METEOROLOGICAL OFFICE

ANNUAL REPORT 1966

HMSO: 8s. 0d.

Met.O.791

ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE

1966

Presented by the Director-General
to the
Secretary of State for Defence

LONDON
HER MAJESTY'S STATIONERY OFFICE
1967

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FOREWORD BY THE DIRECTOR-GENERAL

A busy and eventful year has seen many changes within the Meteorological Office and the initiation of several important plans for the future.

There was an unusual amount of Parliamentary interest in the Office during the year. The Estimates Committee examined meteorological services, and Sub-Committee G visited the Headquarters at Bracknell and the meteorological office at Heathrow. A party from both Houses was invited to visit the Headquarters in October, and other Members of Parliament made individual visits. The number of Parliamentary questions about the Office was considerably higher than in previous years.

We were all greatly encouraged by the favourable report by the Estimates Committee. The Committee was generous in its praise of our efficiency and the quality of our services, but thought that we might do more to make industry aware of the economic value of meteorological advice. We are already doing a great deal. The number of inquiries received from industry and the general public rose during the year to a record total of 1·2 million, while the number of forecasts for aviation also increased to about 1·28 million. Meanwhile the results of cost/benefit studies on the economic value of our current services to industries such as aviation, agriculture, public utilities and construction have received wide publicity and are bound to produce a further increase in demand. In particular, our offer to provide large construction sites with a tailor-made weather service has received an enthusiastic response from the building industry and a pilot scheme is now being prepared. I am convinced that this kind of service can save the major weather-sensitive industries many millions of pounds each year. We are also exploring new ways of coping with the rising tide of inquiries from the general public including the more effective use of radio, television and the automatic telephone weather service.

A review of the functions and structure of the Office revealed the need for a number of changes in the Headquarters organization to produce a more functional structure better suited to current conditions in a period of rapid technological change. Most of the changes, which came into effect on 1 November 1966 and are described in more detail on p. 6, occurred in the Services Directorate where the duties of the two Deputy Directors were redefined to make one responsible for all the forecasting services, and the other responsible for data services and climatology. The revised structure includes a new Branch for Hydrometeorology and a long-range planning unit. Free of day-to-day problems, the latter will be able to consider medium- and long-range developments likely to affect the Office as a whole and incorporate them into a long-term operational plan.

As the first stage of what I hope will be a major expansion of our research effort, a Cloud Physics Branch has been established. This comprises a laboratory physics group (resulting from the transfer of my former department at the Imperial College), a cloud dynamics group, and the radar unit already based at the Royal Radar Establishment, Malvern. The new branch should be able to study clouds and precipitation on a broader scale than was possible in a university department and further enhance the British reputation in this field. However, much will depend upon the Meteorological Research Flight's being equipped with new aircraft, for this will be a key factor in the whole research programme.

The production of routine numerical weather forecasts has made remarkable progress; every day the computer calculates and prints more than 400 charts forecasting weather conditions for up to 48 hours ahead over a large part of the northern hemisphere, both for the surface and for several levels up to 40,000 feet. After receiving these charts for less than a year, the Central Forecasting Office ceased to draw upper-air forecast charts by hand and now relies entirely on the computer product. These operational computed charts portray only the broad features of the temperature, pressure and wind fields; they do not attempt to deal with the smaller-scale motions that are associated with areas of rain, which are often only 50–100 miles across and which constitute one of the most important and difficult problems in weather forecasting. However, recent research in the Forecasting Research Branch has made an important advance towards the solution of this problem and gives us a real lead in this field. This new work makes use of a much more sophisticated mathematical model of the atmosphere which takes into account the presence of water vapour in the air and predicts the pressure, temperature, wind and rainfall at hundreds of places about 25 miles apart. The results so far are most encouraging, showing quite good agreement between the predicted and actual rainfall; but since it takes eight hours of calculation on the ATLAS computer to produce a forecast for 24 hours ahead, a computer some 30 times faster than ATLAS will be required to produce a forecast in time to be of value.

Another important event in weather forecasting occurred in February with the regular direct reception of pictures from the operational weather satellites launched by the United States. Excellent pictures, showing very clearly and in detail the organization and structure of cloud systems over the eastern Atlantic, Europe and the Mediterranean are now received daily at Bracknell and have already, on several occasions, led to a much improved analysis and forecast.

On the international plane, much thought has been given to the World Weather Watch and to formulating detailed proposals for the part which the United Kingdom might play in this important project which, if adopted by the Member States of the World Meteorological Organization next April, will have profound and far-reaching consequences for the science and practice of meteorology everywhere.

Turning now to more domestic problems, the most pressing is the shortage of accommodation at Bracknell. As the Estimates Committee reported, the present Headquarters building, although occupied only five years ago, is already overcrowded and quite inadequate for our present and future needs. In the long term we hope to have a new building on the present Headquarters site, but the room for expansion is limited. We are therefore preparing plans for the erection of a major laboratory building at our experimental site, three miles from the present Headquarters. We aim to concentrate most of the Headquarters eventually at these two sites. In the meanwhile we have to face the prospect of greater dispersal of offices and laboratories over several sites in the Bracknell area to the detriment of the unity and the efficiency of the

Headquarters. However, by acquiring premises to be vacated by the Atomic Energy Authority in July 1967 we shall be able to concentrate our stores in two buildings in Bracknell instead of having stores dispersed in Bracknell, Hendon and Hayes. I am also pleased to report that, at last, satisfactory accommodation has been found for the main Training School which will move from Stanmore to Shinfield Park (near Reading) after the RAF has left that site at about the end of 1968.

A conscious attempt to bring the Office into closer contact with the universities has resulted in many requests for lectures by members of the Office and also an unprecedented number of visits from university staff and students. The recent recruitment of an unusual number of talented young research scientists, including the appointment of five new Research Fellows, augurs well for our expanding research programme but there may be difficulties in finding the necessary supporting staff. The Office is particularly short of experimental officers trained in experimental physics, electronics, computing, etc. and will need to recruit these on a much larger scale over the next few years. The sharp increase in the resignation rate of scientific assistants causes serious concern, and the reasons are being investigated as a matter of urgency. There is now a shortfall of approximately 130 assistants, or 10 per cent of the establishment, and a solution will have to be found if we are to avoid a critical situation.

To end on an optimistic note, I am convinced that meteorology is entering a new era of unprecedented challenge and opportunity, and the Meteorological Office looks forward to being in the very forefront of these new developments.

B. J. MASON

January 1967
Meteorological Office,
Bracknell, Berks.

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APPENDICES

FUNCTIONS OF THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Air Force Department of the Ministry of Defence. The Director-General is responsible to the Secretary of State for Defence through the Minister of Defence (RAF) and the Second Permanent Under Secretary of State (RAF).

The general functions of the Meteorological Office are:

(i) Provision of meteorological services for the Army, Royal Air Force, Civil Aviation, the Merchant Navy and Fishing Fleets.

(ii) Liaison with the Naval Weather Service of the Navy Department and provision of basic meteorological information for use by that Service.

(iii) Meteorological services to other Government Departments, public corporations, local authorities, the Press, industry and the general public.

(iv) Organization of meteorological observations in Great Britain and Northern Ireland, and at certain stations overseas.

(v) Collection, distribution and publication of meteorological information from all parts of the world.

(vi) Maintenance of certain British observatories, and publication and distribution of geomagnetic and seismological information obtained from them.

(vii) Research in meteorology and geophysics.

The Meteorological Office also takes a leading part in international co-operation in meteorology. The Director-General is the Permanent Representative of the United Kingdom with the World Meteorological Organization.

Except for the common services provided by other Government Departments as part of their normal function (e.g. accommodation by the Ministry of Public Building and Works; stationery by Her Majesty's Stationery Office) the cost of the Meteorological Office is borne by Defence Votes.

The gross annual expenditure by the Exchequer for the Meteorological Office, including that on the common services, is of the order of £7,000,000. Of the amount chargeable to Defence (Air) Votes, about £5,300,000 represents expenditure associated with staff and £1,600,000 expenditure on stores, communications and miscellaneous services. Some £1,700,000 is recovered from other Government Departments and outside bodies in respect of special services rendered, sales of meteorological equipment, etc.

METEOROLOGICAL COMMITTEE

Terms of reference:

(*a*) to keep under review the progress and efficiency of the Meteorological Service and the broad lines of its current and future policy;

(*b*) to keep under review the general scale of effort and expenditure devoted to the meteorological services;

(*c*) to ensure the maintenance of adequate contacts between the Meteorological Service and those who use its services.

The membership of the Committee was:

Chairman:	The Lord Hurcomb, G.C.B., K.B.E.
Members:	Mr S. Earl
	Colonel A. Raymond Mais, O.B.E., T.D.
	Professor J. P. Hudson, M.B.E., G.M.
	Professor P. A. Sheppard, C.B.E., F.R.S. (Chairman, Meteorological Research Committee) (*ex officio*)
Secretary:	Mr B. M. Day (Secretary, Meteorological Office)

The Committee met three times in 1966.

ADVISORY COMMITTEE ON METEOROLOGY FOR SCOTLAND

Terms of reference:

(*a*) to review the development of meteorological science and its application to Scotland;

(*b*) to submit to the Meteorological Committee any proposals in connexion therewith.

The membership of the Committee was:

Chairman:	Dr B. J. Mason, F.R.S. (Director-General, Meteorological Office)
Members:	Professor J. N. Black, F.R.S.E. (University of Edinburgh)
	Dr S. C. Curran, F.R.S. (Royal Society)
	Mr J. B. Dempster (Scottish Development Department)
	Mr W. O. Kinghorn (Department of Agriculture and Fisheries for Scotland)
	Mr J. Paton, F.R.S.E. (Royal Society of Edinburgh)
	Professor P. A. Sheppard, C.B.E., F.R.S. (Royal Meteorological Society)
	Dr J. Steele (Department of Agriculture and Fisheries for Scotland)
	Dr R. W. H. Stevenson (University of Aberdeen)
	Professor D. W. N. Stibbs, F.R.S.E. (University of St Andrews)
	Professor P. A. Sweet (University of Glasgow)
Secretary:	Mr R. Cranna (Meteorological Office)

The Committee met on 17 May 1966

METEOROLOGICAL RESEARCH COMMITTEE

Terms of reference:

The Meteorological Research Committee will advise the Minister of Defence for the Royal Air Force on the general lines along which meteorological and geophysical research should be developed within the Meteorological Office and encouraged externally. It shall review progress and report annually.

It is empowered to appoint sub-committees, one of which shall be responsible for advising on the usage of monies allocated annually from Air Votes for research projects conducted outside the Meteorological Office. The Committee will be responsible for co-ordinating the work of its sub-committees.

The membership of the Committee was:

Chairman: Professor P. A. Sheppard, C.B.E., F.R.S.

Members: Professor R. L. F. Boyd

Instructor Captain G. P. Britton, R.N. (Director, Meteorology and Oceanographic Services (Navy))

Wing Commander P. H. J. Buddery, M.B.E. (Air Force Department)

Professor D. R. Davies

Dr G. E. R. Deacon, C.B.E., F.R.S.

Dr E. R. R. Holmberg (Army Department)

Dr B. J. Mason, F.R.S. (Director-General, Meteorological Office)

Mr P. J. Meade, O.B.E. (Director of Services, Meteorological Office)

Mr D. E. Morris (Ministry of Technology)

Mr J. Paton, F.R.S.E.

Mr J. S. Sawyer, F.R.S. (Director of Research, Meteorological Office)

Professor R. C. Sutcliffe, C.B., O.B.E., F.R.S.

Secretary: Mr F. E. Dinsdale (Meteorological Office)

The Committee met twice in 1966 and its sub-committees seven times.

Note: On pp. viii to xii the membership of committees, the Meteorological Office Headquarters Organization, and the list of Principal Officers are as at 31 December 1966.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

B. J. Mason, D.Sc., F.R.S.

DEPUTY TO DIRECTOR-GENERAL

P. J. Meade, O.B.E., B.Sc., A.R.C.S.

DIRECTORATE OF RESEARCH

DIRECTOR	J. S. Sawyer, M.A., F.R.S.

PHYSICAL RESEARCH

DEPUTY DIRECTOR	G. D. Robinson, Ph.D., F.Inst.P.
SPECIAL POST	F. Pasquill, D.Sc.
Meteorological Research Flight	C. J. M. Aanensen, M.Sc.
OBSERVATORIES AND MICROMETEOROLOGY	
Assistant Director	L. Jacobs, M.A., M.Sc.
CLOUD PHYSICS	
Assistant Director	*Vacant*
HIGH ATMOSPHERE	
Assistant Director	R. Frith, O.B.E., Ph.D.
Special Post	K. H. Stewart, Ph.D.

DYNAMICAL RESEARCH

DEPUTY DIRECTOR	E. Knighting, B.Sc.
SPECIAL INVESTIGATIONS	
Assistant Director	R. F. Jones, B.A.
FORECASTING RESEARCH	
Assistant Director	F. H. Bushby, B.Sc. A.R.C.S.
SYNOPTIC CLIMATOLOGY	
Assistant Director	R. A. S. Ratcliffe, M.A.
Special Post	J. M. Craddock, M.A.
Special Post	H. H. Lamb, M.A.
PUBLICATIONS AND TRAINING	
Assistant Director	C. J. Boyden, B.A.
DYNAMICAL CLIMATOLOGY	
Assistant Director	G. A. Corby, B.Sc.
Special Post	R. J. Murgatroyd, O.B.E., Ph.D. A.M.I.E.E.

DIRECTORATE OF SERVICES

DIRECTOR	P. J. Meade, O.B.E., B.Sc., A.R.C.S.

FORECASTING SERVICES

DEPUTY DIRECTOR	V. R. Coles, M.Sc.
CENTRAL FORECASTING	
Assistant Director	R. F. Zobel, O.B.E., B.Sc.
Chief Forecasting Adviser	T. H. Kirk, B.Sc.
TELECOMMUNICATIONS	
Assistant Director	A. A. Worthington, B.Sc.
DEFENCE SERVICES	
Assistant Director	T.N.S. Harrower, M.A., B.Sc.
H Q Bomber Command	S. E. Virgo, M.Sc.
PUBLIC SERVICES	
Assistant Director	J. K. Bannon, B.A.
London (Heathrow) Airport	M. H. Freeman, O.B.E., M.Sc.

OBSERVATIONAL SERVICES

DEPUTY DIRECTOR	R. H. Clements, M.A.
MARINE BRANCH	
Marine Superintendent	C. E. N. Frankcom, O.B.E., R.D. Commander R.N.R. (retd)
CLIMATOLOGICAL SERVICES	
Assistant Director	A. G. Forsdyke, Ph.D., A.R.C.S.
AGRICULTURE AND HYDROMETEOROLOGY	
Assistant Director	J. Harding, B.A., M.Sc.
Special Post	L. P. Smith, B.A.
DATA PROCESSING	
Assistant Director	N. Bradbury, B.Sc.
INSTRUMENTS AND OBSERVATIONS	
Assistant Director	A. L. Maidens, B.Sc.

INTERNATIONAL AND PLANNING	
Assistant Director	C. W. G. Daking, I.S.O., B.Sc.

SECRETARY, METEOROLOGICAL OFFICE B. M. Day, B.Sc. (Econ.)

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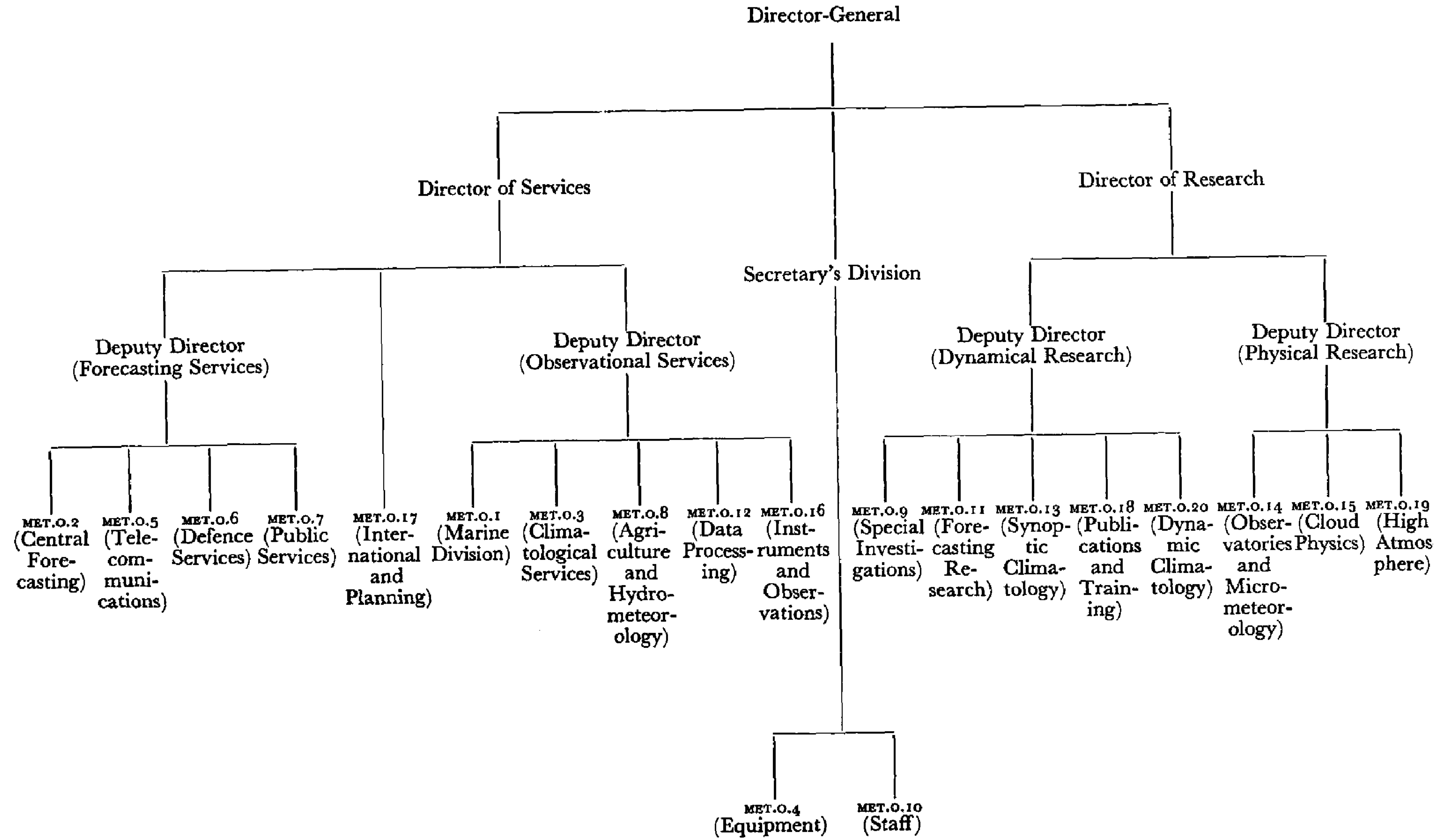
METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION



THE DIRECTORATE OF SERVICES

Special Topic—Agricultural Meteorology in the Meteorological Office

The application of meteorology to the problems of agriculture, horticulture and forestry formed part of the post-war reorganization of the Meteorological Office. In 1947 there existed a small headquarters unit at Harrow plus one field officer who was attached to the regional centre of the newly formed National Agricultural Advisory Service (NAAS) at Bristol. Since that time the number of agro-meteorologists has gradually increased and now officers are also stationed with the NAAS at Leeds and Cambridge, and one at Edinburgh has responsibilities for Scotland and Northern Ireland.

From experience gained in aviation meteorology it was realized from the start that efficient service demanded the closest liaison with agriculturists, and it was for this reason that the outstation staff were attached to the advisory centres of the Ministry of Agriculture, so that they could work in a suitable scientific environment. The contacts of the meteorologists, however, were not confined to the advisory service alone, and every opportunity was taken to visit research stations of the Agriculture Research Council, experimental farms and stations of the Ministry, university faculties, and national and county training colleges and institutes.

This policy has been amply justified by the results. It is probably true to say that there are very few other countries in the world where there is such close personal collaboration between meteorological and agricultural scientists. As a consequence the meteorologist is available as a consultant in a very wide variety of problems, and he can also actively co-operate in current research and experimental work. In a dual subject such as agricultural meteorology, it is very difficult for any one scientist to attain adequate knowledge of both sides of the problem. Mutual personal help is therefore the only practical solution, and almost all the advances made by the agro-meteorologists have been a result of a combined attack. Even on occasions when direct help was impossible, the role of the meteorologist as a catalyst, or pollinator of ideas in the realm of agricultural science, is not to be underestimated.

From the beginning, there was no shortage of problems requiring solution. With limited time, staff and money it was essential that a sensible programme of work should be planned. Two principles were adopted, one that the problem chosen should show promising signs of relatively early solution, and secondly, that the solution should possess an immediate practical value to agriculture. In other words, the agro-meteorologist aimed at carrying out field and operational research in collaboration with the agronomists in order to provide a service of economic value. In this process the maximum use was to be made of existing facilities, from the meteorological observing network as a source of data to the advisory channels of the Ministry of Agriculture as a means of communication to the farmer or grower.

One of the first subjects to which attention was given was that of evaporation and transpiration and their implications in regard to irrigation needs. It was decided to make use of the methods due to Dr H. L. Penman of Rothamsted by which these factors could be calculated from meteorological data—a decision which has been fully justified by subsequent events; this method has since been recognized internationally as the most helpful practical approach to the basic problem of water balance and has consistently given results of acceptable accuracy. The United Kingdom was probably the first country in the world which published (in 1954) data of calculated transpiration in a form in which it could be used for irrigation planning, experiment and practice. It is a testimony to the soundness of this publication that it passed through six reprints before it was found necessary in 1966 to rewrite and recast the information. This revision is being done in conjunction with Rothamsted Experimental Station and the Ministry of Agriculture, Fisheries and Food, and in most of the United Kingdom (and especially in the drier areas) differences in the assessments of transpiration will be small enough to make changes in recommended irrigation needs almost negligible.

This was by no means the only example of how co-operation between the agricultural research stations and the Meteorological Office gave rise to practical results of the greatest importance. Questions of frost incidence and the effect of shelter from the wind were two other obvious opportunities for the application of meteorological knowledge and experience to agricultural problems. Many times a year specific problems of this nature arise, the requests for advice usually having been channelled through the National Agricultural Advisory Service. A typical request would be raised by a farmer interested in growing fruit on land sloping down to a valley. He would recognize the increased risk of frost damage near the bottom of the valley, the recipient area of katabatic flow, and his concern would be to find out how far down the slope he could plant his fruit before the frost risk became unacceptably high. To answer this question, a frost experiment would be mounted, with minimum thermometers at a height of 4 ft exposed in special mounts ('cocoa'-tins—see Plate VIII) placed at several carefully selected positions on the land. The farmer undertakes to ensure that accurate readings are taken regularly and conscientiously each morning of all temperatures throughout the late frost period of April and May. Subsequent comparison by the meteorologist of these figures with those of a nearby standard long-term station enables a frost risk (years in ten after specific dates) to be given for each position. An unusually elaborate experiment of this nature has already been in progress for three years at Thetford Chase in conjunction with the Forestry Commission to determine factors involved in the loss of freshly planted Corsican pine saplings in the early sixties. This experiment is continuing, but already suggestions have been put forward regarding the best shape of clearances for planting out and the optimum types of ground cover. The saplings which were planted out over grass showed considerable stunting due solely to frosting but those planted out over bare soil grew more vigorously. In the realm of shelter, much has been done experimentally in exposed parts of Wales and Scotland in collaboration with the universities and in the West Country with the Ministry of Agriculture, Fisheries and Food; in the light of knowledge gained, the very exposed horticultural lands in the Isles of Scilly are to be planted out for shelter according to suggestions put forward by the Office.

Another realm of fruitful co-operation over the years lay in the effect of weather on the incidence of plant disease. Work in conjunction with the Plant Pathology Laboratory at Harpenden began at an early stage and the network of reporting stations of the Meteorological Office was found to be of the greatest value in the prediction of the incidence of diseases such as potato blight and apple scab. The basis of the solution to both the blight and scab problems lay in the definition of temperature and wetness, and after study of the progress of the disease in relation to these factors, formulae were derived which related the vulnerable period (be it hours or days) to the continuance in particular areas of temperatures above certain levels in association with specified values of relative humidity. The problem having been reduced to a practical operational process, relevant meteorological information from the meteorological reporting stations is passed to the pathologists who then issue the appropriate advice through their own channels; no plant disease forecast is, in fact, issued by the Meteorological Office.

The establishment of any such weather-based warning system demands co-operative research by both agro-meteorologists and pathologists lasting several years; only one testing experiment can be done per year, and the progress from field research to an established service of proved value is perforce slow. Work is now in progress concerning other significant diseases and one of the most important advances concerns the use of air trajectories to determine the movement of spores such as those of the cereal rusts. Maps of upper air pressures and winds, hitherto of use only for forecasting purposes, are being found invaluable for examining the spread of disease. Valuable work has been possible here, in which the disciplines of agricultural physics (Rothamsted) and agricultural meteorology have combined to make use of spore and pollen information obtained as a bonus by flights performed by the Meteorological Research Flight. Such flights have made possible a number of elaborate cross-sections of spore counts over long tracks over the North Sea in varying weather conditions, and much is being added to knowledge of the factors involved in such long-distance aerial transport of spores and pollens. Similar techniques are used to track the movement of insects and a whole new field of meteorological-biological collaboration is being opened up by the investigation of such phenomena. Again, it is not unfair to say that British meteorologists were among the first in the world to use such techniques.

Problems of animal disease have not been neglected. Co-operation with the Veterinary Laboratory at Weybridge has led to logical practical links being established between weather and subsequent disease epidemics. Work first began a little under ten years ago in relation to liver fluke, a disease which depends on the length of time for which grass pastures are wet during the summer. The fluke life-cycle over the year is a complicated one, but an important feature is the need for the fluke after hatching in summer to spend part of its life within a snail; the current weather is important both in the development of eggs after hatching and in the dependence of the snail population on continued but not excessive wetness, and the extent of surface moisture in summer at the critical time can determine the intensity of the threat of an outbreak of liver fluke. Advice on 'wetness' to the Veterinary Laboratory enables a decision to be made on the warning to be given on drenching, and on the use of molluscicides. Transpiration data, prepared for irrigation purposes, were found to be a great help in enabling a meteorological assessment of risk to be made and over years of trial a system of reliable forecasting has been built up. Other diseases of animals are being examined in similar fashion and the results are proving the worth of this dual approach. Perhaps the most unusual and helpful factor in such work is that forecasts of future disease outbreaks can be made, by relying solely on past weather, in time for preventive action to be taken. As experience refines the methods used and increases the confidence in their accuracy, the effect on annual national production can be valued in tens of millions of pounds.

Agricultural meteorology does not only confine itself to the weather and climate of the open field. Questions of the internal climate under glass were examined at an early stage, and recently considerable attention has been paid to the climate of buildings used by pigs, cattle and poultry as well as problems of storage conditions. In such work, the meteorologist's knowledge of the external conditions plus his ability as a physicist to investigate the problems of heat loss, ventilation and similar critical factors enable him to give considerable help in a relatively unexplored subject. Practical work has been done in many animal houses and stores using varying equipment including smoke candles and radioactive tracers. The basic problem has been to determine the air flow within such houses, and to assess changes in the heat and humidity of the air in its passage through them.

One of the original questions posed to the agro-meteorologists was that of the effect of weather on crop yields. This was at first put aside as being too difficult to answer, but in later years a return was made to the problem. Considerable advances were made in relation to grass yields, and more recently work has been done on the influence of climate on barley and hops in regard to both quantity and quality. Furthermore, in conjunction with the Milk Marketing Board, the effect of weather on milk yields was examined in the hope of improving the accuracy of milk production forecasts; results are very promising.

As more and more information becomes available concerning agro-meteorological relationships, it becomes more practicable to place agro-climatology on a sound footing. When this is achieved, the planning of future land use, the choice of farming type and choice of crop can be placed on a sound scientific basis without resorting to the old methods of trial and error. Over several years the Meteorological Office has joined with the Ministry of Agriculture, Fisheries and Food in surveying the counties of Britain in relation to their potential horticultural use.

Much of the work in agricultural meteorology is initially circulated in a series of memoranda to collaborators and associated workers. By this means a rapid circulation of new ideas is assured and new hypotheses can be discussed among experts with the minimum of delay. Over 170 such memoranda on a large variety of subjects have been produced and almost half of these have subsequently been published in scientific journals or trade journals. Assistance has been given to the Ministry of Agriculture, Fisheries and Food in the production of several of their Bulletins, thus making use of the most efficient means of communication to the farming community. The Basic Study No. 1 of the Freedom from Hunger campaign of the United Nations Food and Agriculture Organization, was entitled 'Weather and Food'. It was written by Mr L. P. Smith of the Meteorological Office and published by the World Meteorological Organization.

The contribution of Britain to international agricultural meteorology has maintained the highest traditions. Mr L. P. Smith is the President of the Commission for Agricultural Meteorology of the World Meteorological Organization, and another member of the staff has recently returned from a technical assistance assignment in Turkey. Others have acted as chairmen and members of working groups which have provided Technical Notes which are of great use in every country. A recent UNESCO symposium, held at Reading University on the subject of methods in agro-climatology, was under the technical direction of a member of the Office.

The future of agricultural meteorology, both nationally and internationally is clearly of the highest importance in a world of ever-increasing population. Weather and climate are critical factors in food production, and unless every opportunity is taken to increase our knowledge of the interrelationships it may be impossible to ward off the spectre of increased malnutrition and starvation.

If agricultural meteorology is to be of more use in the distant future, progress must be made in the fundamentals of the science, and basic research must be intensified. Nevertheless it would be unwise to expect rapid advancement in a very complex problem towards a greater knowledge of absolute truth. Major discoveries are few and far between, a state of affairs which is no reflection on the scientists concerned but merely a reflection of the difficulties involved.

The most immediate need is for practical solutions at an acceptable, though imperfect level. Time is short, very short indeed, and if scientifically trained brains can help to increase the efficiency of the use of natural resources, it is literally vital that they should do so. There is not a single aspect of agriculture, horticulture or forestry which remains unaffected by the environment. At present the farmers of the world cope with their weather problems largely in the light of their own past experience and the customs of their forefathers. Science is coming more and more to their aid, but the process must be accelerated. Agriculturists in the more advanced countries are generally more successful and more efficient partly because of the inherited benefit of the past but also because of determined effort in applied research.

This state of affairs emphasizes the need for an expanded programme of technical education and for better systems of communication between the applied scientist and the primary production worker. This need has always been recognized in Britain, and throughout the years many lectures have been given by meteorologists at universities, schools and societies. The results and implications of work in agricultural meteorology have been published not only in scientific journals, but also in the technical press, which reaches a far greater circle of readers.

As has been previously stated, there is no lack of problems and their solution does not necessarily involve a large outlay of money on expensive equipment. The first essential is a number of scientists who have adequate experience and ability in meteorology and also the aptitude for applying such talents in agriculture. The United Kingdom is fortunate in that there is ample opportunity for such men to collaborate with scientists of other disciplines.

Although agricultural meteorology in the British Isles is primarily engaged in solving the problems peculiar to the climate and crops of the country, the principles it employs and the methods it uses are not without importance in solving similar problems in other parts of the world. In this way it may be regarded as an example of the way in which science can become the servant of humanity.

ORGANIZATION OF THE SERVICES DIRECTORATE

During the year a detailed review of the organization of the Services Directorate was carried out and, as a result, it was decided to change the structure to one that would be more functional, and sufficiently flexible to make full use of the most modern facilities. The incorporation of the high-speed computer into routine forecasting, the introduction of weather satellites, the need to exploit new advances in telecommunications, and the prospects of using completely automatic methods of observation, data collection and processing are leading to changes in operational methods and to greater centralization of forecasting services. In addition it is necessary to look forward to new developments in connexion with the World Weather Watch and to be responsive to the increasing and technically more exacting demands for weather services.

The new organization came into force on 1 November. The functions of the two Deputy Directors were changed so that one, D.D.Met.O.(F), became responsible for all forecasting services and their telecommunication facilities; the other, D.D.Met.O.(O), became responsible for observations and associated techniques and procedures, data processing and applications in climatology and similar fields.

At the same time the existing branches of the Directorate were reconstituted in varying degree and the Instrument Development Branch, Met.O.16, was transferred from the Research to the Services Directorate and given additional responsibilities in connexion with observational techniques and the servicing of equipment. Other major changes are briefly discussed below:

(i) The progress made in the operational use of computed forecast charts rendered advisable the incorporation into Met.O.2, the Central Forecasting Office (CFO), of that part of the Forecasting Techniques branch, Met.O.8, which was responsible for the development of computer programmes for routine forecasting. The remaining section of Met.O.8, concerned with smaller-scale forecasting problems, principally for outstations, was transferred to the Research Directorate for close alignment with the training organization.

(ii) The redistribution in the manner described above of the work on forecasting techniques made practicable the allocation to Met.O.8 of responsibilities for agriculture and hydrometeorology, fields in which the work is expanding and is of high economic importance.

(iii) Services for the Defence forces and the associated planning for the various Treaty Organizations, previously carried out in three different branches, were brought together into one branch, Met.O.6, which was made responsible for Defence Services. This change permitted the consolidation into one branch, Met.O.7, of forecasting responsibilities for the public sector—industry, commerce, civil aviation and the general public.

(iv) In order to permit Met.O.5 to concentrate mainly on telecommunications, in which large-scale developments are being planned, responsibilities for upper air stations and for the Regional Servicing Organization were assigned to Met.O.16, the Instrument Development Branch transferred from the Research Directorate.

(v) On the formation of the new Met. O.8, the rainfall work was removed from Met.O.3, Climatological Services, and this branch, which had become overloaded with too wide an area of responsibility, was enabled to concern itself with land surface, marine and upper air climatology.

(vi) By the removal of certain defence responsibilities from Met.O.17 to the reconstituted Met.O.6, it became possible to make provision, within Met.O.17, for a section to undertake long-term planning and organization studies, e.g. overall planning for the country's role in World Weather Watch, studies on integrating and streamlining various facets of the whole organization, and investigations into the value of meteorological services to various users.

As already stated, the functions of the two Deputy Directors were changed in the reorganization. The Deputy Director in charge of Forecasting Services, D.D.Met.O.(F), took control of Met.O.2 (Central Forecasting Office), Met.O.6 (Defence Services), Met.O.7 (Public Services) and Met.O.5 (Telecommunications). D.D.Met.O.(O), responsible for observations and associated services, was placed in charge of Met.O.1 (Marine Branch), Met.O.3 (Climatological Services), Met.O.8 (Agriculture and Hydrometeorology), Met.O.12 (Data Processing) and Met.O.16 (Instruments and Observations). The branch Met.O.17 (International and Planning) reports direct to the Director of Services in his capacity as Deputy to the Director-General.

The reorganization, besides giving greater scope where this was needed, involved a major regrouping of functions. That implementation proceeded quickly and smoothly is a tribute to the staff, who showed great adaptability in dealing with the many practical problems that arose.

Forecasting Services

Central Forecasting Office. The Central Forecasting Office (CFO) has three primary forecasting objectives. The first of these is the provision of guidance for outstations, mainly by means of charts depicting actual and forecast synoptic conditions, augmented by advisory texts covering the next 2–3 days.

Secondly, CFO is responsible for the notification of expected specified weather such as fine spells or warnings of hazardous conditions together with routine forecasts for sea and land areas. The forecasts are mainly intended for dissemination by the Press, broadcasting and television, but some are issued direct to public utilities such as the Central Electricity Generating Board and to industry. The hazardous conditions for which warnings are issued include gales for land and sea areas, fog, snow, icy roads, thunderstorms, frost, thaw and strong upper winds. CFO is also the co-ordinating authority for the issue on the BBC Light Programme of 'FLASH' messages which warn the public of the occurrence of weather conditions likely to cause serious inconvenience to a large number of people.

Thirdly, CFO is a Master Analysis Centre as designated by the World Meteorological Organization. It fulfils this role by the preparation for wireless-telegraphy and radio-facsimile transmission of series of actual and forecast charts covering a large area of the North Atlantic Ocean, Europe and the Arctic.

During the year a much increased reliance has been placed on numerically computed forecasts. All upper air forecast charts for the levels of 700, 500, 300 and 200 mb are now issued from CFO as produced by the computer at intervals of 12 hours. This has permitted the issue to outstations of series of forecast upper air charts having a validity period of 18 hours, in addition to those for 24 hours. These charts are just copies of the computed charts, but the upper air charts of actual conditions continue to be drawn by the forecaster. There are several reasons for this. The objective analysis produced by the computer prior to embarking on the forecasting programme needs to be checked for accuracy against a conventionally drawn analysis. Such analyses have the advantage of being more accurate in matters of detail and they also serve as a plotted record of upper wind conditions. The forecaster is also continuing to predict the 100 mb contour field as this level is not at present taken into consideration by the forecasting programme. Special arrangements have been made to cover the possibility of computer breakdown.

A further innovation during the year has been the use of a new meteorological tool which has become available in the form of cloud pictures (see Plate V) received from the automatic picture transmission (APT) of two United States weather satellites which were launched in 1966. Daily reception at Bracknell of up to about 25 such pictures gives the distribution of clouds over an area extending from eastern Europe to the western Atlantic and from north Africa to well into the Arctic. These pictures provide cloud information which supplements in a most valuable manner the data obtained from the conventional reporting networks. Frequently the cloud pictures have made a decisive contribution to the analysis of frontal systems and forecasters have come to regard this new facility as almost indispensable for the preparation of forecasts of high accuracy.

Charts of ice conditions and sea isotherms, formerly prepared in Met.O.1, are now being prepared in CFO. These charts are broadcast to a regular schedule by radio-facsimile and they are of great value to shipping and to other national meteorological services.

A senior officer was appointed to the new post of Chief Forecasting Adviser during the year and he now advises on the whole of the technical work of CFO as well as undertaking studies of forecasting accuracy and the development of new analytical and forecasting techniques.

The Central Forecasting Office continues to be responsible for the publication of the *Daily Weather Report* with its *Overseas Supplement* and *Monthly Summary*, and the *Daily Aerological Record.*

During the year electric typewriters were installed and the programming of the COMET computer to select and edit the required observations for the typewriters was completed and fully tested in anticipation of operational working as from 1 January 1967.

The computer programming element continues to provide direct support for the work of CFO and of certain major outstations, notably London (Heathrow) Airport and Headquarters, Bomber Command, Royal Air Force. At the beginning of the year the quality of the computed forecasts was marred by rather systematic errors in the predicted level of pressure. This effect regularly produced a considerable loss of pressure in the computed predictions over a large part of the chart which included the British Isles and western Europe. This error has now been much reduced and the computed surface forecast chart now provides valuable guidance to the human forecaster for periods up to 48 hours ahead. At upper levels of the atmosphere there is evidence that the numerically produced forecasts are exceeding in accuracy those hitherto produced by conventional methods. The fact that CFO has been able to fulfil one of its major roles by the use of computed charts is due to the successful application during the year of statistical methods. Direct forecasts are at present produced by the computer for three levels only and statistically based programmes have successfully been written to derive automatically forecasts for the required levels of 700 and 300 mb (10,000 and 30,000 ft). These include forecasts of winds and temperatures in forms particularly suitable for application to aviation, as well as contour charts which are printed out in pattern form to minimize the labour required for their finished drawing.

Further extensions to the numerical analysis and forecast procedures are in hand.

Services for the general public. Forecasting services for the public—including industry, commerce, and the utilities—are provided directly from the various forecasting offices or indirectly through many different channels of communication, e.g. the BBC, ITV, the national and provincial Press, and the GPO automatic telephone weather service. The demands for weather information have continued to increase, the total inquiries for the year reaching 1,204,921, a rise of 4 per cent on the figures for 1965.

Personal presentations of forecasts by 'Weathermen' on BBC sound and television programmes were increased in number. Ten 'live' broadcasts were made daily on the various BBC radio channels and as from October the 'Weatherman' appeared three times daily on BBC 1 television. Forecasts for the weekend were also included each Friday in Scottish Television's magazine programme and, during the summer, in the BBC's South East Region radio programme. The latter took the form of a recorded interview with the 'Weatherman' and was broadcast each Friday evening about three hours after the recording. Facilities for the weathermen at the BBC's television centre at Shepherds Bush were greatly improved and facsimile equipment installed to ensure that the latest developments are known there without delay. Close liaison continued with the independent television companies and efforts were made to ensure that the various companies were at all times broadcasting up-to-date forecasts.

Special broadcasts were made on various BBC sound channels dealing with different aspects of meteorology and its applications. Considerable assistance was given to television companies for filming at Bracknell, at London Weather Centre and elsewhere, and even at sea on an Ocean Weather Ship. Special reference in this connexion should be made to the BBC's television series 'A World of Weather'; to the joint BBC/British Council film on weather forecasting which formed one of a series of films linked to individual sciences and technologies and designed to teach English in the 'English through Television' series; to Granada Television's programme 'Bending the Weather' and to Southern Television's programme on 'Numerical Forecasting'.

With the co-operation of the BBC and the ITV companies, arrangements were made to cover major national outdoor events. Up-to-date forecasts and amendments were supplied directly to the responsible production units. The events included the final of the World Cup; the tennis championships at Wimbledon; Royal Ascot; and the Test matches.

The Meteorological Office also co-operated with the Ministry of Transport, the Home Office and the Chief Constables of the areas concerned, to pass to the BBC any warnings of dense fog on motorways. The arrangements for the 1966/67 winter are being extended as new sections of motorway are opened.

The automatic telephone weather service was introduced into two new areas. The first of these covers Nottinghamshire, Leicester and Derbyshire, the second serves the Thames Valley from Reading to Oxford. In addition several existing services were made available on new exchanges as additional equipment became available. The total number of calls made on this service during the period 1 October 1965 to 30 September 1966 was 8,956,005, compared with a figure of 7,528,450 for the corresponding period of the previous year.

Arrangements for the supply of information to the national Press continued with only minor changes. The most important of these was the supply to the *Daily Telegraph* during the summer months of forecasts of relative humidity for London, Glasgow, Birmingham and Manchester. Efforts were made to encourage the provincial Press to make greater use of their local meteorological offices for the supply of their regional forecasts and other local information.

The Director-General initiated discussions with the London Master Builders' Association aimed at improving the services provided for the building industry. These discussions resulted in the setting up of two working groups each composed of representatives of the National Federation of Building Trade Employers and of the Meteorological Office. The groups are respectively responsible for investigating the meteorological services that can be provided at the planning stage of major developments, and the short-term assistance that can be given to the site manager once work has commenced. In the latter case the group will consider such matters as forecasts specially designed to meet the builders' needs, warnings of inclement conditions for their operations and the costs of such services. Articles written by members of staff for the technical press have served to publicize the action taken. Simultaneously the Meteorological Office has assisted the Ministry of Public Building and Works in the preparation of a new publicity leaflet entitled 'Weather and the Builder'.

The work of the weather centres at London, Glasgow, Manchester and Southampton continued to expand. Changes in the establishment of the first three became necessary to enable them to meet the ever-increasing demands. The total number of inquiries for 1965 and 1966 are given below:

	London	*Glasgow*	*Manchester*	*Southampton*
1965	231,066	55,564	77,806	40,835
1966	299,312	74,495	83,915	63,916

In August London Weather Centre dealt with a record total of 30,828 inquiries.

Services to the various nationalized industries and to public utilities were continued. One major change occurred. British Railways decided to decentralize the arrangement by which the various regions and depots obtained their forecasts and warnings. Each railway region has therefore made its own arrangements with the appropriate regional meteorological office.

Throughout the year London Weather Centre also attended to the needs of most of the oil companies and consortia drilling for oil in the North Sea and prepared special forecasts as required for oil-rigs being towed from one location to another. The Senior Meteorological Officer at the centre visited some of the rigs and also attended an international meeting at De Bilt to discuss the meteorological problems of North Sea oil operations with representatives of the meteorological services of Holland, Belgium, West Germany, Denmark and Norway. Manchester Weather Centre played a leading part in the provision of the meteorological display for the Battle of Britain exhibition held at Platt Fields, Manchester, in September. A complete forecast office was set up and the staff dealt with all the various inquiries posed by the many thousands of visitors.

Glasgow Weather Centre took over from the Prestwick office the responsibility for the supply of forecasts to Grampian Television. They also provided a 'live' presentation of weekend weather for Scottish Television and helped to obtain observations from the Central Highlands skiing resorts. Staff from the centre also took part in several radio and television programmes concerning the weather of Scotland. Southampton Weather Centre assisted at three career exhibitions and three other exhibitions held in the area. Small displays were provided and the officer-in-charge attended each exhibition to advise on careers in the Meterological Office and to answer sundry other inquiries. The centre also provided services for many international yachting and power boat races including the Cowes Week races of the Royal Yacht Squadron, and the international power boat race for the Wills trophy. At the latter a personal briefing was provided by the officer-in-charge.

Preliminary arrangements were made for the setting up of a Weather Centre in Newcastle upon Tyne. The officer-in-charge was appointed and he has commenced work in the new offices. The necessary communications into the centre should be completed by April 1967. The new weather centre is located in a modern office block close to the city centre and the BBC and ITV studios. A questionnaire was prepared to assist in a market survey which is to be held to assess the economic value of the weather centre to the industrial north-east.

A weather radar was installed on the new Post Office Tower in London with its display in the forecast room of the Weather Centre in High Holborn. Negotiations are continuing for the installation of similar radars in Manchester and Newcastle.

Several organizations have shown an interest in using weather information as a window display. The *Daily Mirror* offices will soon show current and forecast weather information relayed electrically from the London Weather Centre. The *Daily Telegraph*, Time and Life, the Automobile Association and the Co-operative Building Society have made inquiries. London Weather Centre already provides daily forecasts for the Thomson 'newscaster' which is installed in Piccadilly Circus. All the evidence points to the continued growth of public interest in the weather.

Services for civil aviation. The Civil Aviation Department of the Board of Trade is responsible for providing technical services for civil aviation. The provision of meteorological facilities is a technical service and is undertaken by the Meteorological Office as the agent of the Board of Trade. The meteorological organization for civil aviation in the United Kingdom consists of a Principal Forecast Office at London (Heathrow) Airport, main meteorological offices at Air Traffic Control Centres, subsidiary offices at other civil airports and observing offices at some minor civil aerodromes.

At civil aerodromes where there is no meteorological office, meteorological forecast services are usually provided by telephone or teleprinter from a suitable meteorological office in the vicinity. Air traffic control staff at these aerodromes are trained in the making and reporting of weather observations.

Meteorological services for civil aviation overseas are provided at a number of joint-user aerodromes (i.e. RAF and civil) in the Near and Middle East Commands. In the United Kingdom the provision of forecasts for medium- and long-range flights operating above 5000 ft is the responsibility of the Principal Forecast Office at Heathrow. Weather documentation for flights throughout Europe and the Mediterranean and transatlantic flights to the USA, Canada and Bermuda is disseminated in processed form from Heathrow to 17 major airports by facsimile transmission (civil aviation meteorological facsimile—CAMFAX). Forecasts of upper winds and temperatures are now largely based on computed data from the Meteorological Office's computer (COMET).

The ICAO Fifth European/Mediterranean Regional Air Navigation meeting held in Geneva during February 1966 gave consideration to the development of Area Forecast Centres in Frankfurt, Paris and Rome to serve air routes from Europe to India, West Africa and East Africa respectively. It is planned that these will come into operation by October 1967 by which time Heathrow should assume responsibility as the European Area Forecast Centre for the North Atlantic. A number of organizational changes have already been made at Heathrow as preliminary steps towards the assumption of these new responsibilities.

Improvements in instrumental equipment at civil airports continue to be made. Cloud-base recorders are now installed at 12 major civil airports and two more are in use for research and development purposes. Responsibility for carrying out routine calibrations of lights used in making runway visual range observations has been accepted at the request of the Board of Trade (Civil Aviation Department).

The end of the year has seen the commencement of trial reception at Heathrow of cloud pictures received direct from the NIMBUS II satellite thus providing a valuable addition to data received from other sources, particularly over remote areas with a sparse coverage of observations.

A number of airlines are intending to computerize their flight-planning operations. Among them BOAC has recently discussed with the Meteorological Office the possibility of relaying the output from the Meteorological Office's computer to their own computer for this purpose.

The meteorological requirements of aircraft under development or planned for the future have been under continuous study throughout the year, in particular the problems associated with the Concord project and supersonic flight operations in general. Much attention has also been given to meteorological aspects of operating civil aircraft in conditions below the existing weather minima.

Methods of measuring and forecasting visibility from the air on approach to the airfield (slant visual range) have been investigated jointly by the Blind Landing Experimental Unit (BLEU) and the Meteorological Office at RAE Bedford. Recently trials have been extended to Heathrow under operational conditions, in co-operation with BEA.

Instrumental methods of measuring visibility are also being investigated by BLEU at Bedford with particular reference to the visual range of markers or lights on the runway (runway visual range). The Meteorological Office has co-operated in carrying out these trials and has commenced a further series of trials at Birmingham Airport.

Services for the Royal Air Force. Forecasting services are provided for the Royal Air Force by means of outstations which are distributed largely in conformity with the RAF organization. There is a Principal Forecast Office at the Headquarters of Bomber Command and Main Meteorological Offices, functioning throughout the 24 hours, are located at the Headquarters of some RAF Groups and control and advise subsidiary offices at RAF stations in the Group. At these subsidiary offices a forecaster is available at times which depend on the needs of the RAF. At observing offices there is no forecaster and the duties comprise the making and issue of weather observations. At RAF Command Headquarters the meteorological unit usually consists of a senior officer of the Meteorological Office who acts as adviser to the Air Officer Commanding-in-Chief and as liaison officer between him and the Director-General of the Meteorological Office. The same general pattern applies both in the United Kingdom and overseas in Western Germany and the Mediterranean, Middle East and Far East areas.

During the year the meteorological arrangements for the Royal Air Force continued without major change. At home the land-line facsimile network linking meteorological offices at Transport Command stations was extended. On this network forecasts and documentation for flights to many parts of the world are provided by the Main Meteorological Office at Headquarters Transport Command. Overseas, forecasting offices were maintained in Borneo and Sarawak during the confrontation with Indonesia and two forecasting units were stationed in Zambia to serve the RAF there after the Rhodesian illegal declaration of independence.

As the United States meteorological satellite programme passed from the research and development to the operational stage, preparations were completed for installing equipment at Changi (Singapore), Gan, Muharraq (Bahrain) and Episkopi (Cyprus) for direct reception of the satellites' automatic transmissions of cloud pictures. This information will assist materially in the study of weather systems and the preparation of operational forecasts, particularly for those areas where meteorological information of a more traditional nature is scarce.

Services for the Army. Liaison continued with the Army Department of the Ministry of Defence and with the Director, Royal Artillery, on meteorological services for the Army.

Five permanent outstations, four of them with radiosonde and radar wind measuring equipment, were maintained at Army Department and Ministry of Technology establishments engaged in ballistic operations. Three other subsidiary stations were manned during periods of practice firings of guided weapons and conventional artillery.

Assistance and advice were given in the training of Royal Artillery meteorological sections and in the installation of meteorological instruments at the School of Army Aviation.

Liaison with the Navy Department. Close co-operation continued with the Director of Meteorology and Oceanographic Services (Navy) on all aspects of the co-ordination of plans to meet the meteorological requirements of the defence forces both at home and overseas.

Services to the Home Office. The wartime meteorological requirements of the Warning and Monitoring Branch of the Home Office have been kept under review and detailed plans are maintained for meeting these requirements as effectively as possible in an emergency.

International defence services. Within the framework of NATO, CENTO and SEATO, the three international defence organizations associated with treaties to which the United Kingdom is a signatory, there are meteorological planning committees on which the meteorological services of the member states are represented. The work of these committees is to co-ordinate the meteorological support needed by the military forces in accordance with joint defence plans and, as necessary, to study the meteorological problems involved. Members of the Meteorological Office play an active part in the committees of all three organizations.

North Atlantic Treaty Organization. The annual meeting of the Standing Group Meteorological Committee took place in Washington D.C. from 14 to 17 June. Mr P. J. Meade, Director of Services, attended as United Kingdom member of the Committee and he was accompanied by Mr R. A. Buchanan, Met.O.17.

The Working Groups of the Standing Group Meteorological Committee on Weather Plans and Weather Communications met twice, in Naples from 8 to 17 March and in Brussels from 27 September to 6 October. Mr Buchanan was present as United Kingdom member of both groups and also as chairman of the Working Group on Weather Plans.

Mr Buchanan, representing the Standing Group Meteorological Committee, Mr A. G. Matthewman and Mr A. H. Hooper attended the second meeting of the NATO Armaments Committee's Group of Experts on Meteorological Measuring Techniques and Equipment, which was held in Paris from 28 June to 1 July.

The SHAPE Meteorological Committee met near Paris from 11 to 13 May. Mr Buchanan represented the Meteorological Office.

Mr Matthewman attended a meeting of the External Ballistics Group of the NATO Armaments Committee held in Paris from 18 to 22 April. Mr Matthewman also led the United Kingdom Delegation to Sub-Group II of this Committee when it met in Paris on 1 and 2 December 1966.

Climatological Services

Whilst there is much economic and social benefit to be obtained from good forecasting of the future weather, it is no less fruitful to study past weather data in the aggregate, that is the climate, and use these data purposefully. Not only is it necessary for the Office to act as the public memory of the weather, in the sense of specifying what happened on certain occasions, but also, and much more important economically, to marshal the facts about the climate in such a fashion as to form a basis for design and forward planning in many industries, e.g. for the design of structures an estimate of the wind speed likely to be exceeded only once in 50 years or for the fuel and power industries an estimate of the coldest three-day spell in 100 years.

To this end the Office collects, examines, analyses and preserves meteorological data from surface and upper air observations and supplies answers to inquiries to which these data are relevant. The area of collection is world-wide though the work carried out is far more detailed in respect of observations made at stations in the United Kingdom and at places abroad where the observing stations are maintained by the Meteorological Office, than in respect of observations made under the supervision of other meteorological services. The data collected and preserved cover all the usual meteorological elements. The inquiries answered are mainly, but by no means exclusively, concerned with climate in the United Kingdom. These inquiries range over an extraordinarily wide field, including town planning, the location of power stations, climate of holiday areas, and wind pressures on large structures. Data for the United Kingdom are published mainly in the *Monthly Weather Report* and its *Annual Summary*, in the yearly publication *British Rainfall* and in occasional publications dealing with climatological statistics.

Many of the data are collected from voluntary co-operating stations maintained by private individuals, local authorities, river authorities, private firms, schools, public utilities, etc.; this is particularly so in the case of rainfall observations (see Table IV). The Meteorological Office sets the required standards for sites, instrumentation and observational procedure and arranges for periodical inspection of stations.

Some investigational work, including field experiments, is also undertaken, this being mainly of a character relevant to the provision of climatological services.

To a large extent an office in Edinburgh deals with climatological services in so far as Scotland is concerned and an office in Belfast carries out a similar function for Northern Ireland. In such matters these two offices act on behalf of, and are supported by, Headquarters at Bracknell.

As a result of a reorganization of the Directorate of Services on 1 November 1966 the work of the Climatological Services Branch relating to rainfall and water supply was transferred to a newly formed branch for Agriculture and Hydrometeorology (Met.O.8). Work in agricultural meteorology and hydrometeorology is described elsewhere in this report.

The year 1966 again saw an increase in the number of climatological inquiries dealt with in the branch. These range from inquiries for which data are readily available and which can be answered almost immediately, to those involving substantial amounts of work in extracting the data, and presenting them and the conclusions derived from them in forms to meet the inquirers' special needs. As examples of such major inquiries may be mentioned those from a number of Gas Boards concerning the frequency and severity of cold spells over past periods as far back as the data permit. Information was supplied to the Ministry of Transport, and consulting engineers, on the incidence of fog and snow on trunk roads and on planned and existing motorways. Information on probable wind speeds at various levels was supplied in connexion with the collapse of a 1000-ft television mast. Exploratory meetings were held, and a working party formed in collaboration with a few large firms, to further the use of climatological services in the building and constructional industry, the objects being to identify the type of climatic data needed for design purposes and for the forward planning of construction work. Further information was supplied for the Committee of Inquiry into the collapse of cooling towers at Ferrybridge in November 1965. Climatological information was supplied for the planning of several development schemes for new towns and the expansion of existing ones. Advice relating to air pollution was given for town planning, and for some smaller projects, and to the Medical Research Council.

In marine climatology, further work was done for a British Standards Institution Committee on climatic hazards in the transport and storage of goods, and on providing information for current and proposed hovercraft services. A *Scientific Paper* (No. 25) was published dealing with the relation between Beaufort force, wind speed and wave height over open sea. Much work was done in preparation for the publication of annual marine climatological summaries for the World Meteorological Organization. Isopleths of mean dew-points for the period 1953–1961 were prepared for the Indian Ocean.

Hydrometeorology

During the past decade there has been a growing awareness, both nationally and internationally, of the great importance of the science of hydrology. In this country one result was the Water Resources Act 1963 and another was the entrustment to the new Natural Environment Research Council of responsibility for research in hydrology; whilst the International Hydrological Decade which began in 1965 calls for co-operation between nations. There has inevitably been an increase in the relevant work in the Meteorological Office, namely that in rainfall and evaporation, and a reorganization on 1 November 1966 took this work away from the Assistant Directorate for Climatological Services and placed it in a new Assistant Directorate for Agriculture and Hydrometeorology.

Hydrometeorological work falls naturally into three sections. First, there is the routine collection, scrutiny, processing and preservation of rainfall data for the United Kingdom, Most of the data are collected from voluntary co-operating stations maintained by private individuals, water supply undertakings, local authorities and river authorities. Regular inspections are made to ensure the maintenance of required standards of site, instrumentation and observational procedures, and some 700 stations were visited during the year. The Edinburgh Office administers and inspects stations in Scotland, handles their data and deals with local inquiries, whilst the Belfast Office has similar responsibilities for Northern Ireland. Rainfall data are published in the

Monthly Weather Report and in *British Rainfall*, and from time to time in non-routine publications and branch memoranda. Increasing use is being made of he computer COMET in processing data for publication.

Second, the inquiries section dealt with a large and increasing number of inquiries covering a wide field of interest, from simple insurance queries to estimates of areal rainfall over catchments at home and overseas. Processed data, including soil-moisture deficit charts, continued to be supplied as a routine to industry, particularly the water supply industry, to the river authorities and for publication in the *Surface Water Year Book*.

Third, the investigational section maintained its close liaison with the Water Resources Board, continuing its advisory work on networks for River Authority hydrological schemes and participating in the planning stage of the Chester Dee regulating reservoir research project. An analysis of sequences of daily rainfall in winter was made for the Middle Land Commissioners in connexion with Fen drainage problems. An analysis of sequences of monthly rainfall was started for the Water Resources Board for an investigation into possible relationships in connexion with water resources. Studies were completed on the maximum probable rainfall over three catchments in Jamaica. Estimates were made of the maximum rainfall for the Chania catchment in Kenya, required in planning for Nairobi's future water supply. Some results of the Cardington investigation on intense rainfalls were passed to the Road Research Laboratory for incorporation in a new edition of the publication 'A Guide for Engineers to the Design of Storm Sewer Systems'. Data collection for the Winchcombe investigation on intense rainfalls continued throughout the summer half of the year. Towards the end of the year a comprehensive analysis was made of rainfall data of the Aberfan area for presentation to the tribunal investigating the coal-tip disaster there.

During the year a Senior Scientific Officer was detached from the Branch to work at the Natural Environment Research Council's Hydrological Research Unit at Wallingford. This arrangement, which had been planned for some time, will ensure that certain important aspects of research into rainfall and evaporation will be carried out in conjunction with research into other important subjects in hydrology. By this means hydrological research will be co-ordinated and integrated over a wide range of problems where such collaboration is most required.

SERVICES FOR AGRICULTURE

Headquarters work on agricultural meteorology is mainly concerned with basic climatological investigations into meteorological matters of importance to agriculturists, and special investigations into the relation between meteorological and agricultural parameters. Staff at stations at Bristol, Cambridge, Leeds and Edinburgh are also engaged on the application of meteorology to the problems of agriculture. Contact with research and advisory workers in agriculture is maintained through the National Agricultural Advisory Service, research stations, experimental farms, universities and farm institutes.

During the year investigational work resulted in some 30 branch memoranda dealing with a wide variety of subjects such as relationships between weather factors and milk and crop yields, drying and storage of produce, animal diseases, glasshouse heating levels, hill farming and shelter. Work was also done on the meteorological factors of land use, and on air-borne movement of insects and spores. Experimental work continued in many quarters, for example on temperatures in Thetford Chase in conjunction with the Forestry Commission, in Cornwall on shelter with the Agricultural Research Council, and with animal housing problems in East Anglia. Advisory work was maintained at a high level, and revealed the increasing interest of farmers and growers in irrigation matters. Notification of Beaumont periods in connexion with the potato blight warning service was provided as in previous years. A general account of the Office's work and objectives in agricultural meteorology is contained in the Special Topic article which starts on page 1 of this Report.

Marine Branch

Regular weather observations over the oceans are of vital importance in weather forecasting procedures and in the provision of data for marine climatological purposes.

One of the ways in which the Office plays its part in obtaining these observations for forecasting purposes is to arrange for them to be made voluntarily aboard British Merchant Navy ships (Table III refers). It is gratifying to record that about 750 British ships are thus participating, this being about one-sixth of the total of voluntary observing ships from all nations. Reports are radioed to a shore station for general dissemination. Distant-water trawlers' observations are often particularly valuable to us as these vessels usually operate away from normal shipping routes. Besides the normal meteorological elements, the observations cover state of the sea and give information allowing computation of surface currents in the oceans.

The United Kingdom also co-operates with France, Holland and Norway, other countries making a financial contribution, in maintaining a constant watch at five ocean weather stations in the North Atlantic. The Meteorological Office operates four Ocean Weather Ships from their base at Greenock, two of them being always on station. Besides making surface and upper air observations these ships record solar radiation, sea temperatures in depth, do some biological work including plankton hauls, and sample rainwater and sea surface water for the Tritium survey.

For the third year in succession our Weather Ships participated in an international oceanographic programme and over 2000 bathythermograph observations and 45 deep soundings of temperature and salinity were taken aboard *Weather Adviser* during the month of the operation. Also during the year echo-sounding apparatus was transferred to the Weather Ships from Naval Survey ships withdrawn from service. The Weather Ships continued routine practices for their air/sea rescue function and provided regular navigational aid and communications facilities for transatlantic aircraft.

Data for marine climatological purposes are obtained through the regular receipt of log books or forms from ships of the British Voluntary Observing Fleet. During 1966, 1042 meteorological log-books were received from regular observing ships and 81 forms from auxiliary ships. After appropriate scrutiny the observations are punched on cards for machine processing. Under a scheme evolved within the WMO the Meteorological Office is responsible for the preparation of marine climatological summaries for a large part of the North Atlantic and many data collected by observing ships of other nations in that area were received during the year, whilst we sent appropriate data to other services responsible for other areas of the oceans of the world.

Early in 1966 the work of the Ice Unit of the branch was extended to include a daily radio facsimile broadcast of the sea-ice situation over much of the northern hemisphere. This work has been greatly helped by the co-operation of airline pilots and by reception of satellite pictures. Towards the end of the year the Central Forecasting Office assumed responsibility for the day-to-day sea-ice work, the Marine Branch retaining responsibility for the published monthly charts and for development work.

The '*Marine Observer*' was again published each quarter. Other publications include ocean current atlases (revision of which will be expedited by a computer programme now being written), climatological atlases of the oceans and various technical books, code cards and forms.

Marine inquiries dealt with during the year followed the normal pattern being mainly requests from solicitors, brokers and insurance companies. There were a number of requests for wind and wave data, both for home waters and elsewhere, from inquirers planning off-shore works (e.g. drilling for oil and gas), hovercraft operators and shipping companies. Yachtsmen, travel agencies, those concerned with transport of goods by sea, research workers and journalists also made requests for data for various sea areas. Information about the frequencies of gales and storms was provided for the International Load Line Conference held in London. Reports were prepared for the Board of Trade in connexion with inquiries into the loss of ships at sea.

Instruments and Observations

The development and testing of meteorological instruments are important functions in the Office, bearing in mind the basic need for observations of appropriate accuracy to be economically obtained.

Instrument development and installation. First models of a magnetic tape recorder suitable for long-term rainfall recording were received from the manufacturer. The recorder was constructed to our specification for operation with the new rain-gauge system.

The first operational automatic weather station in this country was installed at White Waltham airfield and supplied a range of meteorological parameters to Forecasting Office, ATCC Uxbridge. The information could also be obtained by interrogation at Bracknell.

The first operational U.S. satellite ESSA II for the transmission of cloud pictures failed towards the end of the year, but is to be replaced early in 1967. The production of an order for five sets of receiving equipment was well advanced, the first having been installed at Bracknell in December. Reception of cloud pictures from a second experimental satellite, NIMBUS II, continued to be possible.

The installation of a variety of modern observational instruments continued in increasing numbers throughout the year. They included additional wind-finding and weather radars, cloud-base recorders and distant-reading systems for the measurement of pressure, temperature and rainfall. A notable addition was the weather radar mounted on the Post Office Tower in Bloomsbury and transmitting its information by land-line to the London Weather Centre in High Holborn. This radar gives complete weather coverage over the Greater London Area and the Home Counties.

Instrument testing and calibration. Table XV gives the numbers of instruments tested or calibrated both for the Meteorological Office itself and, on repayment, for outside authorities. The number of items exceeded the 1965 total by about 24,000 or 10 per cent. Four foreign meteorological students shared in the work of instrument testing as part of their training.

Thunderstorm location. The four home-based and three Mediterranean stations of the CRDF thunderstorm locating network continued to operate during the year. Data were supplied to various university research workers, at home and overseas, and to the Electrical Research Association. There was collaboration with the Radio and Space Research Station, Slough, the Winkfield Satellite Tracking Station and the Centre National d'Études des Télécommunications, Issy-les-Moulineaux, in experiments devoted to ionospheric research involving the FR-1 satellite.

Surface observations. In the United Kingdom 86 surface observing stations report in international code every hour, day and night, throughout the year. A further 46 stations report every three hours. In addition 129 stations report at various times during each day of the year. Of this total of 261 stations 117 are manned by full-time professional staff and 144 by voluntary observers most of whom have attended the Meteorological Office Training School course on observing.

Reports in plain language are received from 17 town offices of the Automobile Association, 17 police or fire service stations and 27 road maintenance depots located alongside the motorways.

The Marine Branch section of this Report gives information on the arrangements for obtaining observations over the oceans from British ships.

Upper air observations. Upper air stations were maintained at eight locations in the U.K., at seven RAF airfields overseas, and on the four Ocean Weather Ships operated by the Office. The new wind-finding radar was installed at a further two stations during the year, making eight in all.

The 'double' 500-gramme balloon, in which one balloon is inflated within a similar one, was successfully used in previous years but because of the risk of explosion its operation was discontinued during 1966. The average maximum height achieved in upper wind observations was therefore lower than in previous years. Table V summarizes the heights achieved by upper air ascents.

Regional Servicing Organization. This was set up in 1965 to provide technical maintenance and emergency repairs for the more advanced electrical equipment and was subsequently extended to cover all Meteorological Office stations within the United Kingdom. The scheme involved the formation of four geographical regions, each with a Regional Servicing Centre (RSC) competent to maintain all the equipment used within its region and to deal with virtually all breakdowns, however complex. To provide rapid repair service each region is subdivided into areas within which area offices are placed in proximity to the likely maximum work load. Although not so fully equipped as the Regional Centres, these area offices are able to deal expeditiously with the more common points of maintenance which may arise. The staff of the Regional Servicing Organization is composed wholly of technicians trained in electronics.

The Organization also maintains regular technical inspections of the corresponding equipment at overseas Meteorological Office stations, and provides repair services on request.

International collaboration. In addition to the training of foreign students a considerable volume of advice was supplied to Commonwealth and some foreign countries. In particular, correspondence with India, Australia and New Zealand was frequent and covered a wide range of subjects.

Computing and Data Processing

Computing and data processing services are centralized in one branch, Met.O.12, which operates the computing laboratory and punched-card installation and also provides a programming and consultancy service for all other branches of the Office. Training courses are provided for a wide range of staff so that knowledge of machine methods of analysis and computation may become widespread. In the fields of computing and data processing some of the most rapid technological advances are to be found and it is therefore an important responsibility of the Assistant Director in charge of the branch that he should keep abreast of developments in equipments and techniques of potential value to the Office.

COMET *Computing Laboratory.* The laboratory is equipped with an English Electric-Leo-Marconi KDF 9 electronic computer which was installed in the summer of 1965. Within the Office this computer is known as COMET and it is able to run up to four programmes simultaneously. Its peripheral equipment consists of six magnetic tape units, three paper-tape readers, three paper-tape punches, one punched-card reader, one high-speed line-printer and a magnetic drum backing store of 40,960 words. During the year its high-speed random-access core store was increased from 12,288 to 16,384 words. Plans have been made for a further increase to 24,576 words in order to provide the service which has been foreshadowed for 1967. The laboratory also contains ancillary rooms furnished with a range of tape-editing equipment for data and programme punching, and 'off-line' printing from paper tape.

For much of the year the computer was operated from 0600 to 2200 clocktime seven days a week. On 26 September the hours of operation were increased to round-the-clock working except for about two hours a day routine maintenance. Intensive staff training was given to provide the increased service by the due date.

One of the main tasks performed on the computer comprises operational numerical forecasting runs, carried out at fixed times. Rather more than seven hours a day are devoted to this work which is carried out during four periods of intense computer activity. Other important tasks are computations for research projects, and for parts of the long-range weather forecasting routine, routine data processing (e.g. the checking as a monthly routine of rainfall data from about 5000 stations), and the preparation of tabular and numerical material for certain publications e.g. *British Rainfall.* During the year COMET was increasingly used for checking land surface climatological data for accuracy and consistency. Work was also commenced on the build-up of a comprehensive general-purpose library of meteorological data on magnetic tape, mainly at present by conversion from punched cards.

During the year four programming courses were held, three in the computer language Algol and one in Usercode.

Punched-card installation. This installation is equipped with a range of modern punched-card machines, including automatic punches and verifiers, sorters, collators, tabulators, etc. Since it was set up in 1920, a library of 45 million standard 80-column punched cards containing marine, surface and upper air meteorological data has been accumulated. The present punching rate of British data is over a million cards a year, some of these being punched at other government installations. A selection of foreign data is acquired through international exchange.

Punched-card machines are used for the simpler jobs of data processing which do not involve much calculation such as frequency distributions, listing and tabulation of data, the larger computing jobs from data on punched cards being carried out on COMET.

Other activities—present and future. The production of a weather-chart plotter was subject to further delays but delivery is now expected by the summer of 1967. There was also a disappointing setback in the production of automatic equipment to draw isopleths of meteorological charts computed in the numerical forecast programmes, and it was necessary to invite further tenders from industry.

Planning work was begun on the specification of a more powerful computer system needed by the early 1970's. The relevant papers and brochures have been studied and visits have been paid to establishments producing or using advanced computing machinery. In October/November a team consisting of the Assistant Directors responsible for data processing and forecasting research carried out a programme of visits in the USA where much experience has already been gained in the use of very high-capacity computers for meteorological work with its predominantly real-time requirement.

TELECOMMUNICATIONS

The efficiency of a meteorological service, especially in relation to its forecasting responsibilities, is greatly dependent upon the telecommunications facilities which are used for the collection and redistribution of raw and processed data. The facilities required by the Meteorological Office are obtained through the Director General of Signals, Royal Air Force.

The organization of meteorological telecommunications covers both international and national aspects. To meet international requirements the World Meteorological Organization (WMO) has arranged for the Meteorological Communications Centre at Bracknell to be responsible for two radio-teleprinter broadcasts; one a regional broadcast of reports of weather observations over Europe and the North Atlantic and the other a sub-regional broadcast giving data for north-west Europe and the eastern North Atlantic. The Centre makes a radio-facsimile broadcast of processed data which includes analyses and forecasts of the WMO Master Analysis Centre at Bracknell. It is also one of the seven European centres of the International Meteorological Teleprinter Network of Europe. As such, it has a commitment to collect reports of weather observations made in the United Kingdom, the Republic of Ireland, Iceland and Greenland, to collect reports made by three ocean weather stations in the North Atlantic and reports from merchant ships received via British coastal radio stations and to transmit all these reports into the network.

As regards national requirements, the Centre at Bracknell is responsible for the collection and distribution of data to meet the needs of the meteorological services centred at Bracknell and the needs of meteorological offices throughout the country. The coverage of data collected is the whole of the northern hemisphere; the depth of coverage being greatest over the United Kingdom and adjacent areas. The data comprise both basic data (reports of weather observations) and processed data (analyses and forecasts). Collection and distribution is largely by teleprinter and facsimile land-line networks.

During the year there have been a number of changes and considerable development. The wireless telegraphy (W/T) receiving station for the collection of reports from the ocean weather stations 'A', 'I' and 'J' was transferred from Dunstable to Bracknell on 11 January 1966. The few remaining W/T commitments at the Dunstable radio-receiving station were transferred to Bampton on 28 March 1966 and, after recovery of technical equipment, the site at Dunstable was vacated by the Meteorological Office on 1 July 1966.

The distribution by land-line teleprinter broadcasts of basic data and of some processed data from Bracknell to meteorological offices within the United Kingdom was reorganized in terms of three channels with effect from 11 October 1966. Meteorological Communications Channel One (MCC 1) carries data relating to the U.K. and a narrow surrounding fringe of north-west Europe and the eastern North Atlantic. MCC 1 is received by all meteorological offices. MCC 2 provides data for Europe and the North Atlantic and is received by most forecasting offices. MCC 3 conveys data for Russia in Asia, North Africa and eastern North America and its purpose is to meet the special needs of a few forecasting offices. MCC 3 replaces the former North Atlantic teleprinter broadcast and the former Mediterranean broadcast.

The facsimile centre at London (Heathrow) Airport was redesigned early in 1966 in association with the U.K. Civil Aviation Meteorological Facsimile Network (CAMFAX) which became fully operational in May 1966. A redesigned meteorological communications centre at Uxbridge was brought into operation in June. Planning of the meteorological telecommunications for the new London Air Traffic Control Centre at West Drayton went ahead during the year and detailed requirements for circuitry and telecommunications equipment were drawn up.

A new facsimile centre was opened at HQ Transport Command in June 1966 and an associated land-line facsimile network, to serve Transport Command airfields, was completed in July 1966.

The Cyprus W/T broadcast was converted to radio-teleprinter operation on 31 October 1966, and radio-facsimile receiving equipment was supplied to meteorological offices at Lusaka and Ndola in Zambia and the meteorological offices at El Adem and Muharraq.

In planning for a computer age in meteorology there is clearly a need to speed up meteorological telecommunications. A most important development in this direction has been the planning, during the year, of a telephone-type circuit for the transmission of North American data from Washington to Offenbach, Bracknell and Paris. Data transmission, to begin with, will be approximately 1000 words per minute (compared with normal teleprinter working of 66 words per minute) and, later, at double that speed. The system is scheduled to come into operation in January 1967.

At the invitation of WMO, trials have been conducted in speeding up facsimile transmissions and arrangements are in hand to take part in studies concerned with the introduction of error control in radio-teleprinter broadcasts and the speeding up of radio transmissions in the high-frequency band. In the interest of speeding up the collection of data, trials of automatic message sending equipment have been carried out. Results so far have not been very satisfactory but the trials are to continue.

International and Long-term Planning

The international character of meteorology inevitably leads to a number of international conferences each year. Most, but not all, of these are held under the auspices of one or other of three organizations. The World Meteorological Organization (WMO) deals with the science and practice of meteorology in all their aspects. The International Civil Aviation Organization (ICAO) deals with all international questions affecting civil aviation and many of its meetings are concerned either directly or indirectly with the meteorological aspects of civil aviation. Thirdly, various aspects of meteorological support for the armed forces of the North Atlantic Treaty Organization (NATO) are discussed at meetings of committees and working groups set up for that purpose. There are also meteorological committees associated with the other international military organizations in which the U.K. is concerned.

Delegates and representatives from the Meteorological Office at these various meetings are drawn from all parts of the Office according to the subjects to be discussed. An account of the principal meetings attended will be found in the 'International Co-operation' section (see page 53).

The Foreign Office, Commonwealth Office and Ministry of Overseas Development and other Government Departments regularly require advice or comment on administrative, financial and technical aspects of meteorological matters which arise in the general international field particularly with respect to United Nations and World Meteorological Organization activities. These matters are dealt with by Met.O.17 in co-operation with other branches of the Office.

Within the Office the activities mentioned above are co-ordinated by the Assistant Director in charge of Met.O.17 who also assists the Director-General in his capacity as a Member of the WMO Executive Committee. In this connexion much time was given during the last few months of the year to preparations for WMO Fifth Congress which is to be held in Geneva in April 1967. The work included the drafting of United Kingdom briefs and supporting papers, and numerous consultations with other Government Departments and with the U.K. Mission in Geneva on various aspects of the country's participation in the World Meteorological Organization. Preliminary work was also begun for the Scientific and Technical Conference on Aeronautical Meteorology which is to take place in London in March 1968.

Towards the end of the year the Assistant Directorate also became responsible for the preparation of long-term planning and organization studies required by the Director-General for consideration of long-term developments in the responsibilities and functions of the Office. This work will be largely concerned with the wider aspects of organization both to improve efficiency and to ensure that the Office anticipates and responds effectively to new demands.

P. J. MEADE
Director of Services

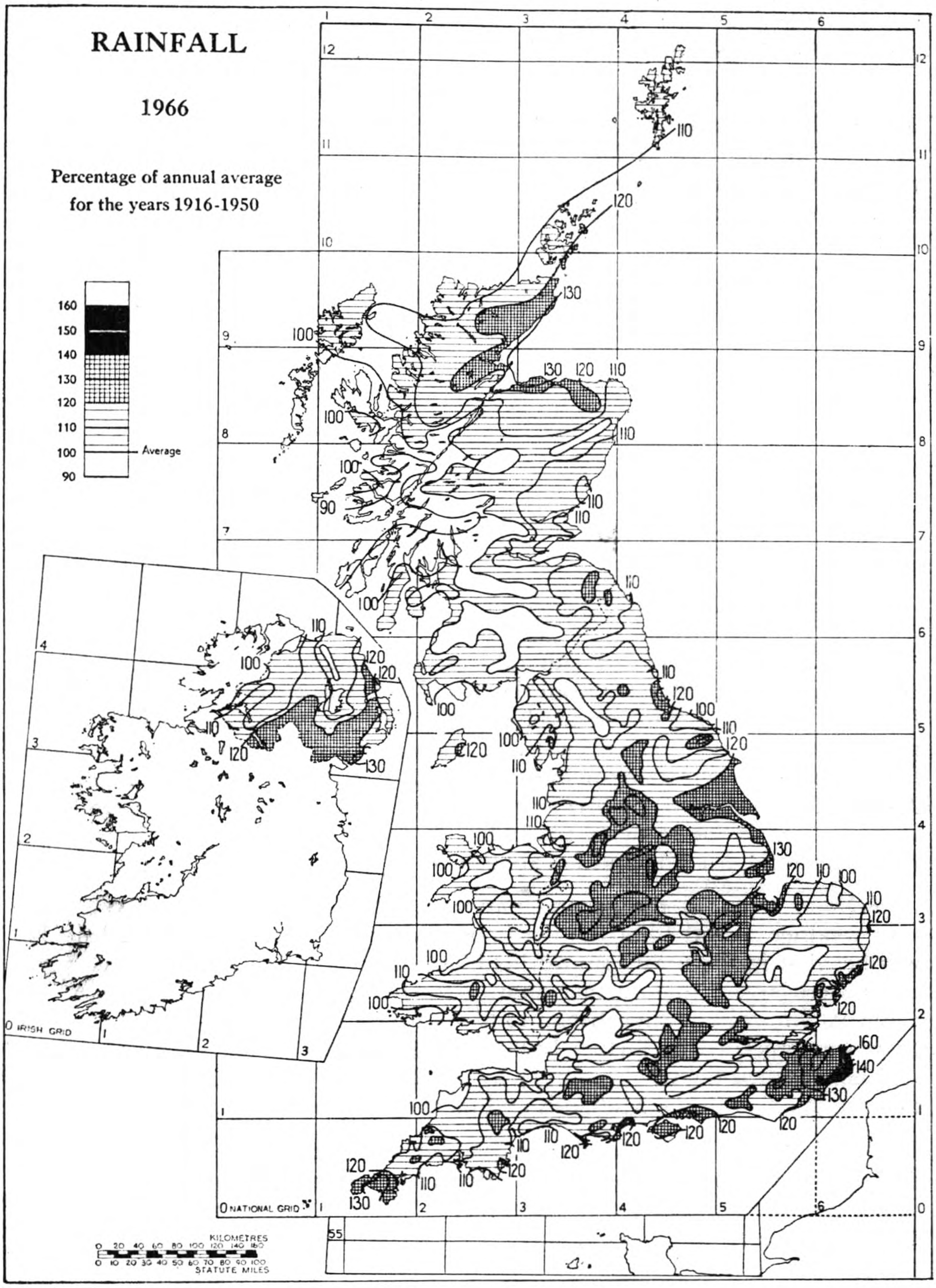
SUMMARY OF THE WEATHER OF THE YEAR (1966)

January began and ended with mild and sometimes stormy weather but it was very cold for about 10 days from the 9th. There was snow in parts of southern England reaching 4–6 inches level depth on Salisbury Plain. There were also periods of snow in eastern districts. In many parts of the country temperatures failed to rise above freezing-point on the 18th and 19th. The thaw began on the 20th, being preceded by freezing rain in parts of southern England and accompanied by fog in many places for the first three days. Weather was very mild over southern England for about five days at the end of the month.

February repeated the general pattern of the weather of January but the cold weather spread from the north between the 7th and the 10th. Snowfall was heaviest in the north, snowdrifts blocking some roads in Yorkshire. Night frosts were severe and further snow occurred over the eastern part of the country. The cold weather began to break from the south on the 18th, but the thaw was preceded by further heavy falls of snow in the north. Much milder weather reached the whole country by the 20th and rain and melting snow led to some flooding in the Midlands and parts of northern England and Scotland.

March started mild and changeable but was mainly rather quiet and dry during the middle 10 days. Afterwards rather cold north-westerly winds were rather persistent and frequently strong to gale force. The month was drier than average in the south and east.

April was dull and wet on the whole, with snow at times. Northern England and North Wales had snow falls early in the month and on the 14th the southern half of England suffered what was probably the worst fall so late in the season for at least 16 years. London had its coldest spell on record for so late in the year. However, the last week was mainly dry and sunny, the last three days being particularly warm in the south, temperatures reaching 22°C on the 30th.



RAINFALL 1966

May was changeable with a warm start and a sunny ending. There was unbroken sunshine in much of England and Wales during Whitsun.

Mere averages show the summer months June, July and August, as disappointing for most holidaymakers. However, the fine interludes were long enough to satisfy those fortunate enough to strike them whilst those not so lucky had to endure really wet weather. The summer was perhaps noteworthy for having better weather in many parts of Scotland than further south.

June started fine, temperatures reaching 27°C in southern England on the 4th. Thereafter the month was changeable with frequent thunderstorms and periods of heavy rain in many parts of the country.

Both *July* and *August* were cool with heavy rain at times. However, northern areas of Britain had a sunny warm week from 17 July, the south being cold and wet. 19–21 July was a particularly cold and wet period in south-east England. South-west England and South Wales experienced some flooding on 1 August and the floods were more extensive in northern England and southern Scotland from 9 to 13 August. In the south the best spell of weather occurred during the third week, being broken on the 20th by some violent thunderstorms. Much of the last week was mainly dry but cool, although widespread thunderstorms occurred on the 29th (August Bank Holiday).

September started with unsettled weather and there was extensive flooding in the Lake District on the night of the 3rd/4th. However, the weather became dry and quiet for much of the second half of the month, though fog formed in the Midlands and south on many nights and persisted all day in places after the 22nd. The last few days had changeable weather again.

October was a wet month in most areas, though rainfall in western Scotland was below average. Widespread fog occurred on the nights of the 8th and 9th; there were tornadoes near Oxford and Bournemouth on the 16th and widespread gales on the 18th and 19th and there was some flooding in southern England on the 22nd.

November was cold on the whole with frequent northerly winds and snow at times in the north. There were, however, some mild periods.

December was a stormy wet month, being mild in the south and cold in northern Scotland. The month opened with one of the deepest depressions to cross the country for many years. It gave heavy rain and gales, and snow penetrated southwards across many areas in its wake. There was a short cold spell in the middle of the month but milder weather had returned by the 16th. At this time there was very heavy rainfall in western Scotland and with melting snow and rapid runoff there was extensive flooding. In the variable weather of the remainder of the month, Christmas Day was fine and sunny in most places and there was snow cover in the north, whilst it was very mild in southern England at the year's end.

STATISTICS OF THE SERVICES DIRECTORATE

The quantitative analyses in this section are intended to provide an indication of the distribution of work within the Directorate of Services and of the extent of the services provided.

TABLE I—NUMBERS OF OFFICES OF VARIOUS TYPES STAFFED BY METEOROLOGICAL OFFICE STAFF AND OPERATING ON 31 DECEMBER 1966

	Within U.K.	*Overseas*
Principal Forecast Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF	7	6
Subsidiary offices associated with the RAF	44	15
Observing offices associated with the RAF	8	5
Principal Forecast Offices associated with civil aviation	1	—
Main Meteorological Offices associated with civil aviation	3	1
Subsidiary offices associated with civil aviation	11	1
Observing offices associated with civil aviation	6	—
Upper air observing offices	8	7
Public service offices	4	—
CRDF offices	5	3
Port Meteorological Offices	5	—
Offices associated with the National Agricultural Advisory Service	3	—
Other offices	28*	7

Notes

A Principal Forecast Office meets the needs of aircraft flying over very long distances and operates throughout the 24 hours.

A Main Meteorological Office operates throughout the 24 hours for the benefit of aviation and normally supervises the work of subsidiary offices.

A subsidiary office is open for that part of the day necessary to meet aviation requirements.

At an observing office no forecaster is available.

Public service offices are located in certain large cities.

An upper air observing office may be located with an office of another type if this is convenient.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

*Eight of these stations are administered by D.R.Met.O.

TABLE II—OCEAN WEATHER SHIPS

To meet its obligation under the ICAO North Atlantic Ocean Station Agreement the United Kingdom operates four Ocean Weather Ships which work in rotation with two ships each from France, Netherlands and Norway/Sweden jointly. The British ships serve at four of the five ocean weather stations in the eastern North Atlantic; each vessel makes, on an average, 8 voyages a year and spends 24 days on station during each voyage. Some statistics for 1966 for the British Ocean Weather Ships are shown below.

Total number of days on station	741
Total number of days on passage	160

	Station A	*Station I*	*Station J*	*Station K*
	Average number per voyage of 24 days			
Aircraft contacted	432	717	1392	279
Radar fixes to aircraft	363	454	1004	251
Weather messages to aircraft	289	225	458	127

TABLE III—MERCHANT NAVY SHIPS

A total of about 4500 ships of the merchant navies of the world make and transmit meteorological reports to the appropriate meteorological centres ashore under arrangements co-ordinated by the World Meteorological Organization: most of these, including British ships, do this on a voluntary basis. Ships which report in full at four specified times daily are known as 'selected' ships, those which report at the same times daily but in a less complete form are known as 'supplementary' ships. A number of coasting vessels, lightships, distant-water trawlers and 'auxiliary' ships also make and transmit meteorological observations. On 31 December 1966 the number of British ships reporting was:

Selected ships	502	
Supplementary ships	65	including 9 trawlers
Coasting vessels	108	
Lightships	13	
Trawlers	20	
Auxiliary ships	50	
Total	758	

The British Voluntary Observing Fleet includes ships of over 100 shipping companies; the numbers on the various routes are as follows:

U.K. to Australasia	105
U.K. to Far East	79
U.K. to Persian Gulf	32
U.K. to South Africa	43
U.K. to West Indies	38
U.K. to North America	92
U.K. to South America	29
U.K. to Pacific Coast of North America	12
U.K. to European Ports	53
U.K. to Falkland Islands and Antarctica	2
World-wide tramping	82

During two typical days, one in June, the other in December, the numbers of reports from ships received in the Central Forecasting Office were as follows:

	Reports	
	June	*December*
Direct reception from:		
British ships in eastern North Atlantic	108	101
Foreign ships in eastern North Atlantic	11	78
British trawlers in North Sea	3	29
British merchant ships in North Sea	11	12
Total	133	220
Reception via other European countries:		
Ships in eastern North Atlantic	538	343
Ships in Mediterranean	74	144
Ships in North Sea	49	51
Ships off North Russia	27	14
Ships in Pacific	72	104
Ships in other European waters	77	106
Total	837	762
Reception via U.S.A. and Canada:		
Ships in North Atlantic	466	410
Ships in North Pacific	298	396
Ships in other waters	39	118
Total	803	924

TABLE IV—CLASSIFICATION OF STATIONS RENDERING CLIMATOLOGICAL RETURNS

A large amount of meteorological data is obtained for climatological purposes from stations which are not part of the Meteorological Office organization. The following table shows how the sources of climatological information in the United Kingdom (including Meteorological Office stations) were distributed on 31 December 1966.

	Stations					*Autographic Records*		
	Observatories	*Synoptic*	*Agro-meteorological*	*Climatological*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north ..	1	9	0	27	330	24	8	10
Scotland, east ..	0	11	9	57	575	47	15	12
Scotland, west ..	1	14	3	52	508	32	20	14
England, north-east ..	0	11	4	25	433	27	16	8
England, east ..	0	13	13	18	516	29	27	9
England, Midlands ..	0	13	19	47	1278	61	44	7
England, south-east (including London) ..	1	18	20	51	847	65	95	16
England, south-west ..	0	10	8	31	563	32	10	4
England, north-west ..	0	5	4	23	480	25	20	12
Wales, north ..	0	2	3	17	258	10	4	2
Wales, south ..	0	4	9	14	320	21	7	5
Isle of Man ..	0	2	0	1	17	3	1	2
Scilly and Channel Isles ..	0	3	0	4	21	7	0	3
Northern Ireland ..	0	9	7	40	319	21	24	8
Total ..	3	124	99	407	6465	404	291	112

* Includes stations in earlier columns

TABLE V—HEIGHTS REACHED IN UPPER AIR ASCENTS

The following table shows the number of upper air ascents giving observations of (i) temperature, pressure and humidity and (ii) wind, which have reached specified heights, and height performance of largest balloons.

Observations of temperature, pressure and humidity

	Number of observations	*Percentage of all balloons reaching*				*Percentage of largest balloons reaching*
		100 mb 16,000m (approx.)	*50 mb 20,000m (approx.)*	*30 mb 24,000m (approx.)*	*10 mb 30,000m (approx.)*	*10 mb 30,000m (approx.)*
Eight stations in United Kingdom ..	5780	91·7	68·0	32·3	8·5	54·2
Seven stations overseas ..	4747	96·5	78·9	38·3	5·3	37·1
Four Ocean Weather Ships ..	1428	86·8	55·1	17·5	0·1	—

Observations of wind

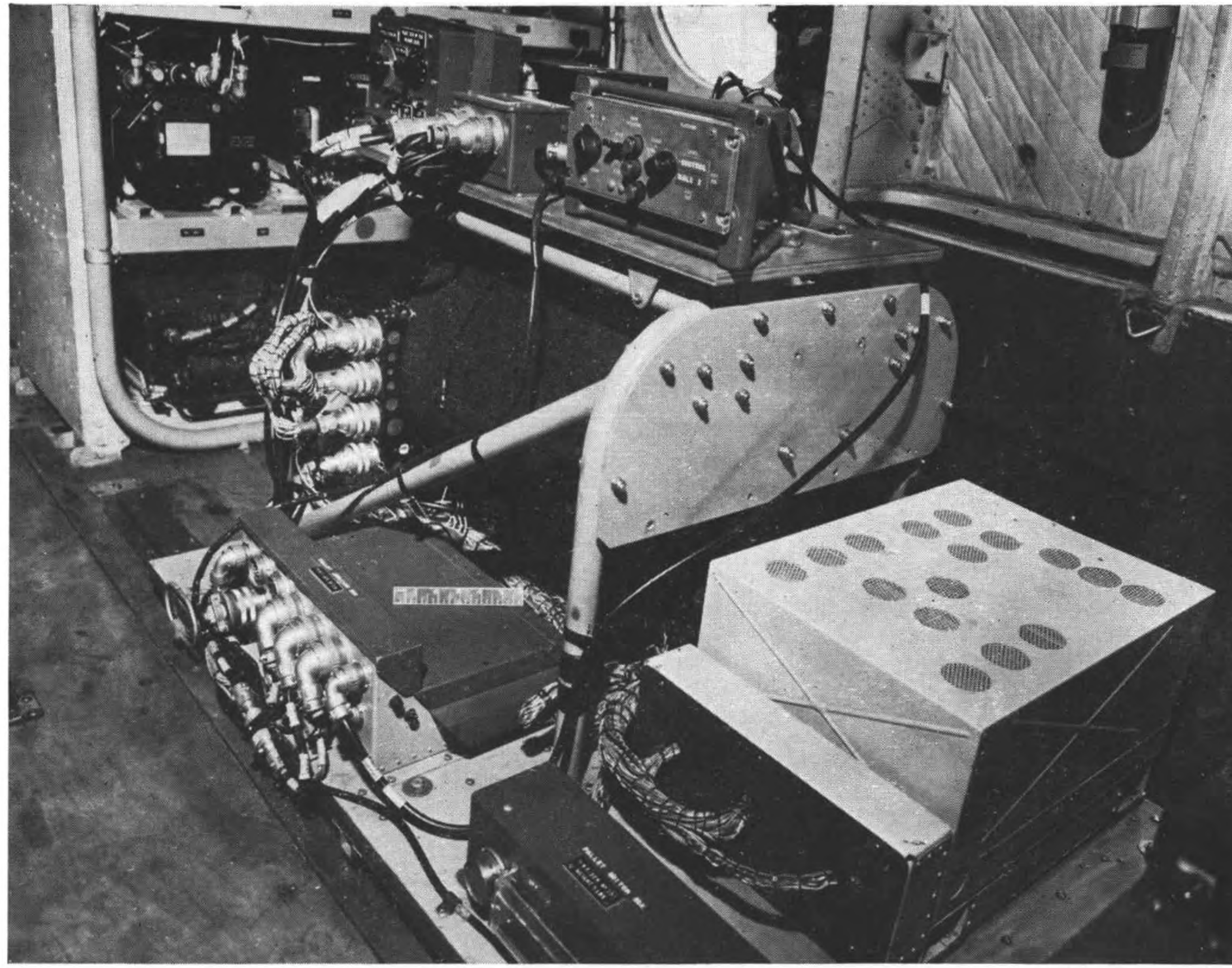
	Number of observations	*Percentage of all balloons reaching*				*Percentage of largest balloons reaching*
		100 mb 16,000m (approx.)	*50 mb 20,000m (approx.)*	*30 mb 24,000m (approx.)*	*10 mb 30,000m (approx.)*	*10 mb 30,000m (approx.)*
Eight stations in United Kingdom ..	11,545	83·9	50·4	16·7	4·1	50·3
Seven stations overseas ..	8310	87·7	58·7	19·6	3·5	41·9
Four Ocean Weather Ships ..	2786	73·8	37·0	8·0	0	—

An aerial view of the GPO Tower showing the weather radar installation. This is a Plessey 42A Weather Radar and is to be seen at the top of the 40-foot lattice mast.

PLATE II

Photograph by courtesy of Eastern Daily Press

The oil-rig Neptune I on station in calm conditions in the North Sea.

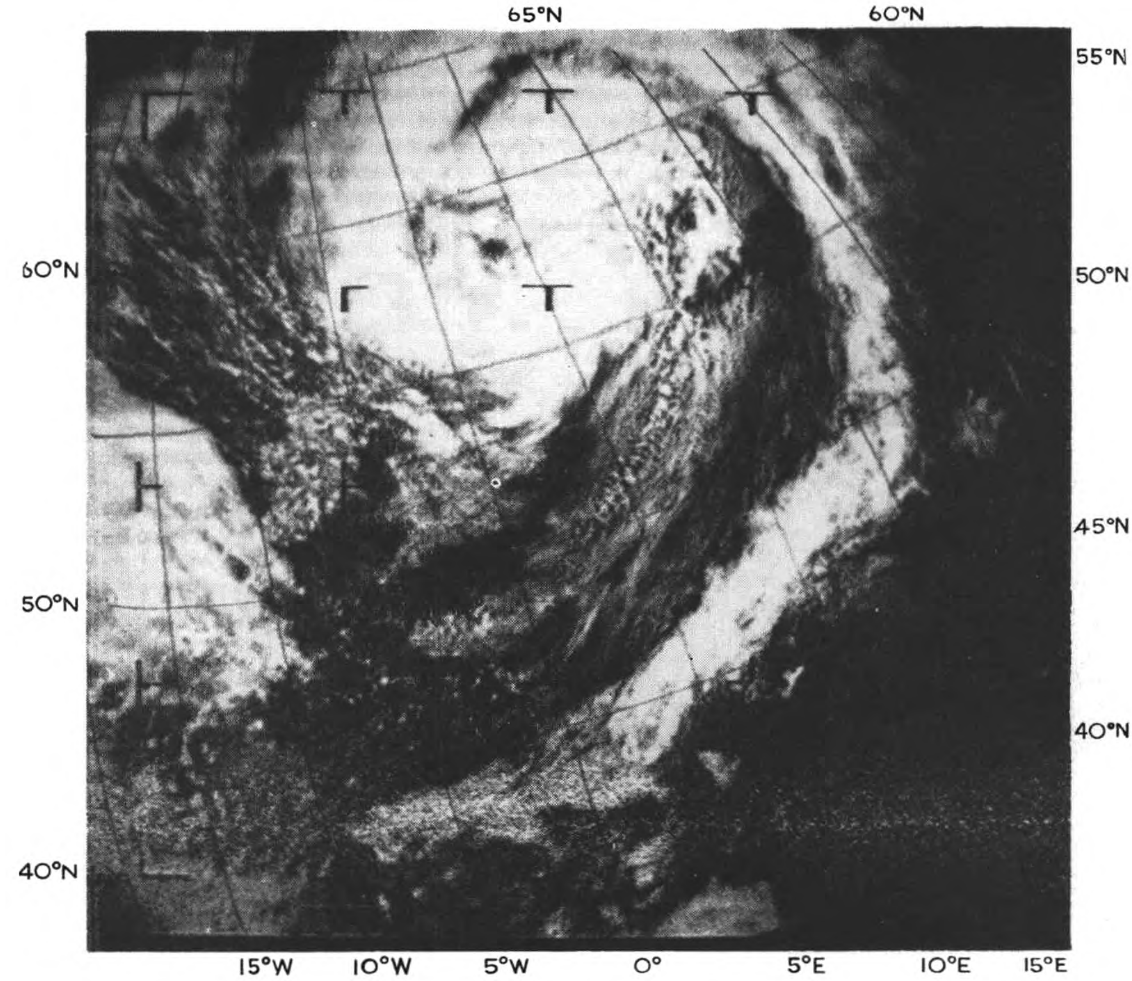


The stable platform in the Meteorological Research Flight Hastings aircraft. This is used to determine accurately the three-dimensional velocity and orientation of the aircraft so that small-scale variations of the wind can be determined, including, in particular, its vertical component. The gyroscopes and accelerometers together with some ancillary electronics are contained in the large cylinder in the centre of the photograph.

PLATE IV

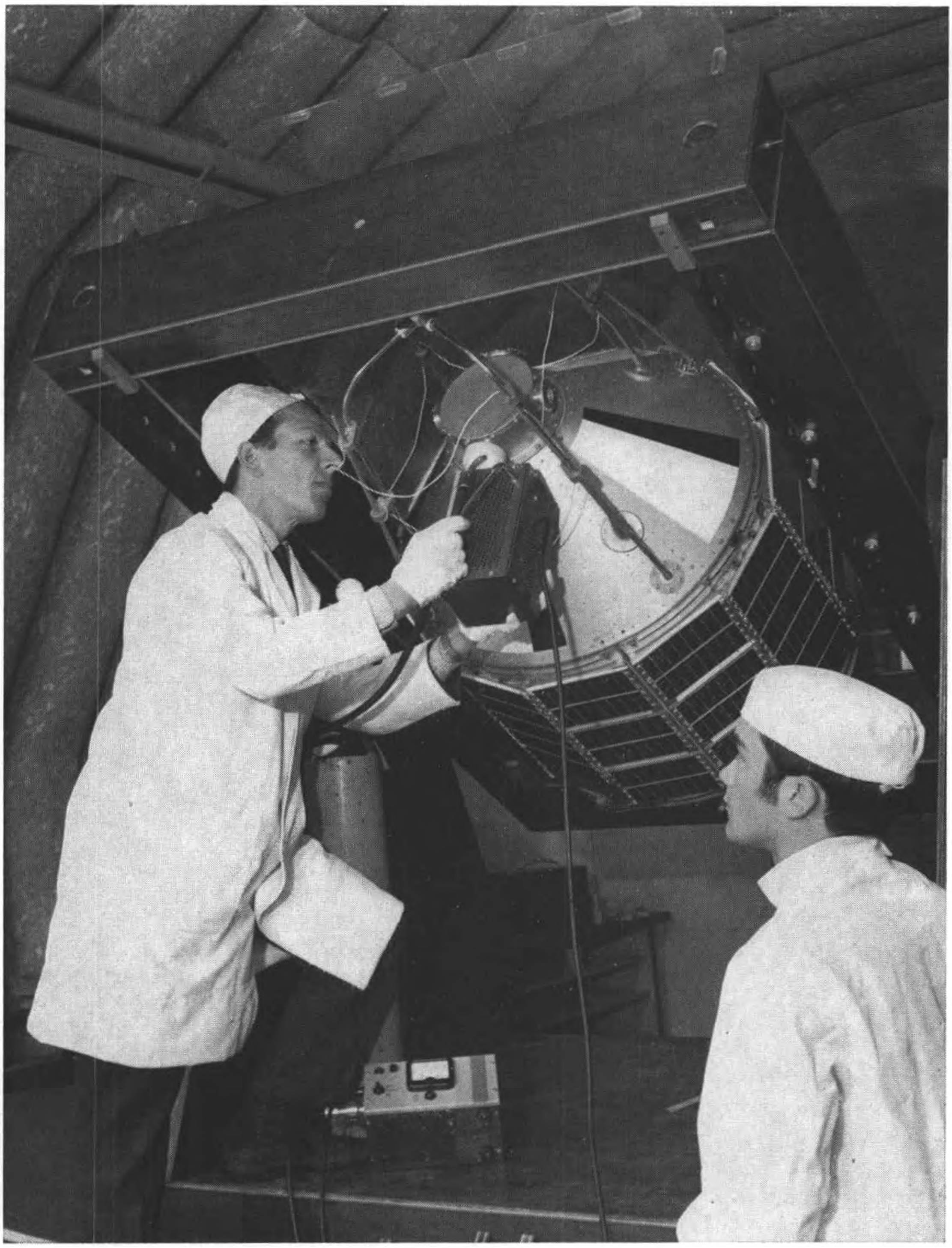
Photograph by courtesy of Hawker Siddeley Dynamics Ltd., Coventry

The Automatic Picture Transmission picture receiving station showing the prefabricated hut and helical aerial. Several of these stations are being installed at home and abroad for the reception of cloud pictures from weather satellites

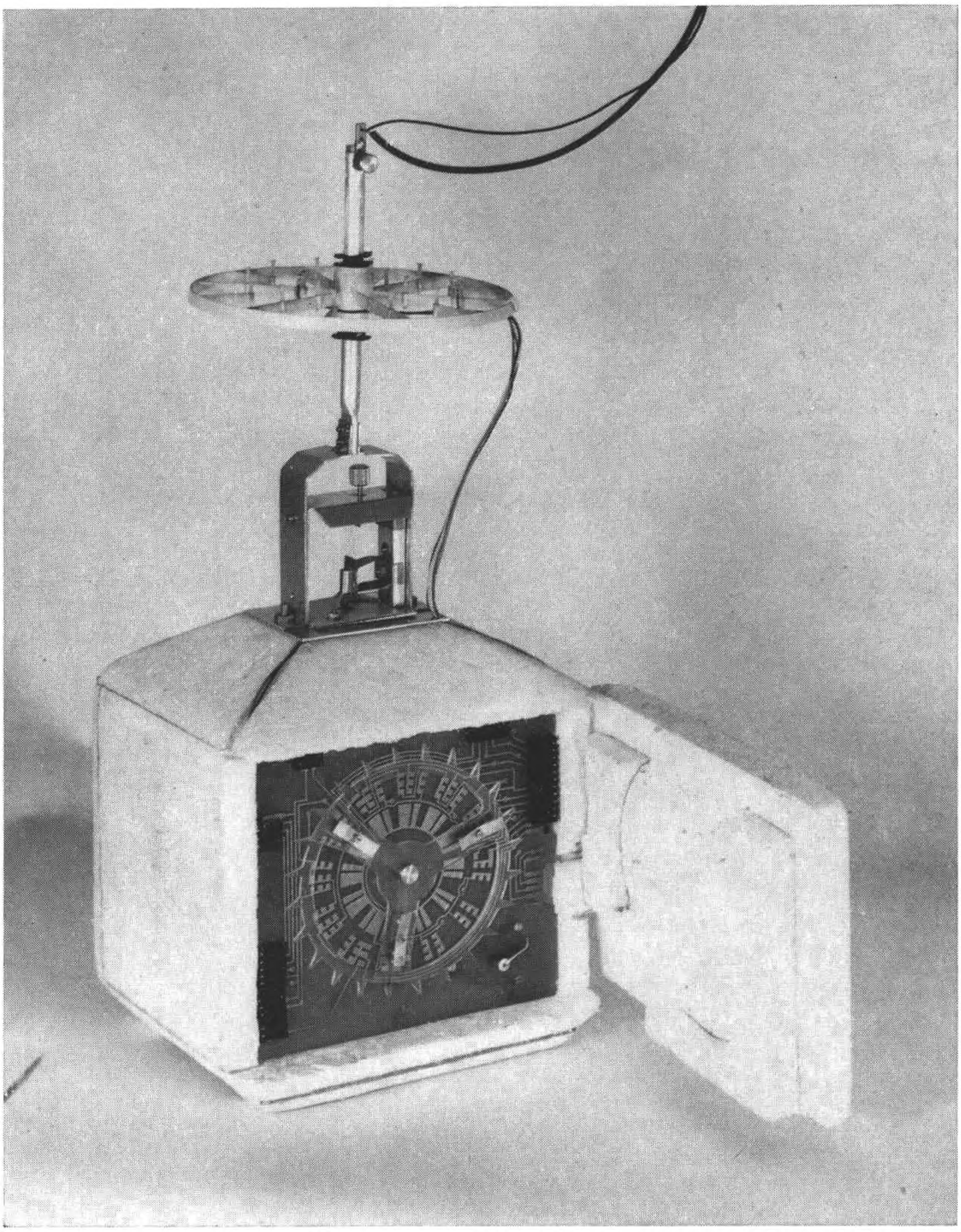


A depression to the north-east of the British Isles as seen by ESSA-II at 0915 GMT on 23 May 1966. The 'eye' of the depression can be seen and the associated cold front with cumuliform masses behind. Ireland and much of England are readily distinguished.

PLATE VI

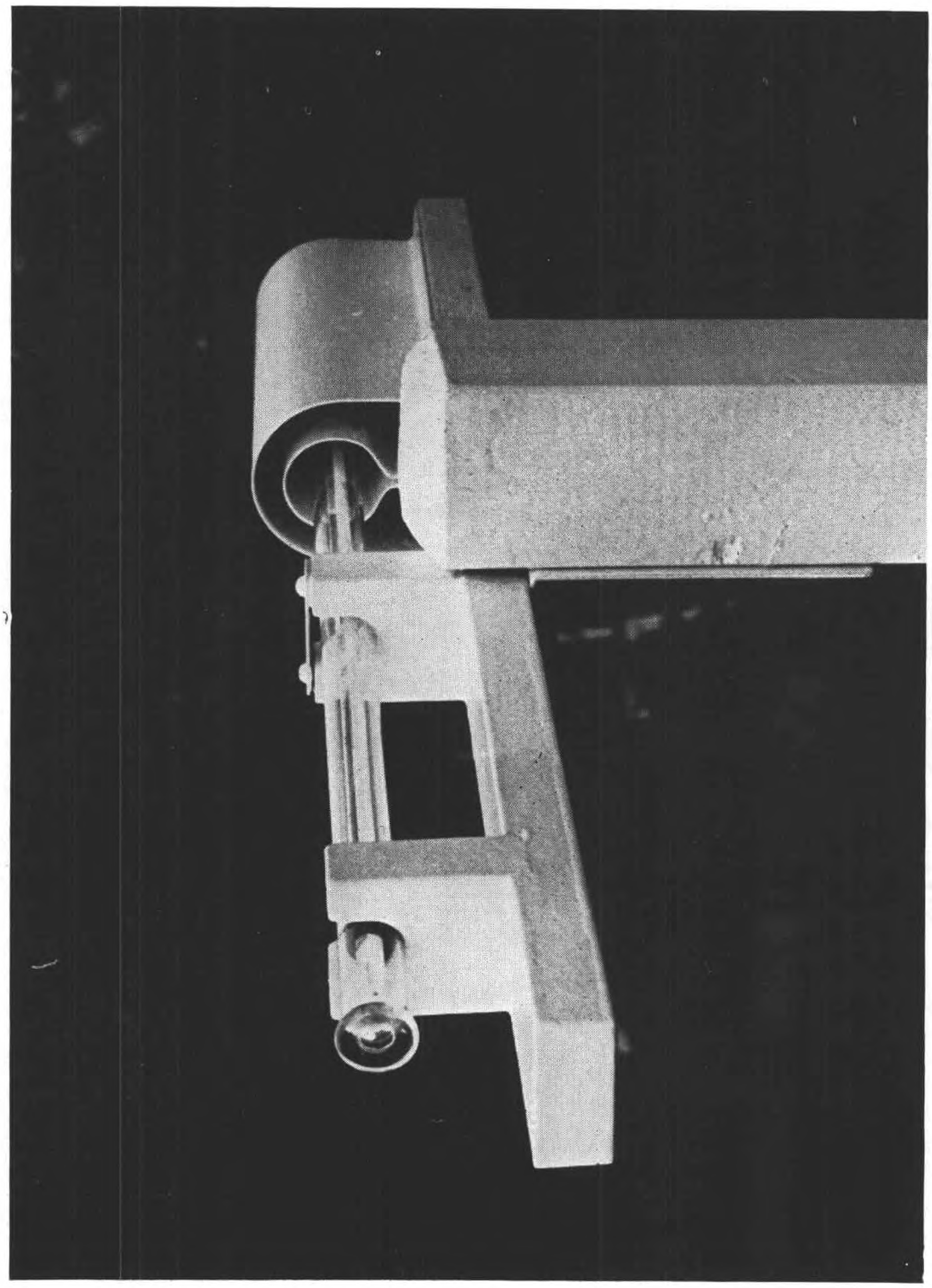


Carrying out final checks on the Meteorological Office Molecular Oxygen Experiment on the satellite UK-3.



Pre-production model of Radiosonde Mk 3b. This instrument is designed to transmit radio signals representing values of atmospheric temperature, pressure and relative humidity. The insulating housing is about nine inches high. When borne aloft by a hydrogen-filled balloon the sonde provides data up to an altitude of 45 kilometres. (See page 39).

PLATE VIII



'Cocoa-tin' thermometer mount (see page 2).

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network	74,772

TABLE VII—METEOROLOGICAL COMMUNICATIONS TRAFFIC

Almost all the national and international exchanges of meteorological data, which are used in the construction of synoptic charts and the production of forecasts, is effected by either coded messages or facsimile charts. The coded messages are composed of groups of five figures and there may be three to thirty such groups in one message. The messages are exchanged by radio and land-line. The following figures give an analysis of the traffic through the Meteorological Office Communications Centre for one typical day (24 hours) taken near the end of December 1966 and, for comparison, some corresponding figures for one day near the end of 1965.

Telecommunications traffic for one day

		Number of groups in one day		
Coded Messages	*In*	*Out*	*Total*	*Total in 1965*
Land-line teleprinter	352,997	253,590	606,587*	724,990
Radio	169,319	187,534	356,853	340,853
Facsimile Charts		*Number of charts in one day*		
Land-line	5	169	174	88
Radio	107	76	183	186

* This total is considerably below the 1965 total mainly owing to the large reduction in the data exchange with Montreal (approx. 60,000 groups less) and closure of the North Atlantic Broadcast (approx. 56,000 groups).

TABLE VIII—SPECIAL SEASONAL FORECASTS

There is a need for forecasts of a particular type at certain seasons. These are described in Met.O. Leaflet No. 1. The numbers of customers receiving such specialized forecasts are as follows:

	Year	*No. of customers*	*Year*	*No. of customers*
Fine spell notifications (a summer service primarily for farmers)	1965	642	1966	566
Weekend temperature forecasts (a winter service primarily for industrialists) ..	1965–66	43	1966–67	39
Snow and icy road warnings (primarily for Local Authorities)	1965–66	256	1966–67	261

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office is almost solely concerned with analysis of the weather situation, the issue of guidance in outline to other offices and the issue of forecasts to the BBC and the national Press. Thus the volume of work in the Central Forecasting Office shows little variation from year to year. The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings which took place during 1965 and 1966. They do not include warnings and routine general forecasts.

	1965	*1966*
Number of meteorological briefings for		
aviation in United Kingdom	348,806	347,648
aviation at overseas stations	68,863	69,537
Number of aviation forecasts issued for		
aviation in United Kingdom	951,932	979,659
aviation at overseas stations	283,356	302,278

TABLE X—NON-AVIATION INQUIRIES

Non-aviation inquiries are handled by four weather centres specially established at London, Manchester, Glasgow and Southampton to meet the needs of the general public for forecasts for special purposes. Many of the forecast offices are established primarily to meet aviation requirements, but also answer telephone requests, for forecasts and other weather information, from the general public, public corporations, Press, commercial firms etc. (the *Post Office Guide* lists 39 such offices). All but an insignificant proportion of these inquiries refer to current or future weather and are categorized according to the purpose of the inquiry in the figures below. Climatological inquiries are dealt with in Table XIII.

	1965	*1966*
Grand total of inquiries (all offices)	1,162,107	1,204,921
Percentage of inquiries connected with agriculture, etc.	11·5	11·1
buildings, commerce, industry	10·1	10·3
holidays	17·3	18·3
marine matters	16·5	16·6
Press	8·7	8·9
public utilities	8·7	8·6
road transport	12·8	10·4

TABLE XI—BBC FLASH WEATHER MESSAGES

FLASH weather messages, which are passed to the BBC for broadcast on the Light Programme, are effectively warnings of the actual occurrence of weather conditions which might cause considerable inconvenience to a large number of people. The following table shows the kind of weather and areas of the country for which FLASH messages are broadcast and the number issued in 1966.

Area	*Dense fog*	*Moderate or heavy snow*	*Very heavy rain*	*Glazed frost*
Edinburgh	—	—	—	—
Central Clydeside	—	1	1	1
Belfast	—	—	—	—
Tyneside	—	1	1	—
Merseyside and south-east Lancashire	2	—	—	1
West Yorkshire	—	—	—	—
Industrial Midlands	—	1	—	—
Bristol and industrial South Wales	2	—	—	—
Greater London	2	1	2	—
Southampton/Portsmouth	—	—	—	—
Plymouth	—	—	1	—
Total	6	4	5	2

In addition one warning of heavy rain of a more general nature was issued.

TABLE XII—AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

The total number of calls made on the service during 1966 showed an increase of 12 per cent over the previous year. Forecasts were made available at 5 more GPO Information Centres bringing the total of such Centres to 25. The number of forecast areas increased from 17 to 19. The figures below are supplied by courtesy of the Postmaster-General.

Information Service Centre	*Forecast Area*	*Number of calls 1965*	*1966*	*Remarks*
London	London	3,544,904	3,585,999	
London	Essex Coast	194,665	192,330	
London	Kent Coast	170,194	180,800	
London	Sussex Coast	241,138	247,593	
Colchester	Essex Coast	120,965	137,244	
Brighton and Hove	Sussex Coast	212,992	255,007	
Birmingham	Birmingham	446,666	510,967	
Liverpool	South Lancashire and North Cheshire	239,947	243,713	
Liverpool	Lancashire Coast	72,801	80,748	
Liverpool	North Wales Coast	41,605	56,335	
Manchester	South Lancashire and North Cheshire	294,338	302,536	
Manchester	Lancashire Coast	60,506	57,302	
Manchester	North Wales Coast	28,672	31,098	
Cardiff	Cardiff	248,874	272,877	
Belfast	Belfast	208,944	311,684	
Glasgow	Glasgow	350,662	367,858	
Edinburgh	Edinburgh	234,947	318,596	
Bristol	Bristol	257,163	304,494	
Portsmouth	Southern Hampshire	146,339	165,895	
Southampton	Southern Hampshire	198,030	194,675	
Canterbury	Kent Coast	121,223	118,396	
Blackpool	Lancashire Coast	150,058	153,227	
Southport	Lancashire Coast	51,204	55,290	
Plymouth	South Devon and East Cornwall	44,538	61,359	Started May 1965
Exeter	South Devon and East Cornwall	11,538	46,699	Started September 1965
Newcastle	Tyne-Tees	57,397	195,660	Started September 1965
Blackburn	Central Lancashire	2455	58,364	Started December 1965
Blackburn	Lancashire Coast	731	25,656	Started December 1965
Bournemouth	Southern Hampshire	—	43,281	Started March 1966
Nottingham	Nottingham, Derby and Leicester	—	51,586	Started March 1966
Leicester	Leicester, Derby and Nottingham	—	30,732	Started March 1966
Middlesbrough	Tyne-Tees	—	24,301	Started June 1966
London	Thames Valley	—	10,026	Started October 1966
Oxford	Thames Valley	—	8841	Started October 1966
	Total	7,753,476	8,701,169	

TABLE XIII—CLIMATOLOGICAL INQUIRIES

Most of the inquiries dealt with by the offices outside Headquarters refer to current weather or to forecasts. Met.O.3, Met.O.8, Edinburgh and Belfast receive a number of inquiries relating to past weather, to climatology, and to the application of meteorological data to agriculture. The following figures give the total number of inquiries and the percentages of this number arising from the main reasons for the inquiries.

	1965	*1966*
Total number of climatological inquiries	9819	11,006
Percentage relating to		
Agriculture (farming, forestry and market gardening)		13·9
Building and Design (including siting)		15·0
Commerce (sales, marketing and advertising)		4·8
Education and literature		6·3
Heating and Ventilation		2·2
Industrial and manufacturing activities		7·2
Law (damage, accidents, insurance)		16·7
Press and Information Centres		3·9
Research		5·1
Water Supplies		8·0

TABLE XIV—DATA PROCESSING

Punched-card installation

Number of cards punched by the Meteorological Office installation	772,782
Number of cards punched elsewhere on behalf of the Meteorological Office	949,194
Number of cards converted to paper tape	18,000
Number of cards converted from paper tape	729,379
Number of non-routine investigations completed	168

Computer installation

The electronic computer COMET was used for computing during 5927 hours.

TABLE XV—INSTRUMENT TESTING AND CALIBRATION

The numbers include those of instruments tested or calibrated for outside authorities on repayment.

	Numbers of tests or calibrations
General meteorological instruments	58,075
Balloons	94,487
Radiosonde batteries	16,390
Radar reflectors	31,981
Electrical/electronic instruments and components	41,122
Radiosondes calibrated	19,158
Total	261,213

In addition 2317 radiosondes were recovered after flight and 78 per cent of these were serviced and reissued for further use.

THE DIRECTORATE OF RESEARCH

SPECIAL TOPIC—INSTRUMENT DEVELOPMENT IN RECENT YEARS

This article is concerned with a representative selection of instruments which have been developed and, in some instances, introduced into service in recent years for the routine collection of data needed by the Office to fulfil its many functions. It does not deal with any instrument produced for a research project where the scientist has been in close touch with its operation and use. It is not always appreciated that these two categories of instrument may be quite different. Equipment intended for routine use by people who have not been closely associated with its construction must have a degree of simplicity in use, a built-in tolerance against misuse, and an overall reliability and robustness. These qualities are not necessary to anything like the same extent when the equipment is to remain in the hands of a skilled operator who may require it to function only for short periods without knowledgeable attention. Furthermore, if manufacture of any instrument is to be initiated and is to proceed smoothly the design must take account of the need of the manufacturer to have permissible tolerances in the characteristics of its component parts. The production of laboratory models and working prototypes may however be undertaken without regard to such considerations, and instruments intended for research use may well never proceed beyond this stage. The instrument designed for routine use must be economically priced if it is to be put into widespread service; it must be capable of easy calibration in considerable numbers and must retain its calibration over long periods; it should have a long shelf life without the need for special storage conditions; it will often be required to operate correctly over a wide environmental range; and it must be constructed to withstand normal transport risks. These desirable characteristics, which are often incompatible amongst themselves, must be fully considered in a detailed design. It is unlikely that any two designers working independently on the same project would produce identical solutions; each would make his own compromise between the often conflicting requirements.

Meteorological instrumentation has a fairly long history and a brief reference to this background is appropriate. When meteorology started to develop as an organized science about the middle of the last century the mercury barometer and thermometer were well-established instruments. Interest in the provision of further instrumental aids led to a multiplicity of different instruments for the measurement of each individual parameter. A notorious example is the number of variants of the basic rain-gauge introduced during the second half of the last century. The early years of the present century were largely devoted to the introduction of standardization in the manufacture, calibration and exposure of meteorological instruments for use near the ground and to reduction of the number of types in service. This process continues today, a recent example being the introduction of the standardized rain-gauge system which will be referred to later. Interest in instruments designed for use at ground level waned in the late 1920's when observation of the conditions in the upper atomosphere became feasible, firstly by the use of mechanical instruments carried on aircraft or on small free balloons (which subsequently had to be recovered in order to extract the data) and later by balloon-borne radiosondes from which the meteorological information is transmitted by radio to the ground and can be used immediately. The 1940's and the early years of the 1950's saw the development and introduction into routine meteorology of upper air observations and only in the last 10 years has active interest in the redesign of the old 'surface' instruments been revived. This revival has been largely due to the advent of electronic devices and has resulted in a new generation of instruments which are now finding their way into service. Interest in the further improvement of upper air observing equipment continues, however, and considerable effort is currently being applied to extend such observations to greater heights and to achieve better accuracy and reliability.

The work of the Instrument Development Branch of the Office has been deliberately slanted towards satisfying the needs of the general observational network, although it helps the various research branches in the acquisition of equipment for their own work. It also tries to look ahead to the future requirements of the network and conducts some research into instrument design and performance. The remainder of this article will describe some of the developments of recent years which have already been applied in service and will refer to others which have yet to be introduced.

The importance of electronics has already been mentioned and its impact on meteorological instrumentation is well illustrated by the automatic weather stations which are now being introduced. The Meteorological Office automatic station has become possible as a result of the development of a series of sensors or transducers for each of the commonly measured meteorological parameters. These sensors are themselves meteorological instruments but, unlike the traditional instruments, each measures the particular parameter in terms of an electrical output which can be presented by one of a variety of signalling techniques at some distance from the point of observation. They can be used singly or in any combination for this purpose and eliminate the need for staff to leave other duties in order to make observations. In general they operate from low-voltage sources so that the provision of mains power, though still a convenience, is not essential. Their accuracy and reliability are at least comparable with, and in some cases better than, those of traditional instruments.

In the United Kingdom the operational need for automatic stations has until recently been marginal for it has been possible to find people whose normal work requires them to live in the more remote areas and who have been willing to accept the part-time task of observing with the aid of traditional instruments. However, with the coming of automation in other fields and the realization that it might be possible to obtain better observations and to fill gaps in the network at permissible cost, development of an automatic system was started. It will be apparent that the task was to produce a system for automatic observing in reasonably accessible places rather than one for use in extremely remote areas where servicing visits could only be undertaken at very infrequent intervals. The essentials of any automatic station are a number of sensors or transducers to transform the values of the parameters which it is desired to measure into electrical signals, and a means of transmitting the information to the place at which it is required. Other requirements are, of course, a power supply, a programming unit or clock to control, for example, the order in which the measurements are made, a means of displaying the information at the receiving end, and possibly a recorder at either the transmitting or receiving position. The automatic station now available senses, records, and transmits on demand values of most of the normally observed meteorological elements to accuracies which approach those usually obtained at manned stations. For example, atmospheric pressure is measured to $\pm 0 \cdot 5$ mb. The corresponding figure at manned stations is about $\pm 0 \cdot 3$ mb. Temperature is certainly reliable to 0·2 degC and wind speed to 0·5 kt in the 10-minute mean which is the required form of presentation. All the transducers use electronic components, particularly solid-state devices, and breakdowns are very rare. Each produces a voltage output, normally in the range 0 to 1 volt, which is linearly proportional to the value of the element being sensed. At present no transducer for 'cloud amount' has been constructed and it is difficult to imagine how this observation could be obtained by automatic means. Cloud-height determination is also not included in the system now being introduced into service, but a sensor is available and if the measurement were required it could be provided by a parallel system. Transmission of the information is achieved by the use of the GPO telephone system, the observational site having a normal exchange telephone number. The transmitter, which is part of the remote station, converts the transducer output voltages into audio tones which are then passed over the line to the receiver where they are re-converted to voltages and displayed on dials. The dials are calibrated in terms of the meteorological elements. The system enables up to 12 different elements to be displayed and the information is obtained by telephoning the remote site in exactly the same way as one would telephone any other subscriber. The data may be read from the dials during the course of the call or at leisure after its termination. There is no limitation to the distance between transmitter and receiver and various features are incorporated in the telemetry system to guard against malfunction and the presentation of erroneous data. Any one receiver may be used to interrogate any number of transmitters and any one transmitter may be used in conjunction with any of a number of receivers. The remote station console normally incorporates a recorder which operates continuously and independently of the telemetry thus enabling climatological data to be extracted at any convenient time. The basic equipment is very flexible in application. For example, plans have been made to use it to obtain temperature, humidity and wind information, on demand, from various levels on a 1000-ft high tower.

Development of other surface instruments for which a remote reading or telemetry role is not necessarily needed has not been neglected. Here may be cited two examples, namely a modern replacement for the familiar mercury barometer and new standardized rain-gauge equipment. The Kew pattern mercury barometer which has been in general use in the Meteorological Office for many years is simpler than most precision barometers but even so requires that two independent readings be taken to arrive at a value of station-level pressure. These readings are the height of the mercury column and the temperature of the mercury in the instrument. Both readings are made by eye interpolation against divided scales and care is needed in taking them. Owing to the construction of the barometer it is not easy to move it from site to site and many breakages occur. Furthermore, it is found that after it has been set up at a new site a considerable period elapses before reliable pressure observations are obtained. The precision aneroid barometer, which has already replaced the mercury barometer on 'selected ships' and will soon be introduced at meteorological offices supplying information for aviation, overcomes many of the difficulties associated with mercury barometers. Because of the ease with which it may be moved from place to place without damage, it offers for the first time a means of making frequent and systematic checks on barometers which are in service. To arrive at a value of atmospheric pressure only one reading is needed and this is obtained from a numerical counter which considerably reduces the possibility of observational error.

The new rain-gauge system is a good example of development which not only achieves rationalization but takes advantage of new constructional materials to obtain enhanced performance and a saving in cost. Over past decades copper has been the material predominantly employed in rain-gauge construction. It is not ideal for this purpose since it has a high thermal conductivity and the character of its surface finish changes with time. A glance at any handbook of meteorological instruments will show that many different shapes and sizes of rain-gauge have been in use, even in recent years, to cover the complete range of rainfall measurement needs. These needs can now be satisfied by only four interchangeable collecting units incorporating two funnel sizes and made in glass-reinforced plastic. A fifth component which completes the system is a tipping-bucket switch, which may be attached to either of the two funnel sizes provided, to yield electrical impulses at each 1 mm or 0·2 mm increment of rainfall. These increments may then be recorded against time on an analogue-chart recorder or on a magnetic-tape recorder which is currently under development as part of an attempt to present most meteorological recordings in a form easily adapted to processing by computer. The gauges may be used in conjunction with a rain measure in the normal way if daily totals of rainfall only are required.

It will be readily appreciated that within the Meteorological Office large numbers of recording instruments are in continuous use. These in general produce records in ink on paper and then much effort is required to extract and tabulate data from the recordings. This work is tedious and provides ample opportunity for mistakes and for differing subjective assessment from person to person. If records are taken in a form which can be fed directly into tabulating and computing machines, a gain in speed and consistency results, together with the elimination of much drudgery. An early example of a step in this direction was the provision of the so-called Meteorological Office Data Logger Type 1. This machine accepts the output from up to 12 transducers and records their output in turn on punched paper tape. About 15 of these machines have been in use at home and abroad and bearing in mind that they were introduced into service some four years ago and the fact that they were our first attempt at using equipment of this type, they have given good service. However, they were not intended for use with individual instruments and for this purpose it is planned to provide magnetic-tape recorders—the magnetic-tape rainfall recorder is an example. Currently steps are being taken to obtain such recorders for solar radiation instruments, for the automatic weather stations and to replace the data logger itself by a new type.

There have been advances in instrumentation for the measurement of humidity, cloud height, visibility, wind, etc. which an article of this length cannot discuss. Rather, an attempt has been made to give some account of the general trend of development in surface instrumentation before proceeding to outline recent work on the improvement of upper air observational equipment.

For some years there has been a keenly felt need to extend current upper air observations to greater heights and to obtain more accurate and consistent information. Upper winds are determined by the use of ground-based wind-finding radars working in conjunction with balloon-borne targets. Temperature, humidity and pressure are determined by the use of a radiosonde, normally attached to the same balloon as the wind-finding radar target and operating in conjunction with special ground-based receiving equipment. An overall improvement in upper air observations therefore calls for enhanced performance from radar, the balloon and the radiosonde system. New wind-finding radars are currently being installed at home and abroad. They provide an increase in range and, because they are able to follow a target automatically, they also provide the more accurate and consistent bearing and elevation determinations required for increased accuracy in the upper-wind calculations. It is, of course, essential that the balloons themselves reach greater heights before bursting. Constant effort has been devoted to the trials of new balloon materials and types with this aim in view, and encouragement has been given to manufacturers to produce balloons of better performance, but progress has been disappointingly slow. In the normal course of operations in 1961, soundings using rubber balloons reached an average of 19 km. The corresponding figure for the first half of 1966 was 22 km, using balloons with twice the nominal rubber content of those used in 1961. The outlook is not encouraging unless the use of more expensive materials for balloon manufacture becomes generally acceptable. Neoprene balloons, flown by selected stations on a trial basis, have achieved heights between 30 and 34 km depending on location and season. Generally speaking, as the size of the balloon increases the extra height reached increases only slowly, whilst the cost increases rapidly.

The present radiosonde has been in use for over a quarter of a century and has given excellent service. The fact that no large changes have been made during this period demonstrates the soundness of the original design. Over the last 10 years, however, the performance has failed to match the advance in meteorological requirements and the point has been reached when a new sonde is urgently required. The user of sonde data needs a closer approach to uniformity between one sounding and another, a better representation of the vertical profile of temperature and humidity, and increased accuracy. A completely new design of sonde known as a Mark 3 is at present undergoing flight trials and is expected to provide a substantial improvement in performance (see Plate VII). In designing a new radiosonde it is not enough to provide a means of satisfying today's needs. The basic concept should be such that changes can be made in the future without a further complete re-design. For example, it is to be hoped that a better humidity sensor will eventually become available and it should be possible to accommodate any likely developments in this field.

The most significant atmospheric property measured by a radiosonde is temperature. The new sonde uses a fine wire resistance thermometer strung as a coiled coil around a plastic frame. The most important advantage of this thermometer over that hitherto used is its ability to follow temperature changes very rapidly. Corrections for the effects of solar radiation are necessary with any thermometer, and those applied in normal operations are necessarily appropriate to average conditions. In practice the radiation intensity to which the thermometer is subjected differs from the mean values assumed. The difference leads to errors in the deduced temperatures which are essentially proportional to the thermometer's sensitivity to radiation. The new thermometer is not only much less sensitive to radiation but it is sensitive to only some of the disturbing effects present in the existing sonde design. Overall, the new design has a residual temperature error in the stratosphere which is about ten times less than that of the present operational instrument. The ability to follow temperature changes is especially important in a radiosonde which traverses the whole range of atmospheric temperature from perhaps +40°C to −70°C in the course of 50 minutes or so. The lag in response of the present operational thermometer is large, and corrections, again necessarily imperfect, have to be applied. The new thermometer has a lag which increases from milliseconds at the surface to about half a second at an altitude of 40 km. In the radiosonde context such lags may be neglected. Other useful properties of the new thermometer are the consistency of its performance from one sounding to another and its stability over a long period, properties which lead to a reduction in the effort spent in calibration and to less uncertainty in the observations. The new thermometer is regarded as a major advance in radiosonde temperature measurement. It cannot be embodied in the present operational sonde design and the advantages to be derived from its use would alone justify a new design of sonde to carry it.

The second most important atmospheric parameter measured by radiosonde is humidity, which, in the present operational equipment, is sensed by gold-beater's skin. No suitable alternative to this primary sensing material has yet been found and it will be adopted, for the time being, in the new sonde. Provision has been made for the use of another type of humidity sensor if a suitable one is developed.

The third parameter measured in routine ascents is atmospheric pressure which is used as a scale to which temperature and humidity are related. Because of the logarithmic decrease of pressure with altitude, it is necessary that the pressure sensor provide better resolution at low than at high pressures. A wholly satisfactory solution to this requirement must, at the present time, consist of two pressure sensors each covering part of the complete range. Cost considerations make this solution unattractive. An aneroid capsule has been developed which, although not meeting the requirement in full, nevertheless provides useful pressure data over a much greater altitude range than does that in the existing operational sonde. At the same time the new sonde design allows for the inclusion of a second, low-pressure, sensor if the extra cost should become acceptable.

It has been necessary to ensure that the telemetry link between the balloon-borne sonde and ground receiver does not degrade the data, and the opportunity has been taken to incorporate circuits which make the telemetry signal pattern suitable for direct processing by electronic digital computer. This possible further step in the overall system, which offers improvements in arithmetical accuracy and somewhat greater speed in the reduction of the data to the form required by the user, is currently under evaluation.

Another function of each sounding consists in the tracking of the ascending balloon by means of radar in order to determine the upper winds. Electronic computation offers enhanced accuracy in this aspect as it does for the radiosonde data. The new radar is such that units may be added to it to provide the necessary computer input signals if these should be required.

The emphasis within the whole field of meteorological instrument development at the present time can be summarized as the employment of modern materials and electronic techniques to provide greater accuracy of measurement together with enhanced convenience to the operator. Coupled with this is the desire to reduce, where practicable, the variety of instruments with otherwise similar functions, and to standardize and make automatic the methods of recording and processing meteorological data.

ORGANIZATION OF THE RESEARCH DIRECTORATE

Some important changes were made in the organization of the Research Directorate during the year. A new research branch was formed for the study of the physics and dynamics of clouds. It will provide for the continuance of the British work in cloud physics which had previously been centred in the Department of Cloud Physics at Imperial College, London, internationally recognized as a leading centre in this field. Details of the organization and work of the new branch are given on p. 44.

The new branch absorbed the research on cloud physics which had previously been carried out within the Office under the Assistant Director (Atmospheric Physics), but the important work of assessing the frequency of clear-air turbulence, strong temperature gradients and other atmospheric phenomena of significance to aircraft design and operation were transferred to the Assistant Director (Special Investigations) who was already responsible for advising on other meteorological factors relevant to aircraft design and operation.

As part of the general reorganization of the Office at the end of October the Instrument Development Branch was transferred to the Services Directorate and now forms a major responsibility of the Assistant Director (Instruments and Observations). An account of some aspects of the work of the Instrument Development Branch over recent years is given as a 'Special Topic' preceding this section of the report. Other aspects of the work are described with the activities of the Services Directorate.

When the Services Directorate was reorganized on 1 November 1966, a small headquarters research group was transferred from the disbanded Forecasting Techniques Branch to the Research Directorate (Publications and Training). This group studies and advises on the techniques employed at forecasting offices. Its work is briefly described along with other research on short-range weather forecasting on p. 46.

Steps were taken to co-ordinate the work of the Office on turbulence and diffusion in the lower atmosphere under the scientific direction of Dr F. Pasquill and to develop Cardington as an observational site for the experimental work on this subject.

Three members of the scientific staff continued to give lectures at Reading University to students in the Department of Meteorology.

A review of the research programme of the Office was maintained by the Meteorological Research Committee and its sub-committees and nine meetings took place. Valuable advice and assistance were contributed by the committee members from the universities and other government departments. By means of visits and lectures, close liaison was also maintained with university departments with interests in related fields of physics and dynamics; three members of university staffs spent periods at Bracknell during the summer as consultants on various topics.

An exchange of research scientists was arranged with the Environmental Science Services Administration (ESSA) of the USA as a result of which Dr F. B. Smith of the Meteorological Office is spending a year at the Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, Tennessee to continue his studies of turbulence. In exchange Dr Lester Machta, Director, Air Resources Laboratory, Institute for Atmospheric Sciences of ESSA is spending a year at Bracknell and, in collaboration with scientists of the Meteorological Office, is continuing his work on the transport of radioactive dust in the stratosphere.

PHYSICAL RESEARCH

Micrometeorology. This subject, which covers the study of turbulent air motion in the lower atmosphere, the climate near the ground and the dispersion of atmospheric pollution, is one which has been studied intensively for many years within the Meteorological Office and it was decided that it should be one of the fields in which the expansion of research effort should be concentrated. A beginning was made on study of the interaction between the atmosphere and the sea, and a newly appointed Senior Research Fellow collaborated with Navy Department scientists in an investigation in waters off Malta of the detailed structure of the upper layers of the sea. Work is proceeding on plans and equipment for a similar expedition in 1967, and it is hoped in subsequent years to extend the measurements to the lower atmosphere and to investigate other localities. Plans are also being made, and equipment is being constructed, for an investigation, more intensive than any hitherto undertaken by the Meteorological Office, of air movements in the lowest 1000 m of the atmosphere over land, with the intention of relating the smaller-scale motions to some aspects of the behaviour of larger weather-producing systems.

Study of the microclimate in crops continued, in co-operation with the Botany School of Cambridge University and the Plant Breeding Institute at Trumpington. The experiments included some in which artificial drought conditions were produced within a crop and others in which very detailed records of solar radiation and illumination were made within crops of different densities, the growth rates and yields being monitored.

Radiation recording. The first results were obtained from an instrument, located at Bracknell, which continuously measures the solar radiation reaching the ground in 15 wavelength-bands selected by interference filters. Some instrumental problems remain to be solved. Much work was done on programmes for quality control and processing of continuous records of solar and terrestrial radiation at ground level from about 20 stations (15 of them controlled by the Meteorological Office). By agreement within the World Meteorological Organization, U.K. radiation data are being published in a standard format by the Hydrometeorological Service of the U.S.S.R. and the first batches of British data, for 1964 and 1965, were sent to Russia.

Meteorological Research Flight. The research programme of the Flight again experienced much delay because of the unserviceability of its aircraft, and the Hastings was finally grounded pending a decision on its future. It will be out of service for a year or more. A working party with Air Staff and Meteorological Office representation examined in some detail the suitability of various aircraft types for the Meteorological Research Flight and reported towards the end of the year.

For safety reasons restrictions were placed on the use of the Flight's Canberra aircraft in turbulent conditions above 35,000 ft. Gratifying progress was, however, made in the investigation of clear-air turbulence at rather lower levels, and a flight plan was evolved which resulted in an unexpectedly high number of encounters. The synoptic patterns and the details of local atmospheric structure on these occasions are being analysed.

Problems associated with high-level flight and the supersonic transport aircraft. It was decided that the Ministry of Aviation (subsequently Ministry of Technology) should be responsible for the programme of experimental flying at the highest altitudes in connexion with certification of the Concord supersonic transport. The aircraft carrying out this survey of meteorological conditions at high speeds will be operated by the Royal Aircraft Establishment. One scientist from the Meteorological Office was attached to the unit concerned from 1 December to assist in the planning of flights and the interpretation of results. The Meteorological Research Flight programme of investigations into clear-air turbulence is concerned with establishing an understanding of its mechanism and strengthening the basis for forecasting its occurrence. This programme is complementary to and co-ordinated with that of the Royal Aircraft Establishment: it can be pursued at present at the lower heights accessible to the Meteorological Research Flight aircraft.

Meteorological Office scientists have given advice concerning the instrumentation of the prototype and pre-production Concords, and have taken part in the deliberations of the tripartite (France, United Kingdom and United States) committees studying problems of supersonic flight. A study was prepared of meteorological aspects of the 'sonic boom' problem.

Cloud physics and cloud dynamics. For many years laboratory and theoretical investigations in cloud physics in this country were centred in the Physics Department of Imperial College, London, under Professor B. J. Mason. When Dr Mason was appointed as Director-General of the Meteorological Office the College decided to disband the Cloud Physics Laboratory. It therefore became necessary to increase the research effort in this direction within the Meteorological Office. Key members of the Imperial College team joined the staff of the Office and essential equipment was transferred in September to rented accommodation close to the Headquarters building at Bracknell. By the end of the year the new laboratory was in full operation, though hampered by the shortage of supporting staff. Of the problems which had previously been under study within the Meteorological Office good progress was made in the counting of atmospheric freezing nuclei. The technique of using microfilters was further developed and very thoroughly tested in the laboratory and open air. Sampling from Meteorological Research Flight aircraft will soon begin.

The decision to open a cloud physics laboratory at Bracknell was coupled with a proposal to increase the strength of the Meteorological Office unit located at the Royal Radar Establishment, Malvern, which uses sophisticated radar techniques to investigate the structure of clouds and the air movements in and around them. The agreement of the Director of the Royal Radar Establishment was secured, together with a promise of a parallel increase in scientific co-operation and technical support from his own staff. The unit continued its previous work using Doppler radar to investigate air movements in frontal rain and several situations were analysed. Plans were made for intensification of this work in co-operation with the cloud physics laboratory at Bracknell and the Meteorological Research Flight.

Staff of the Meteorological Office were invited to join in the work of the National Severe Storms Laboratory at Norman, Oklahoma and two scientists and one technician spent periods of four to eight weeks there during April, May and June. It is hoped, and expected, that this valuable collaboration will continue.

High Atmosphere. Late in 1965 the team preparing an experiment designed to measure the concentration of molecular oxygen in the atmosphere at a height of 160 km, to be incorporated in the satellite U.K.-3, was compelled to withdraw its proposal, as manufacturers were unable to meet the specification of a vital component of the equipment. Early in 1966 the Science Research Council accepted for the same satellite an alternative method of making the same measurement. Work has continued on this project, and suitable equipment will be ready in time for incorporation in the satellite, which is expected to be launched in March 1967.

Analysis of the data from the ozone measuring equipment on satellite ARIEL II is still far from complete, though about 80 cases have already been processed by computer. With a very few exceptions these cases yield identical results, within the limits of experimental error. In connexion with the ozone-measuring experiment, equipment was flown on four Skylark rockets during the year, two of them launched from Woomera in the programme sponsored by the Science Research Council and two from Sardinia in the programme of the European Space Research Organization. The two experiments launched from Woomera were apparently successful. One of the Sardinia experiments was a total failure and one was partially successful, but in each case there was no fault in the Meteorological Office equipment. The unstabilized Skylark rocket is not the ideal vehicle for this work, and it is hoped at a later stage to mount equipment on stabilized rockets, using the moon as a light source in the first instance. Equipment is being built for this work, but it is not yet known when suitable rockets will be available.

Examination of the results of earlier rocket experiments, whose primary purpose was ozone measurement, combined with some of the ARIEL II results has revealed the presence of dust concentrations in the atmosphere at heights of 20–30 km, far greater than those expected. The indications are that most of the dust was injected by the eruption of Mt Agung, Bali, in March 1963.

A subsidiary experiment was carried on the two Skylark rockets fired from Woomera. This was an attempt to confirm the recent finding of Brewer and Wilson that the solar intensity at a wavelength of 2100Å is considerably less than (possibly $\frac{1}{3}$ of) that usually assumed. Our measurements were made at a rather longer wavelength (2250Å). Reduction of the observations is nearly complete; the indications are that the Brewer–Wilson result is confirmed, with measured solar intensity one half, or less, of the usually accepted value. Apart from its intrinsic interest this result has some repercussions on the computation of the final results of the ARIEL II experiment.

There were two very successful campaigns of Skua rocket firings from the South Uist range. These rockets eject a radiosonde which permits temperature measurements from heights about 65 to 70 km downwards and wind measurements below 55 to 60 km. Twelve soundings were made between 9 February and 10 March and 27 between 27 September and 6 December. Overall about 85 per cent of possible data were recovered, an advance on the already very high 1965 figure of 75 per cent. There were only two total rocket failures and eight partial failures of the meteorological sonde.

Geophysical research. The Natural Environment Research Council is now responsible for research in geomagnetism and seismology and during the year appointed a Gassiot Fellow in Seismology. The Meteorological Office acted as its agent in operating seismological and geomagnetic recording instruments at Eskdalemuir and Lerwick Observatories and gave general administrative assistance to a Senior Research Fellow in Geomagnetism who is accommodated in the Physics Department of Edinburgh University.

Dynamical and Synoptic Research

Research related to short-range weather forecasting. There are two main methods of approach to research into short-range weather forecasting. The first is the numerical method in which the physical laws which determine how the atmosphere will behave are exprèssed in mathematical form; then for any particular occasion these equations can be solved to yield a forecast of the future atmospheric patterns. This method has already been used successfully to predict the pressure and wind changes from the ground up to 40,000 ft for a day or two ahead on the broad synoptic scale and has become one of the chief weapons in the forecaster's armoury. The second and older is the empirical method and relies on organizing experience of past weather events, either qualitatively or quantitatively in terms of statistics. Such research is guided by physical and dynamical understanding of the atmosphere and it is by using its results that the forecaster deals with the day-to-day problems of forecasting weather phenomena such as rain, visibility and temperature.

There is considerable incentive to attempt to extend the numerical method to the problems of forecasting rainfall and other such weather features. Progress will be difficult and hard-won; the prize will be a deeper understanding of the weather-forming processes and better and more accurate methods of forecasting the weather itself. Attention has been concentrated on numerical investigations of the movement and development of rain-bearing systems. The calculations have been carried out using the Science Research Council ATLAS computer and are of sufficient volume to tax even its resources. Some of the results are most promising, showing reasonable agreement between the predicted and actual rainfall, both with respect to amount and location; but much further experimentation will be needed before the results can be translated into a technique suitable for operational purposes.

Research continued into extending the methods for making numerical forecasts for a day or two ahead in order to obtain forecasts for four or five days ahead. Early in the year much effort was given to the elimination of some shortcomings in the routine numerical forecast procedure. The problem of ensuring the compatibility of the analyses of the initial wind and pressure fields also came under scrutiny and this led to an alternative method of computation of the forecast wind and pressure fields at about 18,000 ft which gives encouraging results.

Empirical studies of the important problem of forecasting the amount of precipitation were continued. Examination of the occurrences of heavy falls of rain has revealed a correlation with the winds at about 20,000 ft which has proved useful to the forecaster. An attempt is being made to formulate statistical rules connecting the amount of rainfall with other measurable atmospheric properties, using data from many years. Attempts to formulate new and better rules relating the occurrence of hail and thunderstorms over south-east England to the appropriate upper air observations have met with success but further testing is desirable. Studies of the distribution of winter shower activity in relation to large-scale weather features have yielded useful practical results.

There are a number of forecasting problems which can only be dealt with locally; examples are forecasting the height of cloud-base, the visibility and the night minimum temperatures at particular places. When there are empirical relations connecting the quantity to be forecast with measured quantities, the constants in the relations have local values; their determination requires local observations and knowledge. When a new rule is advocated it must be tested in each locality and its success compared with that of other rules. Investigations of this sort are carried out at the forecast offices concerned and the results are collated centrally. Evaluations have been made of techniques for forecasting the night minimum temperature, the intensity of showers and thunderstorms, and whether precipitation will be rain or snow. Work continued on the provision for London (Heathrow) Airport of diagrams enabling objective visibility forecasts to be made for three and six hours ahead for the winter months; tests show that the results obtained from diagrams are comparable with the forecasts made by a team of experienced forecasters.

Research related to long-range forecasting. It is not as yet possible to prepare extended-range forecasts for more than a few days ahead in the same way and with the same detail as with the short-range weather forecasts. Throughout the year forecasts have been made for a month ahead at the beginning and middle of each month, predicting on a regional basis the general character of the following period as regards temperature, rainfall and general weather type. The temperature forecasts fall into one of five categories; the rainfall forecasts into one of three. The broad succession of weather types is also predicted with mention of any outstanding weather features, such as an expected increase in the number of foggy days over the normal for the time of year. These forecasts are made available to the press and broadcasting media which give them publicity. A more detailed copy of each forecast is printed and sold for a small sum to subscribers, who now number over two thousand. The standard of success continues to be much the same as in the last two years, with about 75 per cent of forecasts being at least in moderate agreement with events.

The method used to make these monthly forecasts is described in the Special Topic in the 1965 Report and remains unchanged; it consists of identifying analogue periods in the past when the weather over a large area has been analogous to that in the few weeks preceding the forecast period and then basing the forecast on the known weather in the sequels to the analogue periods. It depends considerably upon having past weather records available in a suitable form and further progress was made in assembling these data. The catalogues of daily weather types at London back to 1723 were completed, and long-period records of temperature and rainfall for four other stations in the British Isles were extracted, while many data from abroad were processed. The process of assembling, selecting and retrieving data is largely carried out on the electronic computer and continued effort has been applied to the general-purpose computer programme designed for this work.

Synoptic studies aimed at improving the long-range forecasts have continued and the variety of methods used in the selection of analogue periods has been increased with the availability of data. The possible long-term effects of abnormal surface conditions on weather have also been studied.

Forecasting for a longer period ahead has also received attention, using an approach similar to that employed for the monthly forecast. Additional effort has also been directed to studying possible relationships between the weather elements some months apart; such studies must embrace the data from much of the northern hemisphere at least.

General circulation of the atmosphere. The importance of quantitative studies of the general circulation of the atmosphere has been underlined during the year by the continued scientific interest shown internationally in the possibility of large-scale weather modification by human action, deliberate or accidental. Without comprehensive understanding of the air motions of the atmosphere as a whole, proposals for large-scale modification cannot be seriously considered. A preliminary study of the large-scale mid-atmospheric motions has now been completed and has led to valuable knowledge of the role played by frictional forces near the ground and by mountain ranges. New computations are being launched which use the basic dynamical and thermodynamical equations to predict the behaviour at a number of levels, paying attention to the physical forces which supply and degrade energy in the atmosphere. The formidable problems are those of representing these physical processes in an adequate way and of solving the mathematical difficulties associated with the numerical solution of the equations. The computations involved demand the most powerful computing facilities and the research will be carried out on the Scientific Research Council ATLAS computer. Much effort has been devoted throughout the year to overcoming the mathematical difficulties. These have been studied by devising and testing methods of solution which are appropriate for somewhat simpler systems of equations which, nevertheless, preserve the essential nature of the mathematical problem; these efforts have been brought to a successful conclusion and a start has been made on programming the main computation for the ATLAS computer.

Atmospheric circulations in the stratosphere are important because they determine the transfer of ozone and particulate matter at those heights. Efforts are now being made to extend the previous research on the mean meridional circulations to include the zonal circulations also, and they require a close scrutiny of the turbulent transfer at these levels. We are fortunate this year in having Dr L. Machta, Director, Air Resources Laboratory, Institute for Atmospheric Sciences, ESSA, USA as a visiting scientist working in this field of research.

Studies of the mean seasonal flow at 30 mb have continued and will be published in due course.

Climatic change. Work continued on establishing the facts of climatic history and on the interpretation of the marked changes in the wind circulation, rain and temperature which have been observed in many parts of the world in the current decade. A comparison of the large-scale atmospheric circulation during the period 8000 to 0 BC with that of the present day was published in a symposium report and the rainfall over England and Wales for the past 200 years is being analysed for changes and sequences in the rainfall régime.

Storm surges in the North Sea. In collaboration with the Storm Tide Warning Service, investigational work continues into the relation between storm surges and weather conditions, and it has led to the establishment of improved empirical formulae for forecasting dangerously high tides at some east-coast ports. Close collaboration with the National Institute of Oceanography and the Liverpool Tidal Institute has been maintained, and advice has been given in connexion with the meteorological conditions and data associated with surges.

Special investigations. Government departments, industrial and commercial firms, and other bodies called upon the Office for advice on meteorological problems which fell outside the main stream of research work and these inquiries called for special investigational studies. A number of the studies entailed considerable work; among them were:

(1) Advice on air pollution at possible sites for installations.

(2) Inquiry into the meteorological conditions prevailing at the time of the Tokyo aircraft accident.

A paper was also prepared indicating the expected accuracy of temperature information for supersonic transport operations at high levels on the Europe–America route and the cost of improving their accuracy.

Through membership of a number of departmental and inter-departmental committees advice was also given on atmospheric pollution, atmospheric turbulence and climatic extremes.

Library and Publications

The National Meteorological Library, extending over much of the entrance floor of the Bracknell Headquarters, is used mainly by research workers in the Office but is also available to other research workers and the general public. Besides being a comprehensive library of meteorological books and papers from all parts of the world, it includes material in other branches of geophysics and supporting subjects.

The library is used mainly for reference and borrowing but, in addition, it gives an information service, providing answers to a wide variety of questions or linking the inquiries with the appropriate research branches. A measure of the activity is given by Table XVI on page 51. The holdings of the library include an increasing number of transparencies and photographs which are borrowed for such purposes as lectures, television talks and book illustrations. There is a collection of material in microfilm, and four modern viewers are available to users of the library.

The majority of the staff of the library are meteorologists, but they keep abreast of developments in librarianship by representative membership of associations devoted to special library and information work. In March a Meteorological Office colloquium was held to stimulate the interest of headquarters staff and add to their knowledge of the library facilities available.

The Archives occupy a building about half a mile from the main Office. These Archives, like those at Edinburgh (for Scotland) and Belfast (for Northern Ireland), are appointed under the Public Records Act of 1958 as repositories for original meteorological observations and other records of the Meteorological Office. Much time is still being spent on the task of checking, cataloguing and binding the material they contain. Current work continues to increase. In 1966 there was another increase in the amount of borrowing by research branches of the Office and in the number of visitors. An increase was also found in the number of requests, from this country and abroad, for prints and microfilms of original data.

The Editing Section prepares for printing most of the publications of the Meteorological Office. Preparation involves sub-editing and consultation with the author, followed by supervision of the publication through all subsequent stages. Results of research are published from time to time in the two series

Geophysical Memoirs and *Scientific Papers*. In addition to these series there are occasionally new publications, and revised editions or reprints of current works. General editorial responsibility is undertaken for the *Meteorological Magazine*, a monthly journal containing accounts of research, reviews and items of interest to meteorologists. This section is responsible also, in collaboration with HMSO, for handling copyright inquiries received by the Office.

The Cartographic Drawing Office is responsible for the preparation for printing of all diagrams for publication by the Meteorological Office. These include many charts which are used by forecasters for various areas of the world and which are frequently altered to meet changing forecast needs. Many hundreds of diagrams are produced during each year.

Training

The Meteorological Office itself provides the professional training needed by its staff. The greater part of the class instruction is given at the Training School at Stanmore. Training in radiosonde operation is provided at Hemsby. At Easthampstead, near Bracknell, classes have been held for technicians in the maintenance of electronic meteorological equipment.

While all courses aim to give the student a sound and adequate theoretical understanding there is an emphasis on practical aspects. The formal instruction is therefore normally followed by a period of outstation training lasting from a few weeks to several months.

The main function of the School at Stanmore is the provision of general meteorological training at four levels. Assistants take a 9-week course designed to teach them the basic ideas of meteorology and to equip them for work at a forecasting station. In the Experimental Officer Class the first stage of training is a 17-week course, preceded by a short preliminary course if the officer is unfamiliar with the work of an assistant. After some years of experience in forecasting the officer returns to the School to spend 4 weeks studying and discussing more advanced ideas and newer techniques. The highest level of training is that given to Scientific Officers, whose training normally extends over a year. The first six months are spent at the School and the next six mainly at major forecasting stations so as to provide a fairly general picture of the activities of the Office before the student settles down to research.

The training in radiosonde operation, provided at Hemsby, is given to staff who, if they are in the Meteorological Office, will be engaged on full-time radiosonde duties at a land station or on an Ocean Weather Ship. The initial course lasts for 8 weeks and there is an advanced 4-week course for staff experienced in basic operations; if necessary the latter is preceded by a 4-week refresher course.

Compared with 1965 there was some reduction in the number of trainees at Stanmore (See Table XVII on page 52). This was due mainly to the 6-month suspension of Assistant training there because of the acute shortage of staff at outstations. Courses were resumed in August and modified training is planned in the spring of 1967 for the assistants recruited in the earlier part of 1966. Staff shortage was also the reason why it was not possible to hold either the background courses designed for the more experienced assistants or the officer-in-charge courses given in conjunction with the Civilian Training and Education Branch of the Air Force Department.

The intake of students from overseas was maintained (See Table XVII on page 52), and as usual they formed the larger part of the Tropical Meteorology Courses. Some of the overseas students are financed by their meteorological services, but many are helped by United Kingdom Technical Assistance or are holders of United Nations Fellowships. Most of the latter are granted by WMO, but during the year two students came to the Stanmore school on FAO Fellowships prior to service with the Desert Locust Control Organization. A number of overseas students were given 'on-the-job' training, either at the conclusion of class training or without having attended a formal course.

At the present time the office is sponsoring 7 students who are taking sandwich courses at the City University. In addition nearly 300 members of the staff were given assistance with part-time study in scientific subjects.

STATISTICS

TABLE XVI—LIBRARY

Items received including duplicates but excluding daily weather reports	8018
Individual books, pamphlets, articles, microfilms classified and catalogued	5358
Transparencies acquired	344
Publications lent (excluding daily weather reports and internal 48-hour loans)	11,741
New agreements for exchange of publications	7
Total number of exchange agreements	418
Number of pages translated by Library translators	
Russian	2162
German	85
Icelandic	15
Total	2262

ARCHIVES

Number of loans	1266

TABLE XVII—TRAINING

The following figures give details of courses completed during 1966 at the Meteorological Office Training Schools at Stanmore, Hemsby and Easthampstead.

	Number of courses	*Length of course in weeks*	*Number of students*
Scientific Officers	1	22	10
Senior Forecasters	1	3	13
Forecasting (Preliminary)	2	4	25
Forecasting (Initial)	2	17	52
Forecasting (Advanced)	4	4	35
Tropical Meteorology	2	3	13
Mediterranean Meteorology	1	2	5
Climatology	1	4	7
Instruments (Advanced)	3	2	23
Assistants	7	9	103
Auxiliary Observers	1	1	16
Voluntary Observers	2	1	39
Antarctic Observers	1	8	7
Radiosonde (Initial)	8	5	32
Radiosonde (Refresher)	4	2	2
Radiosonde (Advanced)	4	5	20
Technicians	2	15	18
Total			420

Students from the following territories attended courses which terminated during 1966:

	Number of students
Austria	4
Belgium	2
British Antarctica	7
Burma	1
East Africa (Kenya, Uganda and Tanzania)	9
Hong Kong	6
India	4
Iran	1
Jamaica	2
Jordan	2
Libya	2
Malaysia	1
Nigeria	4
Rhodesia	1
Sierra Leone	4
Switzerland	2
Syria	4
United Arab Republic	2
Yugoslavia	1
Total	59

INTERNATIONAL CO-OPERATION

International meetings attended during 1966

World Meteorological Organization

The Eighteenth Session of the Executive Committee was held at the Headquarters of the Organization in Geneva from 16 May to 10 June. It was attended by the Director-General, Dr B. J. Mason, a member of the Committee, who was assisted by Mr C. W. G. Daking, Assistant Director (Defence and International) and Mr D. G. Harley (Met.O.17). The session was more than ordinarily important because of the need to discuss arrangements for the Fifth Congress of WMO (April 1967), to discuss plans for the World Weather Watch and prepare a document for submission to Congress and to examine and comment upon the Secretary-General's programme and budget for the Organization for the Fifth Financial Period (1968–71). The reports and recommendations of the WMO Advisory Committee, the Commission for Aerology, the Commission for Synoptic Meteorology, the Commission for Climatology, the Commission for Instruments and Methods of Observation and of the Executive Committee's Working Group on Antarctic Meteorology were studied and decisions taken for future action by Members and the Secretariat of WMO. Mr R. F. Jones, Assistant Director (Atmospheric Physics), presented a paper entitled 'Some meteorological problems associated with the design and operation of supersonic transport aircraft' as a contribution to one of the scientific discussions at this Session.

Other sessions of constituent bodies of the Organization which took place during the year included the Fourth Session of Regional Association V (South-West Pacific) which was held in Wellington, New Zealand from 7 to 18 February. The United Kingdom did not send an observer but Dr J. F. Gabites, Director of the New Zealand Meteorological Service, kindly undertook to present the views of the United Kingdom on appropriate agenda items.

The Commission for Synoptic Meteorology met in Wiesbaden, Germany for its Fourth Session from 8 March to 3 April. Its agenda was large and the work heavy because of the detailed discussions required on matters related to the planning of the World Weather Watch and a general review of codes and telecommunications questions. The United Kingdom was represented by Mr V. R. Coles, Deputy Director (Forecasting Services), Mr L. H. Starr, Assistant Director (Telecommunications), Mr C. J. M. Aanensen (Met.O.6) and Instructor Captain J. R. Thorp, RN.

There was a meeting of Presidents of the WMO Technical Commissions in Geneva from 18 to 20 May to discuss the role of these bodies in the planning of the World Weather Watch and other questions of concern to the Technical Commissions as a whole including their status in the Organization. Mr L. P. Smith, President of the Commission for Agricultural Meteorology took part in these discussions. The President's report to the Executive Committee was considered together with the general question of the organization of the scientific and technical work of WMO and a document on this subject was prepared for Fifth Congress.

Mr P. J. Meade (Director of Services) as a United Kingdom member of the WMO Commission for Agricultural Meteorology and as observer for WMO attended meetings of the UNESCO Symposium on Methods in Agroclimatology at Reading University between 23 and 30 July.

International Civil Aviation Organization

Commander C. E. N. Frankcom, Marine Superintendent, was in the chair at the annual meeting of the Advisory Committee of European Operating States on North Atlantic Ocean Stations held in Paris from 11 to 13 May.

The ICAO Fifth European–Mediterranean Regional Air Navigation Meeting was held in Geneva from 1 to 26 February. Mr D. G. Harley (Met.O.17), and Mr A. A. Worthington (Met.O.6) attended as members of the United Kingdom Delegation.

The ICAO Fourth Caribbean Regional Air Navigation Meeting was held in Mexico City from 22 November to 17 December. Mr D. G. Harley (Met.O.17) attended as a member of the United Kingdom Delegation and as an adviser on meteorological questions to Governments of that area which are members of the Caribbean Meteorological Council.

Other WMO Meetings or Joint WMO Meetings with other international bodies in which Meteorological Office staff took part were as follows:

Subject	*Place and Date*	*Attended by*
Working Group on Aviation Forecasting and Techniques	Geneva January	Mr D. G. Harley (Met.O.17)
Working Group on Antarctic Meteorology	Melbourne February–March	Mr D. G. Harley
Symposium on Interaction of Upper and Lower Layers of the Atmosphere	Vienna May	Dr R. Frith, Assistant Director (High Atmosphere) Dr R. J. Murgatroyd (Met.O.20) Mr G. R. R. Benwell (Met.O.11) Mr S. F. G. Farmer (Met.O.19)
Working Group on Radiation	Uccle (Brussels) May	Mr R. H. Collingbourne (Met.O.14)
Symposium on Polar Meteorology	Geneva September	Mr H. H. Lamb (Met.O.13)
Technical Conference on Automatic Weather Stations	Geneva September	Mr V. R. Coles, Deputy Director (Forecasting Services) Mr W. R. Sparks (Met.O.16)
Working Group on the Processing and Exchange of Meteorological Data for Research	Geneva October	Mr R. H. Clements, Deputy Director (Observational Services) Mr E. J. Sumner (Met.O.12)

Subject	*Place and Date*	*Attended by*
Seminar on the Interpretation and Use of Meteorological Satellite Data	Moscow October	Dr D. G. James (Met.O.11) Invited Expert
Working Group on Meteorological Transmissions (Regional Association VI—Europe)	Geneva October	Mr L. H. Starr Mr A. A. Worthington Assistant Directors (Telecommunications) Mr E. J. Bell (Met.O.5a)
Planning Meeting on Global Telecommunications and Global Data Processing System	Geneva November	Mr A. A. Worthington Mr E. J. Bell
Working Group on Tropical Meteorology	Geneva November	Mr J. S. Sawyer (Director of Research)
Study Group on Network Density and Frequency of Observations	Geneva September	Mr G. A. Corby, Assistant Director (Dynamical Climatology)

Attendances at international conferences sponsored wholly or primarily by bodies other than WMO were as follows:

Subject	*Place and Date*	*Attended by*
Committee on Space Research and International Space Symposium (ICSU)	Vienna May	Dr G. D. Robinson, Deputy Director (Physical Research) Dr R. Frith, Assistant Director (High Atmosphere)
Conference on World Climate (Royal Meteorological Society)	London April	Messrs H. H. Lamb, R.F.M. Hay, R. Murray and P. B. Wright (Met.O.13) Mr M. H. Freeman, former Assistant Director (Synoptic Climatology), Mr S. G. Cornford (Met. Research Flight)
Conference on Aircraft Noise and Disturbance (Board of Trade)	London November	Mr G. Needham (Met.O.9)
General Assembly of the International Scientific Radio Union (ICSU)	Munich September	Dr W. T. Roach (Met.O.9)

Subject	*Place and Date*	*Attended by*
Maritime Safety Committee (IMCO)	London February	Cdr C. E. N. Frankcom (Marine Superintendent) as WMO Observer
Sub-committee on Radio Communications (IMCO)	London October	Cdr C. E. N. Frankcom as WMO Observer
Symposium on the Collection and Processing of Field Data	Canberra August/ September	Dr N. E. Rider (Met.O.16)
General Assembly of the International Biological Programme	Paris April	Mr L. P. Smith (Met.O.8)
International Biometeorological Conference	New Brunswick U.S.A. August/ September	Dr R. W. Gloyne, Mr W. H. Hogg, (Met.O.8)
Symposium on Methods in Agroclimatology (UNESCO)	Reading July	Messrs L. P. Smith, G. W. Hurst, A. Bleasdale, J. Grindley, W. H. Hogg, C. V. Smith, W. McKay, J. B. Stewart and Dr R. W. Gloyne (Met.O.8), Mr H. C. Shellard (Met.O.3), Mr M. J. Blackwell (Met.O.14)
International Biometeorological Conference	Lablouk, Lebanon April	Dr R. W. Gloyne, Mr G. W. Hurst
Dynamics of Clouds and Cloud Systems (NATO)	London July	Dr B. J. Mason, Director-General Mr J. S. Sawyer, Director (Research) Mr C. J. Aanensen (Head of Met. Research Flight) Messrs S. G. Cornford and D. R. Grant (Met. Research Flight)
Symposium on Chimney Plume Rise and Dispersion (International Clean Air Congress)	Leatherhead October	Dr A. G. Forsdyke, Assistant Director (Climatological Services)
Diffusion in the Atmosphere and Oceans	Tokyo September	Dr F. Pasquill (Met.O.14)
Symposium on Boundary Layers and Turbulence (ICSU)	Kyoto, Japan September	Dr F. Pasquill
Symposium on Geophysical Theory and Computers	Cambridge June/July	Dr W. F. Stuart (Met.O.14)

Subject	*Place and Date*	*Attended by*
Symposium on Solar–Terrestrial Physics (ICSU)	Belgrade August/September	Dr W. F. Stuart
Symposium on Antarctic Oceanography (ICSU)	Santiago, Chile September	Mr C. H. Dean (Met.O.14)
Pacific Science Congress	Tokyo August/September	Dr G. D. Robinson
Technical Committee of the International Radio Maritime Committee (IMCO)	London December	Cdr C. E. N. Frankcom (Marine Superintendent)

There were three international meetings during the year on operational and research matters relating to the development of a supersonic aircraft. These took place in London and Paris and were attended by Mr R. F. Jones, Assistant Director (Atmospheric Physics) and Mr A. A. Worthington, Assistant Director (Telecommunications) as appropriate.

Dr W. T. Roach (Met.O.9) attended planning meetings for the U.S. National Severe Storms Project at Norman, Oklahoma in February and participated in the project from 12 April to 25 June. Messrs T. W. Harrold and G. Lowe (Met.O.15) were also detached for duty with the U.S. National Severe Storms Project from 20 April to 1 June. In October, Dr Roach took part in planning meetings in the U.S.A. and at Bedford in preparation for investigations of mountain waves in February/March 1967.

Mr N. Bradbury, Assistant Director (Data Processing) and Mr F. H. Bushby, Assistant Director (Forecasting Research) spent several weeks in the United States in October/November during which visits were made, jointly or separately, to various formations of the U.S. State and Military Meteorological Services located throughout the country, to certain Meteorological Research Institutes and to manufacturers of computing machines. The purpose of these visits was to study present and planned future use of advanced computer systems for meteorological data processing including numerical weather prediction, so that an assessment of Meteorological Office requirements in the early 1970's could be made more effectively.

Dr F. B. Smith (Met.O.11) left for the United States in September to spend a year at Oak Ridge, Tennessee working on problems of atmospheric turbulence in association with Dr Gifford of the U.S. Environmental Sciences Service Administration.

Mr J. H. Brazell (London Weather Centre) represented the Meteorological Office at an informal meeting at De Bilt from 7 to 9 November, to discuss meteorological support for oil and gas exploration in the North Sea. Representatives of the Netherlands (convener), Belgium, Denmark, Norway and Western Germany also attended.

Mr A. A. Worthington attended a meeting between the Ministry of Aviation and the U.S. Federal Aviation Agency held in Washington D.C. from 21 to 25 March and took part in discussions on methods of measuring runway visual range.

The following members of the staff were released during the year to take up international appointments overseas.

Mr K. E. Best—Senior Scientific Assistant, was appointed to a Technical Assistant post in the WMO Secretariat, at its Headquarters in Geneva in January.

Mr J. D. Lowrie—Senior Scientific Assistant, was seconded to the Meteorological Service of Malawi in May under arrangements made with the Crown Agents.

Mr H. S. G. Rich—Senior Scientific Assistant, was seconded in June for service in the New Hebrides Condominium under arrangements made with the Ministry of Overseas Development.

Mr R. Frost—as a Senior Principal Scientific Officer became Director of the Zambian Meteorological Service in July under arrangements made with the Ministry of Overseas Development.

Mr A. Ward—Chief Experimental Officer, was temporarily transferred to the Ministry of Defence Central Staffs for service at Supreme Headquarters, Allied Powers, Europe in November.

Mr F. E. Lumb—Principal Scientific Officer, took up a senior post in the WMO Regional Training Centre at Nairobi in November, under arrangements made with WMO.

STAFF

GENERAL

The names of the principal officers of the Meteorological Office are listed on pages x–xi and the organization of the Office is shown in the diagram on page xii. At the end of 1966 the total number of posts of all grades was 3774, an increase of 34 over the year. The actual strength at the end of the year including Research Fellows was made up as follows:

Scientific Officer Class	
Chief Scientific Officers	3
Deputy Chief Scientific Officers	5
Senior Principal Scientific Officers	25
Principal Scientific Officers	77
Principal Research Fellows	3
Senior Scientific Officers	23
Senior Research Fellows	3
Scientific Officers	19
Junior Research Fellow	1
Administrative Class	
Assistant Secretary	1
Experimental Officer Class	
Chief Experimental Officers	21
Senior Experimental Officers	242
Experimental Officers	411
Assistant Experimental Officers	211
Scientific Assistant Class	
Senior Scientific Assistants	305
Scientific Assistants	1152
Marine Staff	
Marine Superintendent	1
Nautical Officer Class	7
Ocean Weather Ships and Base	
Officers	73
Crew	121
Technical and Signals Grades	286
Executive and Clerical Grades	162
Typing and miscellaneous non-industrial grades	129
Industrial employees	83
Locally entered staff and employees overseas	213

During the year, five Research Fellows were assigned to the Office by the Civil Service Commission, three being Principal Research Fellows. Recruitment to the Scientific Officer class was rather above average, eight new officers joining the class during the year. Towards the end of the year the number of inquiries about careers in the Office from highly qualified honours graduates increased significantly. It is hoped that this will be reflected in the 1967 recruitment. The requirement in the Experimental Officer class increased by nearly forty posts, but shortages continue despite good recruitment. The number of Scientific Assistant posts remained almost static. Recruitment was average, but unusually high wastage created a larger shortfall in the class than for many years. In the latter part of the year the number of inquiries for assistant posts increased and the wastage rate declined materially, but the staffing of the class remains a major problem. An inquiry into the causes of wastage is under way. The supply of Radio Meteorological Technicians improved considerably, and the number of vacancies is now very small.

Eight Assistant Experimental Officers from the Office who were taking Sandwich Courses leading to a Diploma in Technology shared the year between the Office and the City University. Four college-based Sandwich Course students spent their extra-college periods with the Office. Two Scientific Officers and two Assistant Experimental Officers were granted leave of absence to pursue degree-course studies. A further 281 members of the staff enjoyed study concessions. Twenty university undergraduates were chosen from among many applicants to work in the Office as Vacation Students.

CHANGES IN SENIOR STAFF

Mr P. J. Meade, O.B.E., B.Sc., A.R.C.S. was appointed Director of Services on the retirement of Dr A. C. Best, C.B.E.

Mr R. H. Clements, M.A. was appointed Deputy Director (Observational Services) on the retirement of Mr B. C. V. Oddie, C.B.E., B.Sc.

Mr V. R. Coles, M.Sc. succeeded Mr P. J. Meade, O.B.E., B.Sc., A.R.C.S. as Deputy Director (Forecasting Services).

Mr R. F. Jones, B.A. replaced Dr A. G. Forsdyke as Assistant Director (Synoptic Climatology).

Mr R. A. S. Ratcliffe, M.A. succeeded Mr M. H. Freeman, M.Sc. as Assistant Director (Synoptic Climatology).

Dr F. Pasquill received a Special Merit promotion to Deputy Chief Scientific Officer.

There were three promotions to Senior Principal Scientific Officer posts, comprising two Assistant Directorships and one post at the Meteorological Research Flight, Farnborough.

Three Principal Research Fellows were appointed to positions in the Office during 1966.

HONOURS AND DISTINCTIONS

Mr A. F. Crossley, M.A. was awarded the I.S.O. and Miss D. J. Wordsworth the B.E.M.

The University of Nottingham conferred the degree of D.Sc. (*honoris causa*) on the Director-General on 3 September.

Dr G. D. Robinson, F. Inst. P. was elected President of the Royal Meteorological Society.

The L. G. Groves Memorial Prize for Meteorology was awarded to Dr N. E. Rider and Mr B. W. Butler received the L. G. Groves Memorial Observer's Award.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

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APPENDIX II

A SELECTION OF THE LECTURES AND BROADCASTS GIVEN BY MEMBERS OF THE STAFF

J. T. Bartlett, Ph.D.
A physicist's view of clouds. *Physical Society, City University, London.* 22 November.

G. R. R. Benwell, M.A.
Upper winds with special reference to those at 50,000 ft to 100,000 ft. *Training course for Scientific Intelligence Officers (Civil Defence), University of Birmingham.* 21 May.
The behaviour of the first six zonal wave numbers at 50 and 500 mb during some winter months in 1958 and 1959. *WMO/IAMAP/COSPAR Symposium on interaction between upper and lower layers of the atmosphere, Vienna.* 3–7 May.

N. Bradbury, B.Sc.
Some aspects of numerical forecasting activities in the United Kingdom. *Omaha Branch of the American Meteorological Society.* 27 October.

J. H. Brazell, M.Sc.
Weather forecasting for oil drilling in the North Sea. *Joint Meeting of the Petroleum Exploration Society of Great Britain and the Exploration and Production Group of the Institute of Petroleum, London.* 20 October.

K. A. Browning, Ph.D.
Convergence and deformation in widespread precipitation. *Department of Meteorology, Imperial College, London.* 29 November.

F. H. Bushby, B.Sc.
Some mathematical aspects of meteorology. *Mathematical Association, London.* 5 March.
A ten-level atmospheric model and frontal rain.
British Theoretical Mechanics Colloquium, Southampton University. 19 April.
NATO Conference on the Dynamics of Clouds and Cloud Systems, Imperial College, London. 7 July. *Massachusetts Institute of Technology, U.S.A.* 13 October.
Geophysical Fluid Dynamics Laboratory, ESSA, U.S.A. 21 October.
U.S. Fleet Numerical Weather Facility, Monterey, U.S.A. 2 November.
Department of Meteorology, University of California, Los Angeles, U.S.A. 3 November.
Royal Meteorological Society (Edinburgh). 25 November.

V. R. Coles, M.Sc.
Short-range forecasting. *Symposium of the Society of Environmental Engineers, Imperial College, London.* 21 April.

J. M. Craddock, M.A.
Statistics and forecasting. *Regional Branches of Royal Statistical and British Computer Society, Bristol.* 20 January.
Some aspects of long-range forecasting. *Norwich Branch of the Geographical Association.* 4 October.
Analysis of time series, arising in situations over which man has no control. *Institute of Statisticians, Margate.* 19 November.
Computational and statistical aspects of weather forecasting. *Branch of Royal Statistical and British Computer Society, Sheffield University.* 24 November.

C. H. Dean, M.Sc.
Sea waves in and near a field of pack ice. *SCAR/SCOR/IAPO/IUBS Symposium on Antarctic Oceanography, Santiago, Chile.* 16–17 July.

A. G. Forsdyke, Ph.D.
Some extreme combinations of world weather conditions and their causes. *University of Southampton, Institute of Sound and Vibration Research.* 21 January.

C. E. N. Frankcom, O.B.E., R.D., Commander, R.N.R. (retd).
The general problem of weather routeing—by the Shipmaster himself or as advised by the Meteorologist ashore. *Special meeting of the Honourable Company of Master Mariners. H.Q.S. 'Wellington', London.* 9 March.
Weather routeing and Facsimile Weather Maps. *Department of Maritime Studies of the Welsh College of Advanced Technology, Cardiff.* 14 July.

M. H. Freeman, O.B.E, M.Sc.
Long-range forecasting.
London Chapter of the American Meteorological Society. 13 May.
Rotary Club, Godalming. 17 May.

R. Frith, O.B.E., Ph.D.
Talk on Skua results. *COSPAR 7th International Space Science Symposium, Vienna.* 17 May.
The upper atmosphere. *Course for senior RAF Officers, Bristol University,* 18 *July.*

R. F. M. Hay, M.A.
Long-range forecasting. *Poynting Physical Society, Birmingham University,* 25 January.

N. C. Helliwell, B.Sc. and D. J. Holland, M.A.
Hydrometeorology. *Department of Civil Engineering, Imperial College, London.* Series in February.

W. H. Hogg, M.Sc.
Effect of recent rains in Wales on farming in the next month or two. *BBC Wales television.* 25 February.

D. G. James, Ph.D.
Six lectures to WMO seminar on the interpretation and use of meteorological satellite data in operational work, Moscow. 4–22 October.

R. F. Jones, B.A.
BBC sound broadcast on clear air turbulence for North American Overseas Service. 6 May.
Some meteorological problems associated with the design and operation of supersonic. transport aircraft. *Executive Committee of WMO, Geneva.* 26 May.

J. F. Keers, B.Sc.
Storm surges in the North Sea. *Royal Meteorological Society Summer Meeting, University of Sussex.* 27 July.

E. Knighting, B.Sc.
Numerical weather prediction. *Eighth British Theoretical Mechanics Colloquium, University of Southampton.* 19 April.
Weather prediction. *The Institute of Science Technology, London.* 13 October.

H. H. Lamb, M.A.
Our understanding of climatic variations. *Geographical Department, Leicester University.* 4 May.
Climatic variations affecting the far South. *ICPM/SCAR/WMO Symposium on Polar Meteorology, Geneva.* 8 September.
Climatic change in Britain. Joint Conference—*Country Bee Keeping Instructors and National Agricultural Advisory Service, London.* 10 November.
Our climate: meteorological investigations of its behaviour and history. *Red House Museum and Art Gallery, Christchurch.* 12 December.
Britain's changing climate. *Royal Geographical Society, London.* 12 December.

B. J. Mason, D.Sc., F.R.S.
Some recent developments in cloud physics. *Cambridge Philosophical Society.* 24 January.
Thunderstorms. *Royal Institute of Chemistry, Winchester.* 4 February.
Recent developments in the physics of clouds, rain and snow. *University of Nottingham Physical Society.* 25 February.
Mathematical aspects of collision, coalescence and disruption of water droplets in clouds. *Imperial College Mathematical Society.* 28 February.
The generation of cloud electricity. *Institution of Electrical Engineers, Savoy Place, London.* 3 March.
Weather forecasting today. *St Paul's Junior School, Hammersmith.* 30 June.
Essential microphysics of clouds. *Summer School on Cloud Dynamics, Imperial College, Silwood Park, Ascot.* 4 July.
The role of meteorology in the national economy. *Royal Meteorological Society Summer Meeting, University of Sussex.* 26 July.
Some recent developments in cloud physics. *London Chapter of the American Meteorological Society.* 22 September.
The physics of clouds, rain and snow. *Selby Lecture, University College of South Wales and Monmouthshire, Cardiff.* 14 October.

B. J. MASON, D.Sc., F.R.S.
Weather forecasting by computer. *Royal College of Science Mathematical and Physical Society, London.* 1 November.
The physics of clouds. *Nottingham University Physical Society.* 11 November.
Recent developments in the physics of clouds, rain and snow. *Leeds University Physical Society.* 18 November.
Can man control the weather? *Bristol University Chemical Society.* 24 November.
Contribution to programme on weather control. *Granada TV.* 25 November.

P. J. MEADE, O.B.E., B.Sc.
Rainfall and evaporation—distribution in space and time. *British Association Symposium on Water Conservation and Resources, Nottingham.* 5 September.

R. MURRAY, M.A.
Long-range forecasting. *Warren Spring Laboratories, Stevenage.* 7 December.

F. PASQUILL, D.Sc.
Lagrangian similarity and vertical diffusion from a source at ground level. *Meteorological Society of Japan, Tokyo.* 17 September.
The vertical component of atmospheric turbulence at heights up to 1200 m. *IUGG/IUTAM Symposium on Boundary Layers and Turbulence, Tokyo.* 24 September.

G. D. ROBINSON, PH.D., F.INST.P.
Another look at some problems of the air–sea interface.
Presidential address to the Royal Meteorological Society, London. 27 April.
Canadian Branch of the Royal Meteorological Society, Sherbrooke. 8 June.
Research activities in the British Meteorological Office.
Canadian Weather Bureau, Toronto. 1 June.
Meteorology Department, McGill University, Montreal. 6 June.
Artificial modification of weather and climate. *Atomic Energy of Canada Ltd, Chalk River, Ontario.* 3 June.
The energy budget and heat transport in the sea at an Ocean Weather Station. *Eleventh Pacific Science Congress, Tokyo.* 23 August.

J. S. Sawyer, M.A., F.R.S.
Mathematics applied to the large-scale dynamics of the atmosphere. *Scottish and Bristol Branches of the Institute of Mathematics and its Applications.* 24 February and 22 March.
BBC sound broadcast 'Who Knows?'. 6 June and 17 October.
The possibilities of weather modification and control. *Diplomatic Service Summer School, Cambridge.* 22 July.
BBC sound broadcast—contribution on hurricanes to 'Science Review'. 4 October.
The future of weather forecasting. *Royal Aircraft Establishment Technical Society, Farnborough.* 2 November.

L. P. SMITH, B.A.
Work of the UNESCO Agroclimatological Symposium, Reading 1966. *BBC Overseas Service.* 3 August.
'Can I help you?' *BBC Home Service.* 19 October.
Meteorological factors in agriculture. *Reading University.* 30 November.
Meteorology and agriculture. *Popular lecture, Royal Meteorological Society, County Hall, London.* 6 and 7 December.

H. C. SHELLARD, B.Sc.
Environmental extremes in various parts of the world. *Symposium of the Society of Environmental Engineers, Imperial College, London.* 19–21 April.

K. H. STEWART, PH.D.
Rocket and satellite meteorology.
Exeter University. 18 February.
Scottish Branch of the Royal Meteorological Society. 28 June.

G. A. TUNNELL, B.Sc.
The technique of preparing weather routeing advice ashore—an account of the ship routeing methods developed by the Royal Netherlands Meteorological Institute. *Special meeting of the Honourable Company of Master Mariners, H.Q.S. 'Wellington', London.* 9 March.

J. D. Woods, Ph.D., D.I.C.

Observations of internal waves and breakers. Seminar on United Kingdom studies in environmental prediction. *Navy Department, London.* 31 October.

Steps towards a model of the summer thermocline. *Seminar on Geophysics and Fluid Mechanics at the Department of Applied Mathematics and Theoretical Physics, Cambridge.* 30 November.

The following Meteorological Office Staff contributed to the BBC television series 'A World of Weather':

Mr J. H. Brazell, Mr H. V. Foord, Dr R. Frith, Mr R. F. Jones, Mr H. H. Lamb, Mr P. J. Meade, Mr J. S. Sawyer.

APPENDIX III

PUBLICATIONS

The publications prepared by the Meteorological Office are generally issued by Her Majesty's Stationery Office as official publications. A complete list, with the prices at which they can be purchased through any of the sales offices or usual agents of Her Majesty's Stationery Office, is sent free to any applicant.

The following official publications were issued during the period of this Report:

PERIODICAL

Daily Aerological Record, containing information respecting meteorological conditions in the upper air over the British Isles (to 20 December 1966).

Daily Weather Report, containing weather maps for the northern hemisphere, British Isles, etc. and data (to 30 December 1966).

Daily Weather Report, Overseas Supplement, containing surface and upper air data (to 19 July 1966).

Meteorological Magazine (to December 1966).

Monthly Weather Report (to August 1966).

Seismological Bulletin. A diary of seismological disturbances recorded at Eskdalemuir, Dumfriesshire on the standard American World-wide Seismograph System together with observations from a short-period vertical seismograph at Kew Observatory (to January 1966).

Marine Observer (quarterly) (to October 1966).

Monthly Weather Survey and Prospects, a monthly publication containing climatological data for Britain, the weather of the past month, a general survey and inference, and weather prospects for the coming month in Britain; a supplementary document, containing survey, inference and prospects only, is published in mid-month (to December 1966).

SERIAL

Geophysical Memoirs:

110. Secular variations of the atmospheric circulation since 1750, by H. H. Lamb, M.A. and A. I. Johnson, B.Sc.

Scientific Papers:

23. Surface and 900 mb wind relationships, by J. Findlater, T. N. S. Harrower, M.A., B.Sc., G. A. Howkins, M.B.E., M.Sc., and H. L. Wright, M.A.

24. An atmospheric diffusion slide-rule, by C. E. Wallington, M.Sc.

25. The relation between Beaufort force wind speed and wave height, by R. Frost, B.A.

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