface wind were of no use, the true circulation was masked by land and sea breezes or by katabatic winds. Air streams had to be identified either from cloud motion or from pilot-balloon observations. The determination of upper air trajectories was perhaps even more important than pressure distribution.

Malaya had equipped two ships which gave observations between Singapore and Bangkok on some days, and the Dutch had a station in the China Seas. A first class station was also to be established at Labuan. A wide network of stations was necessary for identifying the type of air. For forecasting, the drawing of upper air charts was an absolute necessity. Small maps were plotted for 1,000, 4,000, 7,000 and 10,000 feet and contained pilot-balloon observations at three stations, soon to be increased to four, and direction of cloud-motion. In equatorial regions more than one chart a day was necessary, at present two were prepared for a fairly wide area and it was hoped that two local charts might soon be added.

Mr. Sellick said that he had read Mr. Stewart's memorandum with much interest and sympathised with his difficulties. As set out in his own memorandum (Appendix V(*c*)), in general the weather of *Southern Rhodesia* depended on wind—SE. winds, NE. winds, NW. winds—all were accompanied by their own characteristic weather; and when any of these winds had persisted for a day or two one could be fairly sure of what the weather would be. Weather was mostly of the persistent type. Surface winds were often conflicting, and converging winds might go on for days at a time.

With only one map a day it was useless to attempt forecasting by the method of fronts, the front might pass over the whole country in 12 hours.

Rainfall had a large effect on both temperature and pressure. A sudden fall of temperature of 20° F. accompanied by rain was nothing unusual; pressure might change 3 mb. in a few seconds, and such a change might be double the normal gradient across the whole territory. Winds were frequently found to be at variance with the isobars. A light N. wind overrun by a deep SE. current sometimes gave rapid formation of thunderstorms travelling with the SE. current across the surface wind.

Data from two pilot-balloon stations had been available for some years; the main fact that had emerged from a study of the data was that if the wind turned clockwise it would tend to be fine, if it turned anti-clockwise it would tend to be wet.

Dew point had been used for the identification of air masses, and charts had recently been constructed for the rapid calculation of wet-bulb potential temperature.

Mr. WALTER said that in *East Africa* synoptic charts had been drawn only since the beginning of the current year, but they had revealed various points of interest. There were two main methods of forecasting, one was to follow the air masses, and these had been traced both from south and north of the equator. Weather in East Africa was chiefly due to the interplay of weather systems travelling from west to east along the two great anticyclonic belts which lie north and south of the equator. Mr. Walter exhibited charts illustrating an occasion of a westerly current coming up to Tanganyika with a NE. wind over Kenya. The line between the two was marked by a series of thunderstorms in the afternoon following the morning on which the chart was drawn. The incursion of a cold SE. current over the high lands gave typical rain which was regarded as frontal, but it was difficult to detect a definite frontal line. Variable upper winds in the morning, spreading out fanwise, were nearly always followed by heavy thermal convection rain in the afternoon, and definite forecasts could be made of which as many as 90 per cent were correct. Forecasts of heavy thunder showers were often issued for Imperial Airways in the early morning for the late afternoon. Although the method of forecasting from air masses was in its infancy in East Africa it had been found possible of application; there was also some possibility of tracing a cold current up the Mozambique Channel to Kenya which gave cold squally weather before the advance of the SE. trade to the north of the equator. Forecasting from isobaric systems over the equator was at present hardly practicable; the systems were only vaguely identified and had no definite travel.

Dr. SCHUMANN said that although regular observations on upper winds had now been carried out in *South Africa* for several years at some six or seven stations little use had been made of these observations for the purpose of forecasting. The service was in the process of reorganization and it was hoped soon to be able to make more use of the data.

Mr. SUTTON said that in *Egypt* nine different types of pressure distribution were identified, some of which, especially the north-east type, persisted over long periods. On many occasions the passage of fronts had been found useful in forecasting the end of a period of warm weather, especially of the khamsin type, and a change to a cool north-west type. Such a change was usually but not always accompanied by severe dust-storms. Warm fronts were not very definitely marked on a map but cold fronts could be identified even from surface temperatures. They had been traced for about three days from the Mediterranean coast to the equator though not all went so far. It was extremely difficult to anticipate their speed of travel and they often moved faster than was expected.

One of the main difficulties of forecasting in Egypt was to determine whether a depression which had moved along the Mediterranean at a fairly uniform rate would continue to move at the same rate after reaching Cyprus, or whether it would remain stationary over the island. If the depression remained stationary it gave three or four days bad weather over Egypt. He would welcome any suggestions that could be made for the elucidation of that problem.

Upper winds were used for forecasting. For example, a station had recently been started by Imperial Airways at Wadi Halfa and had led to the identification of small depressions crossing the Sahara and north Sudan in about lat. 20° N., where it had not been known before that depressions existed. These depressions were sometimes related to those travelling along the Mediterranean. Their identification might make it possible to anticipate when bad visibility would occur between Wadi Halfa and Khartoum.

The barometric tendency was usually not sufficiently correct to be of much use. In the case of the few stations that were dependable the practice was to use the difference from normal.

It was often difficult to get the strength of the wind from the pressure gradient. Sometimes there might be a pressure difference of only 1 mb. in the 130 miles from Alexandria to Cairo, and then an increase to as much as 2 mb. in the 12 miles between Cairo and Helwan; strong NE. winds reaching gale force might occur there with quite light winds a few miles further north.

Dr. KIDSON said that within the last two or three years meteorologists in *New Zealand* had been interested in the Norwegian methods of plotting, and of chart analysis. The data in New Zealand were all plotted on one chart and he hoped to be able to adopt the accepted international method. The Norwegian method had been found to be of great use. Fronts were as a rule well-marked and their motion was fairly regular. Papers on the subject had been published and were available for those interested, and specimen charts could be exhibited.

New Zealand was in the region of the well-known moving anticyclones between which was a frontal zone. The family of cyclones usually moved poleward along the front while the front itself moved from west to east. The general distribution might be to some extent modified by the large scale local effects due to the Australian continent. Cold air could be traced to very low latitudes, sometimes almost to the equator.

In the temperate regions the principles of analysis were similar to those used in Great Britain, but with some local modification. Most of the weather was associated with the movements of depressions and fronts.

In the tropics it was difficult to make allowance for the large diurnal variation of pressure and for the rapid changes in pressure (probably dynamic in character) which had been referred to by other speakers, but in spite of this both pressure and wind observations were useful in plotting the charts and in tracing the movements of the systems. Air which had crossed the equator and arrived as the NW. monsoon behaved as warm air when it struck the SE. current. He had recently experienced an interesting example of a front in equatorial regions near Panama when the SE. trade, which the vessel in which he was travelling had followed over the equator, gradually fell away to a very light wind and the NE. trade was encountered as a cold air mass at a very typical cold front. The north wind was strong and remained so.

Mr. WATT said that in *Australia* everyone was interested in the weather. Charts had been drawn there for 50 years and had been published in the newspapers since about 1908. The systems were in the main fairly simple and the frontal method had not been applied. He was a little discouraged in making the attempt by reading the paragraph in Mr. Corless' memorandum as to the difficulty that had been experienced in drawing fronts even in European regions.

Mr. SUTTON said that Mr. Watt might be encouraged to know that fronts drawn independently at Cairo and Heliopolis showed good agreement.

Mr. WATT asked whether any meteorologist had demonstrated the possibility of locating the cold front by " static " or " atmospherics ".

Dr. KIDSON said that the question had been raised by Prof. Laby in Melbourne, and that an attempt had been made to correlate the observations of atmospherics with those of cold fronts but he was doubtful whether it would be of much practical use.

Mr. PATTERSON said that the possibility of locating local thunderstorms from observations of atmospherics had also been examined in the United States and in Ottawa, and had met with some success when atmospherics could be observed from two or three stations.

Dr. SCHUMANN referred to some interesting work which was being carried on by Dr. Schonland in South Africa on locating the travel of thunderstorms.

Sir GEORGE SIMPSON said that there was a good deal of experience in Great Britain on the location of thunderstorms by atmospherics—but in general the results had been disappointing. It was possible to locate the point of origin of the atmospherics, but it was by no means always in a thunderstorm, often it was only a region of unsettled weather. Electrical phenomena undoubtedly occur on fronts, but it was not possible to draw the position of the cold front from observations of atmospherics; thunderstorms could be more easily identified on a synoptic chart than by radio observations.

Sir George said he had been interested in the discussion on forecasting in tropical regions. It was clear that the main development came from the study of air masses. The introduction of the new nomenclature had helped considerably towards the progress of the study. He was surprised to have heard so little about the weather resulting from instability. Sir George referred to the possibilities for getting more information about thermal conditions in the upper air and thought kites might be of value, though their use had been discontinued in Great Britain for many years. The radio-sonde had been found to give satisfactory results, but it was expensive and the calibration of the instruments was troublesome.

4. Methods of plotting data. (Appendix VI.)—The PRESIDENT called on Col. Gold to give an account of the international proposals.

Col. GOLD said that the question of the method of plotting data was part of the discussion of methods of forecasting because it depended on the method of forecasting used. In making a forecast (apart from single observer forecasting) one must diagnose the existing situation and its recent changes, and to do this one must see the information in relation both to the rapidity of the changes and to the density of the stations. With only a few stations it might be undesirable to give as much detail as would be given with a larger number of stations; and with only one chart a day it was not worth while giving as much detail as with frequent charts.

These considerations led to a question on which it was very difficult to get a unanimous opinion, namely, whether all the information should be set out on one chart or whether several different charts should be used. The British system was a compromise. It was desirable that the Conference should come to some conclusion on the matter because the method of plotting must depend on the choice that was made. If only one chart were used it would be necessary to adopt an abbreviated method of plotting and the symbols must be small, but if several charts were used the need for small symbols was not so essential; moreover different colours might be adopted for indicating different régimes on the charts as had been done in France.

Another question was whether each service should adopt the system best suited to its special purpose. In years gone by that would undoubtedly have been the best solution, but with the coming of aviation and at a time when pilots were flying all over the Empire it was essential to have uniform charts and uniform symbols and a method of plotting that was similar in all countries. One solution was to prepare two types of charts, one on a uniform system for aviators and others for local use, but this increased the work considerably, and in any case it was necessary to agree upon the common system.

From the international point of view the Commission for Synoptic Weather Information had endeavoured to arrive at a system that would meet all needs. In devising the system the influence of the European countries had inevitably been predominant but it should be possible to use it in any place where observations are made and reported in accordance with the international scheme. The method was set out in the Report of the Commission (Secretariat O.M.I, No. 19) and inevitably looked complicated. It provided for pressure, temperature, barometric change, wind, weather, cloud amount and height, and humidity—if the method of frontal analysis were used all this information was necessary. In the system devised by the Commission some of the symbols, for example, that for continuous heavy snow, appeared complicated. But the complicated symbols were those which were most rarely used, but which when they were used were of outstanding importance so that it was desirable that they should be conspicuous on the chart. The principle adopted was that the information of most importance should stand out most clearly.

Col. Gold said that in its broad features the system would be supported at the forthcoming international Conference, but that some points gave rise to considerable difficulty.

Cloud amount and rain.—The difficulty arose here because the international symbol for rain was a black circle or dot: but many services had for many years used that symbol for an overcast sky and were unwilling to change their practice. The British method was to use a circle for the position of the station with a number of lines across it to indicate cloud amount—four lines indicated overcast sky. One of the reasons given for adhering to the black dot as representing overcast sky was that when a small circle was used for the station, as was the practice in New Zealand and in Bergen, it was difficult to draw lines across it. To show the cloud amount it was easier to blacken quadrants of the circle, blacking the whole circle to indicate overcast sky, with a smaller dot by the side for rain. This practice was at variance, however, with the principle that the more important information should be the more conspicuous.

Wind force.—In the British system an arrow was used with a number of feathers corresponding with the wind force on the Beaufort scale. In the new scheme a short feather corresponded with force 1 on the Beaufort scale, a long feather with force 2, two long feathers with force 4 and so on. This method reduced the number of feathers, but represented a considerable change in British practice and also probably in that of many other services.

Barometric tendency.—Another point of variance which affected especially the temperate zone was the colour to be used for barometric tendency. The British practice was to show rising tendency in red and falling tendency in black; the reverse method was the one suggested for international adoption, partly because red was universally used as a danger signal and was, therefore, more appropriate for falling pressure.

Fronts.—The system of presentation on which international agreement was sought included also a method of showing fronts by colours on manuscript charts and by circles and arrows on published charts. A system of this kind had never been put forward before but would obviously be a great improvement.

In conclusion, Col. Gold urged that it would be a substantial advantage if the British delegates could go to Warsaw with a common policy.

Mr. JEFFRIES (Hong Kong) expressed approval of the proposal to represent rain by a black dot.

Dr. KIDSON said that it would undoubtedly be a great advance to have a uniform system. Meteorologists in tropical countries would want supplementary charts, but that need not interfere with the general scheme of getting the international information on one chart. He pointed out that the Norwegian system was devised in a country very similar to New Zealand—a mountainous country, and one which experienced rapid changes of weather that could not be ignored. Such countries needed a close network of stations, and the general tendency was to increase the closeness of the network and to plot the data on a small scale. For many years a black dot had been used as a symbol for rain and had been found useful because it represented an important observation; but frequently the reports from Australia gave no rain at the actual hour of observation though rain might have occurred at other times of the day; in such conditions there were advantages in having a conspicuous symbol for overcast sky. For that reason he thought it might be necessary to have two systems for plotting cloud amount, but if the Conference came to a definite decision New Zealand would try to adopt it.

Mr. STEWART said that he thought it should be possible to get agreement on the points raised by Col. Gold especially as it was only a question of how the elements should be represented and not of what should be represented. He had used a black dot for rain for many years and thought it was undesirable to use the same symbol in different sizes for different elements.

He thought that the representatives from tropical countries would recognize that the European services had had considerable experience in synoptic work, and that they would not lightly set aside recommendations that were the results of this long experience.

Dr. SCHUMANN said that in South Africa a red dot was used to represent rain, but that the international system would be adopted as soon as finality had been reached.

It was agreed that a Sub-Committee should be appointed of those representatives who were going to Warsaw and that a meeting should be called for Friday morning, August 16, at 10 a.m. It was desirable to get as close agreement as possible, but not to adopt any formal resolution. [*See* p. 101.]

The meeting adjourned at 1 p.m.

(Signed) J. PATTERSON.

MINUTES No. V

Fifth Meeting, Wednesday, August 14, 1935, 3 p.m.

The following delegates were present:—Mr. J. Patterson (Canada), *President*, in the Chair, Lt.-Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Capt. A. Bertram Smith (Trinidad), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Dr. M. A. F. Barnett and the following members of the staff of the Meteorological Office, London—Lt.-Col. E. Gold, Mr. H. W. L. Absalom, Dr. C. E. P. Brooks, Mr. R. Corless, Mr. F. Entwistle.

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1. **Charts** were exhibited from Canada, Egypt, Great Britain, India, New Zealand and Southern Rhodesia.

2. **Documents circulated.**—Minutes of the first and second meetings (Minutes Nos. I and II).

3. **Methods of plotting data.** (Appendix VI.)—The discussion begun at the meeting in the morning was continued.

Dr. Normand (India) said that Col. Gold had explained the need for standardization of the method of plotting, and for aviation it was obviously desirable that the working charts should be readily interpreted, but he was doubtful how far it was desirable to go beyond that point. There were two aspects to be considered. In India all the data received were not plotted on the main working chart, and even with that practice the draftsman could not keep pace with the telegrams; to increase the number of items on the main chart would obviously increase the delay in its completion—he might call that the time-aspect. The second was the space-aspect, namely that on the chart of the scale 1 to 10 million, the symbols as set out on Col. Gold's specimen would occupy the equivalent of a 100 mile square and in many parts the stations were only 70 miles apart. He wished to make it quite clear that he hoped in spite of these difficulties that India would be able to follow closely any international recommendations that may be passed.

Mr. Sellick (Southern Rhodesia) said that he thought the symbols for cloud amount were more complex than could be readily shown, especially that for cloud greater than 9 and less than 10. Such information was of little use to the forecaster though it might be important for a pilot. He was doubtful whether the information could be shown on a chart of 1 to 5 million, especially by services without a trained draftsman. Mr. Sellick said that after consultation with Mr. Walter 1,200 gdm. had been adopted as the datum for drawing isobars over the African plateau. He asked further whether any agreement had been reached as to the interval for which isobars should be drawn.

In reply, Sir George Simpson said that the figures in the code were all considered necessary and no symbol had been proposed that did not represent a code figure. He thought the question of the isobaric interval might be decided by the separate services. In Great Britain a 2 mb. interval was used irrespective of the scale of the chart. With regard to the question of plotting the data he said that in London until recently plotting had been done by one of the senior scientific officers, but that it was gradually being transferred to trained draftswomen and such a practice might ultimately be necessary in other services.

In general he was opposed to stereotyping the methods to be used because it gave less elasticity and reduced the possibility of making experiments, but he thought that the time had now come when stereotyping the code was necessary. The International Meteorological Organization however, had no legislative powers and gave all services latitude to adopt their own methods. He thought the symbols should be regarded as shorthand and it was desirable that all should use the same method. He pointed out that the question of the height to which pressure was reduced affected the codes as well as the charts.

Mr. Stewart said that in Malaya he had found no difficulty about the time taken in drawing a chart in accordance with the new method. He said further that with stations 50 miles apart he was able to get all the symbols entered on a chart of 1 to 9 million.

Mr. Patterson said that at present Canada was not concerned because America was still using a word code. If a new code were adopted he would then try to follow the standard international practice.

With regard to the height to be used for observations in the upper levels Col. Gold said that the standard international heights were, mean sea level, 1,000 m. and 2,000 m. and that it was advisable to adopt those heights if possible. They involved reduction of pressure over a height interval of not more than 500 m. though in the case of charts for sea level a reduction over an interval of 800 m. was permissible.

Mr. Walter (East Africa) said he was willing to draw charts for international levels if he could find a sufficiently accurate method of correcting the pressure, but so far he had been unable to do so. For that reason he had been compelled to adopt the level of 1,200 gdm. and to choose his barometer stations as nearly as possible at that level.

Mr. Sellick (Southern Rhodesia) agreed with Mr. Walter and said that after eight years' experience he had found it impracticable to reduce pressures to a level of 1,000 m.

With regard to the correction of pressure to sea-level in the tropics Mr. Stewart said that in the case of two high level stations he had found it possible to get pressures consistent with sea-level values when reducing from 180 m. but not when reducing from 300 m.

Mr. Patterson said that the problem was a very real one. It had been studied many years ago by the U.S. Weather Bureau and they adopted what was known as a "plateau correction" for stations even as low as 300 feet or 400 feet above sea level. He added that in Canada the temperature used for the reduction was the mean of the value at the time of observation and at 12 hours before that time.

Mr. Sellick said that according to a recent study the Weather Bureau were also using maps at 5,000 feet. Mr. Patterson replied that this was only for the mountainous regions.

Dr. Normand said that pressures in India were reduced to sea-level, and when large discrepancies occurred the pressures were checked by examination of an auxiliary chart giving departures of pressure from normal.

4. **Scales, projections, relief, etc., for synoptic charts.** (Appendix VII.)—Sir George Simpson said that at the previous Conference certain broad principles were laid down with regard to the scales and projections to be used and it would be of interest to know what the experience of other countries had been with regard to them.

Mr. Sellick said that he had little to add to his memorandum (Appendix V (*c*)). In Southern Rhodesia he was using charts of a scale of 1 to 20 million and 1 to 5 million on a conical projection. The objections to a cylindrical projection were very great in the case of charts which had to cover the whole of Africa. Mr. Walter agreed.

Col. Gold said that a Sub-Commission of the International Meteorological Organization was considering the question of projections and that Dr. Hesselberg was the representative of the Commission for Synoptic Weather Information on that sub-commission. He suggested that Mr Sellick might get into touch with Dr. Hesselberg.

Mr. Churchill (Nigeria) said that at a recent Surveyors' Conference the question of the projection for a map to cover the whole of Africa was considered and information might be obtained from the Director General of the Ordnance Survey or from the War Office.

Mr. Patterson reported that a new map for the Canadian region had been prepared in accordance with the principles laid down at the last Conference, with standard parallels at 30° and 60°. The map had been produced by the Surveyor General. The distortion in the south was less than 2 per cent and in the north about 5 per cent. Elevations were shown by tints. (Appendix VII (*a*).)

Dr. Normand said that new maps had also been prepared in India in accordance with the recommendations of the last Conference, they were drawn roughly in the Meteorological Office and were then produced by the Photo-zinco Drawing Office.

It was reported that the maps used in the Meteorological Office in London were usually produced by the Map Section of the Air Ministry which acted in conjunction with the Ordnance Survey.

5. **International Code, 1929.** (Appendix VIII.)—The President, introducing the discussion, said that at present Canada was concerned only with the Marine code and that that was working satisfactorily.

Col. GOLD wrote down the two forms of international code.

(i) IIIC_LC_M wwVhN_L DDFWN BBBTT U$C_H$abb RRjjj*

(ii) IIIU wwVC_LN_L DDFWN BBBTT RRjjj*

The first was the general form and the second was intended for those countries who could not give sufficient information for the first. In practice it was chiefly tropical countries that used the second form. It was suggested that delegates should state what changes they wished to introduce and that a sub-committee should then be formed to consider the details.

Mr. WALTER (East Africa) said that the suggestions put forward in his memorandum (Appendix VIII (*a*)) were only tentative and he was quite willing to consider other proposals. He would like it to be recognized that a code devised for temperate regions was not always suitable for the tropics. At present many codes were in use in different parts of Africa, and considerable confusion resulted.

Mr. STEWART said that, as stated in his memorandum (Appendix VIII (*b*)), Malaya used the first form, but did not want all the information it contained. His primary requirements were (1) an accurate measure of dew-point or of something from which it could be derived, (2) the direction of low cloud, and (3) the time of commencement of rainfall. In practice for internal use this information was added at the end of the message but it would be better for it to be incorporated in the code. At recent Conferences both Java and Siam had expressed their agreement as to the additions that were needed. In countries where Asiatic observers were employed mistakes would arise if they were asked to use more than one code. He hoped shortly to be able to draw a map for a wide area around Malaya so that now was an appropriate time to get additional information that was required to insure that the new map should be as complete as possible.

Mr. SELLICK said that the first form of code had been adopted in Southern Rhodesia using the groups up to the end of group 4. Additional groups were added containing dew-point (which was essential as half the forecasts were based upon it) and maximum and minimum temperatures. He said that he would prefer that the code for C_L and C_M should be simplified to a one figure code; in its present form it was suited especially for the temperate zone and was too complicated for use by untrained observers.

Dr. NORMAND said that India received little information from other countries and transmitted even less, so that he had not much experience of the code, especially since the broadcast from Karachi had been discontinued. After 1929 they had recast the Indian internal code to include the three main groups of the second form of the international code, and information was also obtained of humidity (2 figures), direction of motion of low and high cloud (2 figures), maximum and minimum temperatures, and the time of commencement not of rainfall only but of the phenomena reported in ww. He expressed himself in agreement with Mr. Stewart's requirements.

Col. GOLD said it would be easier to agree to replace U by two figures rather than to endeavour to get humidity expressed as dew-point.

Mr. CORLESS said that more than a year ago the British forecasters had asked for two figures for humidity as it was used to determine the position of fronts.

Mr. PATTERSON said that the American code gave dew point because it was of importance for forecasting fog and in summer for the issue of forest-fire hazards. Time of rainfall was also an important item in order to show how fast fronts were travelling, and intensity of rainfall had also been found useful. He thought it would be valuable if these could be added to the international code.

It was agreed that the details of the code should be considered by the representatives of the tropical countries in consultation with Col. Gold. [*See* p. 102.]

The meeting adjourned at 4.50 p.m.

(Signed) J. PATTERSON.

* The letters are used with their standard meanings which are given in such publications as Publication No. 9 of the International Meteorological Organization, or Annex G of the International Air Convention, or Meteorological Office, London, Publication, M.O.252.

The PRESIDENT announced that arrangements had been made for a photograph of the members of the Conference to be taken at 1 p.m. on Friday, immediately after the morning meeting.

A visit to Croydon aerodrome had been arranged and the party would leave the Meteorological Office, South Kensington, on Thursday afternoon, August 15, at 3 p.m.

MINUTES No. VI

Sixth Meeting, Thursday, August 15, 1935, 11 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Mr. W. H. Beckett (Gold Coast), Lt.-Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. P. E. L. Gethin (Tanganyika), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Cmdr. G. S. Ridgway (Bermuda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Capt. A. Bertram Smith (Trinidad), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Dr. M. A. F. Barnett, Prof. D. Brunt and the following members of the staff of the Meteorological Office :—Lt.-Col. E. Gold, Dr. F. J. W. Whipple, Mr. H. W. L. Absalom, Mr. R. Corless, Mr. F. Entwistle and Cmdr. L. G. Garbett.

It was announced that a Meeting of the Sub-Committee appointed to consider the symbols for the representation of synoptic weather information would be held on Friday, August 16, at 10 a.m. It was hoped that time might be found then to consider also the code for tropical countries. All delegates who wished to attend would be welcome.

1. **Documents circulated.**—Minutes of the third meeting.

2. **Value for forecasting of observations from ships and of upper air data.** (Appendix IX.)—The PRESIDENT asked Mr. Corless to open the discussion.

Mr. CORLESS said that in Great Britain the value of observations from ships was very great. Weather came from the west so that observations from the ocean on the west were necessarily important. On some occasions secondary depressions formed rapidly at the end of the occlusion of the primary, and if these depressions formed on the south-west of Ireland a gale might be blowing in full force before the forecaster was aware of the existence of the depression; a ship's observation would be invaluable in such a case. The system of selected ships had been extremely successful up to a point, especially as the reports came according to a definite roll-call which was broadcast each day. The reports were received at Portishead in rapid succession, and all on the same wave length; they were sent from there by land line to the Air Ministry, and so reached the forecaster before the time of the morning observations on land. They were not quite synchronous with the land observations, but one great advantage of receiving them early was that they could be included in the synoptic message which was picked up by Paris. The accuracy of ships' observations was extremely high, and Capt. Brooke Smith had been very active in investigating any doubtful values. The barometric tendencies were used after correcting them for the ship's motion according to a simple method, and these also had proved of great value.

With regard to upper air observations it was the practice to enter temperature against height, and wind against height, and also to plot the temperature on a diagram with co-ordinates of log (absolute temperature) and log (pressure). Tephigrams were also plotted on a form which was modified from that described by Sir Napier Shaw in Vol. III of the "Manual of Meteorology." In summer the tephigram was valuable for examining the stability or instability of an air column and getting an estimate of the probable maximum temperature of the day and hence forecasting thunderstorms. In winter it was used mainly for giving the position of a sloping front.

Maps of the upper air were published with isobars for the levels of 1 and 2 Km., and on these were plotted observations from pilot balloon, aeroplane and radio-sonde, and data from mountain stations. Temperature observations were received from about 12 stations of which one was in Great Britain. The run of the isobars was determined mainly from the winds supplemented by one pressure value from Duxford. Specimens of the *Upper Air Supplement of the Daily Weather Report* were circulated and also of the pilot-balloon form.

Cmdr. GARBETT stated that instructions were included in H.M. Ships Sailing Orders and in Admiralty Fleet Orders and Station Orders that weather reports should be made to the Meteorological Office, London, and to other shore services.

Mr. SUTTON (Egypt) asked whether the Italian ships on the regular service between Italy and Egypt gave regular meteorological reports; he had not been able to pick them up in Egypt. Dr. NORMAND said that in India reports from Italian ships were received as an addressed message, and Mr. STEWART said that the same was true in Singapore. Sir GEORGE SIMPSON said that the policy that had been adopted was that no ship should send an addressed message without a definite request from the Meteorological Service that required it; as far as he knew British selected ships were the only ones that simply broadcast C.Q. messages. He thought that the Egyptian Service would experience no difficulty in arranging for addressed messages to be sent from Italian ships if they were required. Mr. SUTTON said that some Greek ships issued C.Q. messages.

Col. GOLD said he wished to support all that Mr. Corless had said with regard to the value of upper air observations and would emphasize particularly the importance of humidity in the upper air. Without humidity the information required for determining conditions of instability was incomplete. He described the system used in the British service for plotting humidity; it was a method due originally to Dr. Normand. Additional lines were drawn on the tephigram giving the water vapour content of the atmosphere; and, by a simple method of plotting, the maximum water vapour content of the atmosphere at any point of the ascent was determined. In considering the diagram it was assumed that as the air became warmer it would run along the dry adiabatic until it reached the line corresponding with the maximum water vapour content. The air would then move along a saturated adiabatic. If the curve representing the observed values fell below this saturated adiabatic there was instability, and the area of the curve below the saturated adiabatic gave a measure of the amount of instability.

In reply to Mr. Patterson, Mr. CORLESS said that no use had been made in Great Britain of the diagram devised by Prof. Rossby, though it had been studied and discussed. The main reason for its not being used was that one of its co-ordinates was specific humidity—a quantity difficult to measure at low temperatures.

Mr. PATTERSON said that in Canada the Rossby diagram was plotted every day, but that in winter its use was limited. He cited an interesting case of an occasion at Toronto when during an ascent a hair hygrometer showed almost no change of humidity, while the wet bulb as long as it was ice-covered showed rapid changes, first a decrease and then an increase. Apparently a hair hygrometer was of little use for temperatures lower than 10° F. The Rossby diagram used co-ordinates of specific humidity and potential temperature and was valuable for showing the amount of moisture that was available for rain.

In Canada, values of temperature and humidity at different levels had also been found useful for indicating the type of air mass. A change of temperature at say 2 Km. might indicate a change in air mass. By plotting a vertical section across the continent over a distance of some 3,000 miles it was possible to trace the changes and movements of the air masses. The great problem in Canada was how to get the data plotted in time to use them for the synoptic work. Observations were available from about 20 stations of the U.S. Weather Bureau, of which some were from the Army, Navy, and Air Force, and the rest were obtained by contract with a commercial company. In Canada, observations were obtained for a purely nominal fee from the Toronto Flying Club, acting on a voluntary basis. There was usually one morning flight reaching 7,000 or 8,000 feet.

Dr. SCHUMANN (South Africa) said that he might be able to obtain observations from a single station at Pretoria and inquired as to the value of such observations. In reply, Mr. PATTERSON said that at Boston the Massachusetts Institute of Technology had been making aeroplane ascents regularly to 15,000 or 16,000 feet,

and had received the observations by radio from the machine. These observations had been found useful though naturally ascents over a wide area would be more valuable.

Mr. SUTTON (Egypt) asked where a description of the Rossby diagram could be obtained, and Mr. Patterson offered to send a specimen of the diagram and a description of it to any delegate who would care to have one. Dr. KIDSON added that Prof. Rossby would no doubt send a copy of his publications upon request.

Col. GOLD said that in his opinion the tephigram was superior to the Rossby diagram because it was based on exactly those elements which were observed, namely, pressure, temperature and wet-bulb temperature. No computation of any kind was required. If height were reported by the observer it must be obtained by some artificial computation, the element observed was pressure, and in his opinion it was, therefore, better to plot the pressure values.

Prof. D. BRUNT asked Mr. Patterson what was done in Canada with upper air temperatures when humidity observations were not available. The Rossby diagram used as a fundamental variable the specific humidity which was the worst determined of all variables. The main difference between the Rossby diagram and the tephigram was that in the former the water content lines were equally spaced. But the tephigram could, if desired, be used in precisely the same way as the Rossby diagram. The best procedure was to plot dry- and wet-bulb temperatures on the tephigram, using the ideas due to Normand mentioned by Col. Gold. When humidity observations were not available, the dry-bulb temperatures could still be plotted. The Rossby diagram was used for computing the equivalent potential temperature, but the equivalent potential temperature was a one-valued function of the wet-bulb potential temperature, and the latter could be read off from the tephigram directly, so that the tephigram appeared to be the most convenient form for plotting.

Mr. PATTERSON in reply said that the method of plotting was still only in the experimental stage. At Toronto humidity was obtained from the dry- and wet-bulb temperatures, but in the United States a hair hygrograph was used. The tephigram had not been used in Canada mainly on account of lack of staff.

Mr. SELLICK said that he was intending to start observations of upper air temperature in Southern Rhodesia during the next twelve months, and would be glad to know from those who had experience in the matter what was the best type of instrument to use. It was difficult to know what the reading of an aneroid barometer would mean if it were exposed in the cockpit of an aeroplane travelling at 120 m.p.h.

Dr. NORMAND (India) referred to a letter which Mr. J. S. Dines had written to *Nature** about 10 years ago proposing a method for entering humidity on the tephigram. The method was in effect a Rossby diagram if the isohygric lines and the dry potential temperature lines were regarded as the main co-ordinates. He said that personally he preferred to plot humidity from the wet bulb rather than from the dew point. He showed how by a simple method of plotting it was possible to find which layer of air would give the greatest energy if it ascended.

With regard to the value of upper air temperatures in synoptic work, Dr. Normand said that in India such observations were available at only two stations, Peshawar and Quetta, both of which were near the edge of the map. Their value was therefore limited, but he hoped to be able in due course to get observations from more representative stations.

Upper winds had, however, proved of considerable value, and two examples of their use were described. The first was an occasion in July when the surface map for the morning showed no indication of a depression, while the upper winds gave a definite circulation over south Bengal. There was a depression at the level of 1 or 1½ Km. which had formed in the upper air before it was shown on the surface. It appeared on the surface chart on the next day. The second example was during the cold months. North India was then covered by a layer of air in which conditions were controlled almost entirely by radiation; so much so that on some occasions the temperature at Delhi was lower than at Simla some 6,000 feet above the plain. The top of this cold layer was marked by a layer of haze with a definite upper surface, and it was observations above this surface that were required.

* *Nature, London*, **116**, 1925, p. 709.

Sir George Simpson described the experience of Great Britain with regard to upper air observations. With regard to the radio-sonde which had been developed by Moltchanoff in Russia, Duckert in Germany and Idrac in France, he said that though it had proved fairly satisfactory the values obtained had not been found to be sufficiently accurate for synoptic work. Moreover, it was expensive to use and troublesome to calibrate; in addition to the cost of the instrument itself, a large balloon was required, and it had to be sent up by a meteorologist and listened to by radio. In his opinion the aeroplane was the only means of getting accurate observations. In practice considerable difficulty had been experienced in getting an aeroplane for meteorological observations, and it had been found impracticable to get regular observations from the R.A.F. in the ordinary course of their work. The solution arrived at was to have a definite meteorological flight with the same observers making ascents each day. The meteorological flight at Duxford comprised two flying personnel (one officer and one sergeant), two or three permanent mechanics and two or three aeroplanes. The aeroplanes were chosen so that they could ascend rapidly and to great heights. The expense of high flights was greater because oxygen and electrically-heated clothes were required. It was only within the last few years, after the Office had had considerable experience in using the results, that they had really been able to say that the expense was justified. He felt that ascents from different pilots at different times were of limited value but that it was a question for each service to decide.

Mr. Walter (East Africa) asked Dr. Normand what was the minimum height in tropical regions at which observations were of value. He thought that with large planes going up to say 11,000 feet and reporting by wireless it should be possible to get observations of value. In his opinion the time had come when observations from aeroplanes might be collected in much the same way as observations from ships.

Mr. Stewart (Malaya) thought that near the equator if observations could be obtained they would be useful, but the difficulties referred to by Sir George had been obvious also in Malaya. It was difficult to ask for observations unless there was evidence that they would be of value. He had managed to arrange for a limited number of ascents which were at first made on international days and were now made once a week; some 200 observations had thus accumulated. They were not used for synoptic work, but they were studied in connexion with the synoptic charts, and it was hoped by that means to accumulate sufficient evidence of their use to justify asking for more frequent ascents.

Mr. Patterson said that with regard to the cost of aeroplane observations it had been estimated that for ascents by the Royal Canadian Air Force the out-of-pocket expenses, excluding the cost of machines and the salaries of the personnel, would be about £1,600 a year at ordinary stations and more than double that amount at remote stations. He hoped soon to be able to get daily values up to 15,000 feet.

3. **Organization of synoptic messages in south-east Asia.** (Appendix X.)—The President asked Mr. Stewart to submit an additional report for inclusion in the Minutes.*

4. **Dissemination of information to the public, seamen, airmen, farmers, etc.** (Appendix XI.)—Dr. Schumann (South Africa) inquired what was the practice in other countries with regard to broadcasts addressed only to a special group of people—the case he had in mind was that of citrus farmers in South Africa who required forecasts of frosts.

Mr. Patterson said that in Canada forecasts were issued of conditions suitable for spraying. They were sent to the centre of the district where they were required and broadcast from the local station there. In the case of fruit growers in British Columbia who required forecasts of spring frosts, two local forecasters were sent to the area and a forecast was broadcast locally in the evening in sufficient time for heating to be started. (Appendix XI (*a*).)

Mr. Corless said that in Great Britain forecasts were made for the herring fishing fleet by arrangement with the Ministry of Agriculture in London and the Fishery Board of Scotland. A special message was broadcast from the local broadcasting station, and very favourable comments on its value had been received.

* The Report of the Sub-Committee which considered the subject is printed on pp. 104–5.

Dr. Kidson said that in New Zealand forecasts of frosts for fruit farmers were sent to the Broadcast Board and broadcast locally.

With regard to the relation of the Meteorological Office with the British Broadcasting Corporation, Sir George Simpson said that after some preliminary difficulty it had been arranged that the weather reports should be broadcast in the exact words in which they were received from the Meteorological Office. All the weather information broadcast by the B.B.C. was obtained from the Meteorological Office, and no charge was made.

Mr. Jeffries (Hong Kong) said that he had experienced similar difficulties to those described by Sir George, but had found them fairly easy to put right, and he thought Dr. Schumann would have little difficulty in dealing with the South African B.B.C., which he understood was being taken over by the South African Government.

Sir George Simpson spoke of the desirability of publishing daily observations from synoptic stations, and referred to the resolution on the subject in the "Report of the Commission for Synoptic Weather Information" (Zurich, 1926, M.O. 293, p. 14). The British practice was to publish almost a complete set of data on the back of the *Daily Weather Report*; in many countries the telegrams were published in coded form. He thought it was essential to publish also the daily observations of upper air temperatures and pilot-balloons and he recommended this practice to those services who were beginning upper air work. In his opinion the value of the data well justified the expense involved.

With regard to the circulation of publications, Mr. Stewart (Malaya) asked whether other services liked to receive daily weather reports from countries on the other side of the globe.

Sir George Simpson explained that the tradition was that every organized meteorological service issued a complete set of its publications to every other organized service. This practice had recently been somewhat modified and certain publications had more limited circulation. The Meteorological Office sent every year to all recipients a list of the publications they received and asked them to certify that these publications were still required. If the certificates were not returned, the issue was discontinued.

Mr. Patterson said that a similar practice was adopted in Canada, but the list was revised only every 2 or 3 years. He said that in view of what had been said about publication of data on the daily weather reports he would try in future to include in the report as much of the weather data received by telegram as possible.

Dr. Schumann (South Africa) said that he would be very glad to receive from the directors of meteorological services a list of their publications.

5. **What use is made of the collective messages issued from Rugby?**—Mr. Sutton (Egypt) said that the message was used in Egypt but did not quite replace the messages that used to be received direct. For south Europe it was an improvement on the old system, but that was not true for the central Mediterranean.

Mr. Patterson said that although several attempts had been made by the wireless station at Toronto to pick up the Rugby message it had been found impossible to do so on account of interference. Sometimes they were able to get a message fairly complete but at others there was so much interference that it was impossible to decode the message. The cost of transmission of the collected message from Louisburg, the most powerful of the Canadian stations on the Atlantic coast, was prohibitive, and as a result arrangements had been made to receive from the Weather Bureau at New York about 23 specified European stations and two to four ship reports from the eastern half of the Atlantic in the American word code. The complete copy of the Rugby broadcast was received frequently by mail from the United States Weather Bureau. It was found not infrequently that it was difficult to decode the complete broadcast as received by mail from Washington as some of the letters were out of place in the body of the message, making it very difficult to get the right sequence afterwards.

These reports were used to compile the northern hemisphere map of which a copy was on exhibition. Combining them with the Newfoundland, eastern Canada, Greenland and ship reports from New York, it was possible to draw a fairly satisfactory map of the Atlantic and western Europe. During the few trans-Atlantic flights in which Canada had had the responsibility of forecasting, the reports had been indispensable. Occasionally inquiries were received regarding Atlantic weather. The reports were also of value as providing information with regard to disturbances that might be developing or passing off from the eastern coast.

He said that it was considered desirable to have rainfall included in the Rugby broadcast if it were possible. It was also felt that reports from Siberia, even if they were received a day late, would be most valuable especially in connexion with the weather of western Canada.

Dr. Normand said that the observations from Siberia might occasionally be of use in India in winter but the cost of receiving reports by wireless was large.

Mr. Corless said that the Siberian message was sent from Moscow and it might be possible for India to receive the full message from there rather than the abbreviated message from Rugby. With regard to the difficulty in reception of the message in Canada he pointed out that it was sent out on many wave lengths, including two short wave lengths which were transmitted on high power.

With regard to the suggestion that rainfall should be added Sir George Simpson said that in this country there was considerable interest commercially in the observations of rainfall in America and it might be useful if the information could be added to the message from Arlington. Mr. Patterson said he would be glad to consider this proposal and suggested that Mr. Gregg and Mr. Kincer of the United States Weather Bureau should be consulted.

Col. Gold thought there would be no difficulty in adding the rainfall to the Rugby message by supplementary groups at the end.

6. Exchange and facilities for training of meteorologists within the Empire. (Appendix XII.)—Mr. Patterson (Canada) referred to the difficulty with which all meteorological services were faced in obtaining trained staff. The general practice was to recruit men with an honours degree in mathematics and physics and for the meteorological training to be given in the Meteorological Office, after appointment. This scheme had many disadvantages. Through the initiative of Professor Burton of the Toronto University, arrangements had been made for a one-year graduate course in meteorology which included the physics and mathematics that were specially applicable to meteorology. The meteorological part of the course was given by the staff of the Toronto Office. The scheme had been in operation for two years. In the first year three graduates took the course, and in the second year, five. It was gratifying that one of these had recently received a Beit scholarship in Great Britain.

Of the three graduates trained in 1934 all had been taken on the staff of the Meteorological Office but there was no undertaking that posts would be found for them there. Meteorology was receiving increasing attention in high schools and graduates who had taken the meteorological course and obtained posts as high school teachers could do much to spread meteorological knowledge in schools.

Sir George Simpson explained the attitude of the Air Ministry with regard to the training of meteorologists from other countries. A large number of applications were received in the Air Ministry for training of various sorts and certain rules had been drawn up by which a subscription was paid for the training. The position with regard to the meteorological training was that the Office welcomed anyone sent from one of the meteorological services of the Empire for say 3–6 months to learn the methods of the London Office for the advantage of the service to which he belonged, and in such a case no fee was charged. In the case of someone coming definitely for training, in order to improve his own meteorological knowledge, the Air Ministry ruling was that a fee should be charged. He added that he was always willing, by arrangement with Professor Brunt, for pupils from the Meteorological Department of London University to see the working of the Office.

With regard to the possibility of exchange of members of the staff with those of another Office, Sir George said that while he was very much in favour of it in principle he thought that in practice it was unworkable.

Mr. Stewart (Malaya) said that the difficulty of training assistants was very great in a small service. When drawing up regulations for new entrants into the Malayan service he had specified an honours degree in mathematics or physics or both and a period of from 4–6 months' training in the Meteorological Office in

London ; for that training a fee was paid by the Malayan Government. In the course of the next year or two he might need two or possibly three new meteorologists so that the problem was a very present one.

Mr. Stewart asked whether it would be possible for new entrants to the Malayan Service to be trained in the Department of Meteorology of the University of London under Professor Brunt. If that were possible he would change the regulations and say that candidates for admission must have a degree and attend a course approved by the Director of the Meteorological Office. In Malaya appointments must be made from London and one advantage of a compulsory course of training was that the candidate could be rejected if he appeared unsuitable.

Prof. Brunt said that his experience in the University was limited to one year. In the normal way students were post-graduates taking a two-year course for an M.Sc. degree. The M.Sc. degree could be obtained either by examination or by research in a suitable subject approved by the Professor. The syllabus of the examination included the subjects covered by the book on Physical and Dynamical Meteorology which he had recently published, with the addition of statistics, atmospheric electricity and methods of plotting. The College could also accept graduates as candidates for the D.I.C. which had the same standing as the M.Sc. but might be obtained in one year. The normal course ran from October to June. He could take students for a shorter period but he would recommend that they should take the full course and they would then have a good working knowledge of meteorology.

He hoped in course of time to change the regulations for the M.Sc. in order to ensure that graduates who obtained that degree should be compelled to have a good general knowledge of the subject in which they qualified, and not only of one special part of it. His suggestion was that the first year should be taken up with the general course, followed at the end by a written examination, and that the second year should be devoted to writing a dissertation on some aspect of the work to which the candidate could make some contribution. He attached some importance to the guidance which should be given to research students.

Dr. Schumann (South Africa) said that he gathered from Sir George's remarks that it would be difficult to arrange an exchange of staff with Great Britain, though he appreciated the facilities which were offered. He hoped that in view of what was said in Mr. Patterson's memorandum that it might be possible to arrange some exchange from South Africa with Canada, or some other service of the Empire. He had recently received the sanction of the South African Government to arrange such exchanges with services in the British Empire for periods not exceeding 18 months. The travelling expenses and salary would be paid by the South African Government provided the meteorologist so exchanged returned to the South African service for a period of three years afterwards.

He was therefore in a position to arrange such an exchange and would be glad of an opportunity of consulting individually with other Directors.

Lt. Cmdr. Butler (Nigeria) said that Nigeria was considerably extending its meteorological work and it had been suggested that a number of selected officers should take a short course in meteorology during their leave period. He wished to know whether arrangements for such a course would be possible and what the fee would be.

Sir George Simpson said he would do his best to make arrangements for such a course. The exact terms would be a matter for consultation.

Prof. Brunt said that he anticipated no serious difficulty in giving assistance in training especially if there were a number of men requiring it. He said that the University could take students who had passed their inter B.Sc. before entering ; such students took their degree examination in two years and might qualify for an M.Sc. after their third year. He thought there would be little difficulty in getting such men to study meteorology in their third year if he knew what vacancies for meteorologists there would be.

Col. Gold said that whatever practical difficulties there might be in the way of arranging the exchange of staff in the Services he thought the time had come when the problem must be viewed from the point of view of the development of aviation. It was not a question of merely who would gain, the gain in the long run was bound to be reciprocal, but it was important that in each service there should be a nucleus of men who had an intimate knowledge of the conditions, methods of work and publications of the other services. Such a knowledge would very much facilitate the combined work of the services. He thought Mr. Patterson's proposal ought to receive serious consideration quite apart from the point of view of individuals and individual services. He thought the exchange should be for a period of two years.

Mr. PATTERSON said that he had not yet approached the Canadian Government. Some of the younger meteorologists in his service had taken a year's leave and travelled at their own expense in order to get a wider knowledge of meteorological practice in other countries. He thought it would be very advantageous especially for aviation if such an exchange could be arranged. He thought the Canadian Government would be sympathetic.

The meeting adjourned at 1.25 p.m.

(Signed) J. PATTERSON.

MINUTES No. VII

Seventh Meeting, Thursday, August 15, 1935, 3 p.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Lt.-Cmdr. S. H. Butler, R.N.R. (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A. E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Capt. A. Bertram Smith, R.N.R. (Trinidad), Mr. C. D. Stewart (Malaya), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Dr. M. A. F. Barnett, Prof. D. Brunt, Lt.-Cmdr. T. R. Beatty, R.N., and the following members of the staff of the Meteorological Office :—Mr. E. G. Bilham, Mr. J. S. Dines, Mr. F. Entwistle, Cmdr. L. G. Garbett, R.N. (retd.).

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1. **Documents circulated.**—Report of the Sub-Committee appointed to consider the meteorological organization required for the Khartoum–West Africa Air Service.

2. **Meteorology and military operations.** (Appendix XIII.)—The PRESIDENT called upon Mr. Entwistle to introduce the discussion.

Mr. ENTWISTLE referred to the memorandum (Appendix XIII) which had been circulated and said he would deal only with the information required for military purposes. This might be considered under three heads :—

(1) *Information for gunnery.*—He said that in section 3 of the memorandum was an account of the specialised work carried on at Shoeburyness where accurate observations of wind were made by the 2-theodolite method. The information for field work was less exact, and in the past instructions had been prepared in London for the use of the meteorological stations both in Great Britain and abroad where information was required.

The pamphlet (M.O. 317) dealing with " The supply of meteorological reports to artillery units " enabled meteorologists to supply from observations of pilot-balloons and upper air temperatures the information that was required for artillery purposes. The pamphlet was regarded as confidential and was not circulated outside official services in the British Empire. The computations were facilitated by special pilot-balloon forms. Copies of the forms were circulated.

There were seven places where information of this type was required for coast defence, viz. (*a*) Gibraltar and Malta, which were the concern of the Home Government, (*b*) Aden where at present there was no meteorological station, the observations being made by the R.A.F. and the calculations by the gunners. (It would be of interest to know what prospect there was of the meteorological station at Aden being re-opened), (*c*) two stations in Ceylon, (*d*) Singapore, (*e*) Hong Kong. The normal practice was for the artillery units to apply direct to the meteorological service for the information they required.

(2) *Information for acoustical purposes.*—For this purpose information was required regarding the vertical distribution of both temperature and wind. In this

connexion the War Office had asked for detailed observations from Singapore and Hong Kong. The information required was set out in section 4 of the memorandum, it comprised a year's observations with records of temperature at three heights up to 150 feet, upper wind observations as high as possible, upper air temperature and humidity by aircraft and the normal ground observations. Observations were required at night as well as by day. Special equipment was needed, and he would be glad to know how far Hong Kong and Singapore could supply the information asked for.

(3) *Smoke screens.*—Two factors were important, namely, the variation of temperature with height and the variation of wind with height. The information was very much specialised. He would ask as many countries as possible to supply any information they had, or could obtain, especially with regard to types of wind structure, the diurnal variation of wind, gustiness, and the diurnal variation of temperature. The observations which were asked for from Singapore and Hong Kong for acoustical purposes would be of use also in connexion with smoke screens.

The observations would be useful, not only for the military operations themselves, but also for research into the meteorological conditions affecting these types of operation.

Mr. Entwistle referred to two papers published as *Geophysical Memoirs* of the Meteorological Office which would be of interest to those concerned with the micro-variations of wind and temperature in the lowest layers of the atmosphere ; the first No. 46 in 1929 by N. K. Johnson on " A study of the vertical gradient of temperature in the atmosphere near the ground," and the second No. 65 in 1935 by A. C. Best "Transfer of heat and momentum in the lowest layers of the atmosphere." The latter gave an account of recent work, and of the methods used for obtaining the information detailed in section 5 of the memorandum (page 128).

Mr. Entwistle said that the last part of the memorandum referred to the Meteorological Reserve. This Section of the R.A.F. Reserve had been in existence for some years, and received the usual Reserve training once a year. Most of its members were recruited from the staff of the Meteorological Office, but this was not altogether desirable. There was no doubt as to the importance which meteorology would assume in war time, and the staff of the office might then be required for other purposes.

Mr. Entwistle asked how far meteorological training was given in other countries to people outside the meteorological services, and how far people who were experienced in meteorology were available for enlisting in a Meteorological Section.

In reply to a question by Mr. PATTERSON as to what training was required by a Reservist, Mr. ENTWISTLE said that the observers would be similar to the lower grades in the Meteorological Office and the officers would be trained meteorologists. Sir GEORGE SIMPSON said the main qualifications were enthusiasm and patriotism. He thought there would be no difficulty in recruiting members of the Reserve if its existence were more widely known.

Prof. BRUNT pointed out that the weighted temperatures set out on Table III of M.O. 317 were drawn up when observations were lacking, and the " Hints " were based on the experience of middle latitudes. He asked if Mr. Entwistle could give subsidiary hints for the establishment of weighted temperatures in other latitudes.

With regard to the provision of a meteorological station at Aden he thought such a station was desirable in the interests of gunners and naval units and especially in relation to the use of smoke screens. For this purpose the information that was most important was the time in the evening at which the lapse rate disappeared and was replaced by an inversion, and the length of time that the inversion persisted in the morning.

Dr. KIDSON said that ballistic winds and ballistic temperatures were supplied to the Army in New Zealand.

Mr. PATTERSON said that the artillery in Canada had asked for pilot-balloon equipment, but had not asked the Meteorological Office for other information. He thought it might be possible to organize an auxiliary corps in Canada which should receive training in meteorology.

Mr. JEFFRIES said that Hong Kong had been mentioned as a place from which much would be required. His experience at present was that there was some confusion among those who put forward the requests there, as to what exactly was wanted, possibly because the personnel changed rapidly.

He thought the scheme would have more chance of success if it were put forward by either the Meteorological Office or the War Office. He would be glad to discuss the matter with Mr. Entwistle, and would like to obtain a detailed list of the requirements that he might lay before the Hong Kong Government. Some help was already given to the artillery in Hong Kong.

Mr. WATT said that in Australia a considerable amount of information was already supplied to the army, for example, ballistic data for artillery practice, notes for the Field Service Pocket Book and meteo-telegrams to two forts. At present there was a scheme for meteorological training.

Dr. NORMAND (India) said that the station at Aden had been in operation for two years but was closed when retrenchment became necessary. He thought there was little chance of its being re-opened unless the question were raised officially. In India, ballistic information was supplied to the artillery by the Meteorological Offices at Peshawar and Quetta.

3. **Meteorology for the Navy.** (Appendix XIV.)—The PRESIDENT asked Cmdr. Garbett to give an account of the Meteorological Organization of the Fleet.

Cmdr. GARBETT said that as the members of this Conference were probably aware the Navy attached great importance to meteorology in connexion with all the operational work carried out in the Fleet. Fleet meteorology therefore included not only marine meteorology, but meteorology as applied to gunnery and chemical defence and aviation meteorology in all its branches.

Many of H.M. ships carried aircraft, and Fleet Carriers each carried a number of aircraft.

The Naval Airman had a particularly difficult task operating over the sea from a moving base. If one imagined a number of aircraft released from one carrier all operating in different directions and having to find their way back to their base, which might have moved a considerable distance in the interval and which even under good weather conditions was only visible up to 10 or 15 miles away, one could appreciate the importance to the Fleet of weather information in that connexion alone and the necessity for a meteorological organization in the Fleet itself.

Mr. Patterson in his Presidential address had referred to the Memorandum on Fleet Meteorology discussed at the last Conference in 1929, in which Cmdr. Garbett had asked for the co-operation of the Meteorological Services in the development of a Meteorological Organization in the Fleet on all stations. In this connexion two main points were emphasized:

(1) The need for uniformity of practice on all stations.

(2) The necessity for close liaison between the meteorological services of the Empire and the Fleet.

As a primary and essential step towards securing this uniformity and close co-operation, conferences had been convened by the Naval Commanders-in-Chief on the various Naval Stations, which the Directors of the local Meteorological Services and others were invited to attend. Those representatives of the Dominions and Colonies who attended these conferences would no doubt recall, as he himself did, the cordial atmosphere of the discussions and the mutual help afforded on all sides. As the representative of the Meteorological Office and the adviser to the Commander-in-Chief he had had a special responsibility and could not miss the opportunity of expressing very great gratitude for the help and encouragement which he had received from the directors and staffs of the Meteorological Services and the representatives of the local Governments with whom he came in contact. Without their co-operation it would have been impossible to establish a uniform organization throughout the Navy such as now existed or to arrange for that mutual exchange of services which had been of such benefit to the Fleet, and also he hoped to the Meteorological Services concerned.

Cmdr. Garbett said that during the last six years there had been a considerable expansion of the meteorological organization of the Fleet and the objective to establish a forecasting service within the Fleet, which the Meteorological Office in close co-operation with the Admiralty set out to attain, had now been achieved. He added that the active interest in Fleet meteorology taken by successive Hydrographers of the Navy had been an essential factor in the successful development of that service. H.M. ships as they came in for long refits were having meteorological offices constructed in them and the necessary meteorological instruments installed, and by the end of 1936 there would be established in no less than 24 of H.M. ships a fully equipped meteorological office in charge of one or more officers qualified in meteorology.

In the memorandum (Appendix XIV) which had been circulated he had set out the development which had taken place, and he again asked for the co-operation of the shore meteorological services in further development especially in connexion with war organization. The memorandum was divided into six parts.

Part 2 dealt with the meteorological organization within the Fleet and the only sections in that part to which he need refer were sections (*d*), (*g*) and (*h*). Section (*d*) dealt with personnel for meteorological duties. Up to three years ago the policy had been to train executive officers for meteorological duties and practically all the meteorological officers in the Fleet had been Naval Observers. These officers were considered to be particularly suitable to perform the meteorological duties in ships, for from the nature of their duties in the Fleet Air Arm they acquired a considerable amount of practical experience in the application of meteorology in the operation of aircraft. It became increasingly difficult, however, to release observers to go through a meteorological course or to give time to the duties when appointed, and it was necessary to select some other type of officer. Navigating and Surveying Officers and non-specialist Officers could not normally spare sufficient time from their ordinary duties to undertake the duties and in all cases of executive officers they would be unlikely to be available for meteorological duties for more than six or eight years. The policy now was to train the Instructor Officer in meteorology, and in future the Instructor Branch would provide the majority of the officer-personnel for meteorological duties in ships. Officers of this branch had a scientific training prior to entry into the Navy, and an honours degree, and with the meteorological training obtained in the Meteorological Office should eventually provide good forecasters for the Fleet.

Sixteen Naval Instructors had now qualified and it was proposed to qualify twelve annually. A few observers would still be trained in meteorology and from time to time officers of the Royal Indian Navy and Royal Australian Navy attended the courses. In three or four years' time there might be as many as 70 scientific officers trained in meteorology and practical forecasting in the Fleet. He thought that would be an asset to the progress of meteorology generally.

With regard to the second paragraph of section (*g*) relating to upper air observations, it might be of interest to delegates to know that observations of upper winds were still being received from H.M. ships from all parts of the world at the rate of 1,000 per annum. There were now in the division 4,000 observations. Unfortunately it had not yet been possible to prepare these data for publication, although it was hoped to do so in the near future.

The subject of liaison with Shore Meteorological Services was fully explained in the memorandum, and Cmdr. Garbett said he had nothing to add on that subject.

Parts 3 and 4 referred to the co-operation with Shore Meteorological Services and the completion of peace organization on stations abroad. Cmdr. Garbett said he had already referred to the Naval Meteorological Conferences which were held on the different naval stations. One of the most important results of the conferences from the naval point of view had been the introduction on all Naval stations of a Fleet synoptic message in a standard international form broadcast in most cases from a naval wireless station. In all cases it was not possible immediately after the Conference to institute this message but it had now become world-wide, as would be seen from the table given in Part 3 of the memorandum. It was particularly satisfactory to note that from September 1, 1935, synoptic data, etc., from Bombay and Calcutta, would be issued from the naval wireless station at Matara in addition to that from Colombo and the message would be as recommended by the East Indies Station Conference. In the Halifax broadcast there had been a misunderstanding in the form of the message, for which he took his full share of the responsibility. He was glad to say that from July 22 the message would be in the Fleet Synoptic Form. Although no Naval Meteorological Conferences had been held on the Australian and New Zealand Stations the standard form had now been adopted on these stations also, and he congratulated Dr. Kidson and Mr. Watt on introducing it. He added that on September 12 a Fleet synoptic message for the eastern Atlantic would be issued from the Admiralty wireless station at Cleethorpes. The Fleet synoptic message uniform on all stations was of benefit to the Navy and he was indeed grateful to those Directors who had made its introduction possible.

Cmdr. Garbett then referred to Part 5, Meteorological problems of importance to the Fleet. Visibility was one of the most important meteorological factors affecting Fleet operations and the fighting range of the Fleet depended on it; the accurate forecasting of visibility was therefore of paramount importance.

He said that in the Navy considerable attention was given to air mass and frontal analysis and this method was used whenever possible in the forecasting work of the Fleet. Very little as far as he knew was published regarding air masses typical of the eastern part of the world and the work of the forecasters was much handicapped in consequence.

It would be of great assistance to the Fleet if the Meteorological Services would direct particular attention to the investigation of these problems and make their conclusions available to the Navy. He reminded the delegates that at the Naval Meteorological Conferences the Commanders-in-Chief on all stations agreed to give facilities for shore meteorologists to go afloat if called upon to do so.

Single Observer Forecasting was another difficult problem confronting the naval meteorologist, for observations available when a forecast was required might be very meagre or even in time of war non-existent. An investigation into that problem was being undertaken in the Meteorological Office and in 1932 Lt. Cmdr. Beatty prepared a report which was published by the Meteorological Office and copies sent to the Directors of the Meteorological Services co-operating with the Fleet. These Directors were asked to contribute reports on the use of this method of forecasting in their respective areas. Out of thirteen services approached eleven had sent replies, and he was very grateful for their assistance. It was now proposed to prepare a further report on Single Observer Forecasting and he hoped that the meteorological services of the Empire would give attention to this problem.

In Part 6 reference was made to the preparation of naval handbooks on local meteorology. Naval officers carrying out meteorological work in the Fleet had for a long time past felt the need of comprehensive handbooks on the local weather of the stations on which they were situated, and the Meteorological Office had undertaken to prepare such handbooks. The handbooks would give a synopsis of all available information on local weather likely to be of assistance in forecasting. It was not proposed to enter into any theoretical discussions in these books. The Mediterranean Handbook was being compiled by Dr. Harwood who was for many years Superintendent of the Malta Meteorological Office; it was commenced at the beginning of 1934. The China Seas Handbook was being prepared by Lt.-Cmdr. Dodington who had spent two or three commissions on the China Station as meteorological officer in the aircraft carriers *Argus* and *Hermes*. The typhoon section of that handbook had been completed, and he hoped it would shortly be made available to the China Station.

The handbooks would be divided into three parts, the first part would give an account of the general weather conditions over the different areas of the station, the second part would deal with particular districts and the harbours within that district used by the Fleet, and the third part would be on forecasting. The lay-out of the Mediterranean Handbook had been drawn up and he had available for inspection the " bulk-form " of the Forecasting Section with examples of the text, analysis and charts (Part III), and also a Section of Part II.

Cmdr. Garbett asked for co-operation in the completion of the handbooks, and that delegates who were prepared to assist should visit the Naval Division when the whole scheme could be discussed in detail. In general, the co-operation required from shore services would comprise such items as :—

(1) The compilation of special statistics for the handbooks (examples were given in the draft of the Mediterranean Handbook).

(2) The provision of information regarding local weather, including the selection of charts illustrating certain types of weather, special phenomena, etc.

(3) The critical reading of the draft when it was available.

The PRESIDENT asked Lt.-Cmdr. Beatty to speak about his work on Single Observer Forecasting.

Lt.-Cmdr. BEATTY said that in 1932 the Naval Division had asked for and had received great help from various Empire meteorologists, but there were still a few blank areas left in the oceans.

The reason for the importance of single observer forecasting was that all over the world there was now a network of weather messages broadcast by wireless, but in war this system would be curtailed and so naval officers would have to depend entirely on the resources of their own ship alone, i.e. act as single observers. Even in peace time single observer forecasting was often practised when broadcasts were missed owing to atmospherics and skip-distances and also in adapting general forecasts to local conditions.

In the North Atlantic single observer forecasting depended on air masses and fronts about which much information was available, but more information was wanted from the other oceans. It would be of interest to know whether the weather there depended on air masses, either of the monsoon or trade wind type or of the type more familiar in England, viz., polar and tropical air, and if so, what were the signs available to the single observer of the setting-in of these winds or of their temporary slackening or freshening. Information was also required about local changes of weather such as local fogs, land and sea breezes, katabatic winds, clouds, and coastal mist and rain. Local proverbs were also of interest.

There were Naval officers studying this problem in all oceans, but they were cruising in different areas and had not the same opportunity of making useful discoveries as an observer stationed at one spot on the coast throughout a succession of seasons.

Coastal weather was of great importance to the Navy owing to the needs of navigation and the fact that naval actions were often fought in coastal waters.

Lt.-Cmdr. Beatty said that a copy of the report of his early investigations into single observer forecasting had already been issued. It was desired to issue a revised copy and to include the information for which he had just asked. Finally, he said that the Naval Division would like to be informed of even small details of weather, as such details might often be useful in single observer forecasting although they were not of importance in synoptic work.

Mr. JEFFRIES (Hong Kong) said that he had listened with great interest to Cmdr. Garbett's account of the organization in the Fleet and had noted the requests for additional information. He would be glad if arrangements could be made for copies of the upper air observations to be sent to the local shore services. He understood that a large number of ascents had been made, but so far he had not been able to obtain the results of a single ascent.

Cmdr. GARBETT said that there should be no difficulty in obtaining the results through the liaison officer, but he would take steps to see that copies of the observations on the China station were forwarded to Mr. Jeffries.

Dr. KIDSON (New Zealand) congratulated the Naval Division on the successful organization of their work in its comprehensive nature.

He said that the Navy had always been very helpful in New Zealand and willing to assist, and it was largely due to Naval initiative that so good a reporting service had been established with islands of the western Pacific. Officers concerned with meteorology in all the vessels at present in New Zealand waters had visited the Meteorological Office at Wellington in order to get in touch with local conditions and to offer any assistance in their power.

He was of the opinion that in the case of actual hostilities meteorology in the Fleet would have to be taken over by civilian officers. The Naval officers, though their knowledge of meteorology would still be producing its effects, would probably be required for other duties. He wished to know whether this aspect of the question had been studied.

In Part 5, section (*b*), of the memorandum there were some references to air mass and frontal analysis. There was no doubt that, wherever it was possible, it would be of very great importance to determine the properties of air masses, the distribution of temperature and water vapour in them, and so on, by means of actual observations in the upper air. But there were many regions, and the New Zealand area was one of them, where there was no prospect of obtaining anything like a complete record of the properties of individual air masses. No doubt, in time it would be possible to obtain some idea of the characteristics of certain types of air masses and the range of variation to be expected, but in any actual situation the meteorologist would have to try to gauge the structure of the atmosphere by a process of induction. A great deal could be learned from surface observation. At present he felt that it was not desirable, so far as the Australia–New Zealand area was concerned, to classify and label many different types of air masses. Indeed, there had been too much of this in other regions. So far he had used only the terms " cold " and " warm." Surface observations would usually enable cold and warm air masses to be delineated, or rather one of the boundaries between them, with fair accuracy. They would also give much information regarding their stability or instability, moisture content, the cloud structure in them, and whether subsidence was taking place or not. Air masses in the region of New Zealand would, he thought, usually be found to be of composite origin and structure. They must grade fairly rapidly one into another and their character would frequently change rapidly. He doubted whether the visibility would be so constant a feature as appeared to be anticipated. There would certainly be a wide range in each of the main types.

It was mentioned in Part 5, section (*b*), that very little if anything, had been published in certain countries regarding the typical air masses. This was hardly a fair statement so far as concerned New Zealand, which was included in the list. They had supplied the Royal Navy and the Royal Australian Navy in Australia and New Zealand with a number of publications dealing with the analysis of weather charts. They themselves were only learning by degrees and this fact was reflected in their publications, but in the most recent, at any rate, considerable advances had been made, and he had little doubt that they would at least keep pace with the Fleet's powers of absorption.

In reply to Dr. Kidson, Cmdr. GARBETT said the Instructor Officers could be employed on meteorological duties even in war time ; 100 or more qualified meteorological officers would eventually be available. He thanked Dr. Kidson for the co-operation which had always been received from the New Zealand Office. He regretted that he had omitted to mention the publications on air mass analysis to which Dr. Kidson referred, they had been received after his original memorandum was written.

Capt. BERTRAM SMITH (Trinidad) said that one of the recommendations resulting from the Conference on the West Indies station was that observations from the West Indies should in war time be sent both to Bermuda and Toronto. In accordance with that recommendation Trinidad had now established an observation station, and reports were sent to the U.S. Weather Bureau station at Porto Rico. He had reason to believe that some islands had no observation station under British control, but were controlled by the U.S. Weather Bureau who supplied the instruments.

Cmdr. GARBETT said that the question had been considered by the Commander-in-Chief of the America and West Indies Station who had discussed it with the Governors of the islands, but conditions were not visualised which would lead to cessation of the reports from the U.S. Weather Bureau.

Mr. PATTERSON said that the Canadian Service would be glad to give what assistance it could.

It was agreed that a Sub-Committee should be appointed to consider the meteorological requirements of the Fleet in war (*see* p. 105).

4. **Instruments.**—*Barometers suitable for use in tropical highlands.* (Appendix XV.) Mr. SELLICK (Southern Rhodesia) described the difficulties he had experienced in getting sufficiently sensitive and accurate barometers and said that he had asked for the question to be put on the agenda paper in the hope of getting the benefit of the experience of other meteorological services. At present he was using comparatively cheap foreign barometers but would prefer to use British instruments if a satisfactory type could be obtained.

In reply to a question from Mr. Patterson, Mr. Sellick said that the Kew-pattern barometer could not be relied on to less than 0·3 mb. The readings showed a very large lag and the instrument required very vigorous tapping to get accurate readings ; another difficulty arose from the fact that if it were moved out of the plumb it took a long time to settle down. It was a station barometer not one of the marine type.

Mr. J. S. DINES said he thought Mr. Sellick was possibly expecting greater accuracy from the Kew barometer than was obtainable. The certificate issued by the National Physical Laboratory did not claim an accuracy greater than 0·2 mb. He thought that the correction to sea-level or to " plateau level " would give rise to more uncertainty than an error in the reading.

Mr. SELLICK said that with the cheap French barometers at present in use in Southern Rhodesia which were tested in Salisbury and then transported to the outlying stations he was dissatisfied if on further testing at the same station the error were greater than 0·1 mb. He thought that if barometer readings were not accurate to less than 0·2 mb. it would be better to design some other means of measuring pressure.

The question of the correction for temperature was discussed, and it was mentioned that the accuracy of this reading was only 1 or 2° F. and that in itself might give an uncertainty in the barometer reading of about 0·2 mb.

Mr. SELLICK described further difficulties with the Fortin barometer owing to the flattening of the meniscus which was due apparently to fouling of the surface. The barometer he referred to was a Negretti and Zambra instrument about seven years old ; he said the meniscus was so flat that it was rare to be able to see daylight between the meniscus and the vernier. The vernier graduation was 0·1 mb.

In reply to a suggestion from Mr. Bilham that the troubles might be due partly to the violence of the tapping, Mr. Sellick said that the tapping was resorted to because the more the barometer was tapped the closer were its readings to those of the standard Fortin instrument. The Kew barometer to which he referred was not a recent pattern but was bought more than ten years ago. The casualties to the instruments during transit were so great (about 75 per cent) that their purchase had been abandoned.

Mr. PATTERSON said that barometers of the Kew type had recently been introduced throughout the Canadian service, but the filling of the tubes was done in the Toronto Office. On one occasion the mercury had shown a flat meniscus for no apparent reason but, when the top of the tube was heated and the mercury was driven about 6 inches down the tube, the meniscus recovered. For filling the barometer tube a diffusion pump was used together with heaters and the mercury was distilled into the tubes. He thought that in the earlier barometers the capillary tube was perhaps too small.

Mr. DINES also thought that the difficulty might be in the constriction of the tube. In the Tonnelot barometer the tube connecting the cistern with the top chamber was of about ¼ inch bore and there was no constriction. Most Fortin barometers had unconstricted tubes while Kew barometers had a small tube 1 or 2 mm. in diameter connecting the top chamber and the cistern. In this respect therefore the Fortin and Tonnelot barometers were of similar construction. Perhaps that partly accounted for the good agreement between their readings.

Mr. BILHAM pointed out that marine pattern barometers had finer tubes than those of the station pattern and were designed to have a lag of about 4½ min. The lag of a station pattern Kew barometer should not be more than 30 sec.

Mr. PATTERSON said that in his experience a comparison of readings of constricted and unconstricted barometers showed no appreciable difference.

Mr. STEWART said that in Malaya he had recently changed from Fortin barometers to Kew barometers, but had not detected any difference in the readings. In Malaya the lag was not likely to be great. He had found the Kew pattern barometers to be easily transported.

Mr. DINES said he would be glad to arrange for a consultation with the instrument maker if any delegates desired it.

Standardization of meteorological instruments.—Mr. Dines referred to his memorandum (Appendix XVI) on the subject which described the recent work of the Meteorological Office in standardization. The chief direction in which this had been carried out was in the time scale. Two scales were now adopted for the daily and two for the weekly records. This change had paved the way to the standardization of clocks and would help considerably towards avoiding difficulties of replacement. He had specimens of the standard clocks in the Instruments Division and would be glad to show them to delegates.

With regard to the finish and weather-proofing of instruments in general he said that iron and steel had been almost entirely eliminated. Where steel was required to give the necessary strength stainless steel was always specified.

Cellulose enamel had been found satisfactory for coating the instruments but he could not claim to have found a finish that would remain for ever in perfect condition without attention. He did not think such a finish existed.

Mr. SELLICK asked for advice with regard to paint for thermometer screens. The asbestos roof had been found to be a great improvement but the question of the paint still needed attention.

Mr. DINES said that the subject was at present under consideration by the Instruments Division ; experiments on different types of paint were being made but no completely satisfactory type had been found up to the present ; in any case he was not sure that experience in Great Britain would be the same as that in tropical countries.

Mr. STEWART thought that all services would benefit from the steps taken towards standardization and said that he had suffered considerably from the lack of it. One notable example was that of pressure tube anemometers ; the floats of these instruments were not interchangeable even in the case of instruments bought at the same time. In one case the rod of one instrument would not even go into the collar of another. With regard to weather-proofing he said that even copper corroded. On the east coast of Malaya the strong winds of the NE. monsoon evidently carried up the spray and records from that coast were found to be in error. This had happened in no less than six cases. The trouble had been traced to the float which had become corroded and punctured, presumably on account of some chemical action at the soldered joint. He thought the salt must have blown into the tube and set up some sort of electrolytic action. The difficulty had been overcome by putting in a tap and emptying the container every week.

Mr. DINES said that the float rods of anemometers had only recently been standardized. He emphasised that the use of distilled water was essential if corrosion were to be avoided.

With regard to the Stevenson screen Mr. ENTWISTLE stated that a wide variety of patterns seemed to be in use in different countries.

Mr. DINES said that the British standard had been well known for nearly 20 years and he thought there should be no difficulty about it. A few small improvements had been introduced but the changes made no practical difference to the readings.

Sir GEORGE SIMPSON said that comparisons of various screens had shown that the size of the screen made little difference to the readings, and even the colour of the paint had little effect. He referred to a small screen recently designed by Mr. Bilham.

Dr. KIDSON (New Zealand) congratulated Mr. Dines on the many improvements he had introduced. He hoped that Mr. Dines would see his way to introducing stainless steel into the clock because much trouble had been experienced in the tropics from clock failure.

He said he thought that at the previous meeting Sir George Simpson had not done full justice to the radio-sonde, he thought it had a very valuable future and to many services it seemed to offer the only prospect of getting upper air temperatures.

Mr. BILHAM referred to the standardization of sheathed thermometers. The sheathed thermometer had been in use in at least one Colonial service before it was adopted in this country. The sheath was a great advantage, complete protection was now obtained with no possibility of movement and the dimensions had been considerably reduced. It was on that account that he had been led to design the small screen to which Sir George had referred. Mr. Bilham added that he hoped other Services would consider the advantages of the sheathed thermometer.

Mr. SELLICK said it had been adopted in Southern Rhodesia but he had had to cancel the orders on account of the large number of breakages.

Mr. PATTERSON said that one order for grass minimum thermometers had arrived in Toronto safely but on distributing them to the stations most of them were broken in transit. He had had no trouble with breakages of sheathed thermometers.

He said he had also experienced difficulty with maximum thermometers, which in some circumstances seemed to act as ordinary thermometers. The difficulty was not in the age of the thermometer but he thought it might be due to exposure to temperatures much below the freezing point causing some change in the constriction of the tube. He thought it would be desirable to have some standardization of the constriction, and also with regard to the shaking required to bring the index back to zero.

The meeting adjourned at 5 p.m.

(Signed) J. PATTERSON.

After an interval for tea an informal discussion on instruments continued.

Mr. J. S. DINES gave a short description of the work of the Committee of the British Standards Institution on drafting thermometer specifications and explained that the draft specification of sheathed thermometers which had been issued would be reconsidered and a final specification drawn up when communications had been received from the different services to which it had been circulated.

(Signed) J. PATTERSON.

MINUTES No. VIII

Eighth Meeting, Friday, August 16, 1935, 11 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Lt.-Cmdr. S. H. Butler, R.N.R. (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Cmdr. G. S. Ridgway, R.N. retd. (Bermuda), Dr. T. Schumann (South Africa), Sir George Simpson (Great Britain), Capt. A. Bertram Smith, R.N.R. (Trinidad), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Dr. M. A. F. Barnett and the following members of the staff of the Meteorological Office :—Mr. R. G. K. Lempfert, Lt.-Col. E. Gold, Dr. F. J. W. Whipple, Mr. E. G. Bilham, Capt. L. A. Brooke Smith, R.N.R. retd., Mr. J. S. Dines, Mr. F. Entwistle and Cmdr. L. G. Garbett, R.N. retd.

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1. **Documents circulated.**—Minutes of the fourth meeting.

2. **Instruments (continued).**—The discussion of instruments was continued from the previous meeting.

Methods of generating hydrogen.—The PRESIDENT called on Mr. Walter to give an account of the apparatus he had devised for generating hydrogen.

Mr. WALTER said that in East Africa he had been faced with the difficulty of providing hydrogen for pilot-balloon work to widely scattered stations where the transport of cylinders was expensive and often impracticable. Some method of generating hydrogen on the spot was essential, and the aluminium caustic soda method used originally in Egypt and Ceylon had been adopted. At first the method used was quite primitive and some rather bad accidents had occurred ; they had then adopted a more complicated system with generators costing about £30 each. Certain precautions were taken by inserting a pressure gauge and a double arrangement of cocks for introducing the caustic soda.

As a result of the experience thus gained he had been led to devise a simpler method which was based on the use of " Siko " pressure cookers. These cookers were manufactured in Germany. They were tested for high pressures and were sold in Nairobi for household purposes, so that they were quite safe. The result had been very successful, and it had been found possible to dispense with the heating of the caustic soda altogether. The cooker was sold in standard sizes. Certain modifications were made to the manufactured article—a pressure gauge was substituted for the safety valve, the gas was conducted off from the side of the generator as high up as possible. The washing drum consisted of a 12-gallon Texaco oil drum, and all the fittings were standard-size water piping which could be obtained all over the world.

The cost of the cooker together with its adaptations was about £5.

The procedure was very simple. A strong solution of caustic soda was made and was put into the generator cold, the aluminium was then dropped in. As the action was not very rapid at first, there was time to screw down the lid. If the pressure became too high the lid was raised and the gas escaped without interfering with the filling of the balloon. The gas began to come off freely after 5 or 10 minutes, and when the process was complete the whole generator could be put into a pail of water, thus avoiding the trouble experienced if caustic soda were allowed to remain on the metallic parts of the apparatus. The reason for using the aluminium caustic soda process instead of the silicol caustic soda was the difficulty of transport by sea of the silicol.

The aluminium was obtained from the cuttings of sheet aluminium used in the manufacture of box-body motor cars in Nairobi. It was comparatively cheap (about 35 cents a pound), and if some were required urgently at any station it was light and could be easily and cheaply transported by air. A stock of caustic soda was kept at the pilot-balloon stations, and, to prevent its losing strength after it was opened, it was put into milk cans and then sealed. The quantities of aluminium and caustic soda required to fill one large and two small balloons were approximately 9 oz. of caustic soda and 11 oz. of aluminium. The practice of East Africa was to send up one small balloon for aviation purposes and follow it by a larger one for greater heights if necessary.

Mr. Walter asked whether Mr. Dines could arrange for a Siko cooker to be on exhibition for those delegates who were interested.

Mr. Sutton said that in Egypt cylinders were usually used, but a generator had been made for use where it was impracticable to transport cylinders. His experience with generating hydrogen had been similar to that of Mr. Walter, namely, that to ensure safety the plant had been made heavier than was necessary, resulting in inconvenience in transport and high cost. A two-way tap had been fitted to the top of the collector thus ensuring at all times an exit for the hydrogen. A balloon was fitted to each tap. The generator was connected to the washing container by a thick rubber tube. There was a safety-valve but it was considered unnecessary. An excess of aluminium was always used, the excess being recovered and used again. The caustic soda solution was first heated by a large primus, the flame put out and the primus removed, the aluminium (strips of old mess tins, etc.), previously tied in convenient bundles, dropped in, and the quick-fitting screw cap put in position and then firmly screwed down. The hydrogen was tested for presence of air by taking a sample in a brass test-tube and applying a match, repeated if necessary until the characteristic pop was heard. The hydrogen, after passing through the washing container was dried by being passed through a chamber of cotton-wool fixed to the top of the washer, the two-way tap being mounted on the drier. An iron screw-plug in the bottom of the generator facilitated cleaning the generator after use. No difficulties had been experienced.

Mr. Grabham said that in the Sudan the method devised by Mr. Walter had been followed and much assistance had been received from Mr. Sutton. A difficulty arising from the uncontrolled generation of hydrogen into the balloon was that when the balloon had to be taken off, to test the lift, the hydrogen was being lost, and if a little more were required perhaps generation had ceased before the balloon could be connected again. To obviate these troubles a gasometer had been introduced. The generator supplied the gasometer, which had a capacity of about 750 litres. This gasometer was easily made by local blacksmiths in Khartoum. Probably it was best not to frighten them by attempting to explain the scientific purpose for which the outfit was required. The hydrogen passed through the washing chamber *en route* to the gasometer where it remained stored for at least 12 hours before use. Any spray in the gas had ample time to settle. A pump, about 3 inches bore, with a gland and an inlet tube was used to inflate the balloons. Either the graduations on the gasometer or the number of strokes of the pump served as indices of the quantity of hydrogen, and with a little practice the correct lift was attained at the first trial. With the gasometer, balloon filling was very rapid and convenient, and there was no mess. If there was a burst and a second balloon was required, it could be filled as easily as the first. Practically all the hydrogen generated was used and probably the gas was decidedly purer than that obtained by direct generation. There was less possibility of mixture with air.

Some aluminium obtained from local scrap had been quite satisfactory, but some lots had proved to be alloy and therefore useless. It had been found best to get scrap aluminium from England. Nine grams of aluminium and 13½ grams of caustic soda generate one gram of hydrogen.

Dr. Schumann (South Africa) said he was interested in the subject of generating hydrogen in view of the proposed establishment of a meteorological station at Tristan da Cunha.

Mr. Patterson said that hitherto in Canada cylinders had been used for hydrogen, but the cost and transport of hydrogen was very expensive. He had recently been engaged in designing a small outfit using electrolytic cells, with a commutator for rectifying the A.C. current, a suitable transformer, and a small gasometer. The balloons were filled by a small motor pump. Where electric current was available at the station it appeared that this would be a very economical method of producing hydrogen.

3. The method of making pilot-balloon observations, including the methods of computation. (Appendix XVII.)—The President called on Mr. J. S. Dines to introduce the discussion.

Mr. Dines said that the purpose of his memorandum was two-fold, in the first place to ensure that those services starting pilot-balloon observations might have some idea of the cost involved and of the time taken in making the ascents; and secondly, to assist in the comparison of different methods in use with a view to obtaining additional uniformity. The memorandum did not contain detailed instructions for making pilot-balloon ascents. Such instructions were available in draft and he hoped they would shortly be published.

Mr. Dines said that the Meteorological Office had had considerable experience with pilot balloons, especially during the war, and had evolved a method which he thought required the minimum amount of labour and time, though it was not necessarily the best for all parts of the world.

There were two points about which there were differences of opinion; the first, was in the method of working up the ascents, and the second, in the supply of hydrogen.

In Great Britain the working-up was carried out by slide-rule. The graphical method had the advantage of giving the path of the balloon, but it could not compete with the slide rule in respect of the time taken. Mr. Dines gave a demonstration of the method of working up the results by slide rule. He thought that the main cause of the hesitation shown in adopting it was that it gave a choice of two values, 180° apart, for the wind direction and the rules for deciding which was correct looked forbidding on paper. In practice, however, the choice became almost automatic.

With regard to the generation of hydrogen he said that in Great Britain gas cylinders were used, and were supplied also to the services for which the Meteorological Office was responsible in Egypt and Iraq. A hydrogen generator had been used at the British station at Fort Rae during the Polar Year, and a full report on the method used there had been obtained. The method had been successful in that all the ascents required had been made, but much difficulty had been experienced, and a study of the report had led the Meteorological Office to decide to continue the transport of cylinders to Egypt and Iraq.

The memorandum contained a figure for the cost of transport of cylinders from London to Basra. He thought that for stations in the neighbourhood of a sea-port the transport of cylinders was the better method, but for up-country stations the cost of land transport might be prohibitive.

He was much interested to hear the accounts already given by other speakers, and he emphasised the fact that the Meteorological Office would be very glad to have the experience of other services in the matter of generating hydrogen because, though that method was not likely to be adopted in Great Britain itself, the Office was frequently asked to give advice for stations overseas.

Mr. Jeffries (Hong Kong) asked whether Mr. Dines had ever considered the possibility of carrying the slide-rule method of computation a stage further. He said an assistant in the Hong Kong Observatory had devised a method, based on cotangents, of getting the direction and velocity very rapidly by slide-rule so that the results could be obtained within a minute of the end of the ascent.

Mr. DINES said that, in the early days, pilot-balloon computations were made with an ordinary 20-inch slide rule and that had been quite convenient ; the tables of double entry used in the Meteorological Office were also simple, and he thought the choice of method was a matter of individual preference.

Dr. WHIPPLE said that an additional scale would be required on the slide-rule to give the resultant direction and velocity, but that it could easily be added. The difficulty was that heights were given in feet, while velocities were required in miles per hour and not in feet per minute.

He was much gratified to hear Mr. Dines' approval of the pilot-balloon slide-rule. When it was first designed many years ago Mr. Cave and Mr. Dines who were asked to report on it at South Farnborough had not regarded it as desirable to make any substitution for the ordinary slide-rule. Sir Napier Shaw had, however, sent it to the instrument maker in spite of the report, and Dr. Whipple was glad that it had proved useful.

In reply to a question from Col. Gold about the price of hydrogen generated by the method described, Mr. WALTER (East Africa) said he was unable to give the exact figures though he could obtain them from Nairobi. The cost depended largely on the possibility of getting "scrap" aluminium cheaply. In Nairobi it could be bought at 35 cents (about 4½*d.*) a pound, but in some places it was as much as 1*s.*

With regard to the speed with which observations of pilot-balloons could be worked up, Col. GOLD said that a really expert observer could watch the balloon, enter the observations and have the results worked up at the end of the ascent. With two observers the telegram was ready for the artillery immediately the ascent was over.

Mr. PATTERSON said that in Canada a plotting board was used with tables prepared. The rate of ascent determined the unit of distance. For example, if the balloon rose at 180 m./min. then 180 m. would be represented by 1 cm. in plotting. Two men were employed, one took the observations and telephoned them to the other who completed the plotting while the ascent was being made. In winter the observer was protected by a box with a movable roof which could be opened as required. It was not necessary that two men should be exposed, and the plotting was done indoors.

The cost of hydrogen was £7 per 1,000 cu. ft. plus the cost of transportation, and was a large item of expenditure. That was the reason for trying to get a system of electrolytic production.

Mr. WALTER said that in East Africa velocities were obtained in metres per second and not in miles per hour. The rate of ascent was given in metres per 100 seconds, and a Venner stop watch with 100-second intervals was used so that by taking differences between successive distances the velocity was obtained directly in m./sec.

Mr. ENTWISTLE referred to the method used for adjusting the free lift of the balloon. Some years ago this was done by weights, but more recently a pilot-balloon filler with a valve was used, the filler having the desired weight. Balloons were made to a standard weight, and it was calculated that such differences as occurred in the weight had a negligible effect on the computed wind velocities. The use of fillers had certainly added to the speed with which an ascent could be made. One alleged difficulty was that observers might let go of the balloon during filling and the filler might be lost if the balloon were filled in the open air. If the filling were carried out indoors no such difficulty would occur. Mr. Entwistle gave a brief description of the type of filler used.

Mr. WALTER said that a difficulty occurred with fillers in cases when the balloons had deteriorated. It was then necessary to adjust the lift so that the balloons need not be fully inflated. In that case the lift had to be measured for each ascent, but that was not a long process.

Mr. STEWART said that fillers were used for pilot-balloon work in Malaya. He had had no difficulty with regard to the deterioration of balloons, possibly because they were kept for him free of charge by the Cold Storage Co.

Mr. PATTERSON said that in Canada an ordinary chemical balance was adapted for filling the balloon. The balloon was put on a special holder attached to one of the pans and weighed by moving the rider along the arm until a balance was obtained. Then a standard weight of 200 gm. was put on the other scale pan, and the rider adjusted to give the correct free lift. The balloon was very quickly filled and the balance had the great advantage that it could be used for any free lift desired instead of limited to one.

4. **Marine Meteorology.**—*The working of the scheme for wireless reports from ships.* (Appendix XVIII).—The PRESIDENT called upon Capt. Brooke Smith to give an account of the working of the scheme.

Capt. BROOKE SMITH said that in his opening address to the Conference the President had referred to the multiplicity of different requests to shipping for information of weather, currents, and ice before the first British Empire Meteorological Conference in 1929. Capt. Brooke Smith said that he would call the position regarding organized ships' routine wireless-weather-telegraphy prior to May 1, 1930, chaotic.

When the Conference of 1935 had examined the state of the voluntary work of the officers of British observing ships, and the influence that that work was exerting upon the merchant navies and the meteorological services of the world, he would be surprised if the delegates had not some of the same feeling of pride, which he as an officer of the British Merchant Navy had, in that great service, and in the humble part that the Marine Division of the Meteorological Office had been able to take.

He did not propose to speak at any length, because the position was clearly set out in Appendix XVIII, and in the literature referred to at the end of that memorandum. [The bibliography circulated at the Conference is not reproduced in this report.]

Judging from the other memoranda regarding marine meteorology he said that there was probably some misconception as to the intention of the British Meteorological Office regarding the service of British Selected Ships. He therefore invited the attention of the Conference to a notice which was being not only extensively circulated in print by *Admiralty Notices to Mariners* and by various other nautical authorities, at home and abroad, but which was also being brought daily to the notice of all ships registered in Great Britain and Northern Ireland, as they arrived in ports where the British Meteorological Office had its own nautical officers and merchant navy agents.

The notice was as follows :—

> "The Masters of all foreign-going British ships registered in Great Britain and Northern Ireland are requested to make routine wireless weather reports to all ships or the specified coast wireless stations, WHEN AND WHERE THERE ARE NOT SELECTED SHIPS to perform the service, following the procedure of British selected ships.
>
> "These reports made in conformity with the VOLUNTARY services specified in Article 35 of the Convention for Safety of Life at Sea, are of assistance to navigation, and to the respective meteorological institutions for many purposes.
>
> "The corps of Voluntary Marine Observers is requested to bring the above to the notice of officers of ships which are not in the fleet list published in the *Marine Observer*."
>
> (See also *Admiralty Notices to Mariners* week ending May 11, 1935, No. 19, page 8.)

Capt. Brooke Smith said that no less than 6,100 copies, of the pamphlet M.O.329, which contained the instructions and tables for coding, had been sold.

He had recently called upon the Shipowners' Associations of London, the Bristol Channel, Liverpool and the Clyde ; and his deputies had called upon the Shipowners' Associations of the Tyne and Humber ; and shipowners and their Marine Superintendents were now giving active support and encouragement to the masters, mates and wireless operators of their ships in carrying out this service in the interests of safe navigation.

Capt. Brooke Smith then referred to the Convention for Safety of Life at Sea and said that by encouraging and stimulating the services contracted for in Article 35, not only would shipping and seamen gain, but he believed that the meteorological services would stand to gain most and aviation would more readily receive the assistance which it needs from seamen.

The service was very old; it commenced when Noah sent out doves from the ark. There were some 3,500 British foreign-going ships, fitted with wireless telegraphy, registered in Great Britain and Northern Ireland.

Ships were fitted with wireless for their own purpose, in accordance with the provisions of the Merchant Shipping Act, and subject to the Board of Trade and G.P.O. regulations. Only one in every fourteen ships was fitted for long range transmission. This was one of the reasons why he had been persistent in asking Mr. Self if the policy of aviation was such as to harmonize with shipping, because, if it were in a shipowner's interest, he was more likely to fit his ship with long range wireless.

Capt. Brooke Smith then referred to a chart of the world on which flags showed the position at the moment of every British home registered ship fitted with long range wireless telegraphy. The chart was kept in his room and the movement of the ships was followed and an estimate made of their position at noon from day to day. He thought that by taking trouble now, in years to come the matter would become one of well regulated routine and habit in the merchant navy.

Capt. Brooke Smith then drew attention to another notice:

> "SHIPS' WEATHER REPORTS DESIRED FOR THE LOCAL PURPOSES OF METEOROLOGICAL SERVICES IN SOME REGIONS WHICH DO NOT COINCIDE WITH TIMES FOR OBSERVATION OR COMMUNICATION OF THE GENERAL WORLD-WIDE SCHEME.
>
> "If for local reasons, British ships are asked locally to report weather at times other than those of the routine times for British Selected Ships, they are requested to do so if convenient; but British Selected Ships, and British Ships carrying on the service where there are not selected ships, should in such cases also report at the routine times laid down, so that there may always be a service of routine weather reports made at schedule times for the benefit of navigation."

He hoped that by thus broadening the instructions of the British Meteorological Office to ships registered in Great Britain and Northern Ireland, not only would some of the criticisms received from overseas be met, but that it would result in the maintenance in its entirety, of the system of Selected Ships and the abundant service of reports where they were needed at other than the British world-wide scheduled times.

To the best of his belief, the British Selected Ships' instructions conformed to international agreement, and if the Conference would give its support by leaving these agreements as they were, he believed that in the next five years, the progress made towards the desired end of establishing a daily uninterrupted service of ships' weather reports in all parts of the seven seas, clear of the land, would be greater than it had been during the past five years. To make such a statement, one had to feel pretty confident.

Capt. Brooke Smith added that if any one desired to have detailed information or advice regarding the work of the British corps of voluntary marine observers, and the work of the Marine Division, including organization, statistical work for determining climate, the work of surveying and charting the ocean currents, questions regarding floating ice and ocean pilotage, or meteorological investigations, or as to what data were being passed on to other services, or what could be supplied to assist the Empire Meteorological services, he hoped that they would consult an inquiry bureau which he had set up for the day in the library. Mr. Keeton would be glad to make appointments for delegates who wished to consult Capt. Brooke Smith personally.

Capt. Brooke Smith said that at the Conference in 1929 he had made certain suggestions for enabling the Dominions and Colonies to take over the supervision of the voluntary work of some British home-registered ships stationed in their waters. Some ships had been transferred to India and if delegates who wished for further assistance in the matter would consult him he thought they would be convinced that we were not unmindful of the interest of the Dominions and Colonies.

The PRESIDENT asked for particulars as to how the Ship's reports were received in the London Office. Capt. Brooke Smith in reply said that the procedure was set out in the January number of the *Marine Observer*. The chart he had already referred to gave the position of all British ships at sea that had long-range wireless. From intelligence received from Lloyds it was possible to estimate the position of a ship within 100 miles and usually within 20 miles. By using that chart a roll-call was compiled of the ships chosen to report and this was transmitted to the ships by the ordinary procedure of wireless telegraphy. He thought in years to come the wireless coast stations in different parts of the world would have to take a hand in regulating the reports to be received ashore.

Dr. KIDSON (New Zealand) said that from the position of the country it was quite obvious that in New Zealand ships' reports were of very great value; so much so that he wanted to get reports from all ships in the neighbourhood except those near the coast. By negotiation with the Shipping Companies he had managed to arrange for reports once a day from all ships registered in Australia and New Zealand.

He had, however, been unable to make arrangements for the interception of C.Q. messages; all communications received had to be addressed direct to the Meteorological Office through the normal commercial channels. A request for such reports had been included in the *Marine Observer* and he had had correspondence with, and much assistance from, the Meteorological Office, but so far the response had not been very satisfactory and New Zealand was still only receiving reports from about one third of the overseas ships cruising in her waters. He hoped that as a result of further consultations with Capt. Brooke Smith and the notice recently issued by the Marine Division the position would be improved.

There had been other difficulties, some of which had given rise to correspondence with Dr. Normand and Mr. Watt, but no finality had been reached and he had put forward tentative proposals to the International Committee.

One proposal he wished to make was that the local meteorological authority should determine the time of the observations sent by ships' wireless for the land meteorological service, and that it should be part of their routine to do so. There were two reasons for this—one was that the land observations for the chart were made at 21h. or 21h. 30m. G.M.T., and ships' observations were taken at 18h. or 0h., and that difference of time between sea and land was too great. He thought also that the proposal would be better for the ships themselves. There were not enough ships to enable a synoptic chart to be drawn without using the land stations so that the difference of time was just as great a handicap to the ships as to the shore service.

The second proposal was that S, the state of the sea, should be included in the ships' short code. In his opinion it was a more important observation than the swell.

Dr. Kidson criticised the existing short code used by shipping on the grounds that it gave nothing about the state of the sea and nothing about the barometric tendency, while two groups were taken up with giving the position and the time. He suggested an alternative code, namely:—

9LLll PGGDD FwwBB ATTSV

where 9 was an index figure and the latitude and longitude were given in whole degrees. It required longitude to go through 360°, and some distinctions were required between latitudes north and south of the equator.

The suggested code was to be an alternative to the short code only, and was not to replace the main message.

Dr. NORMAND said that ships' messages were so very valuable to all meteorologists that more were required. This was especially so in the Arabian Sea. On examining the working of the scheme of selected ships during the past three years, he had found that the number of messages received from selected ships in the Bay of Bengal and in the Arabian Sea was fewer than was necessary for determining the meteorological conditions over those seas. It was, therefore, with great pleasure that he had received the concurrence of the London Meteorological Office enabling him to write direct to ships which were always plying in Indian waters, and to obtain reports direct from them.

Of the messages received from the Bay of Bengal 15 per cent came from selected ships and 85 per cent from local ships; while in the Arabian Sea about 50 per cent came from each. He would like to increase the number of messages still further, and thought there were still some ships from which no reports were received.

With regard to the time of arrival of the messages he had asked the ships with which he was in direct communication to send reports at 7h. or 7h. 30m. local time. From the selected ships in the Bay of Bengal the reports were for 0h. G.M.T. ; for most of the year that observation was in the daylight hours, it was somewhat early but was probably sufficiently good and fitted in fairly well with the time at which the main observations arrived at the forecast centre. For the Arabian Sea the times for selected ships were 6h. and 12h. G.M.T. ; that was rather too late to fit in with the land observations as the reports arrived at 11h. 30m. Indian time after the main forecasting work was completed. He would prefer that in the Arabian Sea the time of observation should be 3h. G.M.T.

With regard to the code he would postpone his remarks on that for a Sub-Committee.

Mr. STEWART (Malaya) said that in Singapore he had tried to get into touch with the representatives of ships plying in the China Sea both through the shipping agents and by seeing the Commanders, but he had not been very successful. He asked whether it would be better to make his application through Capt. Brooke Smith and if so whether Capt. Brooke Smith would be willing for him to do so.

With regard to the code he had found the observations so valuable that he had not criticised either the information received or the way it was received, though, no doubt, Dr. Kidson's proposals were based on sound principles.

Mr. WALTER (East Africa) said that there was only about one selected ship a fortnight or even less in East African waters. A further difficulty was that the Postmaster-General had agreed to transmit telegrams received from ships if the ships had been instructed by the London Office to send them. It would be easier for him, therefore, if his requests to the Shipping agents or to the Commanders were sent through the London Office.

Sir GEORGE SIMPSON said he would give a brief account of the policy of the Meteorological Office with regard to ships' wireless reports. The details of the code would be considered in a Sub-Committee of those interested.

He said that by 1929 it was obvious that there must be some sort of international agreement and the scheme must therefore be applicable over the whole globe. The scheme was discussed at the last Conference and at Copenhagen and the system eventually adopted was prepared in the Meteorological Office in London, largely by Capt. Brooke Smith ; it had come to be known as the " Selected Ships " system. Theoretically, it would be good if all ships supplied meteorological observations, but there were difficulties in the way. The wireless authorities had agreed to make no ships' charges, but the feeling among them was that if more than a certain number of ships transmitted their reports there would be considerable congestion. It was finally agreed that there should be 1,000 ships for the whole world selected to take part in the organization, and that each country should provide selected ships in accordance with its proportion of the world's tonnage.

Up to that time there had been no arrangements between the various meteorological services as to what observations should be taken, and they were all making requests and issuing logs of different form so that in some cases 4 or 5 copies of the observations were being made by the same ship for different meteorological services.

It had finally been accepted at Copenhagen that no ship should be asked to do meteorological work except by the country in which the ship was registered. This gave rise to difficulties because most of the British ships were registered in Great Britain, so that the Dominions and Colonies were cut off from communication with ships plying in their own waters. It was, therefore, arranged that ships plying mainly in the territorial waters of any Dominion or Colony should be considered for meteorological purposes as being on the local register. If, therefore, any service would say which ships they would like transferred to their register for meteorological purposes that transfer would be made.

Sir George emphasized that a ship voyaging in all parts of the globe could not be expected to alter its code and times of observations in different parts. The scheme for selected ships must therefore be applicable to all parts, and it had been designed for that purpose. That principle was the backbone of the whole scheme, and it was very undesirable that it should be altered. If selected ships came into territorial waters where the world-wide system did not fit in, either in code or time, then such observations as were required must be made as an addition to the international scheme. If services who required such additional reports would make the arrangements for such reports through the Meteorological Office arrangements would be made with the Captains, but it was, of course, on a purely voluntary basis.

Sir George said he was very anxious to get a close liaison between ships and the shore services. He emphasised that ships required observations from other ships for their own navigational purposes ; he thought that if ships could be made to realise that they were building up a service which was for their own benefit as well as for that of the land services the scheme would have a better chance of success.

Sub-Committee on codes for wireless reports from ships.—Sir George Simpson suggested that as the discussion was likely to be of a technical nature, the meeting in the afternoon should be regarded as a meeting of a Sub-Committee.

The Report of the proceedings is given on pp. 93–7.

The Meeting adjourned at 12.45 p.m. in order that a photograph of the delegates might be taken.

(Signed) J. PATTERSON.

MINUTES No. IX

Ninth Meeting, Saturday, August 17, 1935, 11 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Lt.-Cmdr. S. H. Butler (Nigeria), Mr. G. W. Grabham (A. E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Capt. A. Bertram Smith (Trinidad), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. W. S. Watt (Australia).

There were also present Dr. M. A. F. Barnett, and the following members of the staff of the Meteorological Office :—Dr. F. J. W. Whipple, Mr. E. G. Bilham, Dr. C. E. P. Brooks, Mr. R. Corless, Mr. J. S. Dines.

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1. **Documents circulated.**—The minutes of the sixth meeting.

2. **Reports of Sub-Committees.**—The reports of the Sub-Committee on Meteorological Organization for Aviation along the Persian Gulf and that on the Meteorological Organization required for the Khartoum–West Africa Air Service, were received and the recommendations set out in the reports were recorded. It was agreed that the final reports should be approved at the meeting on Wednesday, August 21.

The report of the first meeting of the Sub-Committee on Symbols, was considered, and a small correction made to the drawing of the symbol for rain. It was noted that general agreement had been reached.

3. **Meteorology in Africa.**—The PRESIDENT referred to Mr. Sellick's memorandum (Appendix XXI) and it was agreed that a sub-committee be appointed with the following membership :—Mr. W. H. Beckett (Gold Coast), Lt.-Cmdr. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. F. W. Hall (Gambia), Mr. N. R. McCurdy (Mauritius), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Mr. F. L. Squibbs (Seychelles), Mr. L. J. Sutton (Egypt), Mr. A. Walter (East African group).

It was understood that other delegates interested in the development of the organization of meteorology in Africa would be welcome. Monday, August 19, 10 a.m., was fixed for the meeting of the Sub-Committee. (The time was subsequently altered to 2 p.m.)

Mr. SELLICK (Southern Rhodesia) asked that a member of the staff of the Meteorological Office might be appointed to assist the Sub-Committee and Mr. Entwistle was nominated.

It was noted that the points requiring consideration by the Sub-Committee were as follows :—

(1) The fixing of hours of observation.
(2) The use of a uniform code with particular regard to the barometer at high levels and the method of reduction.
(3) The improvement of the exchange of daily weather reports.
(4) The publication for exchange of a more complete daily weather report to enable charts to be amplified and corrected.
(5) The question of assistance to backward Colonies.

3. **Classification of meteorological literature.** (Appendix XXII.)—Dr. BROOKS gave a brief account of the steps which were being taken to provide an international classification for meteorological literature.

He stated that the Commission for Bibliography had taken as a basis the decimal classification adopted by the International Institute for Documentation. In addition to the decimal extensions, he drew the attention of the Conference especially to the symbol of the colon which had been adopted as the sign of relationship between two different subjects. This symbol had proved extremely useful in practice. He referred also to the plan adopted for geographical classification.

Dr. Brooks gave a brief account of the history of the preparation of the proposed classification. He said that in view of the fact that a new edition of the whole of the Universal Decimal Classification was in course of publication in Berlin it had been thought desirable that the new meteorological classification should be included therein. The printing of that edition had therefore gone forward on the understanding that the International Meteorological Conference should have power to accept or reject the classification as a whole but not to modify it in detail.

The International Institute for Documentation, which was responsible for the classification, had a mechanism for keeping it up to date ; no doubt changes would be necessary in course of time, but he thought that for the present and for many years to come the classification would be found satisfactory.

In reply to questions during the course of the discussion Dr. Brooks said that it was not intended that the number distinguishing the subject, viz. 551.5 in the case of meteorology, should be omitted from any of the cards but that in the case of a specialised library it should be printed in some distinguishing type. There were some differences between the original Dewey system and that adopted at the Hague ; the latter system contained greater detail. As an example of the use of the classification he said that for annual reports from various countries the number would be 551.5 representing meteorology

06	,,	observational data.
.1	,,	weekly, monthly and annual weather reports.

i.e. 551.506.1 followed in brackets by the number representing the country concerned.

The geographical classification would be included in the report of the Warsaw Conference.

Sir GEORGE SIMPSON said that on account of the fact that the new system had had to be based on an old very imperfect system it was not itself perfect and contained some inconsistencies. It had been found however that it worked well in practice and an attempt to classify part of the library of the Meteorological Office on it had proved successful. Dr. Brooks reported also that the Librarian of the German Meteorological Society had given a favourable report after using it for six months.

Mr. BILHAM said that one point was clearly brought out and that was that it was incumbent on every author to draft the title of his papers in such a way that the subject to which they referred was clear. He gave an instance of a paper of his own which had escaped the notice of meteorological journals because he had entitled it " A problem in economics ".

Sir GEORGE SIMPSON said that it was hoped that in the not far distant future every paper published by a scientific society would be accompanied by the classification number and also by a short abstract.

With regard to the printing of the classification, Dr. BROOKS said that if it were accepted by the Conference at Warsaw it could be taken into use on the basis of the duplicated form, of which a number of copies were available ; it was hoped that a few printed copies would be circulated at Warsaw and that it would be included in the published report of that Conference. This was confirmed by Sir George Simpson who thought librarians would be justified in putting it into use at once.

In reply to a question of Mr. Patterson, Dr. BROOKS said that it was desirable that a copy of the complete classification should be placed in all large libraries ; it could be obtained from the International Institute for Documentation, Oostduinlaan 2, The Hague, Holland. In order to assist the smaller libraries however, an index had been drawn up of the subjects which were likely to be required in connexion with meteorology, and he hoped that that also would be printed in the Report of the Warsaw Conference.*

Mr. PATTERSON said that from his point of view the classification was being introduced at an opportune time because he hoped soon to appoint a librarian at the Toronto Office and could bring the new system into use at once, if, as he hoped, it were approved at Warsaw.

4. **Organized research in Meteorology.** (Appendix XXIII.)—The President called on Dr. Whipple to open the discussion.

Dr. WHIPPLE said that the memorandum dealt with the problem of how far it was possible in a meteorological service to have people whose attention was directly given to research, and who were not closely tied to routine work. The Meteorological Office was in course of reorganization, and there had been a feeling, especially among the younger members of the staff, that they should be given opportunity for research under a Director of Research, and that they should be engaged in investigations of as fundamental a nature as possible. The question was to some extent one of organization, but it was also a question of general principle as to whether a Government service should be engaged in work of which the practical application was not obvious, or whether such work should be left to the Universities.

At present the Department of Scientific and Industrial Research could give grants for research, and there was a small fund at the disposal of the Air Ministry for subsidising research in meteorological matters outside the Meteorological Office, but it made no provision for research by the staff of the Office. He thought that some such provision must have been made in the United States Weather Bureau in the case of Prof. Humphreys who had been attached to the Bureau with no definite routine work.

Dr. Whipple said that as most of the meteorological services were understaffed even for routine work, it was perhaps to some extent visionary to think of their having men available for research, but he thought there was room for a discussion of the general principle.

Dr. Whipple said that the memorandum alluded also to the possibility of such research as was conducted at Cardington—namely, the organization of meteorological work for air services, and the search for information with a bearing on air navigation. It was desirable, when such work was under consideration, to have close liaison between the services concerned.

The memorandum referred also to research in climatology, such as the correlation work associated with the name of Sir Gilbert Walker. Such work was of general interest, and it was desirable that it should be put on such a basis that everyone could get the greatest advantage from it.

Sir GEORGE SIMPSON said that it was good to have ideals, but it was dangerous to apply them in actual administration. In the ideal, Government should apply unlimited money to allow anyone to research who wished ; but in practice, money was limited, and the problem was to know what was the best way to use the money available. The situation of the meteorological services had changed considerably in recent years. When most of the services started the Directors were for the most part Professors—that was why the International Conferences were held in September

* The revised decimal classification was approved by the Conference at Warsaw and will appear in the Official Report together with a skeleton of the geographical numbers. The classification (without the geographical details) has been included in the *Quarterly Journal of the Royal Meteorological Society*, **62**, 1936, p. 134. An index to the whole system is given in " Classification Décimale Universelle," Tome IV, 1933.

during the academic vacation—and the Professors took charge of the meteorological service in addition to their academic duties. In these days, however, meteorology was a full-time occupation.

In the early days of the services, terrestrial magnetism and seismology had as a matter of course been taken over by meteorologists and no definite line had been drawn between what was and what was not meteorology. Even now the Head of the Meteorological Service of India was known as the Director-General of Observatories.

In the Meteorological Office there was a certain cadre, but the higher a man reached on the staff the less opportunity he had for research and the more administrative did his work become. The Meteorological Office had to supply definite information of a meteorological nature to the public, and there was a danger of research being ousted though he thought that during the period of his administration the scientific work of the Office had not decreased. In his experience every new entrant wanted to research, though only a small number were really capable of it. Most of the work at Kew, Eskdalemuir and Lerwick was scientific rather than practical, but even if a man distinguished himself on the scientific side he had eventually to be transferred to administrative work, because the only way to promotion lay in that direction. It was, therefore, becoming less easy to carry on scientific work, and he felt that the ultimate development might be for the Meteorological Office to concentrate on its service to the public. Pure research could not be done to a programme; it was the urge to investigate which led to true research, and for that a man must be allowed to follow hisi nvestigation wherever it might lead.

There were, however, certain types of scientific work that could be legitimately included in the work of the Office. Definite problems constantly arose in the ordinary work of the Office which required scientific investigation for their solution. These investigations were often referred to as scientific research, but he considered them technical rather than scientific, for the science was applied to a definite technical end. Most of the investigations at the National Physical Laboratory were of this nature. There was room for many more of these technical investigations in all meteorological services, and he was pleased to say that he had recently been given increased staff largely for this purpose.

Sir George said that pure research should be carried out in the Universities, and in this country both Prof. Brunt in London and Dr. Dobson in Oxford were engaged on work of that character and to some extent also it was carried out at the Solar Physics Observatory in Cambridge. There should be a very close liaison between the meteorological services and the Universities. As an example, he referred to the relations between the Geophysical Institute at Bergen, where the staff had no administrative duties, and the Norwegian Meteorological Service.

In conclusion, Sir George said that in spite of difficulties he thought the Meteorological Office had carried out a fair amount of research.

Mr. Patterson said the subject was of great importance and was causing most Directors much concern, especially on account of the great development of routine work. A University was ideal for research because it gave greater freedom than could be found in a Government service, but he thought that in spite of that, it was beneficial for research to be carried out by the services. Concentration on routine work killed initiative whereas investigation of new problems, even those of a technical nature, awakened new interest. He thought the ideal was a close relationship of the meteorological services with the Universities, and he hoped to see development of that character in Toronto.

5. **The responsibility of Meteorological Services for Geophysics.** (Appendix XXIV.)—*The proposed establishment of stations at Tristan da Cunha and Chesterfield Inlet.*—Dr. Whipple gave a brief account of the memorandum. He said that it drew attention to the needs of magnetism and seismology in various parts of the world, and raised the question of how far the meterological services were responsible for organizing observations in those subjects, and of who should take the initiative when the meteorological service had not done so. It raised also a practical point as to the response which the British Empire should make to the request of the International Union of Geodesy and Geophysics. The Union had proposed the establishment of magnetic observatories at Chesterfield Inlet, Cape Town, St. Helena, Nairobi, Comorin and Kerguelen. In the case of some of those there was

no doubt as to who should take the responsibility—but he was uncertain what authority should be approached about St. Helena and Kerguelen, and even as to whether Mr. Walter would accept responsibility for Nairobi. Should there be a general attempt for meteorological organizations to take such responsibility?

Dr. Whipple said that similar questions arose out of the proposals to reoccupy certain stations for observations of the secular variations of terrestrial magnetism. It was suggested that such observations should be made every 10 years. The Carnegie Institution at Washington had been very generous in the past in getting observations in all parts of the world, but it was desirable that the whole matter should be in the charge of some organization. In the case of the African stations, which were widely scattered, it would probably be easier for one observer to make a tour of all the stations rather than for each service to make its own observations.

With regard to seismology, a much closer network was needed—in the West Indies, for example, where small earthquakes were frequent and large earthquakes might occur, there was not a single good seismograph on British territory. In early days the British Association had sent seismographs to isolated stations, but with the increase in expense and complexity of the modern instruments the British Association could not continue to take the responsibility. It was very desirable to have a coherent scheme of observation, and to have some recognition of the responsibility of the meteorological services for the observations, but *ad hoc* organization was hardly possible.

Dr. Whipple said that the memorandum referred also to atmospheric electricity, but for that the need for international organization was not so great. He thought it would be beneficial to consider whether the association of terrestrial magnetism and seismology with meteorology was successful and desirable.

Dr. Normand (India) spoke with regard to the suggested magnetic observatory at Comorin and recalled the magnetic observatory established at Trevandrum a hundred years ago which had done such excellent work. Comorin and Trevandrum were both in Travancore and the Maharajah was responsible for the observatory and had financed it. The resolution of the U.G.G.I. at Lisbon to which Dr. Whipple had referred had reached India from various sources and had been placed before the Travancore Government. The Government were sympathetic, but in the present financial situation they had not found it possible to agree to the proposal at present.

With regard to the general question of the association of seismology with meteorology he said that in India it was recognised that seismological work should be under the Geological Survey but as the Meteorological Department had stations and facilities for maintaining instruments it had accepted the charge of the seismographs. The Geological Survey had no fixed observatories and no regular observers.

Mr. Patterson (Canada) said that a magnetic observatory had been established in Toronto in 1839 and from that had grown the meteorological service; that was why the headquarters of the service were at Toronto and not at Ottawa.

Seismological work was started at Toronto about 1898 because it was the only observatory at that time capable of doing it, but the Dominion Observatory at Ottawa had developed seismological work and was engaged on a magnetic survey of Canada. The work of the Meteorological Office was now confined to the observatories as far as magnetic work was concerned.

With regard to the proposal for a station at Chesterfield Inlet, Mr. Patterson said that the station was intended for meteorology, geophysics and the study of the ionosphere. The Marine department was sympathetic, had obtained the magnetic instruments and had prepared plans for the buildings estimated at £4,500 of which £1,500 was for freight. Up to the present, owing to the financial situation, Government sanction had not been obtained for their erection. The locality had been chosen as being within the zone of maximum auroral activity and only 400 miles from the magnetic pole. In making the plans for the buildings it had been recognised that the situation was unique and provision was being made for special investigations which could not be made elsewhere. He would be glad of the opinion of the Conference as to its usefulness.

Dr. Schumann (South Africa) said that for many years the problem of Tristan da Cunha had been before the public notice, and meteorologists had for many years recognised the importance for weather forecasting of a station on the island. Tristan da Cunha was a small island in the South Atlantic, 1,700 miles west of Cape Town and midway between South Africa and South America. The island had about 100 inhabitants who were unwilling to leave. Very few ships crossed the South Atlantic, only a few Japanese ships took that route, so that weather reports from the west of South Africa were almost entirely lacking. Most of the depressions and highs which affected the rainfall of South Africa travelled from west to east, so that reports from the west would be of very great importance. A station nearer would of course be preferable, but as none was available the best solution seemed to lie in the establishment of an experimental station at Tristan. He felt no doubt that its value would be considerable, though it might take some time before the forecaster could judge of the value of the reports. He thought also that the station would be important from the point of view of world weather. The South Atlantic was still only very imperfectly charted.

The estimated expenditure on the expedition was not very great. The staff was to consist of three, a trained meteorologist with a junior assistant, and a handyman with expert knowledge of wireless who could transmit the telegrams to Cape Town. He had not intended to carry out seismological work because he thought the staff would be fully occupied.

Mr. PATTERSON gave instances from his experience in Canada of the great value of reports even from a single station however isolated. In Canada, observations were received from Copper Mine on the Arctic Coast about 1,000 miles from any other station, and were found to be of great value ; for one or two years before Copper Mine was opened there was a police patrol boat at Cambridge Bay not far from Copper Mine, and the forecasters in both Canada and the United States had felt the loss very greatly when the station was closed. He thought that no doubt need be felt about the advantages that would result from the establishment of a station at Tristan.

Dr. SCHUMANN suggested that the value would be further increased if it were combined with upper air observations at Cape Town.

Sir GEORGE SIMPSON said that neither Mr. Patterson nor Dr. Schumann need feel any doubt about the value of the proposed stations. Meteorologists were unanimous in their opinion of their great importance both in the solution of practical problems and in the study of world weather.

He thought that if Dr. Schumann put forward a practical scheme there would be little doubt of its acceptance by the South African Government. Sir George said that he had himself already been in communication with the South African Government about the proposal and would be glad to give Dr. Schumann any assistance he could to insure the establishment of the station. With regard to Chesterfield Inlet, Sir George said he felt equally strongly, all had felt the need of more observations in a magnetically active part of the world.

The Conference expressed the following opinion :—

> " The Conference of Empire Meteorologists has considered from the point of view of both the theoretical and practical applications of meteorology and terrestrial magnetism the necessity of establishing a magnetic station at Chesterfield Inlet and a meteorological station at Tristan da Cunha, and it is convinced that these projects are of very high importance for the progress and practice of geophysics."

With regard to the cost of the additional seismological work which it was suggested should be carried on at Tristan da Cunha, Dr. Whipple said that the cost of the apparatus would be about £300 and the work would be the equivalent of about an hour a day for one man. If the meteorological observatory were a fairly substantial building no special building would be required.

Dr. BROOKS said that a short time ago he had had an inquiry from a commercial firm about Tristan da Cunha. He had not learned any details but the inquiry might indicate the possibility of some commercial development that might lead to improved communications with the island.

The Conference adjourned at 12.40 p.m.

(Signed) J. PATTERSON.

MINUTES No. X

Tenth Meeting, Monday, August 19, 1935, 11 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Dr. L. Balls (Egypt), Mr. W. H. Beckett (Gold Coast), Mr. D. L. Blunt (Cyprus), Lt.-Cmdr. S. H. Butler (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. F. W. Hall (Gambia), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Mr. G. W. Nye (Uganda), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present Dr. M. A. F. Barnett (New Zealand), Mr. D. G. Davis (Ministry of Agriculture and Fisheries), Mr. C. E. Cornford, Mr. W. S. Rogers (East Malling Research Station), Mr. F. Yates (Rothamsted Experimental Station), and the following members of the staff of the Meteorological Office :—Mr. R. G. K. Lempfert, Lt.-Col. E. Gold, Dr. F. J. W. Whipple, Mr. E. G. Bilham, Dr. C. E. P. Brooks.

The PRESIDENT welcomed the representatives of agricultural interests both from Great Britain and overseas, and said that he hoped they would take their full part in the discussions. Meteorologists were anxious to know what information about weather was really wanted by the agriculturist, and they would then endeavour to supply it. A close co-operation between workers in the two fields was desirable.

1. **Documents circulated.**—Minutes of the seventh meeting.

2. **Instruments for measuring soil moisture.**—The PRESIDENT announced that Mr. W. S. Rogers of the Horticultural Research Station, East Malling, had recently developed methods for routine measurements of soil moisture. In view of the importance of soil moisture in relation to agricultural meteorology it had been thought that delegates would like to have an opportunity of seeing Mr. Rogers' instruments. Arrangements had, therefore, been made for Mr. Rogers to attend, and he would demonstrate his instruments in the library.

3. **Climatology and Agriculture.**—Mr. WALTER said that in East Africa he had often been asked for help in the equipment of stations for the study of the relation of crops to weather and especially with regard to micro-climate. In the memorandum (Appendix XXV (*a*)) which he had put forward for the consideration of the Conference, he had set out the information that the meteorological service endeavoured to obtain for agriculturists, viz., the measurement of air movement and of humidities through the growing crops.

He would like to remind the Conference that there was often a marked difference between the " climate " in the crop itself and that in the standard screen. Measurements had been made of temperature in crops showing that on the top of a coffee plant the minimum temperature fell 5° or 6° F. below the minimum in the screen. Information of that kind was of great importance when advising about the selection of localities where a crop should be planted.

Another subject to which he wished to draw attention was that the relationship between rainfall and crop-yield was complicated because a large amount of the rainfall was of no use to the crop. It was necessary to get some measure of " effective " rainfall. For that reason he had read with much interest the account of the new method for measuring soil humidity. A complete installation of filter candles had been set up at Nairobi, but the results had not yet been examined. The main object of the measurements was to find how far soil humidity was affected by rainfall. In examining the relation of rainfall to the sugar crop in Mauritius, the highest correlation obtained had been 0·55, but when soil moisture was used instead of rainfall the correlation increased to 0·75 or 0·8.

It would be a great help to the meteorologist to get some guidance from agricultural research officers as to what elements were of primary importance for plant growth.

In reply to a question from Mr. Bilham about the method of filter candles, Mr. Walter said that it had been described in the *Journal of the American Society of Agronomy*; the principle was to connect the filter candle by a tube filled with a continuous column of water to a basin of mercury, and as the water was absorbed by the soil the mercury rose. The readings of the instrument had, of course, to be standardized.

The problem was of great importance because with tropical rainfall there was always the difficulty of determining how much of the rain was lost and how much was used by the plant. In the case of a long drought, information was needed as to where the crops obtained their moisture. There was no doubt that moisture came up from below, but no information was available as to the rate at which it came.

Mr. Yates (Rothamsted) said that Dr. Crowther had carried out similar work on soil moisture at Woburn in relation to sugar-beet which was grown there on a light soil. In his experiments he had cleared every three weeks half a plot of sugar-beet and sunk tubes to a series of depths, both in the part of the plot which had been cleared and in that which contained the growing crop. At the beginning of each three weeks the readings in both parts were the same and then gradually diverged. The work was carried on to get information about root movements, and to find from what depth the plant obtained its moisture. There was a gradual fall of moisture in the ground growing the sugar beet, and from the measurements it was inferred that the roots penetrated to a depth of 6 feet, this was subsequently confirmed when the plants were dug up.

Mr. Patterson (Canada) said that during a period of drought it had been found that wheat roots had penetrated the soil to a depth of 4 feet in their search for moisture. Mr. Patterson gave a brief account of his memorandum (Appendix XXV (*b*)) and said that the co-operation with the Dominion Experimental Farms which was there referred to promised to lead to important developments. It was hoped that there would be at least two meteorologists co-operating with the agriculturists.

Mr. Patterson referred also to the forecasts of frost which had recently been started for fruit growers in the Okanagan Valley. He said that the forecasts were begun as an experiment, but the growers were enthusiastic, and it was expected that the work would be continued.

Dr. Kidson (New Zealand) said that some work had been done in New Zealand in measuring soil moisture, by the method proposed by Mr. Rogers; the chief trouble encountered had been in the breakdown of the porous pot and also the fact that the pressure indicated varied so greatly with the nature of the soil. Dr. Keen also had raised the objection that there was a good deal of hysteresis, and the amount of suction would be different when a soil was drying from when it was absorbing moisture.

The New Zealand Office had also given warnings of frost in orchards in one district where heating was used. The heating, however, was expensive, and it was doubtful whether or not the orchards should be abandoned rather than that heating should be resorted to.

The greatest asset of New Zealand was its pasture. Rainfall was about the optimum for the various types of crop. Weather certainly controlled crop-yields, but it was difficult to get the necessary detailed correlation. Conditions naturally varied greatly in a mountainous country.

Dr. Kidson said that it was important to learn from the agriculturist what the effect of different conditions in the atmosphere and the soil was on the various processes taking place in the plant. Such information would be of great assistance to the meteorologist in providing for agriculture the information that was desired.

In response to a request from Sir George Simpson, Dr. Balls (Egypt) described the work which had been carried out in Egypt for examining the roots of plants. An underground tunnel had been built, lined with a plate glass sheet, 3 metres in height, so that the roots of the plants might be seen. Much valuable information had been obtained in this way, and it was found that in some cases the roots of wheat went down as much as 3 m. (10 feet). Cotton roots might, under some circumstances, be confined to the top half-metre, but under good conditions would go to 3 metres.

With regard to the measurement of soil moisture, Dr. Balls said that the problem was particularly difficult and was even more complicated than that of measuring soil temperatures. He had himself made measurements by both gravimetric and electrical methods.

In the case of temperature the variability was so great that he had been led to suggest that the only practicable way to integrate the results for Egypt was to use the temperature of the river Nile rather than of the soil. The variation of the moisture of the soil was even worse, it depended on a large number of different factors, viz. depth; type of soil; profile, by which was meant the distribution of the various types in the vertical; contours; exposure; nature of the cover, whether bare or under crop; and so on. A paper had been published showing that in August the cotton crop took most of its moisture from $1\frac{1}{2}$ metres below the surface and not from the surface layers.

The determination of soil moisture from measurements in the soil itself required an enormous number of observations at a very large number of points. As a practical method he thought it might be better to give the run-off, but Rothamsted could give better information how that could be obtained.

Mr. Yates said that at Rothamsted no attempt had been made to measure the run-off. In England most of the rain went into the soil and run-off had not the importance that it assumed in tropical countries.

At Rothamsted measurements of soil moisture were carried out by using three gauges cut out of the natural soil and of depths 20 inches, 40 inches and 60 inches. The water that drained through was collected and so a measurement was obtained of the amount of water that stayed in the soil at various depths. The instrument was self recording and had been in use for 60 years. Mr. Yates said that it would perhaps be better to use a gauge that would give the weight of the soil and water in the gauge. There was evidence that at certain times of the year there was an accumulation of water in the soil, and there was a certain periodicity about the water content, the amount accumulating in winter and then gradually running off or evaporating in the summer months.

Dr. Whipple referred to the work in Prussia of Dr. Bartels who had used an underground chamber with a machine to weigh the soil in a large tank of a capacity of 2 or 3 cubic metres. The weighing was carried out at frequent intervals. He thought that a report of the work had been published.

With regard to the measurement of run-off he said that some time ago details of run-off from a large area had been published in the *Meteorological Office Circular*, No. 7, 1916, p. 4. The area drained was about 9 acres. The upper soil became saturated in the autumn after 5 in. of rain had fallen. During the winter all the rain was carried away by the drains. The observations were made by a farmer working on heavy land with some underground drainage. The rain from a large area converged and drained into a brook in which was a weir which enabled the run-off to be measured. Records had been kept for some years. The great interest of the observations was to find how soon the brook began to fill up in autumn and when the height began to fall in spring.

Mr. Sellick said that in Southern Rhodesia there had been a great development in the investigation of soil erosion and in protection works. Storm drains and contour ridges were constructed to control the water. Areas of from two to five acres had been isolated and provided with storm drains and contour ridges and with automatic rain-gauges. The run-off was led through a weir; a percentage of the water passing the weir was collected in a tank and the amount of silt measured.

In reply to a question by Dr. Whipple with regard to particulars of the difference of temperature of air above the crops and in the screen, Mr. Walter said that the matter was very complicated but it was obvious that there were considerable differences in temperature in different parts of the crop. The question of micro-climates was much more important than had been anticipated, so much so that it seemed doubtful whether the screen temperatures were of any value for giving the temperature in the crop itself. Micro-climate seemed to bear little relation to the climate as measured at the ordinary climatic station and much research was required in order to find to what conditions the plant itself was exposed.

In an attempt to find the conditions favourable for insect growth it had been found that there was greater development on one side of the plant than the other, apparently because there was 30 per cent more sun in the afternoon than in the morning.

Sir GEORGE SIMPSON raised the question as to how far the study of micro-climatology was within the province of meteorologists and asked for the opinion of other directors on the problem. Up to the present the meteorologist had tried to get his measurements in places as far away as possible from the conditions which it was now suggested that he should investigate; and this meant a re-orientation of ideas with regard to climatology. Dr. Balls had pointed out on how many factors the amount of soil moisture depended; it was obvious that it would be difficult to express the results by general laws.

Sir George said that it was difficult to assign the work of micro-climatology either to the meteorologist or the agriculturist; it seemed to require a special department to deal with it. The difficulties which would be met were patent and it might lead to a development of meteorology for agriculture similar to that which had taken place with regard to aviation.

The PRESIDENT suggested that the point which Sir George had raised as to how far the meteorological services were responsible for the study of micro-climatology should be taken up at the end of the discussion of the several memoranda.

Dr. BALLS said that he was surprised to find that the idea of the temperature in a crop being different from that in the screen was regarded as new. In the only paper he had contributed to the *Quarterly Journal of the Royal Meteorological Society* in 1913, entitled " Meteorological conditions in a field crop " he had drawn attention to the low temperature shown in a cotton crop compared with that in the open. This lowering of temperature occurred in dead calm, and was blown away by a puff of wind.

Sir GEORGE SIMPSON asked whether the mean temperature of the atmosphere at say, 1 foot above the surface, could be altered by the growth of a crop.

Dr. BALLS replied that the temperature of soil was definitely higher in fallow land, and the temperature of the air was also different above fallow land from that over a crop.

Dr. NORMAND thought that the air temperature depended on the crop. In a crop of cane sugar the temperature was lower in the day and higher at night than that of air outside the crop, and the mean temperature was not identical.

Mr. WALTER pointed out that for crops it was extremes rather than means that were required. The enormous diurnal range and the extremes of temperature to which the crop was exposed had much more effect than the mean, in determining the growth of the crop. The mean temperature throughout the year changed by only about 3° F.

Mr. SELLICK referred to the effect of wind-breaks on the occurrence of frost. Frost affected the setting of fruit in blossom time and it had been found that the building of a wind-break in a valley subject to frost intensified the frost by damming up the cold air. In valleys where extensive wind-breaks had been built it had been necessary to cut holes in the wind-breaks in order that the cold air might drain away. A station in a valley provided with wind-breaks would show a lower temperature than one without.

4. **Uniformity in climatological observations.** (Appendix XXVI.)—Dr. BROOKS gave a brief account of his memorandum. He said that climatological observations must be regarded as standards of reference and must therefore be strictly comparable. There were three main ways in which the practice at climatological stations differed, viz., exposure of instruments, methods of working up the data, and hours of observation. Dr. Brooks referred to the differences found in each of these categories.

Mr. PATTERSON said that all meteorologists realised the appropriateness of Dr. Brooks' remarks. He thought that most of the Services of the Empire had adopted the recommendations set out in the " Observer's Handbook " and that in consequence considerable uniformity had been attained, though he did not know how far those recommendations agreed with international practice. In order to insure that this uniformity might be continued he suggested that it might be desirable if the Meteorological Office could consult with the directors of other Services before making any radical changes in the practice of observing. He suggested further that the new edition of the " Computer's Handbook " should contain an account of the method of reduction of autographic records.

With regard to the size and exposure of rain-gauges, he said that in Canada gauges were generally exposed at a height of 1 ft., though exact uniformity was not always possible. The gauges had an area of 10 sq. in., which gave a diameter of just over 3 in.; such gauges had been in use for over 60 years. Comparisons had recently been made between this standard gauge and gauges of 5 in. and 8 in. by setting up all the gauges with the rims at a height of 4 ft. at a station where the exposure was good and there was considerable wind. Four of the small gauges were set up about 10 ft. away from the 5-in. and 8-in. gauges, and the readings had so far not differed by more than 0.01 in. or 0.02 in. The effect of wind seemed to make no difference to the results, but no observations had yet been made during a strong gale.

With regard to the times of observation, Mr. Patterson pointed out that there was a difference of 4 hours in time between the Maritime Provinces and British Columbia. Observations at 9h. and 21h. in the Maritime Provinces would be at 5h. and 17h. in British Columbia, so that it was impossible to use the same hours for synoptic and climatological observations. At present two observations a day at 8h. or 9h. and at 18h. (standard time of the place) were encouraged, but it was difficult to get uniformity.

Sir GEORGE SIMPSON said that the recommendations of the " Observer's Handbook " were based entirely on international resolutions; he said that he would be delighted to send proofs of a new edition to any directors who expressed their wish to have them, but he did not wish to give the impression that the London Office was trying to dictate with regard to the methods which should be adopted in the other Services of the Empire. With regard to the " Computer's Handbook," many attempts had been made to revise it, but it had been delayed for various reasons; principally because of the difficulty of the task. He hoped, however, that the difficulties might soon be overcome though he would be glad to hand over the responsibility for its publication to whichever of the Empire Services would undertake it.

With regard to the hours of observation, he thought that Col. Gold and Dr. Brooks, who were attending the Meeting of the Climatological Commission at Danzig, would be glad of the opinion of directors. There was a tendency for the powerful synoptic meteorologists to impose on the climatologists their wishes with regard to times of observations and to scales. It might be desirable to bring the two into line, but it must not be forgotten that the observations for synoptic meteorology were dictated to some extent by what could be included in the telegrams.

He pointed out that there was a difference in the observers at the two types of station; those who took the synoptic observations were under the direct supervision of trained meteorologists, and if their observations could be used also for climatic purposes it would be an advantage.

In Great Britain, four observatories had been established in different parts of the country taking hourly observations, and these hourly observations were used to give the correction to be applied to observations at any one hour to make them comparable with those at a different hour.

Sir George said he would be glad to know whether the Directors considered that the observations for synoptic and climatological work should be separate.

Mr. BILHAM pointed out that though the recommendations of the " Observer's Handbook " were built round British practice an endeavour had also been made to indicate what variations might be desirable in tropical countries, and a note in the introduction invited co-operation and suggestions from all who used the Handbook, including the directors of the Services of the Empire. He hoped that any Director who had any suggestion to make would send it to the Meteorological Office without waiting for a new edition to be advertised. New editions had sometimes to be prepared at short notice, and in such cases it might be difficult to communicate with the Services overseas before publication.

Although he sympathised with the suggestion that climatological observations should be made at the synoptic hours, it had to be remembered that many of the most valuable climatological observations were provided by Corporations and Water Supply Companies. It would be extremely inconvenient for such people if the time were changed to an earlier hour, and he thought such a change would result in a considerable decrease in the number of observers. At present over 300 climatic stations and over 5,000 rainfall stations made observations at 9h.

With regard to the size of rain-gauges, Mr. Bilham said that many years ago a comparison was made of the measurements from gauges ranging from 3 in. to 20 in., and no serious differences had been found. A gauge of 1 in. diameter had at one time been designed for explorers and a specimen was on exhibition in the Office library. He thought the 5-in. gauge was the most suitable for general use. The original Meteorological Office gauge had a diameter of 8-in., but it had now been recognised that this gauge had no advantages to compensate for its higher cost as compared with the 5-in. gauge.

Dr. NORMAND (India) said that while he recognised that the synoptic hours laid down by international recommendation were the ideals to be aimed at, yet in a Service that could afford one or at most two observations a day there were other factors that had to be considered, namely, the hours of light and darkness, the times at which the observers started work, the times of opening of telegraph offices, etc.

Over north India, where two observations a day were made for synoptic purposes, one was made at 8h. and one at 17h., the observations were separated by as great an interval as possible subject to their being within the hours when telegraph offices were open. A postponement of the evening hour would lead to extra fees and the cost would be prohibitive.

For the morning observations for synoptic work, local time was still used, and no disadvantage had been found though the possibility of changing to synoptic time had been considered. The use of local time had, however, certain advantages, for example, in the case of a station with a marked continental climate giving a diurnal variation of temperature of 40° F. in a layer near the ground, what was really wanted for synoptic weather was information above the layer affected by radiation and a comparison of temperature in different parts of the country was easier, therefore, if local time were used. In south India also where the diurnal variation of pressure was large a similar argument held, especially as the diurnal variation was somewhat greater than the day-to-day change. Having chosen the synoptic hours, it was arranged that as far as possible climatological stations should observe at those hours.

Dr. WHIPPLE suggested that in view of what Dr. Normand had said about radiation climate he thought that meteorologists had perhaps been ill-advised to make their observations at 4 ft. and not at some higher level. More use was made by forecasters of temperatures from the sea than of those from land stations. It should not be difficult to get measurements at a height of 10 metres for telegraphic purposes. Perhaps the American practice of observing on the roof might be followed with advantage.

Col. GOLD asked for the views of directors as to the times of observation. Some years ago he had suggested that the synoptic observations should be made according to local time rather than according to G.M.T., and he was of opinion that that was the only practicable way of getting uniformity.

Mr. WALTER (East Africa) said the question had exercised him a good deal because he was dealing with a country that spread over a wide area. Synoptic hours had been adopted, 6h. and 12h. G.M.T., but it had resulted in there being large differences in the reports from different parts of the country. The diurnal variation affected pressure, temperature, humidity and even wind. Some farms had declined to use anything but sun time, and for such the maximum and mean temperatures were utilised.

The question was complicated by the fact that different countries adopted different standard times. Southern Rhodesia was 2 hours fast on Greenwich; Kenya and Uganda 2½ hours fast, whereas in Zanzibar local sun time was used.

Mr. SELLICK (Southern Rhodesia) said that he also had given the matter much attention; 8h. 30m. local time had been adopted, and that differed by half an hour from 7h. G.M.T. The hour was convenient because it was the time of opening for most offices, and, moreover, the monthly mean of the temperatures at that hour gave a figure nearer to the mean monthly temperature than that obtained from the mean of the maximum and minimum.

It was difficult to handle the data from the western side of South Africa because in winter the synoptic observation was at sunrise and agreed with the minimum, while on the east coast the observation was at 9h. It was not uncommon for the observations from Lourenço Marques to be criticised because maximum temperature was read at 21h., and might be less than the temperature at the time of observation.

He thought it would be an advantage to use local time. In any case it was impossible to get comparable observations for climatic purposes if they were made all over the world at 7h. G.M.T.

The difficulty had occurred also in relation to the work in connexion with the Polar Year; he had been asked for observations at 2h. and 14h., just the hours when it was most difficult to make a reduction for height.

With regard to rain-gauges, Mr. Sellick said that a light gauge known as the B.A. gauge with a funnel taking off just below the rim had been introduced after the war. A comparison of this gauge with the M.O. type which was re-introduced later, gave the same average, but with heavy rain the M.O. gauge measured a larger amount whereas it gave no record at all of light rain in the afternoon. Sir George referred Mr. Sellick to Mr. Salter's book on "The Rainfall of the British Isles" for information on the subject.

With regard to the proposal that anemometers should be reduced to a standard level, Mr. Sellick said it was difficult to know what "effective height" to use. He suggested that in the case of out-of-the-way services it might be better to describe the site and reduce the data in the ordinary way and let the experts make their own correction.

Mr. STEWART (Malaya) said that in the last twelve months he had been trying to arrange a synoptic service, and had had to revise his ideas about the value of synoptic observations for a chart covering a radius of 1,500 miles. The diurnal variation was so great that observations from different zones were more comparable if local time were used. Further though a synoptic chart at 7h. might be convenient for the central area it involved observers in the west getting up at an unreasonable hour, while in the east the observations would be in the middle of the morning when the sun had been in action for many hours. He had been led therefore to adopt local time not only from the meteorological point of view but from the practical point of view also.

With regard to anemometers, Mr. Stewart said that in many places the instruments were surrounded by plantations of either cocoanuts or rubber, and it was not always practicable to use a very high mast. He would be glad of information as to the distance at which obstacles affected an anemometer reading at a height of 50 ft.

Sir GEORGE SIMPSON suggested that Mr. Stewart should consult Dr. Brooks. He pointed out that in some cases it would be difficult to use local time because there would be considerable delay in collecting the observations for a synoptic chart especially in a service such as Canada where the region from which the observations were collected lay on the west of the station that prepared the chart. He thought it was hardly practicable to get a regulation that would apply to the whole world.

Mr. PATTERSON (Canada) agreed that each service must adopt the system most suited to its particular requirements. It was impossible to adjust the synoptic hours to fit in with the climatological hours, as in Canada there was a difference of four hours between the east and the west of the continent.

He raised the question of non-instrumental observations and asked for the experience of other services in overcoming the difficulty that arose from the fact that some observers reported all phenomena while others reported none.

Mr. STEWART, Mr. SELLICK, Dr. KIDSON and Mr. WATT expressed themselves as being in a similar difficulty.

Dr. BROOKS said that when collecting data of thunderstorms, unless there were reasons to the contrary, he had adopted the principle of using the maximum number of storms observed.

Dr. KIDSON said that such a practice would be dangerous in New Zealand.

It was agreed that the members of the Conference who were attending the meetings of the International Commission at Danzig, viz., Dr. Normand and Mr. Patterson, should meet with Dr. Brooks to formulate a common policy with regard to questions to be discussed at that meeting.

5. **The form of publication for climatological observations.** (Appendix XXVII.)—Dr. BROOKS said that the purpose of his memorandum was to explain what was done with the reprints from the Colonial Blue Books and to indicate the problems that arose with regard to them. He asked for the help of directors in reporting any changes of practice in making the observations and in getting out the reductions that were used.

In several discussions during the Conference the need for additional observations had been emphasised especially in the case of visibility. It was proposed that these observations which were required mainly for aviation purposes should be printed or manifolded separately.

He added that the Director of the Meteorological Office would be glad to give advice as to the circulation of the publications though he could not undertake to distribute them from London.

Dr. Brooks said the memorandum also raised the question of the future of the Blue Books, especially as during the Polar Year certain services had published their observations locally.

Sir GEORGE SIMPSON said that the memorandum would be printed in the Report of the Conference. He thought that no useful discussion was possible as the people most concerned were not present.

The PRESIDENT suggested that the Directors of Services whose data were published in the Blue Books should consult with Dr. Brooks with regard to the points raised in his memorandum.

With regard to the " Observer's Handbook " and the " Computer's Handbook " Mr. Patterson said he thought that the Meteorological Services of the Empire were grateful to the London Office for producing books which were of such assistance in insuring uniformity of practice throughout the Empire. He was glad to know that the " Observer's Handbook " conformed to international practice and hoped directors would remember to send suggestions with regard to it to the London Office.

The meeting adjourned at 1 p.m.

(Signed) J. PATTERSON.

MINUTES No. XI

Eleventh Meeting, Monday, August 19th, 1935, 3 p.m.

The following delegates were present:—Mr. J. Patterson (Canada), *President*, in the Chair, Dr. L. Balls (Egypt), Mr. W. H. Beckett (Gold Coast), Mr. D. L. Blunt (Cyprus), Lt.-Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. F. W. Hall (Gambia), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltzheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Mr. G. W. Nye (Uganda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir Napier Shaw (President of the Committee on Agricultural Meteorology), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present:—Dr. M. A. F. Barnett (New Zealand), Mr. D. G. Davis (Ministry of Agriculture), Dr. B. A. Keen and Mr. F. Yates (Rothamsted), Mr. W. S. Rogers (East Malling) and the following members of the staff of the Meteorological Office:—Mr. R. G. K. Lempfert, Dr. F. J. W. Whipple, Mr. E. G. Bilham, Dr. C. E. P. Brooks, Mr. J. S. Dines.

The PRESIDENT said that he was glad to see so large an attendance of agriculturists present at the meeting. He expressed the pleasure of the Conference at having Sir Napier Shaw with them.

1. **Documents circulated.**—Minutes of the eighth meeting.

2. **Agricultural Meteorology.**—*Time units for climatological purposes.*—The PRESIDENT said that the subject had been discussed at many Conferences before and was of great importance. In Canada there had been a growing demand for seasonal data, but every type of worker required a different season. Those interested in agriculture desired maps of the principal elements covering the season from planting to harvesting as a rule (although to a limited extent they desired a separate set of values for the harvesting and threshing season). Unfortunately, these seasons over such a large area as Canada are not synchronous. Particularly there is a lag of nearly two months between the preliminary work of spring on the land in south-western Alberta and in the Atlantic provinces. Hydro-electric engineers required seasonal maps which were based upon the season of maximum evaporation and the season of maximum water storage as snowfall. Heating and air conditioning engineers in recent years required seasonal maps of temperature, on the basis of days with mean temperatures below 65° F. for residences and hospitals and 55° F. for factories where the manual labour required a lower temperature to be maintained.

Crop reports were issued weekly in Canada on Tuesdays and in the United States on Wednesdays; both average and extreme values were required for weekly periods. The weekly time unit was definitely established from the standpoint of weather reports. The day, the month and the year were all in general use as time units; for a period shorter than a month he thought the week was the most suitable, though the question of standardizing a five-day period for climatological work was coming up at Warsaw. While this period might have many advantages for theoretical purposes, it was not a practical unit, and as the week had become established on the American continent as a definite period for which to give information to the public, it was to be hoped that the 7-day period or the week would be used instead of the 5-day. The cost of using both periods would be prohibitive for most Services. He said it would be impracticable in Canada to compute data for 5-day periods as well as for the week.

Dr. BROOKS said that the choice of a 5-day period was part of the general scheme of decimalisation which had led also to the suggestion of replacing the Fahrenheit scale by the Centigrade.

Mr. BILHAM said that the week was used in the British Isles and weekly summaries had been issued over a period of 56 years, though recently they had been combined in an annual volume. The weeks were civil weeks, each week beginning on a Sunday. Summaries for the four seasons were also compiled.

Mr. Bilham added that for water supply purposes, data for a " Seasonal Year " beginning on October 1 were included in *British Rainfall*. The summer half-year extended from April to September and the winter half-year from October to March.

Sir NAPIER SHAW said that he did not want, on this occasion, to say much about the months which had been used for 300 years as groups of days for expressing meteorological data. It was a most unsuitable unit because the groups were not equal—31 days, 28 days, and so on. But rightly or wrongly, meteorological science had been satisfied. Habit had, apparently, a strong hold on the observational sciences, so strong a hold indeed, that the astronomers who were our colleagues as acute observers, having found that the sun entered Aries on March 21, had ever since allowed the calendars to note the sun as entering Aries on that day, though it was now 2,000 years since it was true.

Sir Napier said that he wanted to confine what he had to say about time measuring to its relation with agriculture. Weather had a great influence on the growth of crops, and its influence depended mainly on the duration of daylight. Those interested in the relation of meteorology to agriculture must take an interest in the relation of their units to the duration of daylight. He had made two diagrams (of which he distributed copies), one to show the duration of daylight in relation to latitude, and the other derived from it to show the duration of daylight throughout the year in the latitude of London, and in latitude 60° N. and 30° N. The duration of daylight must be borne in mind in considering the relation of the variation of weather to growth.

With regard to the week as a unit, Sir Napier said that if the week was a convenient unit for agriculturists in practice, it was also convenient for the meteorologist, because it enabled him to divide the year into periods which could be related to daylight. There were 52 weeks which could be divided into quarters of 91 days each, with one day over as an appendix. It was better to keep the extra day separate than to make a week of eight days, though worse things than that had been done. The quarters could be centred at equinoxes and solstices, though the centring was not quite exact. The growers' year of the northern hemisphere would begin conveniently on November 6 with a quarter centred at the winter solstice ; the second quarter ran from February 5 to May 6 and so on. Each quarter represented a definite amount of daylight, the same from year to year. That was the most rational way of dividing the year for purposes of agriculture. By beginning the agricultural year on November 6 there were eight complete weeks to December 31, a new week always began on January 1.

There was the awful difficulty, terrifying to the most ambitious and energetic meteorologist, that the week did not always begin on Sunday. Sir Napier said that he had found no difficulty from a scientific point of view, in using a week that did not begin on Sunday. It was not absolutely necessary that meteorologists in serving agriculture should group its days according to the practice of commerce. The extra day, November 5 in this country, was a suitable day to end the year, because it was the time of bonfires.

An American lady had recently suggested a reform of the calendar by dividing the year into 52 weeks and throwing away the extra day. There was no *dies non* in meteorology. The sun would rise and growth would always go on without respect of Sundays or weekdays.

The practice in the old *Weekly Weather Reports* was to use a week always beginning on Sunday and continue the beginning of the weeks one day earlier each year, until, after a time not easily calculated, a year came to have 53 weeks. This arrangement made it impossible to compare corresponding weeks in different years. For preliminary inquiries that might suggest themselves to the forester, the fruit grower or the root grower, comparison of corresponding periods in successive years was of the first importance.

Sir Napier said that he had worked out a scheme for meteorological observations in relation to agriculture on the plan referred to, and had set out the observations for the current year at two stations on that plan. A page was allowed for each week and gave maximum and minimum temperature in the air, on the grass and in the soil, dew-point, humidity, accumulation of heat, rain and sunshine and so on. The arrangement had been called the growers' year.

There remained the question of the second extra day in leap year ; this might be a second appendix at the end of the winter quarter near the beginning of February. That plan would minimise the disturbance of dates caused by intercalating a day at the end of February in Leap Year.

Sir Napier said that our time units were the day and the year. The month was not a time unit, and though the week might be called a unit it was better to regard it simply as a number of days grouped for the convenience of the user of the information. The difficulty about using a 5-day period was that those periods could not be grouped into quarters, nor could they be arranged symmetrically with regard to solstice and equinox. A period of six days was attractive, but suffered from the same disability.

At the request of Sir George Simpson, Mr. LEMPFERT explained the work that was being done by the Agricultural Meteorological Committee in Great Britain. He said that the agricultural stations took meteorological observations for the investigation of the relation of weather to crops. These observations were summarised week by week in the Meteorological Office according to the method suggested by Sir Napier Shaw and were circulated to the observers. November 5 was kept as a separate day. The fact that all weeks did not begin on a Sunday had given rise to no practical difficulty. The returns were sent in monthly. He thought the method suggested gave a very satisfactory division of the year, and had the advantage that the year always began on November 6 and all years were comparable. The scheme was only put into operation in November, 1934, so that data for a full year were not yet available.

Mr. WALTER said that in East Africa no division smaller than a month was used.

Dr. BALLS (Egypt) said that he thought the question was a matter of individual convenience, the fundamental period was the day. There was some objection to the calendar week on account of its shifting one day every year. In Egypt, sympathy was felt for the solar year, no doubt, because it might be regarded as starting in that country. He felt that from the point of view of the computer there was something to be said for the 5-day period.

Dr. KEEN (Rothamsted) said that many agriculturists used the harvest year from October 1 to September 30 ; it was based on the calendar month, and only involved a shift of one month from the usual meteorological seasons. Agricultural meteorologists realised the non-agreement of the calendar with the growth of crops. In order to use Sir Napier Shaw's method the monthly sheet had been arranged so that the division into weeks beginning on the correct day was automatic. He thought this division into weeks would be adopted, it worked easily in practice and it was easy to relate it to the ordinary calendar system. It had the advantage of being much closer to the harvest year which all agriculturists must use.

Mr. BILHAM said that specimens of the forms showing the combination of weekly and monthly figures were available for any delegate who wished to see them.

Mr. YATES (Rothamsted) referred to the fact that for many purposes the data had to be compiled according to the civil week for comparison with data from other sources. The compilation according to two different systems involved some additional labour and the duplication of averages. He thought the civil authorities would not tolerate a week that began on different days in different years.

He pointed out that different crops were all in different phase, and as the fluctuations of weather were considerable the exact coincidence of the meteorological sub-divisions with the solstices and equinoxes was not essential. Using the ordinary civil week the error of phase would never be greater than one in a hundred.

Sir GEORGE SIMPSON expressed his pleasure at seeing Sir Napier Shaw at the Meeting. He said that the delegates were there as Directors of Meteorological Services, and it was impossible to separate the needs of agriculture from those of other branches of meteorology. The Meteorological Services had both to collect and discuss data. If the same workers collected and discussed their own data, they could each do so in the manner best suited to the technical purpose for which the data were to be used. But when the data were being collected for several purposes the position was more difficult. The ordinary citizen was used to a week beginning on Sunday and to the calendar month, and he thought that for the collection of data it was better to continue to use those units. He was not aware that any research had been seriously handicapped by the fact that the data were not compiled in a more scientific form.

Sir NAPIER SHAW asked if there was really such a thing as a calendar week.

Mr. SELLICK noted that in Southern Rhodesia mails arrived on a Friday. Newspapers were published daily and republished at the end of the week for country districts. The meteorological data had therefore to be summarised for a week ending on Wednesday, so that they might be available for despatch on Friday.

Mr. PATTERSON agreed that the question was difficult. He thought that if the data were summarised by the day, the week and the month each investigator could then make what additional compilations he required. Weekly totals were not yet published in Canada, but when they were they must be adjusted to the public requirements. He thought that as far as Canada was concerned it would be impossible to adopt a 5-day period.

The form to be used for expressing the water-vapour content of the atmosphere. (Appendix XXVIII.)—Mr. WALTER said that he had had many inquiries in East Africa for some means of expressing the drying power of the atmosphere and had been uncertain as to what form should be recommended. The question had arisen partly from complaints about the shortage of weight of flour. Observations of the readings of a hair hygrometer and of the weight of flour had been made over a long period. Observations of drying power were required also in connexion with wood-seasoning and with the sisal industry. He would be glad of the advice of the Conference as to the best method of measuring the drying power.

In places where the relative humidity was uniform during the day, a mean value might be representative, but in tropical countries where humidity might vary from 100 per cent to 10 per cent a mean was useless. A mean of the observed vapour pressures divided by a mean of the saturation pressures gave values that sometimes differed by as much as 10 per cent from the value derived from the means of the relative humidities.

Mr. STEWART (Malaya) said his experience was similar to that of Mr. Walter except that he had been asked to give an idea not of the drying power but of the depositing power of the atmosphere in relation to the increase in weight of opium. He had provided the inquirers with 24-hour hygrograph records so that they could get the humidity at the hours when they required it. He thought one solution might be to give the dry-bulb temperature and the dew point.

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Mr. BILHAM said he thought that it was impossible to give a general reply to the question. Many inquiries were received about humidity, but the type of data required varied according to the nature of the activities in relation to which the information was needed. Those interested in questions of air-conditioning needed humidity expressed as weight of water per unit volume of air.

His experience was that when information was needed for industrial purposes some research was required to decide what form was the most appropriate. In the case of an inquiry from the Forest Products Research Laboratory at Princes Risborough, it had been found that the equilibrium moisture content of timber depended mainly on relative humidity and to a smaller extent on temperature. The results had been expressed in an isopleth diagram.

Mr. Bilham said that Prof. Buxton at the Institute of Tropical Hygiene had shown that the rate of loss of moisture from an insect was proportional to saturation deficit expressed as vapour pressure. Some workers expressed the deficit as moisture content, but for a small range of temperature the difference between the two methods was small.

He thought that workers who required the information must determine what rôle moisture played, before the meteorologist could be of assistance. The reason why saturation deficit was of most use to plant and animal physiologists was that evaporation in those cases occurred from surfaces which were nearly at air temperature, and it could be shown that in this case the rate of evaporation should be proportional to saturation deficit.

Mr. Bilham said that each meteorological service must decide how to express humidity data in its publications. In the *Monthly Weather Report* of the Meteorological Office four columns were given, namely, air temperature at the hours of observation, mean depression of the wet bulb (which was directly observed), relative humidity and vapour pressure. Vapour pressure was useful for identifying air masses because its diurnal variation was small. He thought that if four columns could be used, the selection adopted in the *Monthly Weather Report* was the best; all other data could be derived therefrom.

Mr. J. S. DINES said that a recent number of the *Journal of Scientific Instruments* (July, 1935, page 214) contained a description of a new instrument for measuring the saturation deficit directly. The instrument was manufactured by Casella. It consisted of a bimetallic thermograph and a hair hygrograph working on the same drum. The clock of the instrument was removed, and by means of a specially ruled chart the saturation deficit could be obtained by a simple device. The instrument was not self-recording.

Mr. PATTERSON (Canada) pointed out that one great objection to relative humidity was that it was a function of two elements, the temperature and the water vapour. Vapour pressure was useful because it had only a small diurnal variation. In estimating the probability of the formation of cloud and fog, dew point was important, whereas for air-conditioning it was the water content that was required. In reply to Mr. Walter's question he said it was better to publish values of vapour pressure, from which the other elements of humidity could be derived, rather than relative humidity which was dependent on temperature.

Mr. SELLICK (Southern Rhodesia) said that a rough comparison of measurements of evaporation made by a Piche instrument with values of saturation deficiency had given a correlation of about 0.96.

Sir NAPIER SHAW said that different people needed different information about humidity. It was of first importance that the facts should be useful to the man who made the observations. Summarising the observations for other people was a different problem. There could be no advantage in taking a mean of relative humidity. It was equivalent to putting the observations in the waste-paper basket. (The figures for South Farnborough for a certain week of July, 1934, were quite convincing.)

The plan he had recently adopted to keep himself informed about humidity was to imprint the saturation pressure on the thermograph forms by means of a rubber stamp, and then, with the aid of a hygrograph-record, all the items of humidity could be obtained. An example was shown in the "Drama of Weather", of which copies were available for those members of the Conference who were interested in the subject.

It was a curious fact that all natural objects were definitely conscious of relative humidity. Everything that had been alive displayed its condition with regard to relative humidity, but it did not take mean values. Insects in Palestine took advantage of the diurnal variation of humidity by eating the herbage at night when the water content was large, and thus provided themselves with the water required for their existence. Individual observations of relative humidity were important for living creatures. A mean value was nought.

Sir Napier concluded by asking whether the record of a hair hygrograph was affected by wind.

In reply to Sir Napier Shaw, Dr. WHIPPLE confessed his ignorance as to the effect of wind, but thought that the effect must be small because the agreement between the records of the hair hygrometer and the humidity derived from readings of the wet and dry bulb was so close that it gave little margin for error.

He pointed out that in the *Monthly Weather Report* the humidity data were given for each separate hour of observation, and not a mean for all hours. If anyone wanted exact information in regard to the error introduced by deriving mean vapour pressure from mean temperature and mean relative humidity, they could obtain the information by referring to the *Observatories' Year Book*, where values so derived were shown alongside the true mean vapour pressure derived from the daily readings. The difference was usually of the order of a few tenths of a millibar, which was hardly large enough to be of practical importance.

Mr. SUTTON (Egypt) said that the agreement between the hair hygrometer and the humidity obtained from the wet and dry bulbs was not always close. Divergences might be as great as 10 per cent in relative humidity. Instruments that were set to read the same at the beginning of the week showed gradual divergences.

Mr. Sutton referred to the kata-thermometer and asked whether it was in use in England, and whether it gave reliable readings. It had been used in Cairo in the mummy-house.

Sir GEORGE SIMPSON replied that it had not been used in England as a meteorological instrument.

With reference to hair hygrographs, Dr. WHIPPLE said that there was definite hysteresis, the values recorded were liable to be too low when the humidity was rising and too high when humidity was falling.

Soil temperatures. The depth at which observations should be taken and the hours of observation (Appendix XXIX).—Mr. PATTERSON said that soil thermometers were being installed at the experimental farms in Canada, and he would be glad to have information about the hours of observation and the most suitable depths, though he recognised that the latter might vary according to the purpose for which the data were required.

Mr. BILHAM said that for many years the practice in Great Britain had been to use thermometers of the Symons type in steel tubes at depths of 1 ft. and 4 ft. Observations at greater depths had been made at Regents Park, Southport, Edinburgh, Greenwich, Camden Square and Oxford. When the crop-weather scheme was introduced agriculturists wanted observations nearer the surface. A bent-stem type of thermometer was introduced to give measurements at 4 in. and 8 in., and a thermometer of the Symons pattern was used for the measurements at 2 ft. required by horticulturists.

At the present time observations were being made at 4 in., 8 in., 1 ft., 2 ft. and 4 ft., though not all those depths were used at any one station. At a few stations soil temperature at 4 in. and 8 in. was continuously recorded by means of mercury-in-steel thermographs. It had been found that in the conditions likely to be encountered in this country the steel tube used with thermometers of the Symons type did not introduce appreciable errors.

Dr. KIDSON (New Zealand) said that the answer to Mr. Patterson's question depended on the instruments used. A cheap, reliable and convenient thermometer for use in obtaining soil temperatures at shallow depths was much needed. He asked whether the bent-tube thermometers had proved satisfactory, and also whether a thermometer of the Symons pattern could be used at a depth of 1 ft.; he had proved its usefulness for measuring temperature at 3 ft.

Mr. BILHAM replied that the readings of the bent-stem thermometers agreed with those of the Symons pattern. The bent-stem thermometers were cheap, but they were somewhat fragile and breakages were frequent on account of soil-movement during frost. It was found that the thermometer was stronger if the bend were gradual, but it was necessary always to keep spare thermometers available. One slight disadvantage was that they were difficult to test after installation. If a thermometer were inserted in soil near by it was difficult to know whether a difference of reading was a real difference in soil temperature or a difference between the thermometers.

Dr. SCHUMANN said that measurements of earth temperature had been made in South Africa for some time, but he was doubtful whether any use had ever been made of the results. He wished to know whether they were really valuable to agriculturists. He inquired also whether any attempt had been made to calculate the earth temperatures by a Fourier series from a knowledge of the surface temperature and the average conductivity of the soil.

Dr. BROOKS in reply said that in Uganda observations of temperature at 1 ft. and 4 ft. had been made three times a day over a period of about 10 years. He had calculated the conductivity from the annual wave and from the diurnal wave, and the value derived by one method was fifty-seven times as great as that derived by the other. In that case it seemed that the Symons pattern thermometer was not suitable for use in tropical countries.

Mr. WALTER said that in East Africa a special type of bent thermometer had been used that did not disturb the soil. A square hole was dug in the ground, one side was faced and then a small hole was bored in which the stem of the thermometer was inserted. The hole was then filled up with light sand to the level where the thermometer rested on the soil. The thermometers were sold at 30*s*. for a set of five, and were designed for measurements at 5, 10, 15, 20, 25 cm. Hourly observations at an agricultural station had shown that there was little diurnal change below 25 cm. The thermometers were extremely fragile.

Dr. BALLS (Egypt) said that he had taken observations of soil temperature by both primitive and elaborate methods, but there were many practical difficulties.

In 1921, Mackenzie Taylor had started observations at 10, 20, 30, 60 and 120 cm. The results were continued and published as a *Giza Technical Bulletin* in 1928; they showed that the temperature was higher in fallow land than in land under crop. Observations at greater depths were also made by the Meteorological Service on the same farm, but the temperatures were spasmodically affected by waves of underground water. Variations in soil and in water made it difficult to get a true value.

Dr. Balls said that soil temperatures would be especially valuable for forecasting the time when cotton could be planted. Even in Egypt there was some variability in temperature in spring between one year and another, and the time of planting of cotton might vary over as much as three weeks. To sow cotton at Giza at the end of February in a warm spring was not dangerous, but in a cold spring the whole crop might have to be resown. It would be very valuable, therefore, if it were possible to obtain a measurement of the soil temperature early in the spring; but the variability from place to place was too great for this to be done satisfactorily. The temperature varied according to the type of soil and was affected by infiltration of water. The only alternative to taking a very large number of observations at a large number of stations that he had been able to suggest, was to take the temperature of the Nile at the Barrage and regard that as to some extent integrating the soil temperatures.

Dr. KIDSON (New Zealand) asked whether it were possible to measure the temperature of the soil surface by radiation thermometers or otherwise.

Mr. SUTTON (Egypt) said that temperatures had been measured in Egypt with a Negretti and Zambra surface thermometer and fairly satisfactory results had been obtained on stone, road-surfaces and railway lines. He agreed that there was some doubt as to the degree of accuracy of the instrument.

Mr. ROGERS (East Malling) said that soil temperatures were the controlling factor in root growth, but it was the seasonal rather than the daily values that were important. Most roots penetrated to 1 ft. or 2 ft. and perennials usually reached a depth of 4 or 5 ft. He urged that soil temperatures should be taken to depths of at least 2 ft. Observations were of particular importance when plants were to be transplanted, as for root growth the soil must be sufficiently warm and moist.

Mr. YATES (Rothamsted) mentioned that soil temperatures were of considerable interest in connexion with the " Precision " observations on the growth of wheat in the Crop-Weather Scheme. The interval between sowing and appearance above ground (accurately measured by these observations) appeared to be very closely correlated with soil temperature. Later rates of growth were also likely to be considerably influenced by soil temperature.

With reference to the variability of soil temperature from place to place Dr. NORMAND referred to some experiments by Dr. Ramdas in Poona on the effect of varying colour of the surface on soil temperatures. When a thin layer of chalk was spread over the black cotton soil, the average temperature at a depth of a few centimetres in hot weather fell 10 or 15° C. The measurements were tested by a control experiment. The chalk covering was removed after a period of four weeks, and the plot slowly took up the temperature of the neighbouring soil. The experiments indicated that the temperature of the surface soil was largely governed by its colour.

Sir GEORGE SIMPSON asked whether agriculturists would say whether they were able to make use of the soil temperatures that had been published regularly for many years, or whether the fact that the observations were not in the exact locality of the crop made them useless for practical purposes.

Sir NAPIER SHAW said that the question of the value of temperatures at 4 ft. should be put to doctors rather than to agriculturists. Observations at a depth of 4 ft. were originally inserted in the reports on the request of Sir Arthur Mitchell, one of the founders of the Meteorological Society of Edinburgh, because he had found that when the temperature at 4 ft. rose above a certain level an epidemic started. It would be of interest to know whether the recent epidemic of influenza among cats were due to high soil temperature.

Mr. LEMPFERT recalled that the epidemics studied by Sir Arthur Mitchell were those of infant mortality.

In reply to Sir George Simpson, Dr. BALLS (Egypt) said that the values published by the Meteorological Office were of value as providing a base line on which agriculturists could work.

With regard to the importance of soil temperatures he referred to Van t'Hoff's law—growth was roughly doubled for a rise of temperature of 10° C. Since a root system extended in three dimensions this factor had to be cubed. Various activities also doubled so that the functional capacity of a root after a given interval of time might be thirty-fold greater at the higher temperature. Hence a very slight rise in soil temperature above the minimum of root activity was of great importance. A difference of temperature of only 4° C., which might be shown between the temperatures in a warm and a cold spring, might be of vital importance. That was why soil temperatures were required to a seasonal accuracy of $\frac{1}{2}$° C.

Dr. KEEN (Rothamsted) said that he might supplement what Dr. Balls had said with regard to the value of soil temperature. An observation at any station would serve as a basis for a considerable area around, but the observations that were provided by the crop-weather scheme were required before it was possible to specify the area to which the base line provided by standard observations would apply. The introduction of measurements at 4 in. and 8 in. was important, both because the surface layers were important for germination, and also because biological activities took place within the first 8 in. from the surface. A large number of stations was required to give an adequate statistical analysis and when such an analysis had been made it might then be possible to say that observations from a small number of stations would be sufficient.

Mr. ROGERS (East Malling) said that horticultural plants were mainly deep-rooted, and it was desirable to have temperatures both in the surface layers and at greater depths. The position of the wave of heat was important, and it was possible to note the speeding up of growth as the surface layers warmed up in the spring and the continuation of growth at great depths in the autumn where the cooling down was slower.

Mr. PATTERSON said that the problem was difficult; in Canada observations near the surface could only be taken in the frost-free period. In winter a tube projecting well above the surface was needed because it was essential not to disturb the snow cover. In western Canada frost sometimes penetrated to 5 or 6 ft.

Information of soil temperatures was useful in the study of insect pests. Parasites hibernated below the surface and would be killed by temperatures below a certain point, while at other temperatures they might become epidemic.

The meeting adjourned at 5 p.m.

(Signed) J. PATTERSON.

MINUTES No. XII.

Twelfth Meeting, Tuesday, August 20, 1935, 11 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Dr. L. Balls (Egypt), Mr. W. H. Beckett (Gold Coast), Mr. D. L. Blunt (Cyprus), Lt.-Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. D. W. Gumbley (Palestine), Mr. F. W. Hall (Gambia), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Mr. G. W. Nye (Uganda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Dr. M. A. F. Barnett, Professor D. Brunt, Mr. D. G. Davis (Ministry of Agriculture), Mr. F. Yates (Rothamsted), and the following members of the staff of the Meteorological Office :—Mr. R. G. K. Lempfert, Lt.-Col. E. Gold, Dr. F. J. W. Whipple, Mr. E. G. Bilham, Dr. C. E. P. Brooks, Mr. J. S. Dines, Miss L. F. Lewis.

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1. **Documents circulated.**—Minutes of the ninth meeting and of the sub-committee on codes for wireless reports from ships.

2. **Air masses as units in climatology** (Appendix XXX).—Dr. BROOKS said that his memorandum contained a brief history of the investigation of air masses up to the time of the classic paper by Sir Napier Shaw and Mr. Lempfert on the " Life History of Surface Air-Currents " and the beginning of the Norwegian investigation.

The paper went on to describe the ten types of air mass which were recognised at the present time in European weather. It had long been known that the weather associated with any one type was often quite characteristic so that the type could easily be identified by an expert meteorologist though it was difficult to identify the type from meteorological statistics alone.

The suggestion put forward was that climatological summaries should give the frequencies of different types of air mass and hence the frequency of days of different types of weather. Some examples were given in the memorandum.

The subject had been studied also in North America but as far as he knew little work had been done in tropical countries on the study of air masses from the climatological point of view. Dr. Brooks said he had examined the possibilities of identifying air masses in Nigeria and the results were set out in the memorandum. He exhibited a diagram of the observations for March to May, 1934, which showed the marked change in the values which took place about a day after a SW. wind succeeded a NE. wind.

Dr. Brooks recognised that it was not easy at first to recognise the air masses, but he thought it would be useful if a study could be made at one or two stations in each country at which daily observations were available. The suggestion was that a column should be added to the climatological tables giving, in some abbreviated manner, the frequency of the types of air masses experienced during the period to which the summary referred.

Dr. NORMAND (India) said that from the time of the publication of Dr. Bergeron's paper on dynamical climatology in the *Meteorologische Zeitschrift*, the possibility of getting climatological statistics in terms of air mass had been considered in India, and experiments with that in view had been made at Poona. On certain days the differences between different types of air mass stood out very clearly. This was especially so in June when the hot air of the early summer was replaced, either temporarily or for the whole season, by the monsoon. The same could be said

also in November, when a depression passed over south India ; with the onset of the equatorial current there were marked changes both in the values of all the meteorological elements and in their diurnal variation. On its first arrival the monsoon might be a thick deep current, but its height varied from day to day, and when the depth became less, cloudiness also decreased and the effect of sun increased, so that even in air that would be rightly classified as monsoon air there might be very different values of the meteorological elements.

He was doubtful therefore whether it would be possible to apply the analysis day by day ; on some days the type was clearly identifiable, but on other days the classification would be extremely difficult.

Dr. KIDSON (New Zealand) said that one great difficulty was that the properties of an air mass varied greatly during its travel, especially when subsidence was taking place. The same air mass had very different properties in Wellington from those which it possessed when it first reached southern New Zealand ; during its travel the air had subsided. Hence differences in the characteristics of the air depended not only on its place of origin but also on the dynamics of the mass itself ; they were not a constant property of the mass.

Mr. WALTER (East Africa) said that over the south Indian Ocean the phenomenon to which Dr. Normand referred was very marked. Pilot-balloon observations showed that the depth of the SE. trade varied very greatly ; when an anticyclone was passing over, the trade was of great depth, but it became much shallower as the high pressure system passed away. Similar changes in depth were noticed also on the East African coast.

Mr. PATTERSON said that no very intensive study had yet been made in Canada of the identification of air masses from the point of view of climatology. He thought that it might be possible to identify the place of origin of a given air mass, but it would be difficult to assign to it any characteristic properties because the properties changed considerably during the travel of the air mass.

A polar air mass when first it invaded the country was easily identified and had quite characteristic properties, but, as he had explained at an earlier meeting, an air mass which had arrived in Canada as dry and cold polar air might return again, after a few days over the southern States, carrying temperatures of 100° F. or more in summer.

Another type of air mass that was difficult to characterise came from the Pacific. When it arrived in Alaska it would be classified as maritime polar air, but it might have been over the Pacific for only a brief period and have very little moisture, whereas if it crossed the coast further south, after a longer travel over the sea, it would have considerably greater moisture but would still be classed as maritime polar air. A further change in its properties occurred when it passed over the mountains.

He thought, therefore, that it would be difficult, as explained in Appendix XXX (*b*), to classify an air mass after it had been over the land for any length of time. The problem was, however, worthy of investigation, and it would be a considerable advance in climatology if meteorologists could identify and describe the different types. It would, however, require very intensive study.

Mr. SELLICK said that in Southern Rhodesia forecasting was based on air masses, but the problem had not been studied from the climatological point of view. The air mass brought by NW. winds generally had the same characteristics, but the names used to designate air masses in temperate latitudes could not be used in the tropics. In winter the first wave of cold air crossed the Kalahari and entered Southern Rhodesia from the south-west as a dry current, its properties were very different from those of the air-mass carried by a SE. wind which gave overcast weather, drizzle and low cloud.

He thought the scheme was attractive but was afraid that if it were attempted in Southern Rhodesia it would be found that 50 per cent of the days could not be classified. In the beginning the study would be hampered by the lack of a suitable terminology, and he thought it would require five or ten years before such a terminology could be satisfactorily developed. It was desirable that each service should study the subject and publish the results for its own country.

Sir GEORGE SIMPSON said that it was necessary to distinguish the subjects that were suitable for individual research from those to which international organization was applicable. He thought the new type of climatology had come to stay, but for a long time it must be a specialised study that was carried on in places where climatic data could be examined in relation to synoptic charts.

He thought that every meteorological service might classify the various types of air mass that occurred in the region for which it was responsible, and might then work up the meteorological conditions on days when the several types were prevalent. He thought that that work might appropriately be carried on by a central office. Further, when the characteristics of the various types had been clearly set out it might be useful to attempt a classification day by day in order to determine the relative frequency of the different types. There would obviously be many gradations between the different types and such days would have to be classified as transitional. He thought the subject offered great opportunities for investigation, but that the time had not yet come for a change in the orientation of climatological work as a whole.

Mr. PATTERSON agreed that it would be many years before a sufficiently detailed nomenclature had been worked out to enable all days to be classified. He thought it was particularly desirable that appropriate names should be found for the typical air masses that occurred in tropical countries.

3. **Broadcast of climatological data.** (Appendix XXXI.)—The PRESIDENT called upon Col. Gold to give an account of the proposals that were being put forward.

Col. GOLD said that his memorandum gave a brief resumé of the history which had led to the formulation of the proposal in its present form. A suggestion had been put forward soon after the end of the war for the rapid exchange of climatological data, so that the various meteorological offices might be in possession of the data for all parts of the world. This was necessary if they were to be able to comply with the various requests which they received for information from the general public. The information was required for various practical purposes, particularly in regard to certain speculative business, such as the buying of wheat or cotton in order to even out unnaturally large fluctuations in supply and demand. It was needed also for the stimulation of scientific research. Research into climatic variations month by month was of much greater interest if the deductions made could be subjected immediately to practical tests. These were the two main reasons that had led to the proposal of a monthly broadcast of climatological data.

The original proposal had been that the distribution should be made by post, but obviously that method would be too slow if the data were to be of practical value, and it was undesirable also from the point of view of those engaged on research. Dr. Wallén had, therefore, suggested in 1919 that the distribution should be carried out by telegraph through some Central Bureau, and even at that time Prof. Bjerknes had pointed out that the question of publication would be solved if the broadcast were sent by wireless from a sufficiently powerful station to enable other countries to receive it. All the machinery necessary for such a broadcast was now in existence.

With regard to the type of information that should be broadcast, it was obvious that from a practical point of view temperature and rainfall were of the greatest importance, but from a scientific point of view pressure was the element which up to the present had lent itself most readily to generalisation over a hemisphere.

The International Climatological Commission had been formed in 1929, and at its first meeting in Innsbruck, 1931, Prof. Wagner put forward a proposal for the broadcast of climatological data by wireless telegraphy. The proposal was referred to the Commission for Synoptic Weather Information as that Commission had experience of codes and dealt with the machinery for the distribution of reports by wireless. The resolution adopted by the Synoptic Commission at its meeting at De Bilt was set out in paragraph 5 of the memorandum. The proposals had been accepted in essence by the Climatological Commission at Wiesbaden as the best means of initiating the scheme.

The proposal involved first the collection within each continent of the information for that continent ; the information thus collected might be greater than that ultimately issued. It was suggested that this collection should be effected by adding figures representing the mean values for the month at the end of the synoptic message on the 1st, 2nd or 3rd of the month following the end of that to which the mean values applied. It was visualised that data for about 1 in every 5 of the stations used for synoptic work should be included in the monthly broadcast.

The recommendation for retransmission of the data thus collected was that the information should be issued on the 15th of the month ; for north Europe and north Africa from Rugby, for the rest of Africa from Cairo, for America from Washington, for the U.S.S.R. from Moscow, for Australasia from Sydney and for the Far East from Tokyo.

It was proposed that pressure should be given to the nearest millibar by two figures (with provision for its being given to 0·1 mb. in tropical regions), temperature in degrees centigrade and tenths by three figures, rainfall in centimetres by two figures, or in millimetres if the fall were less than 1 cm.

It was recognised that data for a large number of stations were required in order to obtain an index of the rainfall over a large area, but it was undesirable to wait until such an index could be agreed upon. It was thought that for the present reports from a selected number of stations would be sufficient.

Dr. BROOKS referred to the fact that the date for the retransmission of the information had been fixed for the 15th of the month following that to which the data applied. He hoped that in course of time it might prove possible to fix an earlier date. A summary of the weather of the month all over the world, collected chiefly from newspaper reports, was published in the *Meteorological Magazine* which went to press on the 10th, and it would be a great advantage if reports could be received before that date. He said that it was the practice in the Meteorological Office, London, to construct from the *Daily Weather Reports* a monthly pressure map of the northern hemisphere, and the map was completed on the afternoon of the last day of the month to which it applied. If that were possible in a single office, he thought that it should not be beyond the power of international organization to obtain a broadcast before the 15th of the month.

Mr. WALTER asked whether it was proposed to publish the data which were broadcast. He said that he frequently received requests from people in England with agricultural interests in East Africa, for information about rainfall, and he arranged that such information should be despatched each week by air mail. He thought that the rapid publication of the data for the world might be useful.

Mr. BILHAM asked whether the question of expressing the data as deviations from normal and as percentages of normal had been considered. He thought such a form had certain advantages and might simplify the broadcast message.

Col. GOLD agreed with Dr. Brooks that it was desirable that a date earlier than the 15th should be aimed at. The date by which the collection of data could be completed must, however, be left to each individual country. There need be no delay in the issue of the continental message when once the collection was completed. In reply to Mr. Bilham, he said that the figures of actual temperature and rainfall were those likely to be of use to the greatest number of people, and there was the further advantage that no computation was needed in order to obtain them. If any country possessed the normals the departures or percentages could easily be obtained, and if they were not in possession of the normals the percentage figures would have little value.

Dr. BROOKS added that the question of broadcasting deviations from normal had been thoroughly discussed at Wiesbaden before the proposal was put forward. It was proposed that special normals should be compiled for comparison with the broadcast figures.

Col. GOLD agreed that Mr. Walter's proposal for the publication of the data should be considered. It was intended that the Meteorological Office of each country should pick up the broadcast and should make what use of the data it found desirable. It would be necessary to have some form of check either in the message itself or by post, and every service should arrange to get from the observers the total rainfall and the mean temperature of the month for comparison with the data compiled at Headquarters from the daily values.

Sir GEORGE SIMPSON said that for psychological reasons it was much more likely that the collection would be successful if the data were broadcast on a definite date than if they were sent by post ; experience of collecting data for the *Réseau Mondial* had made him acquainted with the difficulties of getting data by post.

One of the difficulties of broadcasting data immediately at the close of the month was that if that were done the data must depend on information received by telegraph and were therefore more liable to error than if they were collected by post. When once a figure was broadcast it was difficult to correct; he thought it was better to have the data late and correct rather than early and liable to error. He thought the data should all be converted into the same units and saw no difficulty about using ° C. for temperature.

It was the intention that normals should be printed possibly by the Secretariat. The choice of the stations for the broadcast was to be left to each service, but it was suggested that, as far as possible, the stations should be those used in the *Réseau Mondial* for which normals were available.

With regard to the payment, the old tradition was being adhered to, namely, that each country carried out the work voluntarily and was repaid by the information it received in return. He thought he would have no difficulty in getting permission for the broadcast to be issued from Rugby if he could assure the Government that the issue was part of an international scheme in the organization of which other countries were taking their proper share.

Mr. PATTERSON said that the Broomhall Corn Exchange was interested in the weather of the wheat-growing district, and received telegrams giving the temperature and rainfall in that region for which they paid the tolls. He emphasised the need for some check on the broadcast message, because if once mistakes crept in it was difficult to correct them.

The Conference was in agreement with the proposals made by the International Climatological Commission for the broadcast of climatological data, and expressed the hope that the necessary arrangements could be made for issuing it.*

4. Computation of meteorological averages. (Appendix XXXII.)—Mr. BILHAM opened the discussion and gave a brief account of the problems described in his memorandum. He said that the problems referred especially to the period for which averages should be computed, the choice between "adjusted averages" and "straight averages" and the question of how often averages should be recomputed.

Mr. Bilham referred to one point of importance which was not mentioned in the memorandum, namely, that in 1921 an important change had been introduced in the régime of observations of maximum and minimum temperatures at stations in the British Isles. Before that date the readings referred to 24-hour periods ending usually at 7h. or 9h. In 1921 it had been decided that for telegraphic stations and for some climatological stations also the observations should refer to the day maximum and the night minimum. The effect of this change on the averages was investigated by using data from Kew Observatory and Falmouth. It was found that, especially in the case of the minimum, the change had an important effect. The averages over a 24-hour period were not the same as those obtained for the day and night periods.

The only satisfactory solution in working up the averages had been therefore to regard the records as beginning in 1921 when the change took place and to discard the earlier observations. In 1926 the climatological stations had all reverted to the practice of using the 24-hour period, and this had introduced a further complication. The practice adopted had been to compute averages only from data for the period during which the observations were strictly comparable with the current practice.

This sharp discontinuity in the observational practice with regard to temperature had led to a thorough investigation of the whole question of weighting, and it had been finally decided that the "straight averages" for temperature should be computed for the period over which the data extended, with the understanding that no average should be given for a period of less than 10 years, and that if data were available for more than 30 years the average for the most recent 30-year period should be given. Thirty years was selected because it was regarded as the maximum period over which homogenous observations were likely to extend.

Mr. Bilham pointed out that quasi-secular trends existed and an average over a long period was not necessarily the best for current purposes. What one

* *See* Resolution 74 of the Conference of the International Meteorological Organization at Warsaw, 1935. It was agreed that the information should be distributed as soon as possible and at the latest on the 5th of the month.

wanted was an average for a period long enough to smooth out casual variations but not so long that the secular trend would introduce a serious departure from the current normal value.

Mr. Bilham referred to the practice of weighting and said that this practice was used in the Meteorological Office for obtaining rainfall averages. The network of rainfall stations was very dense and it was therefore always possible to find a station with a record over a long period which could form a basis for the adjustment of values over a short period at a neighbouring station. Much work had been done on rainfall for the 35-year period 1881–1915, and for that reason it was not proposed to change that period at present.

Mr. Bilham reported that in the case of sunshine and temperature straight averages were used, and for these elements it was proposed to use a 30-year average brought up to date every 5 years; the average had been computed for 1901–30. The intention was to change over later to 1906–35, then to 1911–40, and so on.

Dr. NORMAND (India) said that the main reason for choosing a particular period for averages was in order to obtain adjusted averages for a station with a shorter period and also for convenience in examining climatic variations. He thought that it should be made evident that for each individual station the best average was that obtained by taking *all* the data available for that station. The choice of any definite period did not enable one to say that the averages were then comparable as true normals over a large area because there might be a negative correlation between the climatic variation in one part and that in another. As an example he referred to the fact that at Madras the 30-year average had shown a gradual increase during the last 20 years, while a similar average for Bombay had shown a decrease in the same period. For a network of stations it was best to choose as long a period as possible with the greatest number of stations. Normals might be for 35 years and might be revised every 15 or 20 years as new data became available.

Dr. SCHUMANN (South Africa) said that he had recently had the opportunity of making a thorough examination of the rainfall of South Africa. He had found very large differences in long period averages. In 1890 the average rainfall over a period of about 20 years at Graaff-Reinet was 17 in. whereas the average in the last 20 years was only 12 in. Such changes were very general, and similar changes were found both in South Africa and in parts of Australia. An estimate of the number of sheep in Australia in 1890 was 103 millions, and in 1900 it had fallen to 53 millions; that change was probably due to a change in the amount of rainfall. These figures showed that in some countries a "normal" rainfall had no meaning.

In 1926 rainfall normals had been published for South Africa for all stations, whatever the lengths of their record, and the periods varied from 6 months to nearly 100 years. It was intended to publish new averages in 1936, and he would be glad of advice as to what form they should take. If the averages were compiled for the whole period of the observations they were not comparable because the secular trend was large, if an arbitrary period for example 1906–35 were selected, many stations had records for only a short period and the records would have to be omitted or else adjusted from a study of the secular trend of the particular locality.

A further question arose with regard to the publication of averages for districts when the number of stations in the district differed from year to year. It was difficult to know whether the figures were comparable in those conditions.

Sir GEORGE SIMPSON said that he felt the subject was very important especially for those starting a new service. Dr. Normand had suggested that the period to be chosen should be the longest period available, but in the case of temperature, for example, he was doubtful himself whether this were true. The changes in the quality of the instruments, in the methods of observation and in the precautions taken to secure greater accuracy were so great that he thought normals might be spoilt rather than improved by extending the length of the period. For that reason a period of 30 years had been selected for temperature averages and it was suggested that these averages should be brought up to date every five years, but that the length of the period should remain the same. A period of 30 years was sufficient to smooth out the variations in a country such as Great Britain but for other countries a different period might be required.

Sir George said he thought that if averages were compiled for a definite period without making any adjustment they were more easily comprehensible to the ordinary inquirer. He did not agree with the suggestion put forward in Appendix XXXII (*c*) that it was desirable to eliminate the secular trend before computing the normals.

The question was somewhat different in the case of rainfall and for that the adjustment of figures to a standard average might be legitimate, but even if it were he was doubtful whether " straight " averages might not be preferable. He thought it was a question on which each director must make his own decision ; no rule could be formulated that would be applicable to all countries.

With regard to district normals, Sir George explained that it was the practice in Great Britain to publish monthly normals for districts. In view of the difficulty of adjusting the normal on every occasion when there was a change in the stations used to represent the district, it had been decided that in publishing the values for districts the mean departures from the normal, computed from the means of the departures from normal of each station, should be given. It had been found that the departures from normal showed greater regularity over a large area than the actual values themselves. No normals for districts were now published.

Dr. SCHUMANN pointed out that in drawing rainfall maps some adjustment to a common period must be made before it was possible to draw isohyets.

Mr. BILHAM said he would be glad to show to any delegate the method adopted in this country for drawing rainfall maps.

Col. GOLD said that so far as he knew the only period for averages that had been suggested in international resolutions was 1901–30.

He would like to say a word or two about the question of averages. If one left aside for the moment practical difficulties and effects due to improvements of instruments and methods, then for an element which had a definite secular change there are two logical courses. The first is to compute from the known secular variation the average applicable to the middle of the period concerned, e.g. for use in the decade 1931–40 the average would refer to the epoch 1935. The second is to compute the average from the records available—preferably from the whole of the records—and to say : these are the averages for the period, 1865–1930, for example. One would then add that in 1931–40 the values would tend to be below or above this average by the amount deduced from the secular variation.

For elements showing not a true secular variation but a variation of long period, the logical course is to take the average for a period of years equal to the period of the variation, e.g. if a Brückner cycle were real and regular, a period of about 35 years would be appropriate ; and averages deduced from records for a shorter period should be adjusted to the standard period.

Actually secular changes, if any, and long period changes are irregular and uncertain and in most cases the best average would be one based on the longest series of comparable records available. He thought it necessary that this aspect of the scientific side of the question should not be disregarded.

Dr. KIDSON said that many difficulties had been mentioned in the course of the discussion, and some or all of them were experienced in every country. It was obvious that no one procedure would fit all countries. He thought the problem of getting annual normals was different from that of getting monthly normals. For annual normals a shorter period was required than was required for monthly normals. In New Zealand it was the practice to weight the values when averages for months were compiled. He had found, however, that weighting rainfall records did not always give satisfactory results ; when additional records became available it was sometimes found that straight averages would have given a better value.

There was no regular trend of temperature or rainfall in New Zealand and, for forecasting, the longer the period the better the probable value.

Mr. LEMPFERT thought it might be of interest to recall an old resolution of the International Meteorological Organization at the end of the last century which suggested that data of all elements should be computed for periods of five years, ending with 0 or 5. No service had carried out the resolution in its entirety, though averages for lustra had been published for a number of years by some of the German offices. There was, however, something attractive in the proposal, and it was of interest that the working forms used in the Meteorological Office were on the 5-year basis. They had been found very convenient for record keeping.

Mr. BECKETT said that he had difficulty in the Gold Coast in trying to draw rainfall maps from data for different periods. Another problem occurred there. Something of the order of 2 million acres of forest had been cut down in recent years, and this deforestation affected the records of both temperature and rainfall. For that reason it had been found better to use averages for a short period.

Mr. PATTERSON said that with regard to the adjustment of rainfall values by comparison with adjacent stations, he thought the possibility of such adjustment depended on the character of the rainfall. It was impossible if the rain was chiefly of the thunderstorm type, though it might be practicable with other types. In western Canada the variations from place to place and from year to year were so great that it was impossible to adjust the values. In his opinion the best normal was obtained by using the best information available over as long a period as possible.

Mr. Patterson said that in Canada maximum and minimum temperatures were observed over a period of 24 hours. He asked whether other services experienced the difficulty which he himself had found in getting the observer to enter the data of temperature and rainfall against the right day. In Canada the mean temperature of the day was given as the mean of the maximum and minimum.

Mr. SELLICK said the difficulty had been experienced in Southern Rhodesia, but had been got over to some extent, though it still occurred in the case of new observers. The telegraphic reports were checked with the monthly returns.

Dr. KIDSON reported similar difficulties. In the case of temperature, he said that at some stations a correction was applied to the mean of the maximum and minimum in order to give the mean temperature.

Dr. WHIPPLE asked whether the practice of using a day maximum and a night minimum was in use in any other countries than Great Britain. The method had been introduced because it was found that at stations where observations were made at 7h., if a very low minimum occurred it might count on two successive days when the 24-hour period was used.

Dr. KIDSON said he had found it better to get uniformity rather than precise accuracy. The errors introduced by using a 24-hour value were not very large and could be eliminated by using hourly averages when computing the mean temperature.

Mr. PATTERSON said that in Canada the synoptic hours were such that the minimum frequently occurred after the morning observation which was taken at 5h. in some parts of the country. In Canada maximum and minimum temperatures were taken over a 24-hour period.

Mr. STEWART said that in Malaya the synoptic hour was 6h., and the minimum usually occurred about 6h. 30m. so that a special reading had to be made at 7h.

Mr. YATES speaking as a statistician referred to the work of Prof. R. A. Fisher on the effect of rainfall on wheat-yield. For this purpose he had fitted fifth degree polynomials to the record of rainfall over 60 years. The total rainfall for each year was obtained, together with five other constants for each year, representing various aspects of the rainfall distribution in that year. A trend was found in the total rainfall and in one of the constants, but not in the others. From this work it was obvious that there were complex effects in rainfall trends ; unless elaborate investigation was possible it was better to publish straight averages over stated periods. If one felt justified in saying that there was a trend or a cyclic change another figure representing an " adjusted " average might be added.

The PRESIDENT said he thought the discussion had been very valuable, especially for those who were starting new services and for those who were intending to recompute their normals.

The consensus of opinion was that for computing normals of temperature a 30-year period was the lowest that should be used and a 35-year period for rainfall. That when new normals were to be computed the first years should be dropped and the most recent added.

The meeting adjourned at 1.10 p.m.

(Signed) J. PATTERSON.

MINUTES No. XIII

Thirteenth Meeting, Tuesday, August 20, 1935, 3 p.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Dr. L. Balls (Egypt), Mr. W. H. Beckett (Gold Coast), Mr. D. L. Blunt (Cyprus), Lt.-Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. F. W. Hall (Gambia), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Mr. G. W. Nye (Uganda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir Napier Shaw (President Agricultural Meteorological Committee), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Dr. M. A. F. Barnett, Prof. D. Brunt, Dr. V. E. Wilkins (Ministry of Agriculture), Mr. D. G. Davis (Ministry of Agriculture), Dr. B. A. Keen (Rothamsted), Mr. F. Yates (Rothamsted), and the following members of the staff of the Meteorological Office :—Mr. R. G. K. Lempfert, Lt.-Col. E. Gold, Dr. F. J. W. Whipple, Mr. E. G. Bilham, Dr. C. E. P. Brooks.

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1. **Correlation of general crop-observations with meteorological data.** (Appendix XXXIII.)—Mr. Yates (Rothamsted) gave an account of his memorandum (Appendix XXXIII (*a*)). He emphasised that some technique for securing random selection was essential when taking observations of any kind on samples of a growing crop, and described that which had been devised in connexion with the precision scheme. He said that the technique outlined in his memorandum had, up to the present, only been used for wheat, but it could be used for other cereals.

Dr. Normand (India) referred to Dr. Ramdas' memorandum (Appendix XXXIII (*b*)) which described the work on the correlation of crop observations with meteorological data that was being carried out at Poona by a special Agricultural Meteorological section that had been sanctioned and financed by the Council of Agricultural Research and had been in operation for three years. The acreage data in India were regarded as fairly accurate and Dr. Ramdas had correlated, especially for the Bombay Presidency, the meteorological data, district by district, with the data of the acreage under different crops. The yield data were reputed to be subject to large errors, but as they were the only data available Dr. Ramdas had used them to try to find a correlation with the meteorological data year by year.

In reply to a question by Sir George Simpson as to the meaning of the acreage under crop and as to how it could be correlated with the meteorological data, Dr. Normand said that the amount of land put under cultivation in any year depended to some extent on the weather of the previous months. He pointed out that for getting a forecast of crop the acreage as well as the yield was needed.

An interesting point about the correlation of meteorological data with yield was that different districts showed common features indicating that the yield data approximated more closely to reality than had been anticipated.

Dr. Normand said that it was evident that the agricultural data at present available were insufficient and an attempt had been made at the Agricultural College Farm at Poona to follow the British precision scheme. Two years' data were now available for rice and jowar and it was proposed that the experiments should be continued.

Dr. Normand asked whether every observation required on the plant was included in the precision scheme. He had been told by an agriculturist that on one occasion a failure of wheat in the Punjab had occurred after two days of very dry and windy weather which occurred after the ears had emerged but before they had properly developed. The failure had not been indicated by field observations and was not generally recognised till after the harvest and then it was realised that the yield was unexpectedly small.

Mr. Beckett said that crop forecasting was of great interest on the Gold Coast where the crop on which the Colony depended was cocoa. The yield in different years varied from 194,000 tons to 250,000 tons and it was of considerable importance, both to the Government and to commerce, to know what the crop would be.

Crop statistics were not exact, but when he had obtained fairly accurate data of the yield he had tried to relate it with the meteorological data. Total rainfall, rainfall at critical periods, effective rainfall, humidity and temperature had all been used in an attempt to get a correlation, but the highest value obtained was 0.6. By taking deviations from the rainfall trend and deviations from the yield trend, a fairly high correlation had been obtained but it was not of much assistance in forecasting. The average error was greater than that in the observer's estimate. The total period between flowering and maturity for cocoa was six months, and a forecast was required of the crop four months before it was harvested ; he had found that this could be obtained more accurately from observations of the growing crops than from the meteorological data.

He would be glad of suggestions for obtaining a good correlation between meteorological data and yield for an orchard crop in the tropics.

Dr. Schumann said that in South Africa the main crop was maize and the close correlation between rainfall and maize yield was well known to everyone. Two years ago the total production had been 8 million bags whereas last year it was 22 million and the difference was certainly due to rainfall. Estimates of the crop from meteorological data had little chance of success, what was required was a forecast of the season.

Mr. Sellick said that in Southern Rhodesia for the comparison of meteorological data with the maize crop ten day periods were used ; good correlations were obtained with rainfall and sunshine and a reasonably good correlation also with temperature. The value was about 0.8, and forecasts from meteorological data compared well with the statistical forecasts issued two months later. Not much interest had been taken in them, however, until recently, when the experts differed as to whether the figure should be 1,200 thousand or a 1,000 thousand. According to the meteorological data it should be a 1,000 thousand, but he had yet to await the actual figure.

In reply to a question from Dr. Schumann with regard to absence of rain in the sowing season, Mr. Sellick said that in 1933 the Government were holding one quarter of a million bags of maize and were doubtful whether to export it. The meteorological forecast was for drought, and he had advised the Government to continue to hold ; the forecast had been successful.

In reply to a question of Sir George Simpson as to how far the estimate of an existing crop could be regarded as a forecast, Mr. Sellick pointed out that the crop remained stooked for two months after reaping and a true figure of yield could not be obtained until after the flour was bagged. An estimate of the yield of the standing crop might therefore be regarded as a forecast.

Mr. Beckett (Gold Coast) added that a first estimate of the cocoa crop was made in August when some of the trees were still only in flower. The harvest period extended from October to April.

Dr. Schumann (South Africa) said that he was uncertain as to the exact date when the estimates of the maize crop were made ; but estimates were obtained at various times. The knowledge of the expected yield was important from the point of view of the export quota.

Mr. Yates (Rothamsted) said that he thought it was legitimate to speak of a forecast of the wheat yield when the estimates were made three months before harvest, though it was admittedly a short term forecast. At Rothamsted correlation of wheat yield with the winter rainfall gave a reasonably good forecast of the yield five or six months ahead. No one in the agricultural world would expect a longer forecast than that ; even a one month forecast would be valuable if it could be issued at once, for the crop was usually not on the market until two months after harvesting. Forecasting became progressively more difficult the longer the period.

Mr. Patterson said that in Canada the great problem was in connexion with wheat in the prairie provinces and for that the controlling factor was rainfall. Temperature was also very important but it was found that when the rainfall was good the temperatures were not usually high, whereas when rainfall was deficient temperatures were high and were often accompanied by hot drying winds.

The Dominion Bureau of Statistics issued crop reports and tried to get an estimate of what the yield would be. They had numerous crop correspondents in the wheat districts who sent weekly reports to the Bureau of the condition of the crop, the amount of damage by hail, and also reports on soil moisture. The Meteorological Service furnished the rainfall data. Attempts had been made to get a correlation between meteorological data, chiefly rainfall, and the final wheat yield, but it was found that there were insufficient data for the crops. About ten years ago in co-operation with the Dominion Bureau of Statistics their crop correspondents had included in their reports notes of the dates of sowing, first appearance above ground, of the first shoot, of the head, etc. Mr. Patterson said that the data had been collected but had not yet been investigated. It was hoped they would prove of real value. The problems were difficult, but unless they were studied no progress would be made.

Mr. SELLICK said that in Southern Rhodesia, the " planting rains " in the maize belt occurred almost on a given calendar date, the variation was only between November 25 and the first week in December. In consequence maize was planted at a definite time. As only standard types of white maize were grown, this resulted in a uniformity which facilitated correlation. In the preliminary investigation rainfall totals had been used from telegraphic reports, based on the calendar week, but the fluctuation of the week in the year gave rise to difficulty and 10-day periods had been used instead.

Dr. KIDSON said that in New Zealand the rainfall was near the optimum so that the question was extremely complicated and it was difficulty to isolate the various factors. Mr. Yates had suggested in his memorandum that artificial rainfall might be used, he would like to ask whether such rainfall could be produced. In New Zealand rain sometimes fell continuously for two or three days with mild temperatures and cloudy skies, and on other occasions it was in the form of sudden heavy rain.

Mr. YATES admitted that it might be difficult to produce artificial rainfall in conditions similar to natural rainfall but thought the difficulties were not insuperable.

Dr. KIDSON said that the humidity conditions which accompanied rainfall were important, and pointed out that there were large differences between plants grown under irrigation and those grown under natural rain.

Mr. YATES said that he saw no reason why humidity should be of great importance. Irrigation was different from artificial rain because for irrigation the ground was soaked.

Mr. PATTERSON drew attention to the irregularity of rainfall in the western prairies especially in drought periods. For example in 1933 there was very good rainfall until the end of May, and in places the ground was nearly flooded ; from the beginning of June the weather in the drought region was dry and hot and as a result the crop was ruined. In 1934, again in the drought districts, the early part of the period was dry and dusty ; there were good rains in June and growth in that month was satisfactory, but after that the rain ceased and the crop again failed.

Mr. WILKINS (Ministry of Agriculture) said that he had been much impressed during the discussion by the great interest taken in different parts of the Empire with regard to crop forecasting. In Great Britain, stimulated to a large extent by Sir Napier Shaw, agriculturists and meteorologists were trying to get together on a scientific basis the material for a crop forecast, such a forecast was of paramount importance. He hoped that the work done in Great Britain might be linked up with the work in other parts of the Empire, through the Committee over which Sir Napier Shaw presided.

He emphasised the great value of a crop forecast even if it were only for one month ahead.

Dr. BALLS (Egypt) agreed that the topics under discussion were agricultural rather than meteorological. He thought that it showed a responsibility falling on the agriculturist to provide figures of " analysed " crop yield, progressive through the growing season, which would be susceptible to treatment in connexion with the available meteorological data.

Such data for analysed yield had been available for Egyptian cotton since 1909, increasing in quantity, and it was hoped that there would soon be upwards of two hundred routine observation stations in place of the twenty or so which now existed. The direct utilitarian value of such records was not fully exploited, and their main advantage at present was rather an intellectual satisfaction in closer knowledge of what the crop was doing.

The wide-spread belief that irrigation was so very different from rainfall was not warranted. All the physiological work done on cotton under irrigation had been paralleled by similar work on cotton under rainfall. The temperature of rain had been mentioned, but even the temperature of irrigation water entered into the finer shades of the subject ; there was a common peasant belief in Egypt that the time of the day at which irrigation was carried out affected the crop, and an investigation by some of his colleagues indicated that such was actually the case. He suggested that because heavy rainfall reaching the soil had a perceptible effect on soil temperature if the rain were markedly warmer or colder, a thermograph record of the temperature of rain as it passed through the rain-gauge might conceivably have its uses in agricultural meteorology.

Sir NAPIER SHAW said that his experience of agriculture was limited. The information which had been described was for standard crops; there were many things in forestry, in horticulture and in root crops that needed examination from the point of view of the observer rather than of the calculator. It was very desirable that facilities should be given to meteorological observers for connecting information about crops with the weather.

Two or three years ago a large crop of walnuts and acorns had been attributed to the fine summer of the previous year, but in the preceding discussion he had heard nothing about the effect on the crop of the weather before the crop was sown. Nor had he heard anything about the depth at which the temperature of the soil should be measured. He would be glad to know when the temperature at 4 ft. began to affect the crop grown at the surface. He thought nature was always suggesting that we had a good deal to learn before we should be able to boast of our knowledge. Some years ago a seed had blown into his garden, it had been left to grow for 2 or 3 years and then last year had been cut down by sawing it off at the surface. The crop this year was magnificent. He thought it must be profiting by conditions at 4 ft.

Sir Napier said he thought that there was an enormous amount of information to be obtained from the consideration of why ? before one took up the consideration of how much ?

Forecasting was the end that was really wanted, but the explanation of why the weather yesterday was what it was, was also of interest. He thought there were many questions that could be answered by observations of the temperature and humidity of the soil, and he was gratified to learn that Mr. Rogers had succeeded in devising a simple instrument for measuring soil humidity.

Now that we had the means of obtaining the necessary measurements, we needed intelligent observers who could put together the observations to enable us to form an opinion of the reason why, as well as how much, in the future.

2. **Seasonal forecasting.** (Appendix XXXIV.)—Dr. BROOKS referred to his memorandum which had been circulated, and said that at one time he thought the best line of approach was by direct physical reasoning to relate the conditions in one position at one period with those in another position at a later period. The relationships were very complex, and he was coming to the opinion that Sir Gilbert Walker's method of correlation might be the most logical. The unit Sir Gilbert used was three months, but that was too long a period for the British Isles.

Dr. Brooks said that he had recently experimented on the possibility of forecasting for a month ahead from monthly maps of pressure anomalies. It had been found that such anomalies travelled across the map in much the same way as " highs " and " lows " travelled across a synoptic map. More recently charts for 15 days had been used instead of those for the month, four such charts were exhibited.

Prof. BRUNT referred to the possibility of forecasting by periodicities to which he had devoted a considerable amount of time. He said that his investigation of Greenwich temperatures showed that only one-seventh of the variance could be eliminated by using a curve representing 15 periods.

He referred to the fact that a curve based on a number of periodicities often gave good agreement with the observed values over a long period of years, and then the relationship suddenly broke down. He said that his investigations had demonstrated the futility of attempting to forecast from periodicities in temperate latitudes, but the same might not be true in tropical regions.

Mr. PATTERSON said that the problem was assuming considerable importance in Canada where a great desire was being shown for seasonal forecasts of the weather in the prairie provinces. He had felt that in the present state of knowledge it was impossible to issue a seasonal forecast, but he would be glad to learn what was regarded as the most hopeful method of approach.

Dr. SCHUMANN said that one line of attack had occurred to him in investigating the secular changes of rainfall in South Africa and in Australia. A smoothed curve of the rainfall of the inland regions of those countries, drawn on a percentage basis, showed periods of high rainfall with maxima around 1874 and 1890. He thought that these high values must have a real physical basis, and hoped by investigating other meteorological elements it might be possible to identify two or three outstanding factors which had been responsible for producing excessive rain during those two periods.

A knowledge of the general trend of the rainfall curve was not of much value for forecasting the rainfall of any single year, but it might be of use in problems of afforestation if it were possible to forecast the arrival of a series of wet years.

Mr. BECKETT (Gold Coast) said he thought the rainfall of Trinidad showed similar variations to those which Dr. Schumann had described in South Africa and Australia.

In reply to a question of Dr. Kidson about the rainfall in South Africa in the periods 1910–5 which was dry in Australia, and in 1916–8 which was wet in Australia, Dr. Schumann said that 1917 was wet, but there had been a downward trend since that year. He thought that the rainfall of South America did not show so close a resemblance to that in South Africa as was found in the rainfall of Australia.

Dr. BROOKS referred to a theory recently developed which suggested that the possibility of obtaining periodicities in weather was greater in tropical than in temperate regions. He thought the factors causing the high rainfall in South Africa in 1890 might be world-wide ; that year was a year of marked maximum in the circulation over the South Atlantic as measured by the velocity of the SE. trade.

Mr. STEWART (Malaya) said he had recently discussed with Dr. Berlage the question of periodicities in tropical weather, and the one point which was clearly apparent was that periods could undoubtedly be found, but sooner or later they broke down, though they might begin again at a later time.

In Malaya seasonal forecasting was important for floods, which were disasters of great magnitude and required a special organization to be put into operation for the relief of distress. A flood in the winter of 1926–7 coincided with a fall of rain of 50 in. in three days.

No very definite results had been obtained by using Sir Gilbert Walker's method of correlation, but an attempt to forecast by means of periodicities seemed to give more hope of success. He found that if the 11-year period were eliminated from the curve representing the rainfall of the monsoon season, the resulting figures showed a correlation of 0·9 with those obtained from a pure sine curve ; the data covered a period of 70 years, and the complete sine curve extended over a period of 57 years, so it could hardly be described as a periodicity. Nevertheless a forecast for the rainfall during the last monsoon derived from an 11-year and a 57-year period had proved successful.

In forecasting floods one was concerned with the total winter rainfall, but for rice the problem was different. The amount of rainfall was not sufficient ; a forecast of the time of onset of the winter rains would be of considerable value.

In Malaya the grower's year about which Sir Napier Shaw had spoken varied over four or five months.

Dr. WHIPPLE said that it might be of interest to delegates who might be considering the application of statistical processes to seasonal forecasting, to know that Mr. Bliss, who had assisted Sir Gilbert Walker in his work on correlation, had terminated his employment at the Imperial College when Sir Gilbert Walker's professorship came to an end.

Sir GEORGE SIMPSON said he thought it was important to try to get some physical idea of why variations in climate occurred from year to year, and why the atmosphere did not settle down to a steady state. Dr. Jeffreys had shown that the general circulation was itself of necessity unstable and the general flow must be broken up into a series of whirls.

He thought the attempt to forecast fluctuations of climate from year to year was somewhat analogous to forecasting the position of a particular eddy in a turbulent stream.

In the tropics conditions might be more stable and more directly controlled by solar radiation. That would involve a close correlation between conditions in all parts of the tropics and he was not sure that any such correlation existed. He asked whether any attempt had been made to correlate weather over a whole belt of latitude at the same time.

Dr. BALLS (Egypt) said that he would like, with some hesitation, to direct attention to the existence of striking mechanical analogies to the periodicities which, though quite real, were very elusive on account of damping and change of phase. The smooth running rollers of cotton-spinning machinery developed a complex periodic structure in the cotton which passed through them ; this might run through many consecutive periods and then be thrown out of gear by some accident such as the entangling of one hair on another, after which it would gradually build up again. The similarly smooth revolution of wheels produced the corrugation of road-surfaces and of tramway rails, even when periodicity in the driving mechanism was eliminated.

Col. GOLD said he thought the time had come when cycles might be " stored ". He thought sufficient experience had accumulated to show that there were no regular cycles of importance except those of the day and the year. The same, however, could not be said of " oscillations ". For example, the sun shining on the oceans might set up some sort of regular oscillation. As the sun shone water evaporated, the water vapour in the atmosphere increased and that in time led to increased cloudiness. This meant in turn decreased sunshine, and less evaporation and so there would be an oscillation though it would probably have no regular period. The process would not be annual though it might be related to the size of the continents and oceans. Such oscillations, if they could be identified, might be of considerable meteorological importance.

The meeting adjourned at 5.0 p.m.

(Signed) J. PATTERSON.

MINUTES No. XIV

Fourteenth Meeting, Wednesday, August 21, 1935, 11 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Dr. L. Balls (Egypt), Mr. W. H. Beckett (Gold Coast), Lt. Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A.E.Sudan), Mr. D. W. Gumbley (Palestine), Mr. F. W. Hall (Gambia), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Mr. G. W. Nye (Uganda), Cmdr. G. S. Ridgway (Bermuda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Dr. M. A. F. Barnett, Mr. D. G. Davis (Ministry of Agriculture), and the following members of the staff of the Meteorological Office :—Mr. R. G. K. Lempfert, Col. E. Gold, Mr. E. G. Bilham, Dr. C. E. P. Brooks, Mr. J. S. Dines.

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1. Documents circulated :—

(1) Minutes of the tenth and eleventh meetings.

(2) Memorandum from the Italian Air Ministry with regard to the amendment of the statutes of the International Meteorological Organization and draft statutes of the International Meteorological Organization.

(3) Minutes of the Sub-Committees on Symbols and Codes, The Organization of Meteorology in Africa, and The Synoptic Issues in the Far East.

2. Measurement of evaporation with special reference to (a) water supply and (b) agriculture. (Appendix XXXV.)—Mr. E. G. BILHAM outlined briefly the subject matter of Appendix XXXV (*a*). He said that measurements of evaporation were usually needed to meet some definite requirement; water supply and agriculture were the interests mainly affected, though the requirements of other industries had also to be borne in mind. In Great Britain, ordinary meteorological data, including humidity expressed in the form of saturation deficit, had not been found adequate to meet the agriculturists' demand for data respecting the "drying power of the air" and they were planning to include measurements of evaporation in the routine of the Crop–Weather Scheme. At the present moment trials were being made at Rothamsted with two new forms of porous surface evaporimeter, one designed by Prof. Blackman and the other by Dr. Owens. As Dr. Keen was unable to be present he had asked Mr. Bilham to say a few words about the results obtained to date. The Owens evaporimeter had been arranged at Rothamsted to measure evaporation from moistened filter paper similar to that used in the Blackman instrument. The results showed that the two instruments agreed closely when tested in a room or in a Stevenson screen, but that they showed wide divergences when compared out of doors in a situation shielded from direct sunshine.

Mr. Bilham expressed the view that readings from a standardised form of porous-surface evaporimeter, exposed in a standard manner, would meet most requirements. The results would not be numerically identical with the evaporation from natural surfaces, but they would provide the "base-line" values which an ordinary meteorological station aimed at giving for all elements.

For the determination of natural evaporation losses from soil it seemed clear that one had to use some form of percolation gauge. The ordinary percolation gauge provided no data unless the soil were saturated and the addition of weighing mechanism as suggested by Mr. Yates would be a substantial improvement.

Referring to Dr. Ramdas' memorandum (p. 180), Mr. Bilham said that formulae such as Rohwer's failed to give the sort of seasonal variation found in tank-evaporation data for Great Britain. For London, for example, Rohwer's formulae indicated that the daily evaporation ought to be about three times as great in June as in December; actually, at Camden Square the ratio was more than 30 to 1.

Dr. Schumann said that he had been much interested in Mr. Patterson's memorandum. In South Africa evaporation was of importance in connexion with the work on irrigation. In South Africa an annual evaporation of 106 in. had been measured, so that the problem was obviously of importance in a country where extensive settlements depended on irrigation.

In connexion with a proposal put forward by Dr. Schwarz some years ago for forming a lake of 50,000 square miles in the Kalahari desert by diverting the waters of the Cunene and Zambesi rivers, he had calculated that even if all the water of the Zambesi were used it would hardly be sufficient to keep a lake of 10,000 square miles filled.

He said that some years ago he had been working on the problem of the rate of burning of coal and that that problem had a close analogy with evaporation. The question must be approached by a consideration of the fundamental physical principles. In the case of a free water surface there was a stagnant layer of air near the surface, its thickness was a function of wind velocity, but it was of the order of a millimetre. The only way for a molecule to escape through this stagnant layer was by diffusion, and according to the laws of diffusion escape was only possible when the vapour pressure of the water surface was higher than that of the atmosphere above it. Hence the principal factor in determining whether evaporation or condensation would take place was the temperature of the water and its relation to the temperature and humidity in the air above it.

Mr. Sutton said that in Egypt evaporation was the concern of the Hydrological Service of the Physical Department. All meteorological stations however were supplied with evaporimeters of the Piche type, the instrument being exposed in the thermometer screen. The type of screen affected the readings. He emphasised the necessity, when publishing readings from evaporimeters, of describing the conditions of exposure, as without such a description they were of little value.

He said that comparisons had been made at Abbassia, Cairo, of the evaporation measured by a Piche instrument in a standard screen with those of tanks of various sizes floating in an adjacent reservoir. It was found that evaporation decreased as the size of the tank increased. To reduce to evaporation from a tank 2 metres square, the readings of a 30 cm. square tank had to be multiplied by the factor 0·78; those of a 60 cm. square tank by 0·81; those of a 1-metre square tank by 0·88, while the Piche readings had to be halved. No seasonal variation in these factors, which had been determined monthly, had been detected, and from comparisons made at other stations in Egypt and the Sudan, and from somewhat similar comparisons made at Denver, Colorado, it appeared that there was no place variation. The evaporation from a 2-metre square tank was regarded as the nearest practical approach to that from a free surface, though it was probably slightly too high.

For convenience the standard instrument used in Egypt and the Sudan was a 1-metre square tank, 1 metre deep, made of galvanised steel plates, with a centrally fitted scale of thermometer type. The tanks were supported by a framework raft which also minimised splashing.

A 3-metre square tank had been installed near the Bahr-el-Jebel in the Sudd region—papyrus swamp—of the southern Sudan, and papyrus had been induced to grow in it. Readings of loss of water from this tank had been obtained in order to estimate the losses which occur in the swamp, but he was unable to quote the results obtained. Further details of these experiments would be found in *Physical Department Paper*, No. 26, "The Nile Basin" by Hurst and Phillips.

Mr. Patterson referred to the arrangements made in Canada for the measurement of evaporation as set out in his memorandum (p. 181) and to the comparison between records obtained from a Piche instrument and from a tank. He emphasised the importance of evaporation in the problem of lake levels, and especially with regard to the water level at Montreal, and outlined the methods which were being followed in order to obtain estimates of evaporation from the Great Lakes; he emphasised especially the fact that the measurements must be made on the lake itself, conditions with regard to temperature and humidity were not the same over the lake as over the surrounding land. He referred to the formulae which had been developed for obtaining evaporation from measurements of other meteorological factors and asked for the opinion of other directors on the question. He said that in summer the temperature of Lake Superior was exceptionally cold and that in that season condensation might be taking place instead of evaporation. In winter the lake remained unfrozen and winter was therefore a time of great evaporation.

Mr. Patterson referred also to the methods used for obtaining measurements of evaporation for agriculture, and described the means adopted for obtaining estimates of dryness in connexion with fire hazards.

Dr. Kidson (New Zealand) said he thought that in the experiments described sufficient account had not been taken of the turbulence of the air. He referred to calculations by Mr. O. G. Sutton which had appeared in the *Quarterly Journal of the Royal Meteorological Society*, **57**, 1931, p. 405 [*See also* O. G. Sutton; *London, Proc. roy. Soc.*, A, **146**, 1934, p. 701.]

In connexion with the effect of turbulence Mr. Bilham referred to a paper by Dr. Harold Jeffreys, published in the *Philosophical Magazine* in 1918, on the evaporation from free water surfaces. Dr. Jeffreys had shown that the rate of evaporation from a free water surface depended on eddy diffusion rather than on molecular diffusion. The rate was proportional to the square root of the coefficient of eddy diffusion, and to the square root of the wind velocity. Mr. Bilham said he thought the formula could not be strictly accurate as it implied complete absence of evaporation in a calm.

Sir George Simpson said that the whole basis of scientific work in meteorology was dependent on being able to express numerically the various factors investigated. Rainfall, temperature and humidity could be so expressed, but there were others for which no single value could be given. Recently, meteorologists had come to regard wind velocity as such an element, and evaporation was another. He thought the utmost the meteorologist could do was to measure evaporation in standard conditions and let the people who required the measurements adapt the data to their special requirements. The Piche instrument appeared to be the simplest instrument for obtaining such data. Obviously the evaporation required by a hydrographic engineer was different from that required by an agriculturist, and the meteorologist could not be expected to supply data for all the different requirements.

The problem was to some extent similar to that of the relation of meteorology to aviation, the practice had been established that no member of the staff of the

Meteorological Office should tell an aviator when the conditions were fit for flying, he could only describe the meteorological situation and leave the aviator to make his own decision.

Mr. Patterson had already given an instance of the methods adopted by the forest experts for obtaining an estimate of fire hazard, Sir George said he thought experts in other sciences must each make their own adaptations.

Mr. WALTER (East Africa) asked whether the readings of a Piche instrument varied with the tension of the paper ; Mr. SELLICK, Mr. STEWART and Mr. PATTERSON agreed that the variations were not likely to be great provided the paper remained wet.

Mr. SELLICK (Southern Rhodesia) said that an attempt had been made to make the Piche instrument autographic by counter-balancing the instrument with a weight. It had been found that the readings so obtained differed from the readings of the standard instrument presumably because of a difference of exposure.

Sir GEORGE SIMPSON said that as the readings depended on the ventilation they might be affected simply by differences of the position of the instrument in the Stevenson screen. There were striking differences in the ventilation in different parts of the screen. This had been brought out recently in the course of experiments on corrosion that had been carried out for the Atmospheric Corrosion Board. The corrosion of plates exposed in a Stevenson screen differed very widely according to their position in the screen.

Mr. SUTTON (Egypt) agreed that variations in the position of the instrument in the screen were of importance, and even the position of the evaporimeter in relation to the other recording instruments had an effect. The practice in Egypt was to specify the exact position by means of a diagram.

Mr. BILHAM referred to an objection to the Piche instrument which had been raised by Sir Napier Shaw, namely, that the values at the beginning and end of the record were not comparable because of the replacement of the water by air.

Mr. STEWART (Malaya) thought that the effect of such replacement was likely to be small.

Mr. PATTERSON pointed out that not only was the position of the instrument in the screen of importance but readings of instruments in different positions in the screen might vary with the wind direction.

He said that as a result of the discussion it was evident that the Piche was the most satisfactory and simplest type of instrument. He added that turbulence was of importance, and said that in the Canadian Office they were working on much the same lines as those outlined by Dr. Schumann.

3. **Construction of rainfall maps.** (Appendix XXXVI.)—In the absence of Dr. Glasspoole, Mr. Bilham gave a brief outline of the memorandum. The point he wished particularly to stress was that the handling of rainfall data required a special technique. The first aim should be to construct an accurate map showing the distribution of annual average rainfall. For current use one needed a chart of the annual rainfall and a second chart showing this rainfall expressed as percentage of the normal. The latter map was a very useful tool because it provided the best available means of determining the long-period average for a station with only a few years of observation. By referring to such a map one might find, for example, that in six years, for which data were available, the local percentages were 120, 95, 87, 110, 130 and 88. The mean was 105. If, therefore, one reduced the 6-year average by 5 per cent one would get a close approximation to the standard average.

The annual maps could be supplemented by such monthly or seasonal maps as were found to be necessary.

In connexion with the evaluation of monthly averages, Mr. Bilham referred to the use of "isomeric maps". If one had a sufficient number of stations for which standard monthly averages could be computed, it was possible to draw a series of 12 monthly maps showing the rainfall expressed as a percentage of the annual average. Having drawn such a series of maps it was a simple matter to determine monthly averages for any station whose annual average was available.

In conclusion, Mr. Bilham referred to a special charting machine which had been very useful for handling a number of large charts simultaneously ; it was available for inspection by delegates.

In reply to a question from Dr. Schumann, Sir GEORGE SIMPSON gave a brief outline of the history of the use of the millimetre and the inch as units of rainfall. He said that in 1913 Sir Napier Shaw had endeavoured to introduce systematic units on the C.G.S. system in all the publications of the Office. The units had been introduced in all the stations controlled by the Office, but not at the voluntary stations of the British Rainfall Organization.

Sir George said it was a matter on which there was a wide difference of opinion, the principle he had adopted was that the data supplied for the general public must be in the unit to which they were accustomed.

The present practice with regard to rainfall was to use inches in *British Rainfall* and in the reports supplied to the newspapers, and millimetres for synoptic work and in all other publications. Some measuring glasses were issued graduated in millimetres and others in inches.

Sir George referred to a new conical form of rain measure which had recently been brought into use in the Meteorological Office. Specimens of the measure were exhibited.

Mr. WALTER referred to the fact that in tropical countries where the rainfall was largely seasonal an annual map was of little practical use. In East Africa charts had been published giving the number of days of rain (>0.01 in.) but for some purposes the frequency of different types of rain had been required. He thought that in some countries monthly charts were of more value than annual charts.

A discussion of the comparative advantages of the new conical gauge and of the old Camden gauge took place. It was reported by directors of services in tropical countries that with untrained observers it was difficult to ensure that the gauge was kept vertical when the reading was taken. It was noted that the disadvantage of the Camden gauge was that readings were liable to errors of parallax.

Mr. BECKETT (Gold Coast) reported that he had found it useful to prepare a map constructed by multiplying the figures of the actual rainfall by the number of rainy days. Maps constructed in that way gave an estimate of the degree of wetness and gave a better idea of the effectiveness of rain in its relation to crops than could be obtained from maps of total rainfall.

Mr. WALTER suggested that in constructing rainfall maps it might be possible to give a measure of the periods of maximum and minimum rainfall.

Mr. PATTERSON referred to his memorandum (p. 185) and emphasised the difficulties of drawing rainfall maps in mountainous countries where the stations were in the valley at low levels. He also suggested the drawing of maps to indicate the period of maximum precipitation as explained in the memorandum.

4. **Methods of measuring snowfall.** (Appendix XXXVII.)—Mr. PATTERSON gave a brief account of the difficulties of measuring snowfall as set out in his memorandum.

Sir GEORGE SIMPSON said that he had found it impossible to obtain a satisfactory measure of snowfall in the Antarctic ; the most important measurement there appeared to be the actual accumulation of snow. He said that in Norway a 5-in. gauge was used exposed on a post about 4 ft. high above the general snow level. The gauge was replaced each day and the equivalent water measured.

5. **Methods of obtaining measurements of sunshine in high latitudes with the Campbell-Stokes Sunshine Recorder.** (Appendix XXXVIII.)—Mr. PATTERSON referred to his memorandum. He emphasised that a certain intensity of sunshine was required to obtain a record on the paper ; in high latitudes this involved considerable errors in the computed percentages of sunshine. He referred to the Pers recorder and to the Robitzsch sunshine recorder, and asked for the experience of other directors with regard to those instruments.

Mr. BILHAM said that there were special difficulties in using the Campbell-Stokes Sunshine Recorders in high latitudes. With the ordinary type of instrument the record was liable to additional loss when the solar altitude is low, because part of the aperture was cut off by the frame that held the card. A special type of Campbell-Stokes recorder had been constructed for use in polar regions but the difficulty had not quite been overcome. He referred to the description of the Pers recorder which had recently appeared in *La Météorologie*. He thought the difficulty of standardizing photographic recorders was not as great as was commonly supposed, the difficulty of standardization was not absent even from the Campbell-Stokes cards.

Sir GEORGE SIMPSON said that in the Antarctic large errors had been introduced into the records of sunshine by the frosting of the glass. He thought it was impossible to define the duration of sunshine by a single figure.

6. **Representation of Empire Meteorologists at International Conferences.** (Appendix XXXIX.)—Col. GOLD referred to his memorandum (p. 187) in which he had set out the principal points bearing on the question. The international meetings affecting meteorology at present were :—

(1) The International Meteorological Organization, and

(2) the Meteorology Sub-Commission of the International Commission on Air Navigation.

The latter met usually in winter ; every country which was a party to the International Air Convention had a right to nominate a member. The meetings were, however, held in Europe and far distant countries unable to send representatives were often represented by a member of their Embassy in Paris. The meetings of the International Meteorological Organization were also held in Europe, so that the view tended to be preponderatingly European whereas it ought to be international.

In his memorandum (p. 188) Mr. Patterson had expressed the view that the best method of representation was for the director of a service himself to attend the Conferences, and if he were unable to do so to send one of his own experts.

If the Empire Conference decided that the present method of representation could be improved, Col. Gold suggested the formation of a Sub-Committee to work out details.

Mr. PATTERSON was of the opinion that the work of the International Commissions was becoming of increasing importance, and deprecated the holding of meetings at different times and places rather than grouping them together. He thought it would be of great assistance if a country of the Empire unable to send a representative to a meeting could nominate someone from another Empire service to put forward its views. Dr. Kidson warmly supported this suggestion.

Sir GEORGE SIMPSON expressed his willingness to help and said that on receipt of a request from a director of any Empire Service he would put him in touch with the appropriate member of the Meteorological Office Staff.

Commenting on Mr. Patterson's suggestion that every service should be represented on every Commission, Col. Gold said that this would make the Commission of unwieldly size. Sir George Simpson stated that the International Meteorological Secretariat would send the papers of any Commission to a Director who asked for them. He would then have an opportunity of expressing an opinion before the meeting.

In reply to a question from Dr. Schumann, Sir George Simpson said that voting was not often resorted to at meetings of commissions ; if the consensus of opinion was not in favour of a proposal it would be dropped. He added that meetings of commissions were not confined to members only and that almost anyone interested in the subject was welcomed and could take part in the discussions.

The meeting adjourned at 1.10 p.m.

(Signed) J. PATTERSON.

MINUTES No. XV

Fifteenth Meeting, Wednesday, August 21, 3 p.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Mr. G. W. Grabham (A.E. Sudan), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Cmdr. G. S. Ridgway (Bermuda), Dr. T. Schumann (South Africa), Mr. N. P. Sellick (Southern Rhodesia), Sir Napier Shaw (President of Agricultural Meteorological Committee), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

There were also present :—Prof. D. Brunt, and the following members of the staff of the Meteorological Office :—Mr. R. G. K. Lempfert, Col. E. Gold, Mr. E. G. Bilham, Dr. C. E. P. Brooks, Mr. R. Corless, Mr. F. Entwistle, Cmdr. L. G. Garbett.

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1. **Documents circulated** :—

(1) Report of the Sub-Committee on War Organisation of Fleet Meteorology.

(2) Report of the Sub-Committee on Meteorological Arrangements for experimental flights between Penang and Hong Kong.

2. **Proposal of the Italian Air Ministry with regard to amendment of the statutes of the International Meteorological Organization.**—Sir GEORGE SIMPSON pointed out the implications of the proposal of the Italian Government in relation to international co-operation in meteorology and its difference from the arrangements that had been operative since 1931, and invited delegates to express their views on the proposals. An informal discussion followed.

3. **The responsibility of meteorological services for the study of Micro-Climatology.**—The PRESIDENT said that in his opinion it was desirable that there should be only one service in each country responsible for taking meteorological observations. In Canada the practice was for the Meteorological Office to co-operate with the agriculturists by advice and assistance with regard to the technical side of meteorology.

Mr. STEWART (Malaya) said that he regarded the problem of microclimatology as definitely agricultural rather than meteorological. He thought that the detailed observations should be made by the agriculturists themselves, but that the meteorological service should be willing to give the agriculturists what assistance it could by giving technical advice on the meteorological aspects of the problem. He thought the agriculturists must state the problem they wished to solve.

Sir GEORGE SIMPSON said there seemed to be a tendency for anyone confronted with a problem affected by the weather to expect the Meteorological Office to supply the solution. He asked for the opinion of delegates as to how far they regarded it as the responsibility of the meteorological services to initiate observations of microclimatology.

Mr. WALTER explained the policy of the East African Service, and said that when research officers asked for assistance in agricultural problems, the Meteorological Office established a climatological station and suggested means of overcoming difficulties. In some cases the Meteorological Office also helped with the reduction of the observations because frequently the research officers had no other technical assistance available.

Sir NAPIER SHAW agreed that it was not the responsibility of the Meteorological Services to carry out the detailed observations, but thought that if any agriculturist wished to do so, the Meteorological Services should give all the assistance that lay in their power.

4. **Reports of Sub-Committees.**—Formal approval was given to the recommendations set out in the Reports of the several Sub-Committees.

5. **Minutes.**—It was reported that the Minutes of the first to twelfth meetings had already been circulated and these minutes were approved. Authority was given to the President and the Director of the Meteorological Office to approve the minutes that had not yet been circulated.

It was agreed that the Meteorological Office should have discretion to edit the minutes and memoranda for publication.

6. **Votes of thanks.**—The PRESIDENT expressed appreciation, on behalf of the delegates, of the admirable arrangements for the Conference that Sir George Simpson had made ; to Miss Austin, Secretary, for the very complete Minutes she had prepared of all the Meetings, and to Miss Chambers for the thoroughness with which she had attended to the innumerable details connected with the Conference, and which had contributed very materially to its success.

Dr. KIDSON moved a vote of thanks to Mr. Patterson. He congratulated the President on the successful completion of a heavy programme. Under his genial and suave guidance the meetings had been conducted with great good humour and an entire absence of friction. Mr. Patterson had made very valuable contributions to the discussions and had summed them up in a lucid manner.

In seconding the vote of thanks, Mr. WALTER thanked the President especially on behalf of his colleagues of the Colonial Services for the unfailing tact and patience with which he had conducted the proceedings of the Conference, and stated how much they had all appreciated the valuable contributions he had made to the discussions of the problems brought before them.

Sir GEORGE SIMPSON expressed his thanks to all those who had compiled the memoranda on which the work of the Conference had been largely based, and to the members of his staff who had given so much assistance.

The PRESIDENT concurred in Sir George's thanks to the members of his staff, and said that the Conference was very greatly indebted to all the members of the Meteorological Office staff who had so ably assisted them in their discussions.

The Conference rose at 5.0 p.m.

(Signed) J. PATTERSON.

REPORTS OF THE MEETINGS OF THE SUB-COMMITTEES

SUB-COMMITTEE ON CODES FOR WIRELESS REPORTS FROM SHIPS

Meeting on Friday, August 16, 1935, 3 p.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Lt.-Cmdr. S. H. Butler R.N.R. (Nigeria), Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Mr. R. D. Kreltszheim (Ceylon), Mr. N. R. McCurdy (Mauritius), Dr. C. W. B. Normand (India), Sir George Simpson (Great Britain), Capt. A. Bertram Smith R.N.R. (Trinidad), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

The following members of the staff of the Meteorological Office were also present :—Lt.-Col. E. Gold, Capt. L. A. Brooke Smith R.N.R. retd., Cmdr. L. G. Garbett R.N. retd., Mr. H. Keeton.

1. **Documents circulated.**—Minutes of the fifth meeting were circulated.

2. **The working of the scheme for wireless reports from ships.**—The discussion which had begun at the meeting of the full Conference in the morning (see pp. 47-51) was continued.

Mr. JEFFRIES (Hong Kong) said that he was handicapped in what he had to say by the absence of Sir George Simpson. At the meeting in the morning, Sir George had put very clearly the case for synoptic observations being made at four specified hours, but he would like to bring forward another point of view.

Since 1884 the Royal Observatory at Hong Kong had been in very friendly relation with the shipping companies, and the cordiality of the co-operation had been extremely marked. On the adoption of the scheme for selected ships and of the new international code, the service which had been in operation for so long had been disorganized, the more so as he had felt compelled to press the adoption of the code on the ships' masters, who, being a somewhat conservative class, were rather reluctant to use it. As Mr. Stewart had said, ships' observations were so important to the services in the Far East that they would prefer to get any observation in whatever form it came rather than none at all. Hong Kong had for some time been faced with a serious diminution in the number of reports, but after considerable effort the situation was gradually being ameliorated. He thought that when the relative importance of the work of the selected ships in the China Seas was compared with the information given to shipping by the Hong Kong Observatory there could be no doubt which was the more important.

The chart exhibited by Capt. Brooke Smith showed only three A selected ships in the China Seas, and those were south of Japan in positions where their reports did not affect the Hong Kong Observatory. If it were argued that there should be a *quid pro quo* the balance was certainly on the side of the Observatory which issued a synoptic report, and was trying also to issue a ships' synoptic.

The great difficulty was with regard to time. The Observatory needed observations at 22h. instead of midnight G.M.T. in order that the forecasts might be issued before lunch. A forecast in the afternoon had not the same value. Mr. Jeffries said that the notice which had been read by Capt. Brooke Smith giving permission to the local shore services to make requests to ships in their waters for additional observations would meet his needs, but he had found a tendency for some selected ships to say that they had received their instructions with regard to the meteorological reports and were not prepared to exceed them.

Mr. Jeffries added that he thought the Hong Kong Observatory had probably had more experience of communication between ships and the shore than any other service in the Far East, and he was anxious to get an agreement, by which the selected ships should pull their weight. He wished to make it clear that he had had no trouble with getting reports from H.M. Ships ; from them he had always obtained the information he wanted.

Capt. BROOKE SMITH said that in the temporary absence of Sir George Simpson he would reply to Mr. Jeffries' questions. He said that the notice he had read out in the morning regarding co-operation of ships was to be taken quite literally. The early steps taken with regard to selected ships had been necessary to establish one main world-wide system. He thought meteorologists had underestimated what the work meant to the seamen. The Meteorological Office had had to evolve a service which would carry on the old service with the addition of wireless telegraphy, and which would satisfy and develop the requirements at sea. In the first few years of the working of the scheme it had been necessary to keep strictly to the regulations, and that policy had resulted in a considerable improvement in the voluntary discipline of both the observers and of the wireless officers. Now that the scheme was working smoothly it was possible to consider local requirements by broadening the instructions.

New Zealand had already asked for a special time of observation for ships in her waters, and possibly Australia, India, and other services might want to do the same. He thought it was better for the British Office to continue to give the instructions with regard to the world-wide system, while the local services made known their needs either by asking the Admiralty to issue a notice of them in the *Admiralty Notices to Mariners*, or by arrangements with the Harbour Masters. If directors would leave the Meteorological Office to carry out the main scheme set out in the provisions of the "International Conventions for the Safety of Life at Sea," then the more the Meteorological Services could do locally the better, provided always that it did not interfere with the world-wide scheme.

When Sir George Simpson entered later in the meeting he confirmed what Capt. Brooke Smith had said, namely, that the Meteorological Office would be willing for the directors of Meteorological Services of the Dominions and Colonies either to ask the Admiralty to advertise in the *Admiralty Notices to Mariners* or to make known in some other way what arrangements they required with regard to reports from ships in their locality, provided the general instructions with regard to world-wide messages remain unchanged. He felt sure that Capt. Brooke Smith would, if necessary, do anything in his power to assist directors in making such arrangements, and would arrange for any ship to be visited if it did not carry out the agreed procedure.

3. **Synoptic meteorological code for ships.**—The Sub-Committee proceeded to discuss the code for synoptic reports from ships, especially with regard to a proposal of Dr. Kidson's, made at the morning meeting, that there should be an alternative form of the abbreviated code. With a slight re-arrangement Dr. Kidson's proposal could be put in the form.

9LLll QGGAS DDFww BBVTT

The modification of the present code was in the first two groups where it was proposed to substitute 9LLll QGGAS for the existing groups PQLLL lllGG. This provided for the addition of A and S and of the index figure 9 by the omission of P and the reduction of the figures for latitude and longitude from 3 to 2, which involved giving latitude and longitude to the nearest degree only.

Dr. NORMAND (India) said that his experience after using the code for six years was that P (the day of the week) could be omitted, but that information was required about S (the state of the sea).

Col. GOLD said that there were two proposals—one that there should be a second form of the abbreviated code, and the second that the existing code should be modified by replacing P by S. He thought that the latter would have more chance of being accepted because it would still leave the code the same for the whole world.

Capt. BROOKE SMITH asked whether, if the code were to be modified, the international organization would be prepared to consider some other method of having a code; he referred to the international code of signals which could be understood everywhere.

The Sub-Committee proceeded to discuss the usefulness or otherwise of the various elements represented. There was fairly general agreement that experience showed that P (the day of the week) might be omitted. Cmdr. GARBETT said that he would deprecate the introduction of a second code, but saw no objection to the omission of P.

Dr. NORMAND (India) and Lt.-Cmdr. BUTLER (Nigeria) agreed that TT (air temperature) was not required by them, but recognised that this was not the general opinion.

With regard to the representation of latitude and longitude by whole degrees, the general opinion was that this was undesirable and was likely to meet with great opposition. In the first place the ships had already made considerable sacrifice in giving up the four figures previously used to give latitude and longitude in degrees and minutes. For navigational purposes and for many meteorological purposes also the nearest degree was not sufficiently accurate.

Mr. WALTER (East Africa) noted that for giving the position of cyclones in the south Indian Ocean the whole degree was not near enough, and Col. GOLD pointed out that though any one observation could be plotted with an error of not more than 50 miles, two observations plotted at the same point might come from ships 100 miles apart.

With regard to S (the state of the sea) Dr. NORMAND and Dr. KIDSON agreed that information about S was much needed, especially as it was not included even in the long code. It was valuable in checking the whole message.

Capt. BROOKE SMITH pointed out that an observation of S was of no value for checking the wind observations.

Sir GEORGE SIMPSON reported that the new specification of Beaufort scale at sea was to be based entirely on observations of the sea itself, so that the value of S as a check would be reduced.

The relative advantages of the different scales for reporting sea and swell were discussed. The present practice was to have one figure for K (swell) and one figure for S (state of sea). K was included in the sixth group of the ship's message but no provision was made for reporting S. The scale for sea and swell combined, which had been devised by Admiral Douglas, was referred to—it required two figures in the message. The possibility of reverting to S′ which had been in use some years ago for giving reports of combined sea and swell, in a code requiring only one figure, was also considered.

Capt. BROOKE SMITH said that if two figures were to be used, Admiral Douglas' scale would meet all the requirements of ships.

Dr. NORMAND said that much of the information given by the Douglas scale was unnecessary from his point of view, and that he had found the code represented by S′ as satisfactory, but there had been a strong movement in 1929 to replace it by S and K.

Dr. KIDSON (New Zealand) and Mr. STEWART (Malaya) agreed that S′ was sufficient. Mr. Stewart noted that with the increasing use of flying boats some information about S was essential. A suggestion that W might give the information required was not supported.

Col. GOLD suggested that it might be possible to introduce a figure for the state of the sea in tropical regions—23° N. to 23° S.—and outside the tropics replace it by A (barometric tendency).

Cmdr. GARBETT pointed out that in the Fleet synoptic message the first group was interchangeable but the second and third were the same throughout. The change in the first group satisfied Dr. Normand's requirements.

Capt. BROOKE SMITH asked that if there were a proposal for changing the code, the possibility of separating the navigational part of the message from the purely meteorological part should not be lost sight of.

The possibility of a letter code was considered.

Dr. NORMAND stated that it would be expensive in India to change to a letter code, and it was agreed that mistakes were more likely in a letter code than in a figure code unless words were used instead of letters. Mr. JEFFRIES said that after extensive use of a letter code he had found it sometimes impossible to make out the meaning of a message when a mistake was made. Mr. PATTERSON agreed that even when words were used instead of letters the interpretation of a message was not always easy.

It was agreed that it was useless to add A (barometric tendency) to the first four groups because the information was of no value when the course and speed were not included in the message.

Sir GEORGE SIMPSON said that originally it had been suggested that an index figure should be inserted in the first group to indicate the type of code used in the message which followed, but this had been criticised because one figure in every telegram was wasted ; and it had been decided to agree about the first four groups and allow alternative forms for later groups. This principle had now been adopted, but he saw no objection to substituting another letter for P. The local services could make local arrangements with ships for additional information, but the world-wide message must remain the same.

The PRESIDENT then asked whether it was desired that a proposal should be put forward to the international meetings at Warsaw of the Maritime Commission, and of the Commission for Synoptic Weather Information, to replace P by S in the first group. It was agreed (with one dissentient) that such a proposal should be put forward for discussion.*

With regard to the time of the additional observations, Col. GOLD said that the hours were becoming standardized at 6h., 12h., 18h. and 24h. for regular observations, and he thought it would be desirable that the times midway between those hours, viz. 3h., 9h., 15h., 21h. should be standardized for the additional observations.

This proposal was supported by Capt. Brooke Smith. Dr. Normand and Dr. Kidson said that the hours suggested would fit in with their requirements.

4. Preparation of ocean charts : work by London Meteorological Office.—Capt. BROOKE SMITH said that he had nothing to add to information included in his memorandum (Appendix XVIII). The charts were available for inspection in the library.

5. Exchange of data between London and the Dominions.—Capt. BROOKE SMITH said that, as set out in his memorandum (Appendix XVIII), the Marine Division had already supplied a large number of observations to the Dominions in the southern hemisphere. With regard to the northern hemisphere—Canada, India and Hong Kong might all require data, and a few also were sent to Germany. He said that after the ships' registers had been examined at the end of each year no further use was made of them though they were all kept. Five years of such registers were available in the Marine Division, and he would be glad to send them to any director who wished to have them. They would, of course, be sent on the understanding that they should not be destroyed and that they should be returned if it were decided at any time to establish an international depôt for storing such data.

Sir GEORGE SIMPSON agreed that the sending of the registers would be a useful method of circulating the data. No suggestion for an international depôt was at present under consideration.

6. Collection of rainfall data at sea (Appendix XIX).—Sir GEORGE SIMPSON said that the difficulty of devising a rain-gauge for use at sea was the main reason which had prevented the collection of rainfall data. No gauge had been designed that would collect the rain and not the spray.

Capt. BROOKE SMITH referred to information of rainfall at sea which had been published years ago on the back of the marine charts. He agreed with Sir George that spray in heavy weather destroyed the observations.

Col. GOLD pointed out that there were many occasions when the rain measurements would not be affected by spray, and emphasised that it was very desirable to collect whatever information could be obtained.

Capt. BROOKE SMITH said that if information about frequency of rain were required, it could be obtained from the Hollerith cards. It was intended in due course to produce charts giving the frequency of different weather phenomena. He thought it was useless to publish any article in the *Marine Observer* asking for rainfall observations unless a suitable rain-gauge could be recommended.

Col. GOLD suggested that if frequencies were published the intensity of the rain should also be given.

7. Storm signals. (Appendix XX.)—Mr. JEFFRIES (Hong Kong) said that his reason for introducing the subject of storm signals was that it was a subject of discussion at the last Empire Conference and at a subsequent Conference of Directors of Weather Services in the Far East. The outstanding result of the latter

* *See* Resolution No. 98 (p. 97) of the Conference of the International Meteorological Organization at Warsaw, 1935.

Conference was the decision to adopt a uniform code throughout the Far East. Since then the code had been consistently used at Hong Kong, and it was not until adaptations were proposed from Shanghai about two years ago that he had discovered that the signals were used at Hong Kong only. An agreement had been reached, however, and a code in which 10 symbols had the same or similar meanings was now in use in the Philippines, Hong Kong and Shanghai. The symbols included the four international symbols shown on page 121 of the report of the last Empire Conference with identical signification.

Although the system had been adopted he was not convinced that it would be of the same use over a wide area as it had been to Hong Kong. Giving warning of the approach of a tropical cyclone to one town and to an extensive area were different problems. The four symbols contained a definite warning as to the direction from which the wind might be expected to blow, and when warnings were based on the forecast of the track of the cyclone, it would be unfortunate if the actual track differed from the forecast track by passing on the opposite side of the locality for which the forecast was issued. The gale would then begin from another direction than that forecast.

These international symbols must therefore be exhibited with extreme care, and he thought it was necessary to have additional signals to give warnings of a more general character. It had proved almost impossible to get general agreement in that respect, and though it had been attained in the Far East with regard to the symbols themselves, there were still slight differences in their signification except in the cases mentioned. For that reason he had proposed that five symbols only should be considered for international use, as they would then convey throughout the world a uniform and definite warning of danger. The additional symbol suggested was a black cross to indicate " the approach of the centre of a tropical cyclone to such proximity that winds of hurricane force are expected."

Mr. JEFFRIES pointed out that in the last paragraph of his memorandum he wished to imply that all the signals were rigid shapes—the double cone was a rigid object and not composed of two independent cones, and the description of the cross as three intersecting rectangular prisms was not to be taken literally when constructing it.

Sir GEORGE SIMPSON said that he saw no reason against accepting the black cross as an international symbol. The need for a symbol to indicate a hurricane had been expressed for some time.

Dr. NORMAND said that in India there were three signals to indicate danger, and three to indicate great danger. The practice was to forecast the point where the track would cross the coast. He thought it would be difficult to introduce a new system.

Mr. JEFFRIES emphasised that the present international symbols gave warning of gales from a definite direction. When issuing warnings for a district some more general symbol was indispensable.

Sir GEORGE SIMPSON said that though he felt strongly that an international agreement was required, he realised the local difficulties. His principle had been that when a Service was in doubt as to what system should be employed, it should conform to the international practice, but that unless some opportunity for change arose, the change should not be made in a country where the existing practice was well established.

Mr. JEFFRIES said that the double-cone signal was being tried out.

The meeting adjourned at 4.45 p.m.

(Signed) J. PATTERSON.

SUB-COMMITTEE ON THE METEOROLOGICAL ORGANIZATION REQUIRED FOR THE KHARTOUM-WEST AFRICA AIR SERVICE.

Meeting on Wednesday, August 14, 1935, 9.30 a.m.

The following were present :—Mr. F. Entwistle (Meteorological Office) in the Chair, Mr. W. H. Beckett (Gold Coast), Lt.-Cmdr. S. H. Butler (Nigeria), Mr. J. H. Churchill (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. L. J. Sutton (Egypt).

Mr. Entwistle stated that it was intended that Imperial Airways, Ltd. should operate a weekly service in each direction between Khartoum and Lagos with an extension to Takoradi. The full service, which would carry both passengers and mails, could not be started till 1936 as the aerodrome at Lagos would not be ready earlier. It was therefore intended to commence operating an experimental service between Khartoum and Kano in October, the service to carry mails only.

It was agreed to discuss first the requirements of the experimental service and then to discuss the arrangements that would be necessary for the full service.

1. Experimental service between Khartoum and Kano.—(a) *The Sudan.*—Mr. Entwistle stated that the meteorological organization which had been proposed for the Sudan included reporting stations at El Obeid, El Fasher and Geneina with upper wind observations at El Fasher. Surface and upper wind observations were already made at Khartoum, and regular reports were also made at El Obeid and El Fasher and transmitted to Cairo. He asked whether it would be possible to arrange for the necessary observations by October.

Mr. Grabham (A.E. Sudan) stated that there was no reason why the establishment of the stations should not be proceeded with at once, provided funds were available. The request should be submitted to the Sudan Government. There would not be any difficulty in providing the equipment for upper air observations, provided the necessary funds were sanctioned. The hydrogen generator would be provided locally, but the instruments would have to be obtained from Egypt on repayment.

Mr. Sutton (Egypt) said that he did not anticipate any difficulty in providing the equipment.

Mr. Entwistle stated that with regard to communications it was proposed to ask the Sudan Government to provide medium-wave radio facilities at El Obeid and El Fasher and, in addition, short-wave facilities at El Fasher. The latter were necessary for communication with stations in French West Africa, which were equipped with short-wave radio only.

Mr. Grabham stated that Geneina was already fitted with Post Office radio so that the transmission of weather reports did not appear to present any difficulty. He suggested that the request for meteorological facilities should be submitted to the Sudan Government at the same time as the request for radio facilities.

(b) *French West Africa.*—Mr. Entwistle stated that meteorological observations were made at Fort Lami, but he did not know whether they included pilot balloon observations. It was proposed to ask the French for reports from Abecher, Ati and Fort Lami, together with upper wind observations from Abecher and Fort Lami.

Mr. Sutton said that he did not receive reports from this area in Cairo, and had no information regarding the distribution of meteorological stations.

(c) *Nigeria.*—Mr. Entwistle stated that observations would be required from Maiduguri and Kano and from any intermediate stations that were available. Upper wind observations were required from Kano, but if the French were unable to provide similar information from Fort Lami it would be preferable to have the upper wind station at Maiduguri.

Mr. Churchill (Nigeria) said that the pilot-balloon equipment which had been supplied by the Air Ministry in 1929 in connexion with the R.A.F. non-stop flight to South Africa was still in Nigeria. They had also purchased a hydrogen generator. Provided the staff and funds were available there would not be any difficulty in arranging for the observations. He suggested that from the local point of view, Kano would be the more convenient station for the upper wind observations. Surface observations were already made at Kano, Hadeija and Maiduguri. He stated that a formal request for the meteorological organization required should be submitted to the Nigerian Government.

2. Main service between Khartoum, Lagos and Takoradi.—Mr. Entwistle stated that the route would be continued from Kano via Kaduna, Minna and Ilorin to Lagos and thence to Accra and Takoradi. He said that reports would be required from all these places, including upper wind observations from Lagos, one station between Lagos and Kano and one station in the Gold Coast. It was also desirable that meteorological services should be established in both Colonies in order to provide forecasts and other information required by the air services.

Mr. Churchill said that observations were made at Kaduna, which was a departmental headquarters of the Survey Department, at Ilorin and at Lagos. Observations were also made at Minna, but there was a possibility that the station might be moved. With regard to upper wind observations, he suggested that Ilorin would probably be more suitable than Minna as the wind usually changed more rapidly towards the coast than in the north of Nigeria.

Mr. Beckett (Gold Coast) referred to the proposal made at the Conference of Empire Meteorologists in 1929 that a combined West African Meteorological Service should be formed.

After discussion it was decided to recommend that both in Nigeria and the Gold Coast a full time meteorologist should be appointed to organize the meteorological services with special reference to aviation.

Mr. Grabham referred to the proposals for the establishment of a meteorological service in the Sudan, and said that the Senior Officer should be appointed without delay in order to commence the organization of the service. He suggested that this point should be raised when writing to the Sudan Government with regard to facilities for the West Africa service.

Lt.-Cmdr. Butler (Nigeria) raised the question of the training of personnel in meteorology. He suggested that a small number of selected officers, who would be responsible for the meteorological observations at their respective stations, should take a short course of training in England during leave.

Mr. Entwistle stated that there would not be any difficulty in arranging for this training.

With regard to synoptic meteorology it was agreed that the existing network of stations when properly equipped would be sufficient to commence the collection of observations and the preparation of synoptic charts. It was pointed out that the French maintained an extensive network of stations in West Africa, observations from which were broadcast daily.

Mr. Churchill referred to observations of visibility and stated that at, at least 9 of the 29 stations in Nigeria only limited visibility observations were possible owing to the fact that the stations were situated in the bush.

3. Summary of recommendations.—(1) The Air Ministry should submit to the Sudan and Nigerian Governments through the normal channels requests for the meteorological facilities required in October for the experimental air service between Khartoum and Kano. In the case of the letter to the Sudan, a request should be made that the Government Meteorologist should be appointed without delay in order to commence the organization of the Meteorological Service.

(2) Full-time meteorologists should be appointed in Nigeria and the Gold Coast to organize meteorological services with special reference to aviation.

(3) Arrangements should be made for selected officers from both Colonies to receive a short course of training in meteorology, particularly pilot-balloon observations, in England during leave.

(Signed) F. Entwistle.

SUB-COMMITTEE ON METEOROLOGICAL ORGANIZATION FOR AVIATION ALONG THE PERSIAN GULF

Meeting on Thursday, August 15, 1935, 10 a.m.

The following were present :—Dr. C. W. B. Normand (India), Mr. F. Entwistle (Meteorological Office).

It was pointed out that, as the result of recent negotiations in Iraq, the Iraq Government had agreed to establish a forecast centre at Margil Airport, Basra, for the purpose of collating reports from the Persian Gulf and issuing forecasts for that area. The station would form part of the Iraq meteorological service, but would be maintained by the Port of Basra Directorate.

Information was available at present, or would be available shortly, from the following stations :—

Bahrein } (India Meteorological Dept.). Surface and upper wind observa-
Sharjah } tions, transmitted by airway radio organization.

Bushire } Surface observations received by wireless via R.A.F., India.
Jask . . } These observations were received very late in Baghdad.

Control Ship at entrance to Shat-al-Arab. Surface observations received direct by wireless.

The following additional sources of information had been suggested :—

Surface observations from :

(*a*) Kowait.
(*b*) Anglo-Iranium Oil Co. tankers.
(*c*) Lighthouses under the control of the Director-General of Navigation, Basra.
(*d*) H.M. Sloops operating in the Gulf.
(*e*) Abu-Ali in Saudi Arabia.

Dr. NORMAND pointed out that he already received observations from oil tankers when they were east of the Gulf.

With regard to Kowait, the Political Resident had suggested that the local Sheik should be asked through him to supply two observers who should be trained and should then make the observations required, payment being made by the competent meteorological authority.

It was pointed out that observations from stations controlled by Iraq and received at Basra would be included in the synoptics issued from Baghdad. There would probably be three broadcasts per day on a wave length of 45·6 m.

After discussion, in the course of which it was noted that night flying would take place along the Gulf, involving a 24-hour meteorological service, it was decided to put forward the following recommendations :—

(1) Synoptic stations under the control of the India Meteorological Department and situated on the air route (Bahrein and Sharjah) should transmit their observations to Karachi and Basra by the airway radio system. If possible arrangements should be made for these stations to send directed radio messages to both centres. Additional reports for aircraft would be made in the normal manner.

(2) The India Meteorological Department should aim at establishing efficient synoptic issues from Karachi, including reports from Persian and Mekran stations. Until communications improve, the stations at Bushire and Jask should send their observations by cable to Basra in addition to the normal transmission to India, the Iraq Government to pay for the cables.

(3) Oil tankers should report to Basra when west of longitude 56° and to Karachi when east of this meridian.

(4) The observations at Kowait should be organized by the Iraq Government through the Political Resident, Persian Gulf.

(Signed) F. ENTWISTLE.

SUB-COMMITTEE ON SYMBOLS AND CODES FOR SYNOPTIC METEOROLOGY

First Meeting, Friday, August 16, 1935, 10 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Dr. C. W. B. Normand (India), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. L. J. Sutton (Egypt), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

The following members of the staff of the Meteorological Office were also present :—Col. E. Gold, Mr. R. Corless.

1. Plotting data on synoptic charts.—Col. GOLD stated that the points of difficulty were the following :—

(1) Symbols for indicating cloud amount and rain.
(2) Manner of indicating wind force.
(3) The lay-out of the symbols.
(4) The use of red and black in plotting.

(1) *Cloud and rain.*—Col. GOLD stated that in 1873 the International Meteorological Committee decided that the symbol for rain should be a black circle and that had generally been used. For synoptic charts, however, some services had used a black circle for overcast sky with a small black dot at the side to indicate rain ; additional dots were used to indicate the intensity of rain. The British had used a black circle for rain and a circle with four lines across it for overcast sky. Four different degrees of cloud amount were then represented by different numbers of lines across the circle : and by a small modification two additional degrees of cloud amount were symbolised.

The two fundamental systems are :—

 = sky completely overcast.

 = rain.

At their meeting in De Bilt in 1934 the International Commission for Synoptic Information had adopted the system of symbols shown on Air Ministry Form 2459 (which had been circulated). Some services which had adopted the general system of symbols used a different set of symbols for cloud amount, the main difference being that instead of lines within the circle, complete sections of the circle were blacked in. These services contended that it was impossible to use the system of indicating cloud amounts by lines with circles as small as those they had to use to get the information on their charts. Decision would be required in Warsaw as to which of these two systems should be adopted, or whether the symbol for rain should be changed.*

The difficulty of showing the lines plainly in the small circles which had to be used on small scale charts was discussed, Dr. KIDSON stressed the particular difficulty experienced in New Zealand where it was necessary to have a chart covering the whole of Australia as well as New Zealand, the charts at present in use being of the scale 1 : 15,000,000. Sir George Simpson thought that this difficulty could be overcome by the use of two charts, one on a larger scale for the local area and a smaller scale chart for the whole area. Dr. Kidson said, however, that there might be difficulties—more particularly staff difficulties—in the way.

Dr. KIDSON saw no objection to the use of the two different systems.

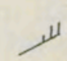
Mr. CORLESS pointed out that aviators would find it difficult to connect the two. The aim should be, he thought, to find the best.

Mr. PATTERSON stated that since the present code in use in Canada was limited, they could adopt without difficulty whichever system was approved internationally.

Mr. WATT said that the same applied to Australia.

All delegates present took part in the discussion and with the exception of Dr. Kidson were in favour of lines within the circle for representing cloud amount. Dr. Kidson expressed his willingness (albeit reluctantly) to accept the decision. He thought, however, that there might be a strong preference at Warsaw for the Norwegian system ; in which case it might be better to agree to use both. Sir George Simpson pointed out that no director was obliged to follow the international practice ; each had to make his own decision.

(2) *Wind force.*—Col. GOLD said that the British practice had been to use one feather to indicate each number on the Beaufort scale ; the new proposal was to use half a feather for each number, thus :—

 = Force 5.

No objections were raised to this proposal.

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* See Resolution XX of the International Commission for Synoptic Weather Information, De Bilt, 1934, which was adopted at Warsaw.

(3) *Arrangement of station model.*—The arrangement proposed at De Bilt in 1934 was shown on Form 2459. Col. GOLD explained that it was the intention that the position of the elements should be the same even though some of the possible information was omitted.

Dr. NORMAND stated that the positions adopted in India for BBB and W differed slightly from those proposed. Col. Gold agreed that since bb (barometer tendency) was not reported at all there would be no likelihood of confusion.

No delegate expressed opposition to the proposed model.

The meeting adjourned at 11 a.m. leaving No. (4) to be dealt with at a later meeting.

(Signed) J. PATTERSON.

Second Meeting, Saturday, August 17, 10 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Dr. C. W. B. Normand (India), Mr. N. P. Sellick (Southern Rhodesia), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

The following members of the staff of the Meteorological Office were also present :—Lt.-Col. E. Gold, Mr. R. Corless.

1. Plotting data on synoptic charts.—(4) *The use of red and black in plotting.*—The question of the use of red and black to show barometer tendency had been left over from the previous meeting of the Sub-Committee. Col. Gold explained that the British practice had been to use red for a rising and black for a falling barometer. The present proposal was for the reverse. He added that the use of red was entirely voluntary, and the whole system could be used with black only. It was, however, much more convenient, where tendencies were given, to employ the two colours.

Mr. SELLICK said that the present practice in Southern Rhodesia was in line with the new proposals. The delegates from the countries where red was not used at all at present on their charts offered no objection to the proposal.

Col. GOLD and Mr. CORLESS agreed that, while they would naturally prefer to continue the present practice, the point was not sufficiently important to warrant opposition.

2. Code for use in tropical countries.—The following information regarding charges for telegrams in the various countries was elicited :—

Australia ..	No actual payment, only book entry.
Canada.. ..	Charges made for telegrams at press rates (different rates for day and night) ; 1*s*. per message for all incoming telegrams ; wireless messages free of charge.
Great Britain ..	Telegrams by land line charged at ordinary rates ; charges made for broadcasting from Rugby ; no charges for messages from R.A.F. stations by wireless nor for broadcasting of synoptic issued from the Air Ministry.
Hong Kong ..	No charges.
SouthernRhodesia	No charges.

The CHAIRMAN said that the aim was to adopt as much as possible of the international code for broadcast messages and add any necessary groups for internal messages, without increasing the cost.

Mr. Stewart had proposed the following form :—

$IIIC_LC_M$ $wwVhN_L$ DDFWN BBBTT dduuu $RRG^1G^1C_H$

where dd is direction of movement of low cloud,

uuu is depression of wet bulb in tenths of a degree,

G^1G^1 is time to the nearest hour G.M.T. of commencement of rainfall.

Objections were raised from various sides and eventually the following modified form was taken as a basis of discussion :—

$IIIC_L$ $wwVhN_L$ DDFWN BBBTT UUC_MC_Ht RRjjj

At present the four-figure group served to identify the code used. Mr. Stewart put forward a proposal to replace the code identification group of four figures by a five-figure group, including two figures for humidity. The ensuing discussion showed that all delegates, with the exception of Dr. Normand, agreed that a code identification group was not essential since the station number and the published particulars made clear the code used. Even if there were a variety of codes in use, there would still be no difficulty since no reports were received from stations of other services until correspondence had taken place.

Dr. NORMAND reminded the delegates of the stress which the airship meteorologists in 1929 had laid on the importance of the identification numbers. Col. Gold pointed out that the identification group removed the uncertainties which arose owing to delays, errors and non-availability of published particulars.

On Col. Gold's suggestion that an attempt be made to keep the first four groups the same in both international forms of message, the Sub-Committee then considered the possibility of including humidity in the fifth group. After much discussion as to the elements which it was most desirable to include in the fifth and sixth groups, and of the order in which they should be given, the Sub-Committee agreed on the following :—

Fifth group :—

UU = humidity,

RR = rainfall,

t = time.

Sixth group :—

D_L = direction of low cloud.

C_H = form of high cloud.

$D_H/_M$ = direction of high or medium cloud.*

$\left.\begin{matrix}MM\\mm\end{matrix}\right\}$ = maximum and minimum temperature.

* If there were no figure for C_H, it would be known that the direction of medium, not high, cloud was given in the third figure.

The whole of the message would then be :—

$IIIC_LC_M$ $wwVhN_L$ DDFWN BBBTT UURRt $D_LC_HD_H/_M{}^{MM}_{mm}$

This would not be only for use in tropical countries, but could be adopted as an alternative form of the international code.

Col. GOLD stated that he would convey the wishes of the Conference of Empire Meteorologists to the International Commission for Synoptic Information.

Before closing the meeting, Col. Gold asked the delegates which of the symbols they preferred for drizzle ; the rainfall dot with a tail at present in use in Great Britain, or the proposed which was supposed to represent stratus cloud with rain falling through it. The delegates preferred the rainfall dot with a tail.

The meeting adjourned at 11 a.m.

(Signed) J. PATTERSON.

SUB-COMMITTEE ON THE ORGANIZATION OF METEOROLOGY IN AFRICA.

Meeting on Monday, August 19, 1935, 2 p.m.

The following were present :—Mr. A. Walter (East African Group) in the Chair, Mr. W. H. Beckett (Gold Coast), Lt.-Cmdr. S. H. Butler (Nigeria), Mr. G. W. Grabham (A.E. Sudan), Mr. N. R. McCurdy (Mauritius), Mr. N. P. Sellick (Southern Rhodesia), Dr. T. Schumann (South Africa), Mr. F. Entwistle (Meteorological Office).

Mr. SELLICK (Southern Rhodesia) referred to the present lack of co-operation between the different meteorological services in the continent of Africa and said that there were several urgent problems which required consideration, such as fixing the hours of synoptic observations and improving the exchange of synoptic information. He suggested that a committee should be set up, composed of representatives of the different services, to discuss these problems with a view to their solution. A question which arose was whether the committee should include the whole of Africa or should be confined to territories south of the equator.

Mr. WALTER (East Africa) thought that the whole of Africa should be included. He stated that the Italian Air Ministry had made a request for a conference to be convened.

Discussion then took place with regard to the best way of convening such a conference. Two alternatives were suggested :

(1) The Conference to be appointed by the Conference of Directors (International Meteorological Organization) at Warsaw.

(2) The Conference to be arranged locally, the Governments affected being approached through the Dominions Office, Colonial Office or Foreign Office.

Mr. ENTWISTLE gave a brief account of the origin and development of the International Air Conference in western Europe, and of the Mediterranean Aeronautical Conference which was formed later. France was represented on both conferences and formed the connecting link between the two. The primary function of these conferences, as far as meteorology was concerned, was to reach agreement on the meteorological organization in the territories concerned from the point of view of aviation. The subjects for discussion, which Mr. Sellick had suggested, would fall within the scope of such a conference. Mr. Entwistle suggested that a conference on these lines might be formed consisting of representatives of the countries interested in securing uniformity in their meteorological arrangements. He said that the time was probably not yet ripe for a full African Conference and additional regional conferences could be formed as occasion demanded.

Mr. SELLICK agreed that aviation seemed the best avenue of approach to the problem.

After further discussion it was agreed to hold an African Conference in the first place. It was decided that Lusaka would be the most convenient centre.

Dr. SCHUMANN (South Africa) said that the Conference should be held during 1936 and that the invitations should be issued as early as possible in order that an agenda might be drawn up and memoranda prepared.

The following resolution was adopted :—

> **In view of the rapid development of aviation in Africa, a Conference of representatives of the meteorological services in that continent should be convened in 1936 to consider the co-ordination of the work of the respective services. It is recommended that the Secretary to the Conference of East African Governors should be asked to take the necessary steps to this end.**

It was further recommended that the above resolution should be communicated to the International Conference of Directors at Warsaw in September, 1935, with a request for their support.*

(Signed) A. WALTER.

REPORT OF THE SUB-COMMITTEE ON SYNOPTIC ISSUES IN THE FAR EAST

Meeting on Tuesday, August 20, 1935.

The following delegates were present :—Mr. C. D. Stewart (Malaya) in the Chair, Mr. C. W. Jeffries (Hong Kong), Dr. C. W. B. Normand (India), Mr. G. K. Thornhill (Ceylon), Mr. W. S. Watt (Australia).

The sub-committee agreed that, in view of the peculiar problems common to all Far East Services and the necessity for close co-operation arising out of the developments of trunk air services, the Conference of Directors at Warsaw should be requested to appoint a regional Commission for aeronautical and synoptic meteorology for the Far East. In addition to the directors of the services named above, the directors of the following services in the Far East should also be asked to act on the Commission :—

Siam.
Indo-China.
Philippine Islands.
Japan.
Netherlands Indies.
Zi-ka-wei.

The sub-committee asked also that requests might be preferred by the Empire Conference, through the Secretary of State for the Colonies, to the governments of British North Borneo and Sarawak, for the establishment of telegraphic reporting stations at or near to Kudat and Jesselton (British North Borneo) and Miri and Kuching (Sarawak). The Malayan Meteorological Service will gladly advise if desired.*

* At the Conference of the International Meteorological Organization at Warsaw, 1935, the Regional Commission for Africa suggested in the above report was appointed; Mr. Walter was elected as President (Resolution 116).

SUB-COMMITTEE ON WAR ORGANIZATION OF FLEET METEOROLOGY

Meeting on Tuesday, August 20, 1935, 10 a.m.

The following delegates were present :—Mr. J. Patterson (Canada), *President*, in the Chair, Mr. C. W. Jeffries (Hong Kong), Dr. E. Kidson (New Zealand), Dr. C. W. B. Normand (India), Dr. T. Schumann (South Africa), Sir George Simpson (Great Britain), Mr. C. D. Stewart (Malaya), Mr. G. K. Thornhill (Ceylon), Mr. A. Walter (East African Group), Mr. W. S. Watt (Australia).

The following members of the staff of the Meteorological Office were also present :—Cmdr. L. G. Garbett, R.N. retd., Mr. A. H. Nagle.

The sub-committee considered the Admiralty proposals for the war organization of Fleet Meteorology and agreed in principle with these proposals so far as they affected the shore meteorological services of the Empire.

(Signed) J. PATTERSON.

SUB-COMMITTEE ON METEOROLOGICAL ARRANGEMENTS FOR EXPERIMENTAL FLIGHTS BY IMPERIAL AIRWAYS, LTD., BETWEEN PENANG AND HONG KONG

Meeting on Tuesday, August 20, 1935, 5 p.m.

The following were present :—Mr. F. Entwistle (Meteorological Office), Mr. C. W. Jeffries (Hong Kong), Mr. C. D. Stewart (Malaya).

Mr. ENTWISTLE stated that Imperial Airways, Ltd., would operate a series of six experimental return flights between Malaya and Hong Kong via French Indo-China. The first flight was due to leave Penang on October 2, 1935, and it was anticipated that the six return flights would be completed within three months from that date. The route proposed was Penang—Kota Bharu—Vin Chao—Saigon—Touraine—Hanoi—Fortbayard—Hong Kong. The single journey would take two days.

Imperial Airways, Ltd., had asked for the following meteorological facilities in Malaya and at Hong Kong :—

Outward flight from Malaya.

Route weather reports and forecast at Penang.
Upper winds from Kota Bharu.
Weather reports and upper winds to aircraft in flight from Hong Kong.

Return flight from Hong Kong.

Route weather reports, upper winds and forecast at Hong Kong.
Upper winds from Kota Bharu to aircraft in flight from Penang.
Weather reports to aircraft in flight from Penang.

* At the Conference of the International Meteorological Organization at Warsaw, 1935, the Regional Commission, suggested in the above report, was appointed.

Mr. STEWART stated that there were no upper wind observations made at Kota Bharu. Observations were available from Alor Star and these could be taken as representative of conditions over the northern portion of the Peninsula. Weather reports were made regularly at Kota Bharu and he could arrange for these to be transmitted to Penang by land-line. There would not be any difficulty in arranging for the necessary forecasts to be available at Penang; they would be prepared at Singapore.

Mr. JEFFRIES stated that the information required could be supplied from Hong Kong. Reports of local weather conditions could be supplemented by observations from two lighthouses and from ships.

Mr. ENTWISTLE said that preliminary arrangements for the supply of the necessary information from French Indo-China would be made when he visited Paris the following week. It was understood, however, that final arrangements would be made locally and would involve co-operation between Mr. Stewart, Mr. Jeffries and the French Meteorological Service in Indo-China.

(Signed) F. ENTWISTLE.

APPENDICES

APPENDIX I.—METEOROLOGICAL ORGANIZATION FOR AVIATION

(Minutes III, pp. 11-15)

(*a*) AVIATION METEOROLOGY IN CANADA.

(*b*) AVIATION METEOROLOGY IN SOUTHERN RHODESIA.

(*a*) Aviation Meteorology in Canada

REPORT FROM THE CANADIAN METEOROLOGICAL SERVICE

1. **Forecasting for aviation.**—At the present time there is a regular aeroplane service from Montreal to Albany, N.Y., for which a daily forecast is issued from Toronto, and during the season of navigation a forecast is given once a week for the mail aeroplane flight from Montreal to Rimouski, a distance of about 300 miles. For this forecast the direction and velocity of the winds at 2,000 feet elevation are estimated, the direction being given to one of eight points and the wind velocity in miles per hour. In the expectation that an air-mail service across the continent will be established in the near future, an intensive study of upper air data for forecasting purposes is being made. An account of the use which is being made of these upper air data is given in Appendix IX.

2. **Visibility and turbulence.**—In regard to visibility observations from airplanes, the pilot observer on the meteorological flight each morning at the central station estimates the vertical visibility according to the following scale prepared by R. C. Jacobsen. The observations are taken at approximately 1,900 metres altitude, corresponding to a pressure of 800 mb. at Toronto.

Vertical visibility scale.—The symbols used are, for vertical visibility V_v, for oblique visibility V_o, and for bumpiness B.

Scale No.	Description.	Definition.
5	Excellent ..	Ground objects sharp and clear, colours undimmed.
4	Good	Details of ground objects easily distinguishable, colours dimmed a little.
3	Fair	Haze apparent, details of objects harder to distinguish, colours except red and yellow tend to same tone.
2	Indifferent ..	Details of objects not visible though outlines still apparent. Definite bluish haze over everything through which only reds and yellows really stand out.
1	Bad	Only larger objects on ground recognized. Colour distinctions hardly apparent.
0	Nil	Nothing on ground visible at all.

Oblique visibility.—Oblique visibility is estimated as the distance measured on the map of the farthest object which is distinguishable over a land surface. The object seen is always named and notes entered when the obscurity of the atmosphere varies with the direction.

Turbulence.—The bumpiness at various elevations during the airplane flight is reported on a scale due to K. O. Lange and given in *Beiträge zur Physik der freien Atmosphäre*, Vol. XVII, p. 95. The following table summarises the limits of each of the four intensities of gustiness defined by the scale.

Scale No.	Description.	Definition.
0	Light	Airplane reacts easily to controls and only light disturbances occur. No rudder required to correct for gusts. Revolutions of motor constant. Air pressure constant.
1	Moderate ..	Frequent movement of airplane around its axis, moderate rolling motion and yawing. Repeated small corrections needed to rudder. Revolutions of motor constant.
2	Strong ..	Airplane goes off course and dances. Strong vertical upthrusts and sudden shocks felt.
3	Violent ..	Airplane responds with difficulty to steering. Passengers are raised from seats. Large variations in propeller revolutions.

It is suggested that standard scales for both vertical visibility and bumpiness be prepared. In oblique visibility the recognition of an object from a standard elevation using the regular visibility scale would probably suffice. The vertical visibility has been found in practice to cover too wide a range between vertical visibility 2 and vertical visibility 4, so that the observers frequently report visibilities of 2½ and 3½.

As the result of investigations on the choice of horizontal visibility marks, it is suggested that:—

(1) It is desirable to choose marks so that (*a*) observations made at different stations shall be intercomparable, and (*b*) observations made by night shall be comparable with those made by day.

(2) The visual range of black or dark grey objects against the sky is a simple one-valued function of the extinction coefficient, which latter measures a property of the atmosphere. The conclusion is drawn that only such objects should be used for visibility observations.

(3) For observations at night it is shown to be practically essential that some form of transmission meter be employed. (*See* Middleton, *Ottawa, Trans. roy. Soc. Can.*, Series III, **25**, 1931, pp. 39-48; ibid., **26**, 1932, pp. 25-33; Buisson and Fabry, *J. Phys. Radium, Paris*, **1**,

1920, pp. 25–32 ; *Rev. Opt. Paris*, **1**, 1922, pp. 1–12 ; Foitzik, *Met. Z., Braunschweig*, **50**, 1933, pp. 473–4.) The observations could be reported on a scale of values of the extinction coefficient corresponding to the steps of a visibility scale.

Additional notes.—In regard to paragraph (2) above, it has recently been shown that objects of any colour are equally satisfactory as marks as long as their reflection factors are not too great.

It is strongly urged that the definition of visibility (see " Visibility in Meteorology," Toronto, 1935, Chap. X) should be changed so as to make the visual range the distance that such an object can be seen. This is in accord with aviation practice on the North American continent.

(*b*) Aviation Meteorology in Southern Rhodesia

By N. P. Sellick, M.C., B.Sc.

(*Government Meteorologist*)

1. **Organization.**—Well-equipped observatories are being established at Salisbury and Bulawayo aerodromes this year and, with the increases in staff authorised, a service extending throughout the hours of daylight will be available. Daily weather charts are plotted at both these posts, and competent forecast officers will be available shortly.

A reasonably close network of stations covering all recognised air-routes except that between Bulawayo and the Falls is available. The majority of observers are Police, who receive special training as recruits, and the stations are inspected annually. A subsidy is paid to the Police for this service, which has proved very satisfactory, but the arrangement may break down in the future as the demand for reports increases.

At present special services are arranged for each flight, but when the reorganization is complete it is proposed to substitute regular fixed hour reports for the special services as far as possible.

The present arrangements for the exchange of information between neighbouring services in southern Africa are far from adequate, and it is suggested that the matter be discussed as between the services.

2. **International tables.**—There appears to be one objection to the International Tables ; pilot balloon observations are normally worked out in metres per second and converted to m.p.h. for aviation, the additional conversion to Km./hr. appears to be rather unnecessary.

3. **Co-operation between aircraft and meteorological services.**—The provision of the requisite weather services for aircraft has made very heavy demands on the time, patience and funds of the Meteorological Office, and up to the present the return in information and constructive criticism has been very small. It is suggested that a discussion of ways and means of obtaining closer co-operation between flying personnel and the Meteorological Offices would form a suitable addition to the agenda.

APPENDIX II.—ICE FORMATION ON AIRCRAFT (Minutes III, p. 15)

Note by the Aviation Services Division, Meteorological Office, London

In certain meteorological conditions, ice may be formed on aeroplanes in flight. The amount of ice formed increases with the length of time during which the aeroplane is subjected to these conditions. The rate of formation of ice, however, varies considerably. Sometimes aircraft have been forced down in a short space of time on account of ice formation ; on the other hand, after prolonged flights in conditions apparently favourable for ice formation, only small amounts of ice may be produced.

Ice is normally formed in greatest quantity on the forward edges of exposed parts ; e.g., on the boss of the propeller, on the leading edges of the propeller blades and of the wings, struts, tie rods, etc. Ice sometimes forms also in certain relatively sheltered parts, e.g., between the wings and the ailerons. Large deposits of ice on the propeller and the plane edges are dangerous because they materially modify the aerodynamical properties of the aircraft, while deposits near the ailerons, etc., may seriously affect the controls. Ice on propeller blades is inclined to break off in large pieces, especially when it is opaque. These pieces may damage other parts of the machine, and after they break away the balance of the engine may be seriously affected.

An aeroplane flying through dry hail or dry snow is not subject to icing ; for the particles of hail or snow are simply swept off the machine without adhering to it. Consequently, aircraft flying at very high levels (say above 25,000 feet in all cases, much lower in some cases) are immune from icing.

The case most favourable for ice formation occurs when an aircraft flies in a cloud composed of " super-cooled " water drops. Such drops have a temperature less than that of the freezing point of water (0° C.), but they remain liquid until the aircraft strikes them, when they (or some part of them) immediately freeze on the machine. If the drops are very small, and if the cloud is in process of formation, compressed rime is produced on the exposed parts of the machine. This consists of an opaque crystalline mass of ice (with numerous air spaces) which may grow forward at a fast rate, and adhere comparatively loosely to the aircraft. If the drops are small and the cloud is dissipating, practically no ice deposition may be expected. If, on the other hand, the drops are larger, then so much water is deposited on the machine that it may not all be immediately frozen, in which case a glassy and compact layer of ice is formed which is only removed with difficulty.

Another case in which a similar deposit of glassy ice (glazed frost) may be formed occurs when the aircraft is flying below a cloud through falling drops of rain, while the temperature of the air around the aircraft is below the freezing point (less than 0° C.). This phenomenon is rare in this country, but it is more frequent on the continent and in North America.

The cloud forms in which ice deposits are produced are of all kinds except the highest. The most favourable air temperatures for formation of ice are from −5° C. to 0° C. Ice in dangerous quantity can, however, be formed at much lower temperatures than −5° C., and it sometimes occurs when temperature slightly exceeds 0° C.

The cloud type in which ice formation is most frequently observed is stratocumulus, which is frequently an " old " cloud composed of big water drops. This cloud is generally found at heights of from 1,500 to 4,500 ft., and its thickness does not as a rule exceed 2,000 ft. Rain seldom falls from this cloud. Moreover, stratocumulus cloud is very often surmounted by a thick layer of clear, dry air. As the layer of cloud may extend unbroken for hundreds of miles, opportunities for ice formation in the layer are favourable, except when the drops are dissipating. Large cumulus and cumulonimbus clouds may be developing or dissipating. In the former case, when showers of rain or hail usually occur, large water drops may be found, especially in the interior of the cloud. Icing is frequently noted in these clouds, but owing to their relatively small horizontal extent, the effects are not serious, except possibly in the tropics, and on occasions when the pilot deliberately remains within the cloud. Nimbostratus and altostratus clouds are generally surmounted by other cloud and by very damp air. Rain or snow usually falls continuously from nimbostratus and from the denser kinds of altostratus, and the clouds themselves are generally due to the condensation of water in small drops from warm, damp air which is pushed up over a wedge of cold drier air (through which, however, the rain falls). The icing of aircraft in this type of cloud is fortunately rather uncommon.

From the above considerations the following action suggests itself as desirable when a pilot observes ice forming on his machine :—

(1) If it is possible to land on an aerodrome it is desirable to do so, and to obtain from the Meteorological Officer or from the Air Ministry advice as to the conditions of cloud and temperature at various heights on the route.

(2) As temperature normally rises as height is reduced, if the flying height where icing occurs is considerable (above 4,000 or 5,000 ft.), and if it is known that there are no clouds below 2,000 ft., fly below the cloud. This will be effective in removing the ice, except on the very rare occasions when " glazed frost " is observed on the ground.

(3) If it is desired not to fly low, and the cloud is of the stratocumulus type, it is generally safe to fly above the cloud layer. On emerging into the very dry and clear air which is usually found above the cloud the ice is removed, mainly by evaporation, but partially also by solar radiation if the sun is powerful enough.

(4) If icing occurs in a " heap " cloud (cumulus, cumulonimbus, altocumulus) avoid the clouds, which are always detached from one another.

(5) If icing occurs in nimbostratus, or altostratus cloud, it is probably best to land if that can be done with safety. Failing that, the best thing to be done if the aircraft is suitable is to climb as rapidly as possible to a great height where only dry snow or dry hail will be found, or to a height or place which is free from cloud.

Rules (2), (3), (4) and (5) amount in practice to the advice :—" If ice is forming on aircraft in cloud, find a layer or position where there is no cloud." Such positions may, however, be above or below the cloud or in the interstices between separate clouds, and the rules governing these different cases are therefore set out separately.

APPENDIX III.—METEOROLOGICAL AID REQUIRED FOR BLIND FLYING (Minutes III, p. 15)

By W. H. Pick, B.Sc., F.Inst.P.

(*Assistant Superintendent, Andover*)

Blind Flying is flying an aircraft solely by the use of instruments. Its practical application is flying in cloud, commonly termed Cloud Flying. Cloud Flying may be carried out either individually or in formation.

The meteorological data required by the leader of a formation when formation flying in clouds is contemplated are the following :—

(*a*) The expected degree of continuity over the route of the cloud in which the flight is contemplated.

(*b*) The probable vertical thickness of the cloud.

(*c*) The probable height of the base of the cloud above the general level of the land over which the flight is contemplated, and whether hill tops or high ground on the route are likely to be enveloped in cloud.

(*d*) The degree of visibility likely to be experienced within the cloud.

(*e*) The degree of bumpiness likely to be experienced within the cloud.

(*f*) If stratocumulus is the cloud layer employed, the probability of that cloud containing cumulus or cumulonimbus.

(*g*) The degree and type of ice accretion likely to be experienced, and if the ice accretion is likely to be slow or rapid. Further, if possible, advice as to the best method of clearing the ice accretion when obtained.

(*h*) The expected wind speed and direction over the route within the cloud, and just above the cloud.

If only one aircraft is undertaking the flight, then (*d*), (*e*) and (*f*) of the above are not required, inasmuch as they are concerned with visibility and bumpiness within the clouds, factors which do not seriously affect a single aircraft.

Some notes on each of the items (*a*) to (*h*) are now offered.

(*a*) Complete continuity of cloud over a long stretch is only given by stratocumulus, and by altostratus and nimbostratus (really the wedge of cloud associated with " warm fronts ") and, possibly, stratus, but stratus is not used normally for cloud flying owing to its very low base. Complete continuity is, however, only needed for certain specific work ; more generally the aircraft pilot pursues a track from A to B and wishes to maintain that track irrespective of the presence or absence of clouds, but he wishes to know through what clouds his track will take him.

(*b*) The probable vertical thickness of the cloud is wanted in order that it may be known if " icing " of the aircraft can be removed by flying above the cloud. It is also needed to know whether flying above the clouds is possible, if desired, either to ease the pilots from the strain of formation flying actually in cloud or for other reasons.

(*c*) The probable height of cloud base over the general level of the country is needed in case of possible forced landings. A clearance of 800 ft. of cloud base above the ground is usually regarded as the minimum necessary for safety. The importance of knowing if hill tops or high ground on the route are in cloud or not is self-evident.

(*d*) The visibility within the cloud is vital for formation flying. The definition of what is " adequate " visibility depends on the size of the aircraft employed and the " tightness " of the formation.

(*e*) The bumpiness within the cloud is again vital for formation flying. Severe bumpiness is clearly a distinct danger in close formation work.

(*f*) Stratocumulus is usually characterised by slight or moderate bumpiness and by a visibility of 13 to 24 yards, while cumulus and cumulonimbus have often severe bumpiness and a visibility of considerably less than 13 yards. A formation flying in the comparatively comfortable conditions of bumpiness and of visibility represented by " pure " stratocumulus may suddenly pass into the severe bumpiness and very low visibility of cumulus and of cumulonimbus with grave resulting danger of collisions within the formation.

(*g*) Ice accretion, if rapid, causes changes in the aerodynamic shape of the leading edges with consequent rapid loss of lift. It also causes loss of balance in, and vibration of, the air-screw. There is also the danger of detached pieces of ice striking the fuselage, the cockpit and the pilot. In addition, instruments may become unworkable, and the added weight of ice has to be carried. Forecasts of the likelihood of rapid ice accretion are therefore greatly desired by the cloud-flying pilot, and any help that the meteorologist can render him as to clearing ice, when formed, is greatly appreciated.

(*h*) The wind speed and wind direction at the height of flight are necessary for navigation, especially as a pilot does not appear when in cloud to have any method of getting wind speed and direction for himself without making a land-fall. Wind speed and wind direction just above the clouds are necessary because under stratocumulus conditions a pilot might go there to clear himself of ice, or a formation might fly there both for that reason and to ease the pilots from the strain of formation flying actually in the clouds : and once again a pilot does not appear to have as yet any workable method of getting wind speed and direction for himself above a continuous layer of clouds.

APPENDIX IV.—CIVIL PILOTS' LICENCES IN METEOROLOGY (Minutes III, pp. 16–7)

MEMORANDUM PREPARED IN THE METEOROLOGICAL OFFICE, LONDON

Civil pilots of aircraft carrying passengers for hire or reward within Great Britain and Northern Ireland and the adjacent parts of the continent are required to be in possession of a Class B licence. Included in the tests preliminary to the granting of this licence is an examination in elementary meteorology.

It is expected of the pilot—

(1) that he should have a knowledge of the different meteorological observations which are made and the use to which they are put, such as the international interchange of weather reports in constructing synoptic charts and in the preparation of forecasts of weather to be expected some hours ahead ;

(2) that he should know how and where to obtain a forecast for any projected flight, and be able to understand the technical terms used in describing details of the wind, weather, clouds, etc. ;

(3) that he should have a knowledge in outline of the general organization of weather reports and forecasts for the established air routes operating in the British Isles and to adjacent parts of Europe ;

(4) that to help in understanding such information, he should possess an elementary knowledge of the structure of the atmosphere, wind circulations, the structure of clouds, the formation of different types of precipitation and of fog, and the local and diurnal variation of these phenomena. He should be aware of any weather features which form a danger to flying and of the preliminary warnings from eye observations of clouds, wind, etc., which indicate the possibility of their occurrence.

Air Ministry Pamphlet No. 53 (2nd Edition, 1934), contains on pp. 5 and 6 the exact syllabus for the examination in Elementary Meteorology, and on pp. 8–11 a number of questions typical of those which may be asked and a list of books which are recommended for the study of the subject. The examination is wholly oral and the questions asked are intended to be of as practical a nature as possible. The standard expected to be attained for a pass is 60 per cent for each subject in this examination for the Class B licence, and an average of 70 per cent for the three subjects, Air Legislation, Air Navigation and Elementary Meteorology.

It is known that pilots of Imperial Airways who navigate to Egypt, South Africa and Singapore must first pass the 2nd Class Air Navigator's licence, as well as the Class B licence. The syllabus of the 2nd Class Air Navigator's licence is more difficult than that of the Class B licence, and it includes

a knowledge of the climatology of different parts of the earth, such as is obtainable from Kendrew's " Climates of the Continents," as well as a knowledge of distinctive meteorological features of special areas ; e.g., trade winds, monsoons, dust storms, etc. The syllabus of this examination is set out on pp. 4 and 5 of Air Ministry Pamphlet No. 44. The examination is partly written and partly oral.

It would be of interest and use if delegates would indicate if any similar examinations are held in their own countries, and if so, whether the scope of the examination differs materially from that indicated in the two pamphlets.

APPENDIX V.—METHODS OF FORECASTING FROM SYNOPTIC CHARTS

(Minutes IV, pp. 17–21)

(*a*) BRITISH ISLES
(*b*) MALAYA
(*c*) SOUTHERN RHODESIA

(*a*) British Isles

BY R. CORLESS, M.A.

(*Superintendent, Forecast and Aviation Services Division*)

Empirical methods based on shapes and movements of isobaric systems still form the basis of much of the day-to-day forecasting in the British Isles for periods of 24 to 36 hours ahead. The movements of isobaric systems are determined partly by the movements of any fronts there may be, partly by barometric tendencies and partly by the direction of motion of the strongest wind in the system (sometimes, but not always, a warm sector wind). Norwegian methods have much improved the short period forecasts of 3 to 6 hours ahead which are required for aviation, but it is necessary to maintain a close network of observing stations in order to keep track of the fronts.

Situated, as we are, on the eastern border of the North Atlantic and the western border of the Eurasian continent, forecasting is rendered difficult by the effects of land on W. winds, and by the fact that most of the active depressions are occluded by the time they affect this country. After occlusion, the forecasting of the movement of a dying depression appears to be subject to no real laws. The depression may fill up rapidly ; on the other hand, it may slowly fill up while remaining almost stationary over the North Sea, giving cold strong winds and rain, especially down the east coasts, sometimes lasting for three days or so.

Now that we have a service of regular weather reports from ships across the North Atlantic, we are often able to trace in fair detail the life history of Atlantic depressions, and to observe the formation in succession of families as first described by Bjerknes. Each member of the family is born as a " secondary " to its parent, i.e., at the southern boundary of the occluded front of the parent, where warm and cold air meet to form the elusive " kink " which heralds the formation of an active disturbance. We have learned to be on the look-out for these offspring depressions, but unless we have ships' observations just to the south-west of Ireland, we are sometimes caught out by sudden developments there which may give rise to dangerous SW. gales in the English or Bristol Channels with little or no warning.

When the last of the " family " of depressions has passed by, there is a break through of northerly winds, pressure rises rapidly from west to east and a period of settled calm weather often results. This regular sequence is very common in winter, and it forms, on the whole, one of the easiest types of weather to forecast.

Next in importance to the sequence just described are the easterly winds resulting usually from the rapid development of a high pressure system over Scandinavia, often apparently due to subsidence and falling pressure in south France and south Germany. This type often develops with extraordinary rapidity, and when once properly established, it is apt to be persistent giving wintry weather and bitterly cold winds from the cold continent in winter and spring. This type often breaks up as rapidly as it is formed. One has to be on the alert for signs of the cutting off of the supply of cold air a long way to eastward, to forecast warmer weather successfully.

In summer, forecasting is of a different character. The general tendency is for Atlantic depressions to be less active and move on more northerly tracks. Part of the continental Azores " high " often covers the whole country or at least the southern portion of it.

Quite often the larger mountain masses, e.g., the Alps, Greenland, the Norwegian mountain mass, deflect the motion of depressions ; but there are numerous occasions when depressions appear to pass right over the high ground. It is difficult to see how much of the original air of a depression over Davis Strait can pass over the 10,000 ft. massif of Greenland ; it is more likely that there is some dynamical or thermodynamical action, the nature of which is not fully understood, which has the effect of transferring the centre of low pressure from Davis Strait to the Greenland Sea.

With moist strong westerlies, orographic rainfall is common in this country in winter. There is a case on record in which more than 4 in. of rain fell over the greater part of the interior of Scotland, when the telegraphic reporting stations (which at that time were situated almost entirely near the coast) showed practically no rainfall at all.

The connexion between Atlantic weather systems and ocean currents is striking. Surface air rapidly acquires the temperature of the sea surface over which it passes. Consequently, fronts with associated depressions are readily formed off Newfoundland where the warm Gulf Stream meets the cold Labrador current, and the system tends to move along the boundary between the cold east Greenland current and the Gulf Stream drift.

The commonest type of air over the British Isles is maritime polar. This is air of polar origin which has been warmed some distance from below usually by a long sea passage over the Atlantic. In higher levels the air retains its low temperature.

Fronts are shown on the daily weather charts published by many European countries. The fronts which appear on the Bergen charts are not finally prepared and issued until 2 or 3 days after the event. In this way, time is available for making any corrections which may be required in the original diagnoses as a result of subsequent events. This fact of itself indicates the inherent difficulty of drawing fronts on many occasions; the difficulty is further confirmed by a comparison of fronts published on other European charts which often differ materially from one another. Consequently, it cannot be said that we are within sight of the solution of the forecasting problem in this country. Indeed, the more one studies the matter, the more intricate the subject appears to be.

The value of upper air observations to the problem of forecasting is self-evident, but a proper technique for their application has not been fully worked out. The atmosphere in any place is in three dimensions, and if upper air observations, free from the numerous disturbing effects of land, could be easily obtained, they would be much preferred by all. If only we had a full set of observations of pressure, temperature, humidity and wind at intervals up to 10 Km. at a sufficiently numerous network of observation stations over sea and land, together with details of the weather at each point, there is no doubt whatever that great advances in forecasting would follow. The solution of the problem of obtaining weather reports at specified heights in an inexpensive manner is an urgent and highly important one for weather forecasting.

(*b*) Malaya

By C. D. Stewart, B.Sc.

(*Superintendent, Malayan Meteorological Service*)

Forecasting in the equatorial belt is a special problem, and the present note is intended to indicate briefly the manner in which it has been attacked in Malaya. In the absence of precedents or of former experience which might have given some guidance, the methods in use are still largely experimental. It is difficult to judge whether Malayan forecasting problems are peculiar to Malaya or whether they may be regarded as typical of equatorial regions generally. It is hoped that the statement of the experience of forecasting officers as set out below may lead to discussion which may be of assistance to all services in the equatorial belt, including Malaya itself.

Malaya is situated between the parallels 1° and 7° N. and the meridians 100° and 105° E., and comes at different times under the influence of the India low pressure, Asiatic high pressure and the equatorial low pressure belts. Between May and August the Australian high pressure belt may also have a considerable influence over the southern part of Malaya.

The winds over Malaya have not the steadiness found in regions further north and this memorandum will commence with a short account of the general winds actually experienced.

(a) *November–February.*—During this season the Asiatic high pressure first extends slowly southwards, retreating later. The most general wind is from NE. and is known as the NE. monsoon, but some effects of the W. monsoon of the southern hemisphere are experienced, particularly in the southern districts, and at the beginning and end of this season both these wind systems may be exercising their influence.

(b) *March–April and September–October.*—These are two inter-monsoon periods when winds are light and variable, with a tendency to NE. winds in March when the Asiatic high may be still retreating and to westerly winds in September or October when the Asiatic high is beginning to advance.

(c) *May–August.*—During this period the Indian low is the dominant feature, and the winds are mainly westerly; but with a decrease in intensity, or a movement of the low to the north, there is a corresponding movement northwards of the SE. trades of the Australian high, and these may extend as far as 4° or 5° N. and may persist for several days as far as 2° or 3° N.

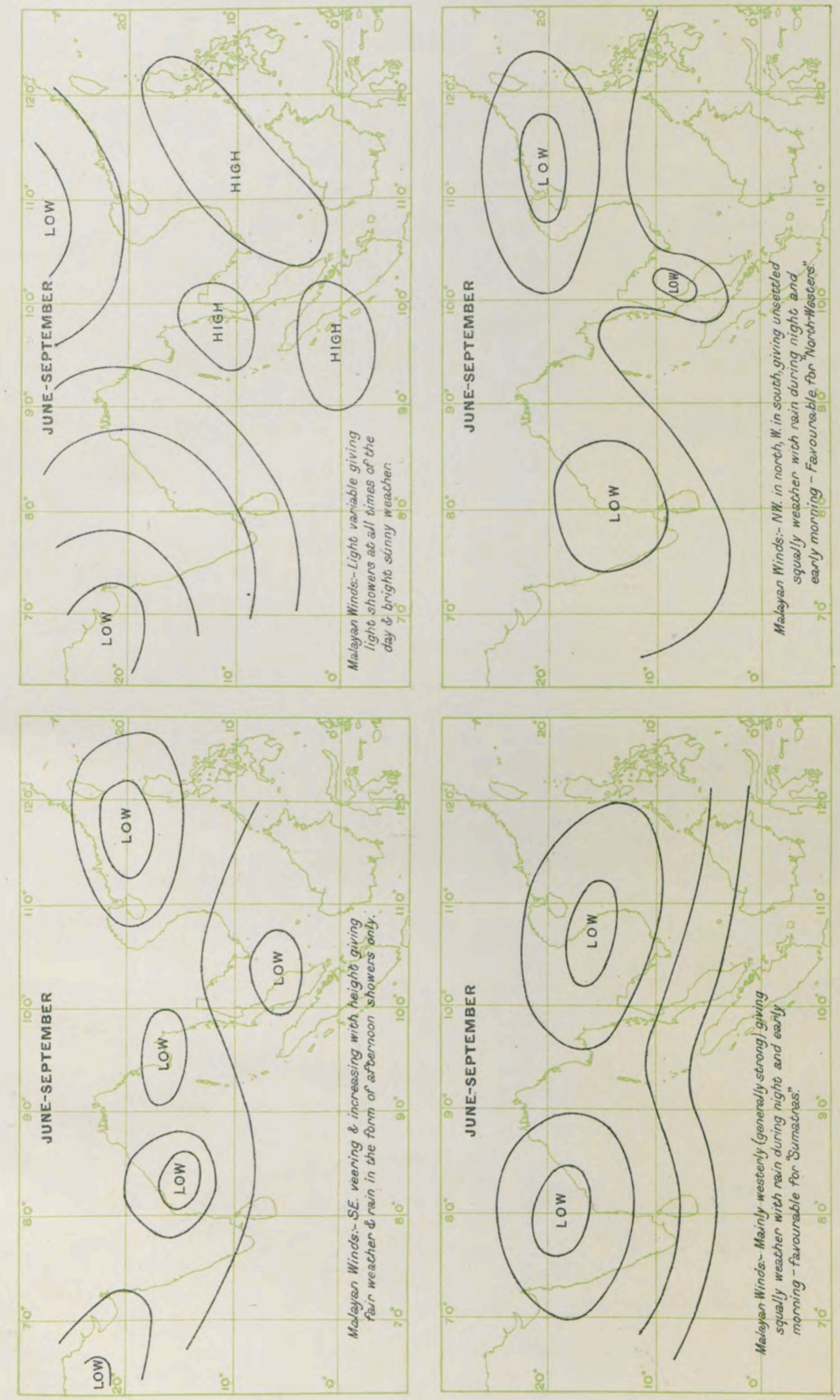
The possible connexion between weather and wind direction is not a new idea, but in Malaya the importance of wind direction arises largely from the lack of serious variation in other determinate meteorological elements. The attempt to develop a forecasting technique has, of necessity, resolved itself to a large extent into attempts to establish a connexion between wind and weather, hence the stress which, from the commencement, is laid on the wind systems. The whole of the information plotted on a synoptic chart is used to determine the air stream and, if possible, to forecast its changes, and the present memorandum is intended to indicate the extent to which this is at present possible and the methods by which weather forecasts are then attempted.

Forecasting on these lines resolves itself into two parts: (1) the determination of the effects of winds from different directions and the modifications, if any, following on changes in speed, ascending or descending currents, and the effects appearing at places where two different wind streams meet; and (2) the determination of the future wind streams. These two will be treated separately but for both it is necessary to have some method of identifying the wind stream.

The ordinary observation of wind direction as reported from an observing station is usually of practically no assistance since it is affected so largely by purely local conditions; land and sea breezes on the coast and katabatic effects inland are for the most part of sufficient intensity to mask the general circulation completely. The wind at 3,000 ft. is therefore taken as a better guide. As there are only three pilot balloon stations it is necessary in other cases to rely on nephoscope observations of low cloud which is usually in the neighbourhood of that height. An estimate of height is reported and certain allowance has to be made at times. Wind reports from ships at sea do not suffer from the uncertainties of the winds at land stations and are used as reported, such observations in the circumstances being

To face p. 112.

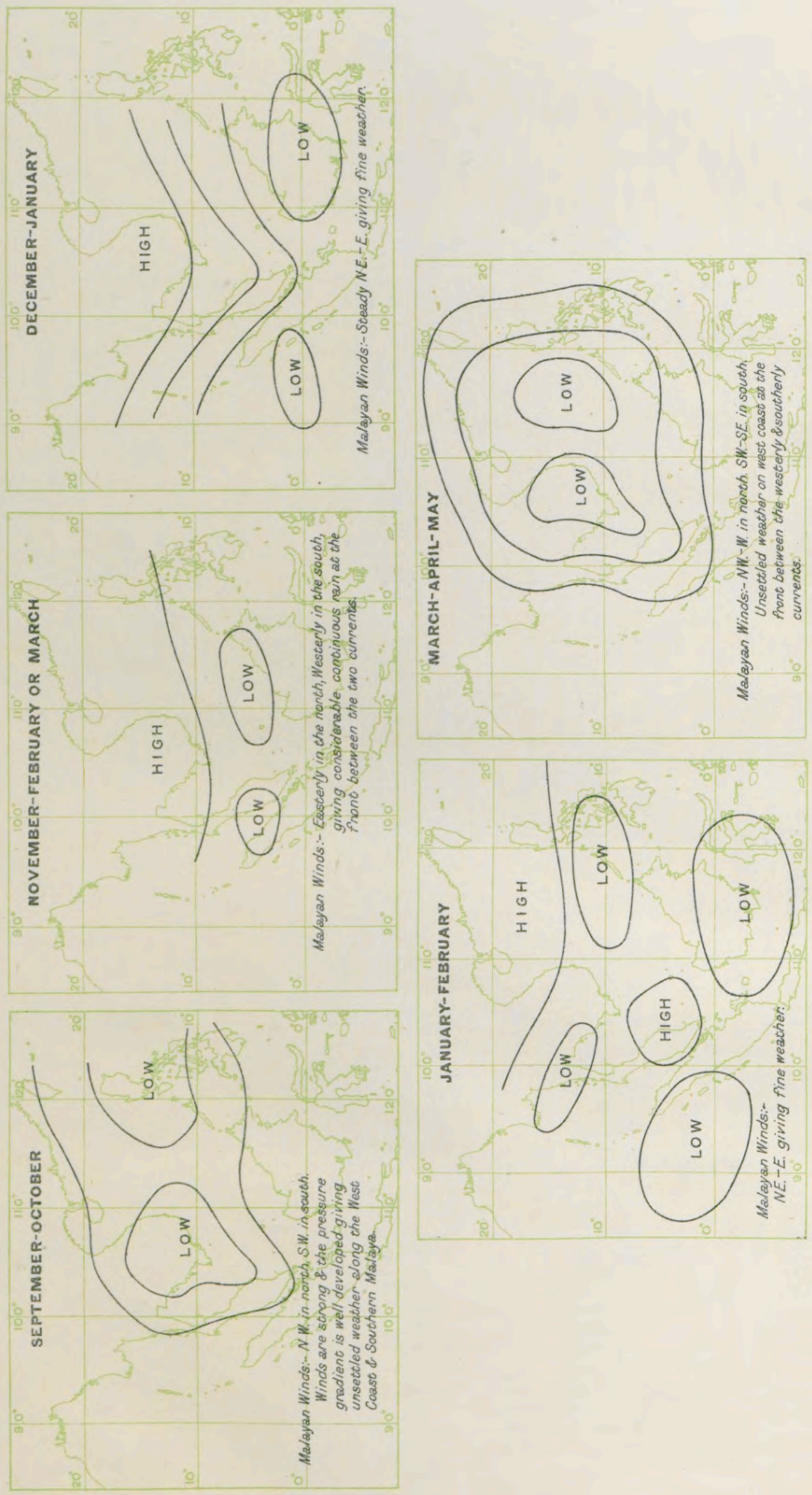
PLATE I.



THE MORE PERSISTENT TYPES OF PRESSURE DISTRIBUTION.

To face p. 113.

PLATE II.



THE MORE PERSISTENT TYPES OF PRESSURE DISTRIBUTION.

H.M. Stationery Office Press, Kingsway, W.C.2.

21259/3094. Wt.36755. D.2644. 6p.908. 375. 12/36.

invaluable. There is also considerable uncertainty about the occurrence of convection, as with the low wind speeds usually experienced the tail method of obtaining height is not always reliable ; the presence or absence of convection cloud at the morning observation requires to be noted particularly and a knowledge of the local peculiarities of each station on the part of the forecaster is most important.

An important feature in the identification of air masses is the dew-point ; this is to some extent subject to local peculiarities, but is probably the most nearly constant of the measurable properties of a given air stream, if allowance is made for occasional changes arising from precipitation. It appears to be a much more promising detail for identification of air than the dry-bulb temperature which is liable to quite considerable fluctuations.

The identification of the source of the air is followed by an examination of the properties of different air supplies. Temperature and pressure do not vary greatly from season to season and it has been assumed, therefore, that a similar air supply will produce similar effects at whatever time of year it may be found ; no seasonal analysis has been undertaken up to the present, though in some respects, such an analysis would bring out more strongly some of the points which appear.

An obvious starting point is the determination of the frequency of occurrence of rain days with winds from different directions ; as local topography also plays a part in the production of rain it is necessary to treat different districts separately. In the present instance, with only three pilot balloon stations, these three are alone considered.

TABLE I.—PERCENTAGE FREQUENCY OF RAIN DAYS WITH WINDS FROM VARIOUS DIRECTIONS

	Singapore.	Kuala Lumpur.	Alor Star.
N.	58	73	57
NE.	69	60	44
E.	65	63	40
SE.	28	95	48
S.	36	67	49
SW.	49	45	45
W.	57	53	68
NW.	73	69	60
All Directions ..	53	62	52

The above analysis is a preliminary one and in this simple form could not be expected to give a practical forecasting rule. Nevertheless at Singapore it is found that with easterly, north-easterly and north-westerly winds rain frequency is considerably above average, while with south-easterly winds it is well below. At Kuala Lumpur, south-easterly winds are almost always rainy, while at Alor Star westerly winds give most rain. Further consideration is necessary with regard to wind speed and the time of day at which rainfall occurs, since at Kuala Lumpur and Alor Star afternoon instability rain is of frequent occurrence and this does not depend on wind direction.

Table II shows the rain frequency for different groups of wind speeds with the various directions.

TABLE II.—PERCENTAGE FREQUENCY OF RAIN DAYS WITH WIND SPEED LESS THAN 10 M.P.H. AND GREATER THAN 10 M.P.H

	Singapore.		Kuala Lumpur.		Alor Star.	
	<10 m.p.h.	>10 m.p.h.	<10 m.p.h.	>10 m.p.h.	<10 m.p.h.	>10 m.p.h.
N.	73	53	80	62	61	61
NE.	50	73	55	58	45	36
E.	57	80	63	67	46	39
SE.	31	25	92	100	53	38
S.	39	32	58	52	46	53
SW.	50	48	50	40	45	47
W.	55	58	49	62	58	70
NW.	74	67	73	70	48	79

The distinction between rain probability at speeds less and greater than 10 m.p.h. is masked to a large extent by afternoon instability rain. Unfortunately, the analysis excluding such rain is not sufficiently complete to be quoted here, but it is found that generally rain is more frequent with low than with high wind speeds except for westerly winds at Alor Star, north-easterly winds at Kuala Lumpur and south-easterly winds at Singapore ; or, in general, what are generally regarded in Malaya as monsoon winds are more likely to give rain at high than at low speeds, the reverse being the case with other winds.

In addition to the rainfall frequencies with definite wind, information has been obtained as to the probabilities with different wind directions, of changes in the wind, changes including veering, backing, increasing and decreasing, also with the various combinations of changes of direction and speed. All changes do not affect the probabilities, but the method has not been without success.

Another detail which has required consideration is the frequency of rainfall at different times of the day. For this purpose the day is divided into 4-hour intervals between midnight and midnight, and the frequency of rainfall for each of these intervals with different wind directions has been analysed. The chief value of the analysis has been the indication it has given of the general character of the rainfall, though a few of the results can be used directly. For example, with SE. winds at Singapore, 28 per cent of the days give rain, and of these days 83 per cent have the rain between 12h. and 16h. (local time). This particular result is more definite than most, but the analysis does provide a starting-point for the examination of the probabilities when details of vertical motion and humidity are also considered. With regard to vertical motion and humidity no rules have been formulated, and it can only be said that each day's wind is examined as far as may be by the aid of first principles. As with the boundary between two independent air masses, each case has to be considered individually.

The above refers to the existing state of affairs, what may be termed " diagnosis." There still remains the problem of forecasting the future wind, or more strictly speaking, the air supply. The weather conditions which hold to-day with, say, a westerly wind will hold to-morrow with a similar wind, but by a " similar wind " must be understood not merely a westerly wind but a westerly wind with a similar history. In Malaya, at all events, to be able to forecast a persistence of the existing wind is equivalent to being able to forecast broadly the persistence of existing weather. The first question considered by the forecaster, therefore, is whether existing conditions are likely to be maintained. If not the second question has to be faced of what the changes are likely to be.

The answers to these questions have to be sought in Malaya, as elsewhere, by an examination of the persistence or changing of the pressure distribution over an area extending well to the north and south of Malaya itself. An immediate difficulty is that the information necessary for drawing synoptic charts has hitherto not been readily available; but arrangements are now under consideration for synchronising observations in Malaya, Siam and the Netherlands Indies, also for securing broadcasts within a reasonably short time of the observations. Up to the present, however, analysis has had to be based on information which is at least 24 hours old and sometimes more. The lack of current synoptic information has hampered progress considerably, and only when this defect is remedied can we hope for much further progress. In the circumstances to devote a large amount of space to the methods employed or projected would hardly be justified, but the broad principles on which forecasting is attempted from such charts may be indicated briefly.

In view of what has been said above it will be understood that charts are examined for types of pressure distribution which seem to be persistent; speaking generally there are such types and they are not difficult to identify, but Malaya is always on the edge of the system in such a case so that small variations in intensity, and the consequent retreat or advance of the "edge", have a disproportionate effect so far as Malaya is concerned. During the SW. monsoon season, winds alternate between the western quarter and the southern quarter, the source of the air being different in the two cases; in the NE. monsoon, winds alternate between NE. and W., the source being again different in the two cases. Charts of the more persistent types of pressure distribution are reproduced in Plates I and II.

The immediate problem is to determine whether the "edge" will move sufficiently to cause a change from one régime to the other and to estimate the local variations when different parts of Malaya are in different systems. While synoptic information is received too late to be of direct assistance, the only method available for estimating changes is to note the spatial variation in wind among the Malayan stations and to estimate, from this and previous charts, what is the general situation most likely to be responsible for this variation. From variations of wind with time an attempt is then made to estimate the changes taking place in the general situation and, from this, to make a forecast of the future wind system. This is a method which must seem to the reader to be somewhat indefinite, but the success met with in using it has been very considerable, though it must be admitted that it has also met with some conspicuous failures.

Reports received from the north, though at least 24 hours late do, when they are available, assist in checking the estimates previously made.

It happens at times that for some days a well-defined surface of separation between air supplies from different sources persists over Malaya. Relative variations in wind speed seem to control the movements of such surfaces and at times the isobars assist in determining them, though the most definite identification is usually obtained from the dew-points. Such a "front" may swing backwards and forwards over considerable distances without losing its characteristics.

The purpose of this note is not merely to point out the difficulties of forecasting in an equatorial region, but also to emphasise the fact that, in spite of time-honoured assumptions, we have to deal with "weather" and not merely with "climate."

(*c*) Southern Rhodesia

By N. P. Sellick, M.C., B.Sc.

(*Government Meteorologist*)

1. **Charts.**—The charts in current use consist of (*a*) a chart on the scale of 1 : 5,000,000 on a conical projection with standard parallels at 11° and 23° and (*b*) a chart of southern Africa on a scale of 1 : 20,000,000 on Sanson's projection. The latter is preferred to the suggested cylindrical projection as it gives less distortion over the effective area. The 1,000, 1,500 and 2,000 metre areas were indicated on the previous charts by layers, but no particular use was found for this and it has been abandoned.

Stations are represented by small circles which are marked to indicate the total cloud amount, and the type of cloud is shown in symbols. Arrows with the circle as head indicate wind direction and force. Pressure, in millibars and tenths, and dry bulb and dew point, in degrees Fahrenheit, all at 1,200 gdm. are entered near the station and present weather is shown when of interest. Isobars are drawn at intervals of 1 mb. on both charts. Auxiliary charts are plotted showing the pressure change in 24 hours, the rainfall in the past 24 hours and the maximum and minimum temperatures reduced to 1,200 gdm.

2. **Times of observation.**—Observations are made at 4h. G.M.T. in Madagascar, 6h. G.M.T. in Northern Rhodesia, 7h. G.M.T. in Portuguese East Africa and at 6h. 30m. G.M.T. in Southern Rhodesia and the Union, and are available before 10h. G.M.T. They are received as collective messages by radio and telegraph, and forecasts are issued between 10h. and 11h. G.M.T.

3. **Pressure.**—Definite pressure systems of the temperate zone type rarely traverse Southern Rhodesia. Lows move from west to east along the south coast of South Africa, and occasionally, in winter, penetrate to Rhodesia. The highs usually move up the east coast and affect Rhodesia as waves of cold air from the south-east succeeded by mild dry easterly winds probably originating in the high. The equatorial low appears in October or November and remains as a semi-permanent low up to some time in March. Its movements in the early and late season appear to be affected by the southerly lows, and troughs are formed which traverse Southern Rhodesia from south to north often accompanied by phenomena of the line squall type. In the general rain periods it appears to operate without the assistance of the southerly lows. Tropical cyclones appear off the east coast in January and February

and exert a direct influence over the eastern part of the colony and an indirect influence over a very wide area. The pressure change over 24 hours is a useful but by no means infallible guide to the future movements of highs and lows.

4. **Winds**—The seasonal change in the mean surface winds is comparatively small, but the winds from NE. to NW. increase in frequency during the rainy season November–March. Upper wind observations, commenced about seven years ago, indicate a marked change between summer and winter, the predominating easterly winds being entirely replaced by westerlies at about 5 Km. above sea-level in winter.

Both surface and free air winds in the lower levels pay some regard to the isobars in Southern Rhodesia; in settled conditions the agreement is at times very close as regards direction, but with an incoming high the winds deviate widely and appear to blow straight down the gradient and the upper winds show little improvement. Very marked convergence is evident in surface winds during periods of rain, the winds frequently approach direct opposition, and there is a good deal of evidence of discontinuities and air currents of considerable extent both rising from and descending towards the surface. The application of the geostrophic wind law to the isobars as at present drawn indicates that most of the rain-bearing air comes from the South Atlantic via Angola and the Belgian Congo, and some from the north-east. The pressures now being received from the British East African Service alter the isobars very considerably, and the matter requires further consideration.

5. **Basis of forecasts.**—Forecasts are based largely on the winds. North-westerly winds are rain winds, north-easterly winds shower winds, south-easterly winds give cool overcast weather and drizzle followed by easterly winds and fair weather. The isobar charts are used to indicate probable changes in wind and conflict of different currents, and very considerable use is made of the tendency for persistence of weather and of the relation between dew point and rain. The existence and importance of travelling weather systems is fully recognised, but the speed of travel is high and with 24-hours' interval between charts and insufficient reports from neighbouring territories the recognition of these systems is of little value in forecasting.

6. **Type of Forecast.**—Forecasts for agriculturists are made three times a week during the rainy season and are transmitted free to post offices. They deal in general terms with the expectation of rain and incidentally cloud for the following two days. Special forecasts are issued to the press daily for publication on the following day and the experimental broadcast service is also supplied twice a week. Forecasts are supplied twice a week to Imperial Airways, these are made in the afternoon, based on the morning observations, and cover the 600 miles of route for the following day. No great precision is attempted, but indications of wind direction and strength, extent of low cloud, weather and visibility are given, and it is understood that the forecasts are of service.

APPENDIX VI.—METHODS OF PLOTTING DATA ON SYNOPTIC CHARTS

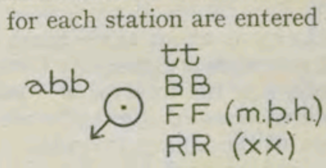
(Minutes IV pp. 22–3 and V pp. 23–5).

(*a*) Canada.
(*b*) British East Africa.
(*c*) Southern Rhodesia.
(*d*) Note on the Barometer on Semi-Tropical Plateaux.

(*a*) Canada

Memorandum Prepared by The Canadian Meteorological Service

The data for each station are entered on the main working chart in the following order:—



Current temperature to 2°.
Barometric pressure to ·02 in.
Wind velocity m.p.h.
Precipitation to ·02 in.

Letters (xx) after precipitation in the same colour indicate time and intensity. Letters in red beside the station indicate barometric tendency, a, and the pressure change, bb, during the previous three hours. The forecasters consider that letters are preferable to symbols. Wind direction is indicated in the usual way by an arrow.

In the station circle R indicates rain; S snow; F fog; the circle clear, from 0 to 2 tenths cloud; half of circle black, 3 to 7 tenths cloud; circle completely black, 8 to 10 tenths cloud. Thunderstorms are indicated near the circle with the usual thunderstorm symbol and the time immediately above. The following secondary maps are also used:—

(1) Maximum and minimum temperatures.
(2) Temperature change in previous 24 hours. Pressure change in previous 12 hours.
(3) Humidity and clouds.
(4) Chart of the northern hemisphere.
(5) During the summer a special map is prepared showing the minimum humidity, maximum temperature and precipitation in connexion with fire weather forecasting.

Grass minimum temperatures are also very important during the late spring and early autumn in connexion with forecasting for the occurrence of frosts.

Cloud data other than indicated above are unfortunately not given on the working map as the word code now in use has not been adapted to the 1931 edition of the "International Cloud Atlas".

In frontal analysis of synoptic maps supplementary maps cannot be easily used. It is most essential that all surface data be plotted on one map.

The time of precipitation and character, whether light, moderate, or intense, which is indicated after the amount of precipitation is very important information for frontal analysis, but is lacking in the International Code. This is a question that ought to be considered by the Synoptic Commission to see if they cannot arrange for this to be included in some of the groups of figures.

(*b*) British East Africa

BY A. WALTER

(*Director, British East African Meteorological Service*)

As the East African Service extends over the high plateau and down to the coast level, two systems are shown on the same chart, the upper one in heavy black ink extending only so far as the plateau observations permit, and the second one in pale violet ink giving the sea-level conditions. No attempt is made to correct sea-level readings to the high plateau, or the high plateau to sea-level except as a guide at one or two points to indicate the general trend of the isobars. It has appeared to us that any attempt to connect up the sea-level conditions with those on the high plateau is worse than useless; in fact it is extremely misleading; but we believe that by increasing the number of pilot balloon stations we may be able to obtain some indication of the trend of the barometric gradients at the high level station from the changes of the wind at different layers.

The information shown on the chart is :—

(1) The position designated by circles in which the cloud conditions are represented.

(2) A wind arrow shown radially from the circumference of this circle.

(3) Three sets of figures; temperature reduced to the 1,200 dynamic metre level, pressure of aqueous vapour to the nearest millibar, and atmospheric pressure in three figures giving tenths of millibars. These three are placed to the right of the circle. A small figure is placed to the left of the circle indicating the direction of the wind in 32 points for drawing isogonol lines. In red ink under the circle the symbols for past weather are placed. The upper winds are shown by means of large red arrows very heavy, about one-tenth of an inch wide for the lower stratum, about a sixteenth for the next and a thin line for the third. Three levels are generally found sufficient to indicate the general conditions, but a small black figure written next to the arrow indicates the height.

(*c*) Southern Rhodesia

A note on the method of plotting in use in Southern Rhodesia is included in Appendix V (*c*), section 1 (p. 114).

(*d*) Note on the Barometer on Semi-Tropical Plateaux

BY N. P. SELLICK, M.C., B.SC.

(*Government Meteorologist, Southern Rhodesia*)

The 24 hour pressure changes on the plateau in the latitudes of Southern Rhodesia are of the order of 1 or 2 millibars rising to a maximum of about 5 millibars on a few occasions during the year. On the average they are considerably less than the diurnal variation which is of the order of 3 millibars.

The barometric characteristic for any succession of three hours is likely to be fairly constant apart from major disturbances which are apparent without the aid of this indicator.

The barometric tendency for any three hours gives misleading indications as, after allowance has been made for the normal diurnal wave the general tendency is masked by irregular fluctuations of upwards of 1 millibar.

On account of the sine term, the geostrophic wind velocity is about three times as great as in Great Britain for the same pressure gradient and as the wind velocities are generally lower the gradients are very weak. In the ordinary way only two or three isobars at the interval of 1 millibar traverse Southern Rhodesia and carefully drawn isobars following minor pressure differences are very irregular and have not, up to the present, been interpreted. In view of the known irregular fluctuations (see previous paragraph) the irregularities are possibly real but it is improbable that the partly trained observers can be trusted to 0·3 mb. on individual readings. The absence of marked gradients puts a premium on accurate levels and barometers, and requires reliable observations and reductions.

The accuracy of pressure reductions based on 8h. 30m. pressures and temperatures, an assumed lapse rate of 3° F. per 1,000 ft. and average humidity can be assessed from the following table which shows the pressure at Mount Nuza 2032m. reduced to Stapleford 1617m., immediately below, and to Umtali 1119m. about 20 miles to the south. The barometer is exposed in an anemometer hut at the extreme top of the mountain and is subject to high winds.

Mount Nuza to—	Average Pressure-Difference.	Number of errors by intervals of 0·1 mb. 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Stapleford ..	40·5 mb. ..	16	19	19	17	4	8	3	1	1	–	2	1	–	–	–	–
Umtali ..	90·9 mb. ..	8	11	13	22	11	5	8	5	2	2	2	–	2	–	–	1

The Mount Nuza–Stapleford reductions agree on the average to 0·1 mb. but a correction of +0·7 mb. has been applied to all readings before comparison with Umtali. The standard deviation in the first case is 0·35 mb. and in the second 0·48 mb. the increase being considerably less than would be expected if the error were entirely due to reduction. It appears likely therefore that an appreciable part is due to minor errors of observation and possibly to wind effects, and that the method of reduction is reasonably correct. A comparison of this method with mean temperatures calculated from the mean of the two dry bulbs, the mean of the maxima and minima, and a mean temperature derived from the previous ten days shows that the first differs little from the adopted practice, the second is inferior and the last method outstandingly bad.

The problem of pressure charts at times other than the morning remains to be tackled. No system using the pressure and temperature at other times of the day can hope for success. The diurnal wave of pressure may be the result of the diurnal variation of temperature but the relationship is not sufficiently close to serve for pressure reductions. It is perfectly obvious from an inspection of diurnal waves of pressure at various altitudes that no conceivable variation of temperature will adjust the differences.

The representation, at sea-level, of pressure conditions on an extensive plateau is somewhat of a farce. Sea-level isobars under these conditions are entirely fictitious and the question of their accuracy cannot arise; at best one can hope to transmit a fair representation of the pressure distribution on the plateau to sea-level and the incidental magnification of pressure gradients will militate against the application of the laws of barometric gradient and wind force and if, as is frequently the case, the pressure distribution varies rapidly with height the chart is likely to present a medley of conflicting information very difficult to interpret.

The alternative is to prepare a chart with isobars at a level comparable with the plateau, the exact level to be selected will be a compromise between the desirability of obtaining, as far as possible, free air (real) isobars and the inevitable inaccuracies introduced in the pressures at coast stations when reduced to high levels. This scheme has two obvious advantages, first that the isobars are largely real and that improved methods of reduction will lead eventually to an accurate representation, and secondly that the laws of barometric gradient and wind force may be applied directly over the plateau. The disadvantage is mainly the difficulty of obtaining reasonable reductions of sea-level pressures, but it is at least an achievement to be in a position to consider the error in the reductions. The coast winds of South Africa appear to blow consistently from high to low and if they concede anything to the real isobars these must bear no relation to those derived in the traditional manner by reduction of plateau pressures to sea-level.

The possibility of drawing isobars at two levels was considered and the scheme has been given a cursory trial. Apart from the Moçambique Channel, where stations now exist on either side, the coast stations are strung along a line and the sea-level isobars appeared as short disconnected lines of doubtful direction and were of no apparent value.

APPENDIX VII.—SCALES, PROJECTIONS, AND RELIEF FOR SYNOPTIC CHARTS

(Minutes V p. 25)

(*a*) CANADA.

(*b*) AFRICA.

(*a*) Canada

NOTE BY THE CANADIAN METEOROLOGICAL SERVICE

A working chart on a scale of one to ten million has been in use since the first of the year. Copies of this map are available. Its boundaries are as follows :—east to west on Lat. 45° from Long. 48° W. to 157° W.; south to north from Lat. 20° N. to Lat. 79° N. It is made in accordance with the International Meteorological Organization's recommendation, namely, conformal conic projections with standard parallels on latitudes 30° and 60°. Tints are given for the following elevations :—0–500 ft.; 500–1,500 ft.; 1,500–3,000 ft.; 3,000–5,000 ft.; 5,000–8,000 ft.; 8,000 ft. and up, with one of the tints also showing the water areas.

A map for British Columbia has also been prepared based on the working chart for America. It has the same projections, the same tints for elevations, but takes in more of the Pacific. Its boundaries are as follows :—east to west on Lat. 45° from 90° W. to 170° W.; south to north at Long. 130° from 31° N. to approximately 73° N.

A daily weather map on a scale of one to twenty-two millions on the same projection as the working chart has also been prepared. The boundaries for the new map are: on Lat. 45° N., from Long. 54° W. to 130° W., and in the south to north direction from Lat. 25° N. to about 70° N. It includes the whole of Canada and most of the United States. The water areas are tinted but otherwise no elevations are shown. The map is printed in the Toronto Office by making a zinc plate, using what is called the chalk plate process. At Winnipeg it is mimeographed by a duplicating process.

(*b*) Africa

BY A. WALTER, *Director of the British East African Meteorological Service*, and N. P. SELLICK, *Government Meteorologist, Southern Rhodesia*

We are of opinion that the cylindrical projection suggested for equatorial regions is not suitable for synoptic work in Africa. Briefly the position appears to be as follows :—

Weather systems as such do not exist in the equatorial region, but deformation of the isobars and isotherms are produced by the passage of highs and lows north and south of the tropics, i.e., across Egypt and South Africa. It becomes essential, in consequence, to include zones far beyond the equatorial region if the weather processes in the tropical and extratropical zones are to be understood and utilised for forecast work. A cylindrical projection introduces too great a deformity in the general outline if extended over the whole of Africa, and the adoption of Sanson-Flamsteed's sinusoidal projection with the central meridian in Long. 25° is suggested for consideration at the Conference. This central meridian can be changed for the different services as found convenient. It is true that on this projection the wind directions at the extreme northern and southern ends of the continent are not correctly drawn due south and due north, but the deformation is so slight that it could not possibly affect any forecast work or conclusions drawn from the synoptic picture.

[A note of the charts in use in Southern Rhodesia is included in Appendix V (*c*), section 1.]

APPENDIX VIII.—INTERNATIONAL CODE, 1929. SOME SUGGESTED MODIFICATIONS TO THE EXISTING CODE FOR THE USE OF TROPICAL COUNTRIES (Minutes V, p. 00).

(*a*) NOTE BY A. WALTER.
(*b*) NOTE BY C. D. STEWART, B.Sc.

(*a*) Note by A. Walter

(*Director of the British East African Meteorological Service*)

In the practical work of forecasting and drawing up the necessary synoptic chart in tropical countries the form of the code as used in temperate regions has not been found practical.

The principal changes which are suggested are to groups (1) and (5), and may be summarised as follows :—

Group (1) More information is required concerning past weather: the changes which take place during the day characterise the type of weather passing over the station. It is suggested, in consequence, that in place of C in the first group W_1 should be used, and that the W of the third group should be designated W_2. W_1 should refer to the period from the morning observations to 18 hours, and W_2 to the period from 18 hours to the next morning's observations. The code for past weather is suggested to read as follows :—

0. Continuous rain throughout.
1. ,, ,, in 1st half of period.
2. ,, ,, in 2nd half of period.
3. Showers in 1st half.
4. ,, ,, 2nd half.
5. Thunderstorms in 1st half.
6. ,, ,, 2nd half.
7. Heavy rain showers with squalls in 1st half.
8. ,, ,, ,, ,, ,, 2nd half.
9. Mainly overcast, but no rain throughout.
X. Generally fair.

or if it is considered inadvisable to employ X for " generally fair " the following :—

0. Generally fair.
1. Mainly overcast with no rain.
2. Mainly overcast with intermittent drizzle or rain.
3. Continuous rain throughout.
4. ,, ,, 1st half.
5. ,, ,, 2nd half.
6. Showers 1st half.
7. ,, 2nd half.
8. Thunderstorm 1st half.
9. ,, 2nd half.

This code in reality divides the day into four periods, two under W_1 and two under W_2.

Group (5) It is suggested that the 5th group should read ttRRR. The small tt representing the wet bulb and the RRR the rainfall in inches.

In tropical countries where convection is the dominating factor an accurate value of the pressure of aqueous vapour is practically essential for the interpretation of the weather maps. It serves, moreover, as a complete check on the work of the observers, who for the most part are natives or Asiatics, and enables the central office to deal with defects in the wet-bulb readings immediately.

In regard to the measurement of rain, or rather the reporting of rain, the code as originally drawn up has caused a considerable amount of trouble. The native observers have never been able to distinguish between the code figure and the amount of rain, and moreover the conversion from inches into millimetres and then into code has led to considerable error throughout the Service. By reporting it in inches, without coding, all these difficulties are overcome. It does not appear to be necessary to include any additional information in the broadcast message which only includes selected stations. It is advisable to keep this message as short as possible, consistent with the object in view of giving essential information to neighbouring Services. The additions to the code, such as :—maximum and minimum temperature, time of rainfall, etc., are of use to each home Service and can be decided upon by them in accordance with their individual needs. It does not appear to be necessary to make these additions the subject of international agreement.

The cloud type code C which suggests itself as being the most useful from the tropical point of view is the following :—

1. Ci., Cicu. and Cist.
2. Ast., thin.
3. Ast., thick.
4. Nbst.
5. St.
6. Acu and Stcu.
7. Small Cu.
8. Large Cu.
9. Cu.
0. Frst and Frcu.

(*b*) Note by C. D. Stewart, B.Sc.

(*Superintendent, Malayan Meteorological Service*)

The International Code has at times been modified and at others completely re-constructed in order to meet the requirements of new developments in synoptic practice. The various codes brought into use have been designed principally for services in the temperate zones, the use of synoptic charts having been for many years almost entirely confined to these services. Now that meteorological services in the tropics are attempting to use synoptic charts to an increasing extent, those responsible for these Services find that in some respects the existing codes are not altogether suitable. It is important that any possible modifications which might make the code better suited for the tropics should be adopted, both for the assistance of the existing Services and for the encouragement of those Services which do not, as yet, use synoptic charts. It is the purpose of this note to suggest some such modifications.

It is not suggested that wholesale changes in the code are necessary ; in fact, there is no doubt that such changes are, in themselves, undesirable.

In the equatorial belt the source of air supplies and the distinction between different air supplies are of paramount importance, while the movements of pressure are very small and only of assistance in so far as they help to verify the movement of air. There are also definite indications from time to time of " front " phenomena. The proposals made below are intended to improve our day-to-day knowledge in these respects. The items on which better information is required are (1) wind direction, (2) humidity and (3) time of rainfall.

(1) *Wind direction.*—In these parts it is practically impossible to draw an air trajectory, even approximately, from surface wind observations, as the general movement of the atmosphere is so slight that land and sea breezes and even katabatic winds are sufficiently strong to mask it entirely. For this reason the direction of movement of low cloud is an observation which would be of real value. From ships these observations are not required as wind observations as made at present give the general air movement.

(2) *Humidity.*—The identification or distinguishing of different air masses is a matter of considerable difficulty in the absence of true wind values. Temperature is often of little assistance where the daily ranges are so great, and true barometric tendency is so small compared with the diurnal variation that it is of no assistance at all. The characteristic which seems, in the absence of precipitation, to have the most persistence, is the dew-point, and for our purpose we should prefer to be able to place this temperature more closely than can be done from the dry bulb and the relative humidity given to the nearest 10 per cent. Whether the dew-point or the depression of the wet bulb is telegraphed should be of no consequence ; but the depression is probably to be preferred as then no assumption is involved as to how the dew-point is computed.

(3) *Time of rainfall.*—At certain times it has been possible to follow a rain front over almost the whole of Malaya, but only by knowing the time of commencement at each station, which information is incorporated in the local messages. It seems at least possible that if similar information were available from outside Malaya it would be a great aid to forecasting.

Modifications suggested.—The standard code message is expressed symbolically as follows :—

$IIIC_LC_M$ wwVhN$_L$ DDFWN BBBTT UC$_H$abb

with further groups which vary. I would propose that for stations between latitudes 10° N. and 10° S. the following modified form be adopted :—

$IIIC_LC_M$ wwVhN$_L$ DDFWN BBBTT dduuu RRG^{1}G^{1}C$_H$

where dd is direction of movement of low cloud,

uuu is depression of wet bulb in tenths of a degree,

G^{1}G^1 is time to the nearest hour (G.M.T.) of commencement of rainfall.

To stations outside the equatorial belt which may receive these reports the barometric tendency, which is missing, would be useless ; uncorrected for diurnal variation it would be meaningless, whereas a corrected value of 0·3 mb. might have involved a correction of 1·5 mb., or thereabouts. The relative humidity can easily be obtained from the depression of the wet bulb if required.

The modifications proposed above involve a minimum of interference with the present codes, and are suggested for use only in the equatorial belt. Only one additional symbol is involved, namely, uuu for depression of the wet bulb ; the advantages which such a modification would confer on a service such as the Malayan Meteorological Service seems to be very much greater than any inconvenience which might be caused by such slight re-arrangements as are here proposed.

APPENDIX IX.—VALUE FOR FORECASTING OF OBSERVATIONS FROM SHIPS, AND OF UPPER AIR DATA (Minutes VI, pp. 27–30).

BY THE CANADIAN METEOROLOGICAL SERVICE

1. **Observations from ships.**—Ships' observations are indispensable in obtaining precision in forecasting for British Columbia on the west coast and the Maritime Provinces and Newfoundland on the eastern coast of Canada. They would also be of great use for forecasting for Alberta. Ships' reports are in general more reliable than land observations in giving the character of the air mass approaching. Unfortunately, the ships' reports from the Atlantic are too few and usually rather late to be of much service for forecasting at the synoptic hour for the eastern coast of Canada. The same remarks apply to the Pacific reports. Also, the full value of the ocean observations cannot be realized until reports are received in the full telegraphic code. As stated elsewhere, they are received in the special marine word code of the United States Weather Bureau. Their value, however, is unquestioned.

2. **Upper air data.**—The upper air data available at the head office consists of pilot-balloon and airplane observations (temperature and relative humidity) from Toronto. Airplane observations from three to six stations in the United States are received every morning except Sunday, but rather too late for the morning forecast. This information is of value in keeping a check on the character of the air masses over the continent.

Method of plotting.—The airplane data are plotted regularly on a small temperature-height diagram for each station. Frequently the temperature change from the previous day is written in red at the kilometre level where it occurs. This enables the forecaster to see at a glance any significant temperature changes. In the winter at stations in north-western United States sharp temperature falls at the lower levels are usually due to the arrival of polar air and considerably colder temperatures at altitudes from 1 to 3 Km. indicate progressive advances of the polar air mass southward and eastward. Furthermore, at high levels the arrival of warm air is sometimes indicated. This, however, has not been as clearly marked as could be wished and the presence of warm air at least in the winter season is often due to an inversion in the rear of the anticyclone. Although the observed values of humidity may be expected to indicate the air mass without ambiguity, this is not always the case. In addition to the temperature-height diagram, the Rossby diagram for each flight is plotted. In the Rossby diagram potential temperature is entered as the ordinate with specific humidity as the abscissa. The height and relative humidity is written in immediately adjacent to each measured point on the curve. During the winter the Rossby diagrams for Canadian and most United States stations have less usefulness than in summer because the specific humidity based on observed relative humidity at temperatures from —10° C. to —40°C. cannot be measured accurately on account of the sluggishness of the hair hygrograph at low temperatures. The main advantage of the Rossby diagram has been to bring out vividly the presence of moisture and to indicate if it is in a state from which precipitation may be immediately expected. The computation of potential temperature and specific humidity requires about one and a half minutes for an experienced computer.

It is unfortunate that at this office more experimental use has not been made of the tephigram so that an estimate of its practical efficiency could be given. The real difficulty has been to find the time necessary to plot these various types of energy diagrams before the forecast. The Rossby diagram gives by inspection a very large number of data regarding the state of each stratum of the air. Possibly with more experience and use the forecaster would interpret equally clearly and quickly the stability of each layer of the atmosphere with the tephigram, as he can now do with the Rossby diagram.

The temperature and humidity of the upper air obtained from a line of airplane stations stretching for 3,000 to 5,000 Km. across the continent provide the best criteria for determining the existence and territorial limits of air masses. In plotting the aerological data the base line used is the approximately straight line on which the stations are located and a satisfactory horizontal scale for America is 1 cm. to 100 Km. The vertical scale employed is 1 cm. to 0·5 Km. Using these co-ordinates, the aerological data are plotted giving the observed temperature, potential temperature and specific humidity for characteristic points in the flight at each station. On this atmospheric cross-section diagram isopleths are drawn for each 5° C. and each gramme of water content per cubic metre. With these diagrams, slopes of the fronts may be estimated from the discontinuity in the directions of the isopleths, although the network of stations available does not make such a determination of the inclination of the fronts entirely decisive.

4. **Use for forecasting.**—The pilot-balloon observations taken at the forecast centre, although reaching only 2 or 3 Km. have particular value in obtaining the general air movement freed from local topographic effects. In the absence of cloud data the pilot balloon observations are especially useful.

The value of airplane observations of temperature and humidity at various elevations to 5 Km. is difficult to estimate as the data from American stations have been available for only ten months. The airplane observations, however, promise to be of even greater use than in Europe because the air-masses may be followed, in America, for a much greater distance over a comparatively uniform land surface. The changes occurring in the polar air mass as it moves outward may be followed for 2,000 miles. These changes are the warming up of the lower layers and the increase of water-vapour content. For the Canadian Service, the return of these masses with widely varying amounts of water content presents a considerable problem in estimating the rain which will occur. The airplane data from the middle states are useful in arriving at a decision.

Another occasion when the airplane data have been helpful is in the forecast of afternoon thunderstorms. The presence of high humidity at altitudes of 3 to 5 Km. with high temperatures seems to indicate with certainty thunderstorms in the lower Lake region. The high temperatures alone are not sufficient to produce the thunderstorms.

APPENDIX X.—ORGANIZATION OF SYNOPTIC ISSUES IN SOUTH-EAST ASIA

(Minutes VI, p. 30)

By C. D. Stewart, B.Sc.

(*Superintendent, Malayan Meteorological Service*)

During the past six years the Malayan Meteorological Service has been developed as a scientific organization for the study of equatorial meteorology. In the course of this development it has become increasingly apparent to the officers responsible that a very considerable improvement is necessary in the synoptic programmes in the Far East, not only for the direct purpose of forecasting and aviation services, but also to enable the meteorologists studying the phenomena to acquire the day-to-day knowledge of developments which is so essential to the success of any research on weather processes.

The present position in the Far East is in striking contrast to that in Europe where the results of observations from the whole of Europe are available in the central office of almost every country within

a very short time of observations having been made. In Malaya we require observations from Hong Kong, Manila, Borneo, the Netherlands Indies, Ceylon, Indian stations between Calcutta and Victoria Point, Siam and Indo-China. The observations which are broadcast at present are as follows :—

	Observation time. G.M.T.	Broadcast time. G.M.T.
Malaya	2300	0400
	0600	0900
Hong Kong	2200	0400
	0600	1200
,, ,, (Collective)	0400	0530
Ceylon	0230	0230
Indian stations (Calcutta–Victoria Point) ..	0730	0730
Indo-China	2300	0105
	0300	0420
	0700	0820
	0900	1030
Siam	2300	} 0600
	0900 (previous day)	}
Philippine Islands	2200	0500
	0600	0845
Netherlands Indies	No broadcast.	

There is no common programme and in many cases the time of broadcast is so much later than the time of observation that the value of the broadcast almost disappears. An attempt has been made by the Malayan Meteorological Service to commence a system with a greater approach to uniformity. The Malayan morning observation time is to be changed to 2400 and the broadcast will be at 0220. A second broadcast will be instituted at 1120 G.M.T. giving observations at 0900 G.M.T. The Siamese Meteorological Bureau has already agreed to observe at the same times and to broadcast at 0230 and 1130 respectively. At the time of writing a conference with the Australian and Netherlands Indies meteorologists is pending and it is hoped that agreement on similar lines will be reached in this case also.

The times have been chosen partly as those likely to secure the most general agreement. The afternoon observation would doubtless be of more use if it were made later, but conditions in many of these countries make it doubtful whether the observations for any later hour could be successfully collected and broadcast. The times are, nevertheless, provisional only and the Malayan Service is prepared to change the times to some extent to secure uniformity. It is important, however, that the morning observation in this part of the world should be made before the sun has been too long in action.

I would suggest to the Conference that it is very important for all the services in this region that a uniform programme of observations and broadcasts should be established. If agreement could be reached among the services of the British Empire in the first place we should be in a stronger position to invite other services to conform.

The lateness of the Hong Kong broadcast is no doubt due to its being a collective issue, but it might be practicable for Hong Kong to issue its own observations separately soon after the observation hour. In this connexion it might be noted that Indo-China already issues its synoptic broadcast within two hours of the time of observation, so that for general purposes between Hong Kong and the equator there is no need for Hong Kong to include Indo-China in its collective message. The time of observation would be more generally useful, I think, if made later by one or two hours in these cases though this is a matter for agreement. Ceylon and Burma have no observations or broadcasts at these times and it would be of the greatest assistance to Malaya if such could be arranged. British North Borneo and Sarawak have no Meteorological Services but it might be suggested to their governments, through the Colonial Office, that without the establishment of such Services it would still be possible and desirable to establish two or three telegraphic reporting stations in each State. No doubt assistance in the way of establishment and occasional inspection could be obtained from Malaya, especially as it is hoped that a station may be opened at Labuan, which will require to be visited from time to time.

The general suggestion of this paper is that, for the Far East, standard times of observation shall be fixed for synoptic purposes by general agreement. It is suggested, further, from the experience of the Malayan Meteorological Service, that the most suitable times are 2400 and 0900 G.M.T. and that broadcasts should follow the observation as quickly as possible but with a maximum interval of three hours.

APPENDIX XI.—DISSEMINATION OF INFORMATION TO THE PUBLIC, SEAMEN, AIRMEN, FARMERS, ETC. (Minutes VI, pp. 30–1)

(*a*) Canada
(*b*) British Isles
(*c*) India

(*a*) Canada

Note by the Canadian Meteorological Service

1. **Forecasts and weather bulletins.**—The radio is undoubtedly the best medium of disseminating forecasts and weather information to the general public at the present time and is used very extensively in Canada. The morning forecasts are broadcast in voice from many stations about noon, and the night forecasts for the whole of Canada, together with the weather synopsis, are broadcast at 10 p.m. eastern standard time, over the Canadian Radio Commission chain to the whole of Canada. In

addition to this, practically all news broadcasts include the weather forecasts. The Government wireless stations on the Great Lakes and on the coasts broadcast the weather forecasts at stated times for the benefit of mariners, and at some of the stations they are given in voice for the benefit of the mariners, fishermen and others.

Storm warnings on the Great Lakes and the maritime coasts of Canada are also broadcast by radio, in addition to the displaying of the usual storm signals at the various storm signal stations.

All the daily papers give full weather reports, embodying maximum and minimum temperatures recorded at representative places throughout Canada, as well as the regional forecasts and synopsis of weather conditions.

Weather bulletins are telegraphed each morning to certain of the larger centres of population. These contain pressure, maximum, minimum and current temperatures, precipitation, direction and velocity of wind and state of weather for selected places in the Dominion and several in the United States. They also give the forecasts for the region to which they are telegraphed. These bulletins are manifolded by the telegraph companies for distribution to shippers, newspapers and other interests.

The St. Hubert Airport is furnished daily with a forecast for the air service from Montreal to Albany. A forecast of probable flying conditions for the Province of Ontario and north-western Quebec is issued to one of the Toronto airports, and other flying forecasts are given, as the occasion demands, for special flights.

Fire weather forecasts are issued during the summer months to the forestry officials in various parts of Canada and Newfoundland, giving the character of the weather they are likely to experience from the point of view of fire hazard.

The occurrence of damaging frosts in late spring and early autumn is disseminated to the vegetable and tobacco farmers by telegraph and radio.

Forecasts with regard to the weather for spraying of fruit orchards are issued during the spring and early summer to the regions requesting them. These are given for the third and even fourth day when it is considered reasonably safe to do so. In all cases they are sent by telegraph to certain centres and then broadcast over the local radio station. The telephone is used extensively, especially in the Maritime Provinces, to give the forecasts from a centre point to surrounding districts.

2. **The Daily Weather Map** is published at the Head Office in Toronto and in Winnipeg each morning, and is based on observations taken at 8 a.m. eastern standard time. The map in the former case is prepared by what is known as the chalk plate process and the latter by a duplicating process. The map itself gives isobars for every 0·1 in. pressure at mean sea level, the state of the weather as to whether clear, partly cloudy, or overcast, the wind direction and velocity on the Beaufort scale, together with the rainfall areas for the previous twenty-four hours. The map includes Canada to about latitude 60° N. and most of United States. A new map will include the whole of Canada.

The printed data give for all Canadian stations, and a few in the United States and Europe, the mean sea level pressure and temperature at 8 a.m. eastern standard time, temperature change in previous twenty-four hours, highest temperature of the previous day, lowest temperature during the previous night, wind velocity at time of observation, and precipitation during the previous twenty-four hours. The map also gives a synopsis of the weather and the forecast for the whole of Canada except British Columbia. The maps are printed with as little delay as possible, and are usually ready for distribution about 11 a.m. eastern standard time.

They are distributed in the city by messenger or by the post office and to outside points through the post office. Copies are supplied to all agencies interested in weather data, libraries, other meteorological services, newspapers, very many schools, shippers of perishable goods, the grain trade, agricultural and forestry interests and many others.

The question is raised as to the most essential elements that should appear on the printed *Daily Weather Map*.

(*b*) British Isles

By H. W. L. Absalom, B.Sc.

(*Forecast and Aviation Services Division*)

The general dissemination of information regarding current and expected weather to all sections of the public is the function of the Forecast Service at Headquarters. In addition, the forecasting centres at R.A.F. and civil aerodromes furnish information and advice in connexion with specific flying operations by individual units and on particular air routes. This memorandum is concerned mainly with the provision of information by Headquarters.

1. **For the general public.**—(1) *Forecasts to the newspapers.*—(*a*) A general inference, forecasts for all districts of the British Isles and for certain cross-channel sea routes, and a further outlook are issued at :—

Winter G.M.T.	Summer B.S.T.	
10 a.m.	10.30 a.m.	for 24 hours from noon G.M.T. of the day of issue ; for evening newspapers.
3.30 p.m.	4 p.m.	for the period 6 a.m. to midnight of the following day ;
8.30 p.m.	9 p.m.	for morning newspapers.

(*b*) A forecast for England and Wales, in less detailed form than those in (*a*) is issued to evening newspapers at about 3.30 p.m. on weekdays and applies to the period from 5 p.m. of the day of issue to noon of the following day.

(2) *Reports of current and past weather to the newspapers.*—(*a*) At about 11.30 a.m. on weekdays during summer months is issued a tabulation of the weather at 10 a.m., of sunshine on the previous day, and of rainfall during the preceding 24 hours, at between 20 and 30 health resorts.

A bulletin of the weather experienced during the day, together with observations of sunshine, rainfall, maximum and minimum temperature at about 100 health resorts, is issued every evening.

(*b*) Notes on the main features of the weather of the British Isles during the past 24 hours are issued every evening.

(*c*) A statement of the latest meteorological observations in London, together with recent readings of maximum and minimum temperature and rainfall is issued about 10.30 a.m. and 8 p.m.

(*d*) The " copy " of the 18h. G.M.T. weather chart is supplied each evening to certain newspapers for reproduction.

(3) *Radio Broadcast Forecasts.*—These are probably the most useful forecasts issued to the general public.

(*a*) Forecasts for the British Isles, according to areas or districts, are prepared for issue by the British Broadcasting Corporation at the following times :—

10.30 a.m.	For the next 12 hours.
6 p.m. weekdays	For the night and following day.
9.30 p.m. weekdays .. / 8.50 p.m. Sundays	For the night and following day.

(*b*) A forecast for Ireland is supplied at noon and about 8.30 p.m. to the Broadcasting Station, Dublin.

(*c*) A forecast for Northern Ireland is supplied at 8.30 p.m. to the Broadcasting Station, Belfast, for issue at about 9.15 p.m.

(4) *Information supplied by telephone and telegram.*—Anyone is entitled to telephone for the latest forecast for any district of, or for the latest report from any station in, the British Isles. No charge is made for this type of inquiry, but in certain cases involving a discussion of details of anticipated weather a charge is made.

Numerous forecasts are sent by telegram, either in response to a reply-paid telegram or by other arrangement. In some cases a forecast has been supplied by telegram at a definite time each day over a long period of years. In the summer months a large number of forecasts, according to a regular routine, are issued in connexion with pigeon racing.

In addition to the forecasts in the usual sense, warnings of the expected occurrence of specific conditions (e.g., frost, thunderstorm, a certain degree of atmospheric humidity, etc.) are supplied by pre-arrangement.

2. **For seamen.**—(1) *Gale Warnings.*—Whenever it is considered, from a study of the synoptic charts, that the wind is likely to reach gale force on any part of the coasts of the British Isles or on the neighbouring seas, a warning to this effect is telegraphed to the gale-warning stations in the region likely to be affected. On receipt of the warning, each of these stations (of which there are some 240) hoists the appropriate (north or south) cone according to the expected direction of the gale as specified in the warning.

The gale warning is also telegraphed to the appropriate Post Office coastal wireless stations (one or more of the following :—Wick, Humber, Niton, Land's End, Valentia, Malin Head). The warning is broadcast immediately by wireless, and, if sent during the period when one-operator ships are not keeping watch, is broadcast again at either of the following times :—0818, 1218, 1618, 2018 G.M.T.

In addition, each gale warning issued between 9.30 a.m. and 5.30 p.m. (8.30 p.m. on Sundays) is passed to the British Broadcasting Corporation to be broadcast at the first of certain specified times.

(2) *Forecasts for shipping.*—(*a*) The Weather Shipping Bulletin, based on observations made at 0700 and 1800 G.M.T., is broadcast by wireless twice daily (at 0910 and 2133 G.M.T.) simultaneously by the Air Ministry and the more powerful station at Rugby. Each message contains (i) a brief general statement of the weather situation, (ii) observations made at 10 coastal stations in the British Isles and at Thorshaven and Reykjavik, and (iii) forecasts of wind and visibility for the next 12 hours for the sea areas (subdivided into districts, as necessary) around the British Isles.

The Post Office W/T stations at Valentia and Seaforth (western area), Niton (southern area), and Cullercoats (eastern area) broadcast the portions of the Weather Shipping Bulletin which refer to their own area.

(*b*) To meet the needs of those vessels which do not carry a wireless operator, the morning Weather Shipping Bulletin is issued by radio-telephony by the B.B.C. Station at Droitwich at 10.30 a.m. clock time immediately after the forecast for land areas referred to in 1 (3) (*a*) above.

In the evening an abridged forecast for shipping near the coasts of the British Isles is issued by the B.B.C. at 9.30 p.m. on weekdays and 11 p.m. on Sundays.

A statement of gale warnings in operation in any part of the British Isles is added to morning and evening forecasts for shipping issued by the B.B.C.

(*c*) Special forecasts are prepared for issue through the B.B.C. during the Scottish Herring Fishery and the East Anglian Herring Fishery seasons.

(3) *Forecasts for Individual Ships.*—A ship at sea may obtain a forecast from the Meteorological Office by communicating through the nearest coast W/T station. Similarly, a ship about to leave port may obtain a forecast by telephone or telegram from the Meteorological Office.

3. **For agriculturists.**—(1) *Radio Broadcast Forecasts.*—The forecast for land areas issued by the B.B.C. at 10.30 a.m. was introduced to meet the requirements of farmers. Notifications of expected spells of fine weather are included in the forecasts issued by the B.B.C. at 6 p.m. and 9.30 p.m.

(2) *Notification of spells of Fair Weather.*—This service of notification, by telephone, telegram, or letter of expected spells of settled fair weather has existed for many years. It is available during the months May to September and was arranged to meet the requirements of farmers during harvesting operations. A warning of the break in the fair spell is sent when necessary. The demand for this service has decreased in recent years owing to the development of broadcasting weather information.

4. For airmen.—(1) *Radio-telegraphic forecasts from Air Ministry* (GFA).—Aviation weather forecasts for Great Britain and Northern Ireland are issued as follows by W/T :—

In winter.	During operation of summer time.	Period of Forecast.
0001 G.M.T.	0001 G.M.T.	Until next forecast.
0825 „	† 0615 „	Until dusk.
1200 „	1200 „	Until dusk.
1530 „	1500 „	Dusk until midnight.
1600 „	1530 „	Following day until midnight.

(† 0825 G.M.T. on Sundays.)

These forecasts, which are intended primarily for the use of the Royal Air Force, are in plain language and consist of (i) general statement of the weather situation with brief mention of fronts as necessary ; (ii) forecasts, according to areas or districts, of the surface and upper winds, weather, cloud amount and height, visibility.

(2) *Radio-telephonic broadcasts of Weather Reports and forecasts from the radio-meteorological station at Borough Hill, Northants.*—Until July 9, 1935, this service had been carried out from Heston for several years. The service consists of the broadcasting by radio-telephony at intervals throughout the hours of daylight of the latest weather reports from selected stations, and of the forecasts mentioned in 4 (1) above. The broadcasts are now spoken from the Meteorological Office, Air Ministry. In the near future the present programme will be replaced by a more comprehensive and more frequent series of broadcasts throughout the period 7.45 a.m. to 8.45 p.m. during the operation of summer time and 7.15 a.m. to 7.45 p.m. during winter time. In this new scheme reports from 12 " key " stations will be broadcast at 15 minutes after the hour of observation, while reports from " main " and " auxiliary " stations will be announced at 30 and 60 minutes after the hour of observation. Weather forecasts, navigational and weather warnings will be broadcast at 45 minutes after certain definite hours.

(3) *Services on International Air Routes.*—In accordance with the international regulations governing the supply of meteorological information for civil aviation, weather reports from stations in south-east England are concentrated at the Meteorological Office, Croydon Airport, and thence broadcast by wireless telegraphy at hourly or half-hourly intervals. Aviation forecasts for south-east England and the English Channel are broadcast at certain definite times. In addition, typewritten route reports and forecasts are supplied to pilots and information as requested is supplied to aircraft in flight. During the night hours when no forecaster is on duty at Croydon all forecasts for the continental air routes are issued by the Meteorological Office, Air Ministry.

The Meteorological Office, Barton Airport, Manchester, though primarily concerned with the internal air routes, supplies information in connexion with the Dutch Air Service (K.L.M.) between Amsterdam and Liverpool.

(4) *Information supplied by telephone or telegram.*—A very large section of the work of the Forecast Division consists in supplying, by telephone or telegram, forecasts for individual flights by R.A.F. Units, commercial aviation companies and private pilots. The great majority of the inquiries are casual but in many cases the supply of forecasts is on a permanent or semi-permanent basis. A 24-hour service is maintained in the Forecast Division, and an increasing number of forecasts is issued in the early morning before the necessary information is available at local forecasting centres.

(*c*) India

By. S. Basu

(*Weather Section, India*)

1. Basis of weather reports and forecasts.

(1) One all-India synoptic chart based on 8h. local time surface and morning pilot-balloon observations.	Prepared at Poona daily.
(2) Two regional synoptic charts based on— (*a*) 8h. local time (4h. G.M.T.) surface and morning pilot-balloon observations. (*b*) 17h. Indian Standard Time (12h. G.M.T.) surface and afternoon pilot-balloon observations.	Prepared at Calcutta and Karachi daily.
(3) Special charts based on special observations requisitioned in disturbed weather.	

2. General weather information to the public.	*Details of issue.*
(1) Daily All-India Telegraphic Weather Summary with forecast for next 24 hours and Heavy Rainfall Warnings for 24–48 hours.	From Poona at noon daily to subscribers and the press.
(2) (*a*) (i) *Indian Daily Weather Report* with tables and weather maps.	Printed at Poona and posted to subscribers same day.
(ii) All-India Weather Report with local forecast for Poona (without tables or map).	Roneoed and distributed locally between 12 noon and 1 p.m. daily at Poona.
(*b*) *Calcutta Daily Weather Report* (Regional) with map and tables.	Lithographed and distributed by 1–2 p.m. to subscribers and the local press.
(*c*) *Karachi Daily Weather Report* with tables but no map.	Do. do.
(*d*) Data of tables of the *Indian Daily Weather Report.*	Made available to the Associated Press, India, daily.
(*e*) *Madras Daily Weather Report* . . (*f*) *North India Daily Weather Report* . .	Prepared at Poona and made available to Madras and Delhi papers through the Associated Press, India.
(*g*) Bombay Daily Weather Summary . .	For seven months from May 1. Telephoned from Poona to Bombay Observatory for roneoing and distributing locally to subscribers and the press.
(3) All-India Weekly Weather Report with map and tables.	Issued from Poona every Wednesday to subscribers and the press.
(4) All-India Monthly Weather Report with tables.	Issued from Poona two months after the month to which it relates ; to subscribers.
(5) Forecast of winter precipitation in north-west India.	Early in January. Issued from Poona with a Daily Weather Telegram and in a roneoed form to the press. Also printed.
(6) Forecast of monsoon precipitation in north-east India, north-west India and the Peninsula.	Early in June. Issued from Poona with a Daily Weather Telegram and in a roneoed form to the press. Also printed.
(7) Forecast of precipitation in August and September in north-west India and Peninsula.	Early in August. Issued from Poona with a Daily Weather Telegram and in a roneoed form to the press. Also printed.

3. Marine warnings.

(1) Weather Bulletins for Arabian Sea and its ports (including advice for hoisting of warning signals) issued from Poona.

(2) Weather Bulletins for Bay of Bengal and its ports (including advice for hoisting of warning signals) issued from Calcutta.

(3) Bulletins broadcast daily from coast Radio Stations at Bombay, Karachi, Madras, Calcutta, Rangoon, Matara, Aden, on receipt of communication from Poona and/or Calcutta, twice a day in ordinary weather and as many as even six times in stormy weather.

(4) System of Synoptic Broadcasts of coastal weather data from wireless stations at Bombay, Calcutta and Matara for ships' use to be introduced in autumn, 1935.

4. Inland warnings.—Issued, whenever found necessary, to those interests which have registered their names and requirements.

(1) *For heavy rainfall and strong winds.*

From Calcutta for north-east India.
„ Karachi for Sind (if officers are in Sind).
„ Peshawar and Quetta for immediate neighbourhood.
„ Poona for remainder of country.

(2) *For cold waves or frosts.*—From Poona at present, to certain officers and agricultural interests in Bombay Presidency and Baluchistan.

(3) *For Nor'wester squalls*—to rivercraft and river ports. From Calcutta through District Police stations.

5. Aviation reports.

(1) *For Civil Flying,* issued from—

(*a*) Poona for southern and central India.
(*b*) Calcutta for east United Provinces, north-east India and Burma.
(*c*) Karachi for Persian Gulf and Mekran coasts, Sind, Rajputana, Punjab, west United Provinces and north Gujarat.

(2) *For Military Flying* over north-west India, issued from Peshawar and Quetta.

(3) *Methods of Supply.*

(*a*) Poona :—(i) By special requisition by individual fliers according to arrangement desired ; (ii) by standing arrangement for regular air services ; (iii) for Karachi-Madras Service : Current weather reports are communicated to certain aerodromes on flying days from certain observatories on route.

(*b*) Karachi and Calcutta:—(i) For trans-India air route between Karachi-Victoria Point.—Route forecasts, twice a day; pilot-balloon reports and current weather observations twice a day from observatories along route as a routine; special current weather reports and observations of heights of base of low cloud, whenever requisitioned; warnings of dangerous phenomena and their improvement, whenever needed: transmitted by wireless to aircraft in flight and to aerodromes and exhibited at the latter; (ii) For other routes.—For stray fliers, by requisition. For regular services by standing arrangement.

APPENDIX XII.—EXCHANGE OF METEOROLOGISTS WITHIN THE EMPIRE

(Minutes VI, pp. 32–4).

BY THE CANADIAN METEOROLOGICAL SERVICE

It is suggested that senior officials could be exchanged from the Canadian Office for a period of three months and junior officials for a period of one year. The period of three months of the senior official would not disrupt the smooth working of the Meteorological Office concerned. At the beginning of the scheme one exchange a year should be made. It would be practically impossible, however, for one senior meteorologist to go into another office and attempt to do the routine work the official he was replacing had to do; moreover, it would be largely a waste of time and energy. If he were carrying on any special investigation, it would be impossible for the relieving official to continue that work. This could be done if the relieving meteorologist carried on the research which he was conducting in his own country from information obtainable in the country in which he was located. The exchange would be of the greatest value if the meteorologist were free to study the work and organization of his own particular branch rather than be responsible for any work undertaken therein. He could also give lectures on the work that he was doing in his own country.

The exchange of junior meteorologists would be of immense advantage to the different Services and to the meteorologists. It would not be difficult for them to fit into the routine work for the year in which they were away. It might also be possible to give them a special subject for investigation that would give them a better insight into the meteorology of the country than would be possible through the routine work, but, of course, one meteorologist could not very well carry on the research the other happened to be conducting in his own country. It might be possible, of course, for him to continue that investigation in the country he was visiting.

In view of the success achieved in the exchange of teachers for many years between Canada and England, the following procedure taken over from their experience is suggested:—

All travelling expenses should be borne by the meteorologists exchanged and all costs of renting suitable living quarters is entirely a matter for the meteorologist concerned. This holds for married couples as well as unmarried. Possibly married couples could arrange to occupy each other's houses.

The salary of the officials shall continue to the person living abroad exactly as if he were to be paid at home. If there is much profit or loss on the normal rate of exchange, it is suggested that the meteorologists exchanged agree to share the profit or loss, but this is a personal matter between them.

It is understood that there is an organization working towards the exchange of Civil Servants within the Empire, and if the Meteorological Services could not make the arrangements above suggested, it might be possible to achieve their purpose if they joined with this organization. In any case, it would be an advantage to keep in touch with the progress that this organization is making.

APPENDIX XIII.—METEOROLOGY AND MILITARY OPERATIONS

(Minutes VII, pp. 34–6).

BY F. ENTWISTLE, B.SC.

(*Superintendent, Army Services Division, Meteorological Office, London*)

The main meteorological requirements of army units in the field in time of war may be classified under the following heads:—

1. Climatological information relating to the theatre of operations, for the use of the General Staff, with particular reference to conditions affecting the state of the ground, viz., rainfall, snow and frost; visibility and cloudiness; adverse weather phenomena such as squalls, duststorms and thunderstorms.
2. Forecasts of general weather and of specified conditions for particular operations.
3. Ballistic wind and temperature information for artillery units.
4. Upper wind and temperature data for acoustical purposes.
5. Information regarding conditions favourable for the use of smoke screens.

In the present memorandum it is not proposed to discuss the organization of a meteorological service in the field nor the actual supply of meteorological information in time of war. The main subject for discussion is the collection of data from various parts of the British Empire which would furnish information of practical value in the event of defensive military operations. Further, although the factors enumerated above cover generally the requirements of Air Force units operating with an army, the special information required for independent air operations is not here considered.

1. **Climatological information.**—The normal climatological data which are prepared as a matter of routine by the meteorological services of the various countries of the Empire would form the basis of the information required for military purposes, and it is not considered necessary at this stage to ask for any additional data.

2. **Forecasts.**—The development of forecasting services in the various meteorological departments of the Empire should enable those departments to meet all military requirements. During operations, forecasts of specified conditions are required for different purposes; the successful preparation of such forecasts usually involves a detailed study of local meteorological conditions and close co-operation between the meteorological service and the army units requiring the information.

3. **Meteorological information for artillery purposes.**—The meteorological requirements of an artillery unit are measurements of upper wind, temperature and humidity, together with surface observations of the usual elements. Added to this, there is the need of presenting the information in a form suitable for immediate use, which involves the proper weighting of the winds and densities in accordance with ascertained ballistic theory. The requirements can be considered under three headings:—

(1) Experimental work and calibration practices.

(2) Field work, practice camps, coastal batteries, etc.

(3) Anti-aircraft work.

(1) *Experimental work and calibration practices.*—In experimental work, such as that carried out at Shoeburyness, the most complete *ad hoc* data obtainable are necessary. The meteorological organization should be at the same place as the experimental artillery establishment and work in the closest conjunction with the officer in charge of experiments. The equipment should consist of facilities for two-theodolite pilot balloon observations on a permanent basis, and there must exist arrangements for the supply of upper air temperature and humidity data. In addition, all the necessary ballistic data must be available.

Calibration practice is really experimental work carried out in field conditions instead of at an experimental establishment. The meteorological requirements for calibration are, strictly speaking, the same as those needed in experimental conditions, but it is usually found impossible to have two-theodolite pilot balloon observations, and less exact methods have to be used. The observations must be complete up to the height attained in the practice, and upper air temperature data (observed if possible, but, if not, estimated) together with surface conditions are required. Wind and temperature weighting factors appropriate to the conditions of firing are also needed. Complete sets of these factors are available at Shoeburyness, and they are supplied to home stations on demand.

(2) *Field work.*—For work in the field, in action, at practice camps and at coast defence batteries, it is desirable that there should be uniformity of practice everywhere. The present method of dealing with these requirements was first evolved during the Great War and has now been established as general practice. Wind observations are required up to the greatest height used in the shooting, and upper air temperatures should be used if available. Otherwise they must be estimated. In addition the usual surface elements are required. Where this method varies from the more exact methods already described is in the means adopted for weighting the winds and temperatures. Factors for these purposes vary with the gun used, its muzzle velocity, its quadrant elevation, type of shell used and other circumstances, and are different for the line and the cross components of the winds. All these points can be taken into account at an experimental establishment, but it is physically impossible to deal with them in field work and similar activities. For such purposes it has been found convenient to classify trajectories into groups and to compute mean weighting factors for these groups, no matter what particular gun or shell may be in use, the same factors being used both for line and cross winds. Similar mean factors have been computed for temperatures. The classification adopted is according to time of flight. It is based on the fact that all guns and howitzers give a trajectory of the same height for the same time of flight approximately, the relation being $h = 4t^2$ to a reasonable degree of closeness. Here h is the height of the vertex of the trajectory in feet and t is the time of flight in seconds. Suitable factors have been prepared for times of flight of 5, 10, 15, 20, 30, 40 . . . 90 seconds and are embodied in a pamphlet published by the Stationery Office under the title "Supply of Meteor Reports to Artillery Units" (M.O. 317). The code in which the results of the calculations are cast for convenience in signalling or telephoning is set out in this pamphlet.

This pamphlet, M.O. 317, was compiled in order to enable any meteorologist who has a set of upper wind and temperature data together with surface observations to supply a field artillery unit, battery commander or coast defence officer with the necessary information in the most useful form. The computation is not a difficult one and is fully explained in the pamphlet. It can be made still easier by the use of the special pilot balloon form which has been drawn up for use in artillery work. This form, [a specimen of which was circulated], has the necessary columns and spaces properly arranged to facilitate the computations, and all the needful tables and factors are printed upon the form itself. It may also be mentioned that the pamphlet contains hints on estimating the weighted temperature (technically known as the ballistic temperature) when actual upper air temperature observations are not available. It is generally this part of the meteorological observations which is lacking.

(3) *Anti-aircraft work.*—Anti-aircraft work presents special problems. Here the meteorological requirements are similar to those of flat fire. Wind and temperature are needed up to the maximum height of the bursts. The ballistic part of the problem, however, is not so straightforward, as it is complicated by the fact that the heights of the bursts as well as the ranges and deviations are affected by both wind and density variations. The weighting factors for these vertical displacements are not the same as those for the horizontal displacements. All requirements can be met at an experimental establishment, but, under field conditions, all that has been found practicable so far is to supply the anti-aircraft unit with a mean wind which is merely the arithmetic mean of the winds observed up to the height required. This particular problem is now under consideration at Shoeburyness, and it is hoped that it will soon be placed on a better basis and brought more into line with flat fire practice.

It should be emphasised that the pamphlet, M.O. 317, is intended for official use only and is not available for supply to the public.

IMMEDIATE REQUIREMENTS WITHIN THE EMPIRE

The immediate requirements are confined to the preparation and supply of information for Coast Defence and anti-aircraft artillery units at Defended Ports. The information required is the condition prevailing at the battery position at the time firing takes place.

The ports at which the information is required are :

Gibraltar.	Trincomali.
Malta.	Singapore.
Aden.	Hong Kong.
Colombo.	

The supply of the necessary information at the first two ports is a matter for the Home Government. As regards Gibraltar, an Instructor in Gunnery has been trained at Shoeburyness in meteorological field work and has been supplied with the necessary equipment. At Aden tentative arrangements for supplying the desired information have been made with the local Royal Air Force Command, but in both cases it would be preferable that the information should be obtained by trained meteorological personnel.

4. **Information for acoustical purposes.**—For acoustical purposes information regarding the distribution of wind, temperature and humidity up to a height of 10,000 or 15,000 ft. is required in addition to ground observations. The places from which information is desired are :—

Malta.
Singapore.
Hong Kong.

It will be convenient to summarise in the following form the type of information required, the method of obtaining it and the times at which observations should be made :—

Observation.	Method.	Time.
(*a*) Air Temperature : 100 ft. –10,000 ft. (15,000 ft. if possible).	Aircraft : Strut thermometer ; wet and dry bulb.	Day : 9 a.m.–3 p.m. Night : 1 to 2 hours after sunset or later.
(*b*) Air Temperature : Surface—100 ft.	Thermometers, preferably hot-wire type at three levels, say 4 ft., 30 ft. and 100 ft. with thread recorder if possible.	Continuous record, if possible ; otherwise an hour or two at mid-day and from 1 hour before sunset to 2 hours after sunset.
(*c*) Wind, upper	Pilot-balloon ascents to limit of observation.	Night : 2 hours after sunset. Day : normal routine.
(*d*) Wind near ground ..	Anemograph	Normal routine. Continuous record.
(*e*) Wind, 100–150 ft. ..	Anemograph	Continuous record.
(*f*) Humidity, upper air ..	Aircraft (see (*a*))	See (*a*).
(*g*) Humidity, ground ..	Hygrograph	Normal routine. Continuous record.
(*h*) Cloud : Amount, type and height.	—	Normal routine.

In order to obtain the information required, it would be necessary to equip a suitable meteorological station with a 100 ft. or preferably 150 ft. mast carrying recording thermometers at 50 ft., 100 ft. and, if possible, 150 ft. levels. The thermometers should be of the hot-wire type recording on a thread recorder. The same mast should also carry a Dines anemograph at the highest level. To avoid the necessity of erecting a special mast it may be found possible to utilise an existing mast such as one of the Wireless Station masts at Cap D'Aguilar and an existing wireless mast at the Royal Air Force Base at Seletar.

For obtaining the information in regard to air temperatures it would be necessary to organize meteorological flights by aircraft both by day and by night. This could probably be arranged in conjunction with the local Royal Air Force Commands. It would also be necessary to arrange for pilot-balloon ascents to be made at night.

The observations of wind and temperature would have to be synchronised and co-ordinated. If possible, the observations should be made from some point from which listening would take place in war.

In addition to the observations specified it would be useful to have information regarding the audibility of any fairly regular known sources of sound.

The recording of meteorological observations on the lines indicated on two days and two nights each week for a period of 12 months would probably provide sufficient information for immediate purposes. Apart from its local value, the information thus obtained would be of considerable interest from the point of view of acoustical research.

5. **Smoke screens.**—The successful employment of smoke screens of all types is dependent on the meteorological conditions in the locality. It is, therefore, necessary to obtain as much meteorological information as possible, and also to investigate the possibilities of forecasting these special conditions.

Considerable progress could be made if the following information were available from different types of country :—

(1) Wind velocity and the vertical gradient of velocity up to a height of 150 ft.

(2) The vertical gradient of temperature up to a height of 150 ft.

(3) Wind gustiness up to a height of 150 ft. The Dines anemograph or cup anemometer is not sufficiently sensitive for the special gustiness required, and only results from very special instruments are of use.

(4) Pilot-balloon observations, especially simultaneous observations on either side of high ridges or mountain ranges.

(5) Forecasting the wind velocity and direction at different heights, including effect of contours.

(6) Contour effects, e.g., katabatic and anabatic winds.

(7) Wind currents in towns.

(8) Any evaporation results if simultaneous observations on wind structure in the surface layers are available.

(9) Soil temperatures.

All the above factors affect, in one way or another, the efficient use of smoke screens. The effect of wind velocity is perhaps the most obvious, a high wind rapidly dissipating the smoke cloud, and so producing poor screening. The vertical gradient of velocity and temperature is another important factor ; a large shear of wind or a large inversion of temperature gradient are indications of stable atmospheric conditions, and so correspond to occasions when smoke screens could be produced effectively. Wind gustiness is again an indication of the instability of the atmosphere.

A knowledge of the influence of contours on the flow of air and also on the type of flow—whether very gusty or with little gustiness—is of extreme importance. Wind direction is often the controlling factor in determining the use of smoke screens, and it is well known that contours can produce important local changes. A problem which requires special investigation is forecasting the onset, strength and direction of these local currents.

6. **Meteorological services in time of war.**—The growing importance of meteorology in relation to military and aircraft operations necessitates adequate provision for meeting the requirements of the fighting services in time of war. At the present time there exists a meteorological section of the Royal Air Force Reserve, most of the members of which are drawn from the staff of the Meteorological Office. This section is called up once a year for a fortnight's training, which includes making meteorological observations under conditions which would obtain in war time, together with normal Service training. In the event of war, the section would be available to proceed immediately to the theatre of operations.

APPENDIX XIV.—ORGANIZATION OF FLEET METEOROLOGY

(Minutes VII, pp. 36–40).

MEMORANDUM BY THE NAVAL DIVISION, METEOROLOGICAL OFFICE, LONDON

1. **Introduction.**—At the Conference of Empire Meteorologists held in London in 1929 the opportunity was taken of laying before the representatives of the meteorological services of the Empire a memorandum on Fleet Meteorology. In that memorandum the meteorological organization then existing in the Fleet was described and reference was made to certain proposals for the development of Fleet Meteorology on stations abroad, in which development the co-operation of the meteorological services of the Empire was solicited. During the past five years, the majority of these proposals have been put into effect, with the co-operation of the shore services concerned, and, at the same time, there has been a considerable expansion of the meteorological organization in the Fleet itself. In this memorandum it is proposed to outline the internal meteorological organization of the Fleet at the present time, and the existing organization of Fleet Meteorology on stations abroad and then to indicate the further developments, particularly in the sphere of war organization, which are considered necessary and which will require the co-operation of shore meteorological services.

2. **Meteorological organization within the Fleet.**—(*a*) *Administration.*—The body responsible to the Board of Admiralty for the formulation of policy is the Fleet Meteorological Committee, which consists of representatives of Admiralty departments, of the Commander-in-Chief, Home Fleet, the Meteorological Office, and the Chemical Defence Experimental Station, Porton, under the Chairmanship of the Hydrographer of the Navy. The Superintendent of the Naval Division of the Meteorological Office is a member of this committee. The work of the Naval Division is primarily to advise the Admiralty, either directly or through the Fleet Meteorological Committee, upon all meteorological matters affecting the naval service, from general questions of policy down to such details as the selection and siting of instruments ; to train and qualify officers for meteorological duties in the Fleet ; and, in effect, to carry out the actual supervision of the meteorological work of the Fleet. Thus, although the meteorological organization in the Fleet has been made, as far as possible, self-contained, to provide for all eventualities, it is not independent of the State Meteorological Service, owing to the fact that the effective control and supervision of the organization is performed by the Naval Division of the Meteorological Office, through the Hydrographer of the Navy.

(*b*) *Station Organization.*—The meteorological organization in the Fleet is arranged on a station basis, the organization being uniform on all stations. The Master of the Fleet or the Fleet Navigating Officer is responsible to the Commander-in-Chief for the meteorological work in the Fleet on the station ; Squadron Navigating Officers are responsible for the work in their squadrons, except in the case of aircraft carrier squadrons, where the senior meteorological officer is responsible for the work.

(*c*) *Ships carrying qualified meteorological officers.*—Until recently only aircraft carriers and a relatively small number of other ships carried officers specially appointed for meteorological duties, but the Admiralty recently approved the policy of establishing fully equipped meteorological offices, under one or more officers qualified in meteorology and appointed for meteorological duties, in the following ships :—

(i) Fleet Flagships.
(ii) Battle Cruiser Flagship.
(iii) Aircraft Carriers.
(iv) At least one ship in each cruiser squadron carrying aircraft and organized as a Fleet cruiser squadron.
(v) Each cruiser carrying aircraft when not organized as a unit of a Fleet cruiser squadron.

The implementing of this policy will result in the establishment of fully equipped meteorological offices in 24 ships by the end of 1936.

(*d*) *Personnel for meteorological duties*.—The officer personnel required for meteorological duties in H.M. ships is at present drawn from several branches: Navigating Officers, Naval Observers, Surveying Officers, Instructor Officers and General Service Officers. In future the Instructor Branch will provide the majority of the officer personnel for meteorological duties in the ships indicated above. All Instructor Officers are to be trained in meteorology and, after passing the qualifying examination at the end of the 12 weeks' course, will be appointed to the above-mentioned ships for meteorological and instructional duties, except in the case of aircraft carriers where they will be appointed for full-time meteorological duties. It is anticipated that these officers, with the scientific training which they have received prior to entry to the Navy, supplemented by the special meteorological training given in the Naval Division, will provide first class forecasters for the Fleet. In addition, Naval Observers will be trained in meteorology and, after qualification, appointed to aircraft carriers for observer and meteorological duties. There will therefore be two Meteorological Officers in each carrier and one in each of the other ships mentioned above. In each ship the Meteorological Officer (or Officers) will be assisted by a selected rating who has been trained in the routine of chart-plotting, care of instruments, instrumental observations, etc. In ships other than those detailed above the meteorological duties, which are considerably less comprehensive than those in a ship carrying a qualified Meteorological Officer, will be carried out by the Navigating Officer.

(*e*) *Training of personnel*.—The preliminary meteorological training of all officer personnel is carried out at the Navigation School, Portsmouth, by an officer qualified in meteorology. Officers specialising in meteorology (Instructor Officers and Naval Observers) receive a 12 weeks' intensive course in meteorology in the Naval Division, and after passing the terminal examination are regarded as qualified for meteorological duties in H.M. Ships. (The prefix " Met " is attached to the names of these officers in the Navy List, where a complete list of these officers will also be found.) After about two years afloat as a Meteorological Officer, each officer qualified in meteorology undergoes a further advanced course of four weeks' duration. Usually three 12-week courses and three 4-week courses are held annually. In addition, all Navigating and Surveying Officers undergo a 1 week's course in the Naval Division, in view of the special importance of meteorology to these officers.

Officers of the Dominion and Indian Navies also attend these meteorological courses.

The training of ratings as assistants to ships' Meteorological Officers is carried out in the ships themselves, only selected volunteer ratings undergoing the training. Ratings who, after completion of their training, are considered qualified to carry out a number of specified duties are certified as " Q.Met " and are available for such duties in ships carrying qualified Meteorological Officers.

(*f*) *Meteorological equipment of H.M. Ships*.—H.M. ships are normally supplied with mercurial and aneroid barometers, medium barographs, portable thermometer screens, and thermometers for obtaining air and sea temperatures.

H.M. ships carrying qualified meteorological officers are equipped in addition with electric psychrometers, distant reading thermographs (dry and wet bulb), open scale barographs and Munro relative wind speed recorders. One or two ships are fitted with Baxendell relative wind direction recorders. Fifty-five ships, including all ships carrying aircraft, are equipped with pilot-balloon gear, and ships carrying aircraft are supplied with strut psychrometers and aeroplane aneroid barometers for obtaining temperature observations in the upper air. Special attention is now being given to the development of a true wind speed and direction recorder and of a pilot-balloon sight for use in H.M. ships.

In aircraft carriers and certain other ships meteorological offices and pilot-balloon filling stations are provided. Similar offices are being provided in new construction ships, and, so far as possible, in other ships now in commission.

Blank meteorological charts for the various stations have been prepared by the Hydrographer of the Navy and are supplied to all ships, together with a library of meteorological reference books.

(*g*) *Meteorological routine in H.M. Ships carrying a qualified meteorological officer*.—The meteorological routine carried out in H.M. ships in which a qualified meteorological officer is borne is very similar to that at a shore meteorological station. A continuous series of weather charts is produced from the synoptic data available on the station and from these charts forecasts are prepared for Fleet operations, gunnery, chemical defence and the operation of naval aircraft. So far as the available data permit the air mass and frontal method of analysis is employed in forecasting. Routine surface observations are made at the standard hours of observation and recorded in the ship's meteorological log. These observations are reported by wireless to the nearest British shore meteorological service.

Upper air observations (upper winds and upper air temperatures) are made by the methods detailed in " M.O.354, Upper Air Observations over the Sea ". These observations also are reported by wireless to British shore services. From the upper air temperature observations tephigrams are drawn and utilised in forecasting. Recently the practice of drawing charts of synchronous upper wind conditions, from shore station and ships' pilot-balloon observations, has been introduced.

The upper air data recorded in H.M. ships' meteorological logs are extracted in the Naval Division. Over 4,000 observations have so far been collected in this manner and the number is now being added to at the rate of about 100 ascents a month. It is hoped shortly to prepare these data for publication in tabular form and eventually to prepare roses of upper winds over the oceans.

(*h*) *Liaison with shore meteorological services*.—At each naval base an officer, normally the King's Harbour Master, is designated as the channel of communication for official dealings with the local meteorological service and H.M. ships and naval shore establishments requiring technical assistance, forecasts, etc., are instructed to forward their requests through this officer. An arrangement of this kind is essential particularly for ships at sea. It is not intended to conflict with the responsibility of the Fleet Navigating Officer for the meteorological organization within the Fleet or to disturb the personal and semi-official relations which exist between naval meteorological officers and meteorologists at shore stations. This personal liaison between the meteorological officers of the Fleet and shore meteorological services has proved an important factor in the development of Fleet meteorology, and the assistance rendered by shore meteorological services has been very valuable. As an example it may be mentioned that recently arrangements were made for 12 telegraphists from a carrier on the Mediterranean station to visit the Meteorological Office, Malta, to see the plotting of weather charts and become familiar with the various broadcast issues and their relative importance in the construction of the chart. A marked improvement in the reception of synoptic messages in the ship has resulted from the insight into the synoptic system gained by these ratings during their visit and it is hoped that the idea will be adopted in other ships and on other stations.

3. **Co-operation with Shore Meteorological Services of the Empire.**—The meteorological organization that has been established in the Fleet is intended to secure that, when necessary, the major meteorological requirements of the Fleet can be met within the Fleet itself. The co-operation of shore services is essential, however, in the provision of synoptic data, in meeting the requirements of H.M. ships not provided with a qualified meteorological officer and out of touch with a ship so provided, and in the provision of special advice and local information which the naval meteorological officer may not be able to furnish owing to lack of local experience.

In the memorandum on Fleet meteorology presented to the last Conference of Empire Meteorologists two main points were stressed in connexion with the organization of Fleet meteorology on stations abroad :—

(i) The need for uniformity of practice on all naval stations.
(ii) The necessity for close liaison between the Fleet and the shore meteorological services of the Empire.

As a primary and essential step towards the attainment of these objectives, conferences to discuss the meteorological requirements of the Fleet on the various stations were convened by the respective Commanders-in-Chief as follows :—

China Station (Hong Kong) : January, 1930.
East Indies Station (Colombo) : March, 1930.
America and West Indies Station (Bermuda) : December, 1930.
Africa Station (Simonstown) : January, 1932.
Mediterranean (Malta) : November, 1934.

Each conference was presided over by a senior naval officer appointed by the Commander-in-Chief, and was attended by the Directors of the local shore meteorological services, representatives of the local governments and naval representatives. The Superintendent, Naval Division, Meteorological Office, attended each conference as the representative of the Meteorological Office, London, and as the meteorological adviser to the Commander-in-Chief.

One of the most important results of these conferences from the naval point of view has been the introduction on the stations of Fleet Synoptic messages, in a standard form, for the use of H.M. ships. In general, the station is divided into areas and the Fleet Synoptic message for each area comprises—

(i) synoptic data from land stations and ships,
(ii) upper air data,
(iii) general inference,
(iv) forecasts for the area or subdivisions of the area.

The message is issued once or twice daily by the appropriate shore meteorological service and broadcast in most cases from a naval wireless station.

Although conferences were not similarly convened on the Australian and New Zealand Stations, there has been correspondence with the appropriate Naval authorities regarding synoptic messages for the Fleet on those stations, and it is satisfactory to be able to report that the standard form has now been adopted on these stations also.

The Fleet Synoptic messages so far arranged are as follows :—

Station.	Issued from	Broadcast from	Form of Land Station Reports		
Home	London ..	Cleethorpes and Gibraltar.	IIIAW	DDFww	BBVTT
Mediterranean	Malta ..	Rinella	IIIAC	DDFww	BBVTT $3C_LC_MC_HN$
East Indies	Colombo, Poona and Alipore (Calcutta).	Matara	IICKW	DDFww	BBVTT*
China	Hong Kong	Stonecutters	IIIAW	DDFww	BBVTT
	Singapore ..	Seletar ..	IIIAW	DDFww	BBVTT $3C_LC_MC_HN$
Africa	Pretoria ..	Capetown (and others).	IICAK	DDFww	BBVTT
America and West Indies	Ottawa ..	Halifax ..	IIIAW	DDFww	BBVTT†
Australia	Melbourne	Richmond	$\left\{\begin{matrix}\text{IIIAS}\\ \text{IIIAN}_L\end{matrix}\right\}$	DDFww	BBVTT
New Zealand	Wellington	Wellington	IIIAS	DDFww	BBVTT
	Apia ..	Apia ..	IIICW	DDFww	BBVTT
	Suva ..	Suva ..	IIICW	DDFww	BBVTT

Ships' Reports are given in the form PQLLL IIIGG DDFww BBVTT with or without the usual supplementary groups.

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* See paragraph 4 below.
† The adoption of this form recommended by the Bermuda Conference is still (1936) under discussion.
[The form IxxAC DDFww BBVTT was eventually adopted with effect from June 15, 1936.]

At these conferences arrangements were made also for the supply of special forecasts and upper air data to H.M. ships on request and the provision of advice and information for the meteorological officers of the Fleet by the shore services. The basis of the arrangements on each station is the exchange of mutual services. The main service rendered by H.M. ships to meteorological offices on shore as a result of these conferences is the furnishing of reports of weather, upper winds and upper air temperatures. Weather reports are made at the international times for ship observations and at any other times specially required by the respective shore services. In addition provision was made at these conferences for the joint investigation of local meteorological problems, and for meteorologists from shore services to conduct investigations at sea in H.M. ships, when desired.

As a further result of these conferences certain developments took place within the shore meteorological services. The importance of the establishment of a first class meteorological station at Singapore was emphasised at the China Station conference and in 1931 the Headquarters of the Malayan Meteorological Service was transferred from Kuala Lumpur to Singapore ; this prompt action was much appreciated by the Fleet. At the Bermuda conference the urgent necessity of the establishment of a meteorological service was brought to the notice of the local government with the result that a service was started almost immediately, with a retired naval officer as its first director. The Bermuda Government is to be congratulated on the institution of this service which is likely to become one of great importance.

Although the recommendations of the various conferences were accepted in principle by the local governments concerned, certain of them still remain to be implemented. In the remainder of this memorandum it is proposed to draw attention to these and to certain other developments in which the co-operation of the local shore services is required, under the following heads :—

Completion of peace organization on stations abroad.

Meteorological problems of importance to the Fleet.

Preparation of Naval Handbooks on local Meteorology.

War organization.

4. Completion of peace organization on stations abroad.—For some time, the Indian Government was unable to implement the recommendation of the Colombo conference that the Matara Fleet Synoptic message should include data for stations in India. With the co-operation of the Observatory, Colombo, a very much abbreviated message, giving data for three stations in Ceylon and one in India, was issued as the Fleet Synoptic message, but it will be appreciated that this message was useful only to ships in the immediate vicinity of Ceylon. It is highly satisfactory to be able to report that, while this memorandum was in preparation, information was received that, on and from September 1, 1935, the message will be extended to include data for the Bay of Bengal and the Arabian Sea areas, as originally intended. [The introduction of the extended form of message eventually took place on January 1, 1936.] In addition supplementary synoptic messages, in the Fleet synoptic form, will be issued from Bombay and Calcutta. This very considerable increase in the broadcast synoptic data available on the East Indies Station will be of great assistance to the meteorological officers in H.M. ships on the station, and the action taken by the Indian Meteorological Service will be much appreciated by the Fleet.

The East African Meteorological Service has so far been unable to implement the recommendation that a Fleet Synoptic message should be issued from Zanzibar. In view of the fact that until this message is instituted, H.M. ships in East African waters will be without synoptic data, and that only this message requires to be instituted to complete the network of Fleet Synoptic messages originally proposed, it is hoped that it will be possible for the East African Service to take early action regarding the recommendation.

5. Meteorological problems of importance to the Fleet.—(*a*) *Visibility.*—Visibility is one of the most important meteorological factors affecting Fleet operations and the use of naval aircraft. The results of the investigation of visibility recently made in England have had little bearing upon the practical aspects of the problem, i.e., the forecasting of visibility. That is the aspect in which the Fleet is very interested and, although it is appreciated that fundamental research is a necessary preliminary, it is important that the ultimate objective should be constantly borne in mind and that the general lines of the research should be directed towards that objective. The problem of forecasting visibility is one which affects all services, and in view of the fact that the problem will present different features on different stations, it would be of great assistance to the Fleet if local services would direct particular attention to the investigation of the problem of forecasting visibility in their respective areas and make their conclusions available to the Fleet.

(*b*) *Air mass and frontal analysis.*—In the training of naval meteorological officers considerable attention is given to air mass and frontal analysis and this method is used, whenever possible, in the forecasting work of the Fleet. An extensive use of the method is prevented by the general lack of knowledge of the properties, etc., of the air masses characteristic of many regions. Owing to the interest taken in this method by shore meteorological services on the Home and Mediterranean stations and on the North American portion of the America and West Indies station, sufficient information is now available to enable the method to be used by H.M. ships on those stations. Very little, if anything, has been published, however, regarding the air masses typical of the East Indies, China, Africa, New Zealand* and Australian stations and of the South American portion of the America and West Indies station, and the work of the naval forecaster is very much handicapped in consequence, particularly in forecasting for aircraft operations, where the timing of phenomena is of prime importance. The naval forecaster cannot be expected to contribute much to the study of the subject, since he normally has other duties to perform in addition to his meteorological work and, further, he is stationed for only a comparatively short period in each area. The study of the subject must fall, therefore, mainly to the shore meteorologist, and it is hoped that the meteorological services on the stations referred to will give earnest attention to investigations on similar lines to those made by Bergeron and other workers in Europe and Willett and Byers in America.

(*c*) *Single Observer Forecasting.*—The difficulty of the problem confronting the naval meteorologist is increased by the fact that observations available when a forecast is required may be very meagre, or even in time of war, non-existent. The Meteorological Officer has then to adopt the methods of the Single Observer Forecaster.

In 1927 a scheme of forecasting from the ship's own observations alone was evolved in H.M.S. *Furious*, and a month's trial of this method was carried out. On conclusion of the trial a report was forwarded by *Furious* to the Meteorological Office giving a description of the method used, details of the various phenomena observed and suggestions as to the deductions to be drawn from these by a single observer. Since this initial experiment, similar trials have been carried out in other aircraft carriers and a number of reports have been received by the Meteorological Office. In view of the importance of the development of this method of forecasting for use in war, the Admiralty appointed Lt.-Cmdr. T. R. Beatty, R.N., to the Meteorological Office in January, 1929, to investigate the problem of single observer forecasting. The object of this investigation is to formulate a series of rules by means of which forecasts can be made by a Meteorological Officer in a ship at sea from his own observations alone. In 1932 a report on the investigation was published by the Meteorological Office. Copies of this report, which dealt mainly with the Home station, were sent to the Directors of the shore meteorological services co-operating with the Fleet, who were asked to contribute reports on the use of this method of forecasting in their respective areas. The response was very encouraging and, out of the 13 services approached, 11 have already sent replies. It is hoped that replies from the remaining two services will be received in due course, and with the information supplied by shore services and further contributions from H.M. ships it will then be possible to prepare a further report on this method of forecasting.

In view of the fact that, in war, delays may occur in the transmission of the data or that it may even be impossible to arrange for the supply of data from certain countries, it may be necessary for shore services themselves on occasion to forecast from a chart with very few observations or in certain cases from observations from one station only. It is desirable, therefore, that shore meteorological services should give further continuous attention to the problem of single observer forecasting, in order that they may be prepared themselves to deal with the situation that may arise in war and may be in a position also to advise the Meteorological Officers of the Fleet upon local peculiarities. It would be appreciated if services undertaking investigations on this subject would keep the Naval Division informed of the progress of the work.

6. The Preparation of Naval Handbooks on local Meteorology.—Naval officers carrying out meteorological work in the Fleet have for a long time past felt the need of comprehensive handbooks on the local weather of the stations on which they are situated. Officers forecasting on a station on which they have not previously undertaken forecasting duties are considerably handicapped by their lack of knowledge of local peculiarities. Further, information regarding local conditions, if available at all, is usually scattered throughout a number of publications. It has therefore been decided to prepare a handbook for each station giving a synopsis of all available information on local weather likely to be of assistance in forecasting. It is not proposed to enter into any theoretical discussions in these handbooks except in so far as they may serve to bring out points of practical importance.

Work was commenced on the first handbook for the Mediterranean Station, in 1934. The work is being undertaken by Dr. Harwood, formerly Superintendent of the Meteorological Office, Malta, but a considerable amount of preliminary work was done on his own initiative by Lt.-Cmdr. V. W. L. Proctor, R.N., when serving as Meteorological Officer in an aircraft carrier on the Mediterranean Station.

The handbook for the China Station has also been commenced, the work being undertaken by Lt.-Cmdr. A. E. M. Dodington, R.N., who has had considerable experience of meteorological work in H.M. ships on the China Station. The typhoon section of this handbook has been completed and, in view of the desirability of promulgating the information to H.M. ships without delay, it has been decided to publish this section forthwith, although it will eventually be incorporated, of course, in the complete handbook. It is probable that the next station to be dealt with will be the East Indies Station.

The " layout " of the handbooks for the various stations will be similar. Each station will be divided into suitable areas, and the corresponding handbook will be in three parts. Part I will be a general introduction to the meteorology of the whole station. Part II will deal with the meteorology of each of the areas. Part III will be a synopsis of practical forecasting methods for the station.

The co-operation of the Meteorological Services of the Empire is sought in the compilation of these handbooks and it would be of assistance if those Directors or their representatives attending the conference, who are prepared to assist, would visit the Naval Division, in order that the whole scheme could be put before them in detail and specimen sections of the Mediterranean and China Handbooks could be examined.

7. War organization of Fleet Meteorology.—A limited distribution of the section of this memorandum dealing with war organization will be made at the conference.

* Since this memorandum was written the following paper has been published dealing with air-mass analysis in New Zealand, and copies have been circulated by New Zealand to the Royal Navy and the Royal Australian Navy :—" Frontal Methods of Weather Analysis applied to the Australia-New Zealand Area," by E. Kidson and J. Holmboe. Part I, Discussion. Part II, Weather Charts. New Zealand, Department of Scientific and Industrial Research, Wellington, 1935.

APPENDIX XV.—BAROMETERS FOR HIGH LEVEL STATIONS (Minutes VII pp. 40–1).

(*a*) Barometers Suitable for Use in Tropical Highlands

(*b*) Note on the Barometer on Semi-Tropical Plateaux

(*a*) Barometers suitable for use in tropical highlands

By J. M. Sil

(*Meteorologist, Instrument Section, Poona, India*)

For the absolute determination of atmospheric pressure on tropical highlands, the mercury barometer of standard design, Fortin Type, with suitable range, has been used with quite satisfactory results in this department. Kew pattern barometers of commercial design have not been found so suitable for the purpose. Mention may be made of an "improved pattern" barometer by Casella, in which a very fine setting of the fiducial point is possible with the help of its built-in optical devices in the cistern (*vide* Casella leaflet No. 574).

Barometric tendencies need self-recording instruments for their determination. An ideal instrument for the purpose is a fully compensated mercurial barograph recording on chart and having a good open scale. Such barographs are, however, expensive, require skilled observers to maintain them, and are not portable; probably for these reasons they have not gained popularity.

(1) King's self-recording barometer—Negretti & Zambra—price £280—ratio 1 : 5—one installed in Liverpool Observatory.

(2) Draper's recording barometer—T. Thomson—price about £50—ratio 1 : 3—two are in use in this department.

(3) Dines' self-recording mercurial barometer—J. Hicks—price £34—ratio 1 : 1½.

The next best instrument is an aneroid barograph of modern design and with open scale—provided its index error in the working range is fairly constant. In India the Precision Recording barometer manufactured by Negretti & Zambra has been found to be satisfactory; it is provided with two sets of aneroid boxes of Sylphon type, has a pen travel of 5 in. on the chart for variation of pressure of 1 in. of mercury, and is capable of being set at any pressure value within a range of 3 in. of mercury, e.g., 22·0 in.–25·0 in. (*vide* M.2071 on p. 42 of Negretti & Zambra list M-2).

It is not known whether any forecaster has made much use of barometric characteristics and tendencies observed near the equator. A statistical examination of the barograms at Quetta (lat. 30° 12′, long. 67° 00′, and height 5,405 ft.) where the diurnal (24-hour) change of pressure rarely exceeds 0·1 in., was undertaken by Flight-Lt. Batty, and the results, published in *India Meteor. Dept., Sci. Notes*, Vol. III, No. 24, may briefly be summarised as follows:—

(*a*) The prevalent idea that, owing to masking of minor fluctuations by large diurnal variation of pressure in the tropics, barometric characteristics and tendencies will be of little practical utility for forecasting, requires to be considerably modified.

(*b*) For 7h. (local time) observation, barometric characteristics were mostly restricted to the International Code figures 0, 3 and 4, the percentage frequencies of occurrences of code figure 4 are, however, greatest during the months associated with unsettled conditions; individual examination of barometric characteristic in the morning, and subsequent disturbed weather during the day, would show that a close relation between the two exists.

The barograph at Quetta was a weekly instrument by Richard Frères made in 1900 and provided with 8 small aneroid capsules—ratio 1 : 1.

(*b*) Note on the barometer on semi-tropical plateaux

By N. P. Sellick, M.C., B.Sc.

(*Government Meteorologist, Southern Rhodesia*)

This memorandum is printed in Appendix VI (*d*), p. 116.

APPENDIX XVI.—STANDARDIZATION OF METEOROLOGICAL INSTRUMENTS

(Minutes VII, pp. 41–3)

By J. S. Dines, M.A.

(*Superintendent, Instruments Division, Meteorological Office, London*)

During the past few years a good deal of attention has been given in the Meteorological Office to the standardization of recording instruments, and as members of the Conference have occasion from time to time to order instruments of Meteorological Office pattern in London, it is believed that they will be interested to learn of the progress which has been made.

It has always been the custom of the Meteorological Office to obtain instruments from the principal London makers, and in the case of the instruments in common use, such as barographs, thermographs, etc., no detailed specification has been issued; particulars of the main essentials, such as the time, pressure and temperature scales, have been given, but the details of construction have been left to the discretion of the maker. The fact that instruments of a good many different types are in common use has naturally led to some difficulty in issuing spare parts in replacement. Standardization would reduce this difficulty. The great drawback that standardization hinders the introduction of improvements in an instrument, the design of which may not be perfect, is well known and has caused the Meteorological Office to move slowly in the matter, but the present policy is to issue more detailed specifications than have been issued in the past, and one or two directions in which standardization has now definitely been adopted are mentioned below.

The first point which came up for consideration was the question of time scales. The time scale for each individual type of instrument has always been standardized. This was clearly necessary in order that the same chart might be available for use on the instruments purchased from the several instrument makers, but the time scales used on different types of instruments bore little or no relation to one another. Thus, the time scale of a weekly barograph differed from that of a weekly thermograph and other similar instances could easily be adduced. When examining meteorological occurrences it is frequently necessary to set the records of different elements one against the other, and the comparison of these records is much facilitated if they are all made on the same time scale. It was primarily for this reason that in the year 1929 it was decided to standardize time scales, and the following four standards were adopted:—

Daily	11·4 mm. per hour.
	15 mm. per hour.
Weekly	20 mm. per 12 hours.
	30 mm. per 12 hours.

The provision of two daily and two weekly scales was necessary as some elements require a more open time scale than others. It is clear, for example, that a gusty wind could not be recorded satisfactorily on so close a time scale as barometric pressure or temperature. It may be noted in passing that the two smaller time scales, 11·4 mm. per hour and 20 mm. per 12 hours, require approximately the same length of chart, 273·6 mm. for the 24-hour run in the one case and 280 mm. for the 7-day run in the other. As the length of chart controls the diameter of the clock drum this means that the same clock drum will serve for either a daily or weekly record. This feature has proved of considerable advantage in the design of a standard clock to which reference will be made below. It will be noticed that while three of the standard time rates are designated by a figure which is a multiple of 5 mm., the first, 11·4, is not a round figure. The daily scale, 11·4 mm. per hour, has been in very wide use for many years. The change from 11·4 mm. to 12 mm. per hour (5 min. per mm., the other daily clock rate being 4 min. per mm.) was considered and was rejected because it would have required a change in the size of the clock drum; and as the existing size of drum is used by instrument makers for other purposes besides meteorological instruments, there would have been substantial difficulty in introducing the change. It was, therefore, decided to standardize the 11·4 mm. per hour rate. The four time scales set out above have now been adopted for all the instruments in common use at observing stations, namely, barographs, thermographs, hygrographs, rain recorders and anemographs. They have not been adopted in all cases for instruments of special design of which only a few are in use such, for example, as the Callendar Radiation Recorder, where the difficulties of introducing a change of time scale would have outweighed any benefits to be obtained. The difficulties, even in the instruments in common use, were considerable, and as Meteorological Office forms are purchased by outside observers and their use is not entirely confined within the Meteorological Office the inconvenience of the change has affected others besides those of us who have had to make the arrangements within the Office. On the other hand, the benefits which accrue from the standardization of time scales are not confined within the Office, but will be felt by all users of the instruments. It may be useful to mention a few of the points which have arisen in dealing with this change of time scale. The majority of the instruments which use daily charts employ the small time scale of 11·4 mm. per hour, and as this has not been changed no difficulties have arisen here. The most important instrument for which the larger time scale 15 mm. per hour is used is the pressure tube anemometer. The scale formerly in use for this was 0·6 in. per hour, i.e., 15·24 mm. The change is not great, but proved to be outside the operation of the clock regulator and adjustment of the balance wheel or hair spring of the clock was called for. The new time scale being slightly smaller than the old no change in the diameter of the clock drum was needed. Of the weekly charts the time scale of the small barograph was formerly 19·8 mm. per 12 hours; the change to 20 mm. was so small that it was within the compass of the clock regulator. Weekly hygrographs were already made with a scale of 20 mm. per 12 hours and required no change. Weekly thermographs were the instruments which caused the greatest difficulty. Here the old time scale was 0·75 in. per 12 hours, and the change to 20 mm. led to an increase in the length of the ruled portion of the chart of 14 mm. This necessitated increasing the diameter of the clock drum, and the only really satisfactory means of making the change was the fitting of a new clock. To meet the few cases where this course was impracticable a paxolin sleeve was devised by the Meteorological Office for slipping over the old clock drum to give the necessary increase in diameter. Adjustment was also needed to the chart clip. This method of altering the time scale proved practicable, but it can hardly be considered as entirely satisfactory, and it is recommended that any clocks which have been adjusted by this means should be replaced by new clocks as soon as they need comprehensive overhaul. The most important instrument using the larger weekly time scale, 30 mm. per 12 hours, is the open scale barograph. It so happened that at the time when the new scales were adopted the old large barographs in the Meteorological Office were being superseded by a much improved type which is known as the open scale barograph. The new type was, therefore, adapted for use with the time scale of 30 mm. per 12 hours from the start, and no attempt was made to convert the time scale of the old barographs, 27·2 mm. per 12 hours, to the new scale in view of the obsolescence of these instruments.

The standardization of time scales paved the way for the introduction of a standard clock for meteorological recording instruments. The clock is the part of an instrument which calls for most frequent renewal, and great difficulty has been experienced in the past in ensuring that when a clock was sent out in replacement it would fit the instrument for which it was intended without considerable work on the part of the observer. Not only were some clocks mounted on a central spindle while others were supported on a pedestal fixed by three screws on the circumference of a circle, but the dimensions of the spindle and the spacing of the three screws varied as between clocks of one maker and those of another. It was primarily this difficulty in the issue of replacements which caused serious attention to be devoted to the introduction of a standard type of clock, and the adoption of standard time scales obviously rendered the task less difficult of solution than it would otherwise have been. If the object in view had been to design standard clock mechanism suitable for use in all future instruments the task would have been comparatively simple, but it was desired to make the clocks adaptable to existing instruments so far as possible, so that as the old clocks became unserviceable they could be replaced by the new and improved type. In view of the multiplicity of types of instruments already in service considerable thought was necessary in designing a universal clock which would be suitable for them all. After full consideration it was found best to make the clock movement in its case a separate unit from the chart drum, and it was ultimately found possible to reduce the main standard components to two types of clock movement, one daily and one weekly, and two drums. One of these drums serves for the two smaller time scales, 11·4 mm. per hour daily and 20 mm. per hour weekly. The second drum serves for the larger weekly scale, 30 mm. per 12 hours. The larger daily scale, 15 mm. per hour, would require a special drum, and has not at present been included in the range for reasons which are mentioned below. The standard clock movement is supported on a base plate designed to be fixed in position by three screws equally spaced on a circle 89 mm. in diameter. In order that the clock may be fitted to instruments where spindle mounting is adopted a circular disc is provided to which the clock movement can be fixed by three screws, this disc having a screwed spindle projecting from its centre. These two standard clock movements with two drums are sufficient to give either daily or weekly records on all of the following instruments :—barographs, large and small, thermographs, hygrographs and self-recording rain-gauges. All instruments of these patterns which are ordered in the future will be suitable for use with the new clock. The clock will also be issued for use with existing instruments as replacements become necessary. It should present no more trouble in fitting than clocks of the old pattern. It will be noticed that the pressure tube anemometer is omitted from the above list. This requires the larger daily scale of 15 mm. per hour. For some years past these anemometers have been fitted by the maker with a type of clock having a greatly superior movement to that fitted to the generality of meteorological recording instruments. Further, these clocks are interchangeable one with another and there was little advantage to be gained by adapting the standard Meteorological Office clock to them. It was, therefore, decided for the present at least to take no action in this direction.

In designing the new clock endeavour was made to eliminate some of the drawbacks which are associated with the existing clocks fitted to the types of meteorological instruments in common use. One of the chief of these is the presence of backlash in the drive. This has been entirely eliminated by taking the drive in the new clocks from the spindle of one of the wheels in the main train. This wheel being constantly pressed in one direction by the main spring of the clock and prevented from rotating at more than the specified speed by the escapement, there is no backlash in its movement and the clock drum which is directly connected to it through a friction clutch has a similar absence of backlash. The clock movement also is of more substantial construction than in previous clocks and the friction clutch which provides for adjusting the drum to the correct time is of improved design. A new type of chart clip has also been adopted which is more convenient in use than the old brass bar. It is believed that the design of the new clock represents a material advance on anything which has been in use in the past.

The Meteorological Office pattern bimetallic thermograph has a clock drum some 50 per cent higher than hygrographs, barographs and self recording rain-gauges. This fact would have necessitated the provision of a special drum for use on the thermograph, but before this step was taken consideration was given to the possibility of reducing the scale of the thermograph so that it would take the standard drum. When the matter was considered the arguments appeared to be substantially in favour of such a reduction in scale. The bimetallic thermograph is not an instrument of extreme precision, readings taken from it frequently differ by 1° F. from those of a dry-bulb thermometer placed alongside and the openness of the old scale which permitted readings to be taken to ½° or ¼° was hardly justified. It appeared that not only would a smaller scale be quite adequate, but that the instrument might even be made more satisfactory mechanically and record the temperature with greater precision if the scale were reduced to 1 mm. per 1° F. in place of the old 1·524 mm. (0·06 in.) per 1° F. It was, therefore, decided to amend the specification of the thermograph and all future instruments purchased according to Meteorological Office specification will have a scale of 1 mm. per 1° F., and will take the standard M.O. clock and drum. A revision of the charts will thus be called for. It is anticipated that the weekly thermographs with the existing scale will remain in service for some years, and that M.O. Forms 4316 and 4317 which are used with these thermographs will remain in print for an equal period. Thermographs with daily clocks are chiefly in use at Meteorological Office stations on aerodromes, and it has been decided that all these shall be replaced by thermographs of the new pattern by the end of the year 1936. After this date the existing Forms 4323, 4324 and 4325 for thermographs with daily charts will become obsolete. The new thermographs will be ordered to a more rigorous specification than has been the case in the past and a considerable degree of interchangeability will be ensured amongst them.

One other feature in which standardization has been adopted recently is in the finish of instruments. Meteorological instruments are exposed to more severe conditions than almost any other type of scientific instrument ; rain-gauges are necessarily completely exposed to the weather, while thermographs and hygrographs though they are placed in the thermometer screen really obtain very little protection as drizzle, mist and fog are blown freely over them. It is, therefore, rather extraordinary that iron and steel should have entered largely into the composition of these instruments in the past. It will frequently be found that when a copper rain-gauge is purchased the wire round which the copper is bent at the bottom of the funnel to give increased strength is a steel wire. No effective steps are taken to keep the water out with the result that after a few years' service the steel is rusted badly and the bottom rim is disintegrated. This is perhaps the worst example of the use of steel, but many others could be adduced. The use of steel in outdoor instruments has now been almost entirely eliminated in current Meteorological Office specifications. Where for reasons of strength steel must be used the stainless variety is specified. The following places where iron or steel have been replaced by non-ferrous metal may be mentioned. The base of sunshine recorders is now made of gun-metal instead of cast-iron, an increase in cost being avoided by altering the shape of the base and lightening its section. Incidentally, the earlier Campbell-Stokes sunshine recorders were made with a slate base, and while the introduction

of cast-iron doubtless facilitated the manufacture it was a very retrograde step as regards weather-proofness. The base casting of thermographs and hygrographs was frequently of iron in the past. Here again gun-metal has been substituted. For the sheet metal covers of these instruments copper is now used and brass gauze for the cage which protects the hairs of hygrographs. These sheet-metal parts are further protected by a coat of cellulose enamel which provides a very weather resistant surface. For parts which it is undesirable to enamel, varnish is used as a finish in preference to lacquer. Experiments on the roof of the Meteorological Office at South Kensington showed that whereas a piece of lacquered brass lost its lustre in the course of a few weeks a similar piece of brass coated with varnish had not seriously deteriorated after twelve months.

There is one other purpose for which copper has been used to some extent to replace iron, and that is in the pressure and suction pipes of the pressure tube anemometer. The replacement has only been partial in this case owing to the considerable increase in expense. The rule adopted is that at coast stations and other places where the atmosphere is unusually corrosive copper shall be used. At inland stations where the air is not contaminated by fumes from industrial districts iron pipes are still employed. Even at coast stations there is little risk of these iron pipes rusting through if they are kept painted on the outside, and the reason for discontinuing their use is the fact that substantial quantities of rust develop inside the iron pipes and fall down to places where the pipes bend ; this reduces the freedom of passage of the air through the pipes and might in extreme cases block them. In this connexion it is relevant to mention that pipes of 1-in. diameter were introduced a few years ago because it was found that smaller pipes did not give sufficient freedom of passage to ensure correct records.

It is hoped that the impression will not be formed that the finish of modern Meteorological Office instruments is perfect and that these will remain in " show case " condition after long periods of exposure to the atmosphere without attention. I am afraid that the achievement of this ideal is not in sight and that no known finish will give such a result, but it is believed that modern instruments, if given a reasonable amount of care and attention by the observer, will do him much more credit after a few years of service than the patterns which were being issued ten years ago.

APPENDIX XVII.—THE BRITISH METHOD OF OBSERVATION BY PILOT-BALLOON

(Minutes VIII, pp. 43–7.)

By J. S. Dines, M.A.

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Observations have been made by pilot balloon in this country for some 30 years. At first the work was undertaken as a piece of pure research and some of the early results were put together by Mr. Cave in his well-known work on " The Structure of the Atmosphere in clear Weather " which was published by the Cambridge University Press in 1912. The Great War gave a tremendous impetus to the work, and it is probably no exaggeration to say that for every balloon sent up in 1913, 50 or 100 were liberated in 1916. Not only so but the results of the observations were required for immediate use so that it became essential to devise methods of observation and computation which gave the required data in the shortest possible time with the minimum of man power. The methods developed in these circumstances, though they have been improved in detail, have remained substantially unchanged to the present day and a short account of them will be given in this note.

There are, broadly speaking, two methods of observation by pilot balloon, the double theodolite and the single theodolite methods. In the former, two theodolites are employed at the ends of a base line and a direct trigonometrical fix of the position of the balloon is obtained at one minute intervals from the readings taken by the two observers. This enables the upper winds to be calculated with considerable accuracy and without the need for making any assumptions. The method is unfortunately not economical of man power. Neither does it permit normally of the computations being completed until some time after the ascent. The single theodolite method which is without these drawbacks is therefore employed almost universally in this country. In this the balloon is filled to give a standard free lift and is observed through a single theodolite only. In its simplest form the method requires the assumption that the balloon ascends at a known rate. Owing to the presence of rising and falling currents in the atmosphere the rate cannot be known accurately and the results obtained may therefore be subject to considerable errors. The method has the advantage of extreme simplicity and notwithstanding the risk of error has given very valuable results. A refinement is sometimes introduced by hanging a tail about 120 ft. long below the balloon, the angle which this tail subtends at the point of observation being measured by a graticule in the eye piece of the theodolite. This additional reading allows the distance of the balloon from the point of observation to be determined and thus its height can be computed from the elevation angle and the assumption of a known rate of ascent is no longer called for. This method does not give the accuracy obtained with two theodolites, but is a material improvement over the simpler method in which a uniform rate of ascent is assumed. A tail is frequently employed on the balloons liberated in Great Britain.

As there are two methods of following the balloon so also there are two means of computing the upper winds from the theodolite observations, the graphical method and the slide rule method. It is probably true to say that most observers when they commence the work prefer the graphical method in which the track of the balloon is plotted on radial paper, owing to the clear picture which it gives of the movements of the balloon. This method cannot be worked at high speed and it is owing to the great saving in time which becomes possible when the slide rule is used that the latter is universally employed in this country. Few observers who have once become familiar with the use of the slide rule would care to go back to the graphical method. Using the special slide rule which has been developed for pilot balloon work it is possible with two observers, one at the eye piece of the theodolite and the other sitting by with a slide rule, to compute the results as quickly as the observations are taken, so that when the balloon is lost to view the winds at all levels passed through are immediately available.

Cases are even on record where a single observer working unaided has been able to follow the balloon and do the computing on a slide rule. This is naturally only possible on favourable occasions when the direction of the balloon is not changing rapidly.

The equipment required for pilot-balloon work is as follows :—

1. Balloons with tails and lanterns for night ascents.
2. Balloon fillers.
3. Hydrogen.
4. A theodolite.
5. A stop-watch.
6. A slide rule.
7. Forms.

Some notes on these individual items follow. The prices of the equipment have been added in most cases in order to enable the cost of carrying out a given programme of ascents to be worked out. The prices naturally vary from time to time, but such variations are usually small and would not affect the gross total of the cost to any material extent.

1. **Balloons, tails, lanterns.**—Rubber balloons are used in this country, those in most common use being the 70 in. and 90 in. patterns. These dimensions indicate the circumference to which the balloon must be capable of inflation without bursting. The balloons are filled to a smaller circumference in actual use. Both the 70 in. and 90 in. balloons are inflated to rise at a rate of 500 ft. per minute. A larger size, 150 in., is available for special work. These balloons ascend at a rate of 700 ft. per minute. There is also a small size, 48 in., ascending at a rate of 400 ft. per minute, which can be used when it is not desired to attain any great height. The balloons are made in three colours, blue, red and undyed. The most suitable colour for use on any occasion depends upon the state of the sky and is also governed to some extent by the individual preference of the observer. The following table gives particulars of the balloons :—

Balloons	48 in.	70 in.	90 in.	150 in.
Weight (gm.)	10	20	30	80
Rate of ascent (ft./min.) ..	400	500	500	700
Free lift (gm.)	20	61·5	71·5	238
Approximate capacity (cu. ft.) ..	1	2½	3	10
Price	2½*d.*	5*d.*	8*d.*	2*s.* 9*d.*

In calculating the volume of gas required to fill a certain number of balloons it is desirable to add at least 25 per cent to the capacities given above to allow for wastage.

Should it be desired to vary the rate of ascent for any reason from the figures in the table the requisite free lift can be calculated from the following formula :—

$$V = qL^{1/2}/(W + L)^{1/3}$$

where V is the velocity of ascent in feet per minute, L the free lift in grammes and W the weight of the balloon and any attached fittings in grammes. The value of q is 310 for 150 in. balloons and 276 for the smaller sizes. An approximate rule which will be found useful is that in order to keep the rate of ascent constant when the load is increased the free lift must be increased by double the increase of load, i.e. if a 10 gm. attachment is to be hung below the balloon the free lift should be increased by 20 gm. to obtain the same rate of ascent.

Tails, for use with the tail method, are constructed out of 120 ft. of thread to the end of which is attached a sheet of coloured paper stiffened by fine aluminium wire. Tails are usually made up locally as required.

When ascents are made at night a small candle lantern, resembling a Chinese lantern, is hung below the balloon. These lanterns cost about 1*d.* each.

2. **Balloon fillers.**—In order that the balloon may be given the lift appropriate to its size shown in the above table and may, therefore, ascend at the known rate which is called for in single theodolite work, a balloon filler accurately adjusted to the correct weight is used. The filler has a nozzle over which the neck of the balloon can be slipped and is also provided with an inlet tube to which a rubber tube from the hydrogen cylinder is attached. Gas is admitted until the balloon has a little surplus lift. The rubber tube is detached and the excess gas liberated by means of a small valve in the filler until the balloon just lifts the filler. It is then detached and its neck tied tightly in a knot or bound with soft string to seal the gas. A set of balloon fillers for the 48 in., 70 in., and 90 in. balloons costs £1 16*s.* ; a separate filler supplied for the 150 in. type of balloon costs 17*s.*

3. **Hydrogen.**—For the work of the Meteorological Office hydrogen is always supplied compressed in cylinders. Generators of different patterns have been tried but it has been found that any saving in cost is more than offset by the additional time required for their use and the attendant difficulties. The gas is compressed to 120 atm. and the cylinders in most common use hold either 100 cu. ft. or 200 cu. ft. of free gas. The smaller cylinder is 4 ft. 6 in. long and weighs 134 lbs., the larger is 8 ft. 6 in. long and weighs 255 lbs. The cost of the gas is 36*s.* per 1,000 cu. ft. to which must be added the cost of transport. This naturally varies widely for different localities. It may be of some assistance to quote the shipping cost from England to Basra where gas is sent for use by the British Meteorological service in Iraq. The cost of sending out the full cylinders and returning the empty ones is £3 10*s.* per 1,000 cu. ft. The initial purchase price of 200 cu. ft. cylinders is about £5 each. A fine adjustment valve is required for use with the cylinders. This is designed to screw into the neck of the cylinders and consists of a screw down valve for controlling the liberation of the gas. The cost is 10*s.* 6*d.* A pressure gauge for testing the pressure in the cylinder is a useful though not essential accessory. Its cost is 38*s.*

4. **Theodolites.**—The theodolites in use in the Meteorological Office are of the Cary or Watts pattern, the latter being the most modern type of instrument. These embody the well-known feature introduced by M. de. Quervain for pilot-balloon work of a prism incorporated in the telescope so that the line of vision is always horizontal whatever the altitude of the balloon. Readings of azimuth and altitude may be taken to 1/10°. A graticule is provided in the eye piece on which the angle subtended by the balloon tail may be measured.

The cost of a theodolite with tripod and carrying case is £45. Where a suitable site is available giving a fairly open horizon in all directions it is convenient to have a permanent mounting for the theodolite in place of the tripod. For this purpose a wall head is supplied for 30*s.* which can be mounted on a concrete base. The theodolite can frequently be left mounted on such a wall head between ascents, protected by a waterproof cover. Thus an appreciable saving in time is achieved.

5. **Stop-watch.**—In order that readings may be taken of the theodolite circles at one minute intervals it is convenient to employ a stop-watch which is started when the balloon is liberated. In the course of pilot-balloon work the watch is liable to suffer damage and it is therefore found best to employ a relatively cheap watch at a cost of about 30*s.*

6. **Slide rule.**—Special slide rules have been developed for pilot-balloon work, these being of two types ; Mark I for ascents where a constant rate of ascent is assumed and Mark II for use with the tail method. The Mark II pattern can also be used for a fixed rate of ascent if desired. The cost of these rules is £4 10*s.* They are extremely easy to use, only one setting of the rule being necessary to obtain the component distance of the balloon to north and to east at the moment of observation when a constant rate of ascent is assumed. The computation of these component distances is the first and principal step in the calculation of upper winds from pilot balloon ascents. When the tail method is employed the computation of the component distances is carried out with very little additional work.

7. **Forms.**—For entering the readings of the theodolite and computing the wind speed and direction at different heights by the slide rule method special forms are obtainable from the Meteorological Office. Where a constant rate of ascent is assumed Form 2080 is used ; with the tail method Form 2081 is appropriate. The cost of these forms is about 1*s.* 6*d.* per 100.

The initial cost of the permanent equipment listed above, including 6 × 200 cu. ft. cylinders, amounts to £85, while the cost of the necessary 70 in. balloons, hydrogen and forms for a programme of one ascent per day will amount to £16 per annum, allowing a round figure of 70*s.* per 1,000 cu. ft. for transit of hydrogen.

When two trained observers are available the making of a pilot-balloon ascent is neither difficult nor does it make any exceptional demand on the time of the staff. The process of setting up the theodolite on its tripod and adjusting it for level and aximuth takes about 5 minutes. If a fixed wall-head is used and the theodolite is already in position this time is reduced to the short interval necessary for checking over the settings. Filling the balloon from a hydrogen cylinder and adjusting its lift takes perhaps a little over 5 minutes. Some observers prefer to inflate the balloons slowly believing that the rubber is less liable to be damaged by this process than by rapid inflation. With a balloon which has not been subject to long storage rapid inflation should do no harm. If the balloon is old and the rubber has lost some of its elasticity, slow inflation may be desirable. If the tail method is employed a few minutes must also be allocated to preparing the tail and attaching it. The ascent can then be commenced. The duration of the ascent varies within wide limits. The presence of low clouds may limit it to a few minutes while an absence of cloud and the existence of a light wind or a reversal of wind direction so that the balloon is brought back overhead in the upper layers may enable the ascent to be continued for an hour or more. In some cases it will not be desired to measure the wind above a certain height. If this height is set at 10,000 ft. and a balloon rising at 500 ft. per minute is employed the duration will thus be limited to 20 minutes. If the second observer is competent to carry out the computing by slide rule while the first observer follows the balloon and takes the theodolite readings, the necessary computation will be completed almost as soon as the balloon is lost to sight. The complete operation can thus be carried out in a period which on the average may not exceed half an hour.

No attempt has been made in this note to give complete instructions for carrying out pilot-balloon work. Such instructions have been prepared in the Meteorological Office and will be published shortly. The object has been rather to give a brief account of the methods in use in the Meteorological Office with sufficient particulars to enable those who may be contemplating taking up the work to judge whether their resources in personnel and on the financial side will enable them to do so.

APPENDIX XVIII.—MARINE METEOROLOGY (Minutes VIII, pp. 47–51)

(*a*) Memoranda by Capt. L. A. Brooke Smith.

(*b*) Working of the Scheme for Wireless Reports from Ships. By The Canadian Meteorological Service.

(*c*) Working of the Scheme for Wireless Reports from Ships. By V. V. Sohoni.

(*d*) Weather Messages from Ships. By C. W. Jeffries.

(*a*) Memoranda by Capt. L. A. Brooke Smith, R.N.R.

(*Marine Superintendent, Meteorological Office, London*)

1. **British Ships' voluntary world-wide routine; wireless weather telegraphy.**—The International Convention for Safety of Life at Sea, 1929, Merchant Shipping (Safety and Load Line Conventions) Act, 1932, First Schedule, Article 35, specifies that :—

"The Contracting Governments undertake to encourage the collection of meteorological data by ships at sea, and to arrange for their examination, dissemination and exchange in the manner most suitable for the purpose of aiding navigation."

In particular—

"(c) To arrange for certain selected ships to take meteorological observations at specified hours, and to transmit such observations by wireless telegraphy for the benefit of other ships and of the various official meteorological services; and to provide coast stations for the reception of the messages transmitted."

Experience had taught the Marine Division of the Meteorological Office of Great Britain that it could organize and lead routine wireless weather telegraphy in the British merchant navy, if it were used both by ships at sea and meteorological services ashore, provided that:—

(1) It only directly guided a suitable number of ships on the British register by publishing a uniform procedure for use in all parts of the world, which could be followed by other British ships when and where desirable.

(2) British shipping was not subject to instructions issued by the meteorological institutions of other countries, those institutions only guiding ships registered in their own countries.

(3) If the reports were not made in plain English, they should only be made in a code used by ships of all nations.

(4) The same Greenwich mean times of observations were fixed for all parts of the world.

(5) Suitable times following the observation times, and suitable wave lengths were specified, so that all ships would be able to receive the messages direct, as well as the shore stations appointed to receive them.

Accordingly before the Conference on Safety of Life at Sea took place in 1929, the Selected Ship scheme was drawn up in the Marine Division in consultation with the Officers of the British Merchant Navy and the marine wireless authorities of Great Britain, both G.P.O. and commercial, and placed before a small Sub-Commission of the International Meteorological Organization in Paris. It was to work this scheme that paragraph (c) of Article 35 of the Convention for Safety of Life at Sea was included in that Convention.

After the British Empire Meteorological Conference of 1929 had been informed of this scheme, it was placed before the International Meteorological Conference at Copenhagen in September, 1929, and resolutions were passed which provided the necessary agreements for its being carried out by the ships of all maritime countries under the guidance of their own meteorological services.

Full particulars with instructions and advice to the masters of British Selected Ships have been published in the *Marine Observer* since January, 1930, and the scheme has been worked by the British Merchant Navy and the British Meteorological Office with steady improvement ever since May 1, 1930.

In January, 1934, the description of the scheme and the instructions were improved, broadened and clarified.

In November, 1934, the Pamphlet, M.O. 329, which has been purchased by British shipowners and placed on board the majority of British ships fitted for wireless telegraphy, was revised, and notes for the guidance of the masters of British ships which are not Selected Ships were included.

As may be seen in "Work of the Year," to be published in the July, 1935, number of the *Marine Observer*, this scheme has become firmly established by British Selected Ships.

Steps have recently been taken, with the co-operation of the Societies of the Merchant Navy, the Chamber of Shipping of the United Kingdom and the Shipowners' Associations, to extend the use of this system to any British ships which may be in a position to report, where and when there are not Selected Ships to perform this service; and *Notices to Mariners* have been published to make this generally known in British ships in all parts of the world. It is hoped that as the past five years' work of British Selected Ships has resulted in this voluntary work becoming a matter of routine in those ships, that the next five years' work may see it established voluntarily in all British ships where and when necessary.

It is essential that the complement of British Selected Ships should be maintained, for it is by the efficiency of the work of those ships that the whole routine wireless weather reporting system of British ships at sea is regulated and led.

For detailed information of the present state of this work, see "Work of the Year," No. 119, Vol. XII, *Marine Observer*, July, 1935, to be published on June 26, 1935.

2. **Present state of the meteorological survey and charting for climate and currents of the oceans by the British Merchant Navy and Meteorological Office of Great Britain.**—By means of the meteorological log, observations for climate, made and logged at the relief of the watch six times daily according to time of place, a great store of data covering all oceans had been collected by British ships up to the Great War. Much of this information and particularly that for the North Atlantic, the North and South Pacific, and the Arctic and Antarctic Seas, had not been extracted and worked up into averages, or used for charting the Oceans; though the Indian Ocean and South Atlantic Ocean had been well charted for climate.

From 1921 observations have been punched on cards so that they may readily be converted to averages by means of the Hollerith Tabulating and Sorting Machine.

In September, 1925, a scheme was outlined for completing the charting of the climates of the oceans from Latitude 60° N. to 60° S. This could not be carried out owing to the Admiralty requiring a much less complete meteorological atlas of the world, for the use of His Majesty's fleet; and accordingly an atlas was prepared in the Marine Division, largely copying the old Pilot Charts of the United States, which was published as "Meteorological Charts for the World."

Largely owing to the heavy work imposed upon the Marine Division through the preparation for, and putting into effect of, the agreements reached at International Meteorological Conferences to organize ships' wireless weather telegraphy, this work of data extraction fell heavily into arrears.

The Honourable Company of Master Mariners petitioned the President of the Board of Trade on March 23, 1931, pointing to the work done voluntarily by British seamen, the object of the work, the charts already compiled from it, and the need for efficient modern meteorological charts for each and every ocean.

The financial crisis occurred shortly after this, but by reducing the number of British regular voluntary observing ships to about 350, the minimum required for efficiency (the Meteorological Log only being kept by a comparatively small number of ships on routes traversing regions from which sufficient data have not been collected), we have been able since January, 1933, not only to extract all observations collected in logs as received but also to make good some of the post-war arrears, and also to extract and punch on cards in one operation a good many of the data collected before the War for the North Atlantic and Pacific.

Following the petition of the Honourable Company of Master Mariners, we clarified the scheme for completing the survey and charting of the oceans. After two years of working this scheme with the existing staff, we were able to report that, given about eight additional clerks for a period of two years, we could extract all the necessary data, and then the Marine Division as it is at present composed, would be able to complete the work for which it was originally established in 1855.

An idea of the proposed form of the charts may be obtained from Fig. 32 on pp. 112 and 113 of a "Handbook of Weather, Currents and Ice for Seamen", M.O. 379; and in Chapter VIII of that book, the purpose of modern charts for ocean pilotage may be seen.

It is anticipated that following certain processes of reorganization which are taking place in the Meteorological Office, the necessary additional clerical assistance will very shortly be forthcoming, so that we can look forward with some confidence to providing information of climate at least over the South Pacific where it is most needed, the North Atlantic and the North Pacific in a few years' time. Such charts, and the averages and data compiled to construct them, will give definite information of the climates of the different regions of the oceans.

The word climate is used throughout in this memorandum in a broad sense.

When this work is completed a comparatively small number of regular observing ships, fitted with self-recording instruments, will be able, without any great expense of money or labour, to provide continuous records over the oceans along the main trade routes.

The completion of this work in a reasonable time is a matter of no small importance to the meteorologists of the British Empire, and it is a matter of considerable importance to the British Merchant Navy; hence the petition of the Honourable Company of Master Mariners.

In 1924, when the *Marine Observer* was established, we adopted a new system of charting the currents. This work, with the great advance of accuracy in navigation which has taken place during the present century, has proved to be the most valuable to navigation of all the work done by the Marine Division.

An Atlas of Currents of the North Atlantic was completed in 1930, and an Atlas of Currents of the Indian Ocean is now being completed. The information resulting from these Atlases and the charts published in the *Marine Observer* has not only enabled us to publish much information of the currents, and their seasonal and other variations, but it has also enabled us to provide the Hydrographer of the Navy with revised information for a number of the Pilots, which are the principal sources of information for the navigators of the Royal and Merchant Navies.

In this connexion, it may be mentioned that through the agency of the Marine Division, water samples have been collected for the Ministry of Agriculture and Fisheries and the John Murray Expedition. This ocean current work, mainly dependent upon the observations of set and drift of regular observing ships, is being compared with the results obtained by other methods of ocean survey carried out by the above-named institutions and the "Discovery" Committee, with satisfactory results.

For detailed information of the Hollerith system of extraction and computation, see the *Marine Observer*, Vol. V, No. 49, January, 1928, p. 10 and Vol. VI, No. 63, March, 1929, p. 57.

3. **The Supply of unpublished marine meteorological observations to the Dominions of the British Empire and Foreign Countries.**—Though the Mercantile tonnage of Great Britain, which in 1900 was no less than 46 per cent of the world's tonnage of all types of ships, had fallen to only 27 per cent in 1934, the disposition of ships registered in Great Britain and Northern Ireland is still such that the Marine Division of the Meteorological Office of Great Britain is supplied with all the data which it requires for all its many purposes, by shipping registered in Great Britain and Northern Ireland only.

As has been shown in the first part of this memorandum, it was necessary to prevent duplication of work, overlapping, and confliction of instructions, to ensure the efficiency of the service of British Selected Ships; and a resolution was passed at Copenhagen in 1929, agreeing that all requests, instructions, etc., to shipping, should be dealt with by the Meteorological Services of the countries in which ships were registered.

In the Selected Ship system, it was agreed that each country should maintain a number of Selected Ships in service, in accordance with its proportion of the world's tonnage, the intention being that there should be 1,000 Selected Ships of all nations.

Now, though the International Meteorological Organization has not gone so far as to make agreements whereby branches of marine meteorological work, other than that of the work of Selected Ships, should be done voluntarily by ships only under the guidance of their own meteorological institutions, Article 35 of the Convention for Safety of Life at Sea is an International Contract, which is undoubtedly intended to cover the entire collection, examination, dissemination, and exchange of meteorological data collected by ships at sea. There can be no doubt that its intention is that all organized voluntary meteorological work performed in this service for safety of navigation should be done by the ships under their own Government institutions; and this contract was made to prevent overlapping and to promote efficiency generally and safe navigation particularly.

The Marine Division of the Meteorological Office of Great Britain has made every endeavour to prevent the voluntary services and good will of the officers of the British Merchant Navy being misused through unnecessary duplication of work at sea, and to supply meteorological institutions of the British Dominions and Colonies and foreign countries with observations made in ships registered in Great Britain and Northern Ireland and collected in London.

There are broadly four kinds of information, viz. :—

(1) That for the investigation of weather, for which synchronised meteorological observations taken at 0000, 0600, 1200 and 1800 G.M.T. are used.

(2) That for the determining of climates, for which observations logged in the meteorological log at 4 a.m., 8 a.m., noon, 4 p.m., 8 p.m., midnight, time at ship, are used.

(3) That for the survey and the charting of the currents for which the set and drift determined in navigation are used.

(4) That of drifting ice reported.

Regarding the above—

(1) Weather Observations are recorded in the ships' meteorological record of synchronised observations, Form 911. In Selected Ships, they are coded on to Form 138, before being transmitted by wireless telegraphy.

Thus, Form 911 gives the Marine Division a permanent record of synchronised weather observations as noted according to the custom of seamen, while Form 138, the Register, enables us to give some check to the coding, and to examine the work of wireless communication. After the end of each financial year, when the whole of the work of Selected Ships is reported upon, these registers are available for passing on the information to other services, and by this means no less than 42,861 observations, made by British Selected Ships south of the Equator, have been supplied to the Meteorological Services of the Union of South Africa, the Commonwealth of Australia and the Dominion of New Zealand ; and 7,169 were also supplied to Norway. By means of these registers, Germany has been supplied with a comparatively small number of observations in the northern hemisphere ; and the registers containing observations in the northern hemisphere for 1930 to 1934 are available should they be desired by the Dominions and Crown Colonies, north of the Equator.

These registers are sent with the understanding that, if required, they will be returned to the Marine Division of the Meteorological Office of Great Britain or to an international centre should one be appointed.

(2) Meteorological observations for the purposes of computing averages of climate are punched on Hollerith cards, see the *Marine Observer's Handbook*, Fifth Edition, pp. 10 and 11. Observations punched on Hollerith cards subsequent to January, 1930, can be printed mechanically, but owing to the Department of Customs and Excise having changed their machines from those which provided for 45-column cards to 60-column cards, and the present Air Ministry machine being of an old type, at present there is no arrangement for printing observations from these cards.

The Meteorological Institute of Holland, which is probably the only country other than Great Britain whose ships have kept the meteorological log throughout, ever since it was agreed to at the Brussels Conference in 1853, have also adopted a similar mechanical system with cards. It is interesting here to note that Holland is one of the few countries who, like Great Britain, has always employed seamen to superintend marine meteorological work.

To Holland, no less than 62,471 observations for climate over the oceans have been supplied by the Marine Division of the Meteorological Office of Great Britain since 1922.

It appears that some meteorological institutions have thought that these observations, logged at ships' time in the meteorological log, were for the purpose of investigating weather. They are not now used for this purpose in the Marine Division, synchronised observations being far more suitable, particularly where investigations are made with a view to any possible improvements in the Laws of Storms (Rules for handling ships in revolving storms), in which case synchronisation is of great importance.

(3) Observations of the set and drift of current are returned by British regular observing ships, both in the Meteorological log and in Form 911. These observations are now considered to be of very high order, as a result of the skill of British navigators, the good steering of modern power-propelled ships, and the accuracy of modern compasses, revolution counters, and logs. The collection of suitable data, and knowing what to accept and what to reject, require the vigilance and understanding obtained through experience in navigating ships.

In charting each part of the trade routes or section of an ocean for current, we copy from the data books, in which the observations of set and drift are first copied, on to tabulation sheets, Form 110, for the purpose of working the vector mean for each small area. While this is done a carbon duplicate is taken. These carbon duplicates are available for loan to the meteorological and hydrographical institutions of the Dominions and Crown Colonies of the British Empire and those of foreign countries. By this means Holland has been supplied with observations.

(4) Ice is reported by British ships to the British Meteorological Office on Form 912. These reports of drifting ice in the North Atlantic are published monthly in the *Marine Observer* and its Supplements. Reports of ice in southern waters are published yearly in the *Marine Observer*. This publication has rendered unnecessary the supply of copies of observations to the Dominions and other countries.

The only observations made by foreign ships and returned to their own institutions, which the Marine Division of the Meteorological Office of Great Britain has asked for since the year 1920, were observations of set and drift of current in the North Atlantic during the re-charting of the currents of that ocean. These observations only covered regions traversed frequently by British ships from which we had ample observations and they did not provide information for areas where we had none.

Experience of the past 15 years has proved that with careful organization of voluntary marine meteorological work, the British Merchant Navy can supply the best and sufficient observations for the purpose of the world-wide covering work done in the Marine Division of the London Office ; and with very little additional expense, by the methods briefly described above, the British Dominions and Crown Colonies can be supplied with a reasonable amount of unpublished observations for the investigation of weather, climate, currents and ice in the regions of the ocean adjacent to them.

(*b*) Working of the Scheme for Wireless Reports from Ships

By The Canadian Meteorological Service

At the present time no wireless reports from ships are received directly by the Meteorological Service of Canada but through the courtesy of the United States Weather Bureau, indirectly from New York and San Francisco, the Bureau recoding the messages in the morning and transmitting them to the office by telegraph. The Weather Bureau selects from their list of ship reports those that are most representative of the Pacific and Atlantic areas from which we require data for forecasting purposes. It is found, however, that there are too few for the western half of the Atlantic received in time to be of the greatest value in forecasting. Approximately ten reports from ships in the Pacific are received by telegraph from San Francisco in the early afternoon, and all the reports a few days later by mail. A number of ship reports collected at Seattle are telegraphed to the Victoria Office in time for forecasting in British Columbia. The recoding of the messages involves a considerable time and as a consequence the ship reports are seldom received in time to be of the greatest use in forecasting on that synoptic hour. It is hoped, therefore, in the near future, to organize a Canadian Service to receive reports direct from both the Atlantic and the Pacific.

As far as we know, the wireless reports from ships are satisfactorily received in the United States Service. They have about 250 ships from which reports are received in the Pacific and a great number in the Atlantic.

Ships on the Atlantic in the vicinity of Sable Island frequently report temperatures much higher than on Sable Island. It is desired to know how often the inspection of thermometers and thermometer screens is carried out, and what confidence may be placed in the thermometer readings from ships. This refers to ships of all nationalities.

It is suggested that the ship reports should include the occurrence of rain in the past twelve hours as it is considered that it would be of very real value for forecasting.

(*c*) Working of the Scheme for Wireless Reports from Ships

By V. V. Sohoni, B.A., B.Sc.
(*Meteorologist, Poona, India*)

In India the fleet of co-operating steamers consists of about a score of British selected ships and about four times that number of other ships plying in Indian waters. The number of wireless reports sent by individual ships varies considerably. A maximum of over 250 messages in a year is attained by a few steamers every year.

A sampling of the statistics of a few months shows that in the Arabian Sea (period October–December, 1934) 597 out of a total of 1,187 messages, i.e., 50 per cent, were from one-operator ships, while in the Bay of Bengal (May, August and October–December, 1934) the corresponding numbers were 2,185 out of 2,453, i.e., 90 per cent. In the Arabian Sea, one-operator ships cannot ordinarily despatch messages before 0400 G.M.T. (i.e., 0930 Indian standard time) each morning ; and in the Bay of Bengal they cannot send or receive messages after 1400 G.M.T. (i.e. 1930 I.S.T.).

As regards the use of International and India Code, the table below based on the statistics for the first half of 1934 shows that the Indian Code is very largely used in the Bay of Bengal, while it is used to an equal extent with the International Code in the Arabian Sea.

Code.	Arabian Sea. No. of wireless messages.	Arabian Sea. Percentage of of total.	Bay of Bengal. No. of wireless messages.	Bay of Bengal. Percentage of of total.
International	805	54	398	13
Indian	681	46	2,633	87

The Indian Ships' code (with 4 figures in the first group) is

PLLL lllGG DDFww BBVAW SKdCN.

Experience has shown that the observations made at international hours in the Arabian Sea are of little use for forecasting. Observations in the Arabian Sea at the principal daylight international hours of 0600 and 1200 G.M.T. of any day arrive at the forecasting centre at Poona only after noon, i.e., after the day's principal forecasting work is finished. For storm purposes also the international hours do not fit in well with the regular daily or special charts. Forecasters in India therefore still prefer the different hours for observation described in the Indian Ships' Weather Code. Some of these are outside the watch-keeping periods of single-operator ships which fact acts as a handicap. But, even if the hours were international, they would still be liable to this handicap ; and, in addition, would not serve so well the practical needs of forecasting.

According to the tonnage distribution, if India (with Ceylon) equips three ships as Selected Ships, or, say, six as observing ships, it seems that she discharges her responsibilities in the matter of the Selected Ships Scheme. This means, of course, that India has little direct interest in the scheme. From India's point of view, it is preferable within the neighbouring sea areas to have a larger fleet of "Indian" selected ships with special hours of observations at 0300, 0900, 2100 G.M.T. in addition to a daily routine hour of 0100 or 0200 G.M.T.

As regards codes, neither of the forms of international code meets the needs of the forecaster in India completely. Standardization of exposure on board ship in tropical waters, after investigation of the behaviour of thermometers in different parts of a moving ship under varying conditions, is still awaiting accomplishment. Until that is done, temperature observations from steamers which the international code provides for, will continue to be unreliable or uninterpretable in tropical waters. On the other hand, sea remarks which the international code does not provide for, are considered as a very important element in India, because they represent the integrated effect of wind and serve as a useful check on other observations at important times. It has been proved that neighbouring ships do not interpret sea and swell similarly; one may stress the swell and another the sea. I am, therefore, inclined to think that it would be worth while to recognise another alternative in the international code, e.g., $9SKdN_L$ $CNAWt_d$ after the usual first four groups; but it would be better first of all to think of giving up P which at least in India does not seem to be essential for the forecasting centres and to consider returning to the old S, international symbol, which incorporated both sea and swell. The forecaster in India has not made use of the information about the distinctions of short, average or long swell contained in K.

(*d*) Weather Messages from Ships

BY C. W. JEFFRIES

(*Director, Royal Observatory, Hong Kong*)

Dr. Kidson made a tentative proposal to the Commission for Maritime Meteorology in the following terms:—

> "That the local meteorological authority should determine the time of, at least, the morning observations sent from ships by W/T for use of the land meteorological service."

Consideration of the proposal was deferred by the Commission until after the deliberations of the Empire Conference.

It does not seem advisable to interfere in any way with the work which ships are doing at the request of the Meteorological Office, and for that reason Dr. Kidson's proposal as it stands should be negatived. Commanders of vessels are usually willing to help the local meteorological services by forwarding extra observations on request, and provided that the synoptic observations of the Meteorological Office are maintained, they might be encouraged to meet the requests of local meteorological services in addition to maintaining that routine.

An impression exists among some officers of selected ships that the synoptic observations desired by the Meteorological Office, and compliance with regulations for the Safety of Life at Sea, comprise the whole of their meteorological duties. If this impression is fostered by means of occasional discouraging intimations, invaluable assistance to local meteorological organizations is likely to be refused. If, however, the ships reporting to the Meteorological Office are encouraged through the *Marine Observer* to comply with the requests of the directors of local weather services when possible, the object of Dr. Kidson's proposal will be attained.

APPENDIX XIX.—COLLECTING INFORMATION ABOUT RAINFALL OVER THE SEA

(Sub-Committee on codes for wireless reports from ships p. 96)

BY S. R. SAVUR, PH.D.

(*Statistical Section, Poona, India*)

The necessity of determining the rainfall over the seas hardly needs any emphasis; especially in view of what Sir Napier Shaw has already written about it, see for example "Manual of Meteorology", Vol. II, p. 176. It will, however, suffice to mention that the amount of rainfall over the sea is in a way a good measure of the amount of convection in the atmosphere and will be of great use in the study of the general circulation in the atmosphere, as it is unaffected by orographical changes which are met with on land.

Various attempts have been made in the past to draw isohyets over the sea using scattered observations made by ships supplemented by observations made on island stations; the most recent attempt appears to be that of G. Schott* for the Indian and Pacific oceans. This method is evidently not quite satisfactory, for in the first place there are very few island stations where the orographical effect on rainfall is insignificant, and secondly these stations are scattered very far apart. Hence isohyets drawn with these data cannot be much relied upon.

Considering the large number of ships that ply nowadays along the several trade routes it may not be very difficult to collect more accurate information about rainfall over the sea. It is suggested that the best means of gathering this information may be discussed at the coming Conference of the Empire Meteorologists.

APPENDIX XX.—STORM SIGNALS

(Sub-Committee on codes for wireless reports from ships, pp. 96–7)

BY C. W. JEFFRIES

(*Director, Royal Observatory, Hong Kong*)

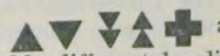
During recent years the development of radio broadcasting has done much for the dissemination of storm warnings, and the necessity for the exhibition of storm signals is not so general as formerly; the majority of ocean-going vessels are kept fully informed of meteorological conditions throughout their voyages and the display of storm warning signals in any port which they enter is principally an intimation that the harbour regulations current in that port in the circumstances must be complied with.

Storm signals remain a necessity for sea-ports in order that small craft may be warned, and that precautions as to mooring, etc., in harbour may be taken. This is particularly the case in regions subject to tropical cyclones. A fundamental difficulty with regard to the exhibition of storm signals in such

* *Ann. Hydrogr. Berlin* **61**, 1933, p. 1.

places, is the necessity for early warning in the interests of small craft, and, where harbour regulations apply equally to all craft, the owners or agents of larger vessels are apt to be somewhat impatient if their commercial activities are restricted prematurely.

Conditions vary very considerably in different parts of the world and it is difficult to formulate a simple code of signals which would be of international utility. It is to be noted that, provided that the urgent signals are of international application, signals could be added in any region according to its needs. The meteorological offices of the Far East which are under European control have unanimously adopted a code of 10 signals which include the four international symbols signifying gales from the four quadrants, and in addition a signal consisting of a black cross which signifies the approach of the centre of a tropical cyclone to such proximity that winds of hurricane force are expected. During the recent meeting at De Bilt of the International Commission for Maritime Meteorology it was decided to recommend this signal  for international use. It has been utilised in Hong Kong for this purpose for over twenty years and was previously used in conjunction with other symbols for a similar purpose.

It would appear that these five symbols  are all that are necessary for international use, and such a limitation would enable different localities to extend their codes in any suitable manner provided that the international symbols were not utilised for any other purpose. The fewer the number of simple symbols which are utilised for international purposes, the greater choice is available for local purposes. In Hong Kong the black cross is formed by the intersection of 3 hollow rectangular prisms of square section, the cone and double cone are rigid shapes. The dimensions of the symbols are such that each can be contained in a rectangular prism 6 ft. in length and 4 ft. square section. The signals at the majority of stations are constructed of rattan to facilitate hoisting. Where superior hoisting arrangements are available they are made of expanded metal which affords greater durability.

APPENDIX XXI.—METEOROLOGY IN AFRICA

(Minutes IX, pp 51–2)

BY N. P. SELLICK, M.C., B.SC.

(*Government Meteorologist, Southern Rhodesia*)

It appears likely, with the possible exception of the extremities of the continent, that the weather sequences over the whole of Africa are closely related, and the development of individual services is bound up with the whole. Owing to the vast areas involved and the sparse civilised population, the burden of maintaining a weather service comparable with European standards is too great even in the most developed areas, and over a large part of the continent meteorology is in a pitifully backward state; furthermore, the continent is cut up into a large number of administrative areas each of which is being developed or not developed without reference to the rest. Under these conditions there has developed a sort of meteorological "Babel" with a chorus of mutes, and future progress is dependent on the formulation of an agreed policy by a central advisory body on lines similar to the Sub-Commissions of the International Committee. As the Empire is possibly the worst offender in Africa it is suggested that the matter receive consideration at the Empire Conference, with a view to placing concrete proposals before the International Conference for the formation of an African Sub-Commission under the Committee for the development of meteorology on this continent.

APPENDIX XXII.—CLASSIFICATION OF METEOROLOGICAL LITERATURE

(Minutes IX, pp. 52–3)

BY C. E. P. BROOKS, D.SC.

(*Superintendent, General Climatology Division, Meteorological Office, London*)

1. **History.**—To make full use of a meteorological library, it is essential that there should be a catalogue in which the entries are arranged under subjects. Probably some form of subject classification is in use in all large meteorological libraries, but almost every library employs a different system. Consequently catalogues or bibliographies published by one institution cannot be utilised to their full extent by other institutions. To unify the practice in different countries a system of classification is required which can be recommended by international authority to the librarians of all meteorological institutions. This question was considered by the International Meteorological Conference at Copenhagen in 1929 and a Sub-Commission was appointed to report on it.

Three main criteria govern the selection of a suitable classification. In the first place, because of the important relationships which meteorology has with other sciences, the classification should not be limited strictly to meteorology, but should form part of some more general plan applicable to all branches of science. Secondly the classification must not be rigidly fixed, but must be capable of extension from time to time to include new developments. Finally, since meteorology in common with other sciences tends towards progressive sub-division, the form adopted must be sufficiently elastic to permit readily of such sub-division.

These needs appeared to be best met by the decimal system invented by Melvil Dewey and adopted and extended by the International Institute for Documentation. This system covers the whole field of knowledge, and it is the recognised duty of the Institute to keep it modernised by additions and revisions from time to time. The Sub-commission accordingly took as its basis the latest edition of the "Classification Décimale Universelle" published by the Institute, but close examination showed that in many respects the section for "meteorology" was not sufficiently complete and logical for specialised meteorological libraries, and that it would need extensive revision.

The International Institute for Documentation at first insisted that this revision must be carried out without altering the meaning of existing numbers. An attempt was made to do this, and a classification was constructed which was probably as good as could be made within the framework of the pre-existing decimal classification for meteorology. That framework was too faulty, however, and many of the faults could be not remedied without a complete reconstruction. This consideration led Dr. Hesselberg, Director of the Norwegian Meteorological Institute, to devise an entirely new classification, on the decimal system but otherwise unrelated to the existing "Universal Decimal Classification."

The International Meteorological Committee, which met at De Bilt in October, 1933, did not accept either of these classifications, but referred the question to a "Bibliographical Commission". Circumstances prevented a full meeting of this Commission being held, but an important discussion took place at The Hague in September, 1934, between Professor van Everdingen, Dr. Hesselberg, Mr. Donker Duyvis, Secretary of the Institute for Documentation, and Dr. Brooks. At this meeting the best points of both the draft classifications previously prepared were combined and re-cast in accordance with the principles of the Universal Decimal Classification, generously interpreted by Mr. Duyvis. With some minor modifications proposed by the other members of the Commission, that is the draft now circulated.

2. **Plan of the Classification.**—The plan of the Universal Decimal Classification is briefly as follows :—All knowledge forms one unit, which is first divided into ten main classes. Each of these is divided in turn into ten divisions, including all the subjects composing the class. These divisions are sub-divided again and again until the requisite fineness of classification has been attained.

"Pure science" forms the class 0.5. The sciences of the earth, geology and geophysics, form the division 0.55, and by continuing the process of sub-division we arrive at a group including the whole of meteorology, which has the number 0.5515. On this theory every number begins with 0, and this cipher with the decimal point can be taken for granted. Further, for convenience in reading long series of figures, the practice has been adopted of using the point not as a decimal point but as a punctuation to divide series of figures into convenient sections. The position of the point is optional, but as a general rule no section should contain more than three figures. Thus the number for meteorology becomes 551.5 instead of 0.5515.

When we sub-divide meteorology itself, we have certain guiding principles. The zero sign 0 is reserved for documents of a character which transcend the strict division of subjects ; the latter are included in the groups 1 to 9. In meteorology this distinction was best observed by including under 0 the practical basis and methods of the science. We have 551.50 Practical meteorology (methods, data, forecasts and other applications), 551.51 to 551.59 Theoretical and descriptive meteorology. The sub-division 9 is customarily reserved for "various" or "miscellaneous" parts of the subject. Further, it is highly desirable to leave some numbers blank, in order to allow for subsequent revisions ; 551.53 and 551.56 were left blank for this purpose. The remaining numbers were allocated in a fairly logical order, giving the following divisions :—

551.50 *Practical meteorology*
- 01 Methods of observation and computation. Observatories.
- 06 Observational data.
- 08 Meteorological instruments.
- 09 Weather forecasts and other applications.

551.51–9 *Theoretical and descriptive meteorology*
- 1 Structure, mechanics and thermodynamics of the atmosphere in general.
- 2 Radiation and temperature.
- 4 Atmospheric pressure.
- 5 Wind.
- 7 Aqueous vapour and hydrometeors.
- 8 Climatology.
- 9 Various phenomena and influences.

In the various sections, wherever possible the attempt is made to give a parallel arrangement by attributing the same significance to identical figures. Thus we have the following sub-divisions :—

1. Structure, microvariations.
2. Distribution at earth's surface.
3. Variations.
4. Vertical distribution in the turbulent layer near the earth's surface.
7. Upper air.

The numbers for some of the minor sub-divisions are rather long, but experience in other subjects has shown that in practice long numbers do not cause any sensible loss of efficiency. In fact, a subject in which the numbers are in general much longer than those proposed for meteorology, namely, electrical engineering, is the one in which the Universal Decimal Classification has been most widely adopted for bibliographical purposes. It seems, therefore, that the practical users of a classification are more concerned to have sufficiently detailed classes than to restrict the symbols to a minimum. In order that any sub-division of meteorology can be picked out readily, the common figures 551.5 can be distinguished in some way, either by printing in special type, or, if typed or written, by underlining.

3. **Auxiliary symbols.**—In addition to the simple decimal classification, the "Universal Decimal Classification" includes several auxiliary symbols. For our purposes we need take account of only two of these, the colon and the round bracket. Examples of both of these occur at the beginning of the tables for meteorology.

(1) *The colon* is the sign of relationship or connexion. For example, the general number for bibliography is 016, and a bibliography of general meteorology would be represented by 551.5 : 016. The order of the two connected series is reversible, and the entry is also written 016 : 551.5, thus stressing "bibliography" rather than "meteorology". The same feature is characteristic of language ; thus we can refer to a "meteorological bibliography" or to a "bibliography of meteorology". The auxiliary number for "bibliography" can be attached not only to meteorology as a whole but to any sub-division, for example a "bibliography of evaporation" would have the number 551.573 : 016.

The colon is an exceedingly useful conception in a subject like meteorology, which deals so frequently with the relations between different elements. It means that without increasing the number of primary sub-divisions, many hundreds of additional sub-divisions are available for use if required. For example, the numerous papers on the relation of evaporation to wind would all bear the numbers 551.55 : 551.573 and 551.573 : 551.55. The only alternative would be to make additional sub-divisions for "Wind, effect on evaporation" and "Evaporation, effect of wind", but it would be impossible to provide for all possible combinations of subjects in this way.

The colon is also useful for classifying works dealing with the relations between meteorology and other subjects, such as agriculture, aeronautics, hygiene, etc. The number for agriculture for example is 63, and an article on agricultural meteorology would have the number 551.5 : 63.

(2) *The Round Bracket* serves a double purpose. When it encloses a number beginning with zero, it is used to distinguish the form, origin or special nature of the work considered. For example a Manual of Atmospheric Electricity would have the number 551.594 (02), (02) being the number for manuals. This has the advantage that all manuals and text-books on a subject can be readily picked out.

When the bracket encloses a number beginning with a figure other than zero it represents "place". For example the number (42) represents England, and 551.577.2 (42) represents distribution of precipitation over England. Geographical numbers can be applied to certain specified sub-divisions of meterorology, including all those which specifically refer to "distribution at earth's surface".

4. **The present position.**—The revised classification will be considered by the International Meteorological Conference at Warsaw in September. Until the result of that consideration is known, it should not be taken into use in meteorological libraries. Meanwhile, however, a new German edition of the whole of the Universal Decimal Classification has been in course of publication in Berlin ; it was obviously desirable that the revised classification for meteorology should be included in this edition, but the printing contract did not allow of a delay until the autumn. It was accordingly agreed that the printing should go forward, and that the classification should be presented to the Conference for acceptance or rejection as a whole, without any modifications of detail.

NOTE.—The full classification was accepted and will be published by the International Meteorological Organization as part of the Proceedings of the Conference at Warsaw in September, 1935.

APPENDIX XXIII.—ORGANIZED RESEARCH IN METEOROLOGY

(Minutes IX, pp. 53–4)

BY LT. COL. E. GOLD, D.S.O., F.R.S. (*Assistant Director, Meteorological Office, London*) and F. J. W. WHIPPLE, SC.D. (*Superintendent, Kew Observatory, Richmond, Surrey*)

The following brief memorandum has been prepared by us as a basis for discussion. It is not an expression of policy.

There are two main divisions of Meteorological Research—The Physical and the Statistical. Broadly speaking the physical problems lend themselves more readily to individual research and statistical problems to co-operative research.

Is an official Meteorological Office concerned with the development of meteorological science purely as a branch of natural knowledge ? It is clearly concerned with any development affecting the efficiency with which it can meet its obligations in regard to the supply of forecasts and information to the public ; and it may be argued from experience that any development in pure science, however academic it may seem at first, will ultimately affect applied science. But that does not really answer the question ; it merely leaves in the background the utilitarian reason which is the real motive force. The answer to the question may be : "Only in so far as the additions to knowledge will be 'useful'. Academic research should be left to the Universities and Research Institutes". It must then be recognised that the answer determines the policy of the office and all the scientific men in it will be set to "useful" work.

If the answer to the question is "Yes", without any qualification, then the policy of the office must be in line, i.e. the scientific officer who has shown ability of a high order in research must be left to do research on his own lines whether it "pays" or no. He may and usually will prefer to do research on one of a series of problems, the solution of which will "pay" : but if he chooses an apparently academic problem of his own, he will be free to do so. In some cases the distinction between academic research and "useful" research is clear, but more researches are of mixed character in this respect.

At the present time there is no doubt that much original meteorological research must be done by the personnel of Meteorological Offices : on the one hand the provision for meteorological research in Universities is not adequate and on the other hand the ablest men are naturally drawn to the Meteorological Offices and the facilities for research, e.g. in the way of literature and records, are greater in the Meteorological Offices.

Ought Meteorological Offices therefore to regard it as a kind of "insurance" to have on their staff some meteorologists over and above the minimum required for the routine work ?

If the best results are to be achieved, then some exchange of information as to what main pieces of research are being undertaken, is desirable. For example, the Meteorological Office, London, a few years ago undertook an elaborate research at Cardington into wind structure. Clearly it would have been a great waste of effort if simultaneously Australia or Canada had undertaken the same research. If that is granted, then a practical question arises as to the best procedure for keeping one another informed.

It is often suggested that Meteorology suffers from the drawback that there is little organized research in the subject. The Meteorological Services publish a stupendous amount of information which should be useful to students, but make little effort to ensure that there shall be students to utilize the information. An historical example is the elaboration of the *Quarterly Weather Report* in which from 1869 to 1880 the autographic records of seven observatories were reproduced with the corresponding weather maps. No systematic use was ever made of this publication because it was nobody's business. Indeed there was only one professional meteorologist with academic standing in the country at the time.

Nowadays there is of course much valuable research going on but the majority of the professional staff of meteorological offices have their official hours well filled with their prescribed duties. They may find time for minor research suggested by phenomena which come to their notice but they are likely to feel that they have not added greatly to the store of knowledge. This is not to say that their time is not well spent. In every branch of science which has practical applications there must as time goes on be a larger proportion of people applying known scientific principles.

In considering organized research the real question to be faced is—Can we imagine discoveries which would be made if certain fairly obvious lines of investigation were followed up? An example of the success of systematic investigation is that started in India and carried on in England by Sir Gilbert Walker on weather correlations and long-range forecasting. This is work which requires to be revised and kept up to date. There are always possible correlations to be explored, so that the extent to which the method is applicable in one part of the world or another may be learned. Further, there are fundamental questions as to the mechanism by which the weather of one season in one part of the world influences the weather of a later season in another part. It is here that systematic research is required. Set the problem to the right man and results of the highest value may be the harvest.

Another line of investigation is that in which Shaw and Lempfert were pioneers when they wrote the "Life History of Surface Air Currents". Nowadays studies of that type have to be carried out with the aid of upper air observations. Material which is more or less suitable accumulates at an alarming rate; it is published to a large extent by the International Meteorological Organization, but no provision is made internationally for the utilization of the material: it is doubtful if it could be made internationally. We cannot even say whether anything would come of a close analysis of all the data for a run of international days. The success of the "Life History of Surface Air Currents" was due to the open time scale. The weather situation was followed from hour to hour. The latest work of the Norwegian school has been on similar lines, several balloon ascents each day having been demanded from each upper air observatory. Is this the key to progress? We are all impressed by the efficiency of the new method but it is hardly credible that useful information could not be extracted from the accumulated material. Useful information means information which can be presented in such a way that the reader will get a new insight into what happened in the atmosphere on a particular occasion, a new insight into what may be expected to happen on future occasions. There is scope here for systematic research. A great deal of labour is needed even before the old ideas can be tested, still more before originality can have an opportunity.

A question which is often raised is whether the practice of forecasting would be improved if there were more opportunity to discuss the failures of forecasts, the unexpected development of a depression, the occurrence of heavy rain where a mere drizzle was anticipated. Naturally a Forecast Service examines these failures as they arise and tries to discover their cause: but a systematic examination by a research section might well prove highly profitable. Occasionally the research section would have at its disposal information which was not available when the original forecasts were made. In particular the results of balloon soundings could be utilized and conclusions might be reached as to the expenditure which would be justified in arranging for radio soundings in key positions.

Another line of investigation would be the testing of mathematical schemes of forecasting such as have been advocated in France and in Norway. English meteorologists are sceptical as to the value of these schemes, but it would be much better if definite conclusions could be reached and published.

It is clear that the obvious openings for work likely to prove profitable to the meteorological service are sufficiently numerous to justify the organization of research.

APPENDIX XXIV.—GEOPHYSICAL SUBJECTS AND THE RESPONSIBILITY OF METEOROLOGICAL SERVICES (Minutes IX, pp. 54–6)

By F. J. W. Whipple, Sc.D.
(Superintendent, Kew Observatory, Richmond, Surrey)

In many countries the meteorological organization has undertaken responsibility for observations which are not directly connected with meteorology. This is a convenient arrangement in that the additional observations require the regular time-table of a meteorological station. The following table shows the extent to which magnetic (M) and seismological (S) stations in the British Empire are associated with meteorological services.

Magnetic and Seismological Observatories

	Attached to Meteorological Services.	Attached to other Government Departments, Universities, etc.	Private.
British Isles	Lerwick (M) .. Eskdalemuir (M) Valentia (M) .. Kew (S) ..	.. Abinger (M) .. .. Aberdeen (S) .. .. Edinburgh (S). .. Durham (S). Oxford (S). Bidston (S).	.. Stonyhurst (S) (M). .. West Bromwich (S). .. Dublin, Rathfarnham Castle (S).
Canada	Meanook (M) Agincourt (M) Toronto (S) .. Victoria B.C. (S).	.. Ottawa (S). .. Halifax (S). .. Saskatoon (S).	
Australia	—	Toolangi (M) Melbourne (S). Adelaide (S). Perth (S). Riverview (S).	.. Watheroo (M) (Carnegie Institution).
New Zealand	—	Christchurch (M) (S) .. Wellington (S). 7 other Stations in New Zealand (S). Chatham Island (S).	2 Stations (S).
Fiji	—	Suva (S).	
Samoa	Apia* (S) (M).		
East Africa	Entebbe (S).		
South Africa	—	Johannesburg (S). Cape Town (S).	
India	Kodaikanal (S) Alibag (M) .. Bombay (S). Agra (S). Calcutta (S).	.. Dehra Dun (M) (S) .. Hyderabad (S).	.. Oorgaum (Mysore) (S).
Ceylon	Colombo* (S).		
Hong Kong	Hong Kong* (S) (M).		
Mauritius	Mauritius* (S) (M).		

* In this table an asterisk indicates that an observatory is responsible for the meteorological service. It will be noticed that there are no effective seismological or magnetic stations in the British West Indies, in west Africa, in the Strait Settlements or in the Atlantic Islands (Ascension, St. Helena and Falkland Islands).

1. **Terrestrial Magnetism.**—Terrestrial Magnetism is a subject of practical importance in connexion with navigation and also in connexion with mining, but the meteorologist's interest in the subject is mainly academic. Any expectation of immediate connexion between magnetic phenomena and weather has been disappointed. For various historical reasons meteorological departments have become charged with the duty of maintaining magnetic observations.

In the British Isles the magnetographs at Kew and Eskdalemuir had been in operation for 50 years and two years respectively before the observatories were taken over by the Meteorological Office.

In Canada the National Meteorological Service seems to have developed from the observatory at Toronto which was originally established for magnetic observations.

In Australia the meteorological service is for the Commonwealth but the principal observatories are maintained by the States. The Commonwealth Weather Bureau is not charged with magnetics or seismology.

In New Zealand the Magnetic observatory at Christchurch and the seismological one at Wellington are, like the Meteorological Service, under the Department of Scientific and Industrial Research.

In India, the head of the Meteorological Department is also the Director General of Observatories. In this capacity he maintains the Magnetic Observatory at Alibag. The magnetic observations at Kodaikanal were suppressed as a post-war economy. The magnetic observatory at Dehra Dun is maintained by the Survey of India.

At the small dependencies Samoa, Hong Kong and Mauritius, the observatories where magnetic observations are maintained are also the centres of the meteorological organizations.

At the meeting of the International Union of Geodesy and Geophysics, in Stockholm, in 1930, a Committee was appointed to make recommendations as to the positions of the new observatories required to facilitate the study of the daily changes of the magnetic elements. Of the points selected by the Committee and shown in the maps accompanying the report† presented at Lisbon in 1933 the following are in the British Empire:—

Canada, Chesterfield Inlet. (Occupied for the Polar Year.)
South Africa, Cape Town.
Atlantic, St. Helena.
East Africa, Nairobi.
South India, Comorin.
Southern Ocean, Kerguelen.

† Bulletin No. 9. Union Géodésique et Géophysique Internationale, Association de Magnétisme et électricité terrestres, Copenhagen, 1934, p. 107.

With the exception of Chesterfield Inlet all of these places are in the southern hemisphere. Kerguelen in lat. 50° and south-south-east of Mauritius would be the most southerly magnetic observatory with the exception of that maintained by the Argentine government at Orcadas.

With regard to the inclusion of stations like St. Helena, Nairobi and Comorin in their list the Committee state :—

> " While the question of distribution of observatories was originally regarded as requiring utmost uniformity of distribution, it has been generally felt that magnetic phenomena in polar regions were so much more varied than in tropical regions that the equatorial belt could be satisfactorily represented by relatively few stations. Thus, for some time, efforts were concentrated toward the establishment of new stations in the polar regions. Later theoretical considerations of magnetic and electric phenomena have, however, clearly indicated that, in order to advance our knowledge of the laws and causes of the geophysical phenomena evidenced in terrestrial magnetism and electricity, attention must be given as well to the accumulation of data within the tropical and subtropical regions. The Committee feels that all interested in the Association's field of investigation must be grateful to the Carnegie Institution of Washington, which in determining upon the locations of two observatories to be operated by its Department of Terrestrial Magnetism, anticipated this fact and placed them in the southern hemisphere, namely, practically on the magnetic equator at Huancayo in Peru and at Watheroo in Western Australia. Both stations are most fittingly located to test more recent developments in magnetic theory concerned with electric currents in the upper atmosphere. The startling records of Huancayo as compared with those of Batavia emphasise the needs of more and better equipped observatories in the equatorial belt. These and the results at Watheroo enhance the potential value of accumulated and continued work at Apia and point to the utmost importance of additional stations in Africa."

At the same meeting at Lisbon another committee presented a list of stations which it was suggested should be re-occupied from time to time for the investigation of the slow changes in the terrestrial magnetic elements. The numbers of stations in various parts of the Empire (with mandated territories) are given in the following list, the existing magnetic observatories not being counted.

Anglo-Egyptian Sudan	3	Nigeria	2
Gold Coast	1	Rhodesia..	2
Kenya	3	Sierra Leone	1
Tanganyika	2	South Africa	8
Uganda	2	South-West Africa ..	3
Aden	1	India	6
Baluchistan	1	Ceylon	1
British Guiana ..	1	Strait Settlements ..	1
Australia	19	New Zealand	2
Canada	17	West Indies	4
Atlantic Islands ..	5	Indian Ocean Islands ..	2
Pacific Islands ..	14		

No doubt the new magnetic ship provided by the British Admiralty will visit eventually the island and coastal stations in this list; arrangements for the necessary observations in Australia, Canada and India can readily be made by the authorities responsible for the observatories in those countries. It may prove most convenient for the stations in Africa to be visited by an observer making a special tour for the purpose.

2. **Seismology.**—Seismographs are maintained at a good many of the observatories attached to meteorological services.

There are two parts of the British Empire where seismology is a subject of vital importance, New Zealand and India. In New Zealand the Director of the Wellington Observatory is Dominion Astronomer and Seismologist and has established, under the Department of Scientific and Industrial Research, a good network of seismological stations. Several of these are equipped with Milne-Jaggar seismographs. In India the interest in seismology is shared with the Geological Survey and it remains to be seen whether an efficient organization for studying the nature of earthquakes will be developed under the stimulus of recent disasters. At present there is in India no observatory with complete equipment including a vertical seismograph, and there are no physicists whose primary duty is to advance seismology.

The following extract from the General Report of the Geological Survey of India for the year 1934 (Records 69 (1935) 26) is relevant.

> " India is but poorly provided with seismographs. There are instruments at Alipore (Calcutta), Agra, Dehra Dun, Colaba (Bombay), Oorgaum (Kolar Goldfields) and Rangoon, but all these instruments, except those of Oorgaum, proved too delicate to give a full record of the earthquake of 15th January, 1934. What is now needed are supplementary, less delicate instruments designed to function even during severe earthquakes. It is understood that an officer of the Meteorological Department is at work designing a type of seismograph that will comply with this criterion. In addition there is a pressing need for a much larger number of seismograph stations, particularly along the Himalayas, but also elsewhere."

There are many parts of the British Empire in which no provision is made for observations in seismology. The need for seismographs is greatest in the West Indies, where minor earthquakes are frequent and where major earthquakes, such as that which wrecked Kingston, Jamaica in 1902, are to be expected. At present it is very difficult to locate earthquakes in this region.*

* Note added July 1936. A Wiechart seismograph was installed at Montserrat in April 1936 as well as a number of Jaggar shock recorders.

Submarine earthquakes occur with considerable frequency under the South Atlantic. It would be of great assistance in locating these if seismographs were in operation at St. Helena, Ascension and the Falkland Islands. It would be appreciated by geophysicists if the authorities which undertake meteorological observations in these places would take steps to establish seismograph stations.

The meteorological service of east Africa has recently accepted responsibility for the seismograph at Entebbe. Considerable earthquakes in this region are fortunately rare, but they are of special interest owing to an apparent association with the Great Rift Valley. To locate such earthquakes two additional seismograph stations in the neighbourhood are needed and it is to be hoped they will be established before long.

3. **Atmospheric Electricity.**—Atmospheric Electricity is a branch of meteorology which is recognised at many meteorological observatories. Most of these confine their attention almost exclusively to recording potential gradient. In this category are Lerwick and Eskdalemuir, Apia, Hong Kong and Mauritius. In the Empire the only active centres of research attached to meteorological services are Kew, Bombay and Poona. Excellent work is being done by Dr. B. F. J. Schonland and his colleagues in South Africa, by Dr. T. W. Wormell at Cambridge, by A. R. Hogg at Canberra, and by Prof. J. J. Nolan and P. J. Nolan in Dublin.

Experience shews that a concentration of effort is desirable. There should be at least one observatory in the tropics with equipment for a thorough study of all the electrical processes in the atmosphere. It may be mentioned that at Kew Observatory the regular observations in fine weather include the measurement of potential gradient, of the conductivity of the air and of the air-earth current. In disturbed weather the charge on rain, the potential gradient and the intensity of point discharge are recorded. There is also apparatus for recording continuously the air-earth current, the ionisation and conductivity of the air. It is hoped that in the near future the intensity of ionising power, the quantity of radioactive matter in the air, and the variations in space charge will be recorded.

It will be realised, that there is a strong case for providing staff and equipment for electrical observations elsewhere and that the British Empire should have more observatories dealing thoroughly with the subject.

Finally it may be mentioned that there are several branches of geophysics which have been developed of late years and have not yet been dealt with in the routine of observatories. Such are the investigation of penetrating radiation, the transmission of wireless waves, the recording of atmospherics, the measurement of the quantity of ozone and the study of the light of the night sky. The question whether systematic and continuous observations in any of these subjects are necessary has to be asked. The place for systematic observations is an observatory, and we should extend our activities to meet the demand. This is in fact a necessity if the efficiency of the observatories is to be maintained. An expert on upper air soundings must be in touch with work on ozone, and an expert on terrestrial magnetism is lost if he does not know the latest work on the Heaviside and Appleton layers.

APPENDIX XXV.—AGRICULTURAL METEOROLOGY (Minutes X, pp. 57–60)

(*a*) Note on Agricultural Meteorology in British East Africa
(*b*) Meteorology and Agriculture in Canada

Note on Agricultural Meteorology in British East Africa

By A. Walter
(*Director, British East African Meteorological Service*)

A great deal of work has been done during the past five years in east Africa in connexion with agricultural meteorology. Attempts have been made to determine directly the soil moistures down to a depth of six feet by means of the new method of filter candles, described, I believe, in the first place by Floyd Heck in the *Journal of the American Society of Agronomy*, 1934.

One of the greatest difficulties in working out correlations between rainfall and crops has been found to lie in the determination of the degree of effective rainfall. It is clear that rain which does not increase the soil moisture to the depth of plant growth cannot be considered effective rainfall from the point of view of plant growth.

Most of our work has been done recently in connexion with the study of microclimates and the following method has been that which has been recommended generally :—

(1) The installation of small anemometers of the Fuess type in the interior of the plants themselves as well as on the periphery.

(2) The determination of humidities within the plant by the use of an Assmann Psychrometer.

(3) The erection of a standard station in the immediate neighbourhood to which all other observations are referred.

(4) The installation of soil thermometers.

The determination of soil temperature is made at 5 depths, from 5 cm. to 25 cm. by means of thermometers of special construction. These temperatures are taken in the open and under various crop covers and mulches, in order to determine the effects of shade. The advantage of this type of thermometer is that it can be used without disturbing the texture of the ground in any way. The great drying power of the sun in east Africa renders economic shading a very important problem.

Another matter which has exercised our attention is the temperature range within the plant itself. It has been found that within a few feet of the summit of certain crops, such as coffee, radiation at night is so intense that the temperature falls several degrees below that of the standard station.

This clearly increases the range of temperature to which the plant is exposed. The best method of dealing with these microclimatic observations could be discussed very fruitfully by others working on the same lines.

In addition to the question of microclimates, another problem has arisen concerning the distribution of insect pests in the various zones over east Africa, and it has become increasingly necessary to determine some means by which the climatic zones can be classified in regard to moisture and temperature. Various attempts have been made at different times to classify climatic zones by means of a single factor, and it would be of considerable use to territories like east Africa if the whole of this matter could be brought up for discussion at the International Conference.

The dominating factor in climate from the point of view of agriculture in such tropical countries as east and central Africa appears to be that of the diurnal variation. The best method of introducing this into the discussion of crops and climate would, I think, form a very useful subject for discussion. The best form of registering instruments for these microclimatic determinations would also form a useful topic. The points to consider are reliability, accessibility and long distance registration. The mercury-in-steel long distance thermometer has been tried out and it has not proved as satisfactory as we thought it would originally.

In regard to the diurnal variation, the problem which presents itself to us is that connected with the effect of the short period variation during the day. At one part of the 24 hours plants are exposed to conditions of tropical heat; during the remainder they are exposed to conditions similar to those of the temperate zone. How do they respond to these two conditions?

Should the critical temperature of the plant itself be the criterion? and, where temperatures or humidities rise above that value, should they be ignored and only those within the range of optimum growth conditions be used? If the plant suffers from exposure to temperatures above or below its optimum conditions, then shading during the day in the one case or during the night in the other becomes essential if the plants are to be grown economically. In many places in east Africa it is possible to grow sugar cane and apples, pineapples and plums side by side, in fact practically the whole range of tropical and temperate zone economic plants, but they do not produce the best results on account, it is thought, of their exposure to short period variations, the effect of which has not yet been sufficiently studied. This matter is of the utmost importance to the whole agricultural interests in east and central Africa.

(b) Meteorology and Agriculture in Canada

Note from The Canadian Meteorological Service

The Dominion Experimental Farms and the Meteorological Service are now very closely co-operating in obtaining full weather statistics from the Experimental Farms which are well located across the Dominion. It has been arranged that the Meteorological Service will supply the instruments, and give the necessary instructions in taking the observations, and the officials of the Experimental Farms will take the observations. There is in this way mutual co-operation but there has not been sufficient time to have the work fully organized. However, it is proceeding as rapidly as circumstances will permit. It is hoped in this way to attack many of the meteorological problems that affect the agriculturist and entomologist.

The Meteorological Service has been giving for some time forecasts to the fruit growers and others for use in their spraying operations during the spring and early summer. This year a new activity was initiated in April by setting up a forecasting service in the Okanagan Valley to give frost warnings during the blossom season. In this intensively cultivated fruit-growing region in British Columbia the orchardists have from year to year suffered partial or entire loss of their crops owing to the temperature during the night falling 5° or 6° F. below the freezing point for a brief period, half an hour to five hours. The growers have recently found it possible by using oil burners, coal briquette stoves, and even by burning brush, to raise the temperature of the orchards 8° or 10° F. above the surrounding district and thus save the crop.

These growers, however, often lit their heaters when the temperature in the early evening fell rapidly, but subsequently remained above the danger point. On the other hand, many of the orchardists had to keep close watch on the temperatures to be prepared for a sudden drop an hour or so before midnight. This year the orchard owners have been assisted by a special forecast broadcast at 7.30 each evening giving the minimum temperature expected during the night at ten orchards in typical locations in the valley, the suitability of the weather for spraying being included in the forecast.

The temperature forecast was in the first place based on the synoptic map. The forecaster had to decide if a front were going to pass. Then, if a cold front should pass, would the temperatures drop an increasing amount as the locality got a greater and greater distance behind the front. Such decisions could only be made by the forecaster from a map with a good network of synoptic stations. The most frequent situation was, however, to determine the minimum temperature when the controlling factor was not a change in the air mass but the radiation from the earth to the sky after sunset. An approximate value of the minimum temperature on these occasions was obtained from the formula due to L. Johnson and based on his observations from 1930 to 1935 for the Okanagan Valley in the State of Washington.

$$T_m = D - \frac{H - 35}{3} + V + V'$$

T_m = Minimum temperature during night usually at sunrise.
D = Dew-point at 4.30 p.m. on previous evening.
H = Relative humidity at 4.30 p.m. on previous evening.

V and V' are constants depending on the dew-point and relative humidity given by the following tables:—

Dew-point. °F	V	Relative Humidity %	V'
19–21	6	16–40	−2
22–25	5	41–52	−1
26–28	4	52–65	0
29–32	3	66–80	
33–35	2		

It was thus necessary to have two station networks, the first one being the regular synoptic network covering western North America as far south as Mexico and as far east as Hudson Bay, Winnipeg and Oklahoma with all available ships from the Pacific north of Honolulu and the 180th meridian. The second network was 23 stations located in the Okanagan which reported by telephone to the forecast office twice daily at noon and 4.30 p.m., giving wet- and dry-bulb temperatures, maximum and minimum temperatures, cloud and wind. This close network of stations in the area is essential. In order to have the network function effectively, it is almost a necessity to put the forecast centre in the area for which the forecast is made. The observers are in touch by telephone with the forecaster and their reports can be obtained and checked quickly. It is almost equally important for the forecaster to see the topography of the ground. Drainage of cold air down gentle slopes, and damming of cold air by obstacles are factors depending on topography that enter to a surprisingly great extent into the temperature which will occur at a definite point in an orchard.

APPENDIX XXVI.—UNIFORMITY IN CLIMATOLOGICAL OBSERVATIONS

(Minutes X, pp. 60–3).

(a) Memorandum by C. E. P. Brooks

(b) Memorandum by The Canadian Meteorological Service

(a) Memorandum by C. E. P. Brooks, D.Sc.

(Superintendent, General Climatology Division, Meteorological Office, London)

For the study of climatology it is important that the meteorological data from different stations should be comparable with one another; that is to say, the observations should be taken with comparable instruments under similar conditions of exposure at the same or comparable hours of the day and the data should be worked up in the same manner. A memorandum discussing these points was presented to the 1929 Conference and is published as Appendix XII to the Report of that Conference.

The meteorological data printed in the Colonial Blue Books do not all satisfy the above conditions; for example:—

1. The exposure of the instruments does not conform to the standard at all stations.
2. The data are not worked up in the same way at all stations.
3. There is considerable variation in the hours of observation at the different stations.

1. Exposure of instruments.—(a) The thermometers are not always exposed in a standard Stevenson screen. At some stations a single-louvred screen is used, at some stations the screen is placed under a shelter and at some stations the thermometers are exposed in a wire cage under a shelter. It was formerly supposed that the best form of exposure for thermometers in tropical countries was a thatched shelter with open sides, but experiments carried out in India by J. H. Field showed that even in hot countries the Stevenson screen in the open gives a better representation of the air temperature than does a thatched shelter. The Stevenson screen has the additional advantage of being cheaper to construct. It should be painted white and repainted at intervals whenever necessary.

(b) The exposure of the rain-gauge is not uniform, the rim of the gauge being at different heights above the ground at different stations. A certain amount of variation may be unavoidable owing to the different types of rain prevailing in different localities. The rain-gauge should be fixed at a height which, for the station in question, is most likely to enable it to record the true rainfall. If the rain-gauge stands too high, in windy weather rain which should fall into it is carried outside it by eddies of wind, it therefore records less than the true amount. If, on the other hand, the gauge is too near the ground, when heavy rain is falling, rain which falls outside the gauge may splash into it causing it to register more than the true amount. In the British Isles the practice is to place the rim of the rain-gauge 1 ft. above the ground, the ground on which it stands being covered with short grass. If, however, at any particular station most of the rain falls in heavy showers without much wind, or if the gauge is standing on a hard surface, a more accurate record may be obtained by raising the rim of the gauge to about 2 ft.; if, on the other hand, the rain is accompanied frequently by strong winds, as in tropical hurricanes, raising the rim may introduce errors.

Some observations have recently been made on the splashing of rain. Splashing does not occur until the surface on which the rain is falling has become thoroughly wet; hence a hard surface such as concrete on which puddles form readily is likely to cause more and higher splashing than a surface covered with turf. This fact appears to have been borne out by the observations; of the surfaces tested, one covered with grass and weeds gave the lowest splashes.* In another set of observations,† a rain-gauge standing on concrete with its rim at the standard height of 1 ft. above the ground recorded one per cent more rain than a similar gauge with the standard exposure on turf. Another gauge standing on the concrete with its rim raised to 21 in. recorded about the same amount as the standard gauge.

* S. E. Ashmore, The splashing of rain. *London, Quart. J. R. met. Soc.*, 60, 1934, p. 517.

† F. J. W. Whipple, Rainfall as measured by gauges set in turf, gravel and concrete. *London, Met. Mag.*, 70, 1935, p. 32.

A rain-gauge should not be placed on a slope or on a wall or a roof if it can be avoided. In such positions a gauge will probably record too little rain. The error would be less if the gauge were placed on the leeward side or in the centre of the roof than if it were on the windward side.

(*c*) The heads of the anemometers at different stations are at different heights above the ground and above the neighbouring buildings. The velocity recorded by an anemometer is dependent on the height of the anemometer and also on the nature of the surface over which the wind has been blowing; hence both the height and the general exposure should be taken into account when interpreting the velocity recorded by an instrument in terms of the true wind speed or when comparing it with records from another station.

The standard exposure of an anemometer in Great Britain is at the top of a mast or skeleton tower 10 m. (33 ft.) high and well removed from all buildings and trees. At many stations such an exposure is not obtainable, but the anemometers should be at least 20 ft. above the top of the neighbouring buildings or trees. For anemometers exposed according to the standard conditions there is a table of equivalents of velocity and wind force on the Beaufort scale. (See " Meteorological Observer's Handbook," 1934, p. 45.) For anemometers whose exposures do not conform to that standard the velocities equivalent to the Beaufort wind forces will be different.

In Great Britain an attempt has been made recently to render the records of wind at different stations more comparable by introducing a quantity known as the " effective height "‡ which takes account of the nature of the exposure as well as the height of the anemometer. It is defined in the *Monthly Weather Report* as " an estimate of the height at which an anemometer would record an equal mean velocity in a situation free from obstructions ". From this quantity " effective height " and a table of variation of the wind velocity with height in an open situation, it is possible to draw up for any particular anemometer a table of velocities equivalent to the Beaufort wind forces. The following is the table of the variation of wind velocity with height given in the " Meteorological Observer's Handbook, 1934 " (p. 43); the velocities at the different heights are given as ratios of the velocity at 10 m.

Height (metres) ..	2	3	4	5	10	15	20	25	30	35	40
Ratio of velocity to that at 10 m.	0·78	0·82	0·85	0·89	1·00	1·08	1·15	1·20	1·24	1·28	1·32

To obtain a table of equivalents suitable for any anemometer, the values in the standard tables should be multiplied by the appropriate factor obtained from the above table.

2. **Working up the data.**—Different criteria are used for defining " rain day ", " day of clear sky ", " overcast day " and " day of gale ".

Rain day.—The customary definition of a " rain day " in this country is a day on which the precipitation amounts to 0·01 in. or more. If measurements are made in millimetres the practical equivalent of this standard is an amount of 0·2 mm. or more.

Days of clear and overcast sky.—Internationally these are defined as days on which the average cloudiness at the hours of observation is less than 2 tenths and more than 8 tenths respectively. A few stations are using different criteria for example, 1 tenth and 9 tenths, and no cloud and 10 tenths covered.

A day of gale should be defined as a day on which the wind reaches force 8 on the Beaufort scale.

3. **Hours of observation.**—The hours of observation at the different stations vary considerably. At stations which observe three times a day there are eight different combinations of hours in use; at stations observing twice daily, there are 12 different combinations, and at those stations which observe only once a day there are four different hours. An important consideration is that in any one area the hours of observation should be as nearly as possible the same. The standard hours for synoptic purposes have been fixed as 1, 7, 13 and 19h. G.M.T. ± 1 hour, and it is proposed that as far as possible the hours of observation at climatological stations should conform with one or more of these hours.

(*b*) Memorandum by The Canadian Meteorological Service

Considerable uniformity has been obtained in climatological data and methods in Great Britain and Canada, especially in regard to the exposure of the instruments and the types of instruments used in both services. One of the main reasons for this uniformity has been the wide use overseas of the British " Observer's Handbook " and undoubtedly the methods of observation given in that book have been followed to a very great extent. It would appear, therefore, that in order to maintain this uniformity it would be very advisable if when new editions of the " Observer's Handbook " are to be issued that the overseas Dominions snould be consulted, as in this way I believe we could maintain as far as the local circumstances permit, uniformity in instruments and methods.

We would also like to see a new edition of the " Computers' Handbook " with complete details of the method of reduction of autographic records in use in the British Meteorological Office. This would be very valuable to the overseas meteorologists and assist in maintaining uniformity.

Rain-gauges.—The notes of the original memorandum are included in Mr. Patterson's remarks reported in Minutes No. X, p. 61.

‡ For further information reference should be made to an article entitled " Anemometers and the Beaufort scale of wind force ". *London, Met. Mag.*, 67, 1932–3, p. 278.

Thermometers.—All our thermometers are now supplied with the National Physical Laboratory, certificate. The chief difficulty is that, at our northern stations where the mercury may be frozen for the whole twenty-four hours, the maximum does not function. There should be some kind of maximum thermometer devised that would permit of accurate maximum temperatures when the ordinary maximum is put out of commission. A small fan is now being built into the Stevenson screen to give adequate wet bulb ventilation and the United States psychrometrical tables are used. Previous to this we used Professor Guyot's tables as published in the Smithsonian collection of Meteorological and Physical Tables for Unventilated Thermometers. We have never used Glaisher's Tables.

Wind.—The 3-cup anemometer is used with a recording anemograph which gives each mile of wind and the direction to eight points. No attempt has been made to reduce the exposure of the anemometer to standard conditions.

Temperature.—In Canada the chief lack of uniformity in temperature observations arises from the fact that the synoptic hour for stations that telegraph their observations to the Head Office is based on eastern standard time, while all other stations use local time. Many of the climatological stations are equipped only with maximum and minimum thermometers while others have also the wet-and dry-bulb thermometers. As a consequence, apart from maximum and minimum temperatures, the temperature data at those stations in the same time zone are not always comparable. On this account it is very difficult to get a proper estimate of the diurnal curve of temperature or to use a formula that would reduce the data to a twenty-four hour standard.

Humidity.—The same remarks apply to the readings for the wet-and dry-bulb thermometers except for stations equipped with hygrograph; the readings obtained from the climatological stations and those from synoptic stations are not comparable.

Non-instrumental Observations.—The Canadian meteorological observers display the greatest lack of uniformity in their attention to such details as the occurrence of thunderstorms, hail, fog, motion of clouds, etc. The question is asked to what extent is the same difficulty encountered by other Services in the Empire and what steps are taken to remedy the deficiency in the case of voluntary observers. This is a real difficulty in climatology. It becomes particularly prominent in the plotting on maps of the frequency of occurrence of hail, thunderstorms, and fog. Areas will be found upon such maps where the frequency differs considerably from the general average, and the greatest frequency is generally to be found at the stations where the observers are generally excellent, and conversely, the frequencies are low where the observers are careless. It, therefore, becomes difficult to interpret the maps. Is it the practice throughout the other parts of the Empire to count one day for thunderstorms no matter how many may occur during the day ?

APPENDIX XXVII.—PUBLICATION OF CLIMATOLOGICAL OBSERVATIONS FROM THE COLONIES (Minutes X, p. 64)

By C. E. P. Brooks, D.Sc.
(*Superintendent, General Climatology Division, Meteorological Office, London*)

1. **The existing climatological tables in the Blue Books.**—The encouragement and general supervision of observations in those parts of the Empire which are not self-governing has been accepted by the Director of the Meteorological Office as part of the duties of that Office since very early days. The Dominions, India and some Colonies have developed their own meteorological services to meet their special needs, but many of the Colonies and Protectorates have not yet established a separate meteorological organization. Meteorological stations are maintained in most of these Colonies, but as a rule the observations are published only as appendices to the Colonial Blue Books, which are not readily accessible to foreign meteorologists.

With a view to making the great body of material in these appendices generally available, in 1910 the Meterorological Office suggested that 100 copies of each meteorological appendix should be reprinted and sent to the Director for distribution to the libraries of meteorological observatories and institutions, at home and abroad, with which the Office maintains an exchange of publications. This suggestion was approved by the Secretary of State for the Colonies, who addressed a circular on the subject, dated June 28, 1910, to the Officer Administering the Governments of British Crown Colonies and Protectorates. In response to this circular, reprints of data for 1909 were received from a few colonies, and for 1910 from 26.

At that time few of the officials responsible for these observations had received any training in meteorology, and the observations, though for the most part regularly and carefully taken, were of very unequal value, but all alike were distributed without comment under the auspices of the Meteorological Office. These reprints were the only source of meteorological data for a large part of the Empire, and, in consequence of the growing number of requests for copies, in 1923 it was necessary to ask the Colonial Office to arrange for the supply of 200 instead of 100 reprints each year.* At the same time an attempt was made to exercise some supervision, by circulating a questionnaire about the site, instruments and methods of reduction. The replies to this questionnaire provided material for a descriptive introduction to the collections of reprints, which was printed by the Meteorological Office and first issued with the observations for 1923. It also formed the basis of a number of letters containing suggestions for the improvement of the observations. Both these practices have been continuously carried on, and the tables included in the reprints, though rather variegated in form, have now reached a general standard of excellence in substance.

* The present list of recipients is shown in the Annex.

The introduction mentioned above, to the collection of reprints is published under the title " Notes on the meteorological observations made in British Colonies and Protectorates ". These Notes are revised every year and it would be greatly appreciated if officials responsible for the observations would co-operate in this revision by forwarding to the Director of the Meteorological Office information regarding any changes in their stations.

In order that full use may be made of meteorological data it is necessary to know the conditions under which the original observations were taken; hence when summaries of meteorological observations are published these conditions should be clearly set out. The following details are the minimum required :—

Latitude and longitude of the station.
Hours of observation and standard of time employed.
Height above sea level of the barometer.
Height of the anemometer above the ground and above the nearest building.
Corrections that have been applied to the pressure readings.

The form of publication assumes that the details of exposure of the instruments, the procedure in reading and setting the self-registering thermometers, and the definitions of days of various phenomena, are in accord with the customary usages. Any departures from convention should be noted in the tables. In the tables themselves it is important that the headings to the columns should indicate clearly the exact nature of the information given under them, and also the units employed. The amount of information published must naturally depend on the completeness of the observations and the space available. Whether daily observations are published or not, there should be a monthly and annual summary including the following data (where available) in this order.

Mean Pressure.—The data should be corrected for temperature and gravity and converted to millibars to one decimal place. " Inches of mercury " are now obsolete. If the station is at a small height either station level or sea level values can be given; for heights between about 150 and 3,000 feet it is better to give both sets of figures. Above 3,000 feet reduction to sea level may present difficulties.

Temperature.—The data should include the mean dry-bulb temperature for each hour of observation, the mean maximum, the mean minimum, and the highest maximum and lowest minimum during each month. The mean temperatures should be given in degrees and tenths and the extreme temperatures to the nearest whole degree.

Relative humidity.—The mean relative humidity should be given for each hour of observation in percentages to the nearest whole number.

Cloud Amount.—The mean amount of cloud for each hour of observation should be given on the scale 0—10 tenths of the sky covered. The observations should refer to the total amount of cloud present. The values should be given to the first place of decimals.

Rainfall.—The total and the maximum in 24 hours should be given in inches and hundredths or in millimetres and tenths.

Sunshine.—If a Campbell-Stokes sunshine recorder is in use, the measurements should be given in the form of mean daily amount (hours and tenths); percentage of possible duration can be added if desired.

Weather.—The columns under this heading should be adapted to the conditions of the particular country; but they should in general include the number of days of rain, clear sky, overcast sky, thunderstorms, hail, fog (i.e. visibility less than 1 Km. or 1,100 yards) and gale (Beaufort force 8 or above); days of snow and frost should be given if these phenomena occur.

Wind.—Where data of wind speed or wind force are available the mean speed can be given, or alternatively the number of occasions on which the wind speed or force lay between certain limits, for example, the number of occasions of calm, forces 1 to 3, 4 to 7, and 8 and over.

Wind directions should be given to 8 points, the number of occasions that each direction occurred being given. If the observer has entered the individual observations to 16 points the additional directions should be divided equally between the directions on either side of them; for example if there are 8 occasions of ENE. wind these should be entered NE. 4, E. 4. If however there is an odd number of occasions the odd one should be thrown clockwise, for example, 9 ENE. winds would be entered as NE. 4, E. 5. If there is a marked diurnal variation of wind direction, it is desirable to give a separate table for each hour of observation.

2. **The need for additional observations.**—The agenda of this Conference includes several memoranda, mainly in connexion with aviation meteorology, which emphasise the need for additional observations for special purposes. These include tables of frequency of different ranges of visibility, height of low cloud, and winds from different directions between specified limits of velocity, both on the surface and in the upper air. The data for British stations are included in a Meteorological Office publication entitled *Monthly Frequency Tables*. The form of the tables was laid down in the " Convention relating to the regulation of aerial navigation dated 13th October, 1919," Article 35 of which provides that " The High Contracting Parties undertake as far as they are respectively concerned to co-operate as far as possible in international measures concerning: (*a*) The collection and dissemination of statistical, current and special meteorological information, in accordance with the provisions of Annex G (2) ".

Upper air work is not yet feasible in all the Colonies which undertake meteorological observations but observations of horizontal visibility are readily made at most stations, requiring only a series of landmarks at certain distances. It is desirable that these valuable observations should be undertaken wherever practicable.

Observations of visibility however cannot be summarised in the usual way by taking averages, for the " average visibility " is an almost meaningless quantity. The information required is the frequency of different ranges of visibility, and since this is often subject to a large diurnal range, each hour of observation must be summarised separately. Hence the visibility summaries are bulky, as also are those of wind speed and direction. It is of little use to prepare summaries unless they are made generally available by publication, and the question of method of publication is submitted for discussion at this meeting.

There are two alternatives; inclusion in the existing tables of the Blue Books, or separate publication along the lines of the *Monthly Frequency Tables*. Inclusion in the Blue Book has two disadvantages; it would add considerably to their bulk while the regular recipients of the sets of reprints are not always those who are most interested in the special observations. Separate publication has the advantages that the list of recipients can be limited to those who will make most use of the data, and that duplication or some other comparatively cheap method of reproduction can be substituted for printing. Separate publication along the lines recommended by the International Commission for Air Navigation is therefore recommended as the more practicable alternative.

After publication comes the question of distribution. The distribution of the reprints from the Blue Books is carried out by this Office, but it will not be practicable for this process to be extended to include separate publications of frequency tables. The Director will, however, be pleased to supply a list of the names and addresses of suitable recipients.

These details of publication and distribution are bound up with another question. Within the last few years the status of meteorology in the Colonies and Protectorates has begun to undergo a change, marked by the development of special meteorological services or the appointment of trained meteorologists in a few of the larger Colonies or groups of Colonies. The tendency is for these new services to take their place as independent organizations, with their own publications independent of the Blue Books. This occurred especially in connexion with the Second International Polar Year. The various Colonial Governments were asked to publish the daily observations for certain stations *in extenso* for international use. Several responded by adding appendices to the usual tables in the Blue Books, but others—Nigeria and Bermuda—have printed special volumes. At present this process of independent publication has not gone very far, and there is still need for the circulation of the reprints from Blue Books. It is necessary, however, to consider the future, and especially whether it is practicable or desirable to encourage the extension of special publications to replace the Blue Book reprints for the purposes of climatology as well as of aviation.

Annex: List of Regular Recipients of Colonial Meteorological Reprints

Meteorological Office, London (6 copies for the use of various divisions).
Captain W. Ellery, Mercantile Marine Dept.
Sir Thomas Middleton, K.B.E., C.B., Development Commission.
Sir Napier Shaw, F.R.S.
Meteorological Office, Edinburgh.
Meteorological Office, Heliopolis, Egypt.
Meteorological Office, Valletta, Malta.
Statens Meteorologisk-Hydrografiska Anstalt, Stockholm.
K. Vetenskaps Akademiens Bibliotek, Stockholm.
Meteorologiska Observatorium, Upsala, Sweden.
Vervarslingi på Vestlandet, Bergen, Norway.
Det Norske Meteorologiske Institutt, Oslo, Norway.
Vaervarslingen for Nord-Norge, Tromsø, Norway.
Det Danske Meteorologiske Institut, Copenhagen.
The Central Geophysical Observatory, Leningrad, U.S.S.R.
Ilmatieteellinen Keskuslaitos, Helsinki, Finland.
Tartu Ulikooli Meteoroloogia Observatorium, Tartu, Estonia.
Instytut Geofizyki, Lwów, Poland.
Panstwowy Instytut Meteorologiczny, Warszawa, Poland.
Reichsamt für Wetterdienst, Berlin.
Meteorologisches Observatorium, Bremen.
H. Landesanstalt für Wetter und Gewasserkunde, Darmstadt.
Luftamt Dresden, Wetterdienst, Dresden.
Bibliothek, Deutsche Seewarte, Hamburg.
Universitäts-Bibliothek, Leipzig.
Luftamt München, Wetterdienst, München.
Luftamt Stuttgart, Wetterdienst, Stuttgart.
Kon. Ned. Aardrijkskundig Genootschap, Amsterdam.
Kon. Ned. Meteorologisch Instituut, De Bilt, Holland.
Institut Royal Météorologique de Belgique, Uccle, Belgium.
The Library, University College of north Wales, Bangor.
The City Librarian, Birmingham.
The Librarian, University Library, Birmingham.
The Botanic Garden, Cambridge.
Solar Physics Observatory, Cambridge.
The University Library, Cambridge.
University College of south Wales, Cardiff.
The Librarian, Trinity College, Dublin.
The Royal Society of Edinburgh.
The Librarian, The University, Glasgow.
The Royal Botanic Gardens, Kew.
The Public Libraries, Liverpool.
The Guildhall Library, London.
The Librarian, Imperial Institute, London.

The Royal Geographical Society, London.
The Royal Meteorological Society, London.
The Astronomer Royal, Royal Observatory, Greenwich.
The Keeper of the Science Library, Science Museum, London.
The Librarian, The University, Manchester.
The School of Geography, Oxford.
The Keeper, The Yorkshire Museum, York.
Académie des Sciences de l'Institut de France, Paris.
Office National Météorologique, Paris.
Service Hydrographique de la Marine, Paris.
Institut de Physique du Globe, Strasbourg.
Servei Meteorologic de Catalunya, Barcelona, Spain.
Observatorio del Ebro, Tortosa, Spain.
Instituto Geofisico, Universidade, Coimbra, Portugal.
Observatorio da Serra do Pilar, Vila Nova de Gaia, Portugal.
" La Meteorologia Pratica ", Perugia, Italy.
R. Ufficio Centrale di Meteorologia e Geofisica, Rome.
Schweizerische Meteorologische Centralanstalt, Zürich.
Institut für Kosmische Physik, Innsbruck, Austria.
Zentralanstalt für Meteorologie und Geodynamik, Vienna.
M. Kir Országos Meteorologiai és Földmágnességi Intézet, Buda-Pest, Hungary.
Státni Ústav Meteorologický, Prague.
Institut Météorologique Central de Bulgarie, Sofia.
Meteorologiska Observatorija, Belgrade, Yugoslavia.
Geofizicki Zavod, Zagreb, Yugoslavia.
Observatoire National d'Athènes, Greece.
Service Météorologique National, Ministère de l'Aéronautique, Athens.
The Meteorological Observatory, The University, Malta.
Observatoire de Zi-Ka-Wei, Shanghai, China.
Weather Bureau of Tyôsen, Zinsen, Korea.
Central Meteorological Observatory, Tokio, Japan.
The Librarian, Physical Institute, Imperial University, Tokio.
The Meteorological Office, Alipore, Calcutta, India.
Mysore Government Observatory, Bangalore, India.
Government Observatory, Bombay, India.
Director-General of Observatories, Meteorological Department, Poona, India.
The Observatory, Colombo, Ceylon.
Malayan Meteorological Service, Singapore.
Kon. Magnetisch en Meteorologisch Observatorium, Batavia, Java.
Weather Bureau, Manila, Philippine Islands.
Institut de Météorologie et de Physique du Globe, Université d'Algèr, Algiers.
Director-General, Physical Department, Cairo, Egypt.
The Officer in Charge, Division of Publications and Meteorology, Department of Agriculture, Accra, Gold Coast Colony.
The British East African Meteorological Service, Nairobi, Kenya.
The Chief Meteorologist, Department of Irrigation, Pretoria, South Africa.
The Meteorologist, Department of Agriculture, Salisbury, Southern Rhodesia, South Africa.
McGill University Library, Montreal, Canada.
The Royal Society of Canada, Ottawa.
The Meteorological Office, Toronto, Canada.
The Gonzales Heights Observatory, Victoria, British Columbia.
University of California Library, Berkeley, California.
American Meteorological Society, Blue Hill Meteorological Observatory, Milton, Mass., U.S.A.
American Geographical Society, New York.
Meteorological Observatory, Central Park, New York.
The Library, Smithsonian Institution, Washington, D.C.
The Library, Weather Bureau, Washington, D.C. (2 sets).
Biblioteca del Observatorio Meteorologica Central, Tacubaya, Mexico.
The Chief of Surveys, Panama Canal, Balboa Heights, Canal Zone.
Meteorological Office, St. Georges, Bermuda.
Observatorio del Colegio de Belen, Havana, Cuba.
Government Meteorologist, Jamaica Weather Service, Kingston, Jamaica.
The Director, Department of Agriculture, Georgetown, British Guiana.
Instituto de Meteorologia, Hidrometria e Ecologia Agricola, Rio de Janeiro, Brazil.
Dirección de Meteorologia, Ministerio de Agricultura de la Nacion, Buenos Aires, Argentine.
Servicio Meteorologico del Uruguay, Montevideo.
Oficina Meteorologica de Chile, Santiago, Chile.
Observatorio del Salto, Santiago, Chile.
Commonwealth Meteorological Bureau, Brisbane, Queensland.
Royal Society of New South Wales, Sydney, New South Wales.
The Divisional Meteorologist, Weather Bureau, Sydney, New South Wales.
Commonwealth Meteorological Bureau, Melbourne.
Meteorological Bureau, Adelaide, South Australia.
Commonwealth Meteorological Bureau, Perth, West Australia.
Commonwealth Meteorological Bureau, Hobart, Tasmania.
Dominion Meteorological Office, Wellington, New Zealand.
Royal Alfred Observatory, Mauritius.
The Harbour Master, Suva, Fiji Is.
The Observatory, Apia, Samoa.

APPENDIX XXVIII.—METHOD OF EXPRESSING THE WATER-VAPOUR CONTENT OF THE ATMOSPHERE (Minutes XI, pp. 67–9)

(*a*) Average Humidities

(*b*) Should the Water-Vapour Content of the Atmosphere be expressed in Terms of Relative Humidity, Vapour Pressure or Dew Point

(*a*) Average Humidities

By A. Walter

(*Director, British East African Meteorological Service*)

This Service is frequently asked to give some measure of the drying properties of the air in East Africa.

The diurnal variation in humidity is at times very considerable. For instance, there are days when humidity will vary from 90 per cent in the morning to 10 and 11 per cent in the afternoon. It is quite evident that an average value which presents a condition very similar to that obtaining at Kew, varying possibly one or two per cent from the European value, does not present the true condition in these regions.

Further, the averaging of percentages where the percentages vary over such a wide range is clearly wrong statistically, and we have adopted the principle of averaging the saturated vapour pressure and the actual vapour pressure and computing the average humidity from their percentage ratio. This process is very laborious, and it is doubtful whether the value obtained is worth the additional labour of computation. The mean certainly varies sometimes as much as 10 per cent from the mean of the percentages. The question, however, arises : does it represent the drying properties of the atmosphere in these regions ? It seems probable that it would be preferable to use the saturation deficit and to divide the day up into two periods, one from 6 p.m. to 6 a.m. and the other from 6 a.m. to 6 p.m., averaging the values out over these two periods ; but even this does not appear to give a measure of the effective drying power of the atmosphere.

The main industries concerned are :—Sisal Industry in connexion with dry decortication ; the Flour Industry in connexion with loss of weight in packing ; the Paper Industry ; the Wood Seasoning Plant ; Refrigeration.

(*b*) Should the Water-Vapour Content of the Atmosphere be expressed in Terms of Relative Humidity, Vapour Pressure, or Dew Point ?

Note by The Canadian Meteorological Service

Hitherto relative humidity has been the standard form in which to express the water-vapour content of the atmosphere. As, however, relative humidity is dependent on temperature, it would seem to be more logical to use the terms that define the water-vapour content independent of other elements. Dew point giving the saturation pressure is a very convenient term when it is desired to know how near the air is to saturation, and should be especially useful in estimating the vapour content of the atmosphere. It would seem that this is more expressive than the vapour pressure which does not itself indicate how near the air may be to saturation.

On account of the great variation in altitude range from sea level to over 7,000 ft. in the case of a mountain station in Canada, it has been suggested that water vapour should be expressed in grammes per kilogram as this allows for the variation at high level stations to be co-ordinated with data from aerological ascents where this ratio is commonly used.

Of recent years in this country air conditioning has come into very considerable prominence and absolute humidity has been the usual term of reference. We have at times been called upon to supply humidity data in the form of grammes per cubic metre, but this does not appear to be as satisfactory as grammes per kilogram and, consequently, it appears preferable to adhere to this latter method of expressing the water vapour content. The experience of other parts of the Empire in regard to the use of these various terms would be very much appreciated.

APPENDIX XXIX.—SOIL TEMPERATURE (Minutes XI, pp. 69–72)

(*a*) Note by The Canadian Meteorological Service

(*b*) Note by L. A. Ramdas

(*a*) Note by the Canadian Meteorological Service

Soil temperature has been measured by means of platinum thermometers for many years at the Meteorological Office at Toronto, and for a short period at the Agricultural College in Winnipeg at eight depths, surface, 4 in., 10 in., 20 in., 40 in., 66 in., 9 ft., 15 ft. Soil temperature has also been measured from time to time at various places in Canada. In co-operation with the Department of Agriculture soil thermometers are being installed at the Experimental Farms, and as this work is just being established, the question is raised as to the depths at which these temperatures are to be taken. It is considered that as far as possible uniformity should be obtained and, if possible, that the same practice should be adopted throughout the Empire. In Canada we are faced with the difficulty of measuring the temperatures near the earth's surface, such as 4 in. and 8 in., throughout the year when owing to frost and snow this cannot very well be done by the ordinary mercurial thermometers. Then at depths of 1 ft. or more if the observations are to be taken it would require the tube in which the thermometers are placed to be about 2 ft. above the ground in order to protect them from the snow. If the snow were kept clear around the thermometer, the earth temperatures would be very different from what they would be with the snow cover. There is, however, the question as to whether heat or cold would be conducted down the tube and affect the readings.

In connexion with earth temperatures, there is the great problem of the temperatures at which insects can thrive or be destroyed, the depth at which they hibernate during the winter and the temperatures they can withstand. Also there is the question of the earth temperatures necessary for optimum growth in plants. It is possible that for these special investigations uniform depths should not be attempted, but that the depth should depend on the type of experiment that is being carried on. However, for regular observations it is considered that certain definite depths should be established, and we would like to know how the particular depths that are being used in England have been chosen.

It would seem that soil thermometers in the zone of diurnal variation should be read as nearly as possible at the times corresponding with their maximum and minimum temperatures, if only two readings can be taken, but as the soil thermometers are just being introduced, the question is raised as to the hours other Services have found most suitable.

(*b*) Note by L. A. Ramdas, Ph.D.

(*India Meteorological Department*)

The diurnal variation of soil temperatures is found to decrease rapidly with depth, becoming negligible at a depth of about 1 ft. below the surface. For agricultural purposes it is useful to record temperatures at (1) surface (a thermometer having sufficiently large range, laid horizontally on the ground, with its bulb kept covered with a thin layer of soil is used at Poona), (2) 3 in., (3) 6 in., and (4) 1 ft. depths. The times of observation at each place should depend upon the epochs of maximum and minimum temperatures and their variation with depth in the soil and with the season. Wherever it is practicable only to record the data four times daily, it is suggested that local times of observation, say 6h., 10h., 14h., and 18h. be chosen. The observatory at Poona has been taking hourly or two-hourly observations in connexion with investigations on the effect of surface " cover " (including colour and vegetation) on soil temperatures during the dry season.

The drawing up of specifications of suitable elbow-type, soil thermometers for shallow depths of soil is desirable.

APPENDIX XXX.—AIR MASSES AS UNITS IN CLIMATOLOGY (Minutes XII, pp. 72–4)

(*a*) Memorandum by C. E. P. Brooks

(*b*) Memorandum by The Canadian Meteorological Service

(*a*) Memorandum by C. E. P. Brooks, D.Sc.

(*Superintendent, General Climatology Division, Meteorological Office, London*)

1. Introduction.—It was early recognised that the weather depends to a great extent on the direction of the wind. Sir Francis Bacon, in his entertaining book " The Naturall History of Windes," goes into the properties of the various winds in great detail, and even quotes the well known derogatory couplet about the wind from the east. Bacon realised that winds derive these properties from the climates of the parts of the earth over which they blow, and further, that winds reaching England from the same direction may have different origins, and hence different properties.

Curiously, the invention of meteorological instruments seems to have delayed the study of air masses. Thus, while Dove knew that (in Bacon's phrase) " every wind has its weather," he analysed the weather into its various elements, and constructed wind roses for each separate element. Natural processes, however, do not depend so much on the isolated effects of temperature, wind, humidity, etc., as on their combined effects. These effects are sometimes highly complicated, and may include factors which are not considered in ordinary climatological analysis. Thus, we hear much about " bracing " and " relaxing " weather, but the precise meteorological significance of these terms is hard to define, and attempts to relate health to individual climatic elements have had little success.

Interest in air masses was not revived until the present century, and at first almost entirely from the synoptic point of view, and especially as part of the detailed study of the structure of barometric depressions. In 1906, appeared the classical memoir by Sir Napier Shaw and R. G. K. Lempfert on " The Life History of surface Air Currents," followed after about ten years by a series of publications by the Norwegian meteorologists. These researches present a picture of the weather processes of Europe as the result of the interactions of a number of great currents or masses of air each of which possesses special characteristics depending on its place of origin and the route which it has followed.

At this point we must consider the meaning of the term " air mass." It cannot be applied to a shallow or local wind such as a sea breeze, for although land and sea breezes may appear to differ considerably in their properties, these differences are merely incidental to the different diurnal variations of temperature over land and sea. Tor Bergeron* gives the following criteria :—The air mass must be deeper than the height to which the entropy can be appreciably altered during 24 hours by influences extending from below, and it must reach at least to the level of important condensation in the temperate zone (Z greater than 1,000 m.). The breadth must be of the order of 1,000 Km. (between 500 and 5,000 Km.) and the length at least 500 Km. An air mass must either be homogeneous in all horizontal directions, or if the extreme limits present differences, the gradient within the air mass must be small and change little.

2. Air mass analysis in temperate regions.—In Europe ten different types of air masses have been distinguished, namely, four types classified according to place of origin as Polar, Tropical, Maritime and Continental ; four types classified according to origin and track as Polar maritime, Polar continental, Tropical maritime and Tropical continental, and two indeterminate types, Indifferent and Mixed air.

* Über die dreidimensional verknüpfende Wetteranalyse. *Oslo, Geofys. Publ.* 5, 1930, No. 6.

Each type of air mass has its own type of weather, often very characteristic, depending on the initial properties of the air and the processes which it has undergone during its journey. For example, polar maritime air is air which, initially cold, has followed a long course over a relatively warm ocean, absorbing heat and moisture from below and becoming unstable. It brings a type of bright clear weather alternating with heavy showers of rain or hail, which is quite characteristic, but would be hard to represent by statistics of temperature, rainfall, etc. On the other hand, warm air masses cooled from below are stable and the flow near the ground is almost laminar ; they can give poor visibility, mist and drizzle but not heavy showers. These processes are described in detail by Bergeron in the publication referred to above.

In any one month a station may successively come under the influence of several different types of air mass, each bringing its own characteristic weather. In the well known American phrase, the weather is made up of " samples." The average temperature, humidity and cloudiness of the month give only a poor idea of the month's weather. Frequency tables of the individual climatic elements do not entirely complete the picture ; for example, a prolonged steady fall of rain constitutes quite different weather from the same amount coming in a series of short but heavy showers. Hence in recent years the application of air mass analysis to climatology as well as to synoptic and dynamical meteorology, has been rapidly gaining ground, and a number of studies have been made, chiefly on the continent of Europe, in which the climate of a station is represented by the frequency of different air masses of different weather characteristics.

A few examples of these studies may be quoted for reference :—

Friedrichs, H. ; Über die Luftkörper. *Beitr. Geophys., Leipzig,* **28**, 1930, pp. 59–100.

Links, F. and E. Dinies ; Über Luftkörperbestimmungen. *Z. angew. Meteor., Leipzig,* **47**, 1930, pp. 1–5.

Dinies, E. ; Luftkörper-Klimatologie, *Hamburg, Aus. d. Arch. dtsch. Seew.,* **50**, No. 6, 1932.

Geiger, R. ; Über die Entwicklung von Luftkörperwetterlagen und über Luftkörperfolgen in München. *Z. angew. Meteor. Leipzig.,* **49**, 1932, pp. 359–70.

Tschierske, H. ; Die geographische Verbreitung troposphärische Luftmassen in Europa. *Leipzig, Mitt. Ges. Erdk.,* **52**, 1933, pp. 171–89.

Voigts, H. ; Zum Luftkörperklima der Lübecker Bucht. *Met. Z. Braunschweiz,* **50**, 1933, pp. 498–503.

A few similar studies have been made in North America, of which the following may be mentioned :

Willett, H. C. ; American air mass properties. *Cambridge, Mass., Pap. Phys. Ocean. Met.,* **2**, 1933, No. 2.

Byers, H. R. ; The air masses of the North Pacific. *La Jolla., Bull. Scripps. Instn. Oceanogr. tech.,* **3**, No. 14, 1934, pp. 311–54.

3. Air mass analysis in tropical regions.—At tropical stations the phenomena of air masses are probably simpler than in Europe, though detailed studies on the basis of synoptic charts may reveal some unexpected features. As an example of the interaction of two strongly contrasted air masses, we may consider the spring weather at a station, Jos, in the interior of Nigeria. In March and April the winds blow mainly from NE., N., NW. and SW. The winds from N. and NE. are almost without exception dry and dusty, hot during the day but cool at night. The SW. winds on the other hand fall into two quite distinct types, one hot and dry, the other cool and moist. From March 1 to April 15, 1934, there were eight occasions of SW. wind at 3 p.m., distributed as follows :—

Continental Type.			Maritime Type.		
No.	Temperature.	Depression of Wet Bulb.	No.	Temperature.	Depression of Wet Bulb.
3	86°–90°	21°–24°	4	68°–76°	3°–4°

There was only one intermediate observation, with a temperature of 82°, depression of wet bulb 15°. The SW. winds of continental type all occurred immediately after a change of wind from NE., and were evidently composed of air which had come from the north-east but was being blown back on its course. The maritime type, on the other hand, was composed of air which had blown direct from the Gulf of Guinea. The NW. winds generally gave weather intermediate between the continental and maritime types.

Taking into account all the criteria—temperature, humidity, dustiness and wind direction—there is rarely any difficulty in classifying the air of any day into continental (C), maritime (M) or mixed (X). During the period considered the characteristics of these were as follows :—

Continental Air.—Temperature at 3 p.m. 84° to 96° F., depression of wet bulb 15° to 32°, wind variable but mainly NE. or N., air generally dusty.

Maritime Air.—Temperature at 3 p.m. 66° to 76° F., depression of wet bulb 2° to 4°, wind generally SW.

Mixed Air.—Temperature 81° to 87°, depression of wet bulb 7° to 15°, wind generally NW.

It is obvious that far more information is given about the weather of, for example, March, 1934 at Jos, by the statement that there were 22 days of continental air, 3 days of maritime air and 6 days of mixed air than by giving merely the mean temperature and humidity for the month, and such information would be a valuable addition to the climatological tables. This is true of any station at which the weather of a month is made up of two or more dissimilar elements, constituting a " Collective climate." Some preliminary research would be necessary to determine the characteristics of different air masses at different stations in different months, and the identification in doubtful cases would be made more sure if daily weather charts were available, but in the example chosen the allocation was generally quite clear from the observations at a single station.

The use of air mass analysis in climatology is accordingly suggested as a promising subject for research in tropical countries.

(b) Memorandum by the Canadian Meteorological Service

The classification of air masses for synoptic purposes is that set out by Willett based largely on Bergeron. For a greater portion of the time the whole of Canada is in polar continental air (Pc) and for shorter periods in transformed polar continental air (NPc). These masses are much more variable in temperature and moisture content than are maritime masses and the great majority of tropical air masses. Thus, although it is known that a station is in polar air, very little information is conveyed as to its temperature. On the other hand, tropical air is comparatively infrequent in Canada but its temperature range is small. The distinction to be drawn between polar air and transformed polar air is often arbitrary. Thus, in attempting to find a basis for the use of air masses as climatological units in North America, the following difficulties were found.

In the winter months the air masses labelled Pc in the American terminology differ so widely in character that no basis could be found from surface observations for the use of Pc as a unit. Referring to Bergeron's maps in the *Meteorologische Zeitschrift,* for September, 1930, it is probable (in winter) that there is a mean position for the fronts separating polar basin air from north Pacific air which lies somewhat south of the Arctic Ocean and crosses through northern Alaska. The cold air masses which appear in the Yukon or at the mouth of the Mackenzie or the western side of the Arctic Archipelago are probably Pc masses coming from the north of this mean front. However, in practice it is found that some of these masses are intensely cold at the surface while others are relatively mild. In some years the intensely cold masses appear fairly frequently. In fact, in February, 1934, several appeared in quick succession. It is more usual, however, for several fronts of very moderate severity to occur before one of remarkable severity is first observed on the Canadian Arctic coast. The subsequent history of these air masses in traversing the northern portion of the continent differs greatly in the case of the mild and severe types. It, therefore, appears that Pc masses may have at least two regions of immediate origin before arriving in Canada. To make climatological units of these two types it will be necessary to have not only surface observations but also data from temperature and humidity at levels above the surface. In the case of Pp units which appear in British Columbia there are three types; sub-tropical, polar-Pacific, and polar basin air masses. The type can be only imperfectly recognised from the coastal observations. Again it will be a prime necessity to have upper air ascents on the Canadian coast in parallel with those made by the American Service at Seattle. In the case of sub-tropical air masses arriving through the United States or continental air masses from the same region, there is or will be probably sufficient upper air data available for the current differentiation of type.

There are also air masses of at present uncertain source but ascribed by Willett to the Polar-Atlantic region. These infrequently invade the Hudson Strait and Labrador region in the spring and summer. There are no available aerological data except those obtained in Boston. The surface indications from wind, temperature, and humidity are insufficient to make certain the identification of such air masses. They should have attained a state approaching equilibrium with Polar-Atlantic conditions before they are deflected sufficiently to the right, while moving south, to affect the Labrador region and to earn a separate classification. As a necessary preliminary to their recognition the establishment of an upper air station at Chimo will be necessary. Chesterfield will generally be too far west for such a purpose.

To summarise, it may be said that the first requisite for the establishment of air masses as climatological units is their certain recognition as units with definite characteristics immediately upon their entrance to the Continent. Once the air mass has been definitely assigned a name and source characteristics, we could then divide our surface meteorological observations according to the travel of these masses. That is to say, instead of using calendar periods for the striking of means and extremes of the different meteorological factors, we could use periods at each station commencing and terminating with the arrival of the new front in the former case and the displacement by a mass of different characteristics in the latter case. By such means we could finally arrive at the average and extreme modifications which such masses undergo in passage across Canada in the different seasons of the year. It might also be possible to distinguish local modifications depending upon topographical peculiarities of the different regions. Eventually such climatological averages of air mass modifications could be useful to forecasters in their prognosis of the weather to be expected during the travel of such air masses along specific routes.

It is obvious that considerable error will arise, probably sufficient to nullify the value of the figures representing continental modification, if these air masses are not identified with the greatest certainty upon their first arrival on Canadian territory. Thus, if we average together, say, Behring Sea-Polar basin air with an air mass which has travelled from the Asiatic high along latitude 55°–60°, we shall in effect be attributing subsequent changes entirely to continental modification. Actually their characteristics aloft are probably sufficiently different to vary their modification on the prairies by continental conditions at the surface. The subsequent history of these two types should be kept separate. But it is difficult, if not impossible, to recognise them as different at Juneau and Prince Rupert. Therefore, the prime requisite before attempting any such climatological investigation will be the establishment of aerological stations: (a) at Aklavik in the Mackenzie Delta, (b) on the Queen Charlotte Islands, (c) on Vancouver Island, (d) in Southern Alberta, (e) at either Chesterfield or Chimo, and also the utilization of United States aerological data. The necessity of the stations at Aklavik, on the Queen Charlotte Islands, and on Vancouver Island for the proper recognition of polar basin, polar Pacific, and tropical Pacific air masses will be obvious. The station in southern Alberta will be necessary on account of the serious and well-known modifications, appearing as chinooks, and extremely hot winds with extremely low humidities, occurring in the plains region from Kansas to central Saskatchewan. The question of the over-running of south-westerly air on the plains by westerlies or north-westerlies from the Pacific cannot be investigated except by aerological ascents. It will be obvious also from the nature of the terrain that balloons will be useless for general dependability in obtaining aerological data. High powered planes will be needed to make regular ascents as is done in the United States at the Army and Navy airplane fields or as at the regular aerological stations at Ellendale, Groesbeck, Royal Center and Due West.

APPENDIX XXXI.—BROADCASTING OF CLIMATOLOGICAL DATA (Minutes XII, pp. 74–6).

By Lt.-Col. E. Gold, D.S.O., F.R.S.

(*Assistant Director, Meteorological Office, London.*)

1. The necessity for rapid dissemination of monthly values of meteorological elements has been recognised from the earliest days of meteorological organization, and at international meetings from time to time the desire has been expressed that the publication of these values should be accelerated. At the first meeting of the International Meteorological Committee after the War a proposal was made on behalf of Japan that a central meteorological bureau should publish and distribute every month the means of the meteorological elements of the preceding month at selected stations. That proposal contemplated that each central bureau should have a provisional bulletin ready for publication within five days of the end of the month, and that the various countries interested should make their own arrangements about the distribution. In the course of the discussion of that proposal Dr. Wallén said that it could best be effected by telegraphic distribution through a central information bureau, while Professor Bjerknes said the problem would be solved if wireless messages from several countries were sent from sufficiently powerful stations so that they could be picked up by the other countries. The Committee considered that further inquiry was necessary before active steps could be taken in the direction indicated.

2. In 1923 I outlined a scheme for international and inter-continental exchange of climatological data on the following lines :—

> " Europe.—Let each country such as Great Britain, Norway, Spain, issue broadcast by wireless (either at the end of a synoptic or preferably at another fixed time) a short coded message (which need be no longer than a " synoptic ") summarising the reports for the month from its " synoptic " stations or if preferred any other selection of its official stations. This should be done by all the countries on the 2nd or 3rd of the month. That ought to be practicable.
>
> All these messages would be picked up by one Institute (as well as by any other Institutes in Europe which wanted them) and that Institute would be charged with the assembling of the data for a " world collective " message to be issued by a wireless station of world-wide range twice, say, on the 4th–5th of the month.
>
> A similar procedure would be arranged in (a) North America, (b) South America, (c) Africa, South of the Equator, (d) Africa north of the Equator, (e) Australasia, (f) India, Mesopotamia, Siam, etc., (g) China, Japan, east Siberia. Oceanic Islands would be done by their respective owners (or by arrangement) and incorporated, e.g., Hawaii and Aleutian Isles by America ; Fiji by Australasia ; St. Helena and Ascension by Great Britain.
>
> Each Institute would then have within five days of the end of the month pretty full data for its own continent and a good skeleton of the rest of the world. The expense, if the thing were tackled in this way, would be relatively small—infinitely small compared with what it would be if cables were used for the exchange.
>
> I don't for a moment think it could all be done at once ; but I think there would be a fair chance of getting America, India, Australasia, Japan and Europe to make a start, if they were asked. And I doubt if anybody will grow enthusiastic over the prompt issue of printed monthly summaries to be exchanged across the world by post. It's twenty years too late for that.
>
> As a code to discuss I suggest BBBMM RRRmm, i.e. just two groups (besides the index group), for the " world issues," giving barometer, maximum temperature, minimum temperature and rainfall ".

3. During the succeeding years the matter remained practically in abeyance, but it was raised again in a communication to the Directors' Conference at Copenhagen, from Professor A. Wagner, of Innsbruck, in 1929. The reasons which had been advanced in 1921 by Dr. Nakamura for the rapid dissemination of climatological data were that it was necessary for business and industry, and to make accessible to specialists in the field of world meteorology the data indispensable for their investigations of seasonal forecasts and other things. Dr. Wagner in his memorandum laid stress on the importance of a rapid distribution of this information by wireless telegraphy with a view to research (a) on the variations in the general circulation of the atmosphere and (b) on the idea of world weather and long distance weather forecasts. Just as ordinary daily weather forecasts had developed, not before but after the collection of daily observations by telegraphy and wireless telegraphy, so Dr. Wagner contended that long period weather forecasts would develop if the data on which they could be based were exchanged rapidly, so that the changes could be investigated before they had become a matter of history, and while they were fresh in men's minds.

4. This proposal of Professor Wagner was referred by the Copenhagen Conference to the Commission for Climatology and the Commission for Synoptic Weather Information. The Commission for Climatology considered the proposal at its meeting at Innsbruck in September, 1931, after the proposal had been discussed by correspondence between the Presidents of the two Commissions. The Commission for Climatology at Innsbruck decided to accept a suggestion of the President of the Commission for Synoptic Weather Information to appoint a Sub-Commission on which were represented the Commissions for Climatology, for Agricultural Meteorology, for Synoptic Weather Information and for the Réseau Mondial. Professor Wagner was charged with the preparation of a memorandum for consideration by the Sub-Commission. The memorandum was prepared and considered by correspondence, and the subject was then discussed at the meeting of the Commission for Synoptic Weather Information at De Bilt in May, 1934.

5. The result of the discussion is given in Resolution XIX of the Meeting at De Bilt, which is as follows :—

Resolution XIX.—In order to give satisfaction to the wishes of the Commission for Climatology and taking into account at the same time financial considerations and the means of transmission available, the Commission considers that it would be desirable to adhere as far as possible to the following rules :—

(*a*) Distribution of mean values for European regions. The mean values will be transmitted at the end of the collective messages of the 13h. observations. They will include one station out of five. There will be two groups for each station.

Further, the Norwegian Service will add to its own reports a certain number of groups relating to the North Atlantic.*

(*b*) Intercontinental exchange (two groups for each 10° square). It is desirable that this distribution should be assured :

by RUGBY for Europe and North Africa ;

by WASHINGTON for America (North and South) ;

by MOSCOW for the U.S.S.R. (Europe and Asia) ;

by CAIRO (Abu Zabal) for Africa (except the north-west) and the south of Asia (from the Mediterranean to Indo-China) ;

by SYDNEY for Oceania ;

by TOKYO for the Far East.

(*c*) The information ought to be distributed as soon as possible. The issues should not be made on Sundays. When this distribution is at the end of the daily synoptic messages, the information can be spread over several days.

6. This Resolution was considered immediately afterwards by the Climatology Commission at its meeting at Wiesbaden. That Commission adopted a number of Resolutions as follows :—

VII. " The International Climatology Commission thanks the Commission for Synoptic Weather Information for the great and opportune work accomplished at its meeting at De Bilt on the question of the wireless distribution of meteorological monthly mean values, and accepts the proposed codes :—

IIIBB TTTNN

While the Climatology Commission is satisfied with two figures for the values of pressure, it considers that it would be desirable in the zone from Lat. 20°N. to Lat. 20°S. that the figures should be in units and tenths of a millibar instead of tens and units, as proposed for the other stations. Further, the Commission expresses the desire that there should be provided for a few individual stations additional information as follows :—

(*a*) For some stations in isolated situations, especially islands, an expression for the air transport (vector mean value) for the determination of the mean pressure gradient.

(*b*) For a few representative coast and island stations and for lightships 3 figures $T_sT_sT_s$ for the temperature of the water surface of the sea in the same scale as that used for temperature of the air.

VIII. In principle the values of pressure BB shall be given reduced to sea level for high level stations as well as for others. The temperature TTT will be in the ordinary code, the precipitation NN in centimetres. If in exceptional cases the precipitation of a month amounts to more than 99 cm., the second figure group should be given with 6 figures TTTNNN. The form DDvv is proposed for the air transport (vector mean value) in which DD is the direction on the scale 00–32, vv the magnitude of the air transport in metres per second. If the value of vv exceeds 10 m/sec. this will be indicated by adding 50 to the figures for DD.

IX. The Commission proposes to aim at the 15th of the month as the day for the issue of information for a continent. It is understood that if the 15th falls on a Sunday the issue should be made on the next day. As an Annex to Resolution II† it is desired that the mean values for the period 1901–30 should be calculated as soon as possible.

X. The Commission requests Dr. Wagner to get into communication with the President of the Commission for Synoptic Weather Information in regard to technical questions which arise and to keep the President of the Climatology Commission informed of the results ".

In the course of the discussion the Commission noted with thanks the fact that the Norwegian Meteorological Service already prepared information about the mean pressure over the North Atlantic and would issue it in the simplified form :

QLIBB

In regard to the question of index figures, the Commission agree with the proposals of the Commission for Synoptic Weather Information and express the wish that the list of stations should be as far as possible prepared for the Directors' Conference in 1935.

* The members of the Commission note that the code which will be proposed to the special Sub-Commission will be the following :—

IIIBB TTTRR (millibars, 1/10°C., and centimetres) for land stations.

QLIBB for oceanic regions.

The reports for land stations would be preceded by the word CLIMAT and the reports for oceanic regions by the word OCCLI.

† Resolution II adopted the period 1901–30 as that for which mean values should be computed.

7. In accordance with the desire of the Climatology Commission, Professor Wagner wrote to me about the points which were outstanding. The principal ones were :—

(1) The expression of pressure between Lat. 20° N. and 20° S. I have agreed with Professor Wagner that in these regions pressure might be given in units and tenths instead of in whole millibars, still using two figures only for pressure.

(2) The transport of air at isolated stations such as St. Helena where there is no practical method of drawing accurately the isobars ; in such cases the direction of transport of air gives a good indication of the direction and strength of the mean pressure gradient. A 4-figure group would be necessary for this.

(3) The temperature of the surface of the sea for representative places, such as lightships. This seems a desirable addition, and I suggested that it would also be useful to have the mean temperature of the surface of the sea for regions of the ocean where there were a goodly number of wireless reports from ships during the month, say for more than half the days of the month.

(4) The code for precipitation provides for it to be reported in cm. Professor Wagner and I have agreed that arrangements should be made for reporting values less than 1 cm. in the following way :—

91 = 1 mm.	96 = 6 mm.
92 = 2 mm.	97 = 7 mm.
93 = 3 mm.	98 = 8 mm.
94 = 4 mm.	99 = More than 90 cm.
95 = 5 mm.	

If 99 is reported in the code group, the actual rainfall would be added in a separate group of two or three figures according to the actual rainfall in centimetres.

(5) There remain outstanding :—

(i) The question of the selection of stations. This ought to be left to the different countries to make proposals.

(ii) The time by which the issue should be made. That ought to be arranged by the Sub-Commission on the Time Table for Synoptic Issues.

(iii) The repetition of the information from other continents by a central wireless station in each continent. That would add to the expense, but it would make the distribution more effective.

(iv) The index figures to be used for stations. As 1,000 index numbers have been allotted to each continent it will be necessary to indicate which series of index numbers is used. This can be done by inserting the words : First, Second or Third after the word Climat in the message to indicate which series the groups refer to, e.g.—

1st = Europe.
2nd = Asia.
3rd = Australasia.

8. That represents roughly the present position of the question. It will come up for consideration at the Conference at Warsaw.

APPENDIX XXXII.—COMPUTATION OF METEOROLOGICAL AVERAGES

(Minutes XII, pp. 76–9)

(*a*) MEMORANDUM BY E. G. BILHAM

(*b*) NOTE BY THE CANADIAN METEOROLOGICAL SERVICE

(*c*) NOTE BY S. R. SAVUR

(*a*) Memorandum by E. G. Bilham, B.Sc.

(*Superintendent, British Climatology Division, Meteorological Office, London*)

The title of this memorandum covers a very wide field, and it would be possible to enumerate a great many problems for discussion under so general a heading. It is my intention, therefore, to limit the subject matter to a few general questions of practical importance, most of which arose for consideration in connexion with the new averages of temperature* and sunshine† at British stations which have recently been published by H.M. Stationery Office. These publications contain station averages for each month and the year which were prepared primarily for use in the *Monthly Weather Report*. Weekly averages derived from the monthly averages for selected stations are used in the *Weekly Weather Report*, but these have not been published.

1. **Period for which averages should be computed.**—It is well recognised that averages based on less than about 10 years of observations are of little use, but little attention has been paid to the complementary question as to whether it is desirable to fix an upper limit to the number of years used. On general grounds it would seem desirable to use all the available data in computing averages for any station. Why use only, say, the last 30 years when you have 50, 60 or 100 years of observations ? Experience indicates that it is a mistaken policy to fix too long a period of years as the standard period when preparing a set of climatological averages for any region. It is generally agreed that so far as possible, the averages at individual stations should be comparable—that is to say, they should refer to the same period of years—and that " straight " averages are preferable to " adjusted " averages.

* Averages of Temperature for the British Isles (M.O. 364).

† Averages of Bright Sunshine for the British Isles (M.O. 377).

If we select a relatively short period such as 10 years, and we are dealing with a region where meteorological observations have been carried on for a considerable time, it will be possible to give comparable averages for a large proportion of the stations. The only omissions will be new stations with fewer than 10 years of observations.

If now we fix a longer period such as 20 years, we shall in general get better averages because the probable error is reduced in the ratio of $\sqrt{20}$ to $\sqrt{10}$, but the number of omissions will be greater because we shall only be able to include stations which have at least 20 years of observations. If we include stations with shorter records, we introduce the element of non-comparability. In the past, it has been the practice to attempt to surmount this difficulty by adjusting the averages for incomplete periods, and this process is still carried out on an elaborate scale in computing British rainfall averages. The adjustment is based on a comparison of the records for station " A " for the incomplete period with those of station " B " for the same period. It is assumed that this comparison determines the differences between the average conditions at stations " A " and " B." Consequently, if we have standard averages for station " B," those for station " A " can be determined. We shall return later to a consideration of the pros and cons of the whole question of adjustment. For the present we merely need to remark that the longer we make the standard period the fewer will be the stations for which we can compute straight averages for the whole period. The difficulties of obtaining a satisfactory set of averages for a large proportion of the observing stations in operation at a given time increase rapidly as the length of the standard period is extended.

On the other hand, there are undeniable advantages in basing averages on a reasonably long period of observations, and it is undesirable that too much should be sacrificed in order to get a high order of comparability. We thus have to make a choice between conflicting considerations. In making the choice, we have to take account of other factors. Everyone knows that the conditions at a station may change in the course of years. Trees may grow, buildings may be erected, a rural site may gradually change into an urban site, the original site may have to be abandoned in favour of a different site, instruments may be changed and so may the hours of observation. All these factors disturb the continuity of the observations.

There is yet another reason for fixing a moderate upper limit to the period for which working averages should be calculated, namely, the existence of secular trends lasting over many years. One way of viewing an " average " or " normal " is to regard it as the most probable value of the element in question—the value to be expected on the evidence of past experience. For that purpose we require the average nearest to the present which is long enough to remove casual variations. The average for a very long period with a secular trend in it is clearly less appropriate.

Having regard to all the circumstances, we fixed 30 years as the upper limit for the averages given in the publications already referred to. None of the averages are based on more than 30 years of observations, although in some cases averages for 50 years could have been computed. Our view is that stations with more than 30 years of homogeneous records are exceptional, and that such long records, though of great interest for special study, should not be utilised as part of the general climatological material used for the derivation of averages for current use.

The following analysis of the periods covered by the averages of bright sunshine (M.O. 377) may be of interest :—

Length of period.	Number of stations.	Per cent of total.
30 years.	58	34
26–29 ,,	13	8
21–25 ,,	44	26
16–20 ,,	30	17
11–15 ,,	13	8
10 ,,	13	8
Total	171	

It will be noticed that about one-third of the stations have records covering the full 30 years. The averages in M.O. 377 are for periods ending 1930, and it is not unlikely that the number of stations with complete records would have been greater, but for the incidence of the Great War. The position was very nearly the same, however, when averages for the period 1881–1915 were computed. Out of 102 stations for which averages of sunshine are given in the " Book of Normals " (M.O. 236), Section I, only 34, or exactly one-third of the total number, had complete records for the 35 years.

The conclusion seems to be that in a meteorological organization like that of Great Britain, one cannot assume that at any given moment a large proportion of stations will possess records for periods longer than about 30 years. Even where such records exist, they will not, in most cases, be completely homogeneous. It is idle, therefore, to adopt a policy in regard to the computation of averages which ignores these facts.

2. **" Adjusted " averages versus " straight " averages for incomplete periods.**—We have seen that if we fix a period such as 30 years as the standard for which working averages should be computed, we shall only be able to give such averages for a minority of stations. There will be a large residue of stations which have been working for periods of from 10 to 30 years, and we have to consider how they should be dealt with. Only three alternatives are available :—

(1) Leave them out altogether.

(2) Give the straight averages for the years available.

(3) Give averages adjusted to the standard period.

Alternative (1) will appeal to the purist, but it is unacceptable because the ordinary public duties of a Meteorological Service demand the existence of some sort of averages for stations which have been in existence for as long as 10 years. Alternative (2) represents a simple and straightforward solution, but its adoption results in a set of averages which are not strictly comparable. Alternative (3) aims at rectifying the faults of (2) by the application of corrections.

As already mentioned, we adopted (2) when preparing the new averages of temperature and sunshine for British stations. In the *Monthly Weather Report* " differences from average " or " percentages of average " based on incomplete records (i.e., records of less than 30 years' duration) are printed in italics in order to warn the reader that they are on a different footing from those derived from the full period of 30 years, which are printed in Roman type. Our reason for abandoning (3) in favour of (2) was because we did not feel convinced that the gain in accuracy resulting from the adjusting process, was worth while. The matter is dealt with at some length in the Introduction to " Averages of Temperature." A table (Table B, p. 11) is given showing the averages of maximum (X), minimum (N) and mid-temperature ($\frac{1}{2}$ (X + N)) for January, April, July and October at five stations, both for the full period 1901–30, and also for various incomplete periods. As a sample, the values for Kew are reproduced below :—

	X.	N.	½ (X+N).	X.	N.	½ (X+N).
	°F.	°F.	°F.	°F.	°F.	°F.
Kew :—		January.			April.	
1901–30	44·8	36·0	40·4	54·5	39·7	47·1
1906–30	44·9	36·1	40·5	54·5	39·7	47·1
1911–30	45·2	36·3	$40{\cdot}7_5$	54·4	39·8	47·1
1901–20, 1926–30 ..	44·4	35·7	$40{\cdot}0_5$	54·6	39·8	47·2
		July.			October.	
1901–30	71·0	54·6	62·8	57·4	44·4	50·9
1906–30	70·7	54·6	$62{\cdot}6_5$	57·0	44·5	$50{\cdot}7_5$
1911–30	71·1	54·7	62·9	57·3	43·9	50·6
1901–20, 1926–30 ..	70·7	54·6	$62{\cdot}6_5$	57·1	44·2	$50{\cdot}6_5$

The following remarks from p. 10 of the Introduction sum up the conclusions reached :—

> " It has been the practice hitherto to weight or adjust incomplete records in order to deduce averages for the adopted standard period. Such a procedure aims at producing averages which shall be directly comparable as between one station and another. The need for such comparability has often been insisted upon and much time and labour have been expended in attempting to achieve it. About half the stations in the " Book of Normals," Section I, have weighted temperature normals. The procedure assumes (*a*) that the changes of temperature as between one period and another are the same at two neighbouring stations, and (*b*) that the normals at the comparison station are entirely free from error. From investigations that have been made it appears that neither of these assumptions is usually true and that " derived normals " cannot ordinarily be regarded as accurate to within less than about 0·5° F. Unless, therefore, there is reason to believe that the averages for the incomplete period differ by more than this amount, from the (unknown) averages for the complete period, little is to be gained by carrying out the weighting procedure. Also, it has been felt to be desirable to print direct arithmetical averages of the data actually available rather than values which have been adjusted by adding or subtracting corrections not revealed to the reader."

Before dismissing this subject, it will be of interest to make some mention of an experiment in the application of the cartographical method to the problem of determining standard averages. This experiment was carried out before the new averages of temperature were computed. For all available stations averages were computed for the period of five years, 1926–30. Let us denote such an average by A_5 and the corresponding average for the standard period as A_s (for the purpose of this experiment the standard period was the 35 years, 1881–1915). For a number of old-established stations we could then determine the value of A_5–A_s and could plot the results on a chart in order to ascertain the geographical distribution of the " anomaly." Assuming such a chart to be constructed and isanomalies to be drawn, we should be in a position to read off the value of A_5–A_s for any locality. If, therefore, the value of A_5 was available for that locality, the value of the standard average A_s could be determined.

The experiment was not a success. When the values of A_5–A_s were charted they did not fit into a system of smooth anomalies. There were curious local differences which were only partly accounted for by changes in hours of observation or of site. Much uncertainty existed, therefore, as to how the lines should be drawn, and although it might be claimed that the method made it possible to evaluate standard averages for stations with only 5 years of observation to within perhaps 0·5° F., it became evident that there were too many uncertainties to permit of its adoption as a routine method of computing averages.

3. **How often should averages be revised ?**—The computation of averages of several meteorological elements for a large number of stations is a fairly heavy task, and it is one that should not be undertaken at unnecessarily frequent intervals. The need for revision arises in two ways: (*a*) the bringing up to date of the data for stations which already have averages, and (*b*) the addition of averages for new stations which have completed the fixed minimum number of years of observation, say 10. In regard to (*a*) inquirers for meteorological data have a very natural preference for recent information ; " give me the average figures for the last ten years " is a common form of request. If we are dealing with periods of the order of 30 years, the averages do not change much as between one epoch and another terminating 5 or 10 years later, and it would suffice for nearly all purposes if revision occurred at intervals of 10 years. The residue of stations (forming the majority), with considerably fewer than 30 years of observation, demand, however, more frequent consideration. One does not like keeping a 10-year average in use if a 15-year average can be calculated.

For some purposes, on the other hand, there are advantages in deciding upon a definite period as a standard of reference and to change it only at relatively long intervals. As an example, we may take the rainfall statistics of the British Isles. The standard period is the 35 years, 1881–1915. Shortly after the end of that epoch the British Rainfall Organization embarked upon the tremendous task of mapping the average annual rainfall for that period on the scale of 2 miles to the inch. The work was continued when the Organization was taken over by the Meteorological Office, and is still not completed. Apart from this Rainfall Survey, an enormous amount of work has been done employing the same period of reference. For example, we possess a series of maps dating back to 1868 showing the rainfall for each year expressed as a percentage of the 1881–1915 average. The maps from 1868 to 1923 are to be found in the "Rainfall Atlas of the British Isles," published by the Royal Meteorological Society, and those for subsequent years in the annual volumes of *British Rainfall*. It is clear that for work of this character, a change in the standard period would have far-reaching consequences, and it is also clear that a policy which we regard as the best for temperature and sunshine may not be the best for rainfall. In this connexion we have to bear in mind that we have a much closer network of stations for rainfall than for any other element. It has already been mentioned that the adjustment of averages to the standard period is carried out on an elaborate scale in the case of rainfall. The process necessitates, and its adoption is justified by, the existence of such a close network.

These considerations lead to the enunciation of a general conclusion. If circumstances are such, as in the case of British rainfall, that the adjustment of averages can be carried out with advantage, the standard period should only be changed at rare intervals. If, on the other hand, unadjusted averages are used, it is advantageous to change the standard period fairly frequently. Having these considerations in mind, it has been decided to revise the averages of sunshine and temperature every 5 years. The present period is 1901–30, the next will be 1906–35, the next 1911–40 and so on.

(*b*) Note by the Canadian Meteorological Service

Climatological averages of the various elements are in the Canadian Service, simply arithmetical means of the individual entries of the climatological elements. No attempt has been made to apply a method of least squares to obtain a better result. It would be a very suitable subject to deal with in a new edition of the "Computer's Handbook." In view of the labour involved, it is most necessary that all Services should adopt the same method and criteria of determining a mean value from a set of data. It is thus an international question, and could very well be considered at the meeting of the Climatological Commission. In this connexion it may be stated that so much depends upon the equipment at the observing stations that it will be difficult to formulate any rigid scheme. In the case of monthly values, however, the reduction to a uniform period of 30.42 days would be an improvement if universally adopted, or any period of uniform length would be still better. In the case of the Canadian Service, however, this will be impossible without a greatly increased personnel. If the reference is particularly to the proposals of Dr. Hesselberg on the computation of mean values, we should say that they are aiming at an accuracy far beyond anything attempted here or, we believe, generally. In the case of stations equipped with autographic instruments we have considered that we have done very well to obtain reasonably correct values at each hour from the curve when corrected by the control readings. Some improvement of mean values could undoubtedly be obtained by mechanical integration of the area under the curve with subsequent corrections from the control readings. There will still remain some error as is evident from the continual small variations between the autographic and the eye readings. In view of this error which it seems impossible to eliminate, the refinements suggested by Dr. Hesselberg do not seem possible to be practically put into operation.

If climatology is to be placed upon the basis of unitary air masses, the whole scheme of computation of averages will need to be completely revised. In this case the changes in technique which will be advisable can only be discovered by actual practice. It is, therefore, too soon to make any suggestions in this regard.

(*c*) Note by S. R. Savur, Ph.D.

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Before computing the average of a meteorological element it appears essential to see whether it has a secular trend. If there be a secular trend, we may look upon the *t*th value as consisting of two parts, the first represented by the function $f(t)$ due to the trend, the second equal to $\mu+d_t$ being the *t*th random sample from a population of mean μ. We may assume as reasonably correct that the distribution in the population is such that the mean of a random sample approaches μ as the sample gets increased. Thus the *t*th value $= f(t) + \mu + d_t$.

An examination for the trend, if any, can be made by the method devised by R. A. Fisher,* by fitting polynomials of various degrees in t to the data. If the polynomials of the first and the second degree be not found significant, we may take it that in a very large percentage of cases where this is true, the higher degree polynomials will also be found to be insignificant. This is suggested with a view to minimise the labour of computation.

When a significant trend is discovered, its equation $f(t)$ is determined incidentally. Using this equation for the trend we calculate its amount for each interval of time and subtract it from the corresponding value of the meteorological element, thus getting from our data values which are free from the trend. The mean, m, of all these values can be very approximately taken to be equal to μ, the mean of the population from which trend has been eliminated. The normal for the *t*th interval is then given by

$$N_t = f(t) + m.$$

* R. A. Fisher. Statistical methods for Research Workers. Biological monographs and manuals No. V, London and Edinburgh. 2nd. edn., 1928.

In such a case it appears preferable to calculate the equation for N_t once in say 5 or 10 years, using all the available data. The re-calculation is not very troublesome, because the sums of the squares, etc., obtained during the previous determination, can be used during the present calculation also.

It is suggested that this method should be applied first to reliable data which are available for more than 40 or 50 years, and which have not been affected by change of site, or of exposure or by change in the hour of observation, etc. If a trend is detected in these data, a like trend may be supposed to exist in similar data in neighbouring regions. If there be no significant trend we may use all the available data to calculate the normals. Of course means computed in this manner are not quite suitable for intercomparison when the periods are not identical and when many of them are small. For it may so happen, to take the example of rainfall, that the period at one station may include a very wet spell of years, in which case the station will appear to be comparatively wetter than the neighbouring places for which the periods for calculating averages did not include this spell. This contention would thus, apparently, point to the necessity of using the same period for all the stations. A common period is, doubtless, advantageous for stations which are climatically similar. But there is the difficulty that a common period is likely to be much smaller than that demanded by the criterion given on pages 10 and 11 of Section V of the "Computer's Handbook," and if so it will be especially unsuitable in the case of a country like India, which has diverse climates and where the climatic changes in some parts are more or less opposed to those in others. The difficulties mentioned above vanish to a large extent if along with the means, computed by using all the available data, their standard errors and the periods on which they are based are also given, these latter two values helping to make the inter-comparisons better.

When this method was applied to the annual rainfall data at Madras (122 years), Bombay (118 years), Calcutta (106 years) and to the monsoon rainfall in the three major forecasting divisions of India, viz., the Peninsula, north-west India and north-east India (60 years in each case), it was found that there was no significant trend. Hence for "normals", it appears advisable to compute "straight" averages, using all the available data.

"Adjusted" averages appear necessary in those cases where the length of the period for which the data are available is not as large as that required by the criterion in the "Computers' Handbook," referred to above. It may be of interest to note here that in the case of Drigh Road (Karachi) the length of the period necessary in order that the standard errors of the means of pressure, temperature and humidity may not be more than 0·001 in., 0·05°F. and 0·5 per cent respectively came out to be 20 years in each case.

In conclusion, it is once more suggested that whenever an average is given, its standard error and the number of years on which it is based should also be given.

APPENDIX XXXIII.—WEATHER AND CROPS (Minutes XIII, pp. 80–3)

(*a*) The Place of Quantitative Measurements on Plant Growth in Agricultural Meteorology and Crop Forecasting

(*b*) Correlation of General Crop Observations with Meteorological Data (India)

(*c*) Correlation of General Crop Observations with Meteorological Data (Canada)

(*a*) The Place of Quantitative Measurements on Plant Growth in Agricultural Meteorology and Crop Forecasting

By F. Yates, M.A.

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It is my purpose in this paper to give an account of the reasons that have led to the introduction in this country of what have been called Precision Records in the Crop Weather Scheme conducted by the Ministry of Agriculture and Fisheries, the Forestry Commission and the Mereorological Office, and also to give an indication of the directions in which the results of these observations are likely to be useful. No examination of the association between the results of these observations and meteorological factors has yet been made, indeed the scheme has barely been running long enough, but at the completion of this year's observations a preliminary examination will be commenced, the results of which should be available in about a year's time.

The influence of the weather on crops is a very obvious one, and at first sight the evaluation of its effects would appear to be comparatively easy. It is somewhat remarkable, therefore, to find that even for the major crops, both in this and other countries, only knowledge of the vaguest and most obvious description is at present available. The reason for this state of affairs lies firstly in the complex nature of the effects of varying meteorological conditions on plant growth, particularly in temperate climates where no one factor is "limiting", and secondly, on the extreme paucity of accurate records of crop yields under comparable conditions. This state of affairs is in marked contrast to the very full and excellent meteorological records that are now collected all over the world, records which, one might say, have their chief practical interest to agriculturists, and consequently require complementary observations of corresponding accuracy on the growth of crops if they are to be of any real use.

There is not space here to give any account of the very considerable amount of statistical work that has been carried out in an endeavour to utilize existing material, but reference may be made to R. H. Hooker's Presidential Address to the Royal Meteorological Society in 1921 (1)*, where an account of the work carried out to that date will be found. The paucity of the data, and the degree to which workers have had to use yield records based on estimates and market returns, subject to all sorts of uncertainties and biases, is clearly brought out by this review.

* The numbers in brackets refer to the list of references on p. 173.

In addition to the research on meteorological effects described in Hooker's review, and later work by Hooker (2) and by Geddes (3), mention should be made of the work of R. A. Fisher (4) and workers under him at Rothamsted (5), (6), using the yield records of the Rothamsted classical fields (which extend for over half a century and are unique of their kind). The statistical methods evolved by Fisher mark a striking advance in statistical technique. From his own work on wheat definite and interesting results emerged, but the parallel work on barley and mangolds, and on the less extensive wheat and barley data at Woburn failed to yield any very conclusive results. This outcome is, I think, a demonstration of the extreme complexity of the phenomena involved, to which further reference will be made later.

Hooker's own work (2), Geddes' parallel work for Scotland (3), and that of Sir Napier Shaw (7), are all based on the Ministry of Agriculture's estimates of yield. It is not the purpose of this paper to enter into a discussion of the reliability or otherwise of these estimates, or of similar estimates in other countries. J. A. Venn (8), (9), and others have argued strongly that such estimates are biased and unreliable in various ways. H. D. Vigor (10) has replied to Venn's criticisms. All opinions on their value, however, must necessarily be subjective, since there are no really reliable figures with known errors with which to compare them. (A method of obtaining such values, and its relation to the Sampling Observations of the Crop Weather Scheme, will be discussed later in this paper.) All that can be said at the present juncture is that the methods of estimation are undoubtedly such that large and unknown biases are possible, and that similar biases are known to occur in other material of the same type, but that the actual biases may in fact be small and unimportant. Only when accurate yield records, known to be free from bias, are available over a series of years, will it be possible to assess the true value of the Ministry's estimates.

It might be maintained that biases in such estimates are unimportant, since all that is required is that the records should be comparable from year to year. This is only partially true. Admittedly a constant error is of no moment in the evaluation of meteorological effects, but three types of error can be very serious: (1) consistent under-estimation of the crop in good years, and over-estimation in bad years, (2) undue influence of secondary characteristics such as straw height which are affected by the weather without necessarily indicating a corresponding change in yield, (3) influence of presumed weather effects on the estimates, e.g. a wet winter, if believed to be bad for wheat, may in itself cause estimaters to return lower estimates.

It may be mentioned that in other connexions the absence of even a constant bias is of great importance. I quote the following passage from Vigor's paper:

> "With precise and authoritative information available, as the result of Government control of flour mills, they (the Commissioners) found that the quantity of home-grown wheat milled in 1917–18, 1918–19 and 1919–20, averaged less than 66 per cent of the estimated crops of 1917, 1918 and 1919. The low proportion was surprising, having regard to the attractive prices then ruling for wheat and to the definite prohibition then in force against the use of sound wheat for any purpose but seed and milling. The Commissioners, without coming to a definite conclusion, suggested as one possibility that there might have been an over-estimate made of the crops harvested in these years."

If the estimates were really reliable, indicating a real loss, it might have been worth while tightening up the regulations or taking other measures to stop the leak. Presumably since there was no certainty that the loss was not fictitious such measures were not considered worth while. Similar difficulties will doubtless occur to my hearers in connexion with the present marketing schemes.

1. Methods of determining the effects of weather.—It may be well to recall that there are several methods of attacking the problem.

(1) *Casual observation.*—It is not difficult, for example, to see that a hail storm is bad for a cereal crop, or that frost may ruin a fruit crop. When, however, we ask ourselves how much damage is done, or how much hail or frost respectively is required to do a given amount of damage, casual observation fails us. Nor is casual observation of much use in evaluating the more subtle effects of rainfall, sunshine and temperature.

(2) *Examination of yield data.*—Broad effects such as the effects of an excess or defect of winter rainfall may be evaluated by this means, but more complex effects are more difficult to evaluate because of the large variety of meteorological factors which might conceivably produce an effect, and their extreme complexity.

(3) *Detailed examination of plant growth.*—Many meteorological events may be expected to leave their mark on the plant within a short time of their occurrence. The plant may afterwards recover and the final yield may consequently be unaffected, or permanent damage may result. The isolation of meteorological events which really produce an effect, and an insight into their mechanism, is therefore likely to be immensely facilitated if a knowledge of the whole life history of the plant is available. It would be idle to postulate that a short dry spell in the growing period accounted for a low yield if it were known that during and immediately after this time the plant continued its growth unchecked. The sampling observations of the Crop Weather Scheme described in this paper are designed to furnish data of this type.

(4) *Controlled experiments.*—There appears to be no reason, other than expense, why rainfall effects should not be investigated by controlled experiments in which artificial rain is applied to some of the plots, and perhaps natural rain withheld from others. Information from such experiments would be extremely valuable in that it would separate direct rainfall effects from associated secondary effects such as insect infestation. Similar experiments on temperature and radiation factors would be more difficult.

2. Crop Forecasting.—The effects of weather on crops have always been of interest because of their connexion with crop-forecasting. Clearly if these effects are known any variation produced in the crop by weather factors can be foretold as soon as the weather factors of that particular year and place are known. It should be remembered, however, that the whole of the weather influencing the crop cannot be known until the crop is actually harvested, and for this reason the applications of such a forecasting method are to a certain extent limited, even when the required meteorological effects have been accurately determined.

An alternative method of approach, which can if necessary, be combined with the above method, is to use the plant itself as an integrator of past weather effects. Thus, the state of the wheat crop six weeks before harvest may be found to be an accurate indicator of its subsequent yield. The second method has the advantage that other factors influencing the yield (such as manurial differences) are also likely to find expression in prior plant growth. To investigate the possibilities of the second method of approach or of a combination of the two methods it is necessary to study the whole growth cycle of the crop and not merely the final yields.

Even an accurate knowledge of the effects of meteorological and other factors will not serve in itself to provide accurate crop forecasts. Knowledge of many other things, such as the acreage under crop, changes in the average level of manuring, advance (or retrogression) in agricultural practice, changes in variety, etc., will also be required. Such factors may, in fact, change very rapidly over large areas owing to the influence of changed economic conditions. Indeed, consideration of such points makes it immediately apparent that the evolution of any practical prediction formula other than one based on measurements of a sample of the standing crop shortly before harvest will be immensely difficult.

In any case it is essential to have an accurate knowledge of the average yields actually obtained on commercial farms in order to test any prediction formula. As has been pointed out the present methods of estimation both in England and elsewhere cannot be regarded as satisfactory.

3. Other applications.—A knowledge of the effect of weather on crops is also important for the control of agricultural practice. If any large change is made in an agricultural system of cropping, it is vital to know as soon as possible whether such change is producing any beneficial or deleterious effects. In a newly irrigated area, for example, deterioration of the soil may set in. Such knowledge can be very much more expeditiously and certainly obtained if allowance can be made for the influence of the weather on the crops over the run of seasons available.

An example is provided by the yields of cotton in the Gezira. An investigation of the relation between these yields and the rainfall has recently been carried out by E. M. and F. Crowther (11). The following is a quotation from the introduction to their paper:—

> "The mean yields from this large and semi-desert area fluctuate violently from year to year in such a way as to suggest the dominance of some climatic factor. It will be shown that the cotton yields are highly correlated with rainfall, and further, that seasonal fluctuations in rainfall, including certain cyclic changes, are sufficient to account for most of the decline in yield on some of the oldest areas. This conclusion has considerable practical importance, because a recent sequence of low yields led some critics of the scheme to conclude that irrigation without drainage had already produced serious soil deterioration. The significance of some of the rainfall effects established may direct attention to new methods of studying problems of soil fertility and the control of pests."

It is clear that the expeditious evaluation of slow changes (or "trends") will enable the effects of all sorts of changes in agriculture such as pest control, changes in rotation cycles, influence of new pests, and of changed economic conditions, to be much more rapidly assessed. The value of supposedly beneficial changes, and the urgency or otherwise of remedial measures for deleterious conditions can consequently be more certainly determined.

4. History and nature of precision observations.—The Agricultural Meteorological Scheme of the Ministry of Agriculture and Fisheries and the Meteorological Office was started in November, 1924, with the object of collecting data which would serve to evaluate the effect of weather on crops. A considerable number of crops, including perennial fruit crops, were observed. The earlier observations were largely qualitative in character, and on many of the crops accurate yields were not recorded, so that one of the chief functions of the observations was not fulfilled. The material on which the observations were made was also faulty in many respects.

To remedy these defects, what was called the "Precision Records Scheme" was introduced for the wheat crop to replace the original scheme of observations for that crop. This scheme owed its inception to the energies of R. A. Fisher, T. Eden, E. J. Maskell and A. R. Clapham. It was started in the season 1928–9 at three stations. In the next three seasons there were five or six stations participating, and for the season 1932–3 a slightly modified permanent scheme was instituted with eight participating stations, two further stations being added in 1933–4. At the end of the present season there will thus be available records at ten stations for periods varying from two to seven years.

The basis of these observations on wheat is a sampling procedure, measurements and counts being made on freshly demarcated samples from blocks of eight plots of two or three known varieties, two of the varieties being common to all stations. The seed is supplied by the National Institute of Agricultural Botany. The observations are made at short intervals (usually a fortnight or three weeks, but reduced at the critical periods to one or two days). The following quantities are observed during all periods at which they are conveniently observable.

1. Plant number.
2. Shoot number.
3. Ear number.
4. Height of shoots.
5. Height of ears.

In addition the harvest yields are obtained (also by sampling) and at two stations dry matter samples are taken on two occasions before harvest. Thus a complete record of the growth of the plant is obtained from appearance above ground to harvest.

From these observed quantities dates and rates associated with certain epochs in the life of the plant have been computed. These epochs are—

1. Emergence above ground.
2. Tillering.
3. Maximum shoot number.
4. Maximum growth rate.
5. Ear emergence.

A summary of the results for each quarter is published in the *Journal of the Ministry of Agriculture*.

It will be seen that the term Precision Records is somewhat misleading. These records are in fact simply quantitative observations of a relatively simple kind, such as can be made by anyone capable of handling a rule; the only laboratory determinations are those for dry matter. The novel feature of the observations lies in the sampling procedure adopted. This is designed to avoid any selective bias on the part of the observer while enabling him to distribute his observations over a reasonably extended area of crop.

The functions of these observations will be immediately apparent in the light of the first part of this paper.

(1) They serve to provide data not only on the final yield but also on the growth of the plant, at places where the meteorological factors are known. Statistical examination may therefore be expected to reveal the effects of these factors both on the final yield and on the whole growth of the plant. The relation between the growth history of the plant up to a given date and the final yields can also be investigated, either alone or in conjunction with the weather up to that date, so that the possibilities of crop forecasting can be studied. In this respect the data have definite advantages over the records of yield of a single field extending over a much longer period of time, for not only is an adequate volume of data collected much more expeditiously, but also a much wider range of soil types and weather conditions is sampled.

(2) The differences and similarities in growth of different varieties are brought into prominence. Such differences, besides being of general scientific interest, may be of great value to the plant breeder, who has previously had no method of estimating any but the most obvious differences.

(3) A body of observers with a knowledge of sampling procedure is automatically being trained. The influence of the present scheme in this respect is much wider than might appear at first sight, since most of the stations are agricultural colleges, where students are encouraged to assist in the observations. The value of such a body of observers in the estimation of crop yields, pest infestation, etc., is likely to be more fully appreciated in agriculture in a few years' time.

5. Sampling of commercial fields.—The results of the sampling observations on the experimental plots cannot themselves provide a complete crop estimation or forecasting scheme. As already pointed out it is necessary to know the yields on commercial fields in order to investigate the relation of these to the yields and other quantities determined on the experimental plots. Only when the commercial yields and their variation are known can the best methods of estimation and forecasting be decided.

In order to make a preliminary investigation of the nature of the variation of the yields on commercial farms, and in particular to evolve and test an expeditious sampling technique for work of this kind, observers of the experimental plots were last year, 1934, encouraged to sample some commercial fields in the neighbourhood. Five observers took part, 17 fields in all being sampled. This year the scheme is being extended. The sampling method proved very successful. Although only 30 metres of drill row per field were sampled the yields of the fields were determined with a standard error of only 8 per cent which is amply small enough having regard to the variation from field to field.

The differences between districts were only very slightly greater than might be expected from random variation of fields within a district. This means that such differences of weather conditions as existed between districts cannot have produced any great differences in yield. In view of the fact that the centres range from Devon to Scotland this is somewhat remarkable. It will be most interesting to see whether districts exhibit greater variation in other years not so favourable to wheat as last year.

Since last year neither the farms nor the fields on the farms were selected at random the results cannot give any completely definite information on the variation on the totality of commercial fields in the country, and cannot therefore be used to determine with certainty the number of fields that would have to be sampled in order to provide a reliable crop estimate. It is, however, interesting to note that those fields which were sampled had a standard deviation of only $22\frac{1}{2}$ per cent. With the variation of this magnitude the sampling of even 100 fields properly selected at random would give an estimate with a standard error of only $2\frac{1}{4}$ per cent, i.e. a maximum error of ± 5 per cent. Probably there was a tendency to select good fields and farms, but even with a true standard deviation per field of twice this, or say 50 per cent, the sampling of 1,000 fields would give an estimate with a standard error of only $1\frac{1}{2}$ per cent provided the fields were properly selected at random.

These observations, therefore, provide a remarkable demonstration of the ease with which accurate and unbiased crop estimates can be obtained at harvest, provided that a team of observers capable of carrying out a proper sampling procedure is available. In these days of marketing schemes there should be no difficulty in making a random selection of fields or in gaining access to selected fields. The opposition which farmers naturally exert when they feel that the information obtained will merely be used for market operations is not likely to arise when the information is collected by a government actively concerned in their own interests.

There are, of course, minor difficulties. Losses in harvesting and after will have to be estimated and allowed for. Co-operation and watchfulness is necessary to ensure that the field is sampled reasonably near harvest. But these difficulties are not serious.

A final and most important advantage of such a method of estimation is that the results can be very rapidly obtained, since only a few observers would be involved and there is no question of waiting till the farmers have completed their threshings. There is no reason why the final estimate for a district

should not be published within a week of the completion of harvest. In crops of which the harvest is spread over several months, such as sugar beet, provisional estimates could be obtained at earlier dates.

6. Need for Extension to Other Crops.—At present sampling observations are being made only on wheat. There appears to be a clear case for extending these observations to other crops of commercial importance. In fact, an extended scheme was drawn up by Dr. Irwin as long ago as 1930. There is not space to argue the matter more fully here; but it should be remembered that results cannot be obtained immediately and that for any crop a period of years must elapse between the inception of the scheme and the accumulation of sufficient data to furnish the required information. A revival of Dr. Irwin's scheme would appear to be overdue.

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(*b*) Correlation of General Crop Observations with Meteorological Data

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The scheme on Agricultural Meteorology which was originally sanctioned by the Imperial Council of Agricultural Research in India in 1930, had made provision for extensive work on the correlation of past weather and crop statistics. Owing to financial stringency the scheme was curtailed and the reduced scheme which was given effect to in August, 1932, had the "experimental or biological" side of the scheme as the major item of work. Nevertheless a certain amount of statistical work has been done on the effect of weather on the "area sown" and the "yield per acre" in the case of the cotton crop in India, in addition to studies on the data of experimental farms. A brief account of the experience gained during the last two years may be of interest.

1. Weather and crop statistics.—The information about weather and crops available for past years consists of estimates of yield over known areas on the one hand and of observations on the general or "macro" climate at the observatories of the India Meteorological Department. The method used by the government departments concerned in arriving at the figures of "area sown" and "yield per acre" of different crops has been described in Dr. Irwin's review of "Crop Forecasting and the use of Meteorological data in its improvement" ("Papers and Discussions, Conference of Empire Meteorologists, Agricultural Section, 1929.") It is sufficient to state here that the acreage figures are reputed to be accurate, whereas the yield (per acre) data are believed to be rough estimates only. No independent check on the past yield (per acre) figures is feasible in view of the insufficiency of the trade and consumption statistics during the years under consideration.

The correlation between cotton statistics and meteorological factors during the growing season has been completed district by district for the Bombay Presidency. The meteorological factors used are (1) monthly rainfall data averaged from the monthly data of a large number of rainfall reporting stations in each district and (2) mean maximum temperature of the different months of the season as recorded at the meteorological observatories, of which there is usually only one in each district. These data are available for more than forty years for most districts.

The acreage figures for the series of years show secular changes. After elimination of these changes by Fisher's polynomial method, significant correlation coefficients have been obtained between rainfall at the time of sowing and the average prices of cotton in the district during the previous season.

The yield (per acre) data also show large secular variations. After elimination of trend by polynomial curve fitting, the yield (per acre) has been expressed as a function of the rainfall and maximum temperature in certain months of the growing season and significant multiple correlations have been obtained. Although the accuracy of the yield data is questionable, it is interesting to note that the relationship with rainfall and temperature shows certain common features from district to district.

It may also be mentioned that studies at Poona on the microclimates of crops (see "Studies in Microclimatology, Parts I and II" by Ramdas, Kalamkar and Gadre, *Indian Journal of Agricultural Science*, Vol. IV, 3, pp. 451–67 and Vol. V, 1, pp. 1–11) show that the temperature, humidity, etc., measured in the open, differ from those measured in the actual environment of a crop at the same time. While the conditions in the open and inside a crop are highly correlated at the epoch of minimum temperature, this is not the case at the epoch of maximum temperature. This difficulty is particularly serious in the case of the taller crops. The use of the " macro " or general weather factors in crop-weather correlation studies appears, therefore, to have certain limitations.

2. **Data of experimental farms.**—The yield data of experimental farms in India, barring a few exceptions, are available only for short periods, but systematic climatological data have rarely been maintained. The Agricultural Meteorology Branch has undertaken the study of the available long series of data. Some progress has been made with data obtained from Cawnpore, Akola and a few other stations. The aim has been to consider the effect not only of the total rainfall but also of its distribution during the season.

3. **Precision observations on crop and weather.**—Some interesting general relationships can no doubt be established with the past data referred to in the previous sections of this note. To study crop-weather relationships in all their aspects, it is necessary to collect, side by side, systematic and detailed information about the climate in the actual environment of the crops as well as the life history of the crop during the growing season from year to year, at selected centres. " Precision crop and weather observations " have, therefore, been collected (1) on wheat during the " rabi " season of 1933–4 at Poona, (2) on jowar during the Kharif season of 1934 at Poona and (3) on rice during the Kharif season of 1934 at Karjat near Poona. The Precision scheme referred to here is an adaptation of the British " Precision Scheme ". The scheme will be further revised in the light of the experience already gained in India and will then be made available to agricultural workers in India.

(*c*) Correlation of General Crop Observations with Meteorological Data

NOTE BY THE CANADIAN METEOROLOGICAL SERVICE

Some years ago we made correlations of crop yields with the weather changes through the season. The date of sowing was ascertained each year and the average date for each district used as a reference date. Averages of the meteorological factors for 30 days prior to sowing and for each 30 days succeeding sowing were made and correlated with the crop yield. In default of humidity observations, except at a few stations, the mean daily range of temperature was used. For the same air mass the relative humidity will rise to a maximum at the time of the minimum temperature and fall to its lowest point at the time of the maximum temperature with little change in the water-vapour content. Therefore, on the average, periods of large daily range of temperature are periods of low vapour content. While fairly high correlation coefficients were found, it was decided that correlating only the end result, that is to say, the crop yield, with the meteorological factors through the season was not eminently satisfactory. It was decided that intermediate values during the growth of the crop ought to be available for correlation with simultaneous weather changes. For this purpose weekly estimates of crop conditions were tried and found unsatisfactory. Since an estimate of crop conditions is a matter of judgment of the observer, purely qualitative, and subject to apparently large personal errors, we desired to substitute something that could be recorded on a numerical basis. The factors chosen were, besides the dates of sowing, the earliest and average date of stooling and the extent of stooling, the earliest and average date of heading, flowering and reaching of the milk stage, as well as the time of maturity and cutting. These have been gathered by several hundred crop correspondents of the Bureau of Statistics and about ten years of data are now ready for analysis. What we hope to find are the conditions most suitable for the encouragement of stooling or branching, and whether rain and wind at the time of flowering have any deleterious effect. It is possible also that we may discover some connexion between the hardness of the wheat and the weather at the different stages. At least we feel we have obtained data which will admit of weather correlation with numerical values obtained during the intermediate stages of growth.

Something of a similar nature was tried for sugar beet some years ago but no method of obtaining numerical data for the intermediate stages could be found. We were, therefore, limited to correlations of yield and sugar-content with the weather factors during growth.

APPENDIX XXXIV.—LONG RANGE FORECASTING (Minutes XIII, pp. 83–5)

BY C. E. P. BROOKS, D.Sc.

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1. **Introduction.**—It can fairly be said that with a very few exceptions long range or seasonal forecasting is still in the experimental stage. The ground is being explored in many directions, and the main features of the problem are beginning to appear clearly, but in very few districts has a safe and certain road yet been mapped out towards the goal of regular and reliable forecasts for a month or more ahead.

The main lines of attack are three : by studying the relations between changes in the appearance of, or radiation from, the sun and subsequent weather ; by studying weather cycles or periodicities ; and by studying the direct relationship between the weather in one part of the earth and preceding conditions in the same or other regions. I propose to refer briefly to each of these, and then to give a somewhat fuller description of the conditions of the problem as it affects this country.

2. **Solar Relationships.**—Since the circulation of the atmosphere derives its energy from the sun's radiation, it would appear at first sight that variations of solar radiation should be the principal factor in changes of weather, the expected relation being that an increase of radiation is followed by an increase in the strength of the circulation of the earth's atmosphere, and an accentuation of the gradients

between the semi-permanent areas of high and low pressure. Various investigations have shown that a relationship of this nature does exist to some extent, but also that we do not yet know sufficient about solar variations to base reliable forecasts on them. For example, variations in the measured intensity of solar radiation, even in monthly or annual means, bear no close relation to the sun's spotted area, yet variations of meteorological elements often show a closer relation to sunspot relative numbers than to measured radiation. It is possible that the effects of variations in the transmission of the earth's atmosphere are not yet eliminated from the so-called " solar constant " with sufficient completeness ; this would account for the annual periodicity which is found in the calculated values of the solar constant. If this is so, some of the terrestrial effects which have been attributed to variations of solar radiation may actually be related to conditions in the atmosphere of the earth itself.

An alternative suggestion which has been made on several occasions to account for the anomalies shown by the correlation of the relative sunspot number with various meteorological elements is that sunspots themselves affect the opacity of the earth's atmosphere. This effect if it exists at all probably takes place mainly in the higher levels, but we are entirely ignorant as to its nature. While all these doubts remain unsettled, attempts to forecast from solar conditions must be gropings in the dark. In a few isolated regions correlation coefficients may be found of sufficient magnitude and persistence to be of use in forecasting, but such forecasts are purely empirical and liable to suffer from unexplained errors.

3. **Periodicities.**—At one time or another nearly every possible interval from two hours to thousands of years has been quoted as the length of a periodicity, and much ingenuity has been exercised in analysing series of data which on the face of them are quite irregular, and in proving that the microscopical periodicities so obtained are real phenomena. The small periodicities found in this way are rarely of any use at all for forecasting. Thus D. Brunt (1) after an exhaustive analysis of a long series of temperature records at Greenwich, found that the effect of correcting the residual monthly means for all the periodicities discovered was merely to reduce the standard deviation from 2·8 to 2·6°F.

Dinsmore Alter(2) constructed a periodogram of the half-yearly rainfall of the British Isles for 91 years up to the end of 1924, and used the main periodicities so obtained to predict the rainfall up to 1940. For a few years the predictions held fairly well, but in the last few years they have gone astray ; they failed, for example, to foretell the drought of 1933–4.

The best known attempt to employ periodicities in long range forecasting is the use of the three-year pressure cycle in Java and northern Australia to forecast the rainfall of Java.(3) There is a rather regular three-year oscillation of pressure at Darwin in northern Australia, and as the corresponding variations at Batavia are on a much smaller scale, there is also a three-year cycle in the east component of wind. During the east monsoon in Java there is sufficient correlation between pressure gradient and rainfall to provide a basis for forecasts of rainfall over the six months as a whole, though not for individual months.

Forecasts on this simple basis were not sufficiently reliable, chiefly because of breakdowns of the three-year pressure cycle, and recently H. P. Berlage, Jr(4) has attempted to improve them by combining with the three-year cycle a longer one of seven years. Berlage's work included a discussion of the whole problem of the mechanism of climatic cycles, as a result of which he draws two far-reaching conclusions. The first of these is that the only natural periods of oscillation in the earth's atmosphere are those of two, three and seven years ; those of two and three years are associated with the movements of great oceanic currents, while the origin of the seven year cycle is still unknown. Nearly all other periodicities of a few years are supposed to be combinations of these three. The second conclusion is that long-period variations of pressure fall into two classes, stable oscillations and unstable self-reinforcing variations, depending on the relative temperatures of the high pressure and low pressure areas involved. If the high pressure area is cooler than the low pressure area, an increase of the pressure gradient between them cools the low pressure and warms the high pressure area. The abnormality of the gradient is first reduced and then reversed, when the opposite process comes into play. Thus a regular stable oscillation is set up, confined within definite limits. On the other hand, if the high pressure area is warmer than the associated low pressure area, an increase in the gradient between them calls into action forces which tend to increase the abnormality still further. Conditions are unstable, and variations become uncontrolled and irregular. The distribution of pressure and temperature is favourable for stable oscillations only in tropical regions and in the extreme north of the North Atlantic Ocean ; in temperate regions the situation favours unstable irregular variations.

If this analysis is correct, successful long-range forecasting by means of periodicities, while it may be possible in tropical regions, is much less promising in temperate regions. Further, since much of the work along the lines of relationships between distant regions is probably in effect an expression of more or less periodic oscillations—as shown for example in Sir Gilbert Walker's term " the Southern Oscillation "—this difference between the nature of pressure variations in tropical and temperate regions makes the problem of seasonal forecasting difficult in middle latitudes no matter from what angle it is attacked.

The possibility of forecasting Australian rainfall on a periodic basis was discussed by H. A. Hunt(5). Here the periodicity was taken as one of four years, but a closer examination of the data shows that it is more probably one of three years with occasional interruptions causing a change of phase, very similar to the Batavian series with which it is probably connected.

4. **Relations between weather in different parts of the earth.**—Most of the serious and moderately successful attempts at long-range forecasting are based on the hypothesis that the weather in one part of the earth depends on preceding conditions in the same or other parts of the earth. There is however a marked divergence between the various methods of attacking the problem so stated. On the one hand we have what may be termed the physical method. The general system of winds and ocean currents affecting the country in question is studied and those factors are selected which appear to

have most influence on the local weather. The causes of variations in these factors are then examined in turn in the hope that it may be possible to build up a formula for forecasting the general weather some months ahead.

As an example, let us consider the factors in the weather of north-west Europe. First in importance we may place variations of temperature in the North Atlantic Ocean. These are important, not so much for their direct effect as for their effect on the intensity and position of the Azores anticyclone and the Icelandic low. It seems fairly clear that a high surface temperature in the Atlantic tends to be accompanied by pressure above normal over the Azores, the British Isles, France, Germany and Southern Scandinavia, and by a pressure below normal in the neighbourhood of Iceland, southern Greenland and north-west Norway, but the physical basis of the connexion is not yet clear.

The temperature of the surface waters of the North Atlantic is governed largely by the warm water from the Gulf Stream and the cold water and ice from the Arctic Ocean. The Gulf Stream is the product of the north-east and south-east trade winds, and we should expect to find a relationship between the strengths of these trade winds and the pressure distribution over the North Atlantic a year to 18 months later. We are fortunate in having a direct measure of the strength of the south-east trade in the anemometer records at St. Helena, though even that is not free from complications, but for the north-east trade we have to rely on the pressure gradient as shown by the pressures at surrounding land stations. The effect of Arctic ice is even more complicated, partly because of the complicated course followed by the main cold current, and partly because of the direct effect exercised by the main mass of Arctic ice on the atmospheric circulation. The main result is a complete reversal of the effect between summer and winter.

I need not follow the factors influencing the surface temperature of the North Atlantic further. What I wished to show was that this apparently simple factor in British weather already involves the use of at least six variables and probably more. But this is not all; conditions to the eastward also have their effect, for example the extent and persistence of the winter snow-cover in Scandinavia, may be expected to affect the frequency of NE. winds in spring, and winter conditions even further east probably influence the movements of the Siberian winter anticyclone. Finally, it has been shown that the whole mechanism is liable to be thrown out of gear by the volcanic dust from great explosive eruptions.

The problem of tracing out the causes affecting our weather by direct physical reasoning thus takes on a hopeless complexity. Further, the checking of the results by statistical methods also becomes difficult. Let us suppose that our weather is completely caused by 25 different physical factors, which is hardly an exaggeration, and let us further suppose for simplicity that these are all independent and of equal importance. Then the correlation coefficient between any single factor and say the subsequent pressure in London would be 0·2, which statistically would have no significance. This is perhaps an extreme case. In some other parts of the world conditions may be simple enough for valuable guidance to be obtained from physical reasoning. An example is the forecasting of the winter rains in California from the surface temperature of the North Pacific; here the complications introduced by Arctic Ice are absent and the direct physical method appears to be simple enough to promise success. Another example is the forecasting of the number of icebergs off Newfoundland, which depends almost entirely on conditions in the Labrador Current, but even here detailed research shows the problem to be far more complex than at first sight it appeared to be. In India the long story of monsoon forecasting began with the physical relationship that an excessive accumulation of snow in the Himalayas would be expected to interfere with the monsoonal inflow of air into Asia, but almost at once it was found necessary to invoke additional factors.

The alternative method arose out of attempts to extend this relationship with the Indian monsoon, and has been extensively developed by Sir Gilbert Walker (6). He has formed series of meteorological data for a considerable number of places in all parts of the world, mostly in the form of means for three-monthly seasons, and correlated each of them with all the others, for the same season and for three and six months before and after. This sounds a formidable task, but the labour involved is minimised by practical methods of approximation, chief among which is the re-calculation of each series as deviations from normal, the unit being so chosen that the standard deviation equals the square root of 20.

Having obtained a large number of correlation coefficients, the next step is to determine which of them probably represent real phenomena. If we correlate a large number of entirely fortuitous series of data, some of the coefficients obtained will have a value which, by itself, would be taken to indicate a real relationship. Hence we must determine the probable maximum coefficient that will arise by pure chance among a given number of correlations between series each of a given length. Any coefficients less than this are regarded as having no significance except on independent grounds.(7) The process of constructing a formula for seasonal forecasts for any element in any region then becomes almost mechanical. From the tables the significant coefficients are picked out with seasons preceding that to be forecast, from all parts of the world, and since the data are already expressed in terms of standard deviation, a regression equation can be written down straightway, or with only a small amount of further exploration.

This method at first sight appears to be crude and unscientific, but further reflection suggests that —quite apart from the consideration that it does appear to give practical results—it has a real physical basis. In the example of the difficulties of the logical method, I quoted the case of 25 factors, all independent. But in practice they are not all independent, more probably they are all inter-related. The main variations of all of them may be associated with variations at certain key stations, which Hildebrandsson termed " centres of action." Sir Gilbert Walker's method is to locate these centres of action by an exhaustive preliminary survey, and then to go straight to his final objective, cutting out the intervening chain of cause and effect, which is generally tangled and obscure. The result has been to replace the original idea of many separate centres of action by the conception of the atmosphere as governed by three great " oscillations," between the high and low pressures in the North Atlantic and

in the North Pacific, and between the American and Indian regions in the great " southern oscillation," and these oscillations have now been represented by single series of index figures, though no satisfactory physical basis has yet been found for them.(8)

So far it has been tacitly assumed that our object is to forecast the average pressure, temperature or rainfall for a whole season of three months. This may be a practicable goal in tropical countries with a definite monsoon, but in middle latitudes where the weather is highly variable from month to month such forecasts would be of little value. It is quite possible for a very wet January to occur between a dry December and a dry February, the rainfall of the winter as a whole being almost exactly normal. Some years ago I was accordingly led to examine the possibility of making forecasts of the general character of individual months from monthly pressure charts along analogous lines to forecasting from daily charts, except that instead of actual pressures I employed deviations from normal.

A chart of pressure anomalies during a month generally shows one or more closed areas in which pressure reaches a maximum deviation above or below normal. These are analogous to the anti-cyclones and depressions of an ordinary daily weather chart, and like the latter they generally occupy different positions on successive charts. A detailed examination (9) of a long series of monthly charts showed that these centres of excess and deficit have a tendency to move from some westerly point to some easterly point, like ordinary anticyclones and depressions, but much more slowly. It was even possible to plot favourite tracks, like those drawn by van Bebber for ordinary depressions.

This result holds out some hope of a possible method of forecasting the distribution of pressure during one month from a consideration of the distribution during the preceding month, by methods similar to those employed in daily forecasting, but since the life-history of a monthly " centre " does not occupy anything like so many months as there are days in the life-history of an ordinary anticyclone or depression, and the monthly tracks are even less regular than the day-to-day tracks of depressions, the process evidently requires a great deal of care. We must have some means of foreseeing the sudden appearance or disappearance of centres of deviation, and also the aberrant tracks which they sometimes follow.

The work of Sir Gilbert Walker and others has shown that the general trend of what we may call " seasonal " weather depends on slowly changing factors operating in all parts of the world—the great southern oscillation, the mighty ocean currents, the enormous masses of floating ice in the Arctic and Antarctic, and perhaps also solar changes and the veils of volcanic dust. These govern the general character of a " season " of three months or more, determining, for example, whether it is wet or dry. Superposed on these are the more rapid changes which we may describe as " intra-seasonal." They may be regarded as summing up the irregular variations from day to day, and from that point of view their origin is more local and in a sense more " accidental " than the seasonal variations. But the seasonal variations in turn sum up the intra-seasonal variations, and just as the general barometric situation governs the birth, movement and death of cyclones and anticyclones, so probably does the seasonal situation govern the birth, movement and death of the intra-seasonal anomalies.

The investigation of the latter was based on monthly charts, because monthly means of pressure are readily available. The month, however, is too long. Experiments have been made with 10-day charts, but the 10-day unit seems to be too short, and the best time unit with which to study intra-seasonal changes appears to be about 15 days. An excellent example of a series of four 15-day charts showing the movement of a low-pressure centre from south-west of Greenland to the neighbourhood of Spitsbergen in December, 1933 and January, 1934, was illustrated in the *Meteorological Magazine* for January and February, 1934. The parallel movement of the anticyclonic centres, though not so striking, is also clearly shown.

This method of attack is probably only of use in middle and higher latitudes; nearer the equator other methods are required, and it seems that in any country the first step in studying the problem of long-range forecasting must be carefully to consider the lines of attack.

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APPENDIX XXXV.—MEASUREMENT OF EVAPORATION WITH SPECIAL REFERENCE TO (i) WATER SUPPLY, AND (ii) AGRICULTURE (Minutes XIV, pp. 85–8)

(*a*) MEMORANDUM BY E. G. BILHAM
(*b*) MEMORANDUM BY L. A. RAMDAS
(*c*) MEMORANDUM BY THE CANADIAN METEOROLOGICAL SERVICE

(*a*) Memorandum by E. G. Bilham, B.Sc.

(*Superintendent, British Climatology Division, Meteorological Office, London*)

1. **Introduction.**—It has been thought desirable to bring the subject of evaporation before the Conference because there is evidence of an increasing demand for evaporation data from various quarters. The subject is a difficult one and the literature is extensive. So far as I am aware no attempt has ever been made to introduce evaporation into the regular routine of observations at meteorological stations in general, and it is questionable whether such an innovation would be desirable. The subject has occasionally been studied purely from the climatological aspect, and more often from the theoretical aspect, but it is probably true to say that most observations of evaporation have been made with some definitely practical object in mind. In view of the probability that the practical aspect of the subject will continue to predominate in any work on evaporation with which Colonial meteorological services may be associated, it has been decided to confine this memorandum to a discussion of methods of measurement with special reference to particular needs.

Questions of evaporation enter into various activities which depend on weather or climate but it may be said that water supply authorities and agriculturists are the two bodies most likely to be interested practically. In this connexion we should note that silviculture or forestry may be included under agriculture. Mr. W. N. Guillebaud, of the Forestry Commission (England and Wales) has drawn my attention to the fact that direct measurements of rate of evaporation have been found to possess considerable value in assessing forest-fire hazard, particularly in Canada.* In regard to general agriculture, the Agricultural Meteorological Committee (Great Britain) has in recent years had to consider means of meeting a demand for data in regard to the "drying power of the air". For a time the demand was partially met by including "saturation deficit", that is to say, the difference between the actual vapour pressure and the saturation vapour pressure measured in millibars, in the weekly summaries circulated to stations and research workers. More recently research has been inaugurated with a view to determining the most suitable form of evaporimeter for routine use at agricultural meteorological stations, so that direct measurements of evaporation may become generally available.

In regard to water supply, it is common knowledge, of course, that some information in regard to evaporation losses must be available before rainfall data can be used to estimate the available yield of a catchment area. By "available yield" we mean the amount of water which will actually find its way into the impounding reservoirs, rivers or underground water-bearing strata from which the supply is drawn. The evaporation loss is the amount of water which is evaporated into the air from all moist surfaces over the catchment area. These include not only open water surfaces but also the foliage of trees, grass and other plants, which transpire immense quantities of water into the air. We shall see later that there is very little connexion between the losses from open water surfaces and the losses due to the transpiration of water from the soil by vegetation. The needs of the water-engineer are therefore rather complex but it is of interest to note here that in regard to evaporation from the soil his interests overlap those of the agriculturist.

2. **Methods of measurement.**—Numerous methods of measuring evaporation have been described, but they fall, broadly speaking, into two definite classes :—

(1) Methods in which the loss of water from an open vessel is determined.

(2) Methods in which the amount of water evaporated from some form of porous surface, continuously wetted, is measured.

The two methods cannot be said to approach the problem from vitally different aspects. In both cases the atmosphere is offered the opportunity of taking up moisture and the amount by which the supply of water is depleted after the lapse of a definite interval of time, say 24 hours, is measured. The results may be expressed either in terms of the mean depth of water evaporated from the whole surface, or in terms of the weight or volume of water evaporated per unit of area. If depth is expressed in centimetres, weight in grams and area in square centimetres, the two modes of expression give practically the same numerical result. In *British Rainfall* evaporation data are always given in the form of inches of water, following the practice used in the analogous case of rainfall.

Although the two methods of measurement are fundamentally similar, experience shows that in general, the results given by instruments of one class do not agree with the results given by instruments of the other class, and also that the results given by instruments in the same class, but differing in dimensions and design, do not agree with one another. Some of the reasons for such differences are set out in a paper entitled "Evaporation ; a brief review of methods and results", read at the Agricultural Meteorological Conference in October, 1934.

3. **Tank evaporimeters.**—The standard evaporation tank used at British stations is a large rectangular cistern usually made of galvanised iron, 6 ft. square and 2 ft. deep, containing therefore about 450 gallons of water. The tank is sunk into the ground so that its rim projects about 3 in. and the water level is maintained about 2½ in. below the rim, water being added or withdrawn as may be

* See for example :—WRIGHT, J. G. Forest-fire hazard research as conducted at the Petawawn Forest Experimental Station, *Canadian Forest Service, Ottawa,* 1932, and WRIGHT, J. G., Forest-fire hazard tables for mixed red and white pine forests, *Canadian Forest Service, Ottawa,* 1933.

necessary. The tank is fully exposed to rain and sun, and should in theory also be fully exposed to wind. Unfortunately, however, if the latter condition is satisfied, serious errors may accrue owing to excessive loss by outsplashing from the tank when rain is falling, or even by water being blown over the lip of the tank. Calculation shows that such losses may be serious in winds of the order of 12 ft. per second at ground level, and it becomes necessary therefore, on this account, to instal the instrument in a place sheltered from strong winds. The measurements of evaporation are made by means of determinations of water level, normally made daily at about 9 h. For this purpose a vernier measuring device known as a hook gauge, or a float gauge operating a pointer working over a graduated arc, is used in order that the level may be determined with sufficient accuracy. Allowance is made for rainfall by using the readings of an adjacent rain-gauge. This allowance involves considerable uncertainty, particularly in windy weather, when eddies round the gauge may cause its reading to differ appreciably from the actual increment of water to the tank.

4. **Evaporimeters using porous surfaces.**—The most familiar instrument of the second class is the Piche evaporimeter. In the instrument as catalogued by Negretti and Zambra, water contained in a glass tube about 9 in. long and 0·6 in. diameter, graduated in cubic centimetres, is evaporated from a disc of blotting paper clipped over the open end of the tube. The other end of the tube is hermetically sealed. When in operation the tube is suspended with the blotting paper evaporating surface downwards and the evaporation is determined by observing the change of level in the graduated tube. At Valentia Observatory it was found that on days without rain the evaporation as measured by a Piche evaporimeter in the Stevenson screen exceeded that measured in a concrete tank by about 30 per cent in light winds and by about 70 per cent in moderate or strong winds.

In other forms of porous-surface evaporimeters the evaporation occurs from surfaces of blotting paper, fabric or porous clay, the latter material being used in the form of plates, cups, tubes or spheres. Most frequently the evaporating member and the water reservoir form two distinct units connected by tubing. Measurements may be made by either volumetric or gravimetric methods. An account of various types of instruments will be found in a paper by B. E. Livingston* who himself devoted much study to the porous cup atmometer.

Two new instruments of the porous-surface class have recently made their appearance, and both are being tested at Rothamsted for the Agricultural Meteorological Committee. In the first, designed under the supervision of Prof. Blackman at the Imperial College of Science and Technology, evaporation occurs from a surface of hardened filter-paper clamped against the perforated base of a flat cylindrical metal reservoir which is connected by a metal pipe to a vertical graduated glass tube on which the readings are taken. It is claimed that the instrument is simple and accurately reproducible ; also that the results are not affected by salts dissolved in the water. Brine may be used, for example, in frosty weather without prejudice to the observations. In the other instrument designed by Dr. J. S. Owens,† evaporation from any material, such as soil, sand, or even small growing plants, can be measured. The material is placed in a cylindrical metal vessel communicating with a graduated glass reservoir of water. By an ingenious mechanical device the water in the evaporator is maintained at a constant level and water therefore flows from the graduated reservoir to compensate for evaporation. The actual amount of evaporation in a given period is thus determined by the difference in the water level in the reservoir at the beginning and end of the period.

5. **Evaporation calculated from measurements of percolation.**—In the evaporimeters described above provision is made for a regular supply of moisture to the surface from which evaporation occurs. They aim simply at measuring the rate of loss of moisture from some arbitrary form of wetted surface, and in so far as they succeed in that aim they provide us with information in regard to what has been called the "drying-power of the air". Such information is desired by research workers in agriculture, particularly in relation to plant physiology, and we may take it for granted that readings of an instrument on the lines of Prof. Blackman's evaporimeter will meet this part of their needs. Readings from an evaporation tank would seem to be the most appropriate data for estimating losses from open water surfaces such as lakes and reservoirs, though it has often been pointed out that any form of tank can only reproduce in a very imperfect manner the conditions which prevail in a large body of water. The losses by evaporation which occur over a catchment area cannot, however, be determined by either type of instrument. In this case the water available for evaporation is supplied by the actual rainfall, and in a region of no rainfall the evaporation loss would be nil, though an ordinary evaporimeter would show a high value for the annual evaporation. It need not surprise us therefore to find that in a catchment area such as the Thames basin there is (i) a negative correlation between the annual loss by evaporation and the annual evaporation from a tank, and (ii) a positive correlation between the annual loss by evaporation, and the annual rainfall over the basin. It appears, in fact, that the actual quantity of water taken up annually from the soil and growing vegetation by evaporation under natural conditions is more closely related to rainfall than to anything else.

At a few voluntary stations in Great Britain there are percolation gauges, which consist of enclosed blocks of natural soil, with or without a cover of vegetation, with means for measuring daily the amount of water which percolates through them. Under steady conditions the difference between the rainfall and the percolation is a measure of the evaporation loss from the soil in the gauge. Measurements made in this way are clearly likely to bear a much closer resemblance to the natural losses from an area of which the gauge is representative than could be obtained from any form of ordinary evaporimeter.

6. **Summary of Conclusions.**—It is clear from the foregoing discussion that no single form of evaporimeter can be selected as suitable for universal use. We can, however, say fairly definitely what

* Atmospheric Influence on Evaporation and its direct Measurement. *Washington D. C., Mon. Weath. Rev.,* **43,** 1915, pp. 126–31.

† *Nature, London,* **134,** 1934, p. 330.

sort of evaporation data are appropriate for use in particular circumstances. The following table is an attempt to set out the types of instrument the readings of which seem suitable for use in connexion with various related studies :—

Related Studies.	*Type of Evaporation Instrument.*
(*a*) Loss by evaporation from reservoirs and other open bodies of water.	Tank.
(*b*) Plant physiology .. .. (*c*) Animal physiology (e.g., certain stages in the life-cycle of locusts) (*d*) Timber seasoning .. .. (*e*) Forest-fire hazard .. .. (*f*) Other studies demanding information in regard to the "drying-power of the air"	Porous-surface evaporimeter.
(*g*) Yield of catchment areas .. .. (*h*) Hydro-geology .. .. (*i*) Land-drainage .. .. (*j*) Transpiration of soil moisture by crops	Percolation gauge.

The table is, of course, very tentative and incomplete, but it is hoped that it may be of assistance as a guide in selecting the type of observations to make in regions where evaporation data are required to meet a fairly well-defined need.

(*b*) Memorandum by L. A. Ramdas, Ph.D.

(*India Meteorological Department*)

1. For the measurement of evaporation in relation to water supply a sufficiently large reservoir ought to be used. For all practical purposes the U.S.A. standard evaporimeter (4 ft. in diameter, 10 in. deep, supported on a grillage of timbers with the top of the tank 14 in. above the ground surface) with still-well and hook-gauge probably suffices, because the measurements with this instrument have been compared in the United States with the evaporation from large tanks, lakes, etc., and it has been found possible to arrive at approximate reduction factors (see "Evaporation from a free water surface," by C. Rohwer, *U.S.A. Dept., Agric., Washington, Technical Bulletin*, No. 271, 1931).

Using the relation

$$E = (1{\cdot}465 - 0{\cdot}0186\,B)\ (0{\cdot}44 + 0{\cdot}118\,W)\ \left(\frac{100}{h} - 1\right) e$$

where E is the daily evaporation in inches from an evaporimeter of the U.S.A. type, B the atmospheric pressure in inches of mercury, W the velocity of wind in m.p.h., h the humidity percentage and e the actual pressure of water vapour in inches of mercury, Raman and Satakopan (*India, Meteor. Dept., Sci. Notes*, Vol. 6, No. 61) have calculated the evaporating power of the atmosphere for various parts of India for different months of the year. Evaporation charts prepared from these calculated values show important features which have been discussed in the paper referred to above.

2. Evaporation in relation to agriculture may be considered from two aspects. Firstly, we have the "evaporating power" of the atmosphere which shows the rate at which the atmosphere can remove water if it is made available, and secondly, the actual "water balance" in the soil as controlled by the actual rainfall, percolation through the soil, evaporation at the soil surface and transpiration from plant surfaces.

To study the reliability of different types of evaporimeters which may be used for measuring the evaporating power of the atmosphere, comparative observations have been taken four times daily for over a year with the following instruments at the Central Agricultural Meteorological Observatory at Poona :—

(*a*) U.S.A. standard evaporimeter.
(*b*) Athavale evaporimeter (circular reservoir 1 ft. in diameter with side tube and micrometer gauge exposed on a masonry pillar 4 ft. high)
(*c*) Wild's evaporimeter.
(*d*) Pickering's evaporimeter.
(*e*) Livingston's atmometers (black and white).
(*f*) Piche's evaporimeters, one inside a Stevenson screen, and a series of instruments at 1 in., 6 in., 1 ft., 2 ft., 3 ft. and 4 ft. above the soil surface in the open.

It is observed that (*a*) is very satisfactory as a standard for a central station ; (*b*) is handier for use at out-stations ; (*c*) is quite satisfactory if exposed inside a Stevenson screen, but is not useful for exposure in the open ; (*d*) and (*e*) are not quite successful because of the drying tendency of cloth or porous sphere during the hot months when evaporation is excessive ; (*f*) is cheap, reliable, and portable. One Piche instrument inside a Stevenson screen and others in different environments, e.g., in the open as well as inside crops at a few levels above ground should provide interesting data ; the evaporimeter inside the Stevenson screen helps also to maintain the continuity of the data during rainy weather when the instruments in the open do not function.

For the estimation of the available moisture in the soil, in addition to direct estimations by taking weekly samples from different depths and desiccating these to dryness, we have set up a series of portable percolation gauges having the same diameter as the ordinary rain-gauge, and filled to different depths of soil. The percolated water is measured and the gauges are also weighed daily. Evaporation from the soil is also measured separately by using soil evaporimeters with larger cross-section and weighing them daily.

It may be remarked that after the rainy season is over, desiccation sets in during the clear season (October–April) which follows ; once the top of the soil has attained a stage of desiccation when its moisture content is limited by its hygroscopic properties further progressive loss of moisture from

day to day is checked although there is a conspicuous diurnal variation of the moisture content due to evaporation during the day from the soil surface and absorption of moisture by the soil surface from the air layers near the ground during the night. These phenomena cause a decrease with height during day and an increase with height during night of the vapour pressure in the air layers near the ground. The epochs of maximum and minimum water content of the surface layer of the soil coincide with the epochs of minimum and maximum air temperature respectively.

The diurnal variation of moisture content is observed to decrease rapidly with depth inside the soil, being practically negligible below one inch.

Comparative observations at Poona with soils from different parts of the country show that the diurnal variation of moisture content is largest in the black cotton soils of the Deccan and least in the alluvial soils of the Indo-Gangetic plains.

The following papers may be referred to in this connexion :—

(i) "Agricultural Meteorology : Preliminary studies on soil moisture in relation to moisture in the surface layers of the atmosphere during the clear season at Poona," by L. A. Ramdas and M. S. Katti, *Indian J. agric. Sci., Calcutta*, 1934, Vol. 4, part 6, pp. 923–37.

(ii) "The variation of moisture in the surface layer of the soil in relation to the diurnal variation of meteorological factors," by L. A. Ramdas and M. S. Katti, *Curr. Sci., Bangalore*, July, 1934, Vol. 3, No. 1, pp. 24–5.

(iii) "The diurnal variation of moisture in the soil during the clear season," by L. A. Ramdas and M. S. Katti, *Curr. Sci., Bangalore*, June, 1935, Vol. 3, No. 12, p. 612.

(*c*) Memorandum by the Canadian Meteorological Service

1. **Measurement of Evaporation with special reference to**—(1) *Water Supply.*—Evaporation from a tank 6 ft. square and 3 ft. deep sunk flush with the ground has been measured at Toronto for many years. There are a considerable number of circular tanks about 4 ft. in diameter and 18 in. deep, sunk into the ground at the Dominion Experimental Farms. Recently a number of Piche evaporimeters have been supplied to the farms and observations have been taken with them in Toronto. The comparison with the tank observations shows that the evaporation as measured by the Piche is greater than that from the tank. This is greater no matter what the character of the day is in regard to sunshine. It was found that the tank equalled 0·89 Piche. For water supply purposes the tank probably gives the most accurate method of estimating the amount of evaporation from reservoirs but for large bodies of water, such as lakes, a tank would be quite unsuitable owing to the impossibility of measuring the evaporation by this means on the open lake. Evaporation is of very great importance in connexion with the water levels on the Great Lakes, and an investigation is now being undertaken to obtain an accurate estimate of it.

It has been estimated from the shore and tank observations that the amount of water lost by evaporation lowers the lake levels by over 2 feet per annum ; this is practically equal to the amount of rainfall that is received on the same area. About one-third of the entire lake basin is occupied by the water surface of the lakes themselves. Consequently, when it is estimated that almost one-third of the entire rainfall on the basin goes up in evaporation from the lake surface the problem assumes one of very great national importance when measures for maintaining the lake levels are under consideration.

If an accurate estimate is to be obtained, it is necessary to obtain a formula that can be applied to the open lakes. To this end laboratory experiments are being carried out under controlled conditions. The evaporation from a pan in a small wind tunnel is being measured, the velocity of the wind is kept constant, the temperature of the water controlled thermostatically, and the experiment conducted during periods when the air temperature remains fairly constant for a considerable period. The results appear to be in agreement with Dalton's formula :—

$$E = (0{\cdot}14 + {\cdot}0066w)\ (e' - e)\ \frac{30}{B}$$

where E = evaporation in inches per hour.
w = wind in miles per hour.
e' = vapour pressure at the water temperature.
e = vapour pressure at the dew-point of the air.
B = barometric pressure in inches.

For a steady wind velocity it was found that the evaporation varied directly with the difference between the vapour pressure of the water and the air. It does not seem possible, however, that the evaporation should be proportional to the wind velocity and this matter requires further experimentation. In the winter when the air temperature and consequently the dew-point is much below the water temperature there is very considerable evaporation. On the other hand, during the spring and fall and possibly at times in the summer when the dew-point of the air is above the water temperature, condensation will take place. Consequently, it is essential that the water temperature, the air temperature, and the dew-point temperature out on the open lake should be known approximately throughout the year. This part of the investigation is being carried out in co-operation with the shipping companies. Mercury-in-steel thermographs have been installed on a sufficient number of boats to give a proper survey of the water temperatures, while air and dew-point temperatures are obtained by the wet-and dry-bulb thermometers installed in an ordinary screen on a considerable number of the boats. In this way it is hoped to obtain a fairly accurate survey of the temperature and water conditions over the lakes and by applying the formula worked out in the laboratory, obtain a fairly accurate means of getting the evaporation. As the investigation has just been undertaken, sufficient data have not yet been collected to draw any conclusions. Any suggestions as to how this investigation could be best carried out would be welcome.

In the case of water supply for engineering purposes the hydro-electric engineers in this country by careful comparison of rainfall data with available stream flow and run-off at various seasons are working out empirical factors to give the amount of loss through evaporation, transpiration from growing crops, and retention in the soil. Probably this will always remain the best method of obtaining an estimate of this loss.

(2) *Agriculture.*—It does not appear that the tank method of evaporation is satisfactory for agricultural purposes. Since evaporation depends chiefly on the air temperature and the dew-point temperature and the temperature of the water in the tank, it may not give the proper representation of the drying power of the air.

Mr. Barnes of the Experimental Farm at Swift Current has carried on a very extensive programme of investigation into evaporation from the region that has suffered most severely from drought during the past three years. Mr. Barnes' method consists of sinking large pails flush with the ground. These pails are cylinders 5 ft. deep, 1 ft. in diameter, and separated by a small air space from the wall of the deep hole in which they are placed. The pails of earth are weighed two or three times a week and the evaporation determined by the change in weight. The evaporation in this case depends on the surface cultivation of the pails and thus gives the total evaporation and transpiration that is taking place from the plants in the pail. The results obtained are believed to be true for field crops growing in that area.

2. **Forest-fire hazard research and practice in Canada.**—The rapidity of the spread of forest fires is a function of the moisture content of the forest fuels—duff, slash, and so forth. A knowledge of this moisture content is, therefore, of great use to the practical forester in organizing means of fighting fires. Unfortunately, however, the direct determination of this quantity is a difficult and time-consuming matter, more suited to the research laboratory than to the field, and, therefore, much attention has been given to empirical means of arriving at an idea of the moisture content of the fuels.

1. *The method due to J. G. Wright.**—The method due to J. G. Wright is entirely empirical. It provides a means of calculating the duff moisture from readings of rainfall, relative humidity, and evaporation, the latter being measured by means of a simple, small metal pan fitted with a hook-gauge. The idea behind the method is that measurements of evaporation provide a means of integrating, as it were, the effect of temperature, sunshine and wind. In the practical application of the method, the time and amount of the precipitation, the minimum relative humidity during the day, and the amount of evaporation (on an arbitrary scale) during the past twenty-four hours are entered on a chart. Then, by the use of appropriate tables, the "hazard index" may be calculated. This quantity is really 300 minus the percentage of moisture in the duff. It was expressed in this manner in order to emphasise to the forester that the higher the index, the greater the hazard. For instance, there is considered to be no hazard (in red or white pine) when the index is below 276; from 276 to 281 the hazard is called low; from 282 to 285 moderate, and so on.

The tables used in this method, as well as the above hazard limits, are the result of much patient experimenting and statistical work, involving a very large number of direct measurements of duff moisture and many more indirect measurements by means of weighing duff-baskets. It need scarcely be emphasised that their justification is entirely pragmatic and that they rest on no theoretical basis whatever. Fundamental work on the absorption of water by such substances as compose the forest fuels and on the exchange and transport of vapour in the atmosphere, in so far as it has been done, has not to the writer's knowledge been applied to this problem.

2. *The "Hazard Stick" method.*—The method commonly known as the "hazard stick" was developed in the western United States, and is now being used in British Columbia and experimented with elsewhere in Canada. It is simplicity itself; it consists merely in daily weighings of one or more small round sticks (½ in. diameter by 18 in. long), which are left exposed to the sun, rain, and wind in a clearing or *brulé*. It is found possible to correlate the weight of these sticks with the moisture content of the forest fuels, and, therefore, it is easy for the forest ranger on the spot to find out whether or not there is danger of fire spreading.

3. *Results.*—Both the above methods seem to be giving satisfactory results, or at least to be repaying many times the small cost of their operation. The "hazard stick" method has the advantage of simplicity; the Wright method the advantage of providing incidentally much valuable meteorological information. It may safely be stated that all the Government foresters and all the managers of Forest Protection Associations who have tried the method would be very unwilling to return to the old plan of relying on the unaided judgment of the forest ranger.

APPENDIX XXXVI.—CONSTRUCTION OF RAINFALL MAPS (Minutes XIV, pp. 88–9)

(*a*) MEMORANDUM BY J. GLASSPOOLE

(*b*) MEMORANDUM BY THE CANADIAN METEOROLOGICAL SERVICE

(*a*) Memorandum by J. Glasspoole, Ph.D.

(*British Climatology Division, Meteorological Office, London*)

1. **Introduction.**—The starting point in the study of rainfall is the setting up of a sufficient number of well-exposed rain-gauges in charge of paid or voluntary observers. Experience shows that owing to the wide variations in the rainfall which may occur from place to place a close network of observing stations is desirable. Fortunately, the observation of rainfall is neither difficult nor costly; while its utility is obvious to the community at large. In the British Isles these considerations have resulted in the accumulation of a vast mass of rainfall statistics mainly furnished by voluntary observers.

* WRIGHT, J. G., Forest-fire hazard research, Ottawa, Dept. of the Interior, 1932, and WRIGHT, J. G., Forest-fire hazard tables for mixed red and white pine forests, Ottawa, Dept. of the Interior, 1933.

The construction of rainfall maps may be viewed from two different standpoints. From one point of view a map may be regarded as simply a means of presenting the results of observations in such a way that their relation to geographical features may be clearly seen. From the other point of view, a map is used as a means to an end. The readings of rainfall are put on the map as a stage in the solution of a problem. We may, for example, desire to know what area received more than 3 in. of rain in a particular storm. In this case all the available readings would be plotted, the isohyetal lines drawn and the area enclosed by the 3-in. isohyetal line measured with a planimeter. A similar method is used in determining the "general" or space average over a specified area, such as the catchment area of a stream or river.

Having regard to the various purposes for which they are required, rainfall maps may be of many kinds. The data mapped may be the actual amount of rain for a day or group of days, a month or group of months, a year or the average for a period of years; we may also map the rainfall of a month or year expressed as a percentage of the average, or the frequency of occurrence of days with rainfall exceeding specified limits. The scale of map employed also varies over a wide range according to the nature of the requirements. Details of the maps prepared for routine or special purposes in the Climatological Division of the Meteorological Office are given in the Annex. These maps all have their particular uses, and the special points involved in their construction are referred to below. The fundamental basis of all this work is a large scale map showing the distribution of the average annual rainfall over the region, and we shall begin by describing how such maps are drawn in the Meteorological Office (British Rainfall Section).

2. **Maps of average annual rainfall.**—Before dealing with the maps of average annual rainfall it is desirable to describe briefly the method employed in arriving at the average for any station. The period adopted as the standard for reference in the case of rainfall is 1881 to 1915. In the case of records complete for this period the mean of the annual totals is adopted. In the case of records incomplete for this period, or which commenced after 1915, a mean for a period other than the standard period is all that is available in the first instance. A comparison of the records obtained in those years at neighbouring stations, for which records are complete from 1881 to date, makes it possible to arrive at a correction factor, which, when applied to the observed mean will give approximately the mean which would have been obtained had the record been complete for the years 1881 to 1915. The stations with complete records are referred to as *ratio* stations (there are usually three or four ratio stations in an area of 500 sq. miles). The annual rainfall at each of these stations is expressed as a percentage of the average for that station for the standard period 1881 to 1915, and the mean of the percentage values for these stations for each year is obtained. The final series of percentage values is used to correct the means of the short records within that area.* It is usual to compute averages only for records covering at least five years, but shorter records are occasionally referred to in areas of few data.

The averages, as computed in this manner, are plotted on maps on a scale of 2 miles to 1 in. (1 to 125,000), the values being plotted to the nearest 0·1 in. The maps used show the configuration of the land with the hills shaded. From the actual observations the average rainfall is determined for a number of points. In drawing the maps, estimates have to be made of the rainfall in adjacent regions by reference to the values at these points and the configuration of the land. The problem consists initially of deciding whether the adjacent areas are likely to receive more or less rain than these points. Observations are more numerous in valleys than on mountains and in order to determine the maximum rainfall of a mountain, reference is made to such observations as give a measure of the increase in the rainfall up that mountain slope or an adjacent one with more data. It is always necessary to consider the effect of the configuration of the land in producing rising air, and not merely the elevation of that region.

The following general principles based on experience in drawing these maps may be enumerated :—

(1) Mountain ranges at right angles to the prevailing wind receive more rain than mountain ranges in the direction of the wind.

(2) Valleys which face the sea to the south-west have a small rainfall for a longer distance up them than similar valleys facing towards other directions.

(3) The maximum rainfall tends to occur just on the leeward side of a mountain ridge.

(4) Valleys surrounded by mountains on all sides have high rainfalls. Thus, Seathwaite is only 400 ft. above sea level, but its effective level from a rainfall point of view is 1,000 ft. or more and its average as much as 129 in. a year.

A comparison of rainfall maps drawn thirty years ago with recent maps shows, in addition to the much greater use made of the configuration of the land, a marked difference in drawing the lines near the coast. In earlier maps the isohyetal lines are invariably drawn at right angles to the coast line, whereas now they are in general drawn parallel to the coast. On theoretical grounds there is clearly no reason why over a long period one coastal strip should receive appreciably more rain than an adjacent equal area along the coast, whereas the increased elevation of the hinterland is ample reason for the increase of the rainfall from the sea to the land. This generalisation as to the run of the lines near the coast has been confirmed by the actual rain-gauge readings.

In the construction of the rainfall map over the County of London and adjacent district, published in *British Rainfall*, 1933, as many as 190 reliable rainfall records were found to be available for an area of some 250 sq. miles. In such a region of abundant data it is possible to test the accuracy of the data and of the method of constructing the map. The rainfall over practically the whole of this area varies only from 22 to 26 inches. It was found that isohyetal lines could be drawn at intervals of an inch, and, if necessary, at intervals of half-an-inch. This suggests that averages computed from adjacent stations in regions of similar rainfall could be expected to agree within 0·2 or 0·3 in. It should be emphasised that in order to attain this accuracy it is necessary to provide adequate supervision to ensure that the exposures of the gauges are satisfactory. In the case of London the majority of the stations had been inspected before carrying out the rainfall survey.

* Further details of the method are given in an article on the Rainfall of Norfolk, *British Rainfall*, 1928, p. 270.

Survey maps on the scale of 2 miles to 1 inch have now been prepared for nearly two-thirds of the British Isles, and maps on a smaller scale are available for the remaining area.

3. **Maps of average monthly rainfall.**—The preparation of these maps, on a scale of 1 to 1,200,000, was last carried out about 1920. The available information consisted of monthly averages for some 550 stations and a map showing, in considerable detail, the annual rainfall. The annual map was based on the values for these stations, on averages for some additional 1,000 stations especially computed, and on the survey maps on a large scale for certain areas as described in the previous section. Instead of computing monthly averages for a large number of stations, an alternative method was adopted. The general principle had already been enunciated that, whereas the average annual rainfall might vary appreciably over a short distance in mountainous regions, the proportion falling during the months remained almost constant. Thus, while the total rainfall recorded at Ben Nevis Observatory, at an altitude of 4,400 ft. is more than twice that at Fort William at the foot of the mountain, the percentages of the annual amount falling in each month (known as the isomeric values) are almost identical. Variations in the isomeric values from place to place are independent of local configuration, and the distribution over the British Isles can be well defined from the 550 stations with complete records. By the use of these isomeric maps, monthly averages could be readily obtained for any place for which the annual rainfall was available. The procedure adopted was to plot the monthly averages for the 550 stations. Points were then fixed on the annual map, the isomeric maps and the monthly rainfall maps at the intersections of horizontal and vertical lines ruled, through places actually 10 miles apart, in a similar manner on each map. For each point the annual and isomeric values were read off the maps and the corresponding monthly averages computed. These values were subsequently plotted and the isohyetal lines drawn.*

The maps are reproduced in the "Rainfall Atlas" published by the Royal Meteorological Society.

4. **Maps of individual years.**—Each volume of *British Rainfall* contains a map showing the distribution of the rainfall of the year in inches (now published on a scale of 1 to 5,000,000). This map is based on the observations from the 5,000 stations whose annual totals are included in Part III of the volume. The annual totals, in whole inches, are plotted on a map on a scale of 1 to 1,200,000. In areas of abundant data, such as the neighbourhood of large towns and certain moorland regions used for securing water supplies, only a selection of the data can be plotted. Isohyetal lines are drawn for the following values :—10, 15, 20, 25, 30, 40, 60, 80, 100 and 150 in. but in some years the 10 and 15 in. and in other years the 150 in. lines do not appear. The distribution on each map is generally similar to that shown on the map of average annual rainfall and a knowledge of this distribution is in fact used subconsciously in drawing each annual map. The distribution is determined mainly by the configuration of the land, and for this reason it is difficult to detect the differences in maps showing the rainfall in inches for various years. Maps showing the distribution of the rainfall as a percentage of the average are therefore prepared. For this purpose some 300 well-distributed stations with averages are used and the map is printed in colours. These maps show clearly the differences in the rainfall year by year, and the maps in *British Rainfall* continue the series published in the "Rainfall Atlas" for the years 1868 to 1923.

5. **Maps of individual months and groups of months.**—Maps showing the distribution of the rainfall of individual months, on a scale of 1 to 1,200,000 for publication in the *Monthly Weather Report*, are prepared from the 1,000 stations, for which records are received monthly. Records from some 4,000 stations are subsequently added and the maps redrawn for inclusion in *British Rainfall*. In *British Rainfall* lines are drawn for the following values :—0, 0·25, 0·5, 1, 2, 3, 6, 10 and 20 in., although the 0, 0·25 and 20 in. lines occur infrequently. The distribution on the monthly maps usually follows fairly closely that on the average monthly or that on the annual map, but the departures from this distribution are much more noticeable than in the case of annual maps. Months occasionally occur in which the heaviest rain occurs along the east coast, or over areas where cyclonic or thunderstorm rains have predominated. It is helpful, therefore, in drawing the map to be familiar with the type of weather prevailing in the various localities.

Just as in the case of annual maps the differences are brought out by considering the rainfall as a percentage of the average, so the rainfall of individual months can be conveniently studied as percentages of the average for that month. Such maps are prepared each month and published in *British Rainfall*. They are based on records from some 200 stations.

Maps are also published in *British Rainfall* showing the distribution of the rainfall during the winter and summer half years and during the seasonal year (October to September) the rainfall being expressed as a percentage of the average rainfall for the similar period. The drawing of the percentage maps calls for little special knowledge.

In determining the rainfall over a specific catchment area for individual months or groups of months, an obvious method is to prepare maps showing the distribution of the rainfall in inches. It often proves simpler, if the average annual rainfall over the area has been determined, to express the rainfall for each station for each period as a percentage of the average annual rainfall at that station. The distribution shown on each map, prepared in this manner, is usually simple and independent of the configuration. This enables an estimate of the general percentage over the area in question to be readily determined and when this is applied to the average annual rainfall over the area, the rainfall in inches can be obtained.

6. **Individual days or groups of days.**—Maps showing the distribution of the rainfall during days of abnormally large amounts are prepared as a matter of routine each year. Usually maps for some 10 or 20 individual days are prepared and of these, about six of the most striking are published in *British Rainfall*, together with a synoptic chart for some definite time during the heavy rain. In drawing the rainfall maps from the data, usually plotted in inches and tenths, it is important to ascertain from the synoptic charts the type of precipitation, whether convectional, cyclonic or

* A description of the method is given in *London, Quart. J.R. met. Soc.* **47**, 1921, p. 101.

orographical. The orographical type of distribution is most highly developed with a steep pressure gradient from the north-west to south-east of the British Isles. In such cases it is essential in drawing the rainfall map to refer to the configuration of the land. Attention must also be paid to the general direction of the wind. Cyclonic rains are typically independent of the configuration, although the rainfall of any day or group of days usually shows some relation to the configuration in some parts of the country. The rainfall records themselves indicate whether the orography is the controlling feature in any locality. Thus, reference should be made to the increase in the rainfall from valley to hill stations. Thunderstorm rain typically occurs in a series of patches of intense local rain across the country, usually from west to east. In such cases there is little or no relationship to the configuration of the land, but in the absence of actual records the rainfall can sometimes be inferred by comparing the local damage to the land in areas where records are available and those from which no information can be obtained.

7. **Rain-days (days with 0·01 in. (0·2 mm.) or more) and wet-days (days with 0·04 in. (1·0 mm.) or more).**—Maps showing the distribution of the annual number of wet-days have been included in *British Rainfall* since 1919, but no maps of rain-days are published. As a matter of routine the total numbers of both rain-days and wet-days are plotted on separate maps on a scale of 1 to 1,200,000. There is frequently a lack of harmony in the annual values reported from adjacent stations, but the statistics of wet-days are usually much more consistent. A map showing the distribution of the average number of rain-days was published after a special investigation in an article in *British Rainfall*, 1926, and maps showing that of each month in the *Quarterly Journal of the Royal Meteorological Society*, 1928 (vol. 54, p. 89). A steady increase in the accuracy of the data is being attained by encouraging observers to read the gauge regularly each morning and recording small amounts in the orthodox manner and by the increasing use of measures showing the 0·005 in. or 0·1 mm. mark.

8. **Droughts and rain-spells.**—A separate section is devoted in *British Rainfall* to the consideration of droughts and rain-spells and reference should be made to that volume for the definitions adopted. The mapping is confined to defining the number of such droughts or rain-spells which occur in various parts of the country and presents no points of special interest.

In summarising the work which has been done in this country on mapping rainfall, attention should be directed to the importance placed on the distribution occurring under average conditions, which has been worked out in detail, and also to the importance of this cartographical study in testing, and thereby increasing, the general accuracy of the data. The map of the average annual rainfall must be regarded as of fundamental importance. The plotting of the data and the construction of rainfall maps frequently brings to light values out of harmony with the general distribution which can be discussed with the observer, and this usually results in some improvement in the exposure of the gauge or the method of taking the observations.

ANNEX

DETAILS OF PUBLICATIONS CONTAINING RAINFALL MAPS OF THE BRITISH ISLES

(1) The *Monthly Weather Report* and the *Annual Summary* give maps on a scale of 1 to 5,000,000 (80 miles to 1 in.), showing the monthly and annual rainfall in inches and millimetres.

(2) Each annual volume of *British Rainfall* contains maps of :—

(i) the monthly and annual rainfall in inches,

(ii) the monthly and annual rainfall as a percentage of the average,

(iii) percentage maps of the rainfall of the winter, summer and seasonal year (October to September),

(iv) the rainfall in inches during certain days of unusual interest,

(v) the number of droughts or rain-spells (specified numbers of consecutive days with little or no rain, or, on the other hand, with rain every day).

Recent volumes of *British Rainfall* have also included a number of special articles showing the distribution of the average annual rainfall over special areas.

(3) *The Rainfall Atlas*, published by the Royal Meteorological Society, gives :—

(i) maps of the average annual and monthly rainfall, and of the wettest and driest years in inches on a scale of 1 to 4,000,000.

(ii) a series of coloured maps showing the rainfall of each year 1868 to 1923 as a percentage of the average on a scale of 1 to 8,000,000.

(4) Maps showing the distribution of the average annual rainfall over some 12 counties were published in *Memoirs of the Geological Survey* on a scale of about 1 to 650,000. Maps showing the average annual rainfall over Norfolk, Pembroke and London, are included in special articles in *British Rainfall*, 1928, 1929 and 1933 respectively.

(*b*) Memorandum from the Canadian Meteorological Service

In Canada two major difficulties are encountered. The first is concerned with precipitation in the mountainous area of British Columbia, the Yukon Territory, and western Alberta. Almost without exception the rainfall observers are at low levels. On the coast, where they are situated in inlets, the rain-gauge is only a few feet above sea in most cases and in a few at heights of little more than 250 ft. Surrounding the station in many cases there are peaks rising to 10,000 ft. or more above sea. In the interior valleys the observer is generally at the level of the river or lake or on the first terrace. In a few cases the gauges are in tributary valleys at no great height above the main valley. There is one station on the interior plateau at a height exceeding 4,000 ft. and there are one or two on the high passes leading into Alberta. The same difficulties, but to a much smaller extent occur in the Laurentian Plateau region of Ontario and Quebec. It is obvious that without actual observation figures at the different levels in British Columbia maps of precipitation have no accuracy beyond that of the valleys and inlets. In one or two districts we have succeeded in establishing a chain of stations commencing on the inner channel and proceeding over the crest of the Cascades to the lowest point of the interior valley. However, the districts chosen were those where the altitude of the pass was low enough to permit an observer to live and find work on the pass. While the data which have accumulated in recent years admit some deductions to be made regarding the change of precipitation with height, yet they are of only local importance and they are insufficient to permit deductions to be used in estimating the amount of precipitation at very high levels. It seems that precipitation maps cannot be constructed for such regions without a chain of high level observatories.

The second difficulty in Canada is the estimate of the water-content of snow, and to this extent our precipitation averages are largely doubtful and the extent of the error can only be conjectured.

In regard to units, as most rainfall maps of the world are constructed with millimetres as a basis, it would be well to agree to use this universally. In Canada, however, the interval between isohyetal lines would have to vary, depending on whether the region was semi-arid or one of excessive rainfall.

A suggestion for the representation of precipitation is offered as follows: At most stations, if the average monthly means are arranged in chronological order, it is possible to recognise the average date of the peak of the rainfall or precipitation maximum. Generally also the peak of the secondary maximum can be ascertained with fair approximation as, for instance, in British Columbia the major peak occurs in southern interior valleys on June 1 and the minor peak about January 1. If the average number of consecutive days, which need to be taken around the date of the major peak to include 50 per cent of the annual precipitation, are plotted upon maps and isolines drawn through them, one gets a picture of the relative distribution of precipitation which is useful from the standpoint of agriculture, forestry, and water storage for power purposes. A similar map covering the number of days around the secondary maximum to encompass 25 per cent of the annual precipitation is also useful. In regions where such peaks cannot be recognised sufficiently well to utilize this scheme, the area can be left blank and marked "approximately uniform distribution throughout the year".

APPENDIX XXXVII.—METHODS OF MEASURING SNOWFALL (Minutes XIV p. 89)

By the Canadian Meteorological Service

In Canada, since the inception of the Service, snowfall has been measured by taking the average of a few depth measurements of freshly fallen snow. In many cases the observers have only a small area available for measurement while in other cases the sites are so open that measurement is difficult on account of drifting. The factor 10 has been used to reduce these snowfall measurements to the rainfall equivalent. In the Lower Lake region of Ontario this factor may be approximately correct when used for monthly totals. The method fails in the case of snow containing ice particles. The error is large also where the snow is granular in form. The error is particularly large where rain and snow occur together or where snowfall follows immediately after rain.

It is probable that the best method would be to use a gauge of sufficiently large aperture to be generally useful in catching all sorts of precipitation. Melting of the contents would often be necessary. The actual depth of snow freshly fallen and remaining unmelted upon the ground could be noted as an additional observation. The gauge would, however, give the total precipitation. By this means we should avoid the error of using the factor 10 for either very dry or very wet snow. This latter error is undoubtedly large in southern British Columbia and on the northern prairies. At Vancouver the snowfall is generally very wet while on the prairies it is often excessively dry, fine, and powdery. On the shores of the Arctic Ocean in Hudson Bay and Strait there is a considerable deposit of snowfall due to winds which lift dry snow off the sea ice and carry it inland a short distance. Sometimes fresh snow and upwhirled snow fall together at stations like Coppermine. There does not appear to be any feasible method of meeting such an extreme condition. In the Laurentian Hills in Quebec a few of the hydraulic engineers have devised a method of measuring snowfall which requires a wooden box which is weighed after each snowfall. After the tare has been subtracted the boxes are emptied as thoroughly as possible and weighed again to determine the tare for the succeeding observations. In this way the weight of any ice which it may be difficult to remove on the box is believed to be compensated for. This method seems to be good from the standpoint of ice particles and granular snow but fails largely when rain precedes the snowfall. In the case of a light rain succeeding a snowfall, the added weight of the rainfall is probably largely included in the measurement. The Marvin snow gauge used in parts of the United States has never been tried in Canada.

On the mountains above the Bow River the Department of Irrigation used a steel-shod graduated staff, which was struck down and left standing. The average of the readings of several staves along a trail was entered in the field book. Settling of the snow as well as fresh falls was thus determined. A few of our prairie observers use much the same practice, noting the total depth of snow on the ground daily instead of determining the depth of newly fallen snow directly. These figures have never been utilized in the Head Office except for snowfall measurement but possibly some use could be made of the several years' data now collected at these few stations from the viewpoint of settling, melting, and evaporation.

APPENDIX XXXVIII.—METHODS OF MEASURING SUNSHINE IN HIGH LATITUDES (Minutes XIV p. 89)

By the Canadian Meteorological Service

If the usual practice of calculating the duration of possible sunshine as the interval between rising and setting of the sun's upper limb is used in higher latitudes, the ratio of recorded sunshine to the possible amount is extremely low. This is partly due to the lack of sensitivity in the Campbell-Stokes instrument, and partly due to the difficulty of setting the instruments to get a record when the sun is north of the prime vertical. We had an observer at Swede Creek in the Yukon who tried changing the card at mid-day, having cut the cards into two equal segments. Even if two instruments are placed back to back, it is doubtful whether the low sun of these latitudes can be satisfactorily recorded except by the use of extremely sensitive paper. If this were done, the difficulty of comparability of records with those made in southern latitudes will arise. We have not tried the American instrument in high latitudes but from experiments at Toronto it seems possible to vary its apparent sensitivity by a rather large amount. Since it is practically a differential thermometer, by varying the tilt it is possible to make the switch act with a fairly thick veil of high mist or cirrus in the sun's place. The same objection, however, may be urged against its use in high latitudes, that is, intercomparability of records.

There has just recently appeared a new Pers sunshine recorder which would appear to be particularly advantageous for use in high latitudes since it can register the entire circuit of the sun. The instrument, however, has not yet been tried in Canada and we would appreciate an opinion on the instrument from any who have had experience with its working.

Instead of using the time between sunrise and sunset as the total possible sunshine for the day, it is suggested that the interval should be shortened by twice the time interval between sunrise and the number of degrees above the horizon the sun has to be before it will burn the card, if this is known.

In connexion with the selection of cards, numerous experiments have been made on cards to find the most suitable for the purpose. Samples of the best we have been able to obtain to date are available on request.

The Robitzsch instrument for measuring solar radiation is being used at a number of our stations. It has been found, however, that the calibration of this instrument does not appear to be satisfactory. From the records that we have received it would appear that the radiation constant of the instrument should be multiplied by 0·68 to reduce to true intensity values. It would be interesting to know whether others who may have tried the instrument have had a similar experience.

APPENDIX XXXIX.—METHOD OF REPRESENTATION OF EMPIRE METEOROLOGISTS AT INTERNATIONAL CONFERENCES (Minutes XIV p. 90)

(*a*) Memorandum by E. Gold
(*b*) Memorandum by The Canadian Meteorological Service

(*a*) Memorandum by Lt.-Col. E. Gold, D.S.O., F.R.S.

(Assistant Director, Meteorological Office, London)

1. The principal international meetings at which Empire Meteorologists need to be represented are those of the International Meteorological Organization and its Commissions, and the meetings of the Meteorological Sub-Commission of the International Commission for Air Navigation. The meetings of the International Meteorological Organization and its Commissions are usually held in the summer or autumn, while the meetings of the Meteorological Sub-Commission of the International Commission for Air Navigation are usually held in the winter.

2. As regards the International Meteorological Organization the Director of every independent service is *ipso facto* a member of the General Conference which meets every six years. He, or his representative, is usually a member of one or more of the Commissions of the Organization. Membership of the Commissions is theoretically not limited in number: practically it is restricted to those who are prepared to take a part in the special work for which the Commission is appointed.

3. As regards the Meteorological Sub-Commission of the International Commission for Air Navigation, every State which is a party to the International Convention is entitled to have two representatives as members of the Meteorological Sub-Commission. The work of that Sub-Commission, as its name implies, covers the field of the application of meteorology to air navigation: clearly a very wide field.

4. The international meetings and conferences of these organizations are usually held in Europe: not as a matter of policy, but because it is practically the most convenient meeting place for the majority of the members concerned. That may not always be the case, but for the present and for the immediate future it is likely to continue. We have therefore to deal with the situation on that basis. The natural result of the meetings being held in Europe is that there is inevitably a tendency to take a European instead of a world view of the questions which arise. It is nevertheless of the greatest importance that the results of the deliberations at these meetings should be truly international and not merely European. The best way of achieving that is to have adequate representation of the Services of other continents.

5. **Method of Representation.**—The best method of representation is for the Director of the Service himself to attend the General Conferences. For meetings of Commissions he may find it better to send one of his staff who is specially expert in the questions with which the Commission has to deal. Naturally the ideal would be for the Director himself also to be available, because general questions are bound to arise, and do arise, in the course of the deliberations of the Commissions, on which a representative would naturally like to consult his Director. The ideal is, however, hardly practicable.

In the past it has been very difficult for the more distant countries to send representatives to many of the meetings, owing to the time which would be taken up in travelling. In the future that obstacle is likely to become increasingly less important, and a much to be desired increase in direct representation at these meetings may be secured.

Where it is not practicable for the Director or for a member of his staff who is an expert meteorologist and fully cognisant of his views to attend the meetings, there are two alternative methods of representation :—

(1) A representative of his Government who is not a meteorologist might be appointed to represent him. This practice has, for example, already been followed by some countries at the meetings of the Meteorological Sub-Commission of the International Commission for Air Navigation. These meetings are usually held in Paris, and a representative from the Embassy in Paris may be nominated as the member of the Meteorological Sub-Commission. This method has obvious disadvantages: the representative has no expert knowledge of the technical questions which arise, and he must be restricted in what he says or in the way he acts by written instructions. These may be effective in preventing mistakes: but as the purpose of these international meetings is really positive and constructive, a negative rôle on the part of a representative, however, perfectly it may be played, does not contribute effectively to the primary purpose in view.

(2) To select as representative a meteorological expert from one of the other Empire Services, who is able to attend the meeting. In that case also it is necessary for the Director of the Service concerned to give the representative selected his views on the questions to be considered at the meeting, bearing in mind that the main purpose of this meeting is for meteorologists to help one another to arrive at the best methods, and to surmount any obstacles in the way of the adoption of the best methods. It is clear that unconditional reservations although they may occasionally be necessary, are not the most useful aids to a representative.

6. There are two kinds of view of the questions which arise at these meetings which are so different that it may be desirable to state them explicitly :—

(1) The first kind of view is the view which the Director may take of a question in his capacity as an expert practical meteorologist: he may for example say that a suggested solution is fundamentally wrong in his view because it is contrary to sound principles (meteorological or other) or because it is inconsistent with the practice approved by some other international meteorological decision. Or again the solution proposed may not take adequate account of the actual meteorological conditions or climate of his country.

(2) The second type of view is that based on the conditions in the Director's own service. He may say for example that the solution proposed is meteorologically or on general grounds a good solution, even an ideal solution, but it is one which he could not adopt in his service for some special reasons.

Views of the first type are naturally the most useful in arriving at a fundamentally satisfactory decision.

Views of the second type do, however, need stating because if they are given beforehand it may be practicable at the international meeting to achieve a solution which either partially or wholly meets the local difficulties, or, alternatively, it may be possible to strengthen the hands of the Director in removing the difficulties.

It may be opportune to state in this connexion that it is a general principle in the International Meteorological Organization that no Resolution should ever be taken with the object of forcing a Director to take action. If a resolution is taken referring to a particular service, the general principle is that it should not be taken if the Director of the Service concerned objects.

7. Although the Director of an independent service is naturally interested in the work of all Commissions, he is more directly affected by the work of some Commissions than by that of others. For example, he is likely to be more concerned with the deliberations of the Commission for Maritime Meteorology or the Commission for Synoptic Weather Information than he is with the deliberations of the Commission for the Investigation of Waves of Explosion or the Commission for Solar Radiation: for the latter Commissions he may be quite content to leave their recommendations for the consideration of the International Meteorological Committee and accept the decisions when they are made. In the case of the former Commissions, however, he ought to take a hand in shaping their recommendations before they reach the International Meteorological Committee. Some machinery appears to be necessary to secure this in cases where the Director is not able to attend the meetings of the Commissions and the same I think applies to the Meteorological Sub-Commission of the International Commission for Air Navigation. The machinery evolved must enable the Director of the Service concerned, or his representative, to consider the agenda and memoranda of the Commission. After they had been received and considered by him and his expert advisers the machinery would have to provide for the presentation of his views and of his contribution to the meeting. One method would be to utilize the services of the International Meteorological Secretariat in selecting a representative for the meeting. Another would be to use the Meteorological Office, London, as the medium of liaison.

8. If the Conference decides that it is worth while making an improvement in the existing methods and indicates the general lines on which progress is desired, then a small Sub-Committee ought to work out the details, because no method is going to be satisfactory if the actual working procedure is not clearly specified.

(b) Memorandum by the Canadian Meteorological Service

At the International Conference of Directors the Directors of the Overseas Dominions should be if at all possible present in person and attend the various commissions that meet at the same time. It is highly desirable that at other times other technical officers from the Services should attend rather

than the Directors in order that they may get acquainted with the work that is going on in the various countries in their particular problem, and a resolution from this Conference might well be sent to the various Governments through the Secretary of State urging the importance of technical officers attending commission meetings.

It is realised, however, that owing to the expense involved in attending conferences in Europe, that it is next to impossible for representatives from the Dominions to attend such meetings frequently. Consequently, it is most desirable that there should be a considerable number of commissions meeting at the same time. One effort therefore the Empire Meteorologists should make at the International Conference is to get more commissions meeting at approximately the same time. As it is at present it would require someone from an overseas Service to be in Europe most of the time if these meetings were to be attended.

The question may well be considered that when the Dominions cannot be represented a member of the Commission from the British Office who is attending should be asked to represent them at the meeting. If this were done, there could be an interchange of ideas before the meeting so that the member could go prepared to represent the views not only of the London Office, but of the various parts of the Empire that he was representing.

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