METEOROLOGICAL OFFICE

ANNUAL REPORT 1970

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ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE

1970

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

LONDON
HER MAJESTY'S STATIONERY OFFICE
1971

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Cover photograph by R. K. Pilsbury

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FOREWORD BY THE DIRECTOR-GENERAL

During a year in which the weather was not particularly severe, the demand for meteorological services of all kinds continued to increase. The number of inquiries answered by our staff reached a total of 1·67 million and, for the first time, exceeded 100 000 in every month. There was a marked increase in the use of the automatic telephone weather service, the number of calls rising from 12½ to 13¼ millions. A more detailed account of these public services is given in the special article on 'Weather Services for the Community'.

The number of forecasts for aviation increased to a total of 1·47 million.

The ship-routeing service produced individual forecasts for 315 ships crossing the Atlantic, an increase of 60 per cent over last year, and achieved some spectacular successes in saving time and damage.

A great deal of effort has been devoted to planning, preparation and training for the new giant IBM 360/195 computer due to be installed at Bracknell in the autumn of 1971. A new deputy directorate has been established to administer the telecommunications, data-processing and computing facilities and this will include a new branch for systems analysis and development. During the year, 110 staff have been trained in the high-level language FORTRAN IV and about 50 in the basic machine language of the new computer. Excellent progress has been made in rewriting our major forecasting and research programmes for the new computer. One of the largest of these, involving ten thousand million numerical operations, operated successfully with the minimum of development difficulties on the prototype machine in the United States. The time taken for the computation was very close to that predicted from the design characteristics of the computer. The computer, the most powerful that has yet been ordered anywhere in the world for meteorology, will be used operationally to make more detailed forecasts of the weather, including the amount and distribution of rainfall likely to occur over the British Isles and most of Europe during the following 24–36 hours, and to predict the evolution of major weather systems over the whole of the northern hemisphere, we hope for up to about a week ahead. The computer will also be employed on a wide range of research problems, some of the more important being concerned with the World Weather Watch and the Global Atmospheric Research Programme referred to below.

Two of many important investigations merit special mention this year. The Dee Weather Radar Project, undertaken in collaboration with the Water Resources Board and Plessey Radar Ltd, whose object is to measure by radar, in real time, the rainfall over a catchment area, has made substantial progress. The equipment is installed and is likely to be in operation by the spring of 1971. In connection with an important study on floods in the United Kingdom, which is being carried out jointly with the Natural Environment Research Council, estimates have been made of the rainfall amounts to be expected at any point in the United Kingdom in any given return period, for durations from 5 minutes to 30 days. Estimates have also been made of the probable maximum precipitation to be expected during periods of 5 minutes to 8 days in a given area.

Turning now to research activities, the topic selected for special mention this year is concerned with atmospheric studies related to aircraft safety and performance. Several of these (for example the effect of meteorological factors on the intensity and distribution of the sonic bang) are relevant to the operation of supersonic transport aircraft. In this connection the newly installed high-power radar in a 25-metre diameter steerable reflector at the Royal Radar Establishment has revealed how clear-air turbulence may be produced by the formation and breaking of waves in horizontal stable layers in the atmosphere and has been responsible for a number of other unique studies.

The results of the second phase of Project Scillonia, whose objective is to study the structure and evolution of frontal cloud systems and the factors that control the duration, intensity and distribution of their rainfall, have revealed organized vertical motions on the scale of 50 km which are correlated with the rainfall distribution. Phase III, involving the operation of several radars on the Isles of Scilly and aircraft dropping sondes to measure the wind and temperature fields, became operational in September but only limited data were obtained by the end of the year because of the lack of suitable fronts in that area. Our research in cloud physics and several other fields will be greatly aided by the decision to allocate a Hercules aircraft to the Meteorological Research Flight. This will be modified and equipped as a flying laboratory with on-board data-processing facilities, and should be ready for use in about 18 months.

Experiments to measure the density of ozone in the high atmosphere were carried out on two SKYLARK rockets launched from Sweden and on one launched from Woomera, Australia. A rocket launched from Woomera resulted in successful measurements of the density of water vapour in the stratosphere, and a rocket from the Hebrides was used successfully to obtain measurements of the airglow from molecular oxygen. Ten SKUA rockets were launched in March from Thumba, India, along with 10 from Gan to measure day-to-day variations over a distance of 800 km in wind and temperature at heights of from 20 to 60 km near the equator.

Work has continued on the development of instrumental techniques for measuring the structure of turbulence in the lowest kilometre of the atmosphere, over both land and sea. Turbulent fluctuations of wind and temperature were measured at various heights from a captive balloon near an ocean weather ship in the Atlantic in preparation for a major experiment planned for 1973 to study the interaction between the ocean and the atmosphere.

The 10-level mathematical model which has been developed for the quantitative forecasting of rainfall at 40-km intervals on the ground has been extended in area to cover most of Europe and has been run successfully on the prototype of the IBM 360/195 computer in the United States. A computation taking 5 hours on the ATLAS computer took about 11½ minutes on the new machine. The same model is being adapted to cover most of the northern hemisphere on a coarser grid with a view to using it to predict the evolution of major weather systems for periods of up to a week ahead. This version has already been run on the ATLAS computer to make a prediction for up to 5 days, and is expected to be used operationally within a year or so of installing the new computer. The success of such numerical forecasting models must, however, largely depend on obtaining an adequate supply of observations from at least the whole of the northern hemisphere, including the oceans. There are important gaps in the observing networks and the best prospects of filling these seem to be offered by meteorological satellites. The infra-red radiometer developed by Oxford and Reading Universities, now flying on the American NIMBUS D satellite, offers the hope of obtaining a daily global coverage of the temperature distribution throughout the depth of the atmosphere, but a number of problems connected with the presence of cloud remain to be solved before data of sufficient accuracy become available for forecasting purposes. As instruments of similar but improved design are planned for later American satellites, it no longer seems worth while to launch such an instrument on a British experimental satellite; accordingly, our plans to do this in 1974 have been cancelled.

Senior members of the staff have been much involved in the planning of two very ambitious international programmes, the World Weather Watch (WWW) and the Global Atmospheric Research Programme (GARP) and have been active in discussions on man's influence on the environment. The first major activity planned for GARP is a major international investigation of weather systems in the tropical Atlantic. The experiment, planned for 1974, which is likely to involve research ships and aircraft from several nations, was the subject of two international meetings during the year, one in Brussels and the second, under my chairmanship, in London. It has been decided to establish an international Board of Management for the project and a permanent group of scientists to plan, manage and evaluate the experiment.

A strong desire has been expressed by the participating countries for the permanent scientific group to be based in Bracknell. The Government has indicated its willingness to provide the necessary facilities and a final decision by the Board of Management is expected early in 1971.

In March work began on the construction of an additional wing to the Headquarters which will accommodate the Central Forecasting Office, the new IBM System 360/195 computer and the automated telecommunications centre which has a major role in the Global Telecommunications System of World Weather Watch. Since the work in this new wing will be closely concerned with numerical forecasting and with research into dynamical meteorology, I decided that it should be named the Richardson Wing in memory of the late L. F. Richardson whose book *Weather prediction by numerical processes*, published in 1920, was the pioneer work in the development of numerical forecasting techniques which, using powerful computers, are now in everyday use. I am very grateful to the relatives of Dr Richardson who readily agreed with this decision. The picture on the front cover of this report was taken in December and, besides illustrating the progress made in the construction, shows the position of the Richardson Wing in relation to the remainder of the Headquarters building. The new wing is expected to be ready for occupation in October 1971.

Work has also started on the new Meteorological Office Training College at Shinfield Park, Reading, and on a new laboratory building at Easthampstead. Both should be ready for occupation during the summer of 1971.

A satisfactory level of recruitment was maintained throughout the year. The Scientific Officer class is up to complement and again almost all the new entrants had first-class honours or higher degrees. The Experimental Officer class is also up to strength. Recruitment in the Scientific Assistant class more than kept pace with resignations and other losses, and this, coupled with a reduction in requirements, has meant that the long-standing shortage in the class has been very much reduced.

B. J. Mason

January 1971
Meteorological Office
Bracknell, Berks.

CONTENTS

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 Parliamentary Under-Secretary of State for Defence for the Royal Air Force.

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 Directorate of the Meteorology and Oceanographic Services 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, including radiation and atmospheric electricity, 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.

(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 Department of the Environment, and stationery by Her Majesty's Stationery Office) the cost of the Meteorological Office is borne by Defence Votes.

The gross annual expenditure on the Meteorological Office, including that on the common services, is approximately £10·5 million. Of the amount chargeable to Defence Votes, about £6·9 million represents expenditure associated with staff and £3·3 million expenditure on stores, communications and miscellaneous services. Some £2·4 million 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.

Membership at 31 December 1970:

Chairman: The Earl of Halsbury, F.R.S.

Members: Mr A. F. Hetherington, D.S.C.
Professor J. P. Hudson, M.B.E., G.M.
Professor R. C. Sutcliffe, C.B., O.B.E., F.R.S. (Chairman, Meteorological Research Committee) (*ex officio*)

Secretary: Mr D. Hanson (Secretary, Meteorological Office)

The Committee met once in 1970.

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 proposal in connection therewith.

Membership at 31 December 1970:

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

Members: Professor J. N. Black, F.R.S.E. (University of Edinburgh)
Sir Samuel C. Curran, K.B., F.R.S. (Royal Society)
Professor G. M. Howe (University of Strathclyde)
Dr P. G. Jarvis (University of Aberdeen)
Mr W. O. Kinghorn (Department of Agriculture and Fisheries for Scotland)
Mr J. Paton, F.R.S.E. (Royal Society of Edinburgh)
Dr J. M. Rushforth (University of Dundee)
Professor P. A. Sheppard, C.B.E., F.R.S. (Royal Meteorological Society)
Mr J. W. Shiell (Scottish Development Department)
Dr J. H. Steele (Department of Agriculture and Fisheries for Scotland)

Secretary: Mr R. Cranna (Meteorological Office)

The Committee met once in 1970.

METEOROLOGICAL RESEARCH COMMITTEE

Terms of reference:

The Meteorological Research Committee will advise the Parliamentary Under-Secretary of State for 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 subcommittees, one of which shall be responsible for advising on the usage of monies allocated annually from Defence Votes for research projects conducted outside the Meteorological Office. The Committee will be responsible for co-ordinating the work of its subcommittees.

Membership at 31 December 1970:

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

Members:
- Instructor Captain J. D. Booth, R.N. (Director, Meteorology and Oceanographic Services (Naval))
- Professor R. L. F. Boyd, F.R.S.
- Professor H. Charnock
- Professor D. R. Davies
- Dr G. E. R. Deacon, C.B.E., F.R.S.
- Dr R. Frith, O.B.E. (Deputy Director, Physical Research, Meteorological Office)
- Dr E. R. R. Holmberg (Army Department)
- Dr J. T. Houghton
- Mr E. Knighting (Deputy Director, Dynamical Research, Meteorological Office)
- Dr B. J. Mason, F.R.S. (Director-General, Meteorological Office)
- Mr P. J. Meade, O.B.E. (Director of Services, Meteorological Office)
- Mr F. O'Hara (Ministry of Aviation Supply)
- Professor R. P. Pearce
- Mr J. S. Sawyer, F.R.S. (Director of Research, Meteorological Office)
- Professor P. A. Sheppard, C.B.E., F.R.S.
- Wing Commander N. E. Wilkins, D.F.C.

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

The Committee met twice in 1970 and its subcommittees seven times.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

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

DEPUTY TO THE 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.
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DEPUTY DIRECTOR	R. Frith, O.B.E., Ph.D.
BOUNDARY LAYER RESEARCH	F. Pasquill, D.Sc.
GEOPHYSICAL FLUID DYNAMICS LABORATORY	R. Hide, Sc.D.
METEOROLOGICAL RESEARCH FLIGHT	C. J. M. Aanensen, M.Sc.
CLOUD PHYSICS	
Assistant Director	P. Goldsmith, M.A.
HIGH ATMOSPHERE	
Assistant Director	R. A. Hamilton, O.B.E., M.A., F.R.S.E.
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	K. H. Smith, B.Sc.
DYNAMICAL CLIMATOLOGY	
Assistant Director	G. A. Corby, B.Sc.
Special Post	R. J. Murgatroyd, O.B.E., Ph.D., C.Eng., M.I.E.E.

DIRECTORATE OF SERVICES

DIRECTOR	P. J. Meade, O.B.E., B.Sc., A.R.C.S.
INTERNATIONAL AND PLANNING	
Assistant Director	D. G. Harley, B.Sc.

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., Strike Command	E. Evans, M.Sc.
PUBLIC SERVICES	
Assistant Director	M. H. Freeman, O.B.E., M.Sc.
London/Heathrow Airport	J. H. Brazell, M.Sc.

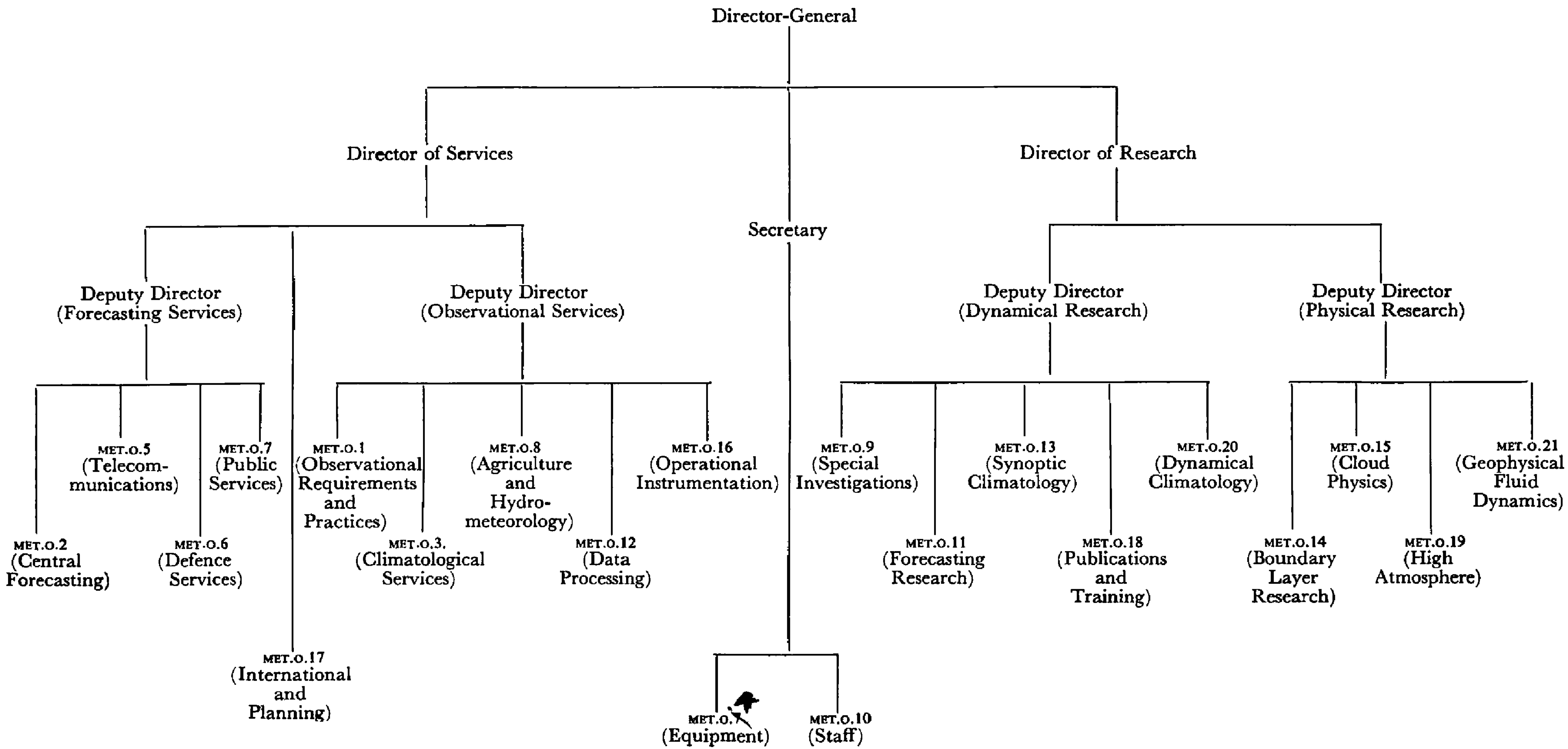
OBSERVATIONAL SERVICES

DEPUTY DIRECTOR	R. H. Clements, M.A.
OBSERVATIONAL REQUIREMENTS AND PRACTICES	
Assistant Director	J. K. Bannon, B.A.
Marine Superintendent	G. A. White, Captain, Extra Master
CLIMATOLOGICAL SERVICES	
Assistant Director	L. Jacobs, M.A., M.Sc.
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.
OPERATIONAL INSTRUMENTATION	
Assistant Director	N. E. Rider, D.Sc.

SECRETARY, METEOROLOGICAL OFFICE D. Hanson, M.A.

METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION

(at 31 December 1970)



THE DIRECTORATE OF SERVICES

Special Topic—Weather Services for the Community

One of the functions of the Meteorological Office, as the State weather service, is to keep the community informed of current and expected weather in and around the United Kingdom. This general function is discharged by providing weather bulletins for transmission by radio and television, for publication in newspapers and for use by the Post Office Corporation in its automatic telephone weather service.

Radio

All four BBC radio channels and most of the BBC local radio stations broadcast weather forecasts prepared by the Office. On the four main channels the total transmission time devoted to weather, excluding special forecasts for shipping, is about four and a half hours each week. From data for 1970, supplied by the BBC's Audience Research Department, the peak listening time on weekdays was in the morning, around breakfast time, when about 10 million people heard the weather forecasts. The pattern of listening was different at weekends; audiences were smaller and on Sundays the mid-evening weather bulletins were the most favoured.

Television

Since 1954, Meteorological Office staff have appeared daily on BBC Television and have described present and future weather with the aid of isobaric and symbolic charts. In 1970 the personal presentations were in the early afternoon, early evening and at the end of the day's programmes—all on BBC 1. At several other times of the day, both on BBC 1 and on BBC 2, charts with legends descriptive of the expected weather were displayed while scripted forecasts were read. On average between 9 million and 11 million people watch these BBC Television presentations of weather each night.

Most of the Independent Television companies show weather forecasts in their programmes, all of them based directly or indirectly on information issued by the Office. The method of presentation is a matter for the company.

Radio and television channels provide a ready means of advising the public of adverse weather likely to affect large sections of the population. With the co-operation of the BBC and the ITV companies, warnings of the occurrence of dangerous conditions such as dense fog, moderate or heavy snow and glazed frost or icy roads are issued on Radio 2, BBC TV and most ITV channels. These are known as FLASH messages. In addition forecasts of fog or strong winds affecting motorways are broadcast on Radio 2 as occasion demands and, for the benefit of local authorities with road clearance responsibilities, warnings of expected snow are transmitted on Radio 2 at 4 p.m.

The Press

Many of the national and provincial newspapers print weather data and forecasts. The form of presentation varies from straightforward reproduction of charts and tabulated information, issued by the Office through the news agencies, to pictorial interpretations of these issues. A drawback to the usefulness to the public of forecasts appearing in the newspapers is the lapse of time between preparation of the forecast and its reaching the reader.

Limitations of both broadcasting time and newspaper space generally prohibit a detailed description of weather for small areas in the forecasts presented to the public by these means. These limitations may not be important to those for whom a broad outline of the expected weather is sufficient. However, many activities are very sensitive to weather conditions and detailed advance information about the weather for the place or area concerned is helpful in that plans can be made to take advantage of favourable weather or to avoid adverse weather. For people engaged in such weather-sensitive activities the generalized forecasts available through radio, television and the Press are not usually adequate. Such people need greater detail and advice of a more specialized nature which may be obtained by telephone either through the Automatic Telephone Weather Service (ATWS) or as a personal service from one of the forecasting offices listed in the *Post Office Guide*.

Automatic Telephone Weather Service

This service, operated by the Post Office Corporation, is available from many telephone centres throughout the kingdom. At each centre tape-recorded messages are maintained, carrying a forecast for the local area. These forecasts are provided by the Meteorological Office and are changed every six hours, or more often if conditions so require. In some parts of the country, as well as carrying detailed forecasts for the local area, ATWS provides forecasts for other districts likely to be of interest. For example, people living in Manchester can get detailed forecasts not only for the area around Manchester but also for the Lancashire coast and for the north coast of Wales by dialling the appropriate numbers. In the London telephone area, forecasts for five other districts in south-east England, as well as for Greater London, are available on the system; for the benefit of foreign visitors, forecasts for the London area are also recorded in French, German and Spanish.

ATWS first started in March 1956, in the London area. It proved popular at once and by the end of 1956 over three million calls had been made. In 1957 services began in Liverpool, Manchester, Birmingham, Glasgow, Belfast and Cardiff. By the end of 1962 the service had been extended to 17 areas and the number of calls had risen to over six million. Since then the Post Office has continued to expand the service and by 1970 it was available from 49 telephone centres and the number of forecast areas had increased to 24, with calls totalling 13 251 614. Over 30 million people live in areas covered by ATWS and can obtain a local area forecast at any time of the day or night for the price of a local telephone call.

Personal service

The second source of detailed advice available to the public differs from all the services so far described in that it enables anyone with a problem about weather to discuss it directly with a meteorologist. This personal service is available from about 40 stations of the Meteorological Office in all parts of the country. The telephone numbers of these stations are given in area telephone directories and are publicized in other ways. In addition some 50 other stations have contacts with the public and deal with weather inquiries.

The demand for personal service provided by these offices has increased year by year. Most of them are aviation forecasting offices and have service to aviation as their first responsibility. With the growth of public demand for personal advice on the weather the pressure on some of these offices increased to such an extent that special offices have been opened to deal with the needs of the community. The first office of this type was the London Weather Centre, opened in 1959 on a ground-floor site in Kingsway with a shop window and ready access by the public; this office subsequently moved to High Holborn. After the establishment of the London Weather Centre other cities acquired similar offices (Glasgow in December 1959, Manchester in June 1960, Southampton in December 1961 and Newcastle in April 1967). The forecasting office at Watnall, near Nottingham, which had previously served aviation, became a public service office in April 1967 with functions similar to those of a Weather Centre.

The increasing demand from the public for personal advice is shown by the following table which gives the annual totals, 1962 to 1970, of inquiries of this kind dealt with by all outstations of the Meteorological Office in the United Kingdom. Totals for Weather Centres and for other (mainly aviation) stations are shown separately, inquiries dealt with by Watnall being included in Weather Centre totals from April 1967 and in 'other stations' before then. For each year the number handled by each category of station is also shown as a percentage of the annual total.

	Weather Centres		Other Stations		Total
	Number of inquiries	*per cent*	*Number of inquiries*	*per cent*	
1962	379 243	48	405 895	52	785 138
1963	435 529	48	477 222	52	912 751
1964	461 327	48	505 938	52	967 265
1965	521 815	45	641 292	55	1 163 107
1966	535 224	46	649 697	54	1 204 921
1967	683 200	54	581 292	46	1 264 492
1968	821 553	55	658 739	45	1 480 292
1969	877 467	55	733 017	45	1 610 484
1970	887 810	54	745 668	46	1 633 478

In 1970 the total of inquiries at all stations had risen to 208 per cent of the 1962 total, at Weather Centres to 234 per cent and at other stations to 184 per cent. Thus the Weather Centres have been taking an increasing share of these inquiries but this has not prevented growing pressure on the other stations.

Study of the monthly totals reveals seasonal peaks in mid-winter and in the summer. This is illustrated in Figure 1 in which are shown the monthly totals for 1962 and 1970 and also the monthly averages for the whole period. Intervening years show the same general shape, with some variations from year to year in the particular months in which the highest and lowest values occur, e.g. in 1964 the summer peak was in June. Variations of this kind can be explained by the occurrence of unusual weather, perhaps the most notable case being the effect of the snowstorms of February 1969 on the demand for weather advice, when 203 820 inquiries were received, the highest monthly total yet recorded. Figure 1 also illustrates the upsurge of inquiries during the nine-year period. By 1970 the number of inquiries in the 'quiet' spring and autumn months was greater than the number in the busiest months in 1962. It is noteworthy that in 1970, for the first time, each individual monthly total exceeded 100 000.

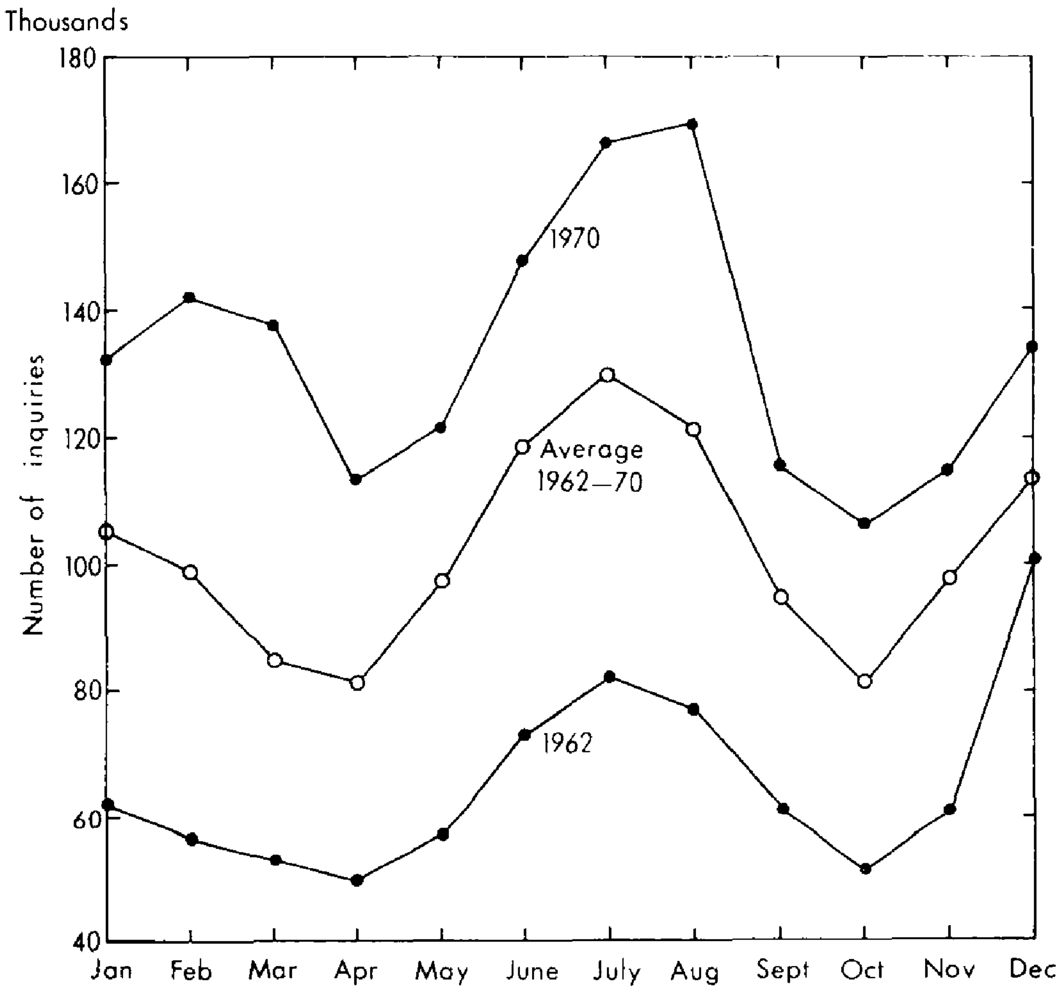


FIGURE 1 — PUBLIC INQUIRIES: MONTHLY AVERAGES FOR PERIOD 1962–70 AND MONTHLY TOTALS IN 1962 AND IN 1970

Offices handling inquiries from the community allocate each one, as far as they are able, to the appropriate category describing the interest of the inquirer. About three-quarters of all inquiries come from five areas of interest: agriculture, industry, holidays and recreation, marine, and road transport. Figure 2 shows the 1962 and 1970 totals in each of these categories. In all five there has been a substantial increase, notably in the industrial, recreational and road transport areas.

It is interesting to look at some of the changes in demand within subdivisions of these categories. The industrial category, in particular, includes inquiries from the public utilities (e.g. gas and electricity boards, British Rail) and from the construction industry. In 1962 the public utilities accounted for 73 000 (54 per cent) of the 135 000 industrial inquiries, and the construction industry for 28 000 (21 per cent). In 1970 the industrial total of 323 000 included 144 000 (45 per cent) from the public utilities and 97 000 (30 per cent)

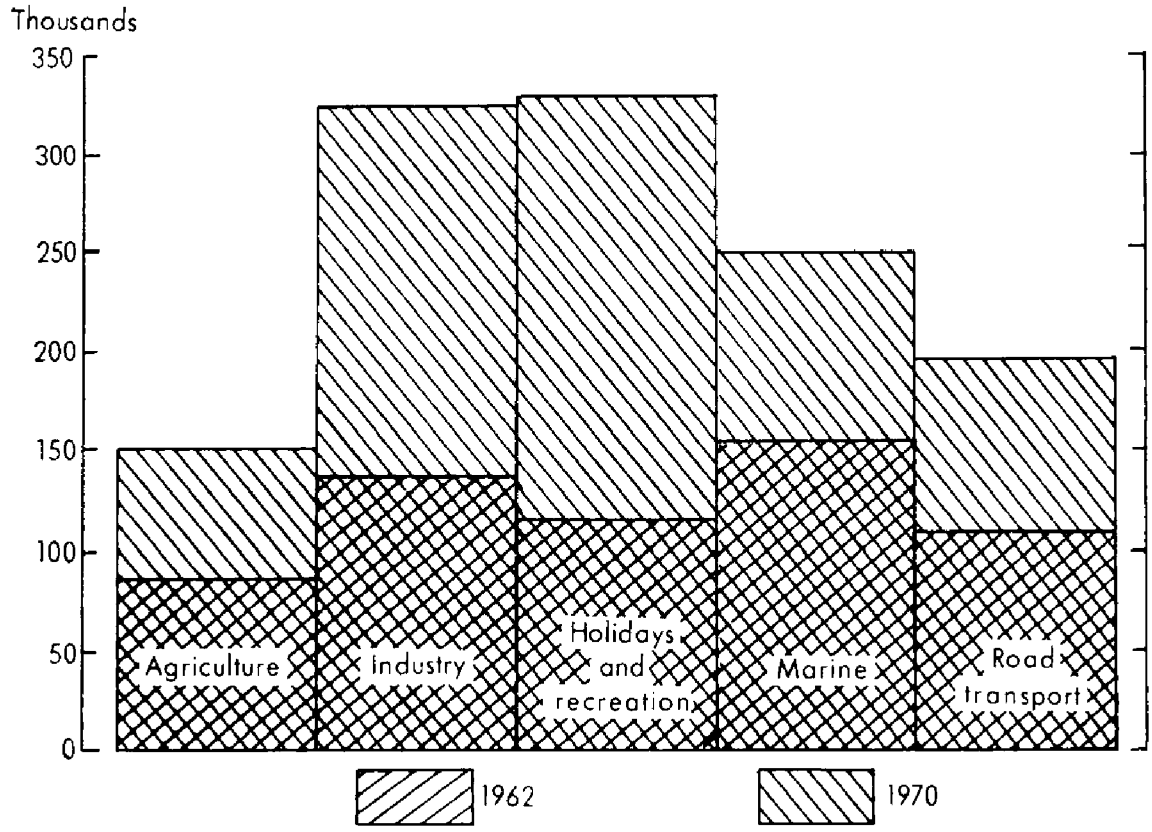


FIGURE 2 — SELECTED CATEGORIES OF INQUIRIES: 1970 TOTALS SUPERIMPOSED ON 1962 TOTALS

from the construction industry. Thus although the number in both sub-categories has increased, the rate of increase in construction inquiries has been greater than that in the public utilities sector. In fact, from more detailed information, not reproduced here, it emerges that inquiries from the construction industry have increased at a greater rate than those from any other section of the community.

The activities giving rise to requests for personal and detailed service are extremely varied and in some cases weather has such an important effect that special arrangements are made with the customer for a routine service of forecasts or for warnings to be given when adverse weather is foreseen. These routine and warning issues account for about one-fifth of the personal service provided for the community. How this specialized and detailed advice on weather can aid the efficiency of industries and organizations that affect the daily life of the community may best be illustrated by describing the work that is done for some of the major service industries and for local authorities.

Services to the North Sea oil and gas exploration and production industries

Oil scientists had long regarded the North Sea as a potential source of oil and gas, but it was the discovery, in 1959, of natural gas in commercial quantities which really stimulated widespread interest and action.

The first drilling operation in that sector of the North Sea allocated by international agreement to Great Britain commenced in 1964. Prior discussions between the oil company concerned and the Meteorological Office had established the forecasting requirements; briefly, these were for forecasts for up to three days ahead to include as much detail as possible on wind speeds and directions and wave heights and periods. The forecasting task was assigned to the London Weather Centre, under overall guidance from the Central Forecasting Office, and forecasting techniques were developed, that for wave forecasting being based entirely on the work done at the National Institute of Oceanography.

The company's assessment of this forecasting service was very favourable and as new operators entered the field they also took advantage of the service offered by the London Weather Centre. By 1970, all companies and consortia operating in the British sector, with one exception, received a service from the London Weather Centre; indeed, in some cases companies operating in sectors of the North Sea allocated to other nations also requested this same service.

After six years of operational experience, the service now established as routine consists of twice-daily forecasts of wind speed and direction, wave height and period, weather, visibility and cloud for 48 hours and 72 hours from the time of issue; additional forecasts, making a total of four per day, are normally issued when a rig is under tow from one location to another.

Services to the gas industry

Weather has always been one of the more important factors which determine gas consumption and this is simply demonstrated in Figure 3, where the daily gas 'sendout' for one of the 12 Area Gas Boards is plotted against 'effective' temperature (a temperature which is weighted to take into account the observed delay between a change in temperature and a change in gas consumption).

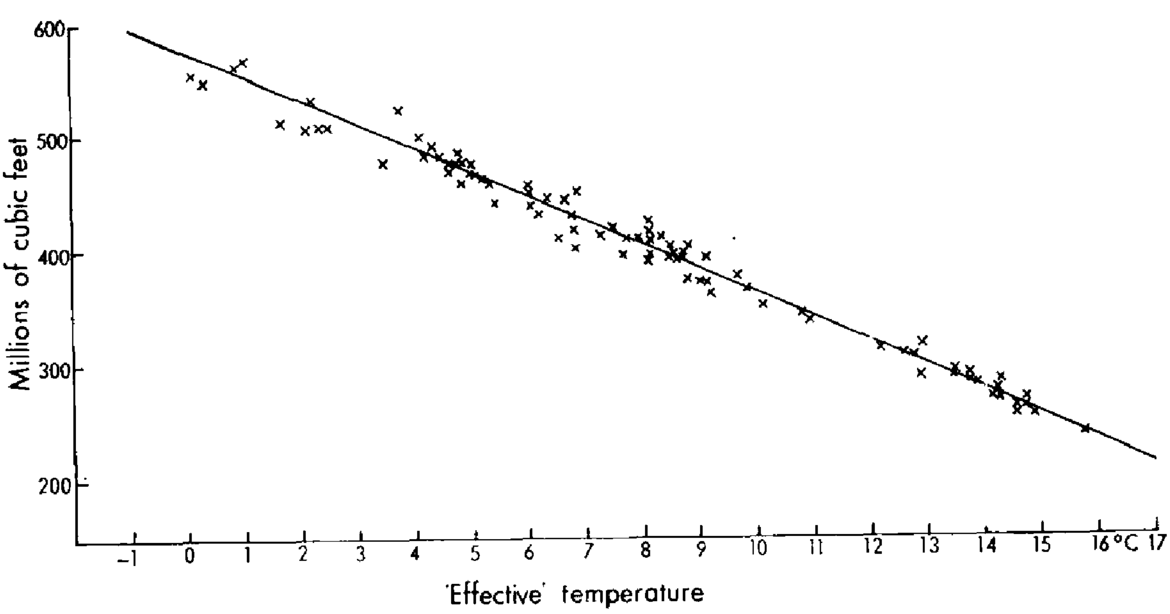


FIGURE 3 — AN AREA GAS BOARD'S DAILY GAS 'SENDOUTS' PLOTTED AGAINST 'EFFECTIVE' TEMPERATURE, WINTER 1968–69, WEEKDAYS ONLY

(Reproduced by courtesy of Mr C. W. Stubbs, North Western Gas Board)

In recent years, the greatly increased use of gas for domestic purposes has made the industry more weather-sensitive than ever. Domestic consumption, in particular that associated with gas fires and central-heating installations, fluctuates widely according to weather. In the past the unexpected, but comparatively small, sudden demands have been catered for by increasing the production of town gas or by drawing on reserves stored in the familiar conventional gas-holders. Accurate weather forecasts lead to improved predictions of gas demand which in turn result in more efficient and economic use of the distribution system, thereby enabling the industry to operate with a smaller margin of reserve.

With the discovery of natural gas in the North Sea and its utilization as a replacement for town gas, the problems of meeting gas demand have remained, although they are somewhat different. Natural gas enters the country at three points from which a gas grid takes supplies to many areas. The gas takes an appreciable time to move across the country through the gas grid and although the pipe-line system can be used for storage purposes by 'line-packing' within certain pressure limits, changes in gas demand have to be met by increasing or decreasing rates of supply from the North Sea Gas Producers. These rates can only be modified on several hours' notice from the Gas Council and thus the importance of accurate weather forecasts, needed in order to assess gas demand and to give the required notices, still remains.

Each of the 12 Area Boards has its own Grid Control Centre which controls the production, storage and supply of gas in its own area. Meteorological services to these Grid Control Centres are provided by 13 forecasting offices. Basically, these services comprise forecasts of the daily maximum and minimum temperatures and a general statement on the weather for up to three days ahead, but the precise requirements vary from one Board to another and, in some areas, detailed forecasts of the hourly temperature changes for periods of 24 hours ahead or more are provided as routine.

Services to the electricity supply industry

In England and Wales there is an integrated power system operated by the Central Electricity Generating Board (CEGB) by means of which the electricity generated at the Board's 193 power stations is made available to the 12 Area Electricity Boards at some 700 bulk supply points. The South of Scotland Electricity Board and the North of Scotland Hydro-Electricity Board are responsible for the generation, transmission and distribution of electricity throughout Scotland and a close working liaison is maintained between these organizations and the CEGB.

For operational purposes, England and Wales are divided into seven Grid Control Areas in each of which there is a Grid Control Centre working to the overall instructions of the National Grid Control Centre in London. In the early days of the original 132-kV Grid system, each Grid Control Area had a sufficient number of power stations to meet its own local electricity requirements. Since then, however, the need to site large coal-fired power stations on coalfields for economy of production and both nuclear and oil-fired stations on the coasts and estuaries has led to the construction of the 400/275-kV Supergrid system to convey large amounts of power to the centres of consumer demand. There are connections between the CEGB system and the systems of the South of Scotland Electricity Board and Électricité de France.

The consumers' demand for electricity varies throughout the day and through the year, but the total amount of generating plant is designed to meet the highest winter demand. Very large savings in fuel and money are made by running just sufficient plant at any one time to meet the consumer demand and by selecting the plant in 'order of merit', that is, by using the plant with the lowest production cost first and progressively bringing in plant with the next lowest production cost as the demand for electricity rises. The interconnecting Grid between power stations and the bulk supply points permits this flexibility of operation.

The economic planning and operation of the Electricity Supply System is dependent on specific knowledge of demand variation and growth. The CEGB system exhibits a marked regular pattern of diurnal, weekly and seasonal variation of electricity demand, but this is to a large extent masked by weather factors, which account for practically the whole of the non-regular variability in demand. On a typical winter weekday, a general fall in temperature of 1 degC increases electricity demand by about 1·9 per cent, or 650 MW nationally; similarly, a change in daylight illumination from a clear to a completely obscured sky can increase demand by up to 5 per cent at certain times of the year. Changes in wind speed and the onset or cessation of precipitation also have an identifiable effect on demand. Foreknowledge of these likely changes in demand is of great value to the CEGB, who require timely notice of probable weather changes so that power stations may be notified of changes in output likely to be required in the short term.

Figure 4 shows the typical daily demand and the maximum daily demand on the CEGB system during the winter of 1969–70. The maximum demand occurred on 8 January 1970 when the British Isles were under the influence of a cold, continental airstream with moderate to fresh, locally strong to gale, south-easterly winds, with slight snow in places and, apart from the extreme south-west, with maximum temperatures between +1°C and +5°C; in brief, a biting cold day.

Routine forecasts and observations of recent past weather are issued several times a day to the Grid Control Centres in England and Wales by seven forecasting offices (the South of Scotland Electricity Board receives a similar service from the Glasgow Weather Centre). Both provisional and final forecasts are provided, the former covering periods of up to 30 hours ahead and the latter periods of up to 5 hours ahead from the time of issue. These forecasts and observations serve the dual purpose of meeting both Area and National Control requirements for short-term demand predictions; they are the basis for the predictions by each Grid Control Centre of its local demand and they are also used by National Control to predict the total demand on the system hour by hour throughout each day, these predictions being continuously updated in the light of actual demand trends and the latest available weather forecasts.

In addition, the medium-range weather forecasts which are issued daily covering the 72-hour period ahead are used by the CEGB in determining the amount of generating plant which may be taken out of service for routine maintenance. A vital factor in this planning is the Friday forecast of maximum and minimum temperatures for Saturday, Sunday and Monday provided by each regional meteorological office to its local Grid Control Centre.

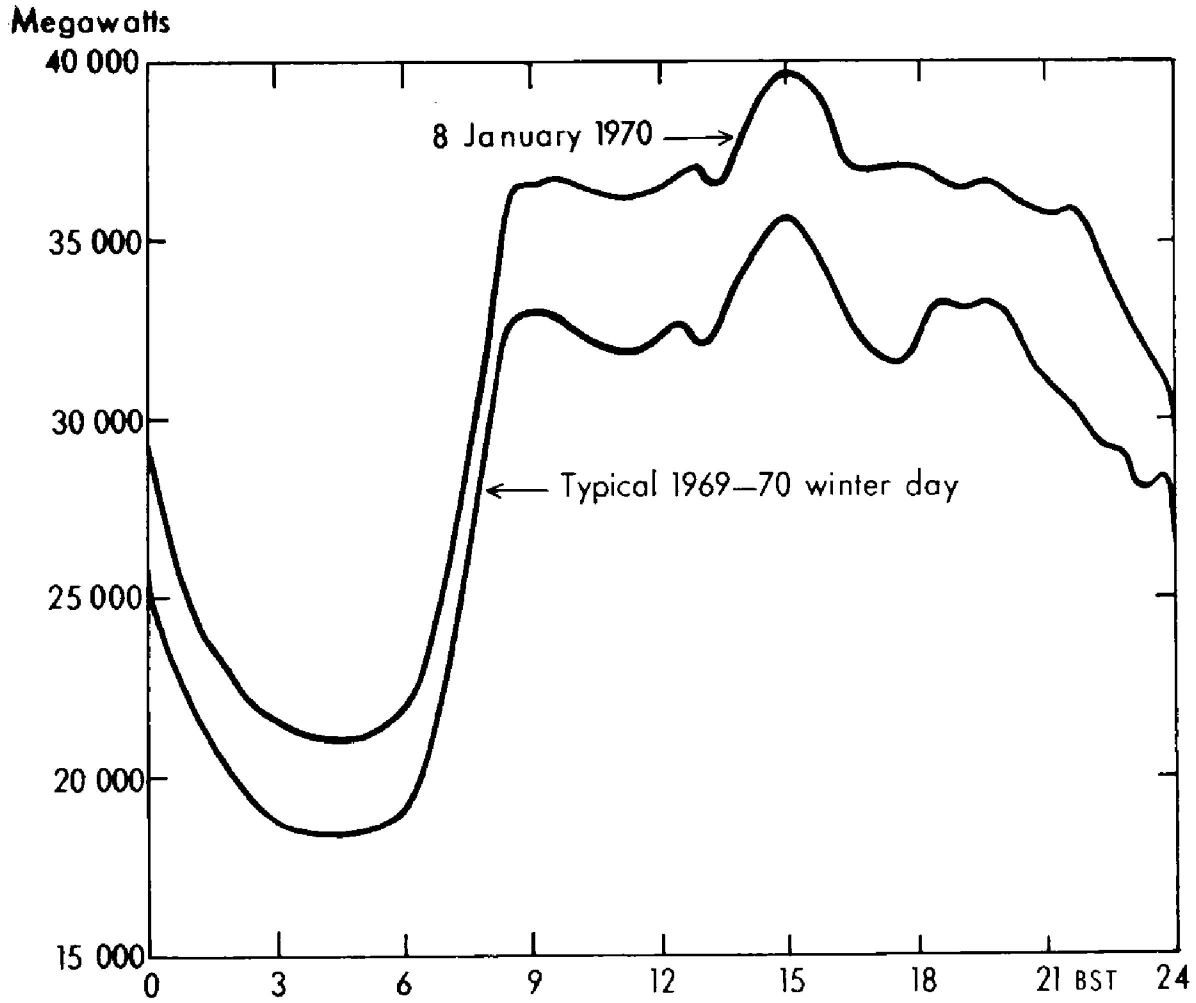


FIGURE 4 — TYPICAL AND MAXIMUM DAILY DEMANDS ON CENTRAL ELECTRICITY GENERATING BOARD SYSTEM DURING WINTER OF 1969–70

Other features of the weather forecasts of value to the CEGB are indications of the level of risk that overhead power lines may be struck by lightning and, in winter, the risk of icing on those power lines passing over high ground.

Services to local authorities

A major problem facing all highway authorities during the winter months is the maintenance of a smooth flow or road traffic under all weather conditions. For many years, the Meteorological Office has operated a scheme whereby subscribers are notified when snow or low temperatures are likely to affect road conditions. Year by year, an increasing number of authorities have subscribed to this warning service, and in 1970 the total exceeded 400, involving some 20 forecasting offices.

Fog is another serious hazard to road traffic, particularly to the fast-moving traffic on the modern motorways, and following multiple motorway crashes in fog in 1965 a close liaison was established between forecasting offices and police authorities for the exchange of warnings and motorway weather reports; with the opening of new motorways this exchange has been steadily expanded.

Conclusion

In recent years, many nations have become increasingly aware of the contribution which Meteorological Services can make to their economic growth and development. In the United Kingdom, the Meteorological Office has done much to publicize and expand its services to the community and now has a senior officer whose sole task is to establish and maintain contacts with all sections of industry whose activities may be affected by weather. Though there has been a notable increase in the past few years in the frequency with which industry has called on the services of the Meteorological Office, and this applies particularly to the construction industry, the Office is conscious of the great economic benefits which would accrue to the nation from still more accurate forecasts and from the ability to forecast with a reasonable level of success for longer periods ahead, up to a season or more, and research continues to be devoted to these ends.

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 two to three days.

Secondly, CFO is responsible for routine forecasts for sea and land areas, for the notification of expected specified weather such as fine spells and for warnings of hazardous conditions. The forecasts are mainly intended for dissemination by the Press, radio 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.

Thirdly, CFO is a Regional Meteorological Centre within the concept of World Weather Watch (WWW). In this role CFO undertakes to meet the needs of various countries in Europe for certain regional forecasts. It fulfils this role by the preparation, for wireless-telegraphy and radio-facsimile transmission, of actual and forecast charts covering a large area of the North Atlantic Ocean, Europe and the Arctic.

Forecasts of wave height and direction are produced as routine by computer for the North Atlantic area, for periods up to 48 hours ahead. These are broadcast as a WWW requirement for the benefit of other European maritime nations and of ships at sea. They are also required by CFO in connection with its ship-routeing service.

During 1970, 315 ships were routed across the Atlantic in one direction or the other. This is an increase of approximately 60 per cent on the 1969 figure. It is gratifying that this service continues to become more widely used. The object is to provide the ships with recommended routes or courses to steer, so that the time of crossing will be the least, commensurate with the avoidance of wave conditions liable to cause damage to the ship or its cargo. The method used remains that adopted for the ship-routeing experiment carried out in 1967. The speed of the vessel along various possible tracks is estimated in relation to the predicted wave fields, having regard also to conditions expected in the outlook period beyond 48 hours ahead. However, before advice to the master of a vessel is offered, it is necessary to consider also a number of other factors, such as fog, icebergs, ocean currents and any special conditions which may be important to a particular vessel on a particular voyage.

Advisory forecasts were supplied to the meteorologist on board the fishery advisory vessel *Orsino* in Northern Iceland waters until the end of April. This service was revived in December, but in a considerably modified form pending the availability of a vessel to replace the *Orsino* which is no longer available.

Cloud photographs from the automatic picture transmission (APT) of the United States ESSA weather satellites have continued to be received at Bracknell daily and are a routine aid in the preparation of analyses over the North Atlantic and European areas. Interpretations of the pictures (neph-analyses) have been prepared for issue to outstations by land-line facsimile and radio-facsimile. These nephanalyses are made from pictures received during the two orbits nearest to the British Isles. They are of considerable value to the outstations in their day-to-day work and in the briefing of aircrews.

The plotting and analysis of ice conditions in the northern hemisphere has continued and regular broadcasts are made to assist navigation in waters subject to sea ice, as well as to assist other meteorological services. During the polar summer the APT pictures mentioned above are of considerable value in delineating the edges of the main icefields, though the resolution is insufficient to depict individual icebergs. The United States satellites have produced infra-red pictures experimentally for a period of several months during the year. They were of some value in this work but their true worth will be shown after operational use during the polar winter. The ice charts also show sea temperature isotherms, and separate charts of isotherms are issued on a daily basis for coastal waters of the British Isles. The temperature data for these purposes are all processed by computer.

The forecasting of the movement of major oil slicks at sea has been undertaken by CFO and such forecasts were issued in connection with the tanker *Pacific Glory* when off the Isle of Wight and in Lyme Bay. Complimentary messages were received from the authorities concerned.

Some consideration has been given to the problem of mapping and forecasting the thermocline as this is a task appropriate to a Regional Meteorological Centre as specified by the Congress of the World Meteorological Organization. No routine work has, however, been done in this respect.

Towards the end of the year some preliminary studies were commenced with the objective of producing forecasts for a week ahead on a regular basis. Earlier trials proved encouraging but there is much to be done in verifying the techniques that have been developed.

The computer programming unit of CFO introduced modifications to the KDF9 computer routines which have been in current use for some years by the routine production of charts of tropopause temperature and pressure as from 12 February. Freezing-level charts were also introduced on the same date.

Objective analyses for the 850-, 700- and 300-mb levels were introduced as routine CFO output as from 27 April, so that all analyses and forecasts, other than those for the surface, which are issued on a routine basis by CFO are now made by computer. In many instances these are line-drawn by an electro-mechanical line-drawer.

With the impending purchase of the new IBM 360/195 computer all staff in the programming unit have received training in FORTRAN and most of them in ASSEMBLER languages. Subsequently a number of programmes which have been written in readiness for the new computer are being tested and developed at the IBM test centre at Croydon.

The work on analysis by means of orthogonal polynomials mentioned in the report for 1969 has continued and a number of papers have been published. A true 4-dimensional analysis system is becoming more urgent in order to incorporate wind measurement from aircraft and temperatures from satellites, both at non-standard times. Further development will necessarily remain restricted until the installation of the new IBM computer.

CFO remains responsible for the publication of the *Daily Weather Report* (DWR) with its *Overseas Supplement* and *Monthly Summary* and the *Daily Aerological Record* (DAR). Copy for these publications is largely extracted by computer methods.

Services for industry, commerce and the general public

Forecasting services for industry, commerce and the general public are provided directly by the Weather Centres and a number of other forecasting offices, or indirectly through the media of radio and television, the Press and the Post Office Corporation's automatic telephone weather service.

The demand for weather information continued to grow during 1970, although at a somewhat reduced rate compared with 1969 and earlier years. Direct calls received at all forecasting offices reached a new record total of 1 633 478 compared with 1 610 484 in 1969; Table X gives a breakdown of these inquiries according to purpose. The general distribution of inquiries remained much the same as in previous years, and it is of interest to note that inquiries in connection with holiday pursuits, the vast majority of which are casual inquiries answered without charge, still occupy the dominant position in the Table.

The dissemination of routine forecast information via the mass media continued, although the year saw some important changes in detail. The reorganization of BBC Radio Services in April involved some alterations in the forecast schedules; a number of broadcasts on Radios 1, 2 and 3 were extended from 30 seconds to 1 minute, and this permitted the issue of a national forecast and outlook in place of the previous brief summary, but changes in timing of some of the Radio 4 forecasts resulted initially in a reduced service to listeners in the South and West Region. The April reorganization produced a greater interest in recorded and 'live' contributions by Meteorological Office staff on weather topics in national, regional and subregional news magazine programmes. This resulted in monthly recorded interviews with London Weather Centre staff for the *Monthly Weather Survey and Prospects* item in the Radio 4 programme 'PM', twice-daily contributions by staff of Glasgow Weather Centre to the Radio 4 (Scotland) programme 'Today in Scotland' and daily presentations by staff of the Main Meteorological Office at Honington, near Bury St Edmunds, in the Radio 4 (East Anglia) programme 'This is East Anglia'. Until a programme revision made this impracticable, Glasgow Weather Centre also carried out a 'live' presentation on the Radio 4 (Scotland) programme 'Farm Journal'. At the request of the BBC, scripted forecasts or brief summaries were provided regularly for inclusion in the Radio 1 'Johnnie Walker', the

Radio 1 and 2 'Late Night Extra' and the Radio 4 'Today' and 'News Desk' programmes.

In October, the BBC made further changes in the Radio 4 procedures with the object of providing greater flexibility in the Welsh, Scottish and Northern Ireland Regions and, in the English Regions, of establishing a more direct relationship between regional news and regional forecasts. As a result, the relay of certain of the London Weather Centre 'live' Radio 4 presentations in Wales, Scotland and Northern Ireland was discontinued, to be replaced by scripted forecasts prepared by the Central Forecasting Office, while in the English Regions the order of presentation of some of the national and regional forecasts was reversed.

Discussions were held with the BBC and the Marine Division of the Department of Trade and Industry with a view to improving the scheduling and content of the 'Weather Bulletins for Shipping' broadcast on Radio 2 and, as a result, certain proposals have been referred for consideration to the shipping industry and other interested parties. To meet specific requests from in-shore fishermen and yachtsmen additional information on sea-level pressures and tendencies was included in the coastal reports which follow the 'Forecasts for Coastal Waters' broadcast on Radio 4.

The eight BBC local radio stations in existence at the beginning of the year continued to make full use of the forecast services and these were extended to new stations as they came into operation. By the end of the year, routine forecasts, together with warnings of severe weather likely to seriously inconvenience the local community, were being supplied to 16 local radio stations.

In the field of television, there were no major changes during the year. However, discussions were continued with the BBC to find additional time for the 'weatherman' presentations during the early-evening peak-viewing periods and there were firm indications by the end of the year that this would be achieved. The situation with regard to independent television was also less discouraging than last year. All companies were offered, as an alternative to their previous tailor-made services, a standard forecast service at a standard charge, which in many cases represented a reduction in their charge, albeit together with a reduction in the service provided; six companies took advantage of this standard service.

A number of broadcasts and talks were given by members of the staff on radio and television; most of these dealt with past and current weather. The Meteorological Office co-operated with the BBC in the production of two documentary programmes dealing with meteorological research for broadcast on the BBC European and World Services. The Inner London Education Authority Television Unit visited London Weather Centre to film sequences for a documentary for school children on weather.

Routine services to the Press continued on much the same basis as in previous years, but the service of 'Lunch-time Reports' provided by London Weather Centre was streamlined with some saving in staff effort. As usual, a large number of requests were received from the national and provincial Press for special interviews or comment on a variety of topics; in answering these inquiries reference was made where appropriate to the Meteorological Office expert in the particular field.

The automatic telephone weather service (ATWS) was extended to Derby and a new recording service for a new forecast area, north Lincolnshire and the

Retford area, was opened at Lincoln. The total number of calls made on ATWS during 1970 was 13 251 614 compared with 12 401 471 in 1969. Some indication of the possible scope for growth in ATWS may be deduced from the experience in Switzerland where, in 1969, a population only one-ninth of that of the United Kingdom, made over six million calls on the corresponding service.

The arrangements for the winter service of 'warnings of certain road dangers due to weather' to local authorities and others were reviewed and a cross-section of authorities was invited to comment on a proposal to substitute 'warnings of road temperatures below freezing-point' for the previous 'warnings of icy roads'. This proposal received overwhelming support and revised procedures were introduced for the 1970–71 season. Registrations for the service reached an all-time record of 404; in addition, 61 Agent Authorities of the Department of the Environment, the Welsh Office and the Scottish Development Department were registered for a limited service comprising warnings of snow between the hours of 1800 and midnight only.

Arrangements made after the *Torrey Canyon* disaster in 1967 for providing a forecast service to local authorities responsible for coastal areas threatened by oilslicks were revised and extended in June. The new service had its first major test in October and November during the salvage and recovery operations following the collision of the tankers *Pacific Glory* and *Allegro* off the Isle of Wight. Throughout the operations advice on the movement of possible oilslicks was given to controlling authorities and other interested agencies. Forecasts of weather were also provided while the *Pacific Glory* was beached and, later, when she was under tow to Rotterdam.

On the industrial and commercial fronts, routine services for the gas and electricity industries, British Rail, London Transport, the North Sea oil and gas exploration and production industries and many smaller concerns were continued. A special forecast service was provided for British Rail during the summer months to assist in track maintenance. The changing requirements of the gas industry, resulting from the expanding use of North Sea gas and the growth of domestic gas central heating, led to several meetings between representatives of the Office and the Gas Council with a view to standardization of meteorological services.

The work of the Weather Centres at London, Glasgow, Manchester, Southampton and Newcastle and the public service office at Watnall (near Nottingham) continued to show an overall increase, though there was some indication of a levelling-off in demand in the London and Manchester areas. However, in Newcastle, where the Weather Centre was opened in 1967, the number of inquiries continues to grow and the 1970 total represents a 14 per cent increase over 1969; Southampton, too, showed a big increase, most of the additional inquiries being from yachtsmen and marine interests. Excluding weather maps provided for shipping at certain major ports, the total numbers of inquiries dealt with by the individual centres over the past three years are shown below:

	London	Glasgow	Manchester	Southampton	Newcastle	Watnall
1968	347 267	83 728	108 838	73 433	41 097	60 101
1969	338 073	95 223	127 508	77 826	63 903	68 549
1970	335 153	101 549	115 776	95 961	72 603	59 922

Grand totals: 1968, 714 464; 1969, 771 082; 1970, 780 964

There was, as usual, much variety in the services provided. The BBC 'weathermen' gave special television presentations in connection with the flight and 'splashdown' of Apollo 13 and again in connection with the General Election; the first 'outside' television weather presentation was made from Wimbledon during the Lawn Tennis Championships. Southampton Weather Centre provided special services for the 'Round the Island' yacht race in June and again for H.M. Yacht *Britannia* during Cowes Week; the routine forecasts supplied for broadcast by Radio Leicester were broadened to include information of interest to inland-waters dinghy sailors; Glasgow Weather Centre provided a forecast service for the Royal Highland Agricultural Show; London Weather Centre supplied forecasts in connection with the construction of the Royal Sovereign Light Tower.

Numerous letters were received at Headquarters from the general public. They covered many topics, e.g. requests for advice on school weather projects, the effect, if any, of thermonuclear explosions on weather, the probable drift of balloons released at a summer fête and the statistical probability of a favourable wind régime for an attempt on the London–Edinburgh cycling record during the summer of 1971.

Services for the general public (overseas)

Our radiosonde office at Muharraq (Bahrain) is co-operating in Messrs Marconi's research programme into anomalous radio propagation in the Persian Gulf.

An offer to assist Cyprus to develop a forecasting service for the general public was accepted by the Cyprus Ministry of Agriculture and Natural Resources. As a result, a forecaster of the Cyprus Meteorological Service is now completing his training at our offices in Cyprus. With the help of facilities at our Nicosia office and using data available there, he will initiate a public forecast service for agriculture and fishing.

Services for civil aviation

The Department of Trade and Industry (Civil Aviation) 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 Department of Trade and Industry.

The Report of the Meteorological Services Working Group, set up by the Board of Trade (now Department of Trade and Industry) to study meteorological services requirements for civil aviation in the United Kingdom, has been completed and its recommendations are now being studied jointly by the Department of Trade and Industry (Civil Aviation) and the Meteorological Office.

The provision of meteorological services for civil aviation is largely centralized at the Principal Forecasting Office at London/Heathrow Airport. Computerized forecasts from the Meteorological Office computer COMET at Bracknell are processed at Heathrow in the form of forecast weather charts suitable for use as documentation for flights throughout Europe and the Mediterranean and also for flights from European terminals to destinations throughout the North American continent and the eastern Caribbean. These charts are prepared at 6-hourly intervals and are disseminated to users in the

United Kingdom, including 13 major airports, by the internal Civil Aviation Meteorological Facsimile Network (CAMFAX). The charts for transatlantic flights are also disseminated by land-line facsimile to Paris, Frankfurt and De Bilt and radio-facsimile (Bracknell GFE broadcast) throughout Europe by Heathrow under its responsibility as European Area Forecast Centre for the North Atlantic. For longer-range flights outside the European area the products of other area forecast centres are used. These are received from Paris, Frankfurt and Rome. Main Meteorological Offices are maintained at three Air Traffic Control Centres and at Belfast/Aldergrove Airport in Northern Ireland; subsidiary forecasting offices are also provided at 11 major airports and observing offices at 6 minor aerodromes. Subsidiary meteorological offices are provided at five research and development aerodromes administered by the Ministry of Aircraft Supply.

Meteorological services for general aviation (private pilots, flying clubs, air taxi services, etc.) are supplied by local civil aviation and RAF meteorological offices on request. With effect from 1 July 1970 a special Light Aviation Warning Service (LAWS) was introduced. The warnings concern the occurrence of light or moderate hail and/or moderate icing below 10 000 ft and are issued by the Meteorological Watch Offices at Prestwick, Preston and West Drayton and disseminated via the Air Traffic Control Centres, certain military aerodromes and Oxford Airport.

Meteorological services for civil aviation are provided at a number of RAF, civil and joint-user (i.e. RAF and civil) aerodromes in the Mediterranean and Persian Gulf areas. Advice on meteorological matters is also supplied, on request, to the civil aviation authorities in Cyprus and Bahrain. Since May 1970 forecasts for civil aviation at Dubai have been sent from our meteorological office at Muharraq (Bahrain) by radio-facsimile broadcast; other civil aviation authorities in the Persian Gulf have shown interest in taking this broadcast.

Meteorological services for civil aviation in the Persian Gulf area after the 1971 Defence Forces withdrawal were the subject of two meetings with the Bahrain government.

Arrangements for the provision of additional cloud-base recorders on the approaches to seven major civil airports in the United Kingdom are proceeding; the first two installations at Edinburgh/Turnhouse Airport and Belfast/Aldergrove Airport have been completed.

The supply of meteorological data to BOAC in a grid-point format from the Bracknell computer to meet their requirement for a computerized flight-planning service for operation across the North Atlantic was continued during the year as was a similar service to the Air Traffic Control Evaluation Unit at Prestwick.

The British prototype Concorde 002 is now in its second year of test flying. The Principal Forecasting Office at Heathrow, through the Concorde forecasting unit at Fairford, Gloucestershire, has continued to provide special forecasts for this test flying.

The interdepartmental committee set up in 1969 to plan requirements of the new international airport at Mahé in the Seychelles, consisting of representatives of the Foreign and Commonwealth Office, the Department of Trade and Industry (Civil Aviation), the Ministry of Overseas Development, the Finance Branch of the Ministry of Defence, and the Meteorological Office, has continued its discussions during the year.

A Meteorological Office representative attended the ICAO Fifth North Atlantic Regional Air Navigation Meeting in Montreal during April 1970 as a member of the U.K. delegation. The Meeting was concerned with planning for the needs of civil aircraft operating on North Atlantic routes over the next 10 years.

Services for the Royal Air Force

Forecasting services continue to be provided for the Royal Air Force by outstations distributed largely in conformity with the RAF organization. There is a Principal Forecasting Office at Headquarters Strike Command, and Main Meteorological Offices, functioning throughout the 24 hours, are located at convenient centres to control and advise subsidiary offices at RAF stations where a forecaster is available at times depending on the needs of the RAF. A few observing offices are also maintained where there is no forecaster and the duties comprise the making of weather observations. A senior officer of the Meteorological Office is located at the RAF Command Headquarters. This officer acts as adviser to the Air Officer Commanding-in-Chief and as liaison officer between him and the Director-General of the Meteorological Office. This general pattern applies in the U.K. and overseas in the Federal Republic of Germany, the Near East, the Persian Gulf and the Far East areas. There has been a slight reduction in the number of meteorological offices and some minor changes in grouping also took place to meet the requirements of the RAF.

Outstation meteorological services continued to meet the various requirements for the operation of RAF aircraft of all types ranging from those flying at high speed and high level to those with many hours' endurance at low levels.

As a result of a survey of the technical organization of the meteorological services provided for RAF Strike Command and Air Support Command the output from their Command meteorological offices was reorganized. Maximum use is now made of the technical support provided by the Bracknell computer and with the revised systems it is planned to absorb increasing workloads generated by present and future development in the Commands.

Meteorological Offices continue to give regular courses of meteorological instruction at a number of schools in Training Command and at Operational Conversion Units. A preliminary study has been made concerning the suitability of meteorology as a subject for programmed instruction at the RAF training schools. An instructional film is also being made for use at these training establishments.

The RAF have decided to introduce a Runway Visual Range System at about 50 aerodromes. Initially the system is to be based on a count of reference lights visible to an observer positioned near the touch-down point. The Meteorological Office is co-operating in this project by providing technical advice and undertaking the calibration of the lights.

Detailed plans were formulated for the changes, in the organization and in the services provided overseas, which will arise from the withdrawal of defence forces from the Far East and Persian Gulf areas at the end of 1971.

In Libya, following the revolution in August 1969, our offices there were closed and all staff were withdrawn by 23 March 1970. The overseas commitment was thereby reduced by 30 U.K.-based staff.

The training of locally engaged staff in Cyprus (forecasters) and Bahrain (assistants) continues. This has resulted in a reduction of 5 U.K.-based staff posts during the year and further reductions will be possible when training is completed.

A small number of staff were on temporary duty overseas from time to time on special exercises.

Services for the Army

A meteorological office was maintained at the School of Artillery, Larkhill, to provide ballistic information and to give advice and guidance in the training of the Royal Artillery Meteorological Section. Ballistic data were also supplied to two practice camps which were manned when required.

Services for Army Aviation were generally provided by the nearest forecasting office while the Army Aviation units at Middle Wallop and Netheravon were connected by facsimile line to the RAF Air Support Command Main Meteorological Office.

Three offices were maintained at Proof and Experimental Establishments to give meteorological assistance for trials.

At Headquarters No. 1 (BR) Corps in Germany meteorological advice was supplied by a forecaster attached to that unit.

Technical assistance was given throughout the year to the Ministry of Defence (Army) in connection with a proposed automated artillery meteorological system.

Liaison with the Navy Department

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

Services for the Ministry of Aviation Supply

A permanent outstation served the needs of the Royal Aircraft Establishment at Aberporth and the meteorological office at Larkhill provided support for the RAE range on Salisbury Plain.

Services to the Home Office

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

International defence services

Within the framework of NATO, CENTO and SEATO, the three international defence organizations associated with treaties to which the U.K. is a signatory, there are meteorological planning committees on which the U.K. is 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.

North Atlantic Treaty Organization

The twenty-seventh meeting of the Military Committee Meteorological Group took place in Brussels, Belgium, from 9 to 11 June. Mr P. J. Meade, Director of Services, attended as the U.K. member and he was accompanied by Mr E. Evans and Mr A. G. Matthewman.

The Working Groups of the Military Committee Meteorological Group on Weather Plans and on Weather Communications met twice during the year. The first meeting, in Brussels from 9 to 18 March, was attended by Mr A. G. Matthewman. The second meeting, in Istanbul from 13 to 20 October, was attended by Mr A. G. Matthewman (Plans), Mr E. J. Bell (Communications) and Mr D. W. Tann.

An *ad hoc* Working Party of the Military Committee Meteorological Group also met at Norfolk, Virginia from 9 to 11 September; Mr A. G. Matthewman attended as U.K. representative.

The Meteorological Panel (Panel XII) of NATO Group AC/224 met in Brussels from 16 to 20 February. Panel XII of NATO Group AC/225 also met in Brussels from 3 to 6 November. Dr P. G. F. Caton represented the U.K. at both meetings.

The Nuclear Biological Chemical Interservice Operational Procedures Working Party of the Military Agency for Standardization met in Rome from 8 to 12 June. Mr K. Bryant attended as meteorological adviser to the U.K. delegation.

Climatological Services

The main function of the Branch is to provide information and advice about climate needed by the various sections of the community. The foundation of the service is the national climatological network of about 650 observing stations of various types. The majority of these stations are manned by voluntary observers and the Office takes this opportunity to thank them for their excellent co-operation in helping to maintain an efficient service. The Branch is responsible for the inspection of the network and for the collection, quality control, publication and preservation of surface and upper air observations made at stations in the United Kingdom. The surface observations are published in the *Monthly Weather Report* (MWR) and its *Annual Summary* and in other non-routine climatological publications. One of the main tables of the MWR continues to be derived by computer processing of the original data; the typed version from the computer is sent to the printers. Similar production of a second table will start early in the New Year. Work was begun on the preparation of programmes for a version of the whole MWR produced by a computer (IBM 360/195).

Developments in the application of climatology to industrial, commercial and social planning are continuing and this is leading to an increase in the number of complicated and diverse inquiries, especially from commerce and industry. Most of these inquiries require data to be processed and presented in the special form needed by the user. Thus the demands on computer facilities are continually increasing but problems are being tackled now, the solution of which would have been impracticable, if not impossible, in pre-computer days. An example of this type of work is the derivation, requested by the Paint Research Station, of day-time periods during which the British Standards Institution (BSI) specifications for temperature and humidity for external painting were satisfied; the number of spells of various stated durations of painting time were given, starting at different times of the day throughout the year. General advice on the meteorological aspects of air pollution problems is now given by the Boundary Layer Research Branch, climatological information being passed to this branch as required.

The total number of inquiries continued to increase, by about 7 per cent this year. There was less increase in connection with the building and construction industry in this year compared with the previous one; this was largely due to the required information on design wind speeds being available in the latter part of the year in the British Standards Institution Code of Practice CP3: Chapter V: Part 2: 1970, Wind Loads. Requests for the 'Climest' service, which gives estimates of the duration of rain, low temperature and strong winds at any site, and was designed to assist the contractor to estimate the time lost because of adverse weather and thus help him to tender and plan for any contract, have decreased markedly during the year; this service could be used more. As usual, the inquiries covered a wide range and included requests for climatological data in connection with research into the manufacture of carbon fibres, with possible siting of a large factory, the start of a commercial vineyard, the planning for a computer building, and the difference between various sites for tests of exposure to corrosion.

While most requests are for information relating to the United Kingdom, the Office must also be prepared to answer inquiries about the climate of any other country. Data to meet this requirement are usually collected by means of an international exchange of processed material. Examples of these inquiries are the consideration of the climate in Finland, Nigeria and the Congo for the design and development of motor vehicles, the supply of wind data for the design of a nuclear power station in New Zealand, the climate of the Seychelles for the possible development of tourism, the calculation of snow loading on buildings in the Falkland Islands, cloud data for planning an aerial survey of the Peruvian Andes, the supply of temperature and sunshine data for investigating anomalous propagation of television transmissions across the English Channel, and general data for Europe, Turkey and India for planning location filming.

The Office continues to collaborate with government or government-associated agencies such as the Building Research Station, the Road Research Laboratory, the National Physical Laboratory and the British Standards Institution. A senior officer continues to serve on the British Standards Institution Committee on Wind Loading, and, in addition to advice regarding winds, he prepared a report, based on the report mentioned last year, on ice formation to be considered in relation to the design of structures; he also attended meetings of BSI committees to determine the need for a Code of Practice on lattice towers and masts, but during the year two other committees on wind loading concluded their task when publication of the new Code of Practice CP3, mentioned above, was agreed. There is a wide interest in the details of airflow over cities, particularly in connection with building design and pollution studies. An interim report has been prepared on wind over London at heights up to 200 m.

Climatological services for Scotland and for Northern Ireland are provided by offices in Edinburgh and Belfast respectively. The demands on the two offices continued to be high and in Scotland there was a marked increase in the number of inquiries relating to new towns. The Superintendent of the Edinburgh office served on three Scottish Development Department working parties dealing respectively with the requirements for climatological data in Scotland, the performance of windows and other components of buildings, and storm sewerage, and he continued to serve as adviser to the Clean Air Council for Scotland. The Belfast office continues to supply information to Northern Ireland government departments as well as to other authorities and to the general public.

In the marine climatology section the collection and processing of ships' observations for the eastern North Atlantic continued for the annual marine climatological summaries, which are to be published by the Office by international agreement. Copy for 1964 was almost ready for publication by the end of the year, its preparation having been greatly assisted by the use of a special electric typewriter, received in February.

The marine climatology section was augmented at the beginning of the year by the transfer from the Marine Branch of the sections dealing with sea ice and surface ocean currents. Monthly charts were issued showing the distribution of sea ice at the end of each month. Observations of ocean currents were extracted from log-books received during the year as part of a larger programme for the acquisition of a bank of computer-checked ocean current data from 1928 to date. The ocean current and sea ice sections of nine volumes of Admiralty *Pilots* were revised. Revised text and charts were prepared for the ocean current and sea ice sections of the publication *Ocean passages of the world* issued by the Hydrographic Department of the Navy. Inquiries relating to marine climatology, ocean currents and sea ice, were dealt with, among the more interesting being one concerning ice conditions on the coast of south-west Greenland in connection with oil prospecting.

The marine climatologist continues to represent the Office on the Working Group on Marine Climatology of the Commission for Maritime Meteorology (CMM) of the World Meteorological Organization, and on the National Physical Laboratory Hovercraft Sea State Committee and he is also a member of the BSI committee dealing with climatic hazards in the transport and storage of goods. Another officer in the section is now a member of the Working Group on Sea Ice of CMM.

HYDROMETEOROLOGY

The hydrometeorological work of the Office falls naturally into three sections; routine, inquiries and investigations. The routine covers regular collection, scrutiny, processing and preservation of rainfall data for the U.K. 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

797 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. In particular, the year saw the completion of the text of *British Rainfall* for 1965 and considerable progress has been made on the 1966 volume. In the inquiries section the number of inquiries handled continued at the high level of recent years. As in former years many of these came from the legal profession, insurance companies and the building and construction industries.

Many of the major inquiries had a bearing on water resources. Rainfall, evaporation and soil moisture deficit data were supplied to a number of river authorities as a contribution to their work arising from Section 14 of the Water Resources Act of 1963 which requires that hydrological surveys of a river authority's area be made every seven years. Rainfall and evaporation data for the Lambourn Valley were supplied to the Thames Conservancy, bringing up to date the data previously supplied as a contribution to the Conservancy's plan to exploit the ground water of the Thames basin. The Water Resources Board was given rainfall and evaporation data for three major divisions of the River Cleddau in connection with a proposed barrage in the river estuary. Work for the Board in connection with a study of ground water resources of the chalk in the Great Ouse basin was completed; this involved estimates of monthly rainfall and potential and actual evaporation for varying periods of years for 22 catchment areas for which rainfall data were available and estimates of average annual rainfall for 49 sub-aquifer units. Estimates of rainfall and evaporation over the carboniferous limestone area of Derbyshire were supplied to the Institute of Geological Sciences and data were supplied to the British Waterways Board and several water boards in connection with water supply studies.

For a number of years the inquiries section has been responsible for estimating evaporation for a network of stations and for investigations of evaporation problems. Soil moisture deficit bulletins, which were first issued in 1962, were supplemented from the beginning of the year by a table of estimates of monthly potential evaporation for some 80 stations throughout Great Britain. River authorities in England and Wales were active in expanding the network of evaporation stations and the Office acted in an advisory and co-ordinating capacity in respect of the stations and resulting data. Investigations were carried out on the applicability of the Penman formula for estimating potential evaporation and advice and assistance given in university research on the design of networks of climatological stations for Penman estimates. Estimates of monthly evaporation from the surface of Lough Neagh were prepared for the period 1954–69 as a contribution to the Water Resources Board's study of the water resources of the area. Estimates of evaporation at overseas locations were also prepared to meet specific inquiries.

Considerable progress was made in assessing end-of-month soil moisture deficits for the period 1941–65 for a network of stations. There was expansion of the network of sites for which weekly estimates of soil moisture deficits were made as an aid to the programme of potato-spraying against eelworm. The varied work of the inquiries section was greatly facilitated by the development of computer programmes to eliminate the need for repetitive calculations by hand.

The investigations section has been active in several fields. In rainfall work there has been almost equal emphasis on various aspects of basic data collection on the one hand, and the development of methods of summarizing and analysing the data, overwhelmingly now by computer, on the other. Data collection problems have involved representation on both national and international (World Meteorological Organization (WMO)) working groups concerned with the accuracy of precipitation measurements and, with other branches, consideration of this matter has been taken into account in the design, development and recommended methods of installation of new equipment, including automatic rain-recorders. Improvement of observational networks has also been pursued on a broad national scale and locally or regionally for specific purposes. In association with the activities of the Lough Neagh Working Group under the auspices of the Water Resources Board there have been notable developments in this sense in Northern Ireland, with prospects of early implementation of schemes to bring operational hydrology and hydrometeorology in the whole of Northern Ireland fully up to the level now reached through the work of the Water Resources Board and river authorities in England and Wales. Other new network improvement recommendations have been for local authorities interested in hydrological investigations, whilst for the river authorities themselves the period has been largely one of consolidation following up earlier recommendations. A start has been made, in co-operation with the river authorities, to improve networks for determining the water-equivalent of lying snow as an aid to thaw forecasting and subsequent river-flow forecasting.

Developments in rainfall analysis included a study of rainfall deficiencies and a comprehensive areal rainfall programme (CARP). An objective of the rainfall deficiency analysis is to find realistic and practically useful criteria to replace the earlier highly artificial criteria for 'drought'. A parallel synoptic study of rainfall deficiencies is being pursued in the branch. CARP is designed to standardize objectively nearly all assessments of rainfall over areas, very often natural drainage areas, as requested so frequently in hydrology. For the first time a significant departure has been made from the former practices of closely tying virtually all rainfall work to the very irregular distribution of actual station values, by the introduction of a regular 5-km rainfall grid. With a close approach to 10 000 points covering the U.K., this grid is rather denser than the average for the actual station network, which now has nearly 7000 points and will probably have about 8000 within a few years. Whilst greater uniformity in the actual station network would be desirable, the 5-km grid is about right for the convenient and realistic representation of the general body of rainfall information. It will have many applications and developments in the future, in particular when rainfall mapping by computer is taken further than its present early stage.

The investigations section also continued its co-operation, in the way of advice, with a number of university and river authority teams working on rainfall analysis; this work has produced important developments in this field.

Data-processing activities have been pursued in a wide context, including internal preparations with other branches for the new Office computer, joint hydrometeorological work with the Water Resources Board and river authorities, and through international (WMO) working groups and international conferences or symposia.

A scheme of work for the meteorological aspects of the United Kingdom Flood Studies was approved by the Flood Studies Steering Committee, Natural Environment Research Council. Considerable progress was made with the work, and provisional estimates were made of rainfall amounts to be expected at any point in the United Kingdom in any given return period, for durations from 5 minutes to 30 days, together with reduction factors for areal amounts. From statistical studies of annual maximum rainfall amounts observed in the different rainfall regions a provisional assessment was made of probable maximum precipitation for durations from 5 minutes to 8 days for these broad regions, with some indication of the likely variation within regions. Attention was given to the seasonal variation of heavy falls of rain, and the changes in seasonal variation with duration of rainfall and from one rainfall region to another. Particular effort is being given to standardization procedures which will enable the results of all the frequency studies to be displayed in a small number of simple diagrams and tables.

Co-operation was maintained with the team of hydrologists working on the hydrological aspects of the United Kingdom Flood Studies.

An assessment was made of probable maximum rainfall for the catchment of the proposed Brenig Reservoir, North Wales, for durations from 15 minutes to 4 days, together with a preliminary examination of a snowmelt sequence for the catchment.

The Dee Weather Radar Project, whose fundamental objective is the measurement of areal rainfalls by radar, demanded continued co-operation with the Water Resources Board, the Dee and Clwyd River Authority and Plessey Radar Ltd. The radar station, known as Llandegla Research Station, has been built, the radar and ancillary equipment installed and the build-up of operational staff begun (see Plate II).

The Senior Scientific Officer attached to the Institute of Hydrology has continued his research work on evaporation from forests. Considerable progress was made, with acquisition of data on many days. Data included temperature, humidity and wind at five or six levels above the canopy and wind at five levels below the canopy. Detailed radiation data were also acquired. Analysis of the data has included forms of wind profiles, albedo variations with time, soil heat flux and net radiation, and temperature profiles. Close liaison was maintained with the Institute on other matters of mutual interest.

The Office continued to contribute to the work of the Hydrology Committee of the Natural Environment Research Council and to be represented at national level in the work of the International Hydrological Decade. A delegate was sent to the sixth session of the Decade's Co-ordinating Council where plans were formulated for the design of a programme of international research in hydrology after the decade. Delegates were also sent to WMO's Technical Conference of Hydrological and Meteorological Services in Geneva where recommendations were made for strengthening WMO's role in operational hydrology. The branch also contributed to international co-operation in hydrometeorology by supplying the chairman of one working group and members of two other working groups of WMO's Commission for Hydrometeorology. Comparison tests of evaporation tanks have continued as part of the world-wide investigation organized by WMO.

Services for Agriculture

Work continued on many projects: animal and plant diseases and pests; cereal mildew; horticultural problems; irrigation; soil moisture deficits and return to field capacity; shelter; surveys of weather in parts of north-west Scotland, the borders and northern England; watercress and the weather, to name only a few. An investigation was started on the relationships between meteorology and crop yields of cereals, especially maize. Research work on foot-and-mouth disease was completed for the present, and the branch collaborated with the Ministry of Agriculture, Fisheries and Food in trial operational exercises with simulated disease outbreaks. The value of the meteorological research into foot-and-mouth disease has been recognized by requests for some 300 off-prints of articles on the subject in the last 1–2 years. Some aspects of the work of the branch were described in a Headquarters' Colloquium given by a member of the staff in February, and a general survey of work in the last five years appeared in the *Meteorological Magazine* in June.

Important work was done as a matter of urgency for the Agricultural Advisory Council in its investigation into soil productivity and soil structure. This involved attending meetings in London and at the various National Agricultural Advisory Regional Centres and meteorological evidence was put forward both in general and in detail for specific sample localities. The evidence given on the subject of return to field capacity is being published in a more comprehensive form in a Ministry of Agriculture, Fisheries and Food *Technical Bulletin.*

Very active international co-operation has continued, though attendances at overseas international conferences were fewer than usual. One member of the staff continued as President of the World Meteorological Organization's Commission for Agricultural Meteorology; he contributed to a symposium in Sweden on plant response to climatic factors, and was the Technical Director of a regional seminar in Barbados in November. Another member of the staff undertook a three-month Technical Training Mission in Turkey starting in September. A third scientist unfortunately had to withdraw from the International Horticultural Congress in March in Israel for health reasons. Many meetings were attended within the United Kingdom, and contributions were made to most; subjects included environmental problems of farm buildings, management and the use of natural resources, biometeorology and different aspects of agriculture and horticulture. Of particular interest was the invitation for one of the branch to be a member of a Visiting Group to inspect and advise on the development work of the Forestry Commission in Scotland.

Lectures were given to many bodies, including agricultural associations of various kinds, university students, etc., and the list of lectures in Appendix II contains a few random samples of these; such is the versatility of the branch that a lecture on meteorology was even given to the British Antarctic Survey course at Stanmore. Published papers numbered 14 during the year, and 45 agricultural memoranda were issued. Of the published papers, one was a WMO *Technical Note*. Work has proceeded on four other *Technical Notes* by branch members during the year, and most are in the process of publication.

As usual, the closest contacts were maintained with universities undertaking research into agriculture and allied subjects, and with the research stations under the Agricultural Research Council and the Ministry of Agriculture, Fisheries and Food. Several individual inquiries from farmers, students and others were also dealt with.

Observational Requirements and Practices

This branch was set up at the beginning of the year with responsibilities over the whole range of requirements, techniques, standards and procedures for meteorological observations on land, sea and in the upper air. In previous years these responsibilities were divided among several branches, one of which, directing the observatories, was in the Directorate of Research. This new branch is an essential link between instrument development and production on the one hand and on the other hand, the forecasting and applied climatology branches which are using meteorological data to meet requirements for services. The nautical organization, headed by the Marine Superintendent, forms part of the branch.

Observational practices

Particular consideration has been given to the nature and frequency of observation of surface wind required to meet the special requirements of the operation of aircraft.

The representativeness of current measurements of the height of low cloud base at an airfield has been examined; the study has applications to the optimum location of cloud-height measuring instruments near runway approaches.

A considerable mass of data has been obtained from readings from an array of several different types of rain-gauge at the Experimental Site, Easthampstead. From these data it is hoped to establish the accuracy and precision of the new rainfall-measuring and recording gauges, and to develop a system for the use of rain-gauges at sea. Some consideration has been given to the design and field trial of an absolute rainfall-measuring device.

Errors in measurements of air temperature and humidity made aboard ships at sea have been studied, and an improved observational procedure to reduce these errors has been introduced. As a first step towards specifying a more effective radiation shield than the present screen for marine thermometers on ships, an investigation has begun at the Experimental Site, Easthampstead, of the behaviour of commercially available screens of advanced design in the varying environmental conditions of wind, rainfall and sunshine relative to the performance of the standard marine screen and the aspirated psychrometer.

The dewcel is an instrument which provides a potential method of obtaining routine dew-point measurements at temperatures below the freezing-point without the necessity of the constant attendance of a skilled observer. This potential, and the accuracy of the dewcel-determined dew-points is being studied from data from operational field trials of the instrument at the observatories and elsewhere.

A revealing examination was made of the mutual consistency of routine observations of air temperature on the ITA mast at Lichfield at four heights up to 1000 feet above ground level.

Promising results emanated from an analysis of data obtained during a practical trial at Shanwell of the use of the LORAN-C navigation aid as a means of observing upper wind velocities at sea.

Observatories

A special function of Kew and Lerwick Observatories, and of the meteorological section at Eskdalemuir Observatory, is to enable new and improved meteorological instruments to be evaluated in an environment that approaches that of routine service, but at the same time with skilled attention almost continuously available. This aspect of their work has been developing during the past year now that the seismological and geomagnetic work has been fully taken over by the Natural Environment Research Council (NERC) and it has been facilitated by the recent reorganization which has placed the supervision of this work in the new Observational Requirements and Practices Branch. At present there is in progress an extensive comparison of evaporation tanks at Kew and Eskdalemuir as well as an evaluation of the use of the dewcel as an instrument for the measurement of dew-point at all three Observatories (see Plate VI).

No major problems have been encountered at Lerwick (a Meteorological Office Observatory) and Eskdalemuir (a NERC Observatory) where both Meteorological Office and NERC staff work together at the same establishment.

Kew Observatory also acts as a Regional Radiation Centre (under the auspices of the World Meteorological Organization) and one of its standard Ångström pyrheliometers was taken to the recent comparisons of international radiation standards organized by WMO (at Carpentras in southern France in 1969, for European countries only), and to the third International Comparisons at Davos in Switzerland in 1970. Many radiation instruments, for a wide variety of users, have been calibrated at Kew during the past year.

Meteorological Office stations measuring radiation were among the first to use automatic instruments recording in digital form on paper tape for subsequent computer processing and considerable experience has been accumulated; it is now planned to produce a replacement equipment which records on magnetic tape; this should be more reliable and also lead to faster processing.

Thunderstorm location

The network of CRDF stations in the United Kingdom and in the Mediterranean area continued to function as in previous years, controlled from a central station at Easthampstead. As is now usual, a number of inquiries were received from specialized institutions and special observations were made and data provided to satisfy these requests.

Surface observations

In the United Kingdom, 72 surface observing stations report in international and 9 in national code every hour, day and night throughout the year. A further 31 stations report in international and 18 in national code every three hours. In addition 40 stations report in international and 83 in national code at various times each day of the year. Of this total of 253 stations, 103 are manned by full-time professional staff and 150 by voluntary observers most of whom have attended a course on observing at the Meteorological Office Training School.

Reports in plain language at fixed times throughout the year are received from 15 town offices of the Automobile Association, 25 Police or Fire Service stations and 39 road maintenance depots located alongside motorways. Non-routine weather information is also received from AA and RAC road patrols and other sources.

Upper air observations

The normal programme of upper air observations was maintained at the eight stations in the United Kingdom, on four ocean weather ships and at six stations overseas. The station at Tobruk closed in March with the general British withdrawal from Libya. Assistance continued to be given, within the limitations of staff numbers, to other branches of the Office in support of investigations concerning the upper air. A meteorologist continued to carry out radiosonde observations from a merchant ship but staff has not been available to allow an extension of the programme (see Plate III).

The improved performance of balloons, reported last year, has been more than maintained, chiefly owing to the greater use of neoprene balloons.

Runway visual range calibration

Routine six-monthly calibrations of runway lights used for assessing runway visual range in poor visibility have continued throughout the year at most civil airports. Initial calibrations have been made at four civil airports at which new high-intensity runway lighting systems have been installed. Preliminary surveys of runways and runway lighting systems have been carried out at some RAF stations prior to the installation of runway visual range systems.

Marine Division

For more than a century—since 1853—merchant ships of many nations have contributed voluntarily to meteorology by regularly making and recording weather observations while sailing the seven seas. In 1878 earlier efforts were co-ordinated by the formation of the International Meteorological Organization (IMO), the predecessor of the World Meteorological Organization (WMO). Since then, many millions of observations have been recorded and transmitted to land stations by ships during the course of their voyages. At present about 6000 merchant ships of many nationalities are participating in the WMO scheme which divides these reporting vessels into the following categories: selected ships, provided with tested precision instruments on loan, which make comprehensive surface observations and transmit the data to specified coastal radio stations every six hours; supplementary ships supplied with fewer instruments with which to make more limited observations; and auxiliary ships which use their own instruments to make basic observations in abbreviated form.

Although the numerical strength of our voluntary observing fleet increased during the year (it is now about 680 ships in total) it fell short of the increase of 50 instrumental ships which was our target for the year.

The building programme of the Merchant Navy is mostly directed towards larger and faster ships whilst the whole tendency of seaborne trade is towards the container ship, bulk carrier and super-tanker. In shipping circles it is confidently predicted that one container ship will be able to do the work of nine conventional cargo ships and this inevitably means a considerable reduction in the number of ships at sea, already noticeable, although the overall tonnage of the British Merchant Navy is increasing.

In the first six months of the year the number of voluntary observing ships was increased by 15, a little more than half the increase hoped for. Even so, this modest increase involved 63 movements of a full set of instruments between a ship and a Port Meteorological Office, for instruments had to be withdrawn from 24 ships, because of the ship being laid up, sold to foreign buyers or broken up, whilst 39 ships had been recruited. The fact that 39 new ships had come on the list in six months shows that there is no lack of volunteers or enthusiasm amongst shipmasters, but proportionately an increase of 50 ships would involve the movement of 210 sets of instruments which, added to the routine visits to ships and the inspection and exchange of their instruments where necessary would stretch the resources of a Port Meteorological Office, as manned at present, to the uttermost even if it could be met.

Early in 1970 our part-time agent in Southampton resigned for health reasons. From 1948 until 1964, a full-time Port Meteorological Officer had been maintained in Southampton but in the latter year with the decline of Southampton as a major port and the desirability of interesting the distant-water fishing fleets in observing, it was decided to 'promote' Hull from an agency to a full-time Port Meteorological Office whilst Southampton reverted to a part-time agency which it had been before the war. More recent years, however, have seen considerable growth in Southampton as a port with a big increase in both passenger and cargo traffic. It is expected that early in 1971 we shall again have a Port Meteorological Officer at Southampton.

Tankers and container ships spend very little time in port and if the good will of the voluntary observing fleet is to be maintained a constant watch must be kept on their movements. Container ships in particular are likely to visit their home port much more frequently than conventional cargo ships, a container ship on the Australian trade for instance being expected to make five voyages a year instead of the two which have been normal for many years past. Scrutiny of the meteorological log-books received from ships shows that the observations are in general carefully made, and radio weather messages regularly sent to the specified stations. An encouraging feature is the number of ships which, in spite of carrying only one radio officer, are sending four radio weather messages each day and it seems to be more generally realized now amongst radio officers that a late radio weather message is better than no weather message at all. The practice of writing letters of thanks and encouragement after each and every log-book has been received has been continued and shipmasters and observing and radio officers have been encouraged to visit the Office when on leave. There can be no doubt that these courtesies have contributed largely to the good will on which the voluntary observing fleet depends.

'Excellent' awards, were, as for many years past, given to the ships which had sent in the most careful and painstaking log-books during the year and a feature of this year's list was that no fewer than nine trawlers, all fishing in the high Arctic, qualified for awards.

Barographs were presented to four shipmasters for their long and zealous work as voluntary observers at sea.

The British Weather Ships completed 23 years of service in the North Atlantic during the year. The present four ships, ex 'Castle' class corvettes, have now been operating for 10–12 years, and despite their age they continue to give satisfactory service. They co-operate with French, Norwegian and Dutch vessels in maintaining four ocean weather stations in the eastern North Atlantic. Four stations in the western North Atlantic are manned by weather ships operated by the U.S. Coast Guard. A number of other countries make financial contributions towards the cost of operating these vessels. The rules and regulations governing the equipment and the operation of the weather ships are made by the International Civil Aviation Organization supported by the World Meteorological Organization. All the North Atlantic weather stations are normally manned constantly, but since July, when the Dutch ship *Cirrus* had to be withdrawn from service because of serious engine defects beyond repair, station Mike has been unmanned for short periods. All ships make hourly surface and 6-hourly upper air observations (for heights reached in upper air ascents see Table V in the statistics section). The following additional observations are regularly made by British ships; solar radiation and radiation balance, sea temperature and salinity down to the sea bed, magnetic variation and some marine biological work including plankton sampling, squid fishing and the collection of surface seawater samples. Communication and navigational facilities were provided for transatlantic aircraft by all the British ships, and air/sea rescue equipment was kept in a constant state of preparedness. Comprehensive search and rescue exercises in which RAF aircraft sometimes participated were frequently carried out.

We continue to be indebted to the Sugar Line for their co-operation during the year in helping us to fulfil our obligation to recruit a small number of merchant ships to make radiosonde soundings during their normal voyages as part of the World Weather Watch programme, for which purpose a meteorologist is carried (see Plate III).

The Division has continued to work closely with the Central Forecasting Office in the weather routeing of ships in the North Atlantic.

Under the reorganization of Met. O. 1, responsibility for the provision of the 10-day ice charts, the extraction of surface ocean currents from ships' meteorological logs and the revision of ocean-current and sea-ice data in Admiralty *Pilots* was transferred in January to the Climatological Services Branch.

The Marine Observer was published each quarter as usual. The number of marine inquiries, most of them from solicitors, shipping companies, universities and industrial firms was about the same as last year.

Operational Instrumentation

On 1 January the branch formerly known as the Instruments and Observations Branch was re-formed as the Operational Instrumentation Branch following an internal reorganization which embraced the creation of the Observational Requirements and Practices Branch. From this date the latter branch assumed responsibility for observational techniques and the control of the upper air network, including the CRDF stations. However, the staff concerned with the latter two functions were transferred with the work and no more effort became available, on this account, for deployment on the tasks which remained, namely instrument testing and calibration, and 'in service' maintenance. Work on the new branch accommodation at Easthampstead, commenced in July and by the end of the year substantial progress had been made. The buildings are expected to be ready for occupation in May 1971. The collocation of laboratories and field-station facilities will be a substantial help in furthering the work of the branch.

Instrument development

It is convenient to report progress by separating development into 'surface' and 'upper air' activities.

On the 'surface' side, following receipt of financial approval for the procurement of an initial chain of eight Mk 2 land automatic weather-observing systems, detailed specifications were prepared and invitations to tender issued to industry. Two Mk 1 systems were modified for installation on the Lichfield ITA mast and Birmingham Post Office Tower. Development of automatic weather buoys continued with the updating of the first air–sea interaction buoy and manufacture of a second buoy to a similar specification. Both buoys were used in the North Atlantic in June during a rehearsal of techniques for an experiment sponsored by the Royal Society and planned to take place in 1972, and data were successfully recorded on magnetic tape for subsequent analysis.

The reliable performance of tipping-bucket rain-gauges, now used at some 50 stations for making hourly synoptic reports of rainfall, has led to their acceptance for general climatological use. A contract was placed for an initial batch of 30 magnetic-tape event recorders for use with these rain-gauges, together with a translator for rewriting the data on conventional computer-compatible tapes.

A study of requirements for magnetic recording of field data throughout the Office, which was initiated by the need to make the best possible use of the new central computing facilities to be installed in 1971 led to the emergence of a design concept for an integrated automatic data-retrieval system. As a first stage towards implementing this scheme, steps have been taken to procure samples of magnetic-tape data loggers to replace the existing general-purpose paper-tape data loggers, and for use with equipment to provide the basic wind statistics currently derived manually from electrical anemographs. When successful operation of these loggers has been demonstrated, consideration will next be given to the question of providing a flexible interface for use with the new IBM computer.

A single system of telemetry has been adopted for transmissometers, cloud-base recorders, anemometers and automatic weather-observing systems. It provides for either continuous analogue, or intermittent digital transmissions. Prototypes of the Mk 4 transmissometer, providing time-averaged signals at both forecasting and observing offices, are now undergoing trials. Development of a new Mk 5 cloud-base recorder, using electronic function generators in place of mechanical cams, has been started. The new Mk 5 electronic anemometer system, designed to telemeter wind data to multiple reception points, is nearing completion.

The Mk 4 anemometer system is being equipped with automated range-change devices, to prevent loss of record in strong winds, and invitations to tender will shortly be issued for runway cross-wind resolvers for RAF Training Command stations.

The foregoing work has been concerned with the creation of new automatic instrument systems and with their manufacture and introduction into service. Greater attention is being given to rationalization of components, methods of construction, environmental engineering, acceptance testing, field trials, ease of maintenance, and long-term reliability in order to meet the demands of remote unattended automatic operation.

The remainder of the programme is concerned with research into new methods of sensing atmospheric variables and development of systems-compatible transducers for use with these sensors. In the intractable field of hygrometry, the commissioning of the new precision humidity generator has opened the way to more accurate evaluation of new types of hygrometers.

Manufacture of automatic dew-point hygrometers is well advanced, and several lithium chloride dew-point sensors are undergoing operational assessment as remote recording devices which continue to function well in sub-zero conditions. Members of the section are also involved in a study sponsored by the World Meteorological Organization and leading to the development and field trials of an international reference psychrometer.

Miscellaneous sensor projects deserving brief mention include a new design of sunshine transducer, a fully engineered version of the rate-of-rainfall transducer, trials on ocean weather ships to determine optimum siting of static pressure heads and of marine screens, and a trial of the new heated anemometer on Mount Olympus, Cyprus.

'Upper air' development effort has been almost exclusively devoted to the major task of the introduction into routine service of the Mk 3 radiosonde system as a replacement for the current Mk 2B design. Delivery has been made of 100 Mk 3 sondes which have been manufactured from production drawings. Comprehensive ground testing of these has shown that they are up to specification and it only remains to conduct limited flight proving trials, of samples picked at random, in order to reach the stage at which a decision to go into quantity production can be taken. These flight trials should be concluded shortly. Work on the development of the ground equipment has progressed at a satisfactory pace. The necessary computer programmes have been revised and extended during the year and are now being expressed in the form of flow diagrams which will serve as part of the station computer specification.

Efforts to improve balloon performance have continued and Table V shows that at the operational upper air stations there has been a worthwhile increase in the heights attained.

The mechanical workshop has been under-staffed for the major part of the period under review, but the situation improved in November and December. The electronic workshop has made a substantial contribution to the work of the branch but it is not yet possible for a general service for this class of work to be provided for the Office as a whole.

Technical liaison and equipment installation

The number of installations carried out was fewer than in the previous year; this was caused by several factors such as non-completion of works services, late delivery from manufacturers, lack of transport for equipment, and staff shortage. Nevertheless two radars were installed, a 3-cm weather radar for Manchester Weather Centre and a 10-cm wind-finder in Cyprus. Twelve cloud-base recorders and three transmissometers were set up at United Kingdom airfields. One APT (automatic picture transmission) set was installed in Rumania for the WMO Voluntary Assistance Programme and training in operation and maintenance was given to local staff.

Two installations of the modified Mk 1 automatic weather station were completed, on the Lichfield ITA mast and on the Birmingham Post Office Tower. The unusual nature of this equipment has inevitably resulted in a continuing commitment to maintain and modify it from time to time.

The programme for electrolytic hydrogen generators has been considerably slowed down by equipment problems. The teething troubles invariably associated with newly designed equipment have proved particularly complex, and have involved both the manufacturer and ourselves in considerable investigation and modification. As a result only three sets have been installed so far.

An active part has been taken in the work of the Operations Group for the Dee Weather Radar Project; at the end of the year the installation and commissioning by Plessey Radar Ltd of the radar and analyser was virtually complete and the equipment was about to be accepted for operational use.

Technical liaison with manufacturers continued in respect of existing and proposed production contracts. Pre-tender discussions took place on the requirement for data print-out systems for existing wind-finding radars and on the request for five additional wind-finding radars. A contract for this equipment was placed at the end of the year.

Liaison also took place with the manufacturer of the 3-cm lightweight wind-finding radar; a contract has been placed for four sets, two of which are expected to be installed overseas.

As usual, detailed liaison and planning with the Ministry of Public Building and Works took place in relation to various installations and advice was again given to the Ministry of Overseas Development in relation to radars and other meteorological equipment provided for use in CENTO countries.

A visit was paid to the United States to examine at first hand possible systems for the remote display of weather radar pictures, this being the first step towards the planning of a scheme to provide national weather radar coverage.

Increasing attention has been paid during the year to the provision of adequate instrument manuals, specifications and other technical documents.

A small post-design services sub-section has been set up to deal with problems which arise with routine equipment. Its main task is to investigate failures in service with a view to preparing modifications to improve overall reliability.

The quantity of Drawing Office work again demanded that the bulk of it should be contracted out to appropriate firms. There is no likelihood of any change in this system in the foreseeable future.

A considerable amount of time has been spent in planning the new buildings at the Experimental Site, Easthampstead and in talking to the architects and others.

Instrument testing and calibration

Table XV shows the number of instruments which passed through the Test Room. Non-routine work was at a higher level than in most previous years. In particular a prototype humidity-element calibration chamber, for use at operational stations when the Mk 3 sonde enters service, was constructed and plans were produced for the layout of a new centrally located temperature- and pressure-element calibration plant for use when this sonde is delivered in bulk quantities. Assistance was given in the calibration of sensors and circuits incorporated in two experimental buoy-mounted automatic weather stations which were subsequently deployed in the North Atlantic for about a month.

Testing and calibration services continued to be provided, on repayment, for other authorities.

The Mk 2 sonde calibration plant was in operation throughout the year. The usual facilities for the instruction of visitors, some from overseas countries, in testing and calibration techniques and practices were provided.

Regional Servicing Organization

The main function of this organization is to provide a comprehensive maintenance and inspection service for all meteorological equipment having a significant electrical and/or electronic content which is installed for operational use at home and overseas. The scope of the work has been somewhat extended throughout the year to cover some minor installation tasks and field calibration of certain equipment.

The amount of installed equipment continues to increase and consequently there is a gradual expansion of the maintenance burden. To meet these additional demands new centres have been opened at Newcastle and Birmingham, bringing the total number to 15 in the United Kingdom. The need for technical staff to man the service continues to grow and newly trained entrants are currently being absorbed as quickly as they become available. The preparations for the opening of the Llandegla Research Station (Dee Weather Radar Project), which will become operational early in 1971, has put an extra strain on available manpower resources.

Training

The facilities for technical training at Easthampstead continued to improve. The basic course content has been reviewed, updated and extended. In particular, visiting specialists are now provided where necessary to support the permanent instructors. Technical staff already in the field have attended short courses to help them keep abreast of new techniques. Overseas students sponsored by the British Council and the World Meteorological Organization, have attended the basic courses. Several university vacation students have been attached to the development laboratories where they have gained some experience in investigational techniques.

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. It also provides a programming and consultancy service for other branches of the Office. At the end of December 1969 it was announced that an IBM 360/195 would be acquired as the next main computer system for installation at Headquarters, Bracknell. Much planning and preparatory work for the 360/195 has been achieved during 1970 and installation in a new wing is expected towards the end of 1971. Technological advances in computers, data processing and associated equipments continue at a very rapid pace. It is an important responsibility of the Assistant Director in charge of the Branch to keep generally abreast of developments so that advances with potential applications to the Office may be more fully investigated and appraised.

New computer project—IBM 360/195

One of the first tasks was the organization of training courses for computer programmers. During this year all formal tuition was given by IBM instructors at their Training Centre at Sudbury Towers, near Greenford. By the end of December about 110 staff had been trained in the high-level language FORTRAN IV and about 50 in the lower-level IBM language known as ASSEMBLER. Arrangements for the testing of programmes at the IBM Test Centre at Croydon were also concluded quickly and testing of some programmes began in April. Requirements for testing built up steadily as more programmers were trained and in September test runs at Croydon were exceeding 200 per week. Up to this time jobs were being either taken to Croydon by teams of programmers for multiple tests on a single visit or transported by delivery vans between Bracknell and Croydon for overnight running with return of computer output to Bracknell on the next working morning. In October a remote terminal, consisting of a card-reader and line-printer, was installed at Bracknell, connected on-line to the 360/65 at IBM Croydon Test Centre and used for remote testing of programmes. The service was available for limited hours of each working day. By the end of December jobs submitted by the remote terminal had reached 150 per week and the overall number of tests at Croydon had exceeded 450 per week. Testing of some programmes required access to an IBM 360/195. The only 360/195 machines available were in the United States of America and arrangements were made for some time to be made available on suitable IBM 360/195 installations in the eastern United States. Teams (from a dynamical research branch) went to the U.S.A. in each of the months October, November and December for limited testing of programmes on a 360/195. The build-up of Met. O. 12 staff for the new computer continued during the year and Met. O. 12 are co-operating and, in many cases, taking a leading or major role in many inter-branch groups considering several topics of great importance for the application of the new computer to a wide variety of tasks. In addition, planning of the new computer room, the physical layout of the computer, its peripherals and associated ancillary offices was completed. In January an IBM Systems Engineer was allocated to work at the Meteorological Office to assist with systems work. In April he was joined by the IBM Account Representative and in late summer an additional IBM Systems Engineer was available at Bracknell. All are co-operating with Meteorological Office staff to prepare for the installation and use of the 360/195.

It is planned that the 360/195 and the Marconi Myriad computers to be installed in the meteorological telecommunications centre at Bracknell shall be linked together. Some consideration has been given to this problem and some tentative proposals for hardware and software have been formulated in conjunction with the Telecommunications Branch but firm decisions had not been made by the end of the year.

COMET computing laboratory

This laboratory is equipped with an International Computers Limited KDF9 electronic computer which was installed in the summer of 1965. Within the Office the computer is known as COMET. The computer is able to run up to four programmes simultaneously. Its high-speed random-access memory consists of 24 576 (48 bit) words and it also has a magnetic drum which provides a further 40 960 words of backing memory. Other standard peripheral equipment consists of six magnetic-tape units, three paper-tape readers, three paper-tape punches, one high-speed line-printer, and one punched-card reader. A variplotter, manufactured by Electronic Associates Limited, is also available as a special 'on-line' peripheral device sharing a peripheral channel with one paper-tape punch. The laboratory also contains ancillary rooms with a range of tape-editing equipment for punching of data and programme tapes and for 'off-line' printing from paper tape.

One of the main tasks carried out on the computer comprises operational numerical forecasting runs at fixed times. Between seven and eight hours a day are devoted to this work during four periods of intense computer activity. These numerical forecast runs consist of large programmes which occupy substantial parts of the immediate-access and magnetic-drum backing stores and also keep the central processor busy for much of the run. Nevertheless, by a judicious choice of suitable programmes to mix with the forecast run it is possible to use the computer in the multiprogramming mode throughout much of the forecast runs. The variplotter has been used to produce about 50 line-drawn charts from the operational numerical forecast runs each 24 hours and the quality is normally adequate for direct operational use. Other important tasks for COMET are computations for research projects and for parts of the long-range weather routine, routine data processing (e.g. checking and processing rainfall data from about 6500 stations in the United Kingdom) and the preparation of tabular material for certain publications, e.g. *British Rainfall*. The build-up of a comprehensive general-purpose library of meteorological data on magnetic tape has continued. Throughout the year the computer has been operated round-the-clock except for periods of routine maintenance which currently amount to 16 hours a week. On the whole serviceability has been good. For much of 1970 the work load for COMET has exceeded capacity; the back-log has built up steadily during the normal working week but has been reduced very considerably and sometimes cleared at weekends. Some additional KDF9 computer power has been obtained by visiting the Defence (Navy) Research Laboratory, Teddington, to use their KDF9 on some nights. Their co-operation is much appreciated. The additional KDF9 capacity has been a welcome addition but it is only a palliative and a full solution to the growing needs for computing must await the commissioning of the new 360/195 computer.

Punched-card installation

This installation is equipped with a range of punched-card machines, including automatic punches and verifiers, sorters, collators, tabulators, tape-to-card converter, etc. Since it was set up in 1920, a library of over 56 million standard 80-column punched cards containing surface and upper air data from land and marine stations and surface data from voluntary observing ships has been accumulated. The present punching rate of British data is about one and a third million cards a year and about a further three-quarters of a million cards of selected foreign data are obtained through international exchange. The Office has continued to utilize spare capacity at other governmental punched-card installations. Punched-card machines are used for the simpler jobs of data processing which do not involve much calculation, such as frequency distributions and listing and tabulation of data, whereas the larger computing tasks from data on punched cards are programmed for and carried out on COMET.

METEOROLOGICAL TELECOMMUNICATIONS

Meteorological telecommunications have always been a vital component of meteorological services. In former days their role was a fairly separate one but nowadays telecommunications enter into almost every facet of meteorological organization. This has largely come about with the advent of automation both in telecommunications and in data processing. Inevitably there will be a dovetailing of data processing and telecommunications into a vast meteorological-services automated complex both in the national sense and in the international sense.

The year 1970 was eventful because it marked the start in the actual implementation of the automated telecommunications component of the United Kingdom meteorological-services automated complex.

Automation of the meteorological telecommunications is planned in terms of four Phases. Phase I relates to the linking of the Meteorological Telecommunications Centre (Met. T.C.) at Bracknell to telecommunications centres at Washington, Paris and Offenbach to form an automated high-speed data-transmission system. The systems allow for time sharing of data transmissions with facsimile (analogue) transmissions. The major hardware items at Bracknell are two Marconi Myriad II Central Processing Units in dual configuration. No-break power supply and air conditioning are provided. Phase II relates to the automation of the data-telegraph transactions of Met. T.C. It embraces all the features of the Phase I System and also provides for extension of the Phase I System into Europe. The Phase II System is being engineered as a separate entity with its own hardware and software so that it can be proved without interfering with the operational status of the Phase I System. It also is based on Marconi Myriad II Central Processing Units in dual configuration. When proved it will of course be made the operational system in place of the Phase I System. Phase III relates to the moving of Met. T.C. from the Napier Shaw Block of the Meteorological Office Headquarters, Bracknell, to the new Richardson Wing now under construction at Bracknell and the provision of a very high-speed data-transmission interface with the new IBM 360/195 meteorological data processor. It will incorporate all the features of the Phase II System with additional medium- and high-speed data inputs and outputs. The engineering of Phase III is under study with attention being given to the maintaining of meteorological services, particularly telecommunications operations, during the move and to optimum utilization of the Phase I and Phase II hardware and software. Phase IV relates to the extension of automation of the meteorological telecommunications beyond Bracknell to meteorological offices throughout the country.

As to time scales of implementation of the various Phases, much depends on the international meteorological telecommunications environment. High- and medium-speed data transmission will be subject to transmission-error detection and control and this means automated centre-to-centre working. Clearly Met., T.C., Bracknell cannot be implemented as an automated high/medium-speed data transmission centre without implementation of the other international centres to which it is to be linked. As regards Phase I, operational trials of the Washington/Bracknell/Paris/Offenbach data/facsimile transmission system are expected to start in March 1971 with the system becoming fully operational some few months later. Implementation of Phase II will follow once Phase I has been seen to be operationally reliable. Timing of Phase III of course relates to completion of the new Richardson Wing and that is expected in October 1971. The time scale of Phase IV has not yet been determined but implementation is likely in the two or three years following 1972.

The effectiveness of meteorological services is very dependent on international co-operation. Every country of the world is expected to contribute basic observational data for the benefit of all. Also over the years the processing of meteorological information in the sense of analyses and forecasts has become more and more centralized and there has grown up an interdependence of countries on one another for processed products.

International meteorological services and, in particular, international meteorological telecommunications are co-ordinated by the World Meteorological Organization so that the needs of all its Members for both basic observational data and processed information can be met to the best advantage. In this context the United Kingdom as a Member of WMO has certain specific international responsibilities for the collection and distribution of observational data and processed information.

Met. T.C., Bracknell, has a commitment to collect reports of meteorological observations made in the United Kingdom, the Republic of Ireland, Iceland and Greenland and of those made by four ocean weather stations in the North Atlantic. It is also a reception centre for reports of observations made on merchant ships and on aircraft. The Centre has to transmit all these reports for international dissemination. It also has the responsibility to provide a radio-teleprinter broadcast of observational information relating to the European Region. The area of required reception embraces the European continent, North America, the northern half of Africa and western Asia.

Internationally the United Kingdom has a responsibility to provide radio-facsimile broadcasts of pictorial information. There are two such broadcasts which carry between them processed information from the WMO Regional Meteorological Centre at Bracknell and from the International Civil Aviation Organization North Atlantic Area Forecast Centre at London/Heathrow Airport. Additional international requirements for processed (pictorial) information from the United Kingdom are met through land-line facsimile facilities connecting Bracknell with Offenbach, Paris, De Bilt and Copenhagen.

As regards national requirements, Met. T.C., Bracknell, is responsible for the collection and distribution of meteorological information (both observational and processed) to meet the needs of the meteorological services centred at Bracknell and the needs of the meteorological offices throughout the country. The coverage of observational information collected is the whole of the northern hemisphere, the density of coverage being greatest over the United Kingdom and adjacent areas. Collection and distribution of the observational information is largely by a data-telegraph land-line system. Processed information is usually in pictorial format and its distribution is by land-line facsimile facilities.

During the year the fullest use has been made of meteorological satellite facilities. Day-time observational pictures from orbital satellites are supplied in real time through the receiving system of Met. T.C., Bracknell, to the Central Forecasting Office at Bracknell, the Principal Forecasting Office at London/Heathrow Airport and other important outstation meteorological offices. Read-outs of night-time satellite observations are also received.

Operation of the telecommunications organization continued at a high level throughout the year. There were also intensive efforts directed towards the implementation of Phase I and Phase II of the automation of Met. T.C.

The Office is indebted to the Director of Signals (Air) of the Ministry of Defence and to the Directorate of Electronics Production of the Ministry of Aviation Supply for their considerable efforts on behalf of meteorological telecommunications.

International and Long-term Planning

The international character of meteorology inevitably leads to a number of international conferences each year. Many of those in which the Meteorological Office is concerned are held under the auspices of one or other of three intergovernmental organizations. The World Meteorological Organization (WMO) deals with the international aspects of the organized practice of meteorology and its applications to human activities. The International Civil Aviation Organization (ICAO) deals with international questions affecting civil aviation, and many of its meetings are concerned directly or indirectly with the meteorological aspects of civil aviation. In addition, 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 this purpose. There are also meteorological committees associated with the other international military organizations in which the United Kingdom is concerned.

A number of other meetings are organized by one or other of the constituent bodies of the non-governmental International Council of Scientific Unions (ICSU). The various bodies included in ICSU are each concerned with the promotion of one or other of the sciences or spheres of scientific interest, such as outer space, the oceans, the Antarctic, especially as regards international requirements. Meteorology has a part to play in several of these, and the Meteorological Office is represented on several of the corresponding British National Committees.

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 79).

The Foreign and Commonwealth Office and other governmental 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 WMO activities.

The Director-General is Permanent Representative of the U.K. with WMO. U.K. Dependencies are included with the U.K. except for those which, having their own meteorological services, are Members of WMO on their own account (Bahamas, Hong Kong, British Caribbean Territories). The United Kingdom ceased to represent the Bahamas when the Commonwealth of the Bahamas itself became a Member in June. The Director-General is an elected member of the WMO Executive Committee in a personal capacity. The Assistant Director (International and Planning) assists him in this work, and acts as the usual channel of communication with WMO on behalf of the Permanent Representative. Much of the work of WMO is carried out by the Members, the Secretariat acting as co-ordinator, so that as the international development of meteorology continually expands so the volume of work falling to the Members also expands.

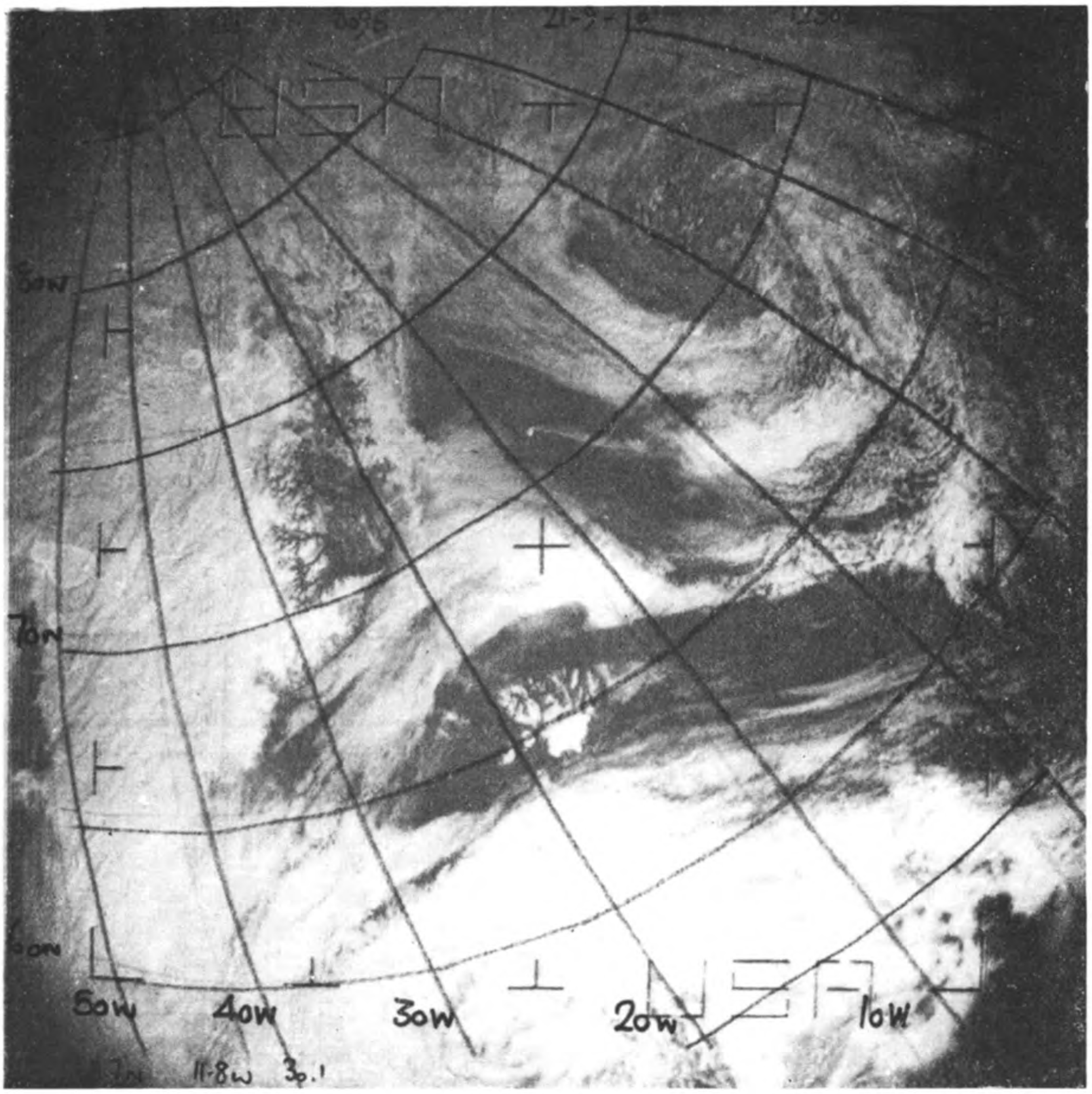
The work of detailed development and implementation of the World Weather Watch (WWW) plan went ahead at both national and international levels. Studies of world-wide standards and procedures for the storage and retrieval of meteorological data for research continued. Development also continued of the detailed operating procedures needed for high-speed international meteorological telecommunications systems. A new system of meteorological codes to meet modern requirements was completed and approved in WMO for testing and for probable introduction in 1975. A revised WWW plan for 1972 to 1975 was drafted by WMO in consultation with Members.

The review of the structure and functioning of WMO in the scientific and technical field continued and proposals were drawn up. The international meteorological aspects of ocean affairs and of hydrology involved extensive discussions. A world-wide network of stations is being organized for recording the 'background' level of air pollution. One of these stations will be Lerwick in Shetland.

Under the Global Atmospheric Research Programme (GARP) a Basic Data Project was run in November 1969 and June 1970 to obtain as complete as possible a set of world-wide synoptic data, as a basis for computational experiments. The planning of the first major GARP physical experiments, both tropical and global, was discussed by representatives of governments, and the system of management of the tropical experiment decided. The Scientific and Management Group for this experiment is likely to be located in Bracknell.

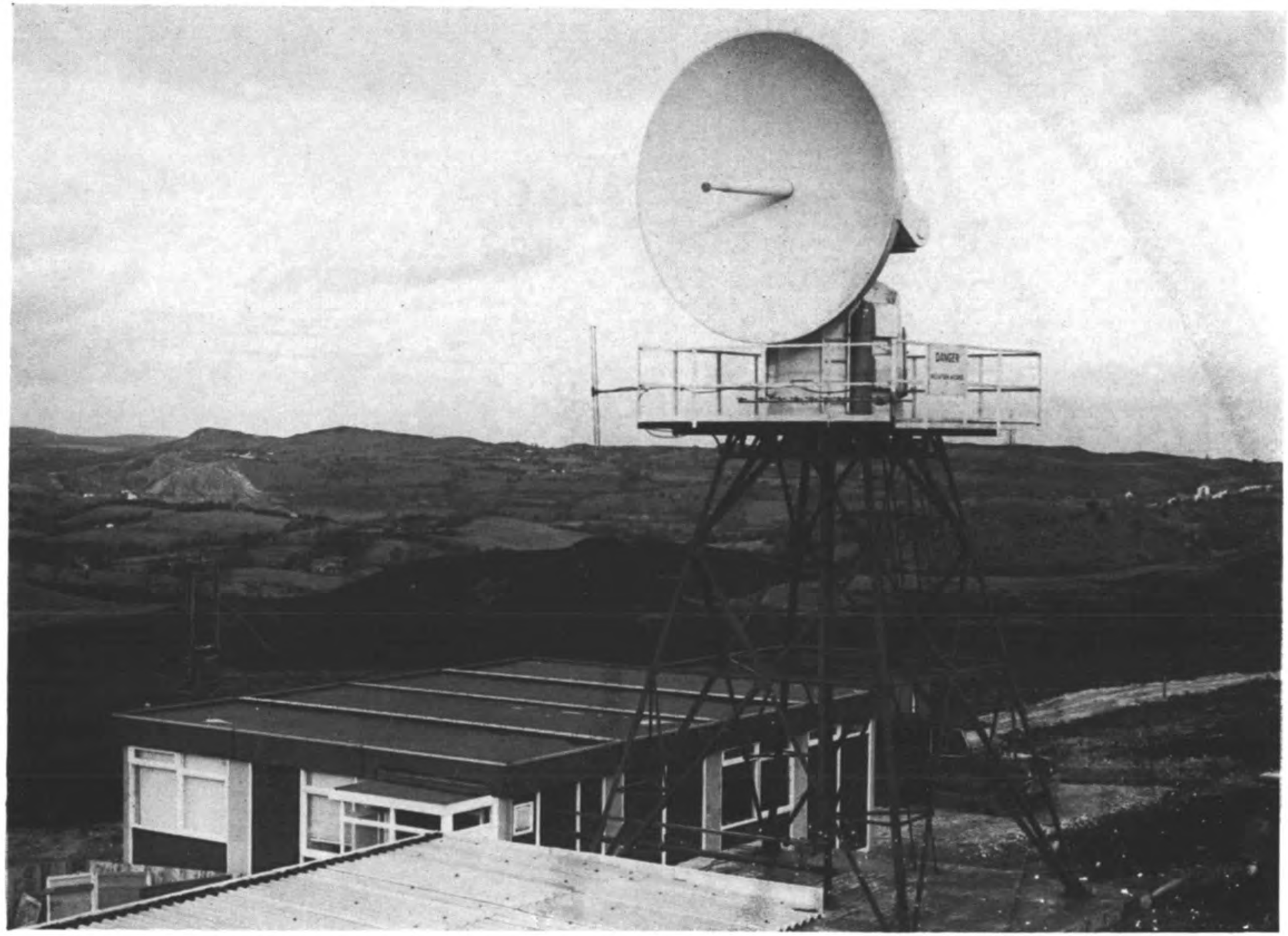
For the new upper air station in support of WWW to be jointly set up in the New Hebrides Condominium, formal agreement was reached with France and detailed preparations went ahead. Planning of WWW upper air stations at Tarawa and Funafuti in the Gilbert and Ellice Islands continued. Advice to the Seychelles Government led to the starting of a meteorological service in connection with the new civil airport.

Under WMO's Voluntary Assistance Programme equipment for receiving satellite pictures was supplied to Rumania, and several similar sets will be supplied to other countries. For these and other meteorological equipment offered in support of WWW, detailed discussion with recipients was carried out. Standard procedural agreements were developed, and several new offers of equipment were made in response to requests received. Training fellowships in



Photograph from U.S. satellite ESSA 8 showing volcanic eruption at Jan Mayen Island, position 71°N 8°W, on 21 September 1970

PLATE II

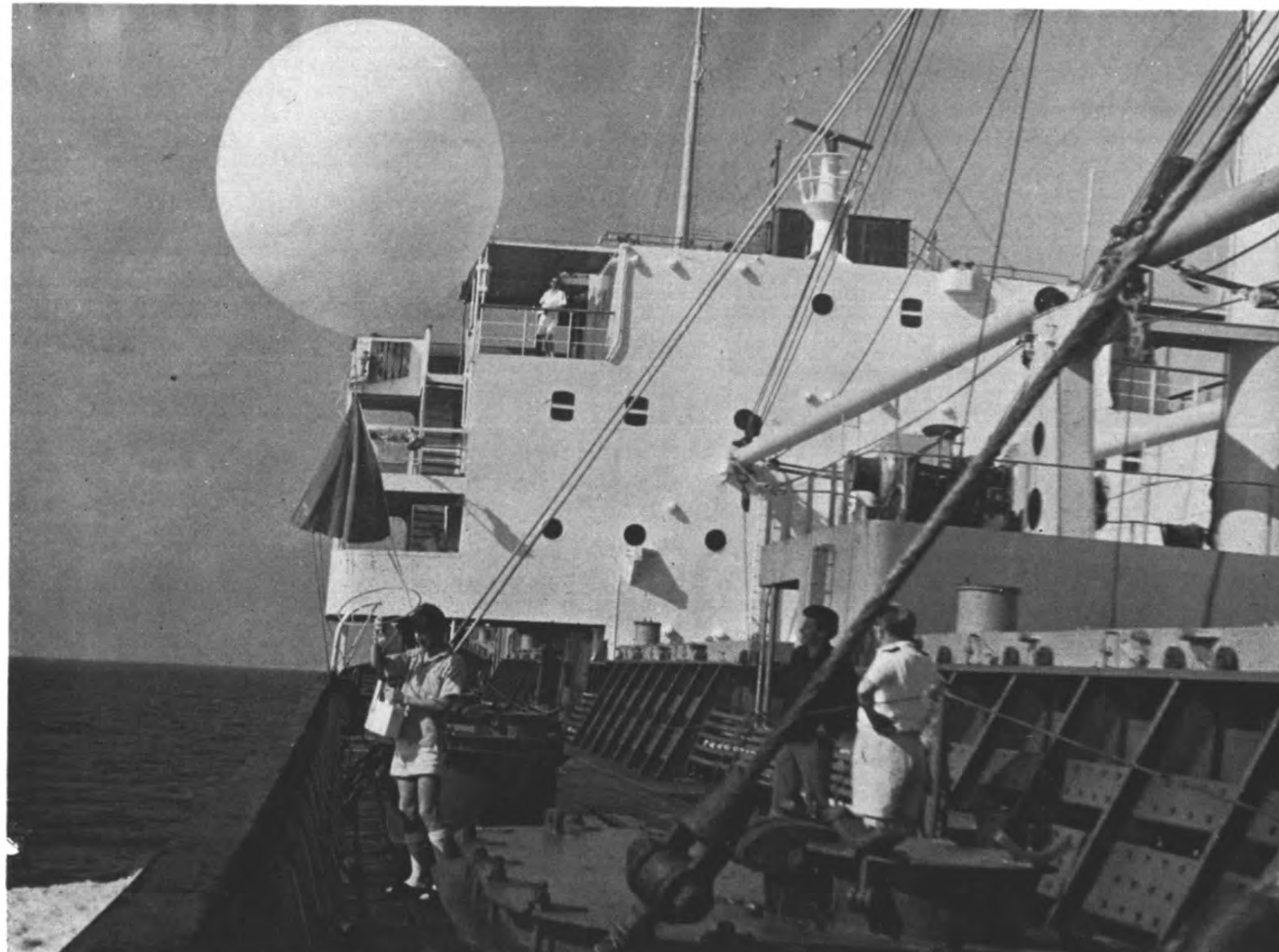


Photograph by C. A. Nicholass

LLANDEGLA RESEARCH STATION

The radar will be used to measure areal rainfalls over the catchment of the Upper Dee (see page 24).

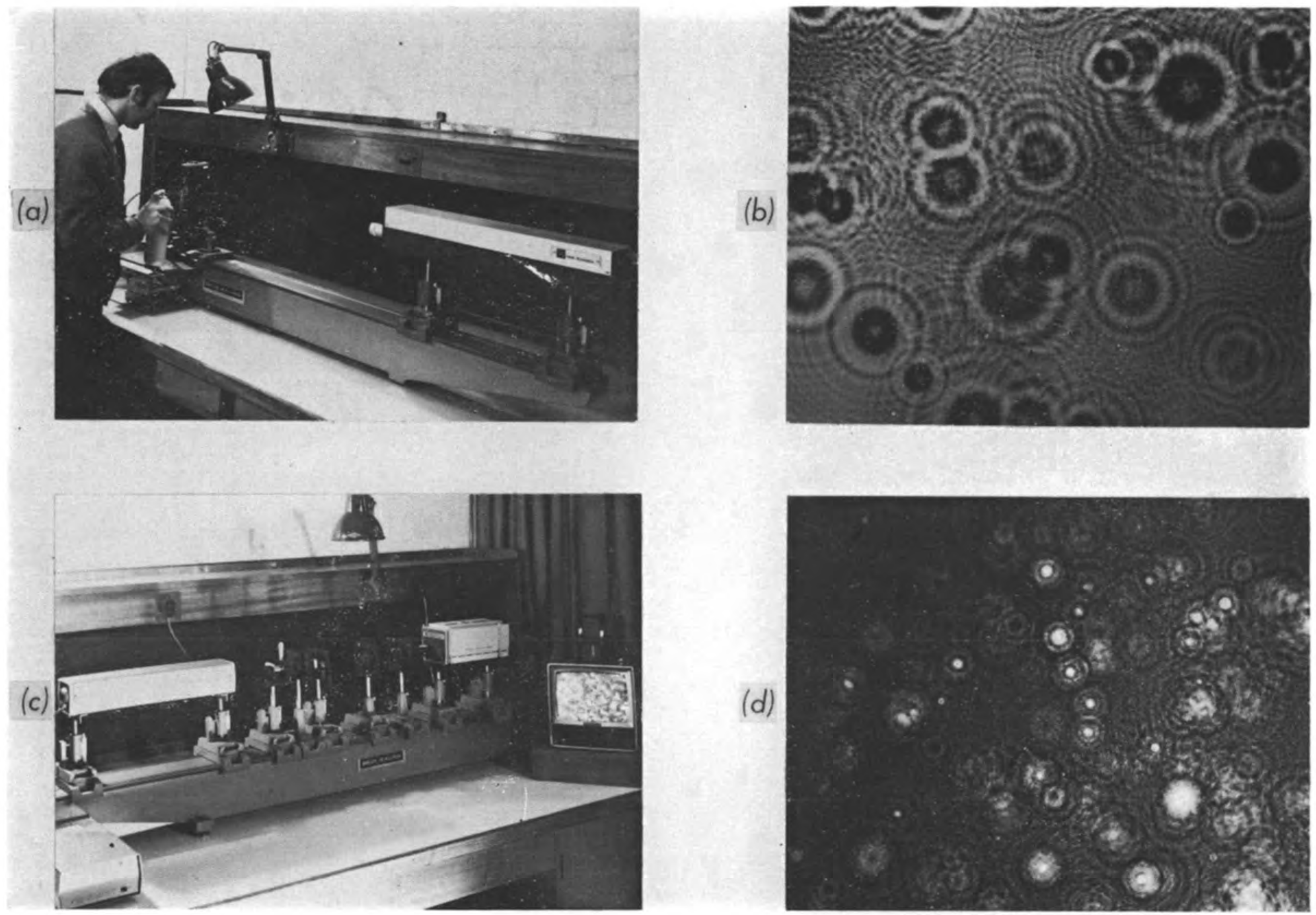
PLATE III



Photograph by J. Cox

LAUNCHING A RADIOSONDE FROM THE 'SUGAR PRODUCER'

See page 30.



HOLOGRAPHIC IMAGING OF SMALL CLOUD DROPLETS

(*a*) The experimental arrangements for recording holograms.

(*b*) Part of a typical hologram (× 12).

(*c*) The experimental arrangement for reconstructing the original wavefront.

(*d*) Part of one plane in the final three-dimensional image (× 12).

Holographic imaging of small cloud droplets

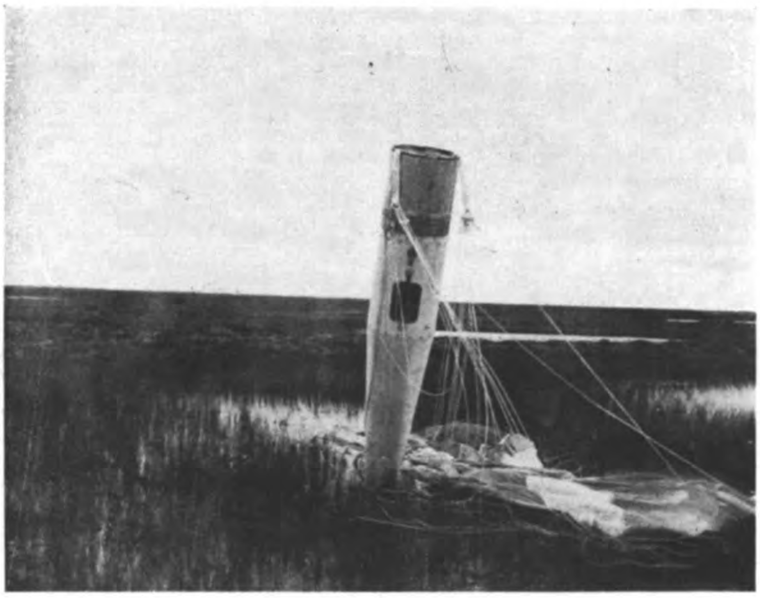
Holography is a technique which enables truly three-dimensional photographs to be obtained. In the first stage the object to be photographed—in this case a cloud of small droplets from an aerosol spray—is illuminated with a beam of monochromatic coherent light. In the arrangement illustrated in Plate IV(*a*), the source of coherent light is a pulsed ruby laser. This produces a pulse of light of extremely short duration (approximately 20 nanoseconds) which is capable of effectively 'freezing' the motion of the small droplets. Light scattered by the droplets interferes with that part of the beam which passes through the cloud and the interference pattern is recorded on a photographic plate. It should be emphasized that no lenses are used in this process.

Part of a typical hologram produced in this way is shown in Plate IV(*b*) (magnified about 12 times). The overlapping interference patterns can be clearly seen.

The original wavefront can be reconstructed by illuminating the hologram with another beam of monochromatic, coherent light, as shown in Plate IV(*c*). In this case the source of light is a continuous-working helium–neon laser which produces a steady three-dimensional image of the original droplets. In the arrangement shown in Plate IV(*c*) the image is being projected on to the photo-sensitive surface of a television camera and viewed on the small monitor screen.

Plate IV(*d*) is a photograph of a part of one plane in the final image (at about $12\times$ magnification). Several droplets whose images lie in, or close to, this plane appear to be sharply in focus, whilst droplets which are located at various distances from the plane appear to be out of focus. These could be brought into focus by moving the camera along the optic axis of the reconstructing system. The smallest droplets in focus in Plate IV(*d*) are approximately 50 μm in diameter.

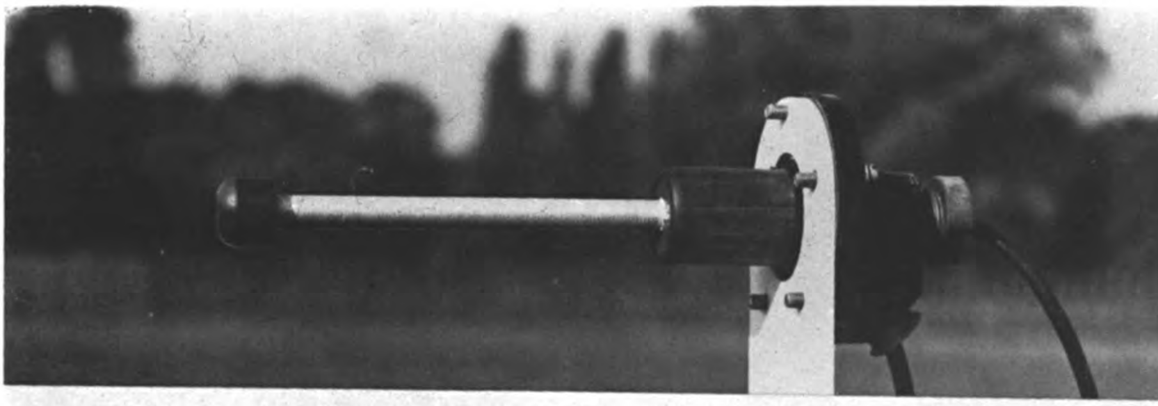
PLATE V



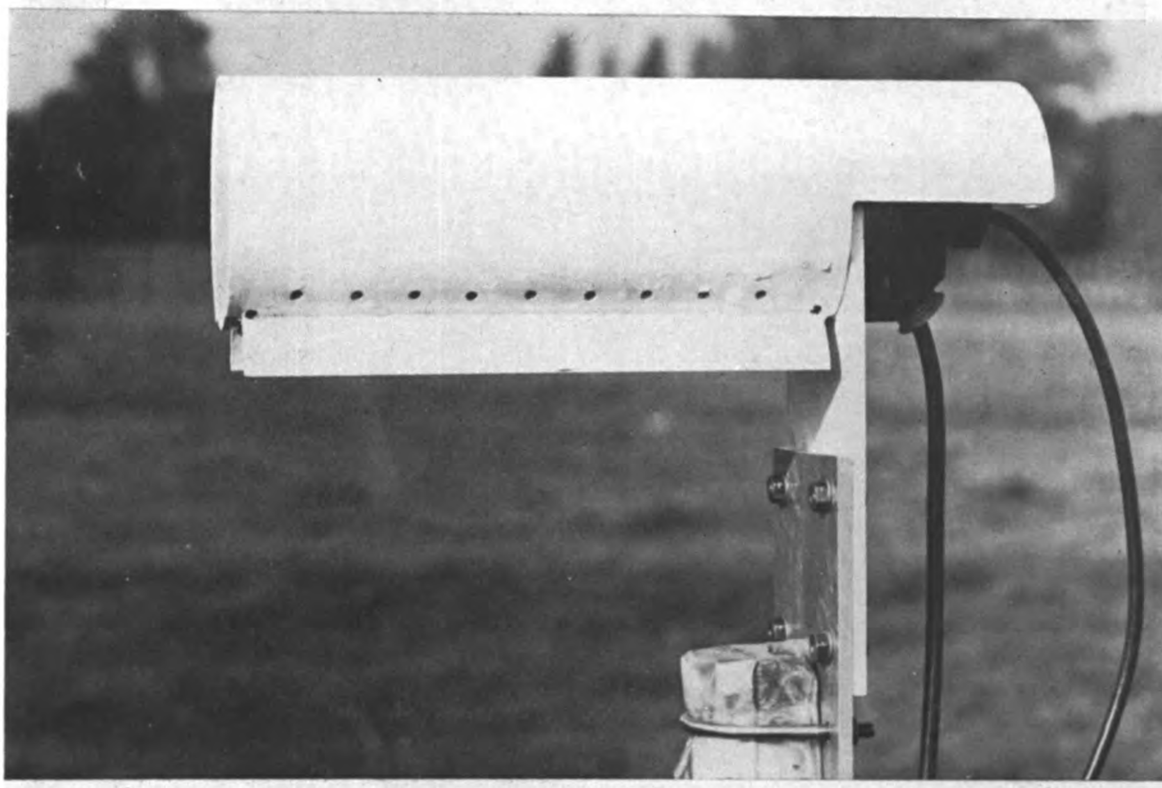
Photographs by courtesy of NRC, Ottawa, Canada

PREPARATION AND RECOVERY OF A NATIONAL RESEARCH COUNCIL OF CANADA ROCKET PAYLOAD CONTAINING EQUIPMENT FROM THE METEOROLOGICAL OFFICE AND THE UNIVERSITY OF SASKATCHEWAN

The equipment measures the ozone concentration and molecular oxygen and hydrogen airglow emissions in the mesosphere.
Upper photograph: Final assembly of the payload before mounting on the BLACK BRANT motor.
Lower photograph: The payload as discovered 70 km down-range from the launcher after a successful flight.



(a)



(b)

LITHIUM CHLORIDE DEWCEL UNDERGOING FIELD TRIALS AT KEW OBSERVATORY

(*a*) The sensitive element. Electrical windings partly cover glass tape impregnated with lithium chloride solution.
(*b*) Complete assembly, including weather shield, mounted on a pole. See page 27.

PLATE VII

ARTIST'S IMPRESSION OF THE RICHARDSON WING NOW UNDER CONSTRUCTION AT HEADQUARTERS, METEOROLOGICAL OFFICE, BRACKNELL

See page 41.

operation were continued where appropriate, and a number of new ones offered and accepted. These fellowships support students from developing countries through appropriate university courses, as a means of training them as meteorologists for employment in their own countries.

Construction began in March of the new wing of the Meteorological Office Headquarters building. The picture on the front cover is a photograph of the Headquarters building showing the progress made by early December. A photograph of an artist's impression of the completed new wing appears as Plate VII. Discussion of detailed requirements and how to meet them continued throughout the year with the Ministry of Public Building and Works (later the Department of the Environment) and with those branches which will occupy the building.

The further implications of the five-year plan for the Office in terms of working accommodation were also studied. The five-year plan itself was revised and extended.

P. J. MEADE,
Director of Services

SUMMARY OF THE WEATHER OF THE YEAR (1970)

A number of notable features occurred in the weather during 1970. These included: a snowy February and March with a blizzard in Kent which seriously affected the county for several days in March; the contrast between a wet April and a dry May, illustrated by Stonyhurst (Lancashire) where the wettest April since 1848 was followed by the driest May since 1895; a damaging fall of hail in the Isle of Ely in June; the severe flooding in the counties of Moray and Nairn in August; dry spells in parts of England during May–June, September and October; a wet November; snow around Christmas.

January. The first week of the year was bright and cold in many areas but heavy snow showers occurred in parts of Scotland. Frost was widespread and often severe, particularly in the north, and it sometimes persisted throughout the day. Ice formed on the sea at Pegwell Bay (Kent) on the 6th. On the morning of the 7th the temperature fell to $-21{\cdot}1$°C at Carnwath (Lanarkshire) and West Linton (Peeblesshire), with Newton Rigg (Cumberland), height 171 m, having its coldest January night ($-16{\cdot}7$°C) since 1940. After snow had spread north-east across all districts on the 8th a rapid thaw soon followed and thereafter the weather was dull and often mild. Many areas had frequent rain and nearly 83 mm of rain fell at Ystradfellte (Brecknockshire) during the 24 hours ending 09 GMT on the 16th. It was the wettest January at Montrose (Angus) since 1869, at Plymouth Hoe since records began in 1893 and over England and Wales generally since 1961. On the other hand it was the driest January at Garthbeg (Inverness-shire) since 1940. The period 9th to 25th was very dull with some places in the Midlands recording 15 consecutive sunless days; Cranwell (Lincolnshire) recorded 26·1 hours of sunshine, its lowest January total since records began in 1921.

February. Gales were more frequent than usual during the month. From the 1st to 3rd a deep depression to the north of Scotland brought heavy rain and showers to northern districts accompanied by gusts of over 70 knots. On the 12th an intense depression moved eastwards along the English Channel; blizzards brought snow which blocked roads and, in south Wales, electric power cables were damaged. From the 17th to 22nd rain or snow occurred frequently and swollen rivers resulted in flooding in places as far apart as Northern Ireland and the south Midlands. Although the weather was changeable, a preponderance of days with long sunny periods led to a very sunny month nearly everywhere. Twice the average amount of sunshine occurred in some areas and a number of places had their sunniest February on record. Notable among these were Oxford (Radcliffe Observatory) and Kew Observatory where both records began in 1881. Despite the sunshine the month was cold, especially in Scotland. From the 10th to 17th severe frost occurred nightly and persisted throughout the day at times in some upland areas in the north. Snow occurred on about twice the average number of days for February. Some northern areas had over twice the average rainfall (including melted snow) and it was the wettest February at Moneydig (Co. Londonderry) since 1923.

March. During the first fortnight winds, mainly from the north, brought frequent wintry showers to most areas and it was cold and frosty. On the 3rd/4th a developing depression moved south-eastwards across the country bringing blizzards to Northern Ireland, Wales and to much of England except the south-west. About 10–15 cm of snow settled in many areas with larger amounts on high ground. Roads were blocked and electric power cables were brought down in many areas. South-east England was especially affected and electric power in some parts of rural Kent was not restored for several days. An interlude of warmer westerly winds occurred from the 16th to 25th but the weather was changeable with stormy periods especially in the north. On the 16th a gust of 85 knots was recorded at Cairngorm (Inverness-shire), height 1090 m, and 78 mm of rain fell at Achnashellach (Ross and Cromarty) in the 24 hours ending 09 GMT on the 17th. Cold northerly winds returned on the 26th and further wintry showers occurred with heavy snowfall in north-east Scotland. In most districts rainfall was above average and sunshine somewhat below average but central Scotland was a notable exception. Both Loch Leven (Fife) and Crieff (Perthshire) had their driest March since 1944 and Paisley and Dundee enjoyed their sunniest March since 1907 and 1933 respectively.

April. A cold and also rather dull and wet month in many areas began with northerly winds everywhere. On the 1st, drifting snow blocked some roads in Scotland and northern England and isolated villages in north Wales. During the first 10 days the weather was wintry in most areas with frost, moderate at times, widespread at night. A changeable spell followed with rain, occasionally heavy, especially in the north and west. Prolonged rainfall occurred in northern England and the Midlands on the 12th/13th and swollen rivers led to local flooding particularly in Yorkshire and Derbyshire; snow blocked roads in the North Pennines. Almost 36 hours of continuous rain occurred in north-west England from late on the 21st to early on the 23rd and 'daily' falls during this period included nearly 182 mm at Seathwaite Farm

(Cumberland) on the 22nd. Wintry weather returned to the north on the 26th. Although snow was much more frequent than usual for April, it was mostly slight and soon melted on low ground. Almost three times the average rainfall occurred in the mountains of North Wales and at Preston (Lancashire), while Stonyhurst, also in Lancashire, had its wettest April since records began in 1848. At the other extreme, rainfall reached barely half the average in south Devon and in parts of Angus, Fife and Perthshire.

May. The month was dull in Northern Ireland and Scotland where, in and around Glasgow, it was the dullest May since 1925. It was, however, drier and warmer than average in most of these areas although around the 21st snow fell on high ground in north Scotland. Farther south the month began warm, sunny and dry; on the 5th the temperature reached 26·1°C at Wisley (Surrey) and at Oxford and the first seven days of the month saw the sunniest start to May at London Weather Centre since records began in 1929. The second week was changeable but easterly winds kept eastern areas dull and cool. Thunder was frequent during this period; on the 10th a boy was killed by lightning in Blackpool and on the 11th over 41 mm of rain fell in 2 hours at Heythrop College, near Chipping Norton (Oxfordshire). More settled weather returned to England and Wales for the second half of the month but on the 20th/21st strong north-westerly winds affected the British Isles and gales occurred in northern and eastern areas. Most districts were drier than average and less than 10 per cent of average rainfall occurred in parts of Lancashire and Lincolnshire. It was the driest May at Strinesdale (West Riding) since records began in 1859 and some places in north-west England and Northern Ireland recorded their lowest May rainfall for over 65 years.

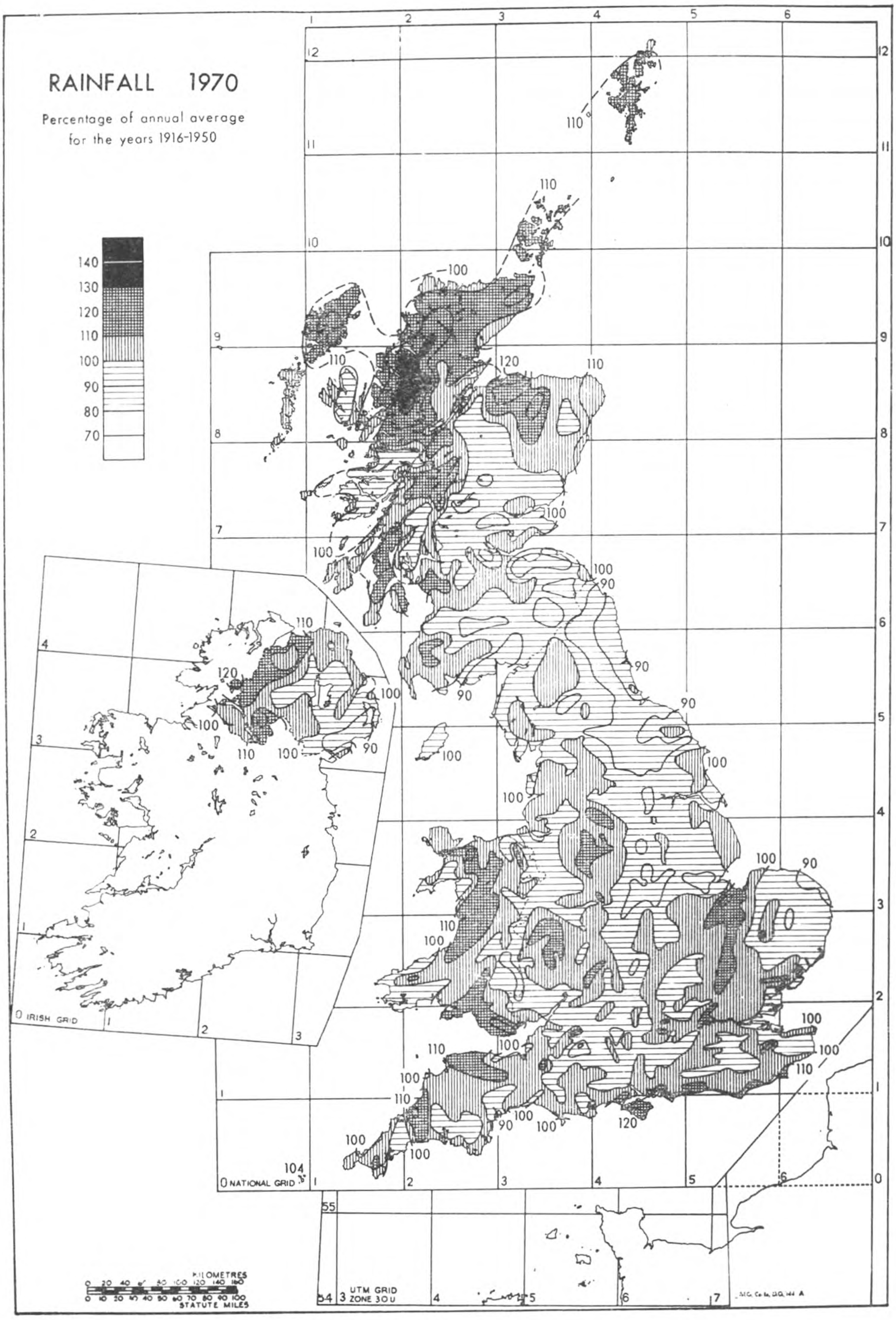
June. Except near the North Sea coast where sea fog was persistent, most areas were mainly sunny and warm during the first 3 weeks and the temperature reached 31·7°C at Maldon (Essex) on the 10th and 30·6°C at Barr (Ayrshire) on the 11th. Although many parts of the country remained dry during this period, violent thunderstorms occurred locally in widely separated areas, especially during the second week. In some places in the Midlands and southern England, the number of days with thunder was twice the June average and four persons were reported killed by lightning in the Midlands. The last 10 days were changeable everywhere and rain fell on most days. A number of intense falls of rain occurred during the month which are classified as 'very rare', notably at Lossiemouth (Moray) where, on the 7th, nearly 93 mm of rain fell in 117 minutes. The June average rainfall at Lossiemouth is 51 mm. On the 11th thunderstorms in England and Wales were accompanied, in some places, by hailstones of some 20 mm in diameter. Violent thunderstorms occurred in the east Midlands and East Anglia on the 27th and large hailstones (described in some cases as 'the size of golf balls') caused great damage to crops and glass-houses in some localities and resulted in serious financial loss to farmers and growers. It was the warmest June around Manchester and Southampton since records became available in these areas in 1877 and 1901 respectively.

July. Although there were short spells of settled weather in the south during the first half of the month, in general it was changeable everywhere with a high frequency of west or north-west winds which led to a cool month.

It was also rather a dull month, especially in Scotland. Heavy rain fell in northern districts on the 5th/6th and nearly 123 mm of rain occurred at Ardgour (Argyll) on the 6th. The next two days were hot in parts of England, Wales and east Scotland. The 7th was the warmest July day in several areas since 1949 and a temperature of 32·2°C was recorded at Aldenham School (Hertfordshire) and at Stratford-on-Avon. Thunderstorms broke out in southern England overnight on the 7th/8th giving spectacular displays of lightning. These storms drifted north to affect many areas during the 8th and there were numerous reports of damage caused by lightning strikes. After the 17th the changeable weather became stormy at times, especially in the west and north, and rainfall was occasionally heavy. During a particularly wet spell from the 22nd to 25th a 'daily' fall of 115 mm occurred at Netherley (Kincardineshire) on the 24th. The last 10 days were very cool; on the morning of the 22nd the grass minimum temperature at Kew Observatory fell to −2·2°C which is the lowest July value there since records began in 1906.

August. Although easterly winds and sea fog kept areas near the North Sea coast cool during the first fortnight and in the last week, many other districts during these periods were warm at times. However, there were also local thunderstorms and on the evening of the 7th a 'very rare' rainfall occurred at Harwell (Berkshire) where about 65 mm of rain fell in 81 minutes. A deepening depression approached south-west England on the 15th and during the next 6 days the weather was often stormy with flooding in widely separated areas. Rainfall was particularly heavy in the mountains in Moray and Nairn and led to the Rivers Findhorn, Spey and Lossie overflowing; crops were destroyed, livestock perished and flood-water caused damage in the towns of Forres and Elgin. Flooding also occurred in Northern Ireland (especially around Belfast) on the 16th; nearly 118 mm of rain fell at Kilroot (Co. Antrim) and Armagh Observatory had its heaviest 'daily' rainfall (78 mm) since records began in 1840. On the same day strong winds affected most areas with gales in places; a gust of 61 knots at Valley equalled the highest August wind speed recorded on Anglesey since at least 1912. Further heavy rain accompanied a slow-moving depression on the 19th and 20th; nearly 100 mm of rain fell on the 19th in parts of the West Country and the west Midlands and flooding was renewed in east Scotland. Further heavy rain fell in northern districts on the 31st.

September. A windy day in Scotland on the 1st heralded a very changeable month in northern districts with below average sunshine but farther south there were spells of more settled weather. After a warm period in England, thunderstorms occurred from the 7th to 10th and were especially widespread and heavy in Northern Ireland and Scotland on the 7th and 8th. On the next day a deep depression crossed western Scotland and brought rain and strong winds to most areas. Gales were severe on western coasts; an hourly mean wind speed of 52 knots occurred at Valley—the highest mean wind speed recorded on Anglesey in September since at least 1912. Very changeable weather continued in all areas and belts of rain, heavy at times, crossed Wales and much of England from the 11th to 15th. At Slapton (Devon), 58 mm of rain were recorded in the 24 hours ending 09 GMT on the 12th. It also became cool during the second week; snow fell on the peaks in the Cairngorms around the 13th and air frost occurred in parts of Scotland on the 15th. The latter half of



RAINFALL 1970

the month saw changeable weather continue in the north but a spell of 13 consecutive days with no measurable rainfall commenced on the 16th in many parts of south and east England. Day-time temperatures during this period were above average in all districts at times but fog occurred widely night and morning in England and Wales and occasionally persisted all day near coasts. The dry spell in the south ended when rain fell in most parts of the country on the last two days of the month.

October. The weather was changeable in north Scotland during much of the month; rain fell on most days and it was the wettest October at Achnashellach since records began in 1922. On the 18th a 'daily' rainfall of 93 mm occurred at Cassley (Sutherland) and a gust of 100 knots was recorded at Cairngorm. Other areas had mainly dry weather, especially in the south and east. Long dry spells occurred in most areas from the 6th to 23rd although it was wet in the west on the 11th and isolated showers fell after the 18th. South Farnborough (Hampshire) recorded 8 mm of rain during the entire month (only 3 mm more than in the exceptionally dry October of 1969) and less than half the monthly average rainfall occurred over large areas in east, central and southern England. Despite this, however, rainfall was sometimes heavy in the north and west near the beginning and end of the month; 153 mm fell at Dalness (Argyll) on the 4th and 91 mm fell at Seathwaite Farm on the 24th. In all parts of the country mean temperature over the month was near average but sleet or snow fell at times in upland areas in the north and sleet was reported on Dartmoor on the 20th. It was generally dull in the north and west; Stornoway (Hebrides) had its lowest October sunshine total since 1933.

November. The month began with mild stormy weather. On the 3rd a deep depression crossed Scotland and brought severe gales to northern England. A gust of 130 knots was registered at Snaefell (Isle of Man), height 620m but the highest wind speed actually recorded by an anemograph was a gust of 102 knots at Great Dun Fell (Westmorland), 857 metres. Nearer sea level gusts exceeded 50 knots as far south as Wiltshire and a gust of 80 knots occurred at Durham. Precipitation fell on every day in north Scotland, and Wick (Caithness) had its wettest November since 1910. Most areas had a wet month and over two-and-a-half times the average rainfall occurred in parts of England and Wales. Ryde (Isle of Wight) recorded its highest rainfall for any month since records began in 1910 and it was the wettest November since 1940 at a number of other places in southern England. It was particularly wet in England and Wales during the third week. Some of the rain was thundery in the south; lightning damaged buildings in the Isle of Wight and in north-west London on the 13th and 29th respectively. Snow was widespread in Scotland towards the end of the second week and affected areas farther south on the 12th and around the 16th; air frost occurred at night in Scotland and northern England around mid-month. Temperatures rose above average during the last week and on the 25th Chivenor (Devon) had its highest November temperature (17·0°C) since continuous records began in 1949.

December. A number of areas in the north and west had a sunny month and, in addition, recorded less than half the average rainfall. It was, however, a cold month on the whole, especially the last 10 days, and frost sometimes persisted throughout the day in parts of England and Wales during the last week. On the 28th patches of ice were seen along the shore at one or two places on the south coast of England. After a changeable first week with gales at times in the north, a spell of quiet weather commenced on the 8th. Overnight fog occurred in many areas at times during the period 9th to 14th, more especially in the Midlands and southern England; fog was sometimes persistent in places and disrupted air traffic. Mild south-westerly winds covered the country during the next five days and temperatures were well above average around the 18th and 19th. However, wintry weather gradually became established and the year ended with a very cold spell of east or north-east winds with snow in many areas but especially in the south of England. Snow showers occurred on the 24th and on the morning of the 25th many parts of south and east England had a thin covering of snow. On the 26th more persistent snow accompanied a shallow depression across southern England and on the next day snow extended to much of the remainder of the country. Following further snow in the south on the 29th, some roads became blocked and deep snowdrifts built up on the higher ground, notably in Kent and on Dartmoor.

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 1970

	Within U.K.	Overseas
Principal Forecasting Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF	7	6
Subsidiary offices associated with the RAF	37	10
Observing offices associated with the RAF	7	4
Principal Forecasting Offices associated with civil aviation	1	—
Main Meteorological Offices associated with civil aviation	4	—
Subsidiary offices associated with civil aviation	11	—
Observing offices associated with civil aviation	6	—
Upper air observing offices	8	6
Public service offices	6	—
CRDF offices	5	3
Port Meteorological Offices	5	—
Offices associated with the National Agricultural Advisory Service	3	—
Other offices	27*	7

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

Notes

A Principal Forecasting 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.

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

Public service offices are located in certain large cities.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

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 from France, one ship from the Netherlands and two ships jointly operated by Norway and Sweden. The British ships serve at four of the five ocean weather stations in the eastern North Atlantic; each vessel makes, on average, eight voyages a year and spends an average of 24 days on station during each voyage. Some statistics for 1970 for the British Ocean Weather Ships are shown below.

Total number of days on station .. 685·9

Total number of days on passage .. 157·3

	Station A	Station I	Station J	Station K
		average number per voyage		
Aircraft contacted	193	313	649	253
Number of aircraft given one or more radar fixes	137	227	431	130
Weather messages to aircraft	19	24	75	64

Table III—merchant navy ships

A total of about 6360 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 them, 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 1970 the numbers of British ships reporting were:

Selected ships	531
Supplementary ships	44
	including 17 trawlers
Coasting vessels	73
Lightships	16
Trawlers	30
Auxiliary ships	53
Total	747

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

U.K. to Australasia	111
U.K. to Far East	106
U.K. to Persian Gulf	37
U.K. to South Africa	41
U.K. to West Indies	30
U.K. to Atlantic coast of North America	89
U.K. to Pacific coast of North America	9
U.K. to South America	15
U.K. to European ports	29
U.K. to Falkland Islands and Antarctica	1
U.K. to distant-water fishing grounds	17
World-wide tramping	90

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	92	75
Foreign ships in eastern North Atlantic	14	49
British trawlers in the North Sea	15	11
British merchant ships in North Sea	38	21
Total	159	156
Reception via other European countries:		
Ships in eastern North Atlantic	398	260
Ships in Mediterranean	42	60
Ships in North Sea	30	102
Ships off north Russia	12	23
Ships in other European waters	17	16
Ships in Pacific	45	22
Total	544	483
Reception via U.S.A. and Canada:		
Ships in North Atlantic	478	376
Ships in North Pacific	663	578
Ships in other waters	—	19
Total	1141	973

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 1970.

	Stations					Autographic Records		
	Observatories	*Synoptic*	*Agrometeorological*	*Climatological*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north	1	9	0	31	327	28	10	13
Scotland, east	0	10	9	67	589	54	19	13
Scotland, west	1	14	2	53	538	30	20	14
England, north-east	0	10	5	25	503	27	16	10
England, east	0	11	14	20	583	29	29	12
England, Midlands	0	14	17	46	1339	60	32	15
England, south-east (including London)	1	19	19	44	891	64	36	16
England, south-west	0	11	8	34	578	35	9	6
England, north-west	0	5	3	26	510	27	18	13
Wales, north	0	2	3	16	285	10	2	2
Wales, south	0	7	9	16	388	21	5	5
Isle of Man	0	2	0	1	19	3	1	2
Scilly and Channel Isles	0	3	0	3	21	7	1	2
Northern Ireland	0	8	7	48	319	26	28	10
Total	3	125	96	430	6890	421	226	133

* 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 (*a*) temperature, pressure and humidity and (*b*) wind, which have reached specified heights, and the height performance of the largest balloons.

(*a*) Observations of temperature, pressure and humidity

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb 16 000 m (approx.)	*50 mb 20 000 m (approx.)*	*30 mb 24 000 m (approx.)*	*10 mb 30 000 m (approx.)*	*10 mb 30 000 m (approx.)*
Eight stations in the U.K.	5777	91·9	74·7	46·5	8·3	58·0
Six stations overseas	4000	92·3	66·7	29·1	9·7	75·5
Four ocean weather ships	1527	90·7	74·5	41·3	1·7	—

(*b*) Observations of wind

	Number of observations	Percentage of all balloons reaching				Percentage of largest balloons reaching
		100 mb 16 000 m (approx.)	*50 mb 20 000 m (approx.)*	*30 mb 24 000 m (approx.)*	*10 mb 30 000 m (approx.)*	*10 mb 30 000 m (approx.)*
Eight stations in the U.K.	11 406	85·0	58·4	27·9	4·5	60·6
Six stations overseas	7 238	89·5	61·7	26·9	6·2	84·9
Four ocean weather ships	2 985	87·4	62·0	30·6	1·0	—

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network:

In 1970	69 811

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 are effected by coded messages. The coded messages are composed of groups of five figures and there may be from 5 to 90 such groups in one message. The messages are exchanged by radio and land-line facilities. In addition there is an exchange, both nationally and internationally, of meteorological information in pictorial format. This information is largely analyses and forecasts derived from processing observational data. The transmission method is analogue facsimile by either radio or land-line.

The following figures give an analysis of the traffic through the Meteorological Office Telecommunications Centre for one typical day (24 hours) taken near the end of December 1970 and, for comparison, some corresponding figures are given for one day near the end of 1969.

	In	Out	Total	Total in 1969
Coded messages		*number of groups in one day*		
Land-line teleprinter	483 196	358 428	841 624	801 321
Radio	177 381	242 212	419 593	427 891
Facsimile charts		*number of charts in one day*		
Land-line	90	603	693	564
Radio	83	128	211	221

TABLE VIII—SPECIAL SEASONAL FORECASTS

There is a need for forecasts of a special type at certain seasons. These are described in Met. O. Leaflet No. 1 (1970). The numbers receiving such specialized services are as follows:

	Year	No. of customers	Year	No. of customers
Fine-spell notifications (a summer service primarily for farmers)	1969	425	1970	336
Week-end temperature forecasts (a winter service primarily for industrialists) ..	1969–70	35	1970–71	32
Winter road danger warnings (primarily for local authorities)	1969–70	365	1970–71	404

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office is mainly 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 that took place during 1968 and 1969. They do not include warnings and routine general forecasts.

	1969	1970
Number of meteorological briefings for		
aviation in the U.K.	396 896	405 346
aviation at overseas stations	59 805	48 853
Number of aviation forecasts issued for		
aviation in the U.K.	1 144 021	1 158 974
aviation at overseas stations	302 202	310 642

TABLE X—NON-AVIATION INQUIRIES

Non-aviation inquiries are handled by five Weather Centres in London, Manchester, Glasgow, Southampton and Newcastle and one other office in Nottingham (Watnall) whose function is to meet the needs of the general public for forecasts for special purposes. Many other forecast offices, established primarily to meet the needs of aviation, also answer requests for forecasts and other weather information, from the general public, Press, public corporations, commercial firms, etc. (The *Post Office Guide* lists 37 offices providing forecasts for the general public.) These inquiries, most of which refer to current or future weather, are listed below according to the purpose of the inquiry.

	1969	1970
Total number of non-aviation inquiries	1 610 484	1 633 478
Percentage relating to		
agriculture	9·4	9·1
building	6·1	6·0
commerce, industry	5·1	5·0
holidays	18·4	20·2
marine matters	13·5	15·1
Press	9·4	9·4
public utilities	8·5	8·8
road transport	14·5	11·7
other known purposes	6·9	6·7
unknown purposes	8·2	8·0

TABLE XI—FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC for broadcast on radio, and to the BBC and most Independent Television Companies for inclusion in their programmes at a convenient break. They 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 1970.

Area	Dense fog	Moderate or heavy snow	Heavy rain	Severe inland gales
Edinburgh and south-east Scotland	1	3	2	3
Glasgow and south-west Scotland	4	2	4	4
Belfast and Northern Ireland	—	1	2	3
Industrial north-east England	2	1	1	1
Industrial Lancashire and Merseyside	2	—	4	2
Industrial Midlands	4	4	3	1
Bristol and Bath	3	—	3	—
South Wales	1	—	1	3
London and south-east England	3	3	3	2
Plymouth and south-west England	—	3	3	2
Yorkshire	3	—	2	—
Southampton and Portsmouth	1	—	4	1
Total	24	17	32	22

TABLE XII—AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

The total number of calls made on the service during 1970 showed an increase of 7 per cent over the previous year. Forecasts were made available at 3 more Post Office Information Centres bringing the total of such Centres to 49. The number of forecast areas was increased from 23 to 24.

Information Service Centre	Forecast area	Number of calls 1969	Number of calls 1970
London	London	3 687 250	3 202 724
London	Essex coast	214 396	188 547
London	Kent coast	183 750	179 303
London	Sussex coast	280 263	303 266
London	Thames Valley	203 017	152 836
London	40 miles radius of Bedford	55 493	89 753
Colchester	Essex coast	192 213	202 070
Brighton and Hove	Sussex coast	433 117	458 558
Birmingham	Birmingham	664 470	578 768
Liverpool	South Lancashire and north Cheshire	305 428	264 615
Liverpool	Lancashire coast	82 828	79 294
Liverpool	Chester and north Wales coast	56 335	58 430
Manchester	South Lancashire and north Cheshire	363 608	375 397
Manchester	Lancashire coast	64 971	77 561
Manchester	Chester and north Wales coast	47 897	46 733
Cardiff	Cardiff	305 658	322 323
Belfast	Belfast	239 469	211 904
Glasgow	Glasgow	414 511	456 765
Edinburgh	Edinburgh	225 623	251 545
Bristol	Bristol	409 286	789 259
Portsmouth	South Hampshire	210 103	270 306
Southampton	South Hampshire	251 589	214 848
Canterbury	Kent coast	177 335	195 434
Blackpool	Lancashire coast	173 669	180 430
Southport	Lancashire coast	62 097	62 040
Plymouth	South Devon and east Cornwall	148 659	153 643
Exeter	South Devon and east Cornwall	94 270	108 670
Newcastle	Tyne, Tees	224 677	241 862
Blackburn	Central Lancashire	115 881	160 831
Blackburn	Lancashire coast	50 553	74 381
Bournemouth	South Hampshire	239 513	340 183
Nottingham	Nottinghamshire, Derbyshire, Leicestershire	358 401	487 380
Leicester	Nottinghamshire, Derbyshire, Leicestershire	206 064	243 427
Middlesbrough	Tyne, Tees	96 694	102 619
Oxford	Thames Valley	123 457	148 906
Colwyn Bay	Chester and north Wales coast	60 700	61 628
Gloucester	South-west Midlands	90 355	112 920
Cheltenham	South-west Midlands	47 479	63 052
Tunbridge Wells	London	45 419	60 456
Southend	Essex coast	83 656	103 080
Chelmsford	Essex coast	54 245	68 725
Bedford	40 miles radius of Bedford	123 270	157 681
Reading	Thames Valley	163 271	181 726
Hereford	South-west Midlands	34 324	45 217
Bradford	Leeds, Bradford, Huddersfield	59 985	78 300
Leeds	Leeds, Bradford, Huddersfield	181 712	201 322
Torquay	South Devon and east Cornwall	53 153	61 281
Sheffield	Sheffield, Chesterfield, Doncaster, Barnsley	157 754	191 404
Medway	Kent coast	35 416	57 842
Chester	Chester and north Wales coast	73 985	95 512
Guildford	London	56 758	76 833
Peterborough	40 miles radius of Bedford	38 815	48 574
Huddersfield	Leeds, Bradford, Huddersfield	48 428	51 242

TABLE XII (continued)

Information Service Centre	Forecast area	Number of calls 1969	1970	Remarks *Opened*
Coventry	Birmingham	18 790	83 059	February 1969
Doncaster	Sheffield, Chesterfield, Doncaster, Barnsley	9 712	26 570	July 1969
Swindon	Bristol	1 699	24 254	December 1969
Derby	Nottinghamshire, Derbyshire, Leicestershire		67 173	January 1970
Luton	40 miles radius of Bedford		52 246	February 1970
Lincoln	North Lincolnshire and Retford area		6 906	November 1970
Total		12 401 471	13 251 614	

TABLE XIII—CLIMATOLOGICAL INQUIRIES

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 various categories.

	1969	1970
Total number of climatological inquiries	13 813	14 498
Percentage relating to		
agriculture (farming, forestry, market gardening)		12·0
building and design (including siting)		20·6
commerce (sales, marketing, advertising)		3·9
drainage		2·5
education and literature		5·8
flooding		0·7
heating and ventilation		2·5
industrial and manufacturing activities		5·4
law (damage, accident, insurance)		15·0
medical and health		1·5
Press and Information Centres		3·2
research		6·6
sport, hobbies, holidays		1·5
transport and communications		1·4
water supplies		7·0
miscellaneous (purpose known)		4·7
miscellaneous (purpose unknown)		5·6

TABLE XIV—DATA PROCESSING

(*a*) Punched-card installation

Number of cards punched by the Meteorological Office installation	1 294 462
Number of cards punched elsewhere on behalf of the Meteorological Office	61 882
Number of cards converted to paper tape	65 573
Number of cards converted from paper tape	130 413
Number of non-routine investigations completed	192

(*b*) Computer installation

The electronic computer COMET was used for computing during 7491 hours.

TABLE XV—INSTRUMENT TESTING AND CALIBRATION

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

	Number of tests or calibrations
General meteorological instruments	43 067
Balloons	68 018
Radiosonde batteries	15 456
Radar reflectors	30 160
Electrical/electronic instruments and components	8 740
Radiosondes, calibrated	13 895
Total	179 336

In addition 2883 radiosondes were recovered after flight and 65 per cent of these were repaired and recalibrated for further use.

THE DIRECTORATE OF RESEARCH

Special Topic—Atmospheric Studies related to Aircraft Safety and Performance

Introduction

An aircraft has to be designed to withstand all but a very tiny fraction of the forces to which it may be subjected during its normal lifetime of several years. Severe stresses and strains are imposed in take-off and landing and in some of the manœuvres the pilot must make during normal flying, for example turning, climbing or descending and accelerating. The forces are much greater during the extreme manœuvres of a fighter aircraft than in the relatively more gentle turns of a civilian transport and the fighter is built more robustly in consequence. Making an aircraft stronger implies extra weight and, for commercial aircraft, weight saved in structure can in some measure be converted to increased pay load. There is therefore a compelling desire to design an aircraft no stronger than it need be. Limitations can be imposed on the way in which an aircraft is flown and on the controls themselves to reduce the strains to which the aircraft is subjected by operation of the controls, and the designer can ensure that the aircraft is everywhere strong enough to meet them. Less well understood are the forces imposed by the turbulent atmosphere and its water content in the form of rain, hail, snow, ice crystals, cloud droplets and vapour. It has been the responsibility of the Meteorological Office over the years to advise designers and the airworthiness authority (Air Registration Board) on the behaviour of the atmosphere and particularly on its more extreme manifestations. Because new aircraft are always being designed which may have different characteristics from their predecessors and because estimates of extremes are never sufficiently precise there is a continuing need to review the advice given and supplement it as new data are acquired or required. Once the aircraft comes into service there is a need to operate it as economically as possible and this requires a knowledge of the normal operating environment over world-wide routes. Thus the operator also relies heavily on advice from the Meteorological Office.

Some of the problems and work being done to solve them are discussed in succeeding paragraphs.

Atmospheric factors affecting aircraft safety

The take-off and landing phases. Because take-off and landing distances are always important there is pressure to keep approach and take-off speeds as low as is prudent. This results in relatively small margins for error which is evidenced by the large proportion of all accidents which occur during take-off and landing. The weather is a significant factor in some of these accidents usually because of the variability of wind or visibility.

(i) *Wind.* To remain in the air an aircraft must fly relative to the air at a speed greater than its stalling speed. (There is also a speed which it should never exceed.) If the wind speed changes, the aircraft speed relative to the air tends to change, but because the aircraft is immersed in the air, it quickly responds to the speed of the air and on the average its speed relative to the air remains constant. If however the wind speed changed very rapidly (in a few seconds of aircraft flying time, say) the delay in responding to the speed of the air might be sufficient for the aircraft to be moving significantly slower or faster relative to the air. Just after take-off, or on approach to land, an aircraft may not be flying sufficiently faster than its stalling speed to prevent a sudden, albeit very rare, tail gust from causing a temporary stall. We need to know, therefore, particularly with the increasing use of automatic aids, the magnitude and duration of such rare gusts *along the aircraft approach path.* Most available information relates to the time history of wind at a point and deductions about the behaviour in space are made by using the so-called Taylor hypothesis that, over the period of time considered, the characteristics of the wind remain unchanged and move past the point with the speed of the mean wind. Four fast-recording anemometers have been erected on a 3° inclined path at Cardington, Bedfordshire, in order to study the time history of the wind as experienced by an aircraft on a 3° approach. It is hoped from analysis of the records, particularly those made in strong winds, to assess the variability along the slant path of the head-and cross-wind components so that the designer of automatic landing equipment may know the conditions with which the equipment should cope, or alternatively the limiting conditions above which the automatic equipment should not be used.

(ii) *Visibility.* Landing in poor visibility still represents one of the most arduous tasks a pilot has to perform and visibility limits are set by the operators below which a pilot must not attempt to land. Visibility, however, as for all other meteorological measurements, is subject to quite rapid fluctuations and changes at a point of 30 to 50 per cent in a few minutes occur on a significant number of occasions. In setting limits of visibility for landing, this variability must be taken into account and a long series of measurements in fog using a photo-electric visibility meter at London/Heathrow Airport has been analysed (Briggs[1]) to give the variability on a sound statistical basis. Problems also arise because of the variability of visibility with distance and with height which means that the pilot gets variable, and sometimes disconcerting, information by relying on visual guidance from lights on the ground. These problems are being actively pursued by the Blind Landing Experimental Unit of the Royal Aircraft Establishment with which the Meteorological Office maintains close contact.

The cruise phase. The main weather hazards encountered in cruising flight are turbulence in cloud and in the clear air, precipitation and icing.

(i) *Turbulence in cloud.* It has long been recognized that the thunderstorm represents the main atmospheric hazard to an aircraft in flight, not because of the lightning but because it represents the extreme manifestation of vertical overturning within the atmosphere. The associated vertical air currents can sometimes, over small horizontal distances, reach strengths almost as great as the strongest horizontal winds experienced near the ground and turbulence between neighbouring upcurrents and downcurrents is often severe. Direct investigation of the worst storms by research aircraft is too hazardous to be undertaken and inferences about the conditions within them must be made by scaling up the knowledge gained by flights through less severe storms, by indirect exploration using radar and by theoretical studies. Much of the flight and radar data were obtained many years ago but more recently there have been special studies of severe storms (Roach[2]) using data kindly made available to us by the Director of the National Severe Storms Laboratory in Oklahoma. Following up this report a study is being made which will provide a climatology of the distribution of severe storms and more particularly of the heights to which the cloud tops will extend. Quite apart from the estimates of the worst conditions which they enable us to make for the guidance of designers, these studies contribute to safety by improving our ability to forecast the likelihood of severe storms developing. A scheme for warning based on these studies was introduced in the United Kingdom in the summer of 1970. It is not expected that occasions for warning will occur more than a few times per year but on these occasions pilots will be warned to keep well clear of all thunderstorm clouds.

(ii) *Turbulence in clear air.* Turbulence in the clear air well away from clouds is not usually as severe as that encountered in convection cloud but its unexpected occurrence, owing to the lack of visual warning, has caused difficulties for pilots and passengers. Recent investigations by the Meteorological Research Flight and the Aerodynamics and Structures Flights of the Royal Aircraft Establishment (see, for example, Burnham[3]) recognize that all occasions of severe clear-air turbulence are associated with strong shear of the wind. Furthermore the most likely situations for such a shear to exist are in association with mountain waves, jet streams, well-marked troughs in the upper air flow or at the boundaries of the inflow at low levels or outflow at high levels of severe thunderstorm clouds. A Meteorological Office scientist (Mr J. M. Nicholls) has been attached to the Royal Aircraft Establishment during the past few years to further the meteorological aspects of these studies. One important result of this co-operation has been to demonstrate the existence of severe disturbances in the stratosphere in strong mountain-wave conditions.

Theoretical studies (Roach[4]) suggest that zones of rapid development of fronts may also become turbulent and case studies of occasions when turbulence was reported by civil aircraft support this view.

(iii) *Precipitation.* As aircraft speeds increase, the damage which may be inflicted on an aircraft by flight through rain or hail also increases. The designer needs to know what size of hailstone the aircraft must be designed to withstand without incurring catastrophic damage and the size distribution of hailstones and raindrops. Drop-size distribution in rain at the ground for various rates of rainfall has been measured on numerous occasions and estimates of the distribution in the free air at all heights at which rain can be expected can be made with acceptable accuracy using, for example, knowledge of the variation of radar echo intensity with height and the results of studies using Doppler radar. Estimates of hailstone-size distributions are less easy since large hail is so rare at the ground that no reliable size distributions have been measured. Nor is the experience at a point on the ground necessarily a good guide to the distribution aloft because of the sorting of stone sizes brought about by different fall speeds through a wind which varies with height. Estimates have been made which are consistent with the radar echo intensities from severe storms and with the highest rates of rainfall and from these estimates, in conjunction with an estimate based on radar of the horizontal extent of the hail-producing volume, the number of strikes by large hailstones on a forward-facing surface of an aircraft traversing a storm can be estimated. Comparison of these estimates with damage suffered by an aircraft inadvertently caught in a storm suggests that the estimates may not be much in error but they can hardly be regarded as satisfactory.

(iv) *Icing.* Ice formation on aircraft can be brought about by flight in clouds containing supercooled water droplets and the physics of its occurrence is reasonably well understood. The situations conducive to the formation of heavy ice accretion on an aircraft are also tolerably well known and there are many statistics of its occurrence. A frequently used method of preventing ice formation, or removing ice if it has formed, is to provide heat to the vulnerable surfaces. Before deciding how much heat to supply the designer needs to know how much ice will form in different temperature bands and this depends on the supercooled liquid water content of the clouds. The water contents are not at present amenable to direct theoretical evaluation and the highest supercooled contents are remarkably difficult to measure but the estimates so far made (many years ago) would appear to have been reasonably representative. Anti-icing heat however is usually provided at the expense of the engine power so that there is a continuing need to make the estimations more precise.

Assessment of extreme conditions for airworthiness standards

If an aircraft were made strong enough to withstand all the forces it could possibly be subjected to it would be too heavy to fly. In all human activities there is consciously or subconsciously an acceptable risk. As far as aircraft design and operations are concerned the safety authorities recognize that there must be an acceptable risk for components or for the aircraft itself. It must of course be a very low level of probability and ideally they would wish to know what extreme meteorological events occur at this same level of probability. They might wish to know, for example, what change in vertical component of wind over a horizontal distance of 100 metres would occur with a probability of 1 in 100 000, 1 in 10 million or 1 in a billion at a particular height in the atmosphere in random flying on a world-wide basis; or what supercooled water content could exist over five kilometres in the temperature band from -10 to -20°C with the same probabilities. Only in respect of the vertical accelerations on aircraft of more or less the same type do the measured data begin to approach the numbers necessary to make reasoned assessment of such low probabilities possible and then only for the aircraft which has already been designed! Transfer of this type of data to aircraft of a radically new design causes considerable (non-meteorological) problems, because the acceleration data measured are a complex result of atmospheric effects modified by pilot control and aircraft characteristics. The approach has therefore been to estimate 'the worst conditions which could reasonably be expected to occur' by the exercise of meteorological experience of world-wide weather conditions and scientific judgement of the meteorological factors involved. This has generally proved satisfactory in that accidents which could be ascribed to aircraft failure brought about by meteorological factors have been rare while on the other hand 'incidents' have suggested that standards have not been made unrealistically high. The position however is unsatisfactory and ways are being sought for placing the estimates given on a firmer statistical basis.

Special problems of the supersonic transport aircraft

From the earliest days following a decision to go ahead with the Anglo-French Concorde project the Meteorological Office has been consulted concerning weather hazards that the aircraft might encounter. In co-operation with French colleagues and the Air Registration Board the Office has produced a document which is intended to be 'a statement of the more extreme conditions which can exist in the atmosphere' between sea level and 80 000 ft. This statement is appended to the appropriate airworthiness standard as an example of the conditions which 'the design of the aeroplane shall take account of'. Meteorological conditions considered which had not formally been taken account of before included hail, ozone, cosmic radiation, radioactive debris, ultra-violet radiation and temperature variation in the horizontal and vertical. On the more conventional problems such as turbulence and icing there was of course little to add to existing standards since the aircraft must also meet the same conditions in the troposphere as existing subsonic aeroplanes. Extension of airworthiness standards to the higher cruise altitudes in the stratosphere was hampered by a lack of data from research aircraft flying at these altitudes and there were particular difficulties in estimating the temperature changes over short horizontal distances. It was recognized that the most likely situation in which large temperature changes would occur would be in the neighbourhood of cumulonimbus tops penetrating the stratosphere and in well-marked mountain waves in the stratosphere. Accordingly valuable results which, along with theory, form the basis of the present advice were obtained (Burnham[3]). Because a fast aeroplane needs a long distance in which to execute a turn and cumulonimbus cloud should be avoided, it was necessary to know how frequently cumulonimbus tops would be encountered near cruising heights. Only the most powerful storms penetrate the stratosphere but in tropical regions the boundary between troposphere and stratosphere (tropopause) may frequently be near the cruising height of a supersonic aircraft. A special study is being made of the distribution of cumulonimbus clouds in time and space using data which are being acquired, by photography of the display tubes, on the meteorological radars in Singapore and Gan. The data obtained should also be valuable to operators when planning operations to avoid the worst storms.

Another problem associated with supersonic transports, namely the sonic boom, has meteorological implications which, although not concerned with safety, are of public concern.

Because the speed of sound relative to the ground is compounded of the speed in still air (proportional to (temperature)[4]) and the speed of movement of the air, the shock wave from the aircraft is refracted in traversing the atmosphere and the amount of bending depends on the temperature and wind structure between the aircraft and the ground. This has been the subject of thorough study within the Meteorological Office (Nicholls[5]) and a computer programme has been produced which enables the location of the focused bang to be forecast on any given occasion. By consideration of extreme meteorological conditions over a period of five years it has been possible to estimate the area within which the focused bang from an aircraft following a set accelerating course will be confined.

Studies related to aircraft operations

Route winds. Variation in time of arrival at a destination is largely determined by the wind so that the requirements for fuel reserves are determined in part by the probable winds *en route*. Planning of airline schedules to achieve a realistic balance between safety, regularity and economy therefore needs knowledge of mean wind régimes and their variations.

The effect of wind on the groundspeed of an aircraft can be represented by an equivalent head/tail wind which gives the same groundspeed as the actual wind. Available wind statistics in the form of mean vector wind and its standard deviation can be manipulated to produce statistics of mean equivalent head-winds for any required route. Such statistics are often needed by operators, especially when new routes are being developed, and the Special Investigations Branch of the Meteorological Office (Met. O. 9) has developed techniques for the ready supply of these data.

Climatology of airports. Adequate allowance for probable weather conditions is an essential requirement for safe and economical operation of airports. Even at the planning stage of an airfield, runway directions and lengths as well as structural needs are all dependent on meteorological parameters. Choice of the actual site from several possible sites is decided to some extent by climatic factors. Factors which the Meteorological Office must determine and present to the operator to aid him in planning fullest use of the airport include frequencies of cross winds of specified intensities, predominant wind directions, and information on variability of air temperature (which largely determines the required length of take-off), on pressure (especially at high-level stations), and on various combinations of runway visibility and cloud base. The Special Investigations Branch produces climatological summaries mainly according to standard World Meteorological Organization formats for all civil airports in this country.

Climatology of the upper air. The practical problems of air navigation are often determined by the high-level winds and, in particular, by a knowledge of the position of jet streams, for these often present regions of intense activity. The climatology of jet streams represents another area in which advice is given.

Air temperature has a strong influence on the fuel consumption of jet aircraft and as a result the most economical route may be determined by the temperature. Allowance for temperature requires knowledge of the seasonal values of mean temperature at each flight level as well as of the standard deviation of temperature.

Another important parameter is the height of the tropopause for this largely determines cloud-top levels and the height of wind maxima. Data on the variability of the tropopause height and on the temperature at the tropopause height must be made readily available to assist determination of the best altitudes for flight, particularly for transition to supersonic flight.

Outstanding problems

In his address[6] to the World Meteorological Organization Scientific and Technical Conference on Aeronautical Meteorology in London in 1968, the President of the WMO Commission for Aeronautical Meteorology listed the four major technical problem areas as: (1) Aerodrome visibility; (2) Severe turbulence—both cloud-associated and clear-air; (3) Improved upper air forecasts; (4) Faster and more effective means of measuring, distributing and presenting weather information to the aviation crew. Work in progress on the first two has already been mentioned and the third problem is a continuing commitment for all weather services towards which a large proportion of the total research effort is devoted. The fourth is a far-ranging problem involving instrument design, communications and computer processing, but an equally important aspect requiring further study in conjunction with operators and pilots is the presentation of the information. There are risks involved in presenting too much information as well as too little.

In addition to the four operational problems mentioned above, probably the greatest outstanding problem for the meteorologist giving advice on design and safety remains accurate delineation of extreme events in terms of magnitude, duration and frequency of occurrence on a world-wide basis—a problem whose complete solution must inevitably be rather slow to arrive.

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Physical Research

Structure of clouds and cloud systems

Substantial efforts continued on the study of detailed air motion, cloud structure and rainfall in selected weather systems approaching the Isles of Scilly (Project Scillonia). The area was chosen because of the freedom from the effects of high ground and the possibility of operating aircraft without too severe limitations imposed by air traffic control.

The results of the second phase of Project Scillonia carried out in January 1969 have yielded promising results. Organized structure in the field of vertical motion in warm frontal conditions on a scale of about 50 km has been examined for the first time. Vertical motions on a smaller scale ($\approx$ 10 km) occur within the larger-scale structure but appear to have much shorter lifetimes. The overall rainfall distribution appears to be mainly correlated with the 50-km pattern.

Preparations for Phase III of the project have gathered momentum during 1970. In particular, further instrument development has been completed and now allows the temperature field as well as the wind fields to be determined from the dropsondes ejected from the aircraft; also a new precipitation surveillance radar was received from the manufacturers in June, and made mobile in August by being mounted on a trailer. Arrangements were also made to use an Argosy aircraft of 38 Group as well as the Varsity aircraft of the Meteorological Research Flight for dropsonde ejection so that the area under surveillance can be considerably increased to as much as 400 x 80 km. All radars, tracking, Doppler and surveillance, were transported to the Isles of Scilly in September and were used in conjunction with local radiosonde ascents in a number of suitable rainy situations during the rest of the year.

Radar echoes in clear air

The high-power radar using the 25-metre diameter parabolic reflectors at the Royal Radar Establishment, Defford, which was used first in October 1969 for meteorological observation of clear-air echoes has fulfilled its original promise. A number of unique studies have been conducted. These are made possible by the high power and narrow beam of the radar. They include investigations of convection and turbulence in the planetary boundary layer, of lee waves produced by the Welsh mountains, of the initiation of showers, and of clear-air turbulence. The radar detects small-scale inhomogeneities of temperature and humidity arising from turbulence, but the movements of the regions of echo also indicate motions on a larger scale.

Cloud physics

Dr A. N. Aufdermaur, a visiting scientist from the Swiss Federal Institute for Snow and Avalanche Research, has been co-operating with Dr D. A. Johnson of the staff of the Cloud Physics Branch in a laboratory investigation of electric charge separation when supercooled water droplets, in the size range 20–100 μm diameter, make a close interaction with an ice pellet in an electric field. Individual events give an electrical signal at the pellet and also at an induction ring downstream of the pellet as the interacting droplet, now charged, passes through. Coincidence circuits ensure that only genuine events are recorded. The results show that significant charge is separated only when an electric field is present, the sign and magnitude agreeing with a theory of charge transfer by induction.

The effectiveness of submicron particles ($\approx$ 0·01 μm) of AgI in the nucleation of free-falling supercooled droplets ($\approx$ 50 μm) when captured by diffusive processes has been determined in the laboratory. It has been found that such particles have a nucleation threshold of a few per cent excess humidity above saturation at -10°C and are fully effective at -15°C. Furthermore, it has been demonstrated that the conventional techniques of collecting freezing nuclei on very fine filters detects only about 1 in 10^4 of such small particles. The question then arises whether the apparent shortage of freezing nuclei in the atmosphere may in part be accounted for by the inability of standard detection techniques to measure very small nuclei which may be effective in the atmosphere by surface nucleation of the supercooled droplets after diffusive capture. Further laboratory experiments with submicron aerosols of such materials as Cr_2O_3, PtO_2, PbI_2 and CuI have given negative results and it is not yet clear whether any part of the atmospheric Aitken nuclei can act in a similar way to small particles of AgI.

A holographic technique for obtaining three-dimensional photographs of fast-moving droplets using a pulsed ruby laser is being developed for ultimate use by the Meteorological Research Flight aircraft. Droplets with diameters down to about 15 μm moving at speeds of 100 m/s have been successfully recorded and their images reconstructed in the laboratory with a size resolution of about 2 μm. (See Plate IV.)

Oceanography

The investigations into turbulent mixing and the micro-structure in the ocean have continued, with increasing emphasis being placed upon establishing the relationship between these small-scale features and the larger geostrophically balanced temperature and motion systems which are the equivalent in the ocean of the atmospheric synoptic-scale systems. During a further six weeks' expedition to Malta detailed measurements of a front in the thermocline were made (see Figure 5 and its response to strong wind mixing was established. A sophisticated

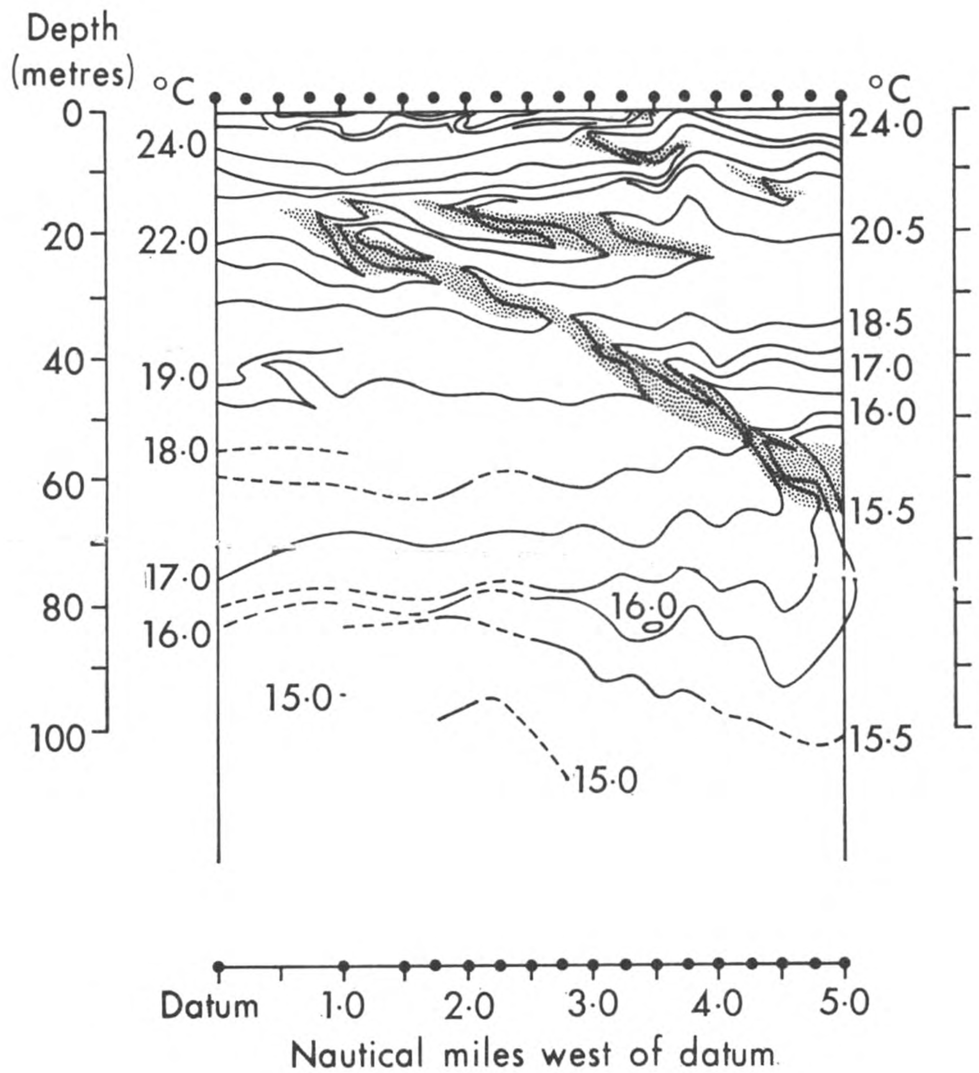

FIGURE 5 — VERTICAL SECTION 5 NAUTICAL MILES LONG AND 100 METRES DEEP THROUGH A FRONT IN THE MEDITERRANEAN SUMMER THERMOCLINE

Isotherms change depth by about 15 metres at the frontal surface, which slopes 1 part in 150. Many features of these oceanic fronts are similar to those of fronts in the atmosphere. The datum was 40 miles east of Delimara on 25 July 1969.

new apparatus was used to measure microstructure in the vicinity of this front and again the Meteorological Research Flight Varsity aircraft monitored the sea surface temperature by means of its radiation thermometer. In another experiment, divers measured the changes in temperature and velocity profiles caused by individual spots of billow turbulence.

Meteorological Research Flight

The Meteorological Research Flight (MRF) is equipped with two aircraft, a Canberra and a Varsity. The Canberra is used for all investigations requiring flights at levels from 25 000 to 45 000 ft and for all measurements of air motion. The Varsity is used for other investigations requiring flights below 25 000 ft.

The Varsity aircraft is primarily a flying laboratory allowing sampling of the atmosphere, development of cloud-physics instruments, launching of radar targets and dropsondes and the measurement of sea surface temperatures by infra-red radiation methods. In July this aircraft was detached to Malta to measure sea surface temperatures in connection with the thermocline investigation. The Canberra has largely been used for the accumulation of data concerned with dynamic stability and turbulence in the upper troposphere and lower stratosphere. Evidence has been obtained of the occurrence of gravity waves in the stratosphere and data are being accumulated relating clear-air turbulence with detailed temperature structures.

The Canberra aircraft has also co-operated with French meteorologists in investigations relating to turbulence by flying special patterns in the neighbourhood of the tropopause and the lower stratosphere during sequences of special radiosonde ascents made near Paris.

Both the Varsity and Canberra aircraft have taken part in Project Scillonia. Dropsondes and radar targets were launched from the former aircraft whilst the Canberra provided weather reconnaissances and investigation of precipitation cells in the high troposphere.

Plans have been developed for the instrumentation and modification of a Hercules aircraft to replace the Varsity.

The contract for the manufacture of the highly accurate magnetic-tape digital recording system for use in MRF aircraft was awarded to the British Aircraft Corporation and manufacture of this is well under way. This system is designed to replace present photographic recordings and, besides giving a considerable increase in both accuracy and quantity of data recorded, it will very materially speed up the reduction of the data and the analysis of results.

High atmosphere

Experiments to measure the ozone density in the upper stratosphere and mesosphere were carried out on two SKYLARK rockets launched from the ESRO rocket range (ESRANGE) at Kiruna, Sweden, in February and on a SKYLARK rocket launched from Woomera, Australia, in April. In addition a water-vapour sensor was carried on the rocket launched from Woomera, to measure water-vapour density in the stratosphere by the occultation technique.

Computation of the measurements of density of molecular oxygen at a height of 180 km by Meteorological Office instruments on the satellite ARIEL 3 is now complete. These measurements show a marked variation with geomagnetic activity, the variation being greater at higher latitudes.

A joint experiment with University College, London, was successfully carried out in January during which SKUA rockets were launched in the Hebrides and from ESRANGE at Kiruna to measure winds and temperatures at heights between 20 and 60 km. A marked stratospheric warming occurred at the New Year, and a second warming towards the end of January.

A collaborative programme was also carried out with the Atomic Energy Department of India during which 10 SKUA rockets were launched in March both from Thumba, India, and from Gan, so that a study could be made of the changes from day to day and of the variations over a distance of 800 km of winds and temperatures at heights of between 20 and 60 km near the equator. In another 'metrocket' campaign at Gan in September measurements were made with a view to determining the change of temperature and wind between sunset and sunrise.

A joint experiment with Oxford University for measuring the variation with height of the intensity of the airglow of molecular oxygen at 1·27 micrometres has been successfully carried out. A SKUA rocket was launched from the Hebrides range on 1 July and the payload, descending on a parachute, operated satisfactorily.

Construction of the equipment for measuring winds in the 80–100-km layer by measuring the Doppler shift of the radar reflections from meteor trails was completed in October and measurements have commenced. It is intended that measurements will be made simultaneously with measurements by similar equipment at Sheffield University.

Boundary layer studies

Good progress has been made in bringing the techniques for the detailed measurements of atmospheric turbulence to the stage required for effectively undertaking full explorations of the whole depth of the atmospheric boundary layer up to 1000 m. Performance on fixed masts and towers near the ground is now adequate for many purposes and it seems likely that the errors arising from the movements of a captive-balloon mounting may soon be eliminated to a useful degree. Remaining major problems to which priority is being given are the conversion of the data-transmission system to radio-telemetry and the addition of measurements of fluctuations of wind direction.

In step with the instrumental developments, data analysis techniques have also been under examination. Useful experience has been gained in the new Fast Fourier Transform procedure for spectral analysis, which for many purposes has substantial advantages in speed over the hitherto customary cosine-transform technique applied to correlation functions.

A version of the captive-balloon-borne equipment for use at sea has been given trial in a pilot study this summer near ocean weather station 'Juliett', in preparation for the major air-sea interaction experiment planned for 1973. Some 30 hours of turbulence records at two or three heights simultaneously are expected to provide valuable data upon which more extensive experiments can be planned.

Collaboration with the Boundary Layer Branch of Air Force Cambridge Research Laboratories, Massachusetts, continues with emphasis at present on comparing the Meteorological Office instrument systems with the American techniques with encouraging success. This work is a prerequisite to a comprehensive boundary layer study on one of the American plains to be carried out jointly with the Air Force Cambridge Research Laboratories.

The actual and analytical studies of vertical transfer processes are being given increased attention. Attention is directed to the transfer of momentum, heat and water vapour and also to the transport of pollutants. The latter aspect has recently taken on greater urgency, especially in respect of long-range transport. Numerical analyses are being undertaken on vertical spread within the boundary layer and on the further extension of this vertical spread under the action of the larger-scale vertical motions.

Geophysical fluid dynamics

The programme of experimental and theoretical research in geophysical fluid dynamics was continued following the lines outlined on pp. 48–51 of the Meteorological Office *Annual Report* for 1969.

Dynamical and Synoptic Research

Research related to short-range weather forecasting

Forecasting the weather for a day or two ahead is one of the major routine tasks of the Office and once again a considerable effort has been put into research into methods of improving the accuracy of these forecasts and extending them in both space and time. The most promising line of research, and one into which the main effort has been directed over the last few years, is that in which the development of atmospheric motions is represented in mathematical form through the equations of motion and energy of gaseous fluid. These are highly complicated non-linear partial differential equations which in principle permit the prediction of the developing patterns of wind, temperature and moisture given the proper observations at the beginning of the forecast period. No useful analytical solutions of these equations are known and the solutions have to be carried out by arithmetical methods; the computations are so extensive that they call for very powerful computers. As the mathematical models are extended to resemble more closely the behaviour of the real atmosphere the computations become more complex and can only be economically carried out on the most advanced and powerful computers.

Attention has been principally focused on the further development of the numerical prediction scheme for solving the equations in such a way as to give more detail in the forecasts and to lead to more realistic forecasts of weather. The success of such a scheme depends upon recognizing the physical processes which are mainly responsible for the development of weather situations and expressing them mathematically in the computation. The computations as now developed take into account the effects of water vapour and water in the atmosphere, of friction with the earth's surface, topography, convective overturning of the atmosphere, large-scale diffusion and of transfer and radiation processes near the surface. The resulting predictions are of temperature, wind and moisture at 10 levels in the vertical and at points of a square grid of approximately 100-km grid length over an area covering much of the Atlantic Ocean and Europe. The rainfall at each of these grid points is also predicted. Development has also been carried out of predictions covering most of the northern hemisphere for a grid of grid-length 300 km.

Much of the activity of the year has been centred around the conversion of the computations from a form suitable for use with the Science Research

Council ATLAS computer into a form suitable for operational use with the new IBM 360/195 computer which is to be installed in the Meteorological Office in 1971 (see p. 35). A large part of this work has been completed and a limited amount of development work has used the IBM 360/195 situated at Poughkeepsie, U.S.A. The operational computations will cover an extended area with about twice as many grid points and much thought has gone into writing the programmes controlling the computations in a form that will use as little computer time as possible. Some further experimental forecasts were obtained using the SRC ATLAS, including forecasts for an occasion which was the subject of special attention by Project Scillonia (see p. 65) and a forecast for an area covering part of Australia and New Zealand; the latter forecast was performed at the suggestion of the staff of the Commonwealth Scientific and Industrial Research Organization where aspects of Australian weather systems are under study. Considerable interest was expressed in the rainfall predictions.

The physical content of the computations has been modified during the year to make it approximate more closely to the physics of the real atmosphere. The need for change became apparent when the computations were tested for the hemispherical area, and the changes have been mainly concerned with the rainfall process and the transfer of heat and moisture at the ground.

In order to initiate the computations it is necessary to interpolate values of wind, temperature and moisture at each of the 10 levels at every grid point from the usual meteorological observations and this presents a problem of considerable difficulty, which has received much attention. Objective analysis schemes are being developed, with a view to their suitability for planned operational requirements both for the fine-mesh area and the coarse-grid hemispheric area; analysis systems are being prepared for the contour-height and humidity fields. When the grid-point values have been computed it is necessary to ensure that the implied wind and temperature fields are in balance, otherwise spurious large-amplitude waves may mask the true meteorological development, and a good deal of research, both mathematical and computational, has been carried out on methods of achieving the initial balance. Test computations show that the initialization methods which have been developed are successful in almost eliminating the non-meteorological motions in computations both for the large and for the small areas. Studies have also been made of mathematical schemes designed to improve the accuracy of the computation and to lighten its load. Attention has also been given to the interpretation of the rainfall predictions.

Experiments have continued in forecasting for seven days ahead, based partly on the developments expected from the numerical predictions for three days ahead and partly on selection of analogues. The Lamb classification of daily weather type is used as a basis for selecting occasions in the historical records when the synoptic situation over a wide area was comparable with that over the five to seven days prior to the forecast period and the 500-mb pentad-mean contour charts are used to select analogous situations at mid-troposphere. The experimental seven-day forecasts continue to show an encouraging degree of success.

Staff at outstations have continued to play an important part in research directed towards the improvement of local forecasting techniques. The investigations cover a wide variety of problems and recent work has included studies of the variation with topography of the occurrence of frost in a fruit-growing area of Kent, the factors which govern the inland penetration of the sea-breeze in Lincolnshire and of the accuracy of a number of recently published techniques for forecasting thunderstorms. Such studies lead to the introduction of new methods at outstations and the refinement of current techniques of forecasting.

Temperature and thickness estimates originating from the satellite-borne NIMBUS 4 Selective Chopper Radiometer experiment have been received from the Department of Physics at Oxford University. The data at a few levels have been plotted on charts and analysed on a daily basis. In addition they have been compared with other available meteorological data obtained from radiosondes, using a specially written KDF9 computer programme, and their possible operational use is being evaluated.

Research related to long-range forecasting

The preparation of weather forecasts for a month ahead has continued. The forecasts are issued at the beginning and middle of each month and are made available to the public through broadcasting media and the Press. More than 2000 subscribers receive, for a nominal charge, a detailed copy of each forecast together with statistics of weather relating to the month in question; the number of subscribers has risen slightly and so has the number of inquiries from commercial firms who are trying to make use of the monthly forecasts of temperature in planning their production. It is not possible to predict over long periods in the same detail as is attempted in forecasts for a day or two ahead and the monthly forecasts indicate the expected mean temperature anomaly in one of five categories and the expected mean rainfall anomaly in one of three categories. The general character of the expected weather sequence is also described and mention is made of any expected outstanding weather features, such as an unusual number of occurrences of frost.

The way in which the forecasts are made was described in the Meteorological Office *Annual Report* for 1965 (pp. 47–54) and the new lines of research have been described in more recent reports. During the year research has been concentrated mainly on further elucidation of the relationships between the sea surface temperature patterns and the weather a month or more ahead. For most months eight patterns of Atlantic Ocean surface temperatures have been recognized and sufficient cases of each have been found in the years back to 1880 to enable forecast expectations to be assessed. Sea temperature anomaly patterns are fairly conservative with an average lifetime of a few months for well-defined large-scale patterns. Each anomaly pattern appears to be associated with certain mean synoptic patterns in the ensuing months and hence with patterns of rainfall and temperature. The expectations for a given sea temperature anomaly pattern are not the same throughout the year and account has to be taken of month and season. Moreover not more than half the anomaly patterns can be placed in the classification, so that caution is required in their application. More recent attempts have been made to extend the investigation to the sea temperature of the Pacific Ocean to see if the anomalies of temperature in key areas there have a recognizable effect on the subsequent weather in the vicinity of the United Kingdom. It appears that the effect of the Pacific Ocean may be important in some cases, but is usually outweighed by that of the Atlantic Ocean.

Studies have continued of the relationship between various types of monthly index and the weather to come. For example, only 2 out of 12 Augusts following Julys with a preponderance of northerly and cyclonic days were warmer than normal. A large number of these relationships based on objective indices have been uncovered, as many as 20 for some months, and some of them are useful in seasonal as well as monthly forecasting.

Experimental forecasts were made for each of the seasons and each showed encouraging success as regards mean temperature and rainfall, while the run of weather was also reasonably well described in winter, spring and summer. The analogue method, of considerable aid in making monthly forecasts, is of less value in seasonal forecasting where the important factors seem to be the ocean temperature anomalies, and the circulation depicted by the mean positions of the 500-mb troughs and ridges and by various indices of the strength of the westerlies and degree of cyclonic activity. The possible effects of the upper atmosphere above the tropopause and of various aspects of solar activity have also been studied.

The success of the research depends to a large extent on having data readily available and a data bank has been created over the years in a form suitable for immediate use by the computer. Some useful additions have been made during the year, including a daily weather-type classification from 1880 to date and daily values of surface pressure at grid points over the northern hemisphere, 1880–1899, both from Germany, and similar grid-point data for 1939–1944 from the U.S.A. The total data bank now contains a very large proportion of all the meteorological data over the last hundred years which are likely to prove useful in long-range forecasting.

The preparation of the monthly and seasonal forecasts and the examination of processed data has been greatly simplified over the last few years by the preparation of a specially designed computer language, and considerable effort has been devoted to the consolidation of this language and to preparing for its translation into a form suitable for the new Meteorological Office IBM 360/195 computer. Progress has also been made in the development of the techniques of analysis which depend on the natural characteristic patterns of the atmospheric motions, a study which combines rigorous mathematical disciplines with large-scale computing. The techniques evolved now play an integral part in the selection of analogues and in the processing of data. Some advances have been made and published in the application of statistics to meteorology.

Climatic change

The study of climatic change has assumed a new importance in view of the conflicting opinions that have recently been expressed about the effect of mankind's activities on our future climate. A study of the past reveals the magnitude of changes in climate that have arisen naturally and it is against these that possible changes caused by mankind need to be measured. Direct observational evidence is available only from the 16th century onwards and earlier evidence is indirect, mainly from botanical, archaeological and oceanographic studies which depend on modern dating methods. The daily weather-type classification for the British Isles for the years 1861 to date has been completed and will shortly be published and effort has been directed towards analysing more completely than hitherto the earlier observations. Some work on the atmospheric circulation during the last ice age was completed and published, showing new insight into the onset of glaciation. An analysis was made of the changes of the frequencies of observed winds during the past few decades over the British Isles and the North Sea with the indications that the frequency of westerly types has been declining over the last few years. The year 1970 itself will probably show a return to normal; this illustrates that there are wide variations within any climatic period.

General circulation of the atmosphere

The study of the general circulation of the atmosphere is internationally recognized as a major problem and research groups have been set up in a number of countries to investigate the factors which govern it. The importance springs not only from the prospect of forecasting for long periods but also from the possibilities of climate modification. Human activity is growing to such an extent that the possibility of changing the climate, either by design or by accident, must be seriously considered and it is essential that the atmospheric reaction to different stimuli be thoroughly understood so that the extent of modifications may be assessed before the event. A second challenging problem is the determination of the greatest period for which useful meteorological forecasts can be made and the observational network which would be required to support these forecasts.

The most promising way of attacking these problems is an adaptation and extension of those numerical methods which have proved successful in short-range forecasting. Work has continued throughout the year on developing a mathematical model of the atmosphere which takes into account the main physical processes which affect the development of atmospheric motions over a long period; they are evaporation and condensation of water accompanied by latent-heat transfer, and the effects of radiation and topography and also of the small-scale motions which cannot be treated explicitly in the model. Included in the small-scale motions are those responsible for frictional dissipation of energy and turbulent transfer processes. (See Special Topic, Meteorological Office *Annual Report* 1967.)

The associated computations are carried out for grid points which are 5° of longitude and 3° of latitude apart and the atmospheric motions which are on too small a scale to be represented on this grid are taken into account in a statistical way. A computation was started last year with the object of establishing the properties of the model's dynamical climatology with a view to bringing to light its main shortcomings and obtaining guidance on how best the model may be improved. The computation has now been carried forward to 60 days after the initial day and at this stage it seems that the stage of quasi-dynamical equilibrium has been reached at a new energy level. Appraisal of the results has led to a number of changes, some of a purely mathematical kind and some concerning the mathematical representation of the physical processes.

As part of the examination of the model's characteristics a detailed study was made of the structure and evolution of one of the depressions which had not been present initially but formed at about the 30th day of the long integration. Although this depression which was produced by the calculations did not correspond with any particular depression which occurred in the atmosphere, its behaviour was quite typical of Atlantic depressions as regards the three-dimensional motion field, the distribution of moisture and precipitation and also in the establishment of zones very like the fronts which occur in the real atmosphere. Apart from this investigation, a comprehensive analysis of the results of the experiment is being undertaken, particularly as regards the energy exchanges and spectral properties of the computed results. Work is well in hand on the preparation of programmes for the computations on the new Meteorological Office computer, and opportunity is being taken to introduce a number of improvements. The exploration of alternative mathematical techniques for carrying out the computations, for example the use of a functional representation in the vertical instead of values of the parameters at discrete levels has been carried out and work initiated on the problem of obtaining suitable initial fields of data on which to base the computations.

The Meteorological Office has continued to receive valuable help from the workers at the Clarendon Laboratory at Oxford in dealing with the radiative transfers in the computations.

The development of a mathematical model of the stratospheric motions on a global basis has continued and the scope is being expanded. The first extended experimental computations made use of a coarse resolution in the horizontal and only two prediction levels in the vertical; the results were encouraging enough to warrant examination of the mean circulations and flux transfers. In view of the great interest in high-level circulations attempts are being made to extend the computations to include mesospheric levels; in this region gravity waves and tidal motions become important and new problems are expected in the production of a stable and successful model.

Charts of mean wind, temperature and contour heights at the 30-mb level over the northern hemisphere for January and July together with an explanatory text and supporting diagrams have been distributed as required. Charts of means for north of 45°N have been prepared for February and March and work on the April charts is nearing completion.

Storm surges in North Sea

Close liaison has been maintained with the Storm Tide Warning Service, the National Institute of Oceanography and the Institute of Coastal Oceanography and Tides in examining the problems associated with the occurrence of abnormally high water at the North Sea ports and abnormally low water in the North Sea. Attention has been directed to the possible changes in frequency of abnormal conditions associated with the climatic changes that seem to be taking place and to their effect on the frequencies of high water in the Thames estuary which have a bearing on the construction of the proposed storm barrier.

Special investigations (*see* Special Topic on page 56)

A great variety of requests for meteorological advice cannot be answered either from the results of current research or from a brief examination of data, and so call for special investigation. Many of these requests call for answers in a short time and some call for considerable investigational effort. Meteorological advice to the Roskill Commission on the Third London Airport has been completed for the present by the attendance of an officer to answer questions verbally at the Inquiry and by the publication of the statistical information already supplied in the Papers and Proceedings of the Commission (Vol. VII Part 2 Chapter 10). A study of the effects of the meteorological conditions on the sonic bang has been completed and the results are being published. Co-operation has continued with the Royal Aircraft Establishment at Farnborough and Bedford on the many aspects of meteorology which affect aeronautics. Among the many other studies have been the assessment of the attenuation of radio waves by rainfall, the transport of debris from the French nuclear bomb explosion at Mururoa, the distribution in space and time of cumulonimbus clouds as revealed by the radars at Singapore and Gan, the accuracy and frequency requirements for aerological soundings, and icing on ground-based structures such as radio aerials and television masts.

General Activities of the Research Directorate

A close liaison is maintained with the Natural Environment Research Council and the Royal Society on matters concerning research in meteorology, and several members of the Meteorological Office staff serve on committees of these bodies. Contact is also maintained with meteorological research in the universities. Six small research projects in the universities are directly supported by grants from the Meteorological Office and eight others are assisted through the Gassiot Committee of the Royal Society. Ten members of university staffs worked in the Meteorological Office as consultants for short periods during the year.

Four research scientists from overseas who carried out research in the Meteorological Office for extended periods during 1970 were supported either by their home institutions or by international fellowships.

Staff of the Office devoted considerable time to the planning of international research in meteorology. Details of the meetings attended are contained in the section on 'International Co-operation'. Activities in support of the Global Atmospheric Research Programme (GARP) deserve special mention. This programme is a major international undertaking aimed at a fundamental investigation of the physical and dynamical basis of the circulation of the atmosphere on the largest scale with a view to understanding the basis of climate, to assessing the likelihood of climatic modification inadvertently or deliberately and to providing the theoretical basis for an extension of weather forecasts to the maximum possible range. The GARP programme co-ordinates the national programmes both theoretical and observational. Two major international observing experiments are envisaged. One aims to provide as complete coverage of the global atmosphere as possible by means of satellite and other modern techniques during a limited period around 1976. The other aims at a detailed study of the atmosphere over the tropical Atlantic for three months in or around 1974. The United Kingdom was the host for an international meeting in July at which the organizational framework for the Tropical Experiment was established, and a senior scientist from the Meteorological Office has been detached to the WMO Headquarters in Geneva as part of the nucleus of scientific staff who are to initiate the scientific planning of the experiment. Geneva is however regarded as only a temporary location for this work and Bracknell has been offered as a location for the scientific and management group which will continue the planning of the experiment.

The scientific research of the Office was reviewed by the Meteorological Research Committee and its sub-committees during the course of nine meetings.

Library and Publications

The National Meteorological Library forms part of the Meteorological Office Headquarters at Bracknell. It is used mainly by staff of the Office but is also available to the professional user from outside the Office and to members of the general public. Over one-quarter of the loans of publications were to borrowers from outside the Office.

The library provides an exceedingly comprehensive coverage of the literature of meteorology and associated subjects. An indication of the activities of the year is contained in Table XVI on page 77. The number of publications lent (15 737) was somewhat lower than that of the previous year owing to a restriction in services during the period of acute staffing difficulties.

The translation needs of the Office kept the two translators on the library staff fully employed and also made considerable demands on freelance translators.

Library staff have continued to participate in the activities of the Association of Special Libraries and Information Bureaux (ASLIB) and the Circle of State Librarians. Students from Library Schools have visited the library in the course of their practical work.

Meteorological observations in manuscript, and other original documents are kept, in accordance with the Public Records Act of 1958, in special repositories in Bracknell, Edinburgh and Belfast. The material in these Archives is being consulted by an increasing number of users.

Extra accommodation in Headquarters Annexe was taken into use at the end of 1969 for the convenience of research workers consulting archives material previously available in Met.O.11 in the Headquarters building.

The Editing Section is responsible for preparing official publications for printing and it works in close co-operation with HMSO. The official publications are listed in Appendix III and include the *Meteorological Magazine* which provides a valuable medium for the publication of short scientific papers of interest and importance to the scientific staff of the Office in their day-to-day work.

The Cartographic Drawing Office prepares diagrams for Meteorological Office publications, for internal memoranda and for reports in scientific journals of research by Meteorological Office staff. It also prepares for various areas of the world the many charts and diagrams which are used as background maps on which meteorological observations are plotted.

In November 1970 the Editing Section and Cartographic Drawing Office moved into temporary accommodation in Market Street, Bracknell.

Training

A start was made in September on the conversion and extension of the former Royal Air Force buildings at Shinfield Park, near Reading, to provide more satisfactory accommodation for the Meteorological Office Training School presently located at Stanmore in buildings erected during the war for use as offices. The new School will be residential.

The move of the School nearer to the Meteorological Office Headquarters at Bracknell was recommended by the Parliamentary Estimates Committee in the third report of Session 1966–67 but it has been delayed by difficulties in finding a suitable site. In the new location it will be possible for specialists working in the various branches of the science at the Headquarters at Bracknell to participate more fully in the lecturing programmes. Shinfield Park lies on the outskirts of Reading, close to the University. There will be the opportunity for mutually beneficial co-operation with the Geophysics Department of the University.

The pace of development of meteorology is such that training curricula have to be kept constantly under review. There were several innovations during the year. The first of the series of four-week courses in advanced dynamical and physical meteorology designed to be taken at the end of the formal instruction in basic meteorology given to new Scientific Officers was held in March. The advanced dynamical lectures dealt with numerical modelling of the atmosphere in some detail. The latest developments in radar meteorology and in studies of the atmospheric boundary layer were also included. The content of the advanced lectures will vary from year to year. The subjects for 1971 will be Climatology, Cloud Physics, the High Atmosphere and Long-range Forecasting. The advanced lectures, although introduced for the benefit of the newly entered scientists, are of interest also to their more senior colleagues. There will be an even wider audience at Shinfield Park.

Increasing use was made of the Basic Meteorology Course for Experimental Officers in providing a grounding for those taking up non-forecasting posts in the research branches or at outstations. The contents of the Extension and Senior Meteorologists' Courses for the more senior members of the Experimental Officer class have also been varied to cater for the growing number filling non-forecasting posts. The Initial and Advanced Forecasting Courses continue to meet the need for formal theoretical and practical instruction for the majority of Experimental Officers. The two courses are normally separated by some years' training at the forecasting bench under supervision. Successful completion of the Advanced Course and a further short period of on-the-job training enables the officer to fill an unsupervised forecasting post, although he remains subject to guidance from the Central Forecasting Office.

The majority of the Scientific Assistants in the Office are engaged in weather observing and in preparing the ground for the forecasters in various ways. They are prepared for this work by the four- and six-week Initial and Advanced Assistant Courses held at Stanmore. However, numbers are also engaged in research and in the provision of services other than forecasting for the general public. For these the Basic Assistant Course has been designed. A successful experimental Refresher and Background Course was held in October–November for more experienced Scientific Assistants. Its aim was to give the trainee a better understanding of the subject and a better appreciation of the work and purpose of the Office.

Fifty-one members of the staff attended courses in management at the Civil Service College, or at the Civilian Training Centre of the Ministry of Defence. Three Principal Scientific Officers and three Chief Experimental Officers took part in residential seminars organized by the Management Studies Centre. Five Experimental, Technical and Signals Officers were given management training at Headquarters, Maintenance Command, RAF Andover. One Principal Scientific Officer attended a six-month course at the Joint Services Staff College.

The course in basic electronics taken at RAF Sealand by new-entrant Technicians was extended to 25 weeks to take in new material. Practical instruction in the servicing of equipment in use in the Meteorological Office was given in a course of some six months' duration at the Experimental Site, Easthampstead.

Training in radiosonde operation is provided in the School attached to the upper air station at Hemsby, on the coast of Norfolk. The Initial Course, lasting nine weeks, caters for new entrants. The Advanced Course, of five weeks' duration, is for supervisors. A five-week Refresher Course is available for those who already have some experience.

Two overseas students sponsored by the United Kingdom under the Voluntary Assistance Programme of the World Meteorological Organization gained M.Sc. degrees at Reading University. Another began the third year of his Ph.D. studies and eight others entered the second year of the B.Sc. degree course in meteorology, mathematics and physics.

New Fellowships were granted under the Programme to one M.Sc. candidate and to three students reading for first degrees.

The number of staff given release for part-time study, mainly at technical colleges, increased to 283 during the year.

The Office has continued its sponsorship of Scientific Officer class staff who are working towards Ph.D. degrees. Three members of the class are proceeding under a scheme organized in conjunction with Imperial College, London University, four more are studying at Reading University and one is under the supervision of Queen's University, Belfast. During the year one Scientific Officer, three Experimental Officers, four Assistant Experimental Officers and one Telecommunications Technical Officer have been allowed sandwich courses or full-time study release to proceed towards degrees. In addition, one Experimental Officer and one Assistant Experimental Officer were awarded Civil Service Department Bursaries for degree studies at the Staffordshire College of Technology and Newcastle University respectively and one Assistant Experimental Officer was awarded a scholarship at the Royal Military College of Science, Shrivenham.

J. S. SAWYER
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY AND ARCHIVES

Library

Items received, including duplicates but excluding daily weather reports	9 133
Individual books, pamphlets, articles and microfilms classified and catalogued	7 308
Transparencies acquired	781
Publications lent (excluding daily weather reports and internal 48-hour loans)	15 737
New agreements for exchange of publications	1
Total number of exchange agreements	379
Number of pages translated by library translators	
Russian	2 646
German	145
Hungarian	34
Swedish	30
Bulgarian	20
Italian	17
French	14
Icelandic	12
Chinese	7
Spanish	4
Norwegian	3
Number of pages translated by freelance translators	597
Total	3 529

Archives

Number of loans	2 725

TABLE XVII—TRAINING

The following figures give details of courses completed during 1970 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	28	9
Initial Forecasting	2	14	50
Advanced Forecasting	5	6	51
Extension Course	2	4	16
Senior Meteorologists	1	3	14
Basic Meteorology	2	4	37
Climatology	1	4	10
Tropical Meteorology	2	3	16
Mediterranean Meteorology	2	3	7
Advanced Instruments	5	2	51
Auxiliary and Voluntary Observers	5	1	66
British Antarctic Survey	1	8	4
Background course for Technicians	3	2	30
Basic Assistants	1	4	8
Initial Assistants	12	4	133
Advanced Assistants	1	6	11
Radiosonde (Initial)	4	9	21
Radiosonde (Refresher)	1	5	2
Radiosonde (Advanced)	2	4	6
Electronics (Easthampstead)	1	23	11
Total			553

Students from the following territories attended courses which terminated during 1970.

	Number of students
Antigua	2
Bahamas	1
Barbados	1
Belgium	4
British Honduras	1
Channel Islands	1
Cyprus	4
East Africa	8
Ethiopia	2
Hong Kong	4
Jordan	1
Kuwait	2
Libya	2
Malaysia	6
Malta	2
Mauritius	3
Nigeria	1
Pakistan	3
Singapore	1
Switzerland	4
Syria	1
United Arab Republic	1
Students sponsored by British Antarctic Survey	5
Total	60

INTERNATIONAL CO-OPERATION

The Director-General visited Washington from 12 to 14 February to take part in a Joint Symposium celebrating the 100th anniversary of the United States Weather Service and the American Meteorological Society's 50th anniversary.

An inter-governmental Global Atmospheric Research Programme Planning Conference was held in Brussels from 16 to 20 March to consider the proposed first GARP Tropical and Global Experiments. The U.K. delegation was led by Dr B. J. Mason and included Mr J. S. Sawyer, Director of Research, Dr K. H. Stewart (Met. O. 19), Professor P. A. Sheppard and Dr J. T. Houghton. An Interim Planning Group on the Tropical Experiment to be held in the Atlantic, probably in 1974, met in the Royal Society's rooms in London from 22 to 24 July. Dr B. J. Mason was in the chair and Mr J. S. Sawyer also took part. Mr Sawyer also attended the session of the WMO/ICSU Joint Organizing Committee for GARP held in Moscow from 1 to 5 June.

The Executive Committee of WMO held its 22nd Session in Geneva from 8 to 16 October. Dr B. J. Mason, who also attended the meeting of WMO's Panel on the Voluntary Assistance Programme on the 7th, was accompanied at the session by Mr D. Hanson, Secretary, Meteorological Office, and Mr D. G. Harley, Assistant Director (International and Planning). Mr Harley also took part in the work of the Preparatory Working Committee from 3 to 6 October which dealt with the less controversial items. Mr J. S. Sawyer attended as President of the Commission for Atmospheric Sciences, and Mr L. P. Smith as President of the Commission for Agricultural Meteorology. Mr P. J. Meade, Director of Services, attended as Chairman of the Executive Committee Panel of Experts on Meteorological Aspects of Ocean Affairs. Major topics included the proposals to be put before the 6th WMO Congress in April 1971 for revising the system of Technical Commissions, the outcome of the immediately preceding Technical Conference on Hydrology, WMO aspects of GARP and the draft plan for World Weather Watch in the years 1972–75. A statement on weather modification and a report on meteorological aspects of air pollution were also approved.

A Technical Conference of Hydrological and Meteorological Services met in the WMO building in Geneva from 28 September to 6 October to consider how WMO could best meet the needs of both kinds of service, within its present responsibilities. The U.K. delegation was led by Mr V. K. Collinge of the Water Resources Board and included Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology) and Mr A. Bleasdale (Met. O. 8) together with representatives of the Institute of Hydrology (Natural Environment Research Council) and the Water Resources Board.

Two Technical Commissions of WMO met during the year. The Commission for Synoptic Meteorology, which has large responsibilities in World Weather Watch, met in Geneva from 15 June to 3 July. The U.K. delegation was led by Mr R. F. Zobel, Assistant Director (Central Forecasting) and included Mr A. A. Worthington, Assistant Director (Telecommunications), Mr R. A. Buchanan (Met. O. 7), Mr N. E. Davis (Met. O. 13), and Instructor Captain R. R. Fotheringham, RN, Directorate of Meteorology and Oceanographic Services (Naval). Major topics included new codes for meteorological messages, the development of the Global Observing Telecommunications and Data-Processing

Systems, and the draft World Weather Watch plan for 1972–75. Mr F. H. Bushby, Assistant Director (Forecasting Research) gave a lecture entitled 'On the use of primitive equations in weather forecasting' to the session.

The Commission for Atmospheric Sciences met in Washington from 17 to 28 August under its Acting President, Mr J. S. Sawyer, Director of Research. Mr P. Goldsmith, Assistant Director (Cloud Physics), also attended and gave a lecture on 'Results of two experiments illustrating the width of present research activities in cloud physics'. Mr J. S. Sawyer was elected President of the Commission. The session considered a wide variety of research topics in meteorology including the measurement of 'background' pollution of the atmosphere.

The North Atlantic Ocean Stations Group of Experts from European Operating States and Prospective Operating States held a meeting in Amsterdam from 27 to 29 January to continue its efforts to find the most practical and economical methods of manning ocean weather stations A, I, J, K and M during the period July 1971 to June 1973. The United Kingdom was represented by Mr V. R. Coles, Deputy Director (Forecasting Services), Captain G. A. White, Marine Superintendent, Mr D. J. Sleigh, F1b(Air) and Mr J. F. Langley, Board of Trade. Subsequently, the Protocol to the Agreement on North Atlantic Ocean Stations, 1954, amending the Netherlands commitment of two vessels to one vessel, was signed in London on 13 May. Mr V. R. Coles signed for the United Kingdom.

WMO's Regional Association V (South-west Pacific) held its 5th Session in Kuala Lumpur from 3 to 14 August. Mr J. C. Gordon, Chief Meteorological Officer, FEAF, participated as observer for the United Kingdom. The session discussed a number of meteorological developments affecting the U.K. dependencies in the Pacific.

An IASH/UNESCO/WMO Symposium on World Water Balance was held in Reading from 16 to 23 July. Members of the Meteorological Office staff who attended were Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology), Messrs A. Bleasdale, B. G. Wales-Smith and J. Grindley (Met. O. 8), Mr G. R. R. Benwell (Met. O. 11), Mr R. Murray (Met. O. 13), and Mr J. Briggs (Met. O. 9).

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*
Informal Planning Meeting on Development of WWW Oceanographic Observing Systems	Geneva February	Captain G. A. White (Marine Superintendent) Mr M. J. Blackwell (Met. O. 16)
Preparation of paper on 'Benefits of World Weather Watch for Hydrology'	Geneva February	Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology)
WMO International Planning Meeting	Geneva February	Mr D. G. Harley, Assistant Director (International and Planning)
Joint ICSU/WMO Planning Conference on the Global Atmospheric Research Programme	Brussels March	Dr B. J. Mason, Director-General, Meteorological Office Mr J. S. Sawyer, Director of Research
Extraordinary Session of Joint Organizing Committee for GARP	Brussels March	Mr J. S. Sawyer, Director of Research

Subject	*Place and date*	*Attended by*
WMO Executive Committee Panel Working Group on Ocean Affairs	Geneva March	Mr P. J. Meade, Director of Services
WMO Meeting on Meteorological Telecommunications Relating to Main Trunk Circuit Washington/Moscow	Moscow March	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met. O. 5)
Meeting of WMO Working Group on Digital Facsimile	Paris March	Mr C. E. Goodison (Met. O. 5)
Meeting of WMO Executive Committee Panel on Meteorology and Economic Development	Zürich April	Mr R. A. Buchanan (Met. O. 7)
WMO Informal Planning Meeting on Collection, Storage and Retrieval of Meteorological Data for Research	Geneva April	Mr J. M. Craddock (Met. O. 13) Mr E. J. Sumner (Met. O. 12)
WMO Executive Committee on the Collection of Meteorological Data for Research	Geneva April	Mr J. M. Craddock (Met. O. 13)
Informal Meeting of WMO Executive Committee	Geneva April	Mr P. J. Meade, Director of Services
FAO/UNESCO/WMO/UNDP Inter-Agency Meeting on Agricultural Biometeorology	Rome April	Mr L. P. Smith (Met. O. 8)
WMO/IAMAP Symposium on Higher Education and Training	Rome April–May	Mr H. Heastie (Met. O. 18)
CMM Working Groups on Observational Network and on Maritime Telecommunications	Geneva May	Captain G. A. White (Marine Superintendent)
GARP Study Group on Numerical Experimentation	Oslo May	Mr G. A. Corby, Assistant Director (Dynamical Climatology) Dr P. W. White (Met. O. 11)
Scientific discussions on GARP	Novosibirsk May	Mr J. S. Sawyer, Director of Research
Discussion between CCl Working Group and CIB	Geneva June	Mr R. H. Clements, Deputy Director (Observational Services)
CIMO Working Group on Instruments and Methods of Observation at Aeronautical Meteorological Stations	Bracknell June	Mr L. Sugden (Met. O. 7)
Joint Organizing Committee for GARP, Fourth Session	Moscow June	Mr J. S. Sawyer, Director of Research
CHy Working Group on the Machine Processing of Hydrometeorological Data	Geneva June	Mr A. Bleasdale (Met. O. 8)
WMO/ICSU/GARP Interim Planning Conference for the Tropical Observing Experiment	London July	Dr B. J. Mason, Director-General, Meteorological Office Mr J. S. Sawyer, Director of Research
CIMO Working Group on Measurement of Precipitation	Wallingford July	Mr A. Bleasdale (Met. O. 8)
WMO Commission for Atmospheric Sciences, Fifth Session	Washington August	Mr J. S. Sawyer, Director of Research Mr P. Goldsmith, Assistant Director (Cloud Physics)
WMO RA V Meeting (as U.K. observer)	Kuala Lumpur August	Mr J. C. Gordon (Met. O. 6)
WMO Technical Conference of Hydrological and Meteorological Services	Geneva September–October	Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology) Mr A. Bleasdale (Met. O. 8)

Subject	*Place and date*	*Attended by*
WMO Technical Mission in Agrometeorology	Turkey September–December	Dr R. W. Gloyne (Met. O. 8)
Meeting of Experts, Historical Sea Surface Temperature Data Project	Geneva October	Mr E. J. Sumner (Met. O. 12)
CHy Advisory Working Group	Geneva October	Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology)
CCl Working Group on Building Climatology and Joint Meeting with Working Group of the International Commission for Building (CIB/CCl)	Lausanne November	Mr R. H. Clements, Deputy Director (Observational Services)
Regional Training Seminar on Agricultural Meteorology with Special Reference to Tropical Areas in Latin America	Barbados November	Mr L. P. Smith (Met. O. 8) Dr N. E. Rider, Assistant Director (Operational Instrumentation)
Executive Committee Panel on Ocean Affairs and Joint Meeting with IOC Committee for IGOSS	Geneva November	Mr P. J. Meade, Director of Services
Meeting of WMO RA VI Working Group on Telecommunications	Geneva November–December	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met. O. 5) Mr R. K. Pilsbury (Met. O. 5)
Interim Planning Staff for GARP Tropical Experiment	Geneva November onwards	Dr N. E. Rider, Assistant Director (Operational Instrumentation)

Attendances, not already listed, at international conferences sponsored wholly or primarily by bodies other than WMO, and other visits abroad were as follows:

Subject	*Place and date*	*Attended by*
ICAO SST Panel	Montreal January	Mr L. Sugden (Met. O. 7) (WMO representative)
ESRO Sub-Group Meeting, Meteorological Instrumentation and Operations	Noordwijk, The Netherlands January	Dr R. Frith, Deputy Director (Physical Research)
ICMUA Symposium and IUCSTP Working Group Meeting on 'Wave Motions in the Upper Atmosphere'	Toronto January	Dr R. J. Murgatroyd (Met. O. 20)
Talk on 'Turbulence in a Stratified Flow' at NATO Advanced School	Brussels January	Dr J. D. Woods (Met. O. 15)
IMCO Legal Committee	London January	Mr G. Needham (Met. O. 17) (WMO representative)
Meeting on Telecommunication Arrangements, Oslo/Bracknell	Oslo January	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met. O. 5)
Republic of Ireland National Committee for Geodesy and Geophysics	Dublin January	Mr W. G. Durbin (Met. O. 7)
Special Meeting of COSPAR Working Group VI	Paris February	Dr R. Frith, Deputy Director (Physical Research)
Meeting of an International Standards Organization Working Group on Standard Atmospheres	Paris February	Dr R. J. Murgatroyd (Met. O. 20) (WMO representative)
Ninth Meeting of the 2ATAF/Northag Meteorological Sub-Committee	Rheindahlen February	Mr W. G. Harper (Met. O. 6) Mr F. J. Burton (Met. O. 6) Mr E. R. Thomas (Met. O. 6)

Subject	*Place and date*	*Attended by*
Meteorological Panel (Panel XII) of NATO Group AC/224	Brussels February	Mr P. G. F. Caton (Met. O. 6)
Eighteenth Meeting of the AFCENT Meteorological Committee	Brunssum, The Netherlands February	Mr W. G. Harper (Met. O. 6) Mr F. J. Burton (Met. O. 6)
Informal meeting on WMO's Technical Regulations	Geneva February	Mr D. G. Harley, Assistant Director (International and Planning)
Joint Participation in Evaluation of Satellite Infra-red Spectrometer Data	Washington February–March	Mr A. Woodroffe (Met. O. 2)
Meeting on Implementation of Segment of Main Trunk Circuit Washington/Bracknell/Paris/Offenbach	Washington February–March	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met. O. 5)
IUGG Conference on Planetary Boundary Layers	Boulder, Colorado March	Dr R. Hide (Head of Met. O. 21) Dr A. J. Gadd (Met. O. 11) Dr F. B. Smith (Met. O. 14)
Discussions on Geophysical Fluid Dynamics	Universities of Florida, Maryland and Chicago March	Mr P. J. Mason (Met. O. 21)
NATO Military Committee Meteorological Group Working Groups on Weather Plans and Weather Communications	Brussels March	Mr A. G. Matthewman (Met. O. 6)
Inspection of Meteorological Telecommunications	Gibraltar, Gan, Singapore March–May	Mr C. E. Goodison (Met. O. 5)
ICAO Fifth North Atlantic Regional Air Navigation Meeting	Montreal April	Mr L. Sugden (Met. O. 7)
Republic of Ireland National Committee for Geodesy and Geophysics and IGOSS Study Group on Oceanographic Observations	Dublin April	Mr W. G. Durbin (Met. O. 7)
Joint U.K./Bahrain Government Commission Meeting on Bahrain Airport	Bahrain April	Mr M. H. Freeman, Assistant Director (Public Services) Mr D. Forsdyke (Met. O. 6) Mr D. W. Tann (Met. O. 6)
IMCO Ninth Session of Sub-Committee on Safety of Navigation	London April	Captain G. A. White (Marine Superintendent) Mr M. J. Blackwell (Met. O. 16) (WMO representative)
Visits to Norwegian Meteorological Institute and Christian Michelson Institute, in connection with Norwegian buoy-mounted automatic weather station programme	Oslo and Bergen April	Dr N. E. Rider, Assistant Director (Operational Instrumentation)
Fourteenth Meeting of the Co-ordinating Group of the NATO Tactical Weather Network	Brussels April	Mr W. G. Harper (Met. O. 6) Mr F. J. Burton (Met. O. 6)
Meeting on Scientific and Technological Co-operation with the European Economic Community	Brussels April	Mr J. S. Sawyer, Director of Research
Meeting on Meteorological Telecommunication Arrangements Brussels/Bracknell	Brussels April	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met. O. 5)

Subject	*Place and date*	*Attended by*
Thirteenth COSPAR Plenary Meeting	Leningrad May	Mr E. Knighting, Deputy Director (Dynamical Research) (as ICDM representative) Dr R. Frith, Deputy Director (Physical Research)
NAOS Advisory Committee Meeting	London May	Mr P. J. Meade, Director of Services Captain G. A. White (Marine Superintendent)
IBM Symposium on Computers and Water Resources Management	Montpellier May	Mr A. Bleasdale (Met. O. 8)
Fourth Session of the IOC Group of Experts on the Legal Status of Ocean Data Acquisition Systems	London May	Captain G. A. White (Marine Superintendent) Captain A. D. White (Met. O. 1) (WMO representatives)
OECD Study Group on Models for the Prediction of Air Pollution	Paris May	Dr F. Pasquill (Head of Met. O. 14)
USAF Second Weather Wing Seminar to mark the Centenary of the United States Weather Service	Wiesbaden May	Mr W. G. Harper (Met. O. 6) Mr F. J. Burton (Met. O. 6) Mr W. E. Billbrough (Met. O. 6)
NATO *ad hoc* Advisory Group on Meteorology	Brussels May	Mr J. S. Sawyer, Director of Research
Meeting on Scientific and Technological Co-operation with the European Economic Community	Brussels May	Mr D. G. Harley, Assistant Director (International and Planning)
Wind-finding flights over Kenya	Nairobi (base) May–June	Mr J. Findlater (Met. O. 18)
European Physical Society Computational Physics Group	Geneva June	Mr E. Knighting, Deputy Director (Dynamical Research)
ESRO Second *ad hoc* Meeting	Paris June	Dr R. Frith, Deputy Director (Physical Research)
Special AMS Symposium on Dynamics of the Mesosphere and Lower Thermosphere	Boulder, Colorado June	Dr R. J. Murgatroyd (Met. O. 20)
NATO Military Committee Meteorological Group	Brussels June	Mr P. J. Meade, Director of Services Mr E. Evans (Met. O. 6) Mr A. G. Matthewman (Met. O. 6)
Visit to Malta Meteorological Office and IOC Committee on Marine Research	Malta June	Mr P. J. Meade, Director of Services
NATO Military Agency for Standardization NBC Interservice Operational Procedures Working Party	Rome June	Mr K. Bryant (Met. O. 6)
UNESCO Panel of Experts on Systems for the Acquisition, Processing and Transmission of Hydrological Data	Paris June	Mr A. Bleasdale (Met. O. 8)
Economic Commission for Europe's Committee on Water Problems, Seminar on River Basin Development	London June	Mr A. Bleasdale (Met. O. 8)
Symposium on Weather Routeing of Ships	London July	Mr P. J. Meade, Director of Services Captain G. A. White (Marine Superintendent)

Subject	*Place and date*	*Attended by*
Fourth ESRIN-ESLAB Symposium on Upper Atmosphere Models and Related Experiments	Frascati, Italy July	Dr R. J. Murgatroyd (Met. O. 20)
IGOSS Executive Co-ordinating Meeting	Paris July	Mr P. J. Meade, Director of Services
NATO Planning Meeting	Brunssum, The Netherlands July	Mr A. G. Matthewman (Met. O. 6) Mr W. G. Harper (Met. O. 6)
UNESCO Co-ordinating Council of the International Hydrological Decade, Sixth Session	Geneva July	Mr J. Harding, Assistant Director (Agriculture and Hydrometeorology)
Meeting on Meteorological Telecommunications, Brussels/Bracknell	Brussels July	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met. O. 5)
Meeting on Meteorological Telecommunications Paris/Bracknell	Paris July	Mr A. A. Worthington, Assistant Director (Telecommunications) Mr E. J. Bell (Met. O. 5)
International Study Conference on the Current and Future Problems of Acridology	London July	Mr D. H. Johnson (Met. O. 18)
SCAR Symposium on Antarctic Geology and Geophysics	Oslo August	Mr H. H. Lamb (Met. O. 13)
AFCENT Working Group Meeting	Brunssum, The Netherlands August	Mr W. G. Harper (Met. O. 6)
WRE Satellite (WRESAT) and Upper Atmosphere Research Conference	Adelaide August–September	Dr K. H. Stewart (Met. O. 19)
General Assembly of the International Association for the Physical Sciences of the Ocean	Tokyo September	Dr J. D. Woods (Met. O. 15)
Third International Comparison of Pyrheliometers	Davos September	Mr R. H. Collingbourne (Met. O. 1)
OECD Study Group on Models for the Prediction of Air Pollution	Paris September	Dr F. Pasquill (Head of Met. O. 14)
IGOSS Study Group on Oceanographic Observations	Dublin September	Mr W. G. Durbin (Met. O. 7)
NATO Military Committee Meteorological Group *ad hoc* Working Party	Norfolk, Virginia September	Mr A. G. Matthewman (Met. O. 6)
Eighth Meeting of the ACEWEX Working Group	Vicenza, Italy September	Mr W. G. Harper (Met. O. 6) Mr F. J. Burton (Met. O. 6)
UNESCO Symposium on Plant Response to Climatic Factors	Uppsala September	Mr L. P. Smith (Met. O. 8)
Boundary Layers of the Atmosphere and Oceans (NATO Advanced Study Institute)	Ramsey, I.O.M. September–October	Mr N. Thompson (Met. O. 14) Mr R. Rayment (Met. O. 14) Mr K. W. Whyte (Met. O. 11)
Scientific Comparison of Instruments	Cambridge, Massachusetts September–October	Dr C. J. Readings (Met. O. 14)
ESRO Third *ad hoc* Group Meteorology Meeting	Brussels October	Dr R. Frith, Deputy Director (Physical Research)
NATO Military Committee Meteorological Group, Working Groups on Weather Plans and Weather Communications	Istanbul October	Mr A. G. Matthewman (Met. O. 6) Mr D. W. Tann (Met. O. 6) Mr E. J. Bell (Met. O. 5)
Technical discussions	Kiel October	Mr C. E. Goodison (Met. O. 5)

Subject	*Place and date*	*Attended by*
Fourteenth Weather Radar Conference	Tucson, Arizona November	Dr K. A. Browning (Met. O. 15)
Meeting of COSPAR Working Group VI	Rome November	Dr R. Frith, Deputy Director (Physical Research)
Investigation of systems for the remote display of weather radar pictures	Washington, Kansas City November	Mr G. A. Clift (Met. O. 16)
Meeting of the Meteorological Panel (Panel XII) of NATO Group AC/225	Brussels November	Dr P. G. F. Caton (Met. O. 6)
Meeting of the Quadripartite Working Group on Meteorology	Manley, New South Wales November	Dr P. G. F. Caton (Met. O. 6)
Meeting on Scientific and Technological Co-operation with the European Economic Community	Brussels November	Mr J. S. Sawyer, Director of Research
NATO Meeting on Meteorological Telecommunications	Istanbul November	Mr E. J. Bell (Met. O. 5)
Visit to National Meteorological Center IBM	Washington, Poughkeepsie November–December	Mr E. Knighting, Deputy Director (Dynamical Research)
Visit to National Center for Atmospheric Research	Boulder, Colorado November–December	Dr P. R. Jonas (Met. O. 15)
Second International Clean Air Congress	Washington December	Dr F. Pasquill (Head of Met. O. 14)
Meeting of the ESRO Advisory Committee on Space Meteorology	Paris December	Dr B. J. Mason, Director-General, Meteorological Office

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

Mr C. E. Wallington	Principal Scientific Officer	Released in January to University of Western Australia, Perth
Mr E. S. Spain	Senior Scientific Assistant	Seconded in May to Zambia through the Crown Agents
Mr H. MacDonald	Scientific Assistant	Seconded in July to Zambia through the Crown Agents
Mr J. M. Merson	Scientific Assistant	Released in July to British Antarctic Survey, Falkland Islands
Mr D. W. Bain	Scientific Assistant	Released in August to Australian Meteorological Bureau
Mr B. C. B. Hearn	Scientific Assistant	Released in August to Australian Meteorological Bureau
Mr J. P. Arden	Scientific Assistant	Released in September to Australian Meteorological Bureau
Mr W. Goodfellow	Experimental Officer	Seconded in November to East Africa through Foreign and Commonwealth Office, Overseas Development Administration
Mr S. W. Francis	Experimental Officer	Seconded in December to East Africa, through Foreign and Commonwealth Office, Overseas Development Administration
Mr J. D. Lowry	Senior Scientific Assistant	Seconded in December to Zambia through the Crown Agents
Mr D. Black	Senior Scientific Assistant	Seconded in December to Zambia through the Crown Agents

The following staff returned to the office from appointments overseas:

Mr J. H. Mitchell	Chief Experimental Officer (now retired)	from the New Hebrides
Mr H. C. Shellard	Principal Scientific Officer	from the Caribbean
Mr H. G. E. Hills	Senior Scientific Assistant	from Zambia

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 1970 the total number of posts of all grades was 3708. 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	6
Senior Principal Scientific Officers	26
Principal Scientific Officers	74
Principal Research Fellows	2
Senior Scientific Officers	36
Scientific Officers	34
Administrative Class	
Assistant Secretary	1
Principal	1
Experimental Officer Class	
Chief Experimental Officers	32
Senior Experimental Officers	241
Experimental Officers	473
Assistant Experimental Officers	154
Scientific Assistant Class	
Senior Scientific Assistants	354
Scientific Assistants	1051
Marine Staff	
Marine Superintendent	1
Nautical Officer Class	9
Ocean Weather Ships and Base	
Officers	95
Crew	110
Technical and Signals Grades	304
Executive and Clerical Grades	173
Typing and miscellaneous non-industrial grades	161
Industrial employees	69
Locally entered staff and employees overseas	180

Recruitment into the Scientific Officer class during 1970 continued at the high level of the last few years with 10 new entrants into the class. The overall manning position in the Experimental Officer class has been satisfactory throughout the year and no difficulty has been experienced in replacing the normal wastage. As always, the main manning problem facing the Office lay in the recruitment and retention of Scientific Assistants. Recruitment has been maintained at the level reached in recent years while losses due to resignations and other causes have also continued at about average level. However, a significant reduction in requirement has led to a marked decrease in the long-standing overall shortage in this class. Full manning in the Technician class was maintained throughout the year and at the end of the year 10 newly trained staff entered the field as a surplus against known future needs.

During the year six college-based Sandwich Course students spent their extra-college periods working in the Office. Study concessions at various levels were enjoyed by 283 members of the staff, their time totalling 1777 course hours per week. Thirteen university undergraduates were chosen to work in the Office during the long vacation while nine 'vacation consultants' from universities contributed to the work of the Office during the year.

HONOURS AND DISTINCTIONS

Mr A. F. Jenkinson was appointed to the I.S.O. and Mr Vassos Efstathiou was awarded the B.E.M.

The University of Durham conferred the degree of D.Sc. (*honoris causa*) on the Director-General on 5 September.

The L. G. Groves Memorial Prize for Meteorology was awarded jointly to Mr R. A. S. Ratcliffe and Mr R. Murray, and Mr D. P. Smith received the Meteorological Observer's Award. Mr D. N. Axford received the Second Memorial Award for 1970.

Mr F. H. Bushby received the Hugh Robert Mill Award of the Royal Meteorological Society for 1970, and Mrs Catherine M. Stevenson was awarded the 1970 L. F. Richardson Prize by the Royal Meteorological Society.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

Adams, R. J., M.Sc. and Bartlett, J. T., Ph.D. *in* Pavitt, K. W., Jackson, M. C., Adams, R. J. and Bartlett, J. T.; Holography of fast-moving cloud droplets. *J Phys, E, J Scient Instrum, Ser* 2, *London*, **3**, 1970, pp. 971–975.

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Bailey, M.; Mountain lee-wave incidents in Scotland. *Met Mag, London*, **99**, 1970, pp. 110–118.

Bartlett, J. T., Ph.D.; The effect of revised collision efficiencies on the growth of cloud droplets by coalescence. *Q J R Met Soc, London*, **96**, 1970, pp. 730–738.

Bartlett, J. T., Ph.D.; Intracloud lightning. *Weather, London*, **25**, 1970, pp. 316–318, 325.

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Brazell, J. H., M.Sc.; Climatological information for the building industry, Glasgow. *Tech Notes, Wld Met Org, Geneva*, No. 109, 1970, pp. 223–232.

Brazell, J. H., M.Sc.; Meteorology and the Clean Air Act. *Nature, London*, **226**, 1970, pp. 694–696.

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Browning, K. A., Ph.D., D.I.C., Harrold, T. W., B.Sc., D.I.C. and Starr, J. R., Ph.D., D.I.C.; Richardson number limited shear zones in the free atmosphere. *Q J R Met Soc, London*, **96**, 1970, pp. 40–49.

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Browning, K. A., Ph.D., D.I.C. and Watkins, C. D.; A high power S band radar for meteorological studies. *RRE Newsl Res Rev, Malvern*, No. 9, 1970, Paper 25.

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Corby, G. A., B.Sc.; The future of extended range forecasting. *Q J R Met Soc, London*, **96**, 1970, pp. 339–340.

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APPENDIX II

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

ADAMS, R. J., M.Sc.
Cloud droplet sizing by holography. *Department of Applied Physical Sciences, Reading University.* 12 November.

BARTLETT, J. T., Ph.D.
Clouds on the terrestrial planets. *Royal Society Planetary Science Study Group, Royal Society, London,* 6 October.
Clouds on the planets. *British Association of Young Scientists, Mid-Kent Group, Maidstone.* 28 October.
The physics of clouds and rain. *West Midlands Physics Teachers Group, Birmingham University.* 10 November.
Sampling cloud particles by holography. *Meteorological Physics Symposium, Cambridge University.* 27 November.
Clouds, rain and rainmaking. *Royal Meteorological Society Popular Lecture, Royal Meteorological Society, London.* 10 and 11 December.
Cloud physics. *Course of* 22 *lectures in the Department of Geophysics, Reading University.* Throughout 1970.

BENWELL, G. R. R., M.A.
Computers in numerical weather prediction. *Birmingham Branch of the British Computer Society, Aston University.* 10 February.

BLEASDALE, A., B.A., B.Sc.
Data analysis. *IBM Symposium on Computers and Water Resources Management, Montpellier.* 27 May.
Adequacy of assessment of precipitation from conventional point measurements. *UNESCO Symposium on World Water Balance, Reading.* 18 July.

BROWNING, K. A., Ph.D., D.I.C.
Air motion and precipitation growth in frontal regions. *Summer meeting of the Royal Meteorological Society, Edinburgh.* 27 August.
Structure of the atmosphere in the vicinity of large-amplitude Kelvin–Helmholtz billows. *Fourteenth Weather Radar Conference, Tucson, Arizona.* 9–13 November.
Measurements of drop size distribution and vertical air motion in widespread rain using pulsed Doppler radar and disdrometer. *Fourteenth Weather Radar Conference, Tucson, Arizona.* 9–13 November. (Prepared by Browning, K. A., Wiley, R. L., Joss, J. and Waldvogel, A.)

BRYANT, K.
Meteorology and nuclear fallout prediction. *Royal Observer Corps, Lancaster University.* 5–6 September.

BUCHANAN, R. A., M.A.
The role of meteorology in civil engineering. *Conference of Institution of Municipal Engineers, Bracknell.* 12 June.

BUSHBY, F. H., B.Sc.
Contribution to BBC 2 *TV programme 'Horizon'.* 20 February.

COCHRANE, J.
Meteorology and horticulture. *Chiltern Edge Horticultural Society, Sonning Common.* 1 October.

COLGATE, M. G., B.Sc.
Long-range weather forecasting. *Colston Research Symposium, Bristol University.* 6 April.

CRADDOCK, J. M., M.A.
Contribution to BBC 1 *TV programme on 'Climatic change'.* 3 April.
Statistical work using a meteorological data bank.
Physics Society of Kent, University of Kent, Canterbury. 3 June.
Statistical seminar, London University. 19 June.

DURBIN, W. G., B.Sc.
Meteorological aspects of air pollution. *Northern Ireland Division of the National Society for Clean Air, British Medical Association House, Belfast.* 7 January.
The services provided by the Meteorological Office. *Queen's University, Belfast.* 10 March.

ELSE, C. V.
Electronics in meteorology. *North-east Section of the Institution of Electronic and Radio Engineers, The Polytechnic, Newcastle upon Tyne.* 9 December.

FREEMAN, M. H., O.B.E., M.Sc.
Developments in weather forecasting.
Unilever Research Laboratory, Bedford. 13 January.
Baconian Society of St Albans. 10 October.

GILCHRIST, A., M.A.
The choice of dissipative terms in a general circulation model of the atmosphere. *Oxford University.* 15 January.
The dynamics of synoptic systems in a general circulation model. *Summer Meeting of the Royal Meteorological Society, Edinburgh.* 27 August.
Imperial College, London. 7 September.

GLOYNE, R. W., Ph.D.
Opened Seminar on Biometeorology in Department of Agriculture, Edinburgh University. 5 March.

GOLDSMITH, P., M.A.
Cloud physics. *National Federation of Business and Professional Women's Clubs, Reading.* 6 April.
Results of two experiments illustrating the width of present research activities in cloud physics. *WMO Commission for Atmospheric Sciences, Fifth Session, Washington.* 17–28 August.
Some recent results of cloud physics research. *Universitätsinstitut für Meteorologie und Geophysik, Frankfurt am Main.* 10 December.

GRAYSTONE, P., B.A.
Contribution to BBC radio French Service programme on 'Future of numerical forecasting'. 25 June.

HAWSON, C. L., B.A.
Weather and the supersonic transport. *Weybridge Branch of the Royal Aeronautical Society, Weybridge.* 14 October.

HELLIWELL, N. C., B.Sc.
Extreme wind speeds for building design. *Brixton School of Building, London.* 11 November.

HIDE, R., Sc.D.
Novel correlations between global features of the earth's gravitational and magnetic field. *Department of Mathematics, University College, London.* 19 January.
Equatorial jets in planetary atmospheres. *Conference on planetary atmospheres, Kitt Peak National Observatory, Tucson, Arizona.* 3 March.
Dynamics of the earth's deep interior.
Institute of Planetary Physics, University of California. 16 and 17 March.
British Theoretical Mechanics Colloquium, University of East Anglia. 26 March.
Royal Astronomical Society Geophysical Discussion, London. 24 April.
Association of British Geodesists, Royal Astronomical Society, London. 3 November.
Contribution to BBC 2 TV programme 'Horizon'. 20 February.
Recent work on baroclinic waves. *Geophysical Fluid Dynamics Seminar, University of California at Los Angeles.* 17 March.
Motions in planetary atmospheres.
NATO meeting on 'The Solar System', Newcastle upon Tyne. 16 April.
Royal Society Planetary Sciences Study Group, Royal Society, London. 6 October.
Rutherford High Energy Laboratory, Didcot. 29 October.
Sixth Form Lectures, Royal Meteorological Society, London. 9 and 10 November.
Royal Astronomical Society, London. 13 November.
On the origin of the earth's gravitational and magnetic fields.
Symons Memorial Lecture, Royal Meteorological Society, London. 29 April.
The atmospheres of the giant planets. *International Astronomical Union meeting on 'Giant Planets', University of Sussex.* 21 August.

HOGG, W. H., M.Sc.
Weather and horticulture. *Course of five lectures. Horticultural Department, Bath University of Technology.*
Weather and agriculture. *College of Agriculture, Gloucester.* 16 December.

HOLGATE, H. T. D., B.A.
Conventional forecasting of rainfull amount. *Meeting of Water Resources Board and River Authority Engineers, Bracknell.* 18 March.

HOUGHTON, D. M., M.Sc.
Weather, *Science Society, Oxford.* 27 April.

HURST, G. W., B.Sc., D.I.C.
Summer temperatures and honey production. *Brecon County Bee Keeping Association, Brecon.* 19 June.

JENKINSON, A. F., I.S.O., M.A.
Meteorological aspects of the United Kingdom flood studies. *Conference of River Authorities Engineers, Cranfield.* 8 July.

JONAS, P. R., Ph.D.
The effect of wind shear on the collection efficiencies of cloud droplets.
National Center for Atmospheric Research, Boulder, Colorado. 25 November.

JONES, I., M.Sc.
The use of computers in weather forecasting. *British Computer Society, Stafford.* 10 February.

KNIGHTING, E., B.Sc.
Mathematics and weather forecasting. *The Union Society, Queen Mary College, London University.* 22 January.
Computers and weather forecasting. *The Union Society, Salford University.* 7 May.

LAMB, H. H., M.A.
Climatic fluctuations, climatic history and its relevance to modern long-range planning.
Charterhouse School, Godalming. 4 February.
George Abbott School, Guildford. 6 February.
The new look of climatology. *Welsh Branch of the Royal Meteorological Society, Swansea.* 17 November.

MASON, B. J., D.Sc., F.R.S.
Weather forecasting in the satellite and computer age.
Student Mathematical Society, Brunel University, Uxbridge. 20 January.
British Association, Sheffield Memorial Hall. 12 March.
The use of large computers and satellites in weather forecasting.
The City University, London. 21 January.
Future developments in meteorology and their likely impact on weather services and the community. *Joint Symposium celebrating the 100th anniversary of the United States Weather Service and the American Meteorological Society's 50th anniversary, Washington.* 12–14 February.
Future developments in meteorology and weather forecasting and their likely social and economic impact (spread over two lectures). *Ballard Mathews Lectures, University College of North Wales, Bangor.* 2–3 March.
The use of computers in weather forecasting. *Physical Society, Reading University.* 10 March.
Future developments in meteorology: an outlook to the year 2000 (Presidential Address). *Royal Meteorological Society, London.* 15 April.
Weather forecasting with the aid of satellites and computers. *Thornton Research Centre, Chester.* 28 April.
Current and future developments in meteorology. *Annual Luncheon of SIRA Institute, Royal Garden Hotel, Kensington, London.* 22 October.
Weather forecasting in the satellite and computer age. *Physical Society, Nottingham University.* 12 November.

MASON, P. J., B.Sc.
Baroclinic waves in a rotating fluid subject to internal heating. *Geophysical Fluid Dynamics Institute, Florida State University, Tallahassee.* 2 March.

MOLLOY, V.
Interpretation of facsimile weather maps. *Department of Oceanography, Liverpool University.* 12 November.

MURGATROYD, R. J., O.B.E., Ph.D., C.Eng., M.I.E.E.
Dynamical modelling of the stratosphere and mesosphere. *European Space Research Institute, Rome,* 7 July.

PASQUILL, F., D.Sc.
Boundary layer meteorology in relation to air pollution. *Advanced Radiological Protection Course, Harwell.* 5 March.
Atmospheric turbulence. *Mathematics Department, Exeter University.* 20 March.
The physical and meteorological basis for the estimation of the dispersion of wind-borne material. *Second International Clean Air Congress, Washington.* 6–11 December.

RATCLIFFE, R. A. S., M.A.
Contributions to:
BBC1 TV programme on aspects of long-range forecasting on '*24 Hours*'. 2 January.
BBC1 TV programme on '*Climatic change*'. 4 August.
BBC radio programme on '*Research in the Meteorological Office*' *for the Overseas Service.* 29 September.
Voice of America programme on '*Background to the Roumania flood situation*'. 16 June.
Long-range forecasting. *Scottish Branch of the Royal Meteorological Society, Edinburgh.* 13 November.

RIDER, N. E., D.Sc.
Meteorological instrumentation with particular reference to agricultural meteorology. *A course of six lectures at the WMO Training Seminar, Barbados.* November.

ROACH, W. T., Ph.D., D.I.C.
On the influence of synoptic development on the production of high-level turbulence. *Royal Meteorological Society, London.* 21 October.
Weather and Concorde. *Basingstoke Scientific Society, Basingstoke.* 12 November.

SAWYER, J. S., M.A., F.R.S.
Global atmospheric research—its mathematics and physical problems.
Institute of Mathematics, Leicester University. 20 January.
Mathematical Society, Exeter University. 24 February.
Contribution to BBC Overseas Service broadcast on tropical cyclones. 17 November.
Mathematical and physical problems of weather prediction.
Institute of Mathematics and its Applications, Edinburgh Branch. 26 November.
Institute of Mathematics and its Applications, Aberdeen Branch. 27 November.

SMITH, C. V., M.A., B.Sc.
Climate, environment and farm buildings. *Agricultural Land Service Conference, Reading.* 6 April.
Meteorology and physics on the farm. Two Lectures. *Biological Resources Course, Cambridge.* 10 July.

SMITH, L. P., B.A.
Assessment of environment. *Seminar at Department of Horticulture, Reading University.* 20 February.
Nematodiritis forecasts. *Veterinary Teachers Association Conference, Scarborough.* 25 March.

STEWART, K. H., Ph.D.
Work of the High Atmosphere Research Branch. *Weapons Research Establishment, Salisbury, South Australia.* 2 September.
Requirements for meteorological satellites. *British Interplanetary Society Symposium, University College, London.* 17 September.

THOMPSON, N., B.Sc.
Turbulent transfer over the sea. *Royal Meteorological Society Evening Discussion meeting On air/sea interaction, London.* 18 November.

WHITE, P. W., Ph.D.
Initialization problems. *Computational Physics Group, Meteorological Office, Bracknell.* 20 February.
Finite difference methods in numerical weather prediction.
Royal Society Symposium on Numerical Methods, Royal Society, London. 5 June.

WOODROFFE, A., B.Sc.
Weather routeing for shipping.
London Chamber of Shipping. 26 January.
British Shipping Federation, Westcliff on Sea. 9 April.

WOODS, J. D., Ph.D., D.I.C.
Mixing processes in the seasonal thermocline. *NATO course on fluid dynamics of air-sea interaction, von Kármán Institute of Fluid Dynamics, Brussels.* 29 and 30 January.
Billow turbulence. *Underwater Association Symposium, London.* 2 April.
Flow visualization in the sea. *British Industrial and Scientific Film Association, Teddington.* 15 April.
Fronts and turbulence in the seasonal thermocline. *SACLANT anti-submarine warfare research centre, La Spezia.* 18 and 19 June.
Military aspects of fronts in the ocean. 203 *Squadron, RAF, Luqa, Malta.* 11 August.
The diver in physical oceanography. *World Underwater Federation Scientific Committee Symposium, Havana, Cuba.* 9 September.
Ocean microstructure and billow turbulence. *Symposium on ocean microstructure, International Association for the Physical Sciences of the Ocean (IAPSO), Tokyo.* 17 September.
Fronts in the seasonal thermocline. *Directorate of Meteorology and Oceanographic Services (Naval), London.* 6 October.
Ocean fronts in the seasonal thermocline. *Royal Meteorological Society, London.* 18 November.
Vertical and horizontal mixing in the seasonal thermocline. *Department of Applied Mathematics and Theoretical Physics, Cambridge University.* 11 December.

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, issued 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 publications were issued during the period of this Report:

PERIODICAL

Annual Report on the Meteorological Office 1969.

Daily Aerological Record containing information in respect of meteorological conditions in the upper air over the British Isles to 22 December 1970.

Daily Weather Report containing weather maps for the northern hemisphere, British Isles, etc., and data to 31 December 1970.

Daily Weather Report, Overseas Supplement, containing surface and upper air data to 30 June, 1970.

Monthly Summary of the *Daily Weather Report* (to November 1970).

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 15 December 1970).

Estimated Soil Moisture Deficit over Great Britain, a seasonal fortnightly publication providing estimates of soil moisture deficit in map form and as a tabular statement for river authority areas (to 31 December 1970).

Monthly (coloured) Ice Maps (to March 1970).

Ten-day Ice Maps (to 16 December 1970).

Meteorological Magazine (to December 1970).

Monthly Weather Report (to June 1970).

Marine Observer (quarterly) (to October 1970).

SERIAL

Geophysical Memoirs: Volume XV.

112. Average temperatures, contour heights and winds at 50 millibars over the northern hemisphere, by R. A. Ebdon.
113. An observational study of the meridional flux and angular momentum in the troposphere and lower stratosphere at latitude 30°N using 1958 IGY data, by A. E. Parker, B.Sc.

Scientific Paper:

30. Orthogonal polynomials as a basis for objective analysis, by R. Dixon, B.Sc.

OCCASIONAL

Handbook of weather messages, Part I, 4th edition (1970). Transmission schedules and station index numbers.

Monthly charts of dew-point temperatures over the Indian Ocean (1969).

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