METEOROLOGICAL OFFICE M.O. 719

THE METEOROLOGICAL MAGAZINE

Vol. 91, No. 1084, November 1962

FOREWORD BY THE DIRECTOR-GENERAL OF THE METEOROLOGICAL OFFICE

This number commemorates the coming-of-age of a body of which the Meteorological Office is justly proud. In a period when committees have tended increasingly to expand and proliferate, the Meteorological Research Committee (MRC) has remained a compact body, pursuing its allotted task of advising on "the general lines on which meteorological research should be developed". In doing so it has done much to forge links between the professional meteorologists and the university physicists and mathematicians who constitute the majority of its non-official members.

It is stimulating for the Office to know that not only can it rely on the wisdom and experience of those who teach and study other aspects of the science of which meteorology is a part, but also that its research work is regularly assessed in discussions that have always been notable for their frankness. Even a large institution like the Meteorological Office could lose impetus and falter were it to confine debate within its walls, and perhaps the most valuable part of the work of the MRC is the new light that from time to time it sheds on the many problems that beset meteorologists.

As Dr. Scrase shows in the opening article in this number, the MRC owes its existence mainly to the foresight and patience of Sir Nelson Johnson, and the encouragement and support of Professor Sydney Chapman, but there is a comparable debt to other founding fathers, notably Sir David Brunt, Professor G. M. B. Dobson, and Sir Charles Normand. The Meteorological Office now holds a notable position in the field of meteorological research, and it is pleasant to be able to thank them and their fellow members for the part they have played in bringing this about.

551.5.001.5:06(09)

THE HISTORY OF THE METEOROLOGICAL RESEARCH COMMITTEE

By F. J. SCRASE
Secretary of the MRC, 1957 to 1961

The advent, on 7 November 1962, of the 21st anniversary of the formation of the Meteorological Research Committee (MRC) is an appropriate occasion for recording its early history. The idea that there should be such a committee goes back to 1938, when it originated with Professor Sydney Chapman, his formal proposal being made at a meeting of the Meteorological Committee on 29 November of that year. Chapman recorded his recollections of the beginnings of the MRC in a letter written to Sir Graham Sutton soon after the death of Sir Nelson Johnson in 1954. At first Chapman pursued his idea privately with Sir Henry Lyons, the senior Royal Society representative on the Meteorological Committee. As members of a committee of three appointed to advise the Air Ministry on the appointment of a successor to Sir George Simpson, Chapman and Lyons decided to take the idea seriously into account and Chapman records that "when N. K. Johnson was invited to an interview he was acquainted with our thoughts on the desirability of a Meteorological Research Committee. With his experience at Porton the idea was one that he naturally favoured. After his appointment he had a number of interviews with me at Imperial College on the matter, and took steps to get approval from the Air Ministry for the institution of the Committee".

Acting on N. K. Johnson's enthusiastic recommendation, the Secretary of State for Air, Sir Archibald Sinclair, appointed the MRC on 7 November 1941 with the following membership: Prof. Sydney Chapman (Chairman), Prof. D. Brunt, Dr. G. M. B. Dobson, Prof. G. I. Taylor, the Director of the Meteorological Office and representatives of the Admiralty (Capt. L. G. Garbett), the Air Staff (Group Capt. H. J. Saker) and of the Director-General of Civil Aviation (Mr. C. B. Collins). The terms of reference were:

(i) to advise the Secretary of State for Air as to the general lines along which meteorological research should be developed.

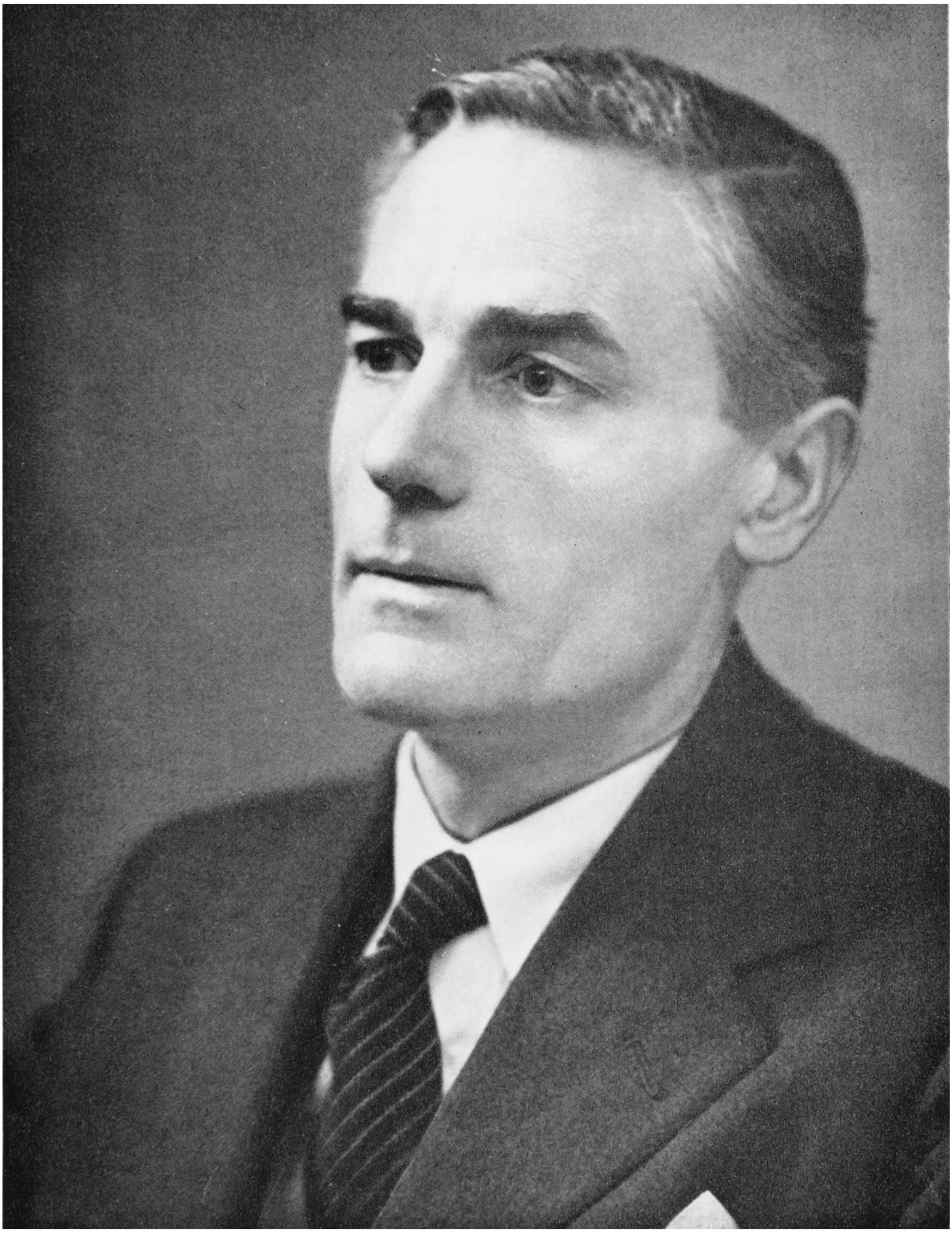
(ii) to advise and assist in the carrying out of investigations and research within the Meteorological Office.

(iii) to receive reports on meteorological investigations carried out in the Meteorological Office or on behalf of the Air Ministry and to make recommendations for further action.

(iv) to co-ordinate the investigations performed in the Meteorological Office with related activities carried out elsewhere, both in this country and abroad.

(v) to make an annual report to the Secretary of State for Air.

The MRC held its first meeting on 10 December 1941 at the rooms of the Royal Aeronautical Society at Hamilton Place, London W.1. The secretary was Miss Flora Jones, B.A. At first the Committee devoted its attention primarily to problems of direct importance to the war effort, concentrating on investigations having an immediate application and likely to be solved in a reasonably short time; one example was the physics of condensation trails. Soon after his appointment as Director, N. K. Johnson planned to set up an organization within the Meteorological Office to undertake research and development, which

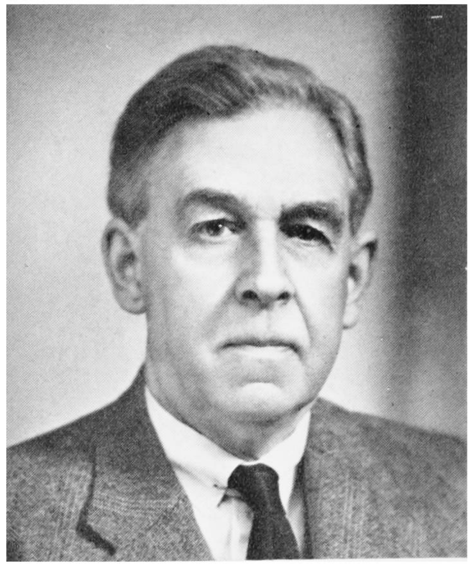


Reproduced by courtesy of Elliott & Fry, Ltd.

PROFESSOR P. A. SHEPPARD, CHAIRMAN OF THE METEOROLOGICAL RESEARCH COMMITTEE

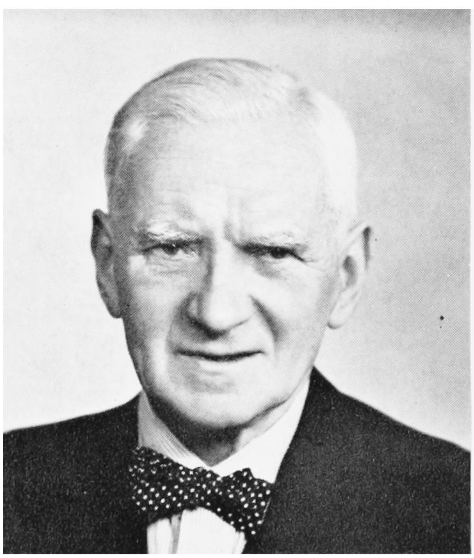
(see p.311)

PROFESSOR S. CHAPMAN, F.R.S. FIRST CHAIRMAN (1941–47)



Reproduced by courtesy of Elliott & Fry, Ltd.

PROFESSOR G. M. B. DOBSON, C.B.E., F.R.S. (1947–52)



Reproduced by courtesy of Elliott & Fry, Ltd.

PROFESSOR SIR DAVID BRUNT, K.B.E. F.R.S. (1952–55)

Reproduced by courtesy of Walter Stoneman, F.R.P.S.

PROFESSOR SIR CHARLES NORMAND, C.I.E. (1955–58)

PAST CHAIRMEN OF THE METEOROLOGICAL RESEARCH COMMITTEE

(see p.311)

hitherto had been left largely to the initiative of individuals. The operational requirements of the war delayed the full realization of these plans, but the facilities needed to undertake the wartime problems along the lines recommended by the MRC were provided within the Office as far as was then practicable.

The new committee issued an announcement in the scientific journals that it would welcome contact and co-operation with university departments or other institutions engaged on work bearing on meteorology. This met with a favourable response and close collaboration with the universities and research bodies has been maintained throughout the 21 years since the MRC was formed; the high proportion of membership on the committee from such institutions has, in fact, ensured this.

Another important step followed from the wartime restriction of the MRC programme to problems of military application. This was for the Air Ministry to invite the Royal Society to co-operate with the MRC by undertaking research on certain aspects of meteorology which, though of fundamental importance for the advance of the subject, might not have an immediate practical application. The problem particularly recommended for study was that of radiation in the atmosphere, with special reference to radiation equilibrium conditions in the stratosphere. The Council of the Royal Society accepted the invitation to co-operate with the MRC and entrusted the immediate responsibility for the work to the Gassiot Committee. Arrangements were made for a grant to be allocated from Air Ministry funds to enable the Gassiot Committee's programme of work to be undertaken at a number of university centres. The idea for this co-operation again originated with Prof. Sydney Chapman, as a further passage from his letter indicates. He wrote "at about the time of the institution of the MRC it became likely, in my opinion, that there would be long-range problems of meteorology that might more suitably be undertaken under the auspices of the Royal Society than directly under the MRC as then envisaged. Egerton* and I went for a brief stay in Merton's* home in Hereford to discuss this question and there, I think at the suggestion of Egerton, it was decided to enlarge the scope of the Gassiot Committee to include such long-term meteorological research. This has proved to be a useful innovation for the Gassiot Committee, giving it much more importance and fruitfulness".

In March 1942 membership of the MRC was widened to include the Director of Scientific Research at the Ministry of Aircraft Production, Dr. D. R. Pye, and in May 1945 the Secretary of State, Mr. Harold Macmillan, agreed to increase the external scientist membership from four to five and invited Sir Charles Normand to serve on the committee. Prof. Chapman continued as chairman until 1947 when he was succeeded in turn by Prof. G. M. B. Dobson (1947–52), Sir David Brunt (1952–55) and Sir Charles Normand (1955–58). Since 1958 Prof. P. A. Sheppard has been chairman. At the end of the war the programme of research was revised with two objects, (*a*) to give greater prominence to longer term aspects of research and (*b*) to enable advantage to be taken of any increased facilities for flying resulting from the change-over from wartime to peacetime conditions.

---

*Prof. A. C. G. Egerton and Prof. T. R. Merton were, respectively, Secretary and Treasurer of the Royal Society at the time.

The MRC has, from the start, taken a close interest in meteorological investigations from aircraft. Originally such investigations for the Meteorological Office were made with the assistance of the High Altitude Flight of the Aircraft and Armament Experimental Station at Boscombe Down, but later these arrangements were changed by constituting the Meteorological Research Flight as a separate Meteorological Office unit at the Royal Aircraft Establishment at Farnborough. Other special research units which were established at the suggestion or with the support of the MRC were a radar weather research unit, formerly at East Hill near Dunstable and now stationed at the Royal Radar Establishment at Malvern, and an agricultural meteorology research unit at Cambridge. Soon after the war, in consultation with the Agricultural Research Council, a programme was drawn up of special investigations required by agriculturalists and steps were taken to carry out this programme with the co-operation of Rothamsted Experimental Station and the School of Agriculture at Cambridge.

From the time of its formation in 1941 the MRC has always maintained close liaison with the Aeronautical Research Council (A.R.C.). The latter, in fact, abolished its Meteorological Subcommittee and agreed to refer all its meteorological problems to the MRC which, in turn, arranged to keep the ARC informed of developments in meteorological research. In July 1947 the MRC appointed representatives to serve on Gust Panel No. 1, set up by the ARC to advise on investigations needed to obtain a reasonable knowledge of gusts. Consideration of the report of this panel led to the formation, in 1949, of a permanent Gust Research Committee, with Sir Geoffrey Taylor as chairman and with up to half the membership nominated by the MRC. The terms of reference are to consider investigations needed to increase the knowledge of gusts in the atmosphere at all heights and to report annually to the ARC and the MRC. The work of the Gust Research Committee is of importance not only to aviation but also to designers of ballistic missiles.

The widespread use of radio and radar during the war led to a number of problems concerned with meteorological aspects being referred to the MRC, and in 1943 it appointed a subcommittee, with N. K. Johnson as chairman, to advise on certain experiments then being carried out under the sponsorship of the Ultra-Short-Wave Panel of the Scientific Advisory Committee of the Ministry of Supply. The subcommittee was first called the S/W Radio Meteorological Subcommittee but the name was soon changed to the Joint Meteorological Radio Propagation Subcommittee and the terms of reference were widened to embrace radio-meteorological problems in general. It continued in existence until November 1950 (having held 25 meetings by then) when it was agreed by the MRC that the meteorological problems of radio propagation could be included within the scope of a recently formed Physical Subcommittee, while specialized radio aspects could receive attention by the Tropospheric Wave Propagation Committee of the Radio Research Board, on which the Meteorological Office is represented.

At its 50th meeting in July 1947 the MRC agreed to a proposal to form three subcommittees to deal respectively with instruments, synoptic and dynamical problems and physical problems, with Prof. P. A. Sheppard, Sir Charles Normand and Sir David Brunt as chairmen. These three subcommittees continued to meet four or five times a year until March 1959 when it was decided to merge two of them into the Instruments and Physical Subcommittee, the other continuing as the Synoptic, Dynamical and Climatological Subcommittee. Membership, which is recommended by the MRC, is composed of scientists from the universities, representatives from government research establishments and senior members of the research branches of the Meteorological Office. From time to time the MRC has also set up temporary panels to consider and advise on special problems. For example, one such panel was formed, with representatives from the Ministry of Supply, to consider investigations relating to ice accretion on aircraft. Another was set up to advise on research in tropical meteorology.

One of the duties of the MRC is to review the research programme, which is revised annually, and to recommend the priorities which should be given to the items on the programme. Up to 1958 nearly all of the papers considered by the MRC and its subcommittees were detailed reports, prepared by members of the Meteorological Office Staff, on the individual items of the programme. In all, more than a thousand of these Meteorological Research Papers were prepared and a large number of them were subsequently published in scientific journals or as official publications. In 1958, however, it was decided to modify the reporting procedure in order to facilitate adequate consideration of the state of the main research subjects and the future course of investigations. The series of Meteorological Research Papers was discontinued and instead papers, restricted to the use of the MRC and its subcommittees, are now prepared on the more general aspects of the main problems. These papers are supplemented by six-monthly and annual progress reports on the more important items of the research programme.

Mention has already been made of the arrangement, started during the war, by which research grants were made by the Air Ministry direct to the Royal Society for disposal through its Gassiot Committee. In 1960, following a recommendation by the Brabazon Committee that these grants should be channelled through the MRC, the latter accepted the responsibility of advising on the administration of such grants and set up a Research Grants Subcommittee composed of the chairmen of the MRC and of the two scientific subcommittees, with the Director of Research, under the chairmanship of the Director-General. The function of this subcommittee is to scrutinize and advise on applications for grants for extra-mural research in meteorological problems. The Gassiot Committee, however, continues in being and some of its work is still being supported by Air Ministry grants on the recommendation of the MRC. The latter considered that it would be advantageous for the Meteorological Office to be more widely concerned with the support of extra-mural research and that the new arrangements should strengthen the study of meteorology at the universities and also help to bridge the gap between meteorology and the subjects bordering on meteorology (such as the photochemistry of the atmosphere) which the Gassiot Committee would continue to foster. Close co-operation with the Gassiot Committee is being maintained by arranging joint meetings to discuss the Gassiot research programme. The history of the Gassiot Committee and its encouragement of meteorological research has recently been recorded by Dr. D. C. Martin.[1]

The most recent step in the progress of the MRC was taken in March 1961 when the Secretary of State for Air approved a revised constitution and more up-to-date terms of reference for the committee. The composition is now (*a*) a chairman and such number of other non-official scientist members as may be invited to serve by the Secretary of State, (*b*) the Director-General and two Directors of the Meteorological Office, (*c*) officers representing the Admiralty, the Air Staff, the Ministry of Aviation and the War Office. Under the revised terms of reference the MRC will advise the Secretary of State for Air on the general lines along which meteorological and geophysical research should be developed within the Meteorological Office and encouraged externally. It will review progress and report annually.

Probably the most useful function that the MRC serves is to facilitate discussion and the exchange of views between the research scientists in the Meteorological Office and their opposite numbers in the universities and other government departments. With the concentration of the research branches at the new Meteorological Office headquarters at Bracknell it is hoped that the external members of the MRC will have more opportunities of inspecting research in progress and of making closer contacts with those actively engaged on the research projects.

In concluding this brief history of the MRC it is appropriate to pay tribute to the two men who shared the responsibility for creating such a valuable means of co-ordinating meteorological research. That the success of the MRC is in large part due to Prof. Sydney Chapman's initiative in the early days and his enthusiasm as chairman in the first six years few would deny, but Chapman himself very generously says, in the letter already mentioned, that "of course it is to Johnson that the main credit for the success of the MRC is due. He took the deepest interest in its work and organized a successful research branch in the Meteorological Office".

REFERENCE

1. MARTIN, D. C., The Gassiot Committee of the Royal Society and meteorological research. *Nature, London*, **190**, 1961, p.212.

551.5.001.5:06.09

RESEARCH ORGANIZATION AND FACILITIES

By R. C. SUTCLIFFE, C.B., O.B.E., F.R.S.
Director of Research, Meteorological Office.

On an occasion of this kind, when we are taking stock after a period of years and especially when that period has seen the growth of our research organization from very small beginnings, it is natural to think in terms of historical development and to see much of interest in the way in which objectives have been defined and difficulties overcome. On the other hand, it may be that the historical record is of primary interest only for those few who have taken part in the step-by-step advance and can look backwards with a sense of achievement. Since most readers will probably be more interested to see the Meteorological Office as it is than as it was or might have been, I shall make little reference to the way things have evolved from the early days of the Meteorological Research Committee when there was, I believe, only one scientific officer post exclusively devoted to research, to the present time when the Directorate of Research stands side by side with the Directorate of Services, taking a large share of the scientific effort. Even so, it is easy to overstate the change that has taken place. Throughout the century of the life of the Meteorological Office, scientific research has been carried out and on a considerable scale although the word "research" was not always used as freely as it is today. As a scientific institution, the Meteorological Office under Sir Napier Shaw was very much alive and the few scientists employed combined research with service without the need to define boundaries. The lack of balance came some years later when the very rapid expansion of advisory services for aviation during and following World War I led to the appointment of many full-time meteorological practitioners for aviation forecasting duties, with no more time for research than has the average medical practitioner today. Service demand rapidly outgrew the scientific base on which it stood, and, to change the metaphor, the Office consumed its seed corn by absorbing creative thinkers of proved ability into the insatiable technical and administrative system until, towards the outbreak of World War II, the Office, although employing numerous staff with excellent academic records, could barely claim a research scientist of the first rank on, so to speak, the active list. The erection on this foundation, even in twenty years, of a research structure to take its place in the modern world, alongside other scientific research institutions, has not been performed without stresses and strains and the revealing of weaknesses. Senior staff with limited research background have had for a time to turn their hands to unaccustomed work and in some cases with such success as to give the lie to the fable of the scientist burnt out at forty. But this phase of growth and makeshift is practically at an end. The leaders of the research groups are more and more becoming research workers of long experience and established position in the world of science, with collaborators who have entered research as a career. What is more, the new buildings at Bracknell provide for the first time a headquarters with the physical facilities of a scientific institution. It is to the description of the present state of affairs, relatively stable after a turbulent period of growth, that I shall devote the remainder of this article.

It will surprise no one to find that this account of a research organization is a description of my research directorate but I must, in order to avoid too gross a misunderstanding, first insist that the division of the Office into two directorates, of "services" and of "research", is the kind of administrative dichotomy which often needs to be imposed even when the distinction in function is far from clear cut. It must be kept in mind that the Meteorological Office is a co-ordinated scientific institution existing to advance the science and to serve the public and that, with the two directorates living together under the same roof with staff in principle and often in the event interchangeable, all-round efficiency is much enhanced by mutual aid and the sharing of facilities to a degree which would be impracticable were there two distinct bodies responsible for public services and scientific research respectively. There are for example one major library, one division for data storage and data processing services, with both mechanical punch-card and advanced computing systems, and one division for basic staff training. All these are in the Directorate of Services where, incidentally, most of the applied research directly related with aviation, agriculture, hydrology or industry is carried out. On the other hand, outside interests continually call upon the Office for advice on problems in atmospheric science less directly concerned with weather and climate but in which an active research programme is in hand. Examples concern atmospheric pollution or radioactivity, turbulence related with diffusion or with bumpy flying conditions, radio propagation, cloud physics (ice formation, rain and hail erosion on aircraft), solar radiation, atmospheric ozone and other rare constituents, problems of rockets and artificial satellites, atmospheric electricity, allied problems of geophysics (seismology and geomagnetism), and a wide range of inquiries related with advanced instrumentation. In all these cases and many others the expert knowledge of research workers is at the disposal of outside interests and to that extent the public service greatly benefits without the need to carry specialists within the Directorate of Services itself. The Office possesses, I am firmly convinced, an effective and healthy combination of public service and scientific research which is in some ways unusual, perhaps unique—for the profession of meteorology has its unique features—but which it would be most unwise and perhaps disastrous to disrupt.

The research directorate divides immediately and conveniently into two parts, deputy directorates, labelled "dynamical" and "physical", with functions not too far removed from the usual connotations of these terms in meteorology. Dynamical research is concerned with the large motions of the atmosphere on the scale of hundreds or thousands of kilometres, those motions which are recognized as the main structural features of weather and climate, fronts and jet streams, depressions and anticyclones and so on, and have immediate relevance to weather forecasting. The total strength of the scientific officer class of the deputy directorate stands at 24, divided into four branches each headed by a senior principal scientific officer. The whole of the work is concentrated in laboratories at Bracknell and is largely a matter of discussing data obtained from all parts of the world, using synoptic analysis, graphical and statistical techniques and, of quickly growing importance, the mathematical methods appropriate to a branch of fluid mechanics. It was in this work that electronic computing was first used in the Office and research in numerical weather prediction still makes a major call upon the facilities. A Ferranti Mercury computer, installed in 1959 at Dunstable and moved to Bracknell when the new building was occupied, has served excellently for research but the elaboration of mathematical models and the need for great speed and complete reliability has justified the purchase of a replacement computer of notably better performance although, at the time of writing, the choice among the number of different systems now available has yet to be made. The requirement is for something comparable with the fastest and largest capacity machines at present being marketed and even this may be unsuitable for calculations of great intricacy such as arise in the full three-dimensional problems of rain-producing systems or in the world-wide problems of the general circulation of the atmosphere and the theory of climate. The most advanced computer, the ATLAS, now being built to Government order, is therefore likely to have its uses for meteorological research.

The deputy directorate for physical research with 35 posts in the scientific officer class is of more varied character primarily because, whereas in large-scale dynamical research the raw data are mainly provided by regular observations of the synoptic and climatological networks, in physical research the making of special observations employing instrumentation designed for the purpose is half the battle. At the Bracknell Headquarters we have drawing offices and workshops and numerous laboratories fitted with all modern conveniences—compressed air, vacuum, and electric power in a range of voltages. Two wind tunnels and two cold chambers maintaining temperatures down to -40°C are special features. The provision of well equipped physics laboratories has introduced a new dimension into the planning of research, and many things which in former times would have been beyond our reach may now be undertaken at our own headquarters. Interesting work in progress includes, for example, the wind-tunnel study of airflow over the Rock of Gibraltar, analyses of freezing nuclei and natural ice crystals obtained in the air, and the development of instrumentation for use in rockets and satellites.

A further facility of the greatest value is the 30-acre experimental site at Easthampstead, only three miles from Bracknell. Excellent buildings on the site provide useful workshops and laboratories and allow instrumental testing and field experiments in favourable conditions. A new programme of work on turbulent diffusion has been started here and, amongst other things, we are developing and testing completely automatic meteorological observing and reporting systems with remote recording, either continuously or by interrogation, in the laboratories at Bracknell.

A considerable proportion of our research in atmospheric physics must however continue to be carried out by detachments elsewhere than at Bracknell to take advantage of special facilities which are to be found at other establishments. Of these the historical priority goes to the observatories—the Meteorological Office outstations at Kew, Eskdalemuir and Lerwick—each of which is a scientific laboratory with its own library and workshop facilities, having special responsibilities not only for maintaining complete meteorological records but also for certain additional geophysical recording, particularly in geomagnetism and seismology. As the years pass the emphasis changes but everything points to the wisdom of maintaining these observatories in perpetuity as going concerns which may at any time meet a new need. Kew has one of the world's longest records of unbroken meteorological observations, a valuable asset in the context of climatic variation, while its facilities have lately been turned to the study of visibility and of radiation budgets as applying to an urban site. A recent story of some interest concerns seismological observations which, until only a few years ago, were languishing in this country with Kew Observatory keeping the records more by tradition than for any great interest excited by them. Then suddenly, in part stimulated by the defence interest in the detection of underground test explosions, the need for new data on seismic events of many kinds, microseisms in particular, became recognized all over the world; a site more suitable than Kew, with its high level of background noise, was looked for and the best that could be found in the country was near our observatory at Eskdalemuir where the ancient Silurian rock emerges. At the present time new and up-to-date instrumentation is being installed there and we shall have once more a first-class station. The creation of a Gassiot Fellowship in Seismology has permitted the Office to appoint for a term of years an expert from outside while a similar provision for geomagnetism is having a correspondingly stimulating effect. We may be sure that the three observatories have many unknown purposes still to serve in the future course of geophysical exploration.

To several other research outstations I can make only passing reference. At

Cambridge, in association with the School of Agriculture of the University, we possess a small but new and attractive laboratory and workshop where one or two scientists and their technical assistants may pursue appropriate field research on such topics as the energy balance and moisture balance of cultivated land. At Cardington the availability of captive balloons has permitted special observations within the first few thousand feet above the ground and the splendid open site with the facilities of the Royal Air Force station have been found valuable in several other ways: experiments on fog clearance and rainfall observations from a close network of synchronized recording rain-gauges are two examples of research tasks which fitted well into the Cardington programme. Then again there is the story of radar meteorology. After many years of experimenting at East Hill, a site near Dunstable, the justification for maintaining a station solely for the purpose was questioned and the decision had been taken to close down when new possibilities of advanced Doppler radar emerged and are now being pursued at the Royal Radar Establishment at Malvern by a combined team including a Meteorological Office detachment.

This account of outstation facilities will be closed with a reference to two units having outstanding records of achievement. The first of these is Porton, the Chemical Defence Research Establishment now under the War Office, where a Meteorological Office research group has been a continuous feature for some 40 years and may fairly claim to have contributed more than any other single institution in the world to the solution of the problems of atmospheric turbulence and diffusion near the earth's surface. It was here that full-time research was introduced early in the Office primarily to tackle the World War I problem of gas warfare and, much as we may deplore the cause, the outcome in knowledge and in scientific leadership has been remarkable. That consecutive heads of the Meteorological Office did their pioneer research work in the Porton group is evidence enough that in the early days the scientific need was well recognized, largely at the instigation of Sir David Brunt, and the work continues to be productive nearly half a century later.

Lastly I refer to the Meteorological Research Flight established at the Royal Aircraft Establishment at Farnborough. This unit, at present having three aircraft, a Canberra, a Hastings and a Varsity, serviced and flown by the Royal Air Force on tasks designed and executed by Meteorological Office personnel, is certainly a proud possession. It was long unique in the world since, elsewhere and even in America, the permanent assignment of aircraft and aircrew for meteorological research took a long time to arrange. The aircraft, instrumented to the scientific needs, backed up by laboratories, workshops and computers to meet any requirement, and flown anywhere within range from pole to equator, have provided data unobtainable by any other means and have contributed in a quite remarkable way to our knowledge of clouds and precipitation, ice formation on aircraft, condensation trails, clear air turbulence, atmospheric ozone and water vapour in troposphere and stratosphere, and many other mysteries of atmospheric structure.

In the following pages the two deputy directors of research will tell something of our scientific achievements and plans. My aim has been to give an impression of a research organization of no mean size employing some 60 scientific officers capable of pursuing meteorological research on a broad front and provided with the assistant staff, modern tools and other facilities, aircraft, balloons, rockets, laboratories, workshops and computers, suited to the age. Although much has been accomplished I believe that the 21st Anniversary of the Meteorological Research Committee which this number of the *Meteorological Magazine* commemorates may well be taken also as the coming of age of research in the office, with the great work of maturity still lying ahead. It is an enticing prospect.

551.5.001.5

PHYSICAL METEOROLOGY: ACHIEVEMENTS AND PROSPECTS

By G. D. ROBINSON
Deputy Director of Physical Research, Meteorological Office

Organized research in physical meteorology by Meteorological Office staff was not unknown even before the formation of the Meteorological Research Committee (MRC). In the years between the wars the meteorological section at Porton (already mentioned on page 318), pioneered the quantitative investigation of atmospheric processes near the earth's surface and it seems appropriate to remind readers of this number of the *Meteorological Magazine* that N. K. Johnson, F. J. Scrase, P. A. Sheppard and O. G. Sutton all saw service there. The observatories at Lerwick, Eskdalemuir and, particularly, Kew offered opportunities for practice of physics out-of-doors and for the sounding of the upper atmosphere by balloon-borne instruments. There were thus some resources of staff and tradition on which to draw when the need and the will to expand research in these fields came and the MRC was established. In this article I try to sketch the progress made in the 21 years since this expansion began. I make no attempt to define physical meteorology—it is not a self-sufficient science—and offer no apologies to any synoptician or climatologist who may feel at times that I am trespassing. I cite some published work: the papers chosen are examples only and are not intended to give a full, or even a representative, indication of the amount and nature of the research in physical meteorology which has been brought to the attention of the MRC.

The structure and movement of the atmosphere near the tropopause.— Perhaps the most significant achievement of those who planned the research effort in the early days of the MRC was the earmarking of aircraft of advanced performance for meteorological research, and I do not think it can be questioned that the most original contribution of what developed into the Meteorological Research Flight has been the work of its high-altitude aircraft. This arose initially from the systematic use of one remarkable instrument, the frost-point hygrometer of Brewer and Dobson. (See photograph between pages 324 and 325.) The phenomena of aircraft condensation trails and their degree of persistence focused practical attention in wartime on determination of the water vapour content of the lower stratosphere, but in 1949 A. W. Brewer[1] gave these observations a much wider significance when he effectively used water vapour as the tracer of a slow circulation, on a global scale, responsible for the exchange of air between troposphere and stratosphere. In following this lead Mosquito and Canberra aircraft of the Meteorological Research Flight have flown at high levels from 10°S to 80°N, and have used observations of ozone and radioactive débris as additional evidence, concentrating attention on the neighbourhood of sub-tropical and frontal jet streams. Figure 1 is an example of this work taken from a paper by J. Briggs and W. T. Roach to be published this year. It shows the concentration of water vapour and ozone in the neighbourhood of a frontal jet on 3 October 1960, with the indication that dry, ozone-rich stratospheric air is entering the troposphere through the tropopause gap. In returning from a flight of this kind on 21 February 1962, a Canberra aircraft of the Meteorological Research Flight was lost, and its crew and meteorological observer severely injured—the first major accident suffered by the flight since its formation.

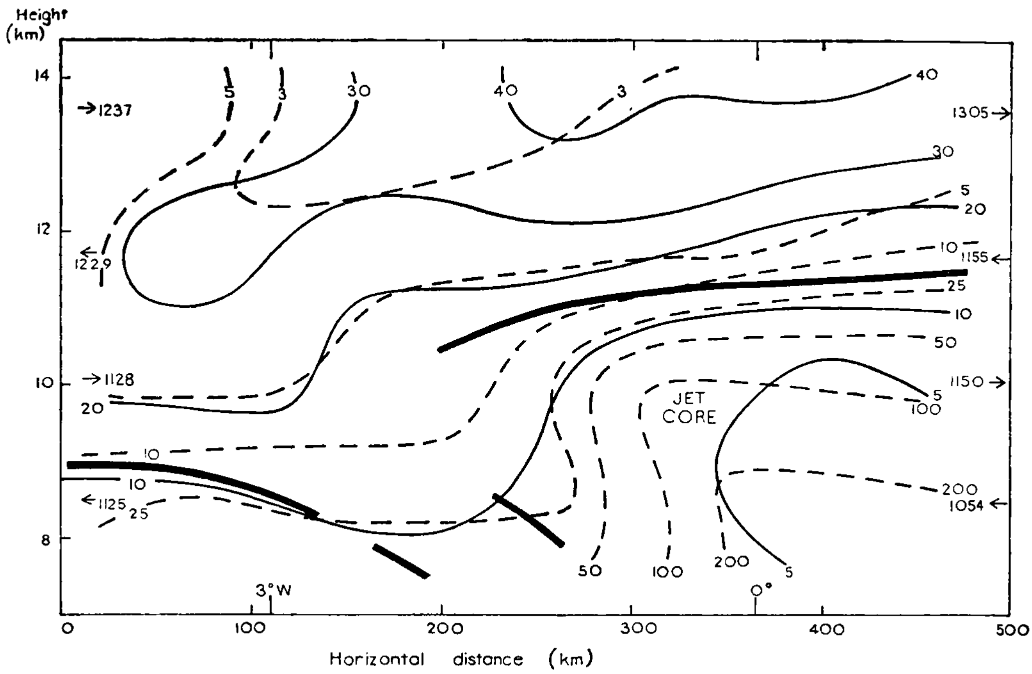


FIGURE I—OZONE AND WATER-VAPOUR CONTENT OF THE AIR IN THE NEIGHBOURHOOD OF A JET STREAM [*Briggs & Roach*]

— Ozone content (mols × 10^8).
––– Water-vapour content (μg/g).
The thick lines and dashes indicate the positions of the tropopause and frontal surfaces. The times (by the arrows indicating direction of aircraft) are in GMT.

Cloud morphology and the structure of fronts. Cloud physics.—In parallel with the activity of the high altitude aircraft, the larger aircraft of the Meteorological Research Flight—Halifax, Hastings, Varsity—have explored the troposphere, concentrating attention on clouds and cloud systems. Over the years many flights have been made to explore frontal structure and reference to J. S. Sawyer's[2] analysis of some of the results will show how radically these modify the early textbook models in some respects. The use of radar to investigate precipitation was just becoming a possibility when the MRC was formed, and the East Hill (near Dunstable) radar station of the Meteorological Office, alone and in conjunction with aircraft, was used to investigate the structure and development of cumulonimbus clouds and the movement of more widespread precipitation systems. The close association between the movement of precipitation belts and the 700 mb wind shown by W. G. Harper and J. G. D. Beimers[3] is an example of the help which radar can provide for the synoptic meteorologist. With the development of more advanced radar techniques, new possibilities opened to the meteorologist, and a coherent pulsed Doppler radar is now being used to investigate the pattern of vertical air movement in cumulonimbus clouds.

The smaller-scale aspects of cloud physics have been probed by both aircraft and radar. Systematic sampling for number and size of condensation nuclei, chloride particles, cloud particles and precipitation particles has been a task of the Meteorological Research Flight for many years—a task involving many hours of laborious work at the microscope. In detail it may be that there are as many size distributions of cloud and precipitation particles as there are precipitating clouds, but some generalities on clouds and raindrops have emerged. "Freezing nuclei" and ice particles offer more difficult problems, and much work on ice clouds and mixed water–ice clouds remains to be done. The pulsed Doppler radar offers a method of determining the size distribution in rain from layer clouds; it is more sensitive for the larger drops and less so for the smaller ones than the aircraft methods, and one of the more rewarding moments in an often frustrating investigation came when, as recorded by J. R. Probert-Jones,[4] the two techniques were found to give concordant results in the region of overlap (Figure 2).

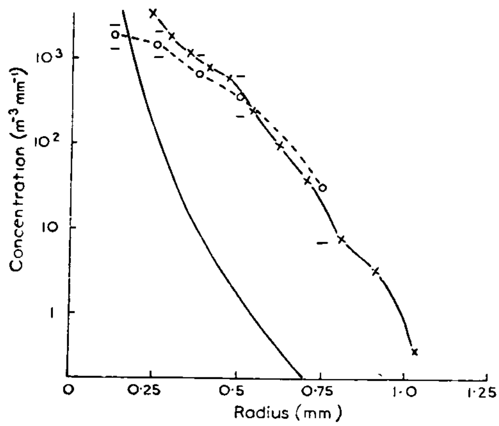


FIGURE 2—DROP-SIZE DISTRIBUTIONS ON 16 APRIL 1959, 1528 GMT, AT 1500 M

[*Probert-Jones*]

× — × Radar concentrations.
o – – – o Aircraft concentrations with their upper and lower 5% probability limits.
——— Radar threshold curve.

Sampling of cloud particles from aircraft is obviously complicated by the problem of the efficiency of the sampler. It is not so clear that similar problems arise if the sample is taken on the ground. Figure 3 is taken from a report by K. H. Stewart[5] on the composition of fogs. It contrasts the results of using a standard sampling instrument (the "cascade impactor") in the standard way with those obtained from consideration of the distribution of light scattered at small angles and transmissivity in different spectral ranges in the visible and infra-red. In passing I would like to commend a study of this report to those physicists who feel that the days of "sealing wax and string" are gone forever.

Radiation in the atmosphere.—There can be few better illustrations of the conservatism of the climatologists of a generation ago than the fact that the Meteorological Office made no continuous records of the amount of solar radiation falling on a fixed surface until 1946. Since that date much work has been done at Kew Observatory on techniques of recording, and the errors of records of solar illumination and radiation. The more difficult task of recording terrestrial radiation and the radiation balance was taken up at Kew at about the same time as it began to be studied, by somewhat different techniques, in

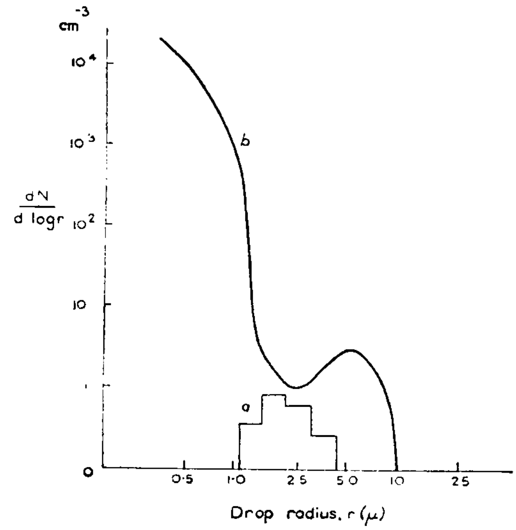


FIGURE 3—DROP-SIZE DISTRIBUTION IN FOG AT KEW ON 20 DECEMBER 1956, 2320 GMT [*Stewart*]

dN = number of drops in size range r to (r+dr).
a — cascade impactor results.
b — "best fitting" curve compatible with optical attenuation, scattering, and impactor results.
Total scatter coefficient from histogram (*a*) = 0.56 km^{-1}.
Total scatter coefficient from curve (*b*) = 13 km^{-1}.
Total scatter coefficient observed = 12 km^{-1}.

America, Germany and Russia. Radiation balance was one of the elements proposed for wide-scale study during the International Geophysical Year (IGY), 1957–58, and the results of preliminary trials at Kew of methods later adopted at several overseas stations during the IGY are discussed by G. D. Robinson[6]. The Meteorological Office took the initiative in instituting continuous radiation measurement at sea. Solarimeters are part of the normal equipment of the North Atlantic weather ships, and attempts to measure radiation balance during the IGY were partially successful and reflect great credit on those concerned with handling the equipment at sea.

Aircraft of the Meteorological Research Flight have for some years been equipped with instruments measuring the upward and downward flux of solar radiation, and results have been published on the albedo of the earth's surface and of clouds, and on the absorption of solar radiation both in "clear air" and cloud. The measured albedos are close to those which were expected—it is interesting that Meteorological Research Flight aircraft and the American TIROS weather satellites report the same albedo for a wide area of the Sahara Desert—but both in "clear air" and cloud the measured absorption of solar radiation is higher than can be accounted for by any published theories. Some clouds have been found to absorb more than 20 per cent of the solar radiation incident on them. In connection with this programme the absorption of solar radiation in a clean atmosphere was recomputed using the most modern values of the relevant absorption coefficients. Both aircraft and surface measurements of solar radiation indicate that absorption by atmospheric aerosol is important locally, and may be an appreciable term in the earth's radiation balance.

Atmospheric turbulence and diffusion. Micrometeorology.— This field of study has always been most actively pursued in the Meteorological Office. O. G. Sutton's text *Micrometeorology*,[7] which sets out the position of the subject soon after the end of World War II, and F. Pasquill's recently published *Atmospheric Diffusion*,[8] contain sufficient evidence of this.

A considerable change in approach to the diffusion problem has occurred in the period under review. Let us consider the movement of a particle in a direction perpendicular to the mean wind. Its velocity in this direction is u and its displacement X. After time T its displacement is

$$X(T) = [u]_T . T$$

where $[u]_T$ is the mean velocity over time T.

If we now take the mean over an ensemble of particles we have for the mean square displacement after time T.

$$\overline{X^2}(T) = \overline{[u]_T^2} . T^2$$

To study the dispersion of particles released continuously from a point source we must study the function $\overline{[u]_T^2}$. If the variance of u in time t is u_t^2 and this has a limiting value u_∞^2 (a necessary assumption in all mathematical treatments of turbulence statistics) and if we write $V(t) = u_t^2/u_\infty^2$, it can be shown that $\overline{[u]_T^2}/u_\infty^2 = 1 - V(T)$ and we can readily establish the following relations between this "variance function" and the autocorrelation (R) and spectrum (F) functions familiar in statistical descriptions of turbulence

$$R(t)\,1 = -\tfrac{1}{2}\frac{\partial^2}{\partial t^2}[t^2 V(t)],\quad F(n) = \int_0^\infty R(t)\cos 2\pi nt\,dt$$

$$V(t) = \int_0^\infty F(n)[1 - \sin^2\pi nt/(\pi nt)^2]dn = \text{approximately} \int_{1/(2t)}^\infty F(n)dn$$

To exploit this method of determining or predicting the diffusion of particles in the atmosphere we must relate $V(t)$—a description of events following the particles and not very amenable to observation—to some readily made measurement, and this in turn, particularly in large-scale problems, to the synoptic weather map. The relation of dispersion statistics to turbulence statistics determined at a point—"Lagrangian" and "Eulerian" statistics—has figured largely in the work of F. Pasquill and his colleagues over the past few years.

The exchange of heat and moisture between air and ground plays a prominent rôle in many meteorological problems, ranging from the general circulation of the atmosphere to local fog formation, and is a central theme in agricultural meteorology. It may be studied in many ways and on many scales. A Meteorological Office unit in close association with the School of Agriculture, Cambridge University, has worked in this field, and reported frequently to the MRC since the end of World War II, being concerned mainly with evaporation from growing crops and its estimation by methods at once reasonably simple, accurate, and applicable to short intervals of time. Similar work has been carried out at Kew Observatory, and also at Cardington where moored balloons have been used to carry instruments away from the immediate neighbourhood of the surface to heights around 3000 feet. Examples of this type of work may be found in N. E. Rider's[9] study of the profiles and flux of momentum, heat and water vapour in the lowest two metres of the atmosphere and in a series of reports to the MRC on the formation of fog in relation to the structure of the lowest 2000 feet of the atmosphere.

Exploration of the high atmosphere.— The greatest change in meteorology since the inception of the MRC is without doubt the enormous expansion of our knowledge of the three-dimensional structure of the atmosphere, a consequence of the availability of an instrument, the radiosonde, reliable enough and cheap enough to be used regularly in a wide network of observing stations, and a vehicle, the small extensible balloon, capable of carrying it regularly to pressure levels around 50 mb. Within the last few years it has become possible to visualize an extension of observations to 5 to 10 mb by the use of extensible balloons, and to unlimited heights by the exploitation of rocket and satellite techniques. Such an extension requires no justification to the meteorologist, who has never had reason to question the definition of meteorology as the scientific study of atmospheres, so it was natural that the Meteorological Office, with the support of the MRC, should form a unit to take advantage of the new opportunities to study the high atmosphere by all available means. Plans have been made for the inception of regular soundings by rockets from a base in the Hebrides and, by arrangement with the Royal Society's National Committee for Space Research, instruments are being prepared to measure the distribution of ozone in the atmosphere from an artificial earth satellite. These instruments have already been tested on a "Skylark" rocket launched from Woomera, Australia, and the vertical distribution of ozone has been determined to its upper limit at the time of this ascent. (See photograph opposite page 324.)

An examination of what is known about the temperature field of the atmosphere between 20 km and 100 km, coupled with computations of its radiative heating and cooling, led R. J. Murgatroyd and F. Singleton[10] to propose a

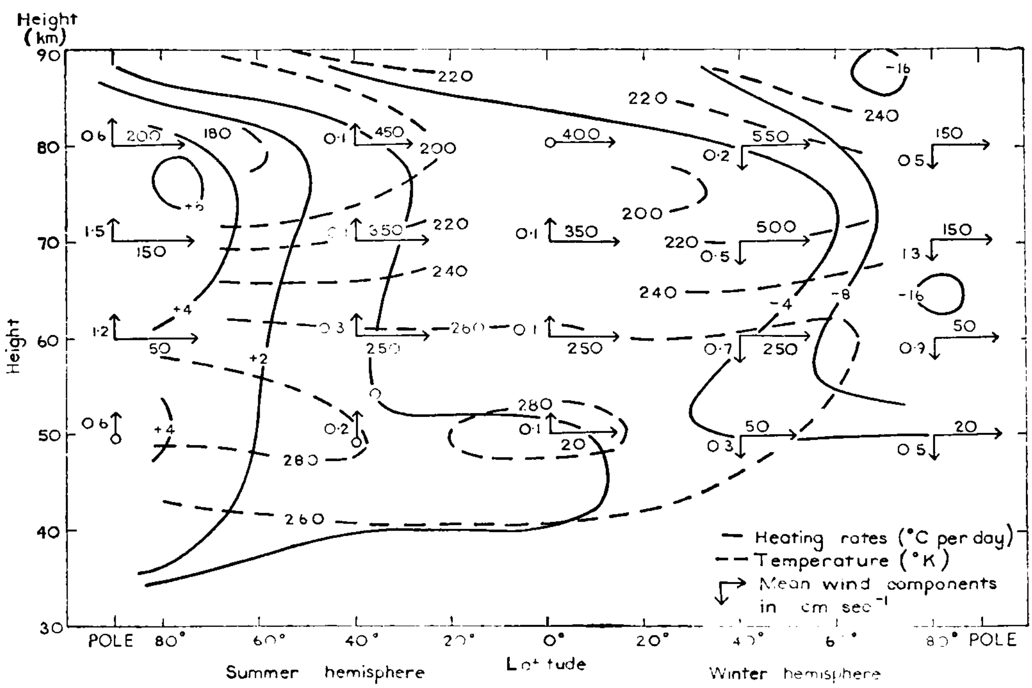
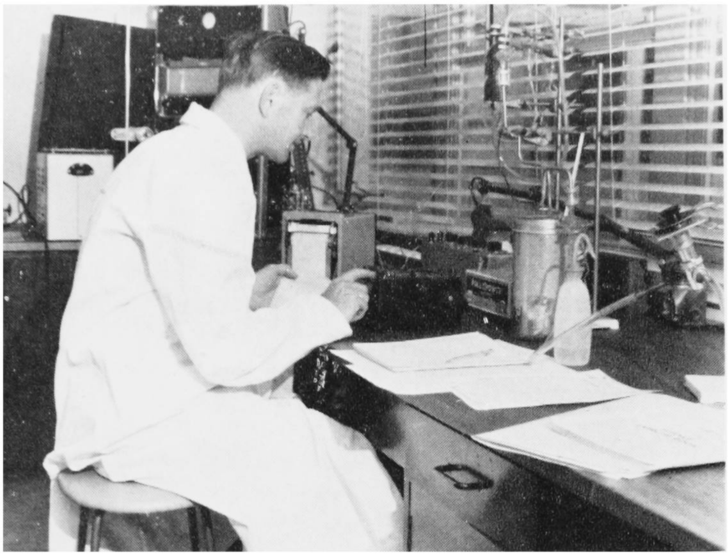


FIGURE 4—COMPUTED HORIZONTAL AND VERTICAL COMPONENTS AT THE SOLSTICE OF A MEAN MERIDIONAL CIRCULATION IN THE MESOSPHERE, WITH THE AIR TEMPERATURES AND RADIATION-TREATING RATES ON WHICH THEY ARE BASED

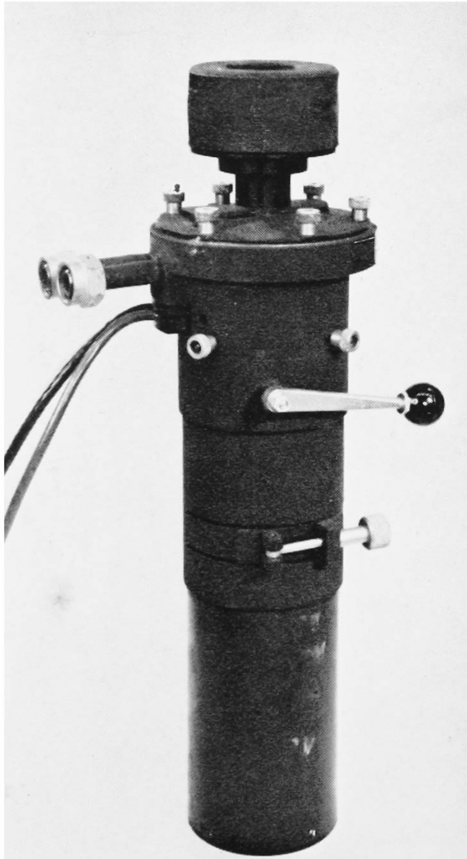
[*Murgatroyd & Singleton*]

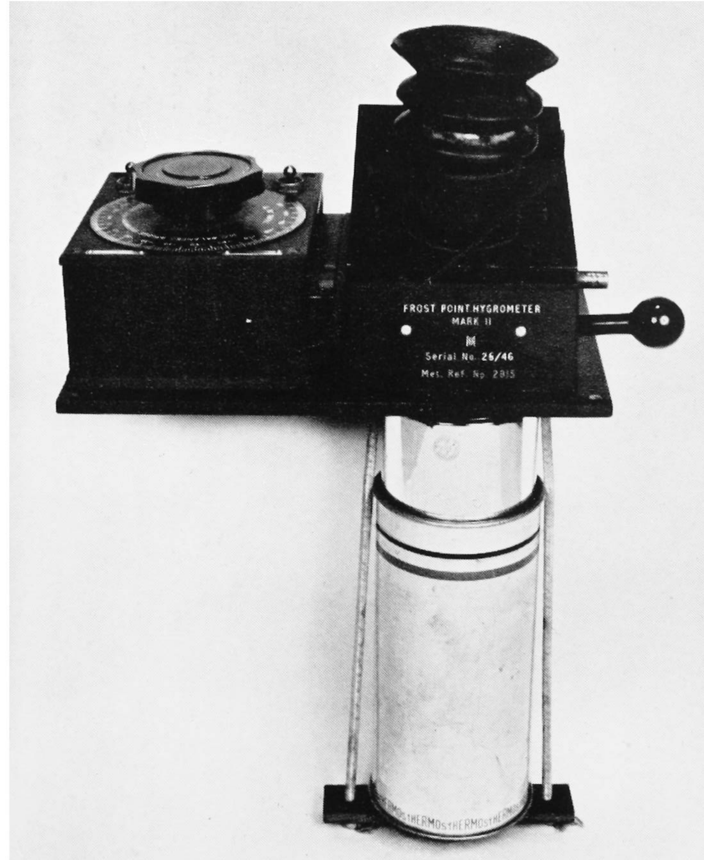


AN EXPERIMENTAL HYGROMETER, DESIGNED FOR USE AT HIGH ALTITUDES ON FREE BALLOONS, UNDERGOES TEST AND CALIBRATION IN THE BRACKNELL LABORATORIES

AT THE BRACKNELL LABORATORIES A FINAL CHECK IS MADE ON EQUIPMENT TO MEASURE THE VERTICAL DISTRIBUTION OF OZONE, MOUNTED IN THE INSTRUMENT COMPARTMENT OF A "SKYLARK" ROCKET.

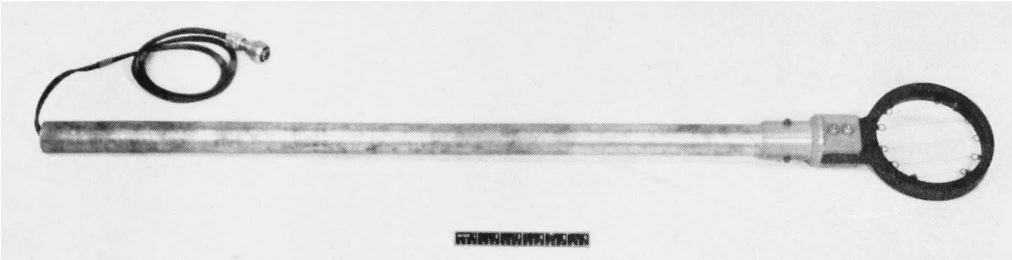
RESEARCH IN THE METEOROLOGICAL OFFICE—PHOTOGRAPHS OF INSTRUMENTS USED IN RESEARCH WORK ARE SHOWN ABOVE, AND ALSO ON THE FOLLOWING THREE ART PLATES AND ON THAT OPPOSITE p.338.

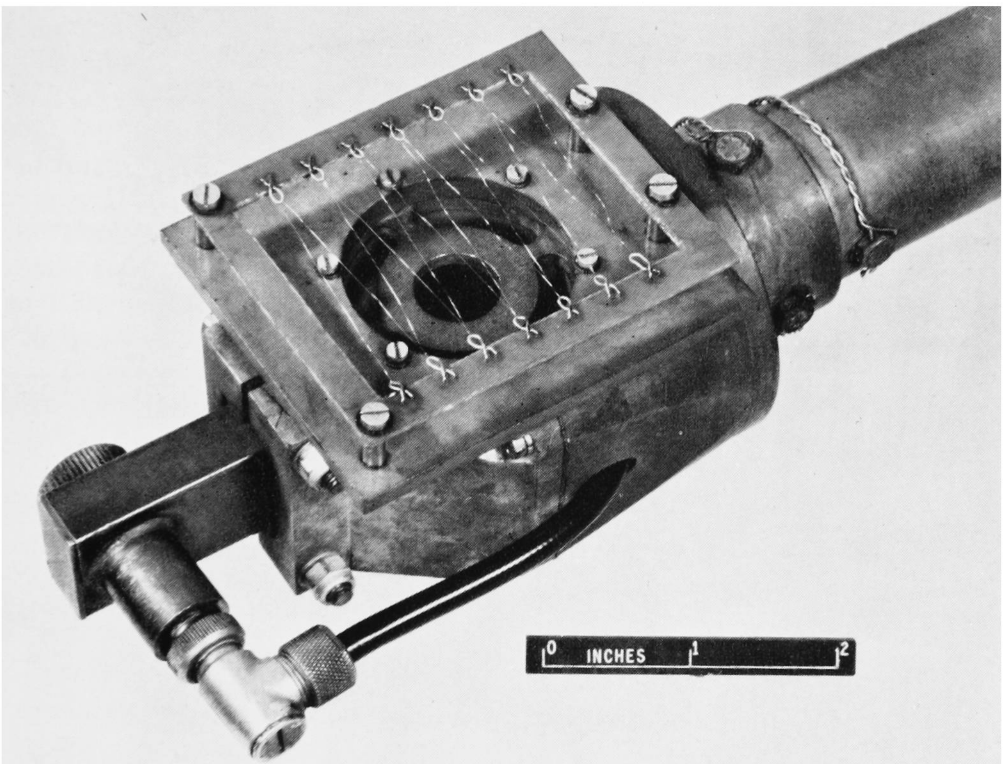




TWO MODELS OF THE DOBSON–BREWER FROST-POINT HYGROMETER.

Left: model with pressurization facilities and liquid nitrogen cooling, as used on Canberra aircraft.
Right: model with CO_2—alcohol cooling, as used on Hastings and Varsity aircraft.





OTHER INSTRUMENTS USED ON AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT.

Top: Probe of a hot-wire water content meter for determining the concentration of water and ice in clouds.

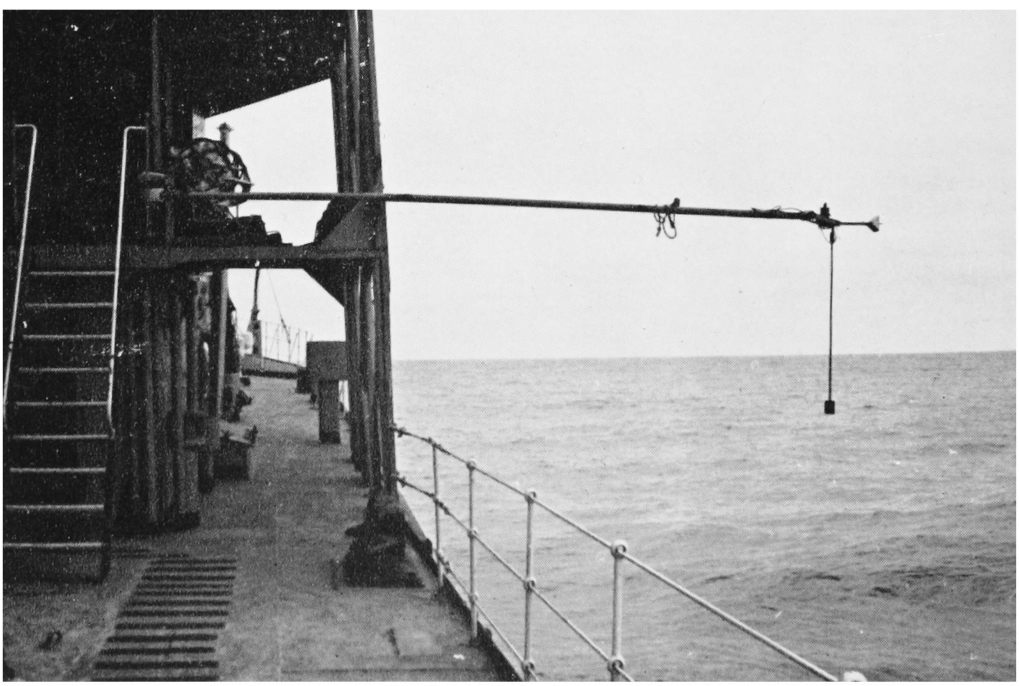
Bottom: Cavity of a microwave refractometer and a rapid-response resistance thermometer.

To face p. 325

Crown copyright

PYRHELIOGRAPHS AT KEW OBSERVATORY.

Thermopiles mounted on heliostats measure the intensity of solar radiation in spectral regions defined by filters.



Photograph by J. F. Moir

RECORDING RADIATION AT SEA.

A radiation balance-meter exposed, in unusually calm conditions, on one of the ocean weather ships. The sensitive surface is shielded from the radiation from the ship, and its output added to that of an instrument, covering the other hemisphere, similarly mounted on the other side of the ship. The radiometer is stabilized against roll but not against pitch.

meridional circulation compatible at its lower boundary with that suggested by Brewer but posing unanswered dynamical and thermodynamical problems at higher levels. Figure 4 illustrates the upper part of this circulation at the solstice.

Prospects.— It is clear from this summary that under the guidance of the MRC the Meteorological Office's work in the domain of physical meteorology has been concerned to a great extent with observations out of doors, with perhaps less emphasis on laboratory physics, numerical experiment, and theoretical investigation than would be desirable in a completely balanced programme. This reflects a provision of facilities for observation in some respects unique. There is also evident a tendency to treat those aspects of physical meteorology which have an immediate bearing on the larger scale problems of climate and weather (tracer studies of the general circulation, radiative properties of clouds, energy transformations at the surface), or those with direct application to problems in aviation, architecture or public health (water and ice in clouds, recording of illumination, diffusion of atmospheric pollutants). This tendency reflects the Meteorological Office's position as a public service.

This survey is written at a time when the Meteorological Office's opportunities for outdoor observation are for the first time matched by the provision of adequate laboratory facilities in the new buildings at Bracknell and Farnborough. It is profitless to attempt to predict the future of a research project in any detail, but in broad outline the plan for the next few years is clear. The new techniques for sounding the high atmosphere must be exploited to the full to map the winds, temperatures, composition and radiative state of the atmosphere above the 10 mb level until the mean state and the structure of the disturbances are as well known there as in the troposphere. In the field this will require the co-operation of many agencies, but there is also the need for much laboratory work on sensors, particularly of temperature and radiation, for use on balloons and rockets, and for mathematical investigations on heat balance and possible circulations. It seems likely that weather satellites will operate continuously, and the refinement of current proposals to employ satellite-mounted instruments at various levels to measure the temperature, some aspects of atmospheric composition and the radiative fluxes, offers a considerable challenge to the laboratory physicist. The precision required of temperature or density measurements in the upper atmosphere, if they are to be properly integrated with the observed wind structure, is readily seen to be very high indeed—it is of course not yet approached in the upper levels of balloon-sonde ascents.

It is likely that the Meteorological Office's first rocket-sonde and its first satellite experiment will both be launched in 1963. Rocket soundings for ozone content will continue, and balloon soundings for ozone, water vapour and radiative flux should follow.

In the domain of cloud microphysics attention is likely to be directed to the ice phase and particularly to the freezing nuclei whose nature, numbers, mode of action and indeed importance to the natural freezing process are all still in varying degrees doubtful. Some aspects of the initiation of precipitation may be clarified by the use of millimetric radar and a combination of radar techniques may be used to investigate the hail problem.

The availability of cloud pictures from satellites will facilitate the study of cloud populations and more quantitative work in this field can be envisaged using photographs from aircraft. Detailed and recondite treatments of the radiative properties of an entirely gaseous atmosphere may have obscured the fact that cloud is perhaps the most important atmospheric radiator, and more attention, empirical and theoretical, to its incidence and radiative properties is overdue.

Quasi-theoretical estimates of the heat budget at the earth's surface differ by amounts which are very significant when attempts are made to link them with circulation studies. An urgent, if rather unglamorous task for the physical meteorologist is to improve methods of recording solar and terrestrial radiation and to encourage such measurements, particularly at sea, because progress in satellite instrumentation is such that it seems likely that the radiation field at the upper limit of the atmosphere will soon be better known than that at the earth's surface. For the same reason an extension to the oceans of the investigations of energy and mass transfer carried on over land surfaces is required.

I began this survey with the remark that physical meteorology was not a self-sufficient science. If we except investigations directed to immediate practical applications, almost all the work I have mentioned contributes to the clarification of some aspect of the central problem of meteorology, the general circulation of the atmosphere. What is required is a mapping of the flux of energy in its various forms as comprehensive as that mapping of temperature and wind which has hitherto been the climatologists' main concern; this mapping involves the application of techniques, both experimental and mathematical, which are the concern of physical meteorology, and which take their place alongside those of the mathematicians and climatologists as essential to our fuller understanding of the atmosphere.

REFERENCES

1. BREWER, A. W.; Evidence for a world circulation provided by the measurements of helium and water vapour distribution in the stratosphere. *Quart. J.R. met. Soc., London,* **75**, 1949, p.351.
2. SAWYER, J. S.; The Free Atmosphere in the Vicinity of Fronts: Analysis of the observations by the Meteorological Research Flight, 1950–52. *Geophys. Mem., London,* **12**, No. 96, 1955.
3. HARPER, W. G. AND BEIMERS, J. G. D.; The movement of precipitation belts as observed by radar. *Quart. J. R. met. Soc., London,* **84**, 1958, p.242.
4. PROBERT-JONES, J. R.; Meteorological use of pulsed Doppler radar. *Nature, London,* **186**, No. 4721, 1960, p.271.
5. STEWART, K. H.; Some observations on the composition of fogs. *Met. Res. Pap., London,* No. 1074, 1957.
6. ROBINSON, G. D.; The use of surface observations to estimate the local energy balance of the atmosphere. *Proc. Roy. Soc., London,* Series A, **236**, p.160, 1956.
7. SUTTON, O. G.; Micrometeorology. McGraw-Hill Book Co. Inc., New York, 1953.
8. PASQUILL, F.; Atmospheric Diffusion. D. Van Nostrand Co. Ltd., London, 1962.
9. RIDER, N. E.; Eddy diffusion of momentum, water vapour, and heat near the ground. *Phil. Trans., London,* Series A, **246**, 1954, p.481.
10. MURGATROYD, R. J. AND SINGLETON, F.; Possible meridional circulations in the stratosphere and mesosphere. *Quart. J. R. met. Soc., London,* **87**, 1961, p.125.

551.5.001.5

RESEARCH IN SYNOPTIC AND DYNAMICAL METEOROLOGY AND IN CLIMATOLOGY, 1941 TO 1962

By J. S. SAWYER, F.R.S.
Deputy Director of Dynamical Research, Meteorological Office.

To glance through the pages of the minutes of the Meteorological Research Committee (MRC) and its Subcommittee II (Synoptic, Dynamical and Climatological Subcommittee) is to review the progress in dynamical and synoptic meteorology of the past two decades. In some respects—particularly in regard to dynamical meteorology and in our knowledge of the upper troposphere and lower stratosphere — progress has been such as to open up entirely new lines of thought and development, while on other topics papers which were presented and discussed at the Meteorological Committee 15 or 20 years ago would have been as acceptable today as they were then.

The main streams of research in climatology and in dynamical and synoptic meteorology are discussed in the following paragraphs. However, such a brief review must necessarily omit many interesting topics to which the Committee devoted its attention at various times.

Dynamical meteorology and numerical weather prediction.— Twenty-one years ago, when the MRC was formed, the radiosonde was only just coming into effective operational use and current knowledge of the free atmosphere was limited to that obtained from the few regular aircraft soundings available and from pilot balloons in clear weather. Prior to World War II it had been possible to draw limited upper air charts to the 500 mb level over a restricted area of western Europe, but with the outbreak of war the area became even more limited.

Without a working familiarity with the three-dimensional temperature and wind structure of the weather systems occurring day by day, progress in the dynamical study of depressions, anticyclones, etc., was necessarily limited. The stimulus for development of the subject came from the expansion of regular upper air charts for most of the troposphere. Drawn primarily for the purposes of wartime aviation over an expanding area, the charts became more complete and comprehensive after the war as the continental networks of radiosondes were expanded and linked by the weather ships.

The need to forecast the upper wind distribution led during the war to the development of the techniques of thickness analysis by the Upper Air Analysis Unit at Dunstable* under Dr. S. Petterssen, and to an increasing understanding of the rôle played by temperature advection and vertical motion in the changes of upper air structure which accompany weather systems on the scale of depressions and anticyclones. Particularly important was the contribution of Dr. R. C. Sutcliffe who, recognizing that the pattern of the 1000–500 mb thickness lines is broadly representative of the temperature distribution through the troposphere, showed how the dynamical and thermodynamical equations could be linked to relate cyclonic and anticyclonic development to the patterns of thickness lines and contours of isobaric surfaces. His fundamental paper was published in the *Quarterly Journal of the Royal Meteorological Society* in 1947,[1] and is important also in its stress on the rôle of the vertical component of

*Units of the Meteorological Office formerly at Dunstable are now at Bracknell.

vorticity.

Further exploitation of these ideas was rendered possible by the establishment in 1948 of a branch at Dunstable for research in short-range forecasting, a step largely due to the foresight of Sir Nelson Johnson, then Director of the Meteorological Office. Studies at Dunstable in the following years showed that it was possible to evaluate many important terms in the dynamical equations from synoptic charts on the basis of the geostrophic wind equation. On the more practical side it was demonstrated how rules based on Sutcliffe's dynamical theory could be applied in a qualitative manner to practical forecasting of the movement and development of particular weather systems. These rules were tested in close co-operation with the routine forecasters at Dunstable and are largely summarized in an important paper by Sutcliffe and Forsdyke[2] published in 1950. They are now part of the accepted technique of forecasting.

As early as 1948 we find the MRC discussing the application of the electronic computer then projected at the National Physical Laboratory to the forecasting problem, and recommending the direction of mathematicians to this problem. However, the steps towards numerical weather forecasting came gradually later, partly under the stimulus of the early work by Charney[3,4] in America and partly as a direct development from the numerical formulation of Sutcliffe's development equation. From the first, attention at Dunstable was directed to a formulation of the numerical forecasting problem which would permit the prediction of both surface and upper air charts, the fundamental paper[5] being considered by the MRC in 1952—attention in America and Sweden being then directed primarily to the barotropic treatment applying only in mid-troposphere.

The results of computations of 24-hour changes in the pressure field on electronic computers in London and Manchester were so encouraging that in 1954 we find the MRC (Subcommittee II) recommending "an intense effort in numerical forecasting with the aid of an electronic computer under the control of the Meteorological Office". Such a machine was provided, and became available in January 1959 when it became possible to carry out extended experiments in numerical weather prediction on a current basis.[6] These have continued intermittently since and have established that upper air charts can be computed with a standard close to that achieved by current subjective methods, but the accuracy of the surface charts predicted by numerical methods remains at present a little below that of the subjective methods. (See the example of a numerical forecast in Figure 2 on page 331.)

Along with the development of numerical weather forecasting has gone the studies of objective analysis and data processing which enable a computer to read the paper tape punched as messages come in by teleprinter, to extract relevant upper air reports, ships' reports, and so on and to interpolate from these the values of the heights of various upper air surfaces at a specified grid of points on the map which are required to initiate a numerical forecast. The latest methods developed by Corby[7] and his co-workers provide a standard of analysis as acceptable for the start of a numerical forecast as can be achieved by the more conventional methods of plotting and drawing charts.

There is no doubt that the work of the last twenty years has given an insight into the fundamental dynamics of depressions and anticyclones from which we can say that the basic mechanisms are now understood. For numerical prediction we need more than this and it is already clear that several secondary processes, orography, friction, latent heat release in precipitation and so on all play a part, so that the improvement of the standard of numerical prediction to a state in which it clearly surpasses subjective methods will call for the painstaking development and improvement of numerical methods to take into account these effects. We can have confidence that such improvement will be effected over the next ten years or so, but every additional factor considered makes the satisfactory formulation of the problem and computation of results more difficult, and progress must be expected to be slow.

Medium range forecasting.— Since its earliest meetings the MRC has stressed the need to develop methods of medium-and long-range forecasting. Under the urgent pressure of wartime requirements in 1942 an experiment was carried out to predict the pressure field over periods from a few days to a month or two, employing harmonic analysis and symmetry points in time series. The experiment was abandoned after about 18 months as a failure.

Medium-range forecasting was not again seriously attempted until 1948 when Sir Nelson Johnson set up a branch at Dunstable for the purpose, under the direction of Dr. R. C. Sutcliffe. Following the experience of a similar team operating in the U.S.A. under Dr. J. Namias, attention was directed to the largest scales of atmospheric motion as displayed on northern hemisphere charts of 500 mb flow, 1000–500 mb thickness, and surface isobars. (By this date the upper air network permitted the regular construction of such charts.) It was soon found that, with experience, extrapolation and dynamical argument based on Sutcliffe's theory of development could be applied to these charts to prepare forecast charts for two and three days ahead, with a sufficient accuracy to provide a useful guide to the weather over the next four days.

This work provided the stimulus for a considerable number of studies of the large-scale and long-lasting features of the upper flow pattern—the long waves, cut-off cold lows, etc. A background of knowledge has thus been provided for the medium-range forecaster, but actual experience of working with circumpolar upper air charts is probably the most valuable asset of the medium-range forecaster.

The preparation of four-day forecasts along these lines was incorporated in the work of the Forecast Division on an experimental basis in 1952 and has gradually become an established part of the routine for giving guidance as necessary beyond the usual 48-hour outlook.

The main requirement in this field is probably to codify and consolidate the forecaster's experience. Some success has been attained in providing more objective rules for weather developments over periods of a few days, [8,9] and there is some indication from America that numerical forecasting methods applied to hemisphere charts can give useful guidance up to three days ahead.

Long-range forecasting.— In addition to the abortive experiment in long-range forecasting to which reference has been made, studies were also conducted by Sir Gilbert Walker in the early years of the MRC into the association between Arctic sea-ice and European weather.[10] However, this work also failed to provide a basis for long-range forecasting.

In 1952 the MRC (Subcommittee II) again turned its attention to the problems of long-range forecasting and the study of the longer-period weather

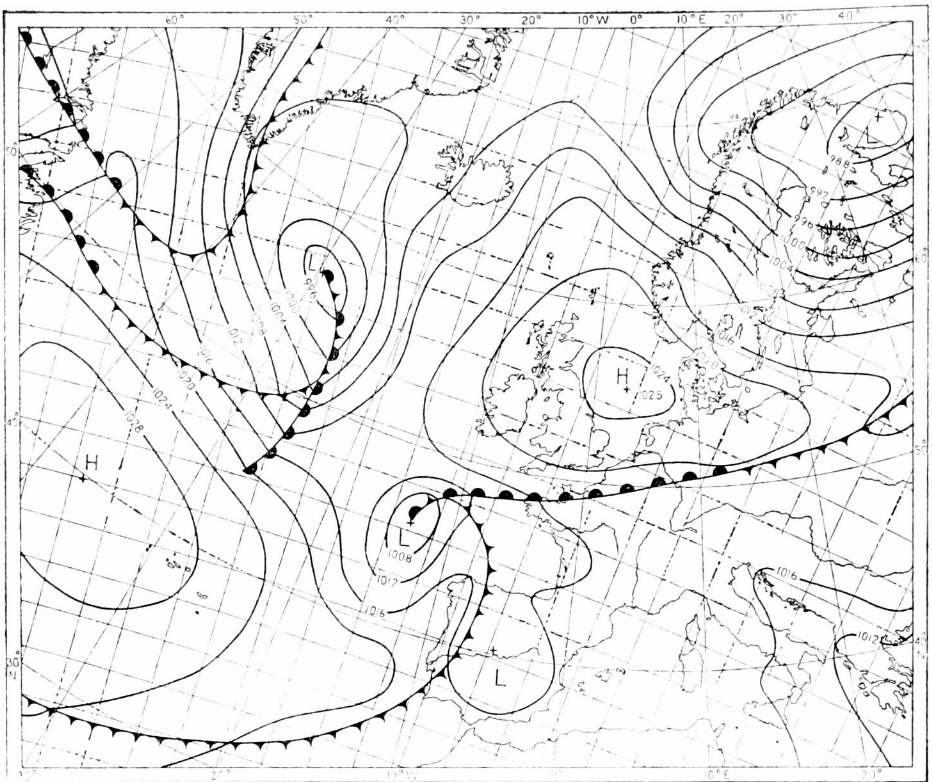


FIGURE 1*a*—SURFACE CHART FOR 0000 GMT, 14 AUGUST 1962

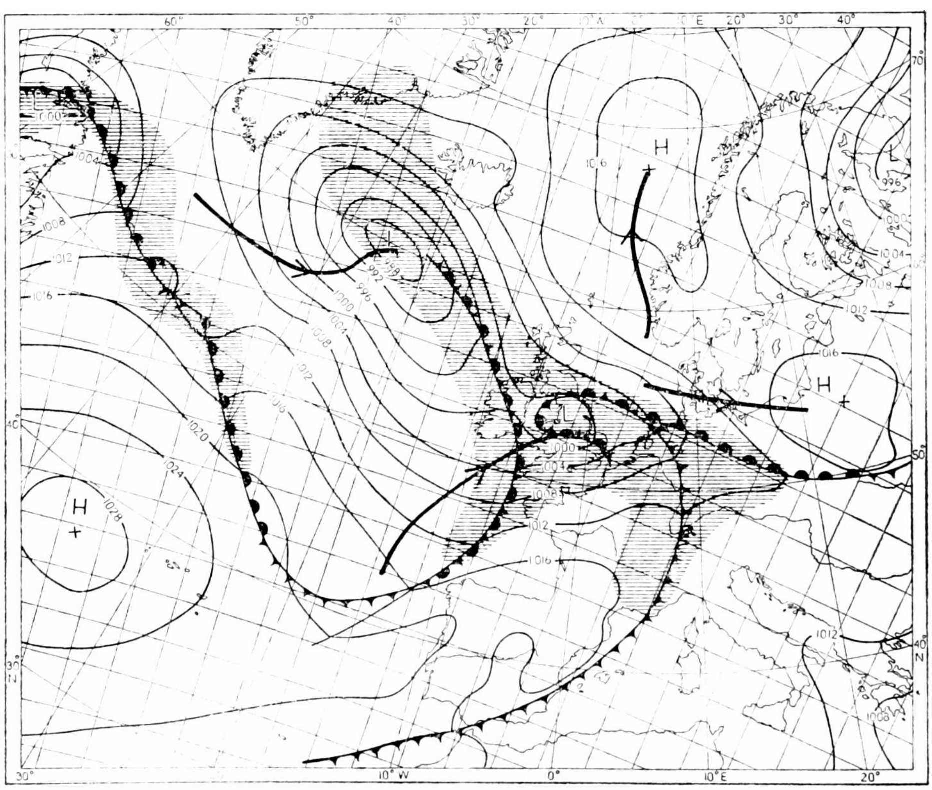


FIGURE 1*b*—SURFACE CHART FOR 0600 GMT, 15 AUGUST 1962

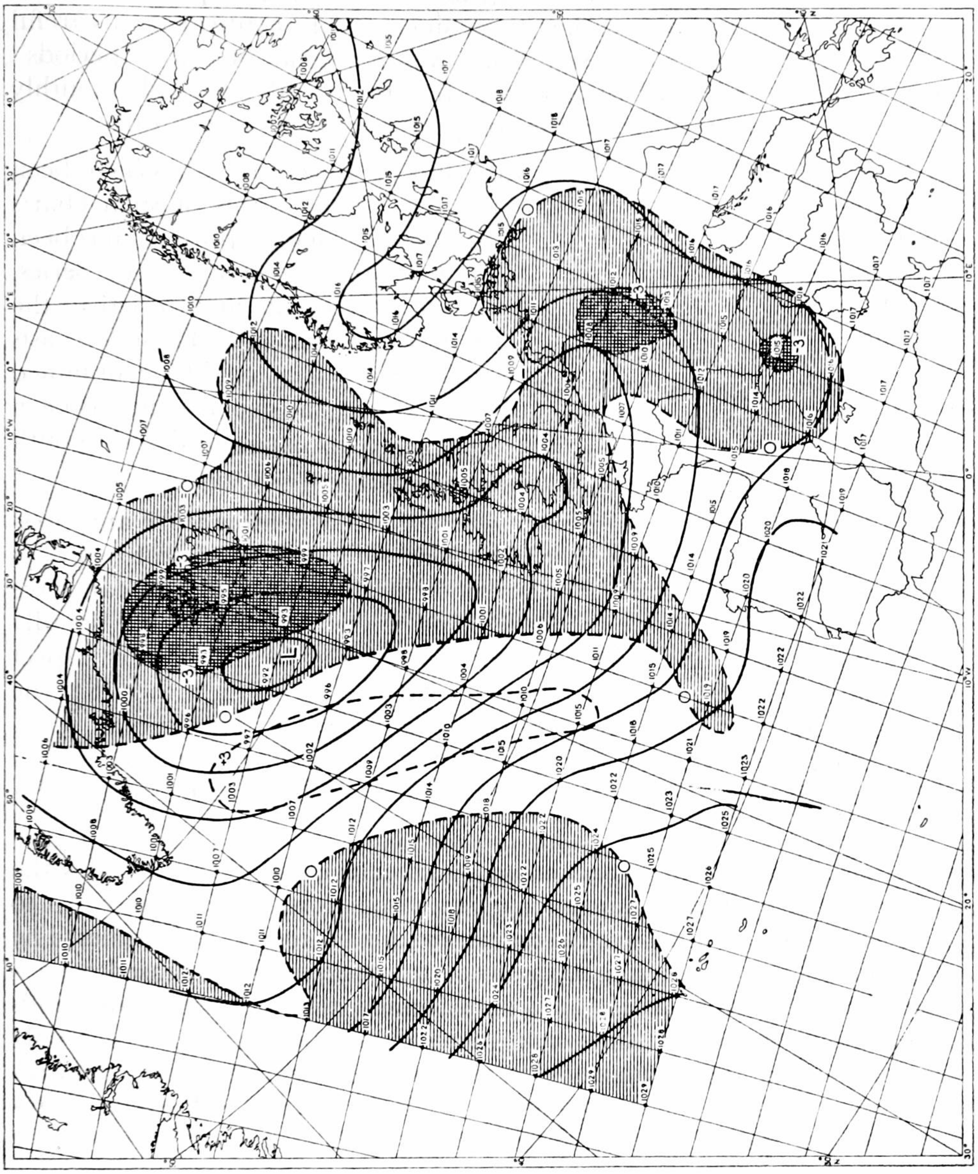


FIGURE 2—NUMERICAL FORECAST FOR 0600 GMT, 15 AUGUST 1962, BASED ON INITIAL CHART FOR 0000 GMT, 14 AUGUST 1962

EXAMPLE OF A NUMERICAL FORECAST

At 0000 GMT on 14 August 1962 the U.K. was under the influence of an anticyclone of 1025 mb whilst there was a depression to the SW and another in mid Atlantic (Figure 1*a*). By 0600 GMT on 15 August 1962 the anticyclone near the U.K. had been replaced by a depression (Figure 1*b*) which gave thundery rain over the country. The area of rain and showers or thunderstorms is shaded in Figure 1*b*. The numerical forecast for 0600 GMT on 15 August 1962 (Figure 2) was computed using a three-level model based on the chart shown in Figure 1*a*, incorporating some of the effects of topography and surface friction. Computed pressure values at the grid points are given, together with isopleths of mean vertical motion in mb/hr for the layer 1000–600 mb, upward motion being shaded. Most of the important changes are very well predicted in the numerical forecast.

changes was started in the Meteorological Office using appropriate time averages. It was then realised, as has been since amply confirmed in careful work by Craddock,[11] that the most significant weather variations have "periods" from about 15 days up to a month or so, and that the readily available monthly mean data are not ideally suited to the study of long-range forecasting.

However, monthly charts of temperature and pressure anomalies have been studied because of their ready availability and a long series of such charts extending back to 1880 for temperature and much earlier for pressure has been built up. Early successes in selecting analogues from the temperature series, and using the analogue year to forecast for the subsequent month, led to the establishment of an experimental series of long-range forecasts. These forecasts have had results only marginally better than those that could be obtained by guessing, and are of little practical utility. Recently the experiment has been broadened, and other bases for a long-range forecast are considered month by month, mainly to build up experience of their practical utility.

Statistical study of the time and space distribution of temperature and pressure anomalies has demonstrated that variations with periods of 10 to 30 days are not the accidental result of shorter-period fluctuations, and one can have reasonable confidence that there are underlying physical factors which broadly determine the character of the longer-scale fluctuations. An important aspect of future research will be to track these down. Since it has been shown that the corresponding anomaly patterns have dimensions on a continental scale, an understanding of the general circulation of the atmosphere and its vagaries is clearly important, and we can look forward to increasing attention to this problem.

Upper winds and their forecasting.— Over the last three decades the normal operational ceiling of aircraft has increased from some 3 km or so to 16 km or more, and their range from a few hundred miles to over 3000 miles. The demand for forecasts of the wind in the free atmosphere has increased correspondingly in range. When the MRC was formed the forecasting of winds in the free atmosphere was a new task—a network of observations was only then becoming available; previously forecasts had been largely made by extrapolation upward from the surface isobars on the basis of a few isolated temperature soundings and pilot-balloon winds.

During the early years of the 1940's, under the pressure of wartime requirements, the techniques of isobaric analysis were firmly established by the Upper Air Unit at Dunstable under the guidance of Dr. S. Petterssen. In later years, as aircraft operated at longer ranges in the upper troposphere and a better upper network of observations became available, interest concentrated on the jet stream and its structure in more detail. A number of synoptic studies were carried out by R. Murray and D. H. Johnson,[12] and special flights were made by aircraft for the purpose.[13,14] The structure of the tropopause also received attention.

Aircraft speed has also increased with the years and the emphasis on the detailed study of upper wind structure has perhaps passed, although much remains to be learned, particularly at levels above 100 mb where the observations which have become available in recent years have not yet been regularly analysed in this country. The forecasting problem has shifted somewhat to the prediction of the general upper flow over the Atlantic and other long air-routes—a field in which numerical forecasting methods can be expected to make an increasing contribution and in which they may ultimately provide an objective routine.

Upper air climatology.— From its earliest days the MRC has emphasized the need for a world network of upper air observations upon which an upper air climatology of the world would be established. Largely as a result of the foresight and enthusiasm of Mr. C. S. Durst and Dr. A. H. R. Goldie, the Meteorological Office was the first service to compile an adequate world-wide atlas of the newly accumulating information. The first world pressure charts were published in 1950,[15] and temperature charts in 1958,[16] but revision of the charts has been continuous as new data accumulate.

The preparation of the atlases has been supported by extensive studies of the statistics of upper wind, which have proved of particular value in the planning of air routes; special studies have given additional insight into the general circulation of the atmosphere.

As observations become better organized and more numerous it is becoming possible, and necessary, to concentrate upon the construction of mean upper air charts for specific periods—usually 5 years. This is necessary because the earlier charts combined data from various periods in different parts of the map and the differences associated with any slow changes in climate were apt to distort the picture.

A wealth of upper air observations is now becoming available from all over the world and the mapping and analysis of them bring many fascinating interrelations to light. The most recent and surprising is perhaps the large-scale alternation between easterly and westerly winds in the equatorial stratosphere with an apparently well defined period of just over two years.[17] We can expect many more interesting studies to be made, thus gradually improving our knowledge of the general circulation of the atmosphere.

Fronts.— Fronts have naturally received the attention of the MRC from its inception. In the early years the emphasis was on techniques of analysis of the surface chart. Later the Committee, Prof. G. M. B. Dobson in particular, stressed the need for observation and study of fronts in space and time. Special flights by the Meteorological Research Flight[18] and other synoptic studies have added much to our knowledge of the frontal and jet-stream systems in the last decade and in many respects the textbook model taken from the early papers of the Norwegian school must be regarded as obsolete.

The greatest need now is for the development of an adequate dynamical treatment of fronts which will explain their existence, persistence and their weather. We are at present only at the beginning of this task but, with the new understanding coming from the work on numerical forecasting, progress may well be rapid in the next decade.

The forecasting of rain.— The need for better methods of forecasting rainfall has been before the attention of the MRC since its inception but although a number of interesting investigations have been carried out it cannot be said that much systematic progress has been made. It is fairly clear that the microphysics of cloud is only important under special circumstances and a physical basis for the prediction of rainfall must involve an understanding of the upward currents which lead to condensation and the factors which control their magnitude. Adequate understanding which would provide quantitative estimates of rainfall magnitude has so far not been attained, neither have empirical methods improved significantly on the forecaster's current methods of extrapolation and experience.

The problem is difficult because motion on many scales is involved, from the scale of the depression down to that of an individual cloud, and both the field of motion and humidity are "patchy" and not observed in adequate detail by the current synoptic network. The forecasting of rainfall is an intriguing challenge to the dynamical and synoptic meteorologist. We can hope that if enough meteorologists take up the challenge our understanding of the rain-producing systems—fronts, convection storms, orographic lifting, etc.—will slowly improve, but with so many different types of rain-producing system the effect on the standard of forecasting will necessarily be slow.

Local forecasting.— Throughout its life the MRC has had before it the important problems of local forecasting of individual weather elements. Indeed, one of the early studies which it sponsored was that of forecasting fog at the wartime bomber bases carried out by W. C. Swinbank.[19]

It is impossible to review all the relevant studies which have been carried out but the recent work by M. H. Freeman[20] on the application of statistical methods to short-period forecasting deserves a special mention. The work was aimed to produce purely objective forecasts of visibility at London Airport, but the technique is easily adapted to other weather elements and other places. An electronic computer is used in the development of the prediction formula from a long series of past data, but the arithmetic involved in making an individual forecast is very simple.

With the increase in the library of weather data in a form available for direct input to a computer, the possibility of extending the range and application of such statistical forecasting methods should increase rapidly in the next decade and we can look forward to their practical use on an increasing scale at least as a guide which codifies a much longer experience of local weather than the forecaster can possibly store in his memory.

The preceding paragraphs briefly review only some of the problems which have constantly been under consideration by the MRC. There are others equally important—climatic change, forecast verification and so on. There is also a wide group of activities in applied meteorology, and on the borderlines of other subjects such as hydrology and oceanography, in which the MRC has an important interest. For example, the activities of the agricultural branch of the Meteorological Office under Mr. L. P. Smith have particularly demonstrated how the meteorologist with a wide knowledge of his subject, its resources and techniques, can give practical aid to the agriculturalist and can pose and solve problems which would not have been formulated without the aid of the meteorologically trained mind. By bringing the meteorologist within the Office into contact with outside scientists with different interests, it is to be hoped that the MRC can continue to contribute to the extension of this close interdisciplinary collaboration in the many other fields in which it is possible.

REFERENCES

1. SUTCLIFFE, R. C.; A contribution to the problem of development. *Quart. J. R. met. Soc., London*, **73**, 1947, p.370.
2. SUTCLIFFE, R. C. and FORSDYKE, A. G.; The theory and use of upper air thickness patterns in forecasting. *Quart. J. R. met. Soc., London*, **76**, 1950, p.189.
3. CHARNEY, J. G. and ELIASSEN, A.; A numerical method for predicting the perturbations of the middle latitude westerlies. *Tellus, Stockholm*, **1**, No. 2, 1949, p.38.
4. CHARNEY, J. G.; On a physical basis for numerical prediction of large-scale motions in the atmosphere. *J. Met., Boston, Mass.*, **6**, 1949, p.371.
5. SAWYER, J. S. and BUSHBY, F. H.; A baroclinic model atmosphere suitable for numerical integration. *J. Met., Boston, Mass.*, **10**, 1953, p.54.
6. KNIGHTING, E., CORBY, G. A., BUSHBY, F. H. and WALLINGTON, C. E.; An experiment in numerical forecasting. *Sci. Pap., London*, No. 5, 1961.
7. CORBY, G. A.; Some experiments in the objective analysis of contour charts. *Quart. J. R. met. Soc., London*, **87**, 1961, p.34.
8. LOWNDES, C. A. S.; The forecasting of dry spells of three days or more at London and in south-east England in May to October. *Met. Mag., London*, **89**, 1960, p.131.
9. MILES, M. K. and LEAF, G. G.; The occurrence and prediction of cold northerly-type spells over the British Isles in winter. *Met. Mag., London*, **90**, 1961, p.227.
10. WALKER, SIR GILBERT; Arctic conditions and world weather. *Quart. J. R. met. Soc., London*, **73**, 1947, p.226.
11. CRADDOCK, J. M.; An analysis of the slower temperature variations at Kew Observatory by means of mutually exclusive band pass filters. *J. R. Statist. Soc., London*, Series A, **120**, 1957, p.387.
12. MURRAY, R. and JOHNSON, D. H.; Structure of the upper westerlies; a study of the wind field in the eastern Atlantic and western Europe in September 1950. *Quart. J. R. met. Soc., London*, **78**, 1952, p.186.
13. MURRAY, R.; Some features of jet streams as shown by aircraft observations. *Geophys. Mem., London*, **12**, No. 97, 1956.
14. HURST, G. W.; The profile of a jet stream observed 1 September 1952. *Quart J. R. met. Soc., London*, **79**, 1953, p.407.
15. BROOKS, C. E. P., DURST, C. S., CARRUTHERS, N., DEWAR, D. and SAWYER, J. S.; Upper winds over the world. *Geophys. Mem., London*, **10**, No. 85, 1950.
16. GOLDIE, N., MOORE, J. G. and AUSTIN, E. E.; Upper air temperature over the World, *Geophys. Mem., London*, **13**, No. 101, 1958.
17. VERYARD, R. G., and EBDON, R. A.; Fluctuations in tropical stratospheric winds. *Met. Mag., London*, **90**, 1961, p.125.
18. SAWYER, J. S.; The free atmosphere in the vicinity of fronts. *Geophys. Mem., London*, **12**, No. 96, 1955.
19. SWINBANK, W. C.; Prediction diagrams for radiation fog. *Prof. Notes met. Off., London*, **6**, No. 100, 1949.
20. FREEMAN, M. H.; A graphical method of objective forecasting derived by statistical techniques. *Quart. J. R. met. Soc., London*, **87**, 1961, p.393.

551.5.001.5

NOTES BY THE CHAIRMAN OF THE MRC, PROFESSOR P. A. SHEPPARD

I shall always remember the morning in 1941 when Air Ministry approval for the formation of the Meteorological Research Committee (MRC) reached Sir Nelson Johnson, then Director of the Meteorological Office. I was only a war-time bird of passage in the Office, but Sir Nelson called me into his room at Victory House to share his good news and to tell me some of his hopes for research in the Office. Johnson was not given to emotional displays but that morning he was like the proverbial dog with two tails, and I am proud to have been allowed to share his excitement. It was not of course just the formation of the Committee itself that occasioned the happiness but the implication it carried that meteorological research was at last to be a recognized function of the Office, no longer to be left to the insufficient efforts of enthusiastic members of its staff at their postprandial dining tables.

And now, after 21 years, has the record of the MRC justified the hopes of its founders and served well the interests of the Office and the subject in research? Has the MRC in fact been really necessary? I do not know how those actually engaged in research in the Office would answer these questions—perhaps that has emerged in the articles in this number—but it is evident that research could have been prosecuted on a broad front, on problems basic and applied, without the services of the Committee; it could have been judged by performance and in the open forum of the published literature, and found its rectifications internally. That after all is how most non-governmental research institutions proceed, and if those involved are sound and imaginative scientists the internal reactions generally suffice; the existence of a committee is in any case no substitute for them. But I do not think it would be wise to make only a direct, scientific assessment of the record in the stocktaking operation for which this birthday provides the occasion. Meteorology and the Meteorological Office are in a very special case relative to the place of most other pure and applied science in the British community: the science has been most inadequately represented in British universities in relation to the tasks set by the science and the Meteorological Office practically the only employer of meteorologists. This is not the place to discuss all the implications of these special circumstances but they do react on the Committee and the Committee should react on them.

Thus, the existence of the Committee has enabled most of the few academic meteorologists of note in this country to become intimately aware of the problems which the Office has to tackle in order to discharge its obligations to the community as well as to advise on research which the Office, by virtue of its special facilities, should be encouraged to undertake. It has also provided an opportunity for scientists outside the Office with skills nearly related to or applicable to meteorology to become more involved with the subject. There may be some disappointment that the involvement has not been greater, but it is not negligible, and the Committee might well regard this as an increasing duty in the future. A healthy Office demands a healthy science, and conversely under the present conditions in this country. Here is a feed-back problem such as we are so used to in the subject itself—there is no one point of "entry" because cause and effect are not the identifiable events of simpler sciences and situations. And the Committee is peculiarly well placed to provide the feed-back if official and non-official sections of the membership realize the need and possess the will. It has already been able to support some research in the universities which might not otherwise have been undertaken and it may well encourage more. Certainly it should miss no opportunity of fanning any lively little academic flame which appears into a real fire, so that the Office will, in due time, feel the warmth of it.

Committees, it is often said nowadays, are a modern disease to which scientists are specially addicted and yet they seem almost to go out of their way to perpetuate the disease. The trouble is that they have discovered no alternative itch, one that will satisfy their promptings to serve society and their subject by a concern for the reactions of one on the other. Moreover, communication is an all-important part of science, provided time remains to produce work worthy of communication, and most scientists thoroughly enjoy the exercise, especially when it can be carried out around a table without great formality. In my now long association with the MRC, since 1947, I remember many enjoyable scientific discussions and I cannot doubt that those whose research was being discussed gained in their work (and noticed sometimes a lack of appreciation of it in others who might have known better) by having this particular forum to bring it to. If this has indeed been the case then the Committee has surely justified itself, educating witnesses and jury. I hope the Committee will continue to provide opportunity for lively and profitable discussion, to the ultimate benefit of the Office, the science, and the community. The Office has tremendous scope and a tremendous responsibility for improving the public image, particularly the scientific public's image, of meteorology. If the MRC can materially assist in effecting this improvement its past and future will be justified whatever more immediate dividends it may provide. So, on reaching its majority, more strength yet to its elbow.

551.5:06

FOURTEENTH SESSION OF THE EXECUTIVE COMMITTEE OF THE WORLD METEOROLOGICAL ORGANIZATION

By C. W. G. DAKING, B.Sc.

The fourteenth session of the Executive Committee, the last full session before Fourth Congress, took place at the Headquarters of WMO in Geneva from 29 May to 20 June 1962. The President of the Organization, M. A. Viaut, Director of the French National Meteorological Service, in opening the session paid tribute to the memory of Mr. L. J. Dwyer, President of Regional Association V (South-west Pacific), who had died some days before. Mr. Dwyer had been a member of the Executive Committee since 1958. M. Viaut then went on to say that M. J. L. Giovanelli, the Vice-President of Regional Association V would represent that Region at the session. Unfortunately, Dr. Po E and General Giansanti were prevented from coming to the session but they were being represented by alternates. Thus, there was a full attendance of members and alternates (18). In addition, the Committee had the benefit of the presence of the Presidents of the three Technical Commissions which had met since the thirteenth session, namely, Aerology, Instruments and Methods of Observation, and Synoptic Meteorology. Official representatives of UN sister agencies such as UNESCO, International Telecommunications Union and International Atomic Energy Agency were present for items of mutual interest between them and WMO.

As the activities of the WMO steadily develop, the agenda for sessions of the Executive Committee grow larger but the work continues to be completed in three weeks because of the superb facilities at the new Headquarters which permit the Secretariat to produce and distribute documents in English and French with remarkable speed.

The highlight of the session was the discussion on "Uses of satellites in meteorology and international co-operation in the peaceful uses of outer space". In December 1961, the United Nations General Assembly adopted a resolution on outer space which, *inter alia*, called upon WMO to prepare a report for Member Governments and the Economic and Social Council on measures:

(i) to advance the state of atmospheric science and technology so as to provide greater knowledge of basic physical forces affecting climate and the possibility of large-scale weather modification;

(ii) to develop existing weather forecasting capabilities and to help Member States make effective use of such capabilities through regional meteorological centres.

A draft report had been prepared by the WMO Secretariat helped by specialists from the U.S.A. (the late Dr. Harry Wexler) and the U.S.S.R. (Prof. V. A. Bugaev) and the Executive Committee Panel of Experts on Artificial Satellites of which Dr. G. D. Robinson of the Meteorological Office is a member. This draft entitled "Advancement of Atmospheric Sciences and their Application in the Light of Developments in Outer Space" was adopted after a number of amendments, mainly on points of detail, had been made. The amended version of the Report was endorsed by the Committee and, in Resolution 27, the Secretary-General was requested to present the Report to the United Nations General Assembly and other interested UN bodies. This resolution also invites support from the United Nations and other organizations and recommends to Congress that high priority be given by WMO to the implementation of the proposals contained in the Report.

One of these proposals was that Congress should set up a WMO Advisory Committee to consider and make recommendations on both the scientific and operational aspects of this question. In the meantime, it was decided in Resolution 28 to establish a Working Group to deal with the scientific aspects, leaving the operational and co-ordinative aspects to the existing Executive Committee Panel of Experts on Artificial Satellites. Dr. R. C. Sutcliffe is a member of this Working Group.

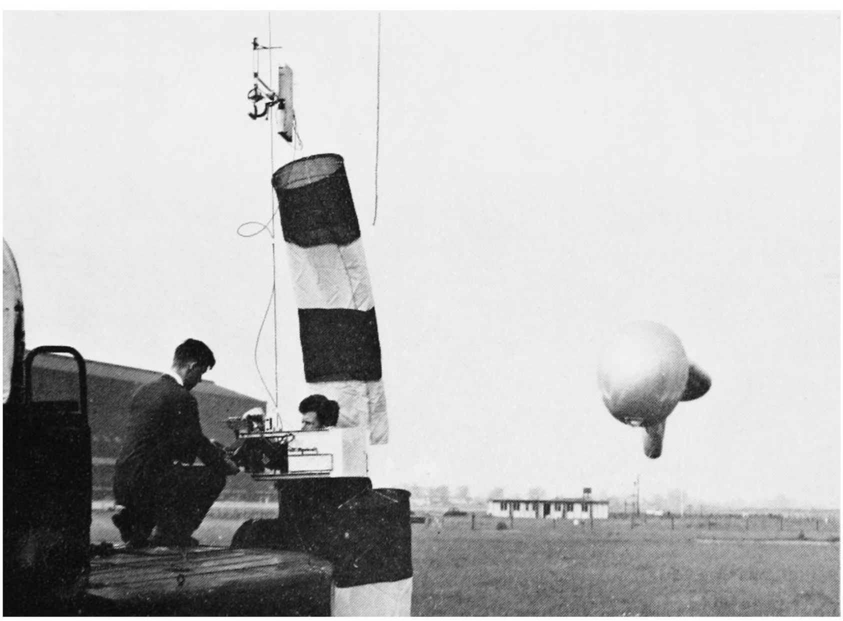
Since Third Congress (1959) the Executive Committee has, on instructions, carried out a review of the Convention of WMO which, having been in force since 23 March 1950, is in need of "modernizing" in the light of experience since that time. Most of the work involved, which has been considerable, has fallen on an Executive Committee Working Group of which the Director-General of the Meteorological Office has been a member, aided by a legal expert of the International Labour Office during its later stages of development. It was only to be expected that at each session of the Executive Committee successive reports of the Working Group would be subjected to criticism and counter-suggestions because the Convention is a treaty between States, and politics must inevitably become involved. However, the proposals of the Executive Committee agreed upon at this session have now been submitted to Members for study, and will be argued, no doubt at length, at Fourth Congress in 1963. The proposals are extensive and virtually present to Members a new text; only some ten Articles out of the thirty-six have neither been amended nor completely recast.

This item, together with financial matters, took up a good deal of the time of the Administrative and Finance Committee, who were confronted with a financial situation which necessitated the production of a supplementary estimate for 1963 in order to meet necessary additional expenditure on important projects during that year, the last of the Third Financial Period (1960–63). This supplementary estimate of some $100,000 has been submitted to Members for their approval for, although Third Congress foresaw that it might be necessary to incur additional expenditure beyond that which it authorized in 1959, it did not agree that the Organization should be committed without consultation of the Members.

Crown copyright

EQUIPMENT CARRYING FINE-WIRE THERMOCOUPLES FOR RECORDING TEMPERATURE AND HUMIDITY AT TWO LEVELS NEAR THE GROUND.

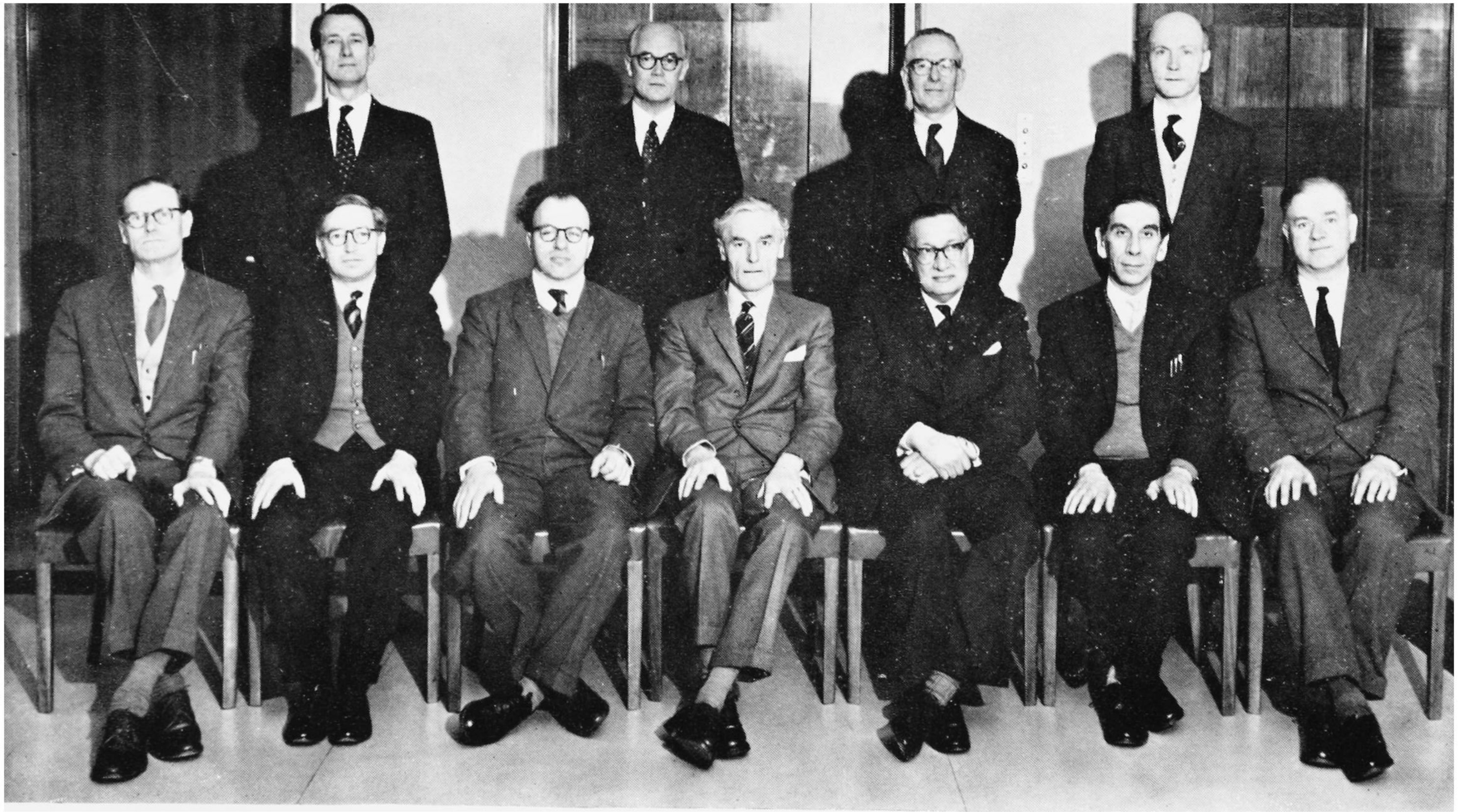
This is used by the unit associated with the School of Agriculture, Cambridge, in studies of the exchange of heat and water vapour between ground and air.



Crown copyright

INVESTIGATION OF ATMOSPHERIC TURBULENCE AND DIFFUSION.

Equipment which telemeters to the ground the speed of the horizontal wind component and the inclination of the wind to the horizontal is fixed to a balloon cable. A drum impactor is being fixed below the anemometer, to sample at intervals the concentration of fluorescent particles which will be released from a source several miles away. In the centre background is the Cardington meteorological laboratory and a second balloon used for experimental purposes.



PRESENT MEMBERS OF THE METEOROLOGICAL RESEARCH COMMITTEE.

Standing: Dr. E. R. R. Holmberg, Dr. R. C. Sutcliffe, C.B., O.B.E., F.R.S., Dr. A. C. Best, C.B.E., Mr. J. K. Bannon (Secretary).
Sitting: Dr. H. L. Penman, F.R.S., Prof. T. V. Davies, Prof. H. Bondi, F.R.S., Prof. P. A. Sheppard (Chairman), Sir Graham Sutton, C.B.E., F.R.S., Prof. V. C. A. Ferraro, Dr. G. E. R. Deacon, C.B.E., F.R.S.

The following members are not in the photograph: Dr. A. W. Brewer, Inst.-Capt. J. A. Burnett, Sqd. Ldr. G. P. Lewis, Mr A. E. Woodward-Nutt, Mr. J. Paton, Prof. Sir Harrie Massey, F.R.S.

Much effort was also devoted to consideration of the budget estimates for the Fourth Financial Period (1964–67). Obviously, it would be inappropriate, to say the least, to disclose details of the Executive Committee's report to Fourth Congress on this subject but one can say that a forward-looking attitude has been taken and that the proposals, if agreed in large measure, will enable WMO to engage in increased activity so that it may fulfil its rôle as laid down in the Convention. It must be obvious to the reader that those concerned in planning activities and budgeting for them for as far ahead as 1966–67 are faced with a difficult task when so many factors can operate to make both these estimates unreal. However, the fact is that the Executive Committee has to make such estimates for a period which ends some 5½ years ahead because of the system of four-year financial periods under which WMO operates.

With the emergence of so many "new" countries, particularly in Africa, the question of meteorological training has become of major importance. WMO asked Prof. J. Van Mieghem, Secretary-General of the International Council for Scientific Unions, to act as a consultant to the Organization and to prepare three reports. These were:

(i) the problems of the professional training of meteorological personnel of all grades in the less-developed countries;

(ii) a plan for the development of professional meteorological training in Africa;

(iii) the establishment of a training section in the WMO Secretariat.

The Committee recognized that two distinct tasks have to be fulfilled by WMO in the field of meteorological training: (*a*) the establishment of training standards to be recommended by WMO—this includes the preparation of syllabi, scrutiny and recommendation of textbooks and technical arrangements for training seminars; (*b*) the preparation and carrying out of training projects financed from UN sources. With regard to the proposal for a training section in the WMO Secretariat, such a section was included in the budget estimates for the Fourth Financial Period and it will consequently be considered in detail by Fourth Congress.

The Technical Committee had fifteen items to consider including the reports of sessions of the Commissions for Aerology, Instruments and Methods of Observation, and Synoptic Meteorology. These reports with their resolutions and recommendations (74 of these latter from the Committee for Synoptic Meteorology (CSM)) were all carefully considered and gave rise to no difficulties except for Recommendation 6 of CSM concerning the units to be used for wind speeds in reports exchanged internationally. As might be expected a battle is now in progress between knots and metres per second, and an overwhelming majority of the delegates at CSM–III voted in favour of the latter. The Executive Committee, realizing that the implications of the recommendation affected other bodies external to the WMO as well as the Commissions for Maritime Meteorology and Aeronautical Meteorology, requested the Secretary-General to refer it for examination by other interested bodies and to report to Fourth Congress with their comments.

Reference has already been made to the excellent facilities provided at the WMO Headquarters, a most attractive building made all the more so by the splendid array of gifts provided by Members, which range from the functional (such as furniture and carpets) to the beautiful (for example, tapestries, vases, wood-cuts, engravings).

Meteorologically, Geneva provided some good extremes of temperature during this visit, day maxima varying from 6°C on 2 June with a strong north-easterly wind to around 26°C on several days later in the month.

REVIEW

The challenge of the atmosphere, by O. G. Sutton. 8½ in. x 5½ in., pp.227, *illus.* Hutchinson and Co. (Publishers) Ltd., 178–202 Great Portland Street, London W.1., 1962. Price: 21*s.*

This is a most excellent book. It is written in a very elementary way that will strongly appeal to anybody with scientific interests. By starting from the most fundamental points, such as the heat balance, and working through the complicated matters of cloud physics to the more detailed matters of weather production etc., the author follows very much the line of thought of a person interested in the intellectual challenge of the field. There is no rushing to get at results, no suggestion that the only aim of meterology is to assist forecasting. It is in the highest scientific tradition to treat a subject for its internal merit. It is because we want to know how the atmosphere behaves and what makes it so complicated that a treatment like this is ideal. The fact that it so happens that to a certain extent this is a useful branch of science must not be stressed at the beginning. If scientific investigations undertaken for their own interest lead to results of practical importance, that is good; but if not, it does not matter either.

By thus following through the natural scientific development, Sir Graham Sutton has written a book which the reviewer, at least, finds as difficult to put down as a very good detective story. The clarity of the exposition, the profound understanding of what is important and what is only incidental, put this book into the very highest class of scientific writing for the non-specialist. However, I would be surprised if there were many meteorologists who could not benefit greatly from reading this book, for even in their superiority they will discover a breadth of outlook and understanding that is always refreshing. H. BONDI

PUBLICATIONS RECEIVED

Glass thermometers (Publication No. T/50/2). 11 in. x 8½ in., pp. 59, *illus.*, Negretti & Zambra Ltd., 122 Regent Street, London W.1, 1962.

Mensteel (mercury-in-steel) thermometers (Publication T.40/3). 11 in. x 8½ in., pp. 40, *illus.*, Negretti & Zambra Ltd., 122 Regent Street, London W.1, 1962.

Meteorological instruments, Part 2—Measurement of atmospheric pressure. (Publication No. M4/IP). 11 in. x 8½ in., pp. 28, *illus.*, Negretti & Zambra Ltd., 122 Regent Street, London W.1, 1962.

OBITUARY

Mr. Roger Miles Lane.— It was with deep regret that we learned of the death on 9 September 1962, in a road accident, of Mr. R. M. Lane, Scientific Assistant, at the early age of 28. Mr. Lane joined the Office in August 1957 at Headquarters, Transport Command, serving there until July 1961, when he moved to Headquarters at Bracknell. He served in various branches there and had been moved to the Special Investigations Branch only three weeks before his death.

Our deepest sympathy is extended to his parents.