

Meteorological Office

Annual Report 1975



ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE
1975

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

LONDON
HER MAJESTY'S STATIONERY OFFICE

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Cover photograph: The Hercules aircraft of the Meteorological Research Flight.

FOREWORD BY THE DIRECTOR-GENERAL

Despite the mild winter and dry, settled summer, demands for meteorological services continued at about the same level as last year. The number of direct enquiries to forecasting offices totalled 1·84 million, only slightly below last year's record of 1·85 million. In addition, 1·8 million forecasts were made for aviation, a new record, and 16·9 million calls were made on the Automatic Telephone Weather Service compared with 16·3 million in 1974.

The complex numerical models, which form the basis of the daily weather forecasts, are undergoing continuous development and a number of improvements in both the underlying physics and computational techniques have been incorporated during the year. There has been a steady improvement in the models' performance, notably in the prediction of rainfall and in the anticipation of major weather changes three days or more in advance. The northern hemisphere model is now used to make, once a day, experimental forecasts of up to six days ahead. The results are encouraging and form the basis of the weekly forecasts issued on the BBC-1 'Farming' program on Sundays.

An IBM 370/158 computer has been successfully linked to the very fast 360/195 machine and the capacity of the disc backing store increased to 2000 megabytes. The smaller computer handles many of the 30 000 tasks generated each month and releases the main processor for the very large computing demands of the forecasting and climate models. It has sufficient power to produce a numerical weather forecast, albeit at much reduced speed, should the large machine break down. The installation of 13 remote terminals allows headquarters branches direct access to the computer on a time-sharing basis. Good progress has been made in the further automation of the Telecommunication Centre leading to considerable savings in staff. With the electronic interface between the telecommunication computers and the main computer now fully operational, we have perhaps the most powerful and flexible meteorological computing system in the world.

There has been continued progress in the development of objective computerized methods of meteorological analysis and these are now being extended to stratospheric levels in support of Concorde operations. Satellite, aircraft and other 'non-standard' observations are being increasingly incorporated into numerical forecasting models, initially by human intervention, through a computer terminal and visual display unit. The object is to fill some of the more serious gaps in the conventional observing system, especially those over the Atlantic Ocean, and to provide the best possible input to the forecasting models. The majority of all the weather charts and diagrams used in the Central Forecasting Office are now produced entirely by automatic plotting and line-drawing techniques.

Special forecasts are provided for more than 50 offshore oil installations and there has been a large increase in the number of forecasts for helicopters serving the oil rigs. A team of forecasters has been established at London Weather Centre to provide a tailor-made service to individual operators. The ship-routing service provided special forecasts and advice for the towing and erection of new drilling rigs including a notably successful transatlantic operation.

The number of climatological enquiries was 23 000, an increase of nearly 20 per cent on last year, the greatest number coming from the building and construction industries. More than a thousand such enquiries came from overseas countries as far afield as Malaysia and Togo. Following the publication of the *Flood Studies Report* in March the number of hydrometeorological enquiries rose by nearly 80 per cent during the year.

A three-year experiment carried out in collaboration with the Water Resources Board and Plessey Radar Ltd has demonstrated that the rainfall over a hilly catchment area such as the Chester Dee can be measured with a single radar and a single calibrating rain-gauge more accurately than by existing rain-gauge networks. Moreover it provides the continuous real-time measurements required for the operational control of dams and reservoirs. Experiments to link three or four such radars together and transmit a composite display of the continually up-dated radar-rainfall maps to any designated centre are now being conducted in collaboration with the Royal Radar Establishment.

The Agricultural Branch continues to search for relationships between plant and animal diseases and weather factors. Notable progress has been made this year in predicting outbreaks of parasitic gastro-enteritis in cows and in introducing an improved system of warnings for potato blight.

Our research activities, which are aimed primarily at improving the accuracy and range of weather forecasts, the understanding of climatic changes, and supporting a wide variety of services to aviation, industry, commerce and the general public, involve experimental and theoretical studies on a broad spectrum of atmospheric phenomena ranging from the growth of tiny fog droplets to the evolution of weather systems many thousands of kilometres in extent.

Complex models of the global atmosphere, run for some hundreds of atmospheric days, have successfully simulated the major features of the present world climate including seasonal phenomena such as monsoons. They are now being used to discover the major factors governing climate, the most probable causes of climatic changes, and the possible effects of man-made activities such as the release of trace chemicals, aerosols, and large quantities of heat from giant nuclear power stations.

The special three-year research program, directed by the Meteorological Office but involving several other government departments and university groups, to investigate the possible effects on the environment of flying large numbers of aircraft in the stratosphere was concluded this year and a comprehensive report has been prepared. It has resulted in considerable advances in our knowledge and understanding of the stratosphere through new measurements of stratospheric composition from the Concorde aircraft and balloons, new data on basic photochemistry through laboratory studies and improved mathematical models of the complex dynamical and chemical processes that take place. The findings are that several hundred Concorde each flying five hours per day would not reduce the stratospheric ozone by more than 0.5 per cent, such a small effect being indistinguishable from the much larger natural fluctuations. We believe that the results of this research, which were presented at a special hearing of the US Senate Committee did much to counteract the alarmist views of some American scientists. However, we are not able to predict all the possible meteorological consequences of pollution of the stratosphere by, for example, the continued release of chlorofluoromethanes ('Freons'), and a good deal more monitoring and research is required.

The development of Concorde (Plate VIII) posed many other questions relating to meteorological conditions in the stratosphere. We have, for example, analysed many hours of flight data to estimate the probability of encountering large and sudden changes in temperature which might affect engine performance.

Much effort has been devoted to developing advanced instrumentation for installation on the Hercules flying laboratory of the Meteorological Research Flight, especially for the measurement of cloud particles and for the measurement of air motions in and around clouds. The latter task will be accomplished by specially developed sondes dropped from the aircraft, their successive positions in space being accurately fixed by the Loran and Omega navigational systems using tracking equipment on the aircraft. In this way it should be possible to delineate the three-dimensional temperature, humidity and wind structure over atmospheric volumes of order $100 \text{ km} \times 100 \text{ km} \times 10 \text{ km}$ deep.

A field program of observations using instruments suspended from the cable of a tethered balloon, together with the results of a numerical model, have identified the important processes that govern the formation and maintenance of a fog. It appears that the depth and density of a fog is determined by a small residual difference between the quantity of water condensed in the air by radiative cooling and that which is deposited on the ground by turbulence and gravitational setting. This explains why it is so difficult to forecast the formation and dispersal of fog and why the visibility is so sensitive to small changes in the wind and in the underlying surface.

The Office has continued to participate in an OECD-sponsored study of the long-range transport of air pollution, especially of sulphur dioxide, from the UK across the North Sea to Scandinavia. The results of sampling flights by the Meteorological Research Flight indicate that about 30 per cent of the sulphur deposited in southern Norway comes from United Kingdom power stations.

Good progress has been made in building radiometers to measure stratospheric temperatures from the next series of US meteorological satellites, the first of which is due to be launched in 1977. Preparations are being made to analyse, and make operational use of, cloud pictures, wind and temperature data from the European geostationary meteorological satellite (METEOSAT) to be launched in the autumn of 1977. A special satellite receiving station for this purpose is being established at Lasham in collaboration with RAE Farnborough. The satellite program is described in more detail in the Special Topic on page 65.

It has been a very busy year for the Meteorological Office College where a record number of 640 students have attended courses, 46 of them from 27 countries overseas.

Recruitment during 1975 was very successful and nearly all vacancies were filled. Applications were received from some 400 graduates for 16 vacancies, five of which were filled by candidates with Ph.Ds.

B. J. MASON

January 1976
Meteorological Office
Bracknell, Berks.

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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:

- (a) The provision of meteorological services for the Army, Royal Air Force, Civil Aviation, the Merchant Navy and Fishing Fleets.
- (b) Liaison with the Director of Naval Oceanography and Meteorology and provision of basic meteorological information for use by the Royal Navy.
- (c) The provision of meteorological services to other government departments, public corporations, local authorities, the Press, television, radio, industry and the general public.
- (d) The organization of meteorological observations, including observations of radiation and atmospheric electricity, in the United Kingdom and at certain stations overseas.
- (e) The collection, distribution and publication of meteorological information from all parts of the world.
- (f) The maintenance of the observatories at Kew and Lerwick.
- (g) 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, and acts in concert with the other Directors of Meteorological Services in Western Europe in the co-ordination of their program.

Except for the common services provided by other government departments as part of their normal functions (e.g. accommodation by the Property Services Agency of 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 expenditure of the Meteorological Office for the financial year 1975/76 including that on the common services (Property Services Agency and HM Stationery Office) is estimated to be £25·7 million. Of the amount chargeable to Defence Votes, about £16·9 million represents expenditure associated with staff and £8·4 million expenditure on stores, communications and miscellaneous services. It is estimated that some £5·6 million will be recovered from other government departments and outside bodies for services rendered, sale of meteorological equipment etc.

COMMITTEES

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 1975:

- Chairman: The Earl of Halsbury, F.R.S.
- Members: Professor A. H. Bunting, C.M.G.
Sir Frederic Harmer, C.M.G.
Sir Arthur Hetherington, D.S.C.
Dr J. T. Houghton, F.R.S. (Chairman, Meteorological Research Committee) (*ex officio*)
- Secretary: Mr A. C. Hughes (Secretary, Meteorological Office)

The Committee met three times in 1975.

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 1975:

- Chairman: Dr B. J. Mason, C.B., F.R.S. (Director-General, Meteorological Office)
- Members: Mr R. J. H. Brush (University of Dundee)
Dr H. E. Butler, F.R.S.E. (Royal Society of Edinburgh)
Dr J. M. Caborn (University of Edinburgh)
Sir Samuel C. Curran, F.R.S. (Royal Society)
Professor S. Desmond Smith, F.I.P., F.R.S.E. (Heriot-Watt University)
Mr J. Ferguson (Department of Agriculture and Fisheries for Scotland)
Professor G. M. Howe (University of Strathclyde)
Mr R. Lines (Forestry Commission)
Dr D. H. McIntosh, F.R.S.E. (Department of Meteorology, University of Edinburgh)
Councillor W. J. McKechin (Convention of Scottish Local Authorities)
Professor H. Meidner (University of Stirling)
Dr I. S. Robertson (University of Aberdeen)

Mr J. W. Shiell (Scottish Development Department)
Dr J. H. Steele (Department of Agriculture and Fisheries
for Scotland)
Professor D. W. N. Stibbs, F.R.S.E. (University of St
Andrews)
Professor P. A. Sweet (University of Glasgow)

Secretary: Mr W. G. Harper (Meteorological Office)

The Committee met once in 1975.

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 use of money 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 1975:

Chairman: Dr J. T. Houghton, F.R.S.

Members: Instructor Captain R. K. Alcock, R.N. (Director of Naval Oceanography and Meteorology)

Mr J. K. Bannon, I.S.O. (Director of Services, Meteorological Office)

Professor R. L. F. Boyd, C.B.E., F.R.S.

Mr F. H. Bushby (Deputy Director, Dynamical Research, Meteorological Office)

Professor H. Charnock

Professor D. R. Davies

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

Wing Commander D. M. Leslie (Air Force Department)

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

Mr F. O'Hara (Procurement Executive, Ministry of Defence)

Professor R. P. Pearce, F.R.S.E.

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

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

Dr P. G. F. Twinn (Natural Environment Research Council)

Secretary: Mr R. A. Ebdon (Meteorological Office)

The Committee met twice in 1975 and its subcommittees seven times.

**PRINCIPAL OFFICERS OF
THE METEOROLOGICAL OFFICE**

DIRECTOR-GENERAL

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

DEPUTY TO THE DIRECTOR-GENERAL

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

DIRECTORATE OF SERVICES

DIRECTOR

J. K. Bannon, I.S.O., B.A.

INTERNATIONAL AND PLANNING

Assistant Director

D. G. Harley, B.Sc.

FORECASTING SERVICES

DEPUTY DIRECTOR

M. H. Freeman, O.B.E., M.Sc.

CENTRAL FORECASTING

Assistant Director

G. R. R. Benwell, M.A.

DEFENCE SERVICES

Assistant Director

I. J. W. Pothecary, B.Sc.

H.Q. Strike Command

R. A. Buchanan, M.A.

PUBLIC SERVICES

Assistant Director

D. H. Johnson, M.Sc., D.I.C.,
A.R.C.S.

London/Heathrow Airport

R. E. Farms, B.Sc.

COMMUNICATIONS AND COMPUTING

DEPUTY DIRECTOR

G. A. Corby, B.Sc.

TELECOMMUNICATIONS

Assistant Director

E. J. Bell, C.Eng., F.I.E.E.

DATA PROCESSING

Assistant Director

G. A. Howkins, M.B.E., B.Sc.

SYSTEMS DEVELOPMENT

Assistant Director

E. J. Sumner, B.A.

OBSERVATIONAL SERVICES

DEPUTY DIRECTOR

N. Bradbury, B.Sc.

OBSERVATIONAL REQUIREMENTS AND PRACTICES

Assistant Director

G. J. Day, B.Sc.

Marine Superintendent

G. A. White, Captain, Extra Master

CLIMATOLOGICAL SERVICES

Assistant Director

R. J. Ogden, B.Sc.

AGRICULTURE AND HYDROMETEOROLOGY

Assistant Director

R. Murray, M.A.

Special Post

L. P. Smith, B.A.

OPERATIONAL INSTRUMENTATION

Assistant Director

M. J. Blackwell, M.A.

DIRECTORATE OF RESEARCH

DIRECTOR

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

PHYSICAL RESEARCH

DEPUTY DIRECTOR

K. H. Stewart, Ph.D.

BOUNDARY LAYER RESEARCH

F. B. Smith, Ph.D.

GEOPHYSICAL FLUID DYNAMICS LABORATORY

R. Hide, Sc.D., F.R.S.

METEOROLOGICAL RESEARCH FLIGHT

D. G. James, Ph.D.

CLOUD PHYSICS

Assistant Director

P. Goldsmith, M.A.

Special Post

K. A. Browning, Ph.D., D.I.C.

HIGH ATMOSPHERE

Assistant Director

N. E. Rider, D.Sc.

DYNAMICAL RESEARCH

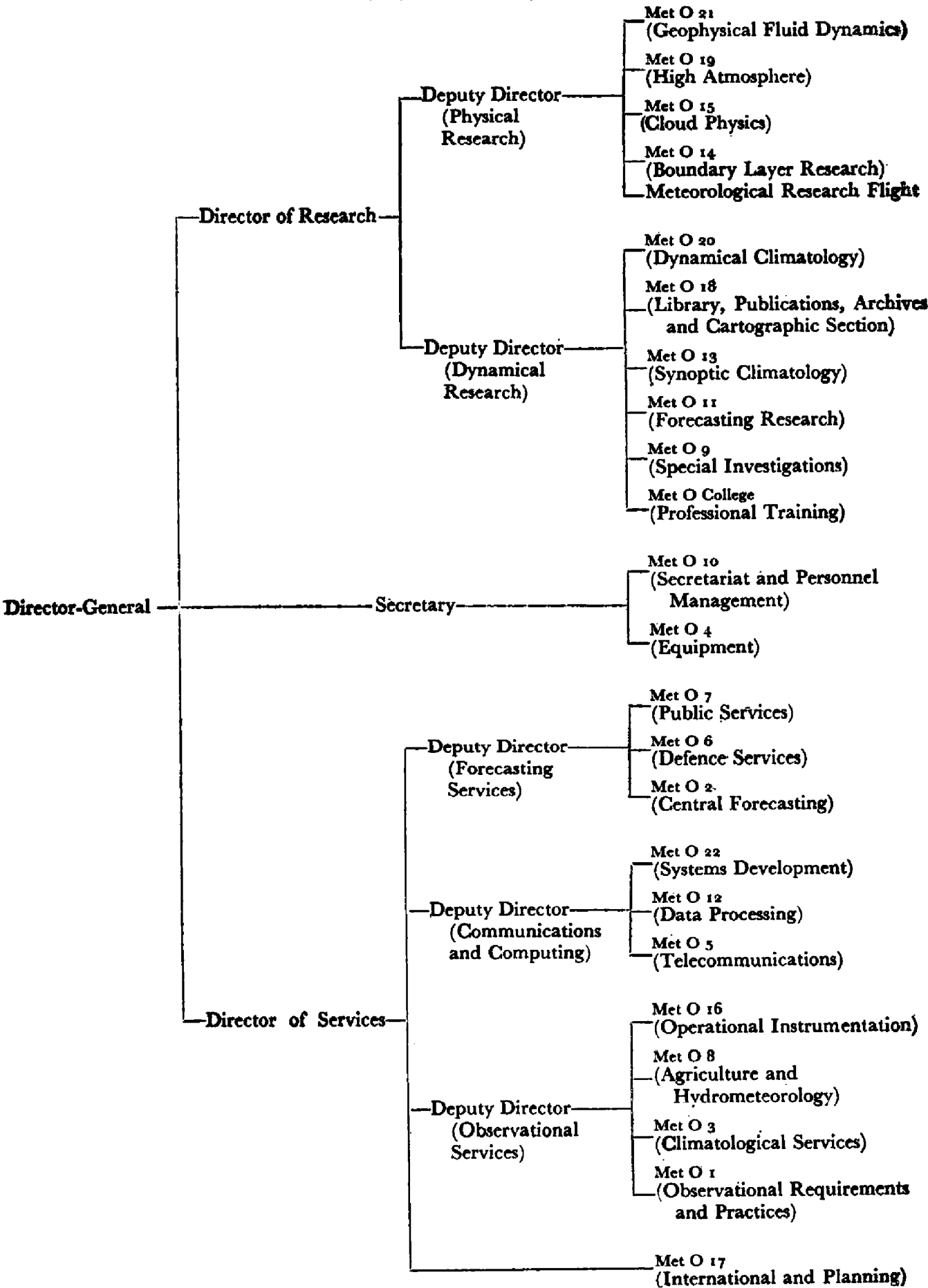
DEPUTY DIRECTOR	F. H. Bushby, B.Sc., A.R.C.S.
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Assistant Director	P. Graystone, B.A.
Special Post	R. Dixon, B.Sc.
SYNOPTIC CLIMATOLOGY	
Assistant Director	R. A. S. Ratcliffe, M.A.
PROFESSIONAL TRAINING	
Assistant Director and Principal, Meteorological Office College	D. E. Jones, M.Sc., D.I.C., A.R.C.S.
DYNAMICAL CLIMATOLOGY	
Assistant Director	A. Gilchrist, M.A.

SECRETARY, METEOROLOGICAL
OFFICE

PERSONNEL MANAGEMENT	A. C. Hughes, M.Sc., M.Phil. W. D. S. McCaffery, B.Sc.
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METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION

(at 31 December 1975)



DIRECTORATE OF SERVICES

SPECIAL TOPIC—METEOROLOGICAL SERVICES FOR AVIATION

Introduction

A substantial proportion of the resources of the Meteorological Office is devoted to meeting the needs of aviation. The characters of civil and military flying are sufficiently diverse to warrant separation within the Office of the organizations which serve them. For each, a central operational role is played by a Principal Forecasting Office, at London/Heathrow Airport for civil aviation and at Royal Air Force Command Headquarters, Strike Command for flights by military aircraft. Meteorological offices located at civil airports and air traffic control centres are administered by the Public Services Branch, whilst those established at Army aviation and Royal Air Force units are under the control of the Defence Services Branch.

The two Principal Forecasting Offices are served by the Central Forecasting Office, the Computer System of the Meteorological Office and the Regional Telecommunication Hub at Bracknell, to which they are linked by direct teleprinter and facsimile communication channels. The important central facilities at Bracknell are described in detail in later sections of this report. They are at the heart of the country's meteorological operational organization and serve aviation's needs along with those of all other industrial, public and military interests.

Organization of services for civil aviation

The Meteorological Office provides meteorological services for civil aviation as agent of the Civil Aviation Authority. It has a dual role in relation to the Authority, first to give technical advice on meteorological matters, and second to provide the staff and technical facilities to meet the Authority's requirements and standards.

Aviation needs have changed with the growth and development of the industry and there has been a notable world-wide trend towards centralization in the provision of meteorological data for flight planning and meteorological documentation for use by the flight crews. The process has been hastened by the introduction of large, fast, subsonic aircraft capable of flights in stages of up to 8000 kilometres. No longer is it necessary to provide for every flight an individual tailor-made forecast. Instead flight documentation is issued which consists of charts of the upper winds and temperatures, predicted for a fixed time, for two or three levels near to the cruising height of the aircraft, a significant-weather chart showing the distribution of weather likely to affect the aircraft near its flight level, and a list of selected aerodrome forecasts, in coded form, to cover the destination airport and possible alternates. The charts embrace very large areas and so can be duplicated in quantity to serve a large number of different flights and routes. Similar documentation, with appropriate variations only in the list of aerodrome forecasts, can serve the majority of the scheduled flights from different airports within a given region. The distribution to the airports of the forecast upper-wind and significant-weather charts is the responsibility of an aviation meteorological office designated as an Area Forecast Centre.

There is a basic need in civil aviation for aerodrome weather observations. They are made half-hourly at all major airports in the United Kingdom and details of the surface wind, the atmospheric pressure, temperature, cloud, visibility and the character of the weather at each location are distributed in coded messages to all those interested throughout Europe. In addition to the observations at fixed times, special reports are made whenever there is a significant deterioration or improvement in the weather which does not coincide with the fixed time. There is an immediate local requirement for current weather information in Air Traffic Control. This information can be obtained from Air Traffic Control directly by aircraft in flight. For the benefit of aircraft *en route*, observations for selected aerodromes are also transmitted through routine voice broadcasts on very high frequency (VHF) known as Volmet (derived from *vol*, the French word for flight). Two such broadcasts serving aircraft flying in the London and Scottish flight information regions originate in the United Kingdom.

Observations made at aerodromes on the hour are among those collected from meteorological stations all over the world through the Regional Telecommunication Hub at Bracknell. They are analysed in the Computer System of the Meteorological Office (cosmos) and form a basis for the prediction of future atmospheric states which are made in the Central Forecasting Office with the aid of a very advanced 10-level mathematical model. Forecast upper-wind data for flight planning and for flight documentation are prepared from the computer output in the Central Forecasting Office for a series of flight levels spanning the 17 km or so of the upper air in which commercial flights are made. For flights within Europe, which are made along strictly controlled airways, the data are issued in grid-point form, that is, the predicted upper winds and temperatures are given numerically for each point of a network distributed at regular intervals over the chart. For Atlantic flights the routes flown are not fixed. They vary according to the winds expected at operating levels and are chosen so as to minimize headwinds. To assist selection of the least-time track the Atlantic forecast upper-wind charts contain pressure contours and isotachs from which wind direction and speed can be deduced for any location or any route. The grid-point form is particularly well adapted for flight planning by computer so that the Meteorological Office is able to send to British Airways over a data link material suitable for direct input to their computer BOADICEA in which flight plans are prepared. Similar data are sent to the Shanwick Oceanic Control at Prestwick for Atlantic flights.

A very important feedback comes from aircraft in flight in the form of meteorological air reports. The air reports contain observations of wind measured by Doppler radar and of temperature at flight level. They are relayed to the Meteorological Office at Bracknell from air traffic control centres and are a valuable supplement to the other meteorological data analysed there. A continuous watch is kept on them so that in case of any serious divergence from the conditions forecast, predictions can be updated for the benefit of following aircraft. As aircraft of greater range have been developed, the accuracies of the upper-wind and temperature forecasts have become less critical for flight safety. They have gained in economic importance, however, with the considerable rises in the cost of aviation fuel.

In the United Kingdom the Area Forecast Centre is the Principal Forecasting Office at London/Heathrow Airport. Flight documents are transmitted

to meteorological offices at airports throughout the country by means of a civil aviation facsimile network (CAMFAX) centred at Heathrow. They include the charts of forecast upper winds and temperatures prepared at Bracknell together with the forecast significant-weather charts which are prepared and issued every six hours at Heathrow itself. On receipt at the airports the facsimile copies are duplicated for issue to the flight crews during the pre-flight briefings which are given by the local forecaster. At some airports a supermarket approach known as self-briefing has been introduced. At Heathrow for example, copies of the flight documentation for many routes are laid out in trays in the briefing room. The current weather charts are on display together with details of warnings of weather hazards which may be in force and other relevant weather information. The crew member or a company representative simply helps himself to the documents which he needs. A forecaster is at hand, however, for those who wish to consult him. The Principal Forecasting Office at Heathrow is also responsible for originating specific warnings (SIGMET) for aircraft in flight of weather hazards likely to be encountered within the London, Scottish and Shanwick (Atlantic) flight information regions. Such hazards include thunderstorms, hail, turbulence, severe airframe icing and mountain waves.

As well as requiring prediction of the in-flight conditions the crews need to know what weather to expect at the destination aerodrome and at others to which they may have to divert in case of difficulty. In forecasting conditions at the ground at any particular place a knowledge of the peculiarities of the local weather is very important. Consequently the task of preparing the aerodrome weather forecasts is the responsibility of the meteorological office at the aerodrome itself. In the United Kingdom all forecasting offices receive advice directly from the Central Forecasting Office on the broad-scale developments of the weather over the British Isles in the form of charts and written matter. This is consistent, naturally, with the developments implied by the flight documentation disseminated from the Area Forecast Centre at Heathrow. The task of the aerodrome forecaster is then to predict the local weather in detail, paying particular attention to those elements, low cloud, fog, heavy rain, snow and so forth, which may be critical for aircraft on landing or take-off. A brief coded forecast of the expected trend of the aerodrome weather over the two hours immediately following is added to and distributed with each half-hourly observation. In addition, coded aerodrome forecasts covering a period of 9 and sometimes 18 hours are prepared every three hours for distribution to those who need them, throughout the world. In the United Kingdom the work of the aerodrome meteorological offices is supervised on a regional basis from main meteorological offices such as those at Prestwick, Preston and Gloucester. Together with Heathrow, these offices are also required to make the 9- and 18-hour aerodrome forecasts for airports such as Leeds/Bradford, Luton, Newcastle and Southend which do not have their own meteorological offices. At such aerodromes the half-hourly observations are made by air traffic control staff who have been trained and certificated in weather observing under the supervision of the Meteorological Office. Since there is no forecaster on the spot at these aerodromes, the two-hour expected weather trends are not prepared and distributed with their observations.

The meteorologist also has a part to play in the separation of aircraft flying at different levels. For air traffic control purposes the flight-level at which an aircraft is directed to fly is expressed in terms of its pressure altitude, as recorded

on its pressure altimeter, and not in terms of its true height above the ground. It is the practice, when an aircraft is about to land at an aerodrome, for the altimeter setting to be adjusted so that the instrument will show that airfield height has been reached when touch-down takes place. Since the instrument is responding to atmospheric pressure, and this changes at the aerodrome hour by hour and minute by minute, it is essential that the altimeter setting is made in agreement with a current reading of barometric pressure at the aerodrome. For this reason airport meteorological offices keep air traffic control constantly supplied with the latest altimeter setting (QNH). In a similar way, all aircraft flying within a given control zone must use a common altimeter setting if a safe vertical separation is to be maintained between them. The setting is fixed taking into account the general level of surface pressure within the zone and its likely variation over a period of one hour. It is a function of the Central Forecasting Office at Bracknell to issue a forecast QNH hourly for each of the control zones for which the United Kingdom is responsible.

Special requirements of civil aviation

The organization so far described serves almost all the scheduled flights along airways within Europe and over the Atlantic. Some other types of aviation call for more specialized attention. The term general aviation is applied in this country to the very large number of aircraft which fly privately. They include executive aircraft, air taxis, flying-club aircraft and helicopters. The majority operate within the lower layers of the atmosphere and for this reason and also because of their smaller size their flights tend to be more weather sensitive than those of the larger commercial aircraft. This is also true for a minority of scheduled flights such as those which serve the Scottish Isles. A tailor-made flight forecast is provided for such aircraft. If there is no meteorological office at the departure aerodrome the forecast can be obtained by telephone or telex from the nearest aviation meteorological office. Many such flights are made under visual flight rules and for these a trial answerphone service sponsored by the Civil Aviation Authority has recently been in operation. Inquirers can ascertain the weather state, in code, for areas of England and Wales, the weather information being provided by the Meteorological Offices at Preston and West Drayton.

Helicopter operations have become especially important for the offshore industry. Landing conditions on North Sea platforms and rigs are often critical and there has been a large increase in the work generated by helicopter traffic at meteorological offices serving such aerodromes as Aberdeen, Coltishall, Leconfield and Sumburgh.

As might be expected, flights by Concorde during development and proving have extended the height and range of the aviation forecaster's purview. A Concorde Forecasting Office has been maintained at Fairford with special forecasts being supplied from Heathrow where experience is being gained in handling the fresh meteorological problems which supersonic flight has posed, including the prediction of the vertical distribution of temperature in the stratosphere. During the development of Concorde and its approach to certification, support was given by the Meteorological Office in assessing the chances of occurrence of specific meteorological conditions, for example the probabilities of encountering sudden large changes of temperature or of entry into high storm-cloud tops.

Most of the research carried out by the Meteorological Office benefits civil aviation directly or indirectly. Improvements in the performance of the 10-level mathematical model for instance, benefit civil aviation along with all other users of the forecasting services. Some investigations are made however directly in response to a particular aviation need. Information on such matters as the probability of very low cloud or of poor visibility or of dangerous cross-winds at airports can readily be assessed by computer analysis of records held in the data bank or in archives at Bracknell. Other problems, such as the development of methods of predicting clear-air turbulence accurately require tackling by theoretical studies, painstaking evaluation of aircrew reports and the testing of forecasting techniques devised in this country and elsewhere. Of increasing concern in civil aviation is the occurrence of large wind shears in the lowest two or three hundred feet of the atmosphere which can cause difficulty for aircraft about to land. These have been studied using the detailed wind soundings made from Shoeburyness. Investigations of this kind are normally carried out in the Special Investigations Branch of the Meteorological Office and there have been many such in recent years. The same branch prepares airfield weather diagrams which succinctly describe the meteorological characteristics of each location and climatological memoranda relating to weather along air routes.

Aviation needs are taken into account in the development of specialized instrumentation. The development in the Meteorological Office of such instruments as 'transmissometers' (which measure atmospheric opacity and can be used to derive estimates of visibility) and of cloud-base recorders has been of direct benefit to aviation. The Meteorological Office also co-operates with other government organizations, notably the Royal Aircraft Establishment, when meteorological aspects of their work arise.

International aspects

Weather data are continuously exchanged internationally for aviation purposes. The Meteorological Operational Teleprinter Network Europe (MOTNE) exists solely for the quick circulation amongst airports and control centres in Europe of civil aviation weather observations and forecasts. For transmission further afield the Aeronautical Fixed Teleprinter Network (AFTN) can be used. The exchange of flight documentation material has also become international. The Area Forecast System was sponsored by the International Civil Aviation Organization and the Area Forecast Centre at Heathrow does not originate documentation for departures solely from the United Kingdom. Through facsimile links with Europe it provides flight forecasts for all transatlantic flights departing from European airports and bound for destinations in North America. Radio-facsimile broadcasts of some United Kingdom Area Forecast Centre products are made for reception in Africa, the Near East and elsewhere. In return, Heathrow receives forecast charts prepared at other Area Forecast Centres in Nairobi, Rome, Frankfurt, Paris and Washington which are suitable for flights to Africa, the Near East, the Caribbean Area, South America and so on. The documentation received from overseas is then redistributed through the CAMFAX network to meteorological offices at other airports in this country which need them.

At certain aerodromes overseas where Meteorological Office staff work in support of the Royal Air Force, services are also provided for civil and general aviation. In recent years these have included Wildenrath, Gütersloh, Gibraltar,

Luqa, Nicosia, Masirah and Salalah. The various civil aviation authorities concerned have been given technical advice when this has been requested.

Successful international co-operation demands careful and detailed planning. Organizational and technical problems arising in the provision of meteorological services for civil aviation are discussed at regular world and regional conferences, working group meetings and committees of the International Civil Aviation Organization (ICAO). Meteorological Office staff, with members of the Civil Aviation Authority and of the Department of Trade, have represented the United Kingdom at many of these. The World Meteorological Organization (WMO), at which the Director-General of the Meteorological Office is the permanent United Kingdom representative, also devotes much attention to the operational and technical problems of aviation meteorology. One of the eight technical commissions of WMO, the Commission for Aeronautical Meteorology, is solely concerned with services for aviation. The Meteorological Office provides the United Kingdom representative for the Commission and members of its staff have regularly served on WMO Working Groups concerned with specific aviation problems and have contributed to the technical literature on the subject published by WMO.

Services for military aviation

To ensure that the Director-General of the Meteorological Office is kept aware of the operational requirements of the Royal Air Force, senior members of staff of the Office are located at Headquarters, Strike Command and at Headquarters, Royal Air Force Germany. These officers act as advisers in meteorological matters to the Air Officers Commanding-in-Chief. One section of the Defence Services Branch at Bracknell deals with the needs of the Army and a meteorological officer is attached as adviser to the General Officer Commanding, Headquarters No. 1 (BR) Corps, Detmold in the Federal Republic of Germany. The Defence Services Branch maintains close liaison with the Directorate of Naval Oceanography and Meteorology.

There is a Principal Forecasting Office at Headquarters, Strike Command and Main Meteorological Offices, functioning throughout the 24 hours every day, are located at various centres to control and advise subsidiary offices at aerodromes and enable them to meet the requirements of aircraft of several types operating in different roles. At the subsidiary forecasting offices a forecaster is on duty at times which depend on the stated requirements of the Royal Air Force.

Maximum use is made of the technical support which is provided by the large computer system at Bracknell. At Headquarters, Strike Command and at Headquarters, No. 38 Group, comprehensive six-hourly programs of preparation and issue of area and route forecasts in chart form are maintained as routine to meet the majority of operational requirements. These routine issues include a forecast surface-analysis chart and a significant-weather chart in addition to upper-air forecasts for standard levels. The charts are distributed by land-line facsimile to the subsidiary offices where they are duplicated for issue to aircrews at pre-flight meteorological briefings. As far as possible the flight documentation is made available in self-briefing format, but personal briefing of aircrew by forecasters remains an important feature of work in the Defence field.

Mobile meteorological units are established to support elements of the Royal Air Force and Army participating in certain field exercises in the United

Kingdom and overseas. Each unit has its own air-transportable set of meteorological and communication equipment for use at locations which are remote from permanent meteorological offices. The facilities include radio-teleprinters, radio-facsimile recording equipment, and special apparatus for receiving satellite cloud pictures. Forecasters in the mobile units hold commissions in class CC of the Royal Air Force Reserve of Officers.

A military Volmet broadcast of plain-language weather reports for major RAF aerodromes is provided mainly to meet the needs of aircraft returning from overseas to bases in the United Kingdom.

FORECASTING SERVICES

Central Forecasting Office

Bracknell is a Regional Meteorological Centre (RMC) within the framework of World Weather Watch. The latter is a concept ratified by the Congress of the World Meteorological Organization (WMO), whereby the meteorologically more advanced nations assist the less advanced. In the sphere of weather forecasting this assistance is achieved by the establishment of three World Meteorological Centres (WMCs) at Washington, Moscow and Melbourne, and by a number of RMCs. The Central Forecasting Office (CFO) at Bracknell has undertaken, as an RMC, to meet the stated needs of various National Meteorological Centres (NMCs) in Europe for regional forecasts and guidance. This it does by the preparation, for wireless-telegraphy and radio-facsimile transmission, of analysed and forecast charts covering a large part of the North Atlantic, Europe, and the Arctic; in some instances these are transmitted in the form of data for agreed arrays of grid points used in the analysis and forecast programs. In addition to its role as an RMC in the World Weather Watch, CFO is also the chief forecasting centre of the State Meteorological Service.

The main tasks of CFO continued substantially unchanged from previous years. An important responsibility of the Senior Forecaster is the regular issue of guidance to outstation forecasters in the form of charts depicting actual and forecast conditions augmented by advisory texts describing the expected weather. The routine forecasts are for the British Isles, surrounding seas and the eastern North Atlantic; the charts cover a much wider area. CFO issues warnings of hazardous conditions such as gales over sea and land, fog, snow, icy roads, frost, thaw and thunderstorms.

CFO makes major use of the forecasts produced from the 10-level numerical forecasting models, the basic procedures remaining similar to those described at length in previous *Annual Reports*.

Refinements to the operational numerical forecasting system are introduced as a result of continuing research work. During 1975 further improvements were made to the orthogonal polynomial analysis scheme, to the semi-implicit time integrations used to compute the forecast and in the way in which intervention action was taken, all areas in which changes were also made in 1974, as described in the *Annual Report* for that year. Another important change was the use of the new 170/158 computer to produce the numerical forecast, albeit more slowly, on the rare occasions when the powerful 360/195 was unserviceable.

Considerable attention was also given during 1975 to the production of a comprehensive scheme of analysis for both the troposphere and the stratosphere.

Previously the analysis of the lower levels needed for the 10-level-model integrations was carried out by one method and the analysis of the more remote higher levels was obtained by a different method. The resulting analyses at 100 mb, which level is common to both methods, were not identical and were in some cases markedly different. The comprehensive method involves extending the orthogonal polynomial scheme adopted in 1974 for operational analyses, to include the higher levels of 70, 50, 30, 20 and 10 mb. At these latter levels background fields must, perforce, at least for the present, be based on persistence, whereas the basic background fields for the lower levels (1000–100 mb) are provided by the 12-hour forecasts from the 10-level model. This analysis-development work is continuing with a view to improving the upper-wind and temperature guidance required for the Concorde operations.

Greater use of automatically plotted charts is still a top priority and the installation of a second Calcomp 1670 microfilm plotter together with the introduction of automatic data handling in the Bracknell meteorological communication centre late in 1975 should result in the dissemination by facsimile of automatically plotted hourly charts early in 1976. For most of 1975 the three-hourly European charts transmitted by facsimile were automatically plotted and most of the upper-air and circumpolar charts used internally within CFO were similarly produced.

The increasing number of visitors to CFO, especially from other meteorological services and institutions overseas, reflects the continued interest in the way the British Meteorological Office is responding to the demands for more and better weather guidance. Of prime interest is the way in which satellite and other less-conventional data are being incorporated into the mainly objective numerical-forecasting scheme through human intervention. The great use of visual display units to manipulate data and the background and analysis fields in the cosmos computer system before the running of the operational forecast programs has received favourable comment.

There have been more requests for guidance beyond the outlook period of 48–72 hours from agricultural, industrial, and manufacturing interests, as well as from offshore operators engaged in such weather-sensitive operations as pipeline laying, oil- and gas-rig installation, and maintenance and supply services to these rigs and platforms. The numerical forecast is extended to six days ahead once daily from the full 12-GMT data bank. Trial forecasts have shown that this extension of the 72-hour forecast shows some skill into the fifth and sixth days. Improvement is needed, but the forecasts are considered to be of some use to the medium-range forecasters who are attempting to meet requests for forecasts beyond the normal outlook period.

CFO continued to be responsible for the publication of the *Daily Weather Report* (DWR) with its *Overseas Supplement*, the *Monthly Summary* and the *Daily Aerological Record* (DAR).

In the international field the Assistant Director (Central Forecasting) serves as a member of the Working Group on the Global Data Processing System (GDPS), one of the working groups of the WMO Commission for Basic Systems (CBS).

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 by a number of other forecasting

offices, or indirectly through radio, television, the Press, and the Post Office's automatic telephone weather service. Most of the work is undertaken by some 37 offices in various parts of the country, whose telephone numbers are published in the preface to area telephone directories, official leaflets, and many trade journals. A further 50 unpublicized offices also handle requests for advice from industry and the general public.












Despite the settled nature of the weather during much of the summer, which resulted in a large reduction in the number of casual requests for advice from holidaymakers, the total number of enquiries over the year was not far short of 1974's all-time record. Direct enquiries to forecasting offices totalled 1 840 820 in 1975 as against 1 854 387 in 1974.

Calls on the Post Office's automatic telephone weather service (ATWS) also held up well, totalling 16 935 351 as against the record of 16 255 932 calls in 1974. For some years past ATWS forecasts for London and other areas in the south-east have been recorded by members of the London Weather Centre staff rather than by Post Office staff. Long-standing plans to extend this practice to other areas were reviewed in the light of the growing cost of fully sound-proofing suitable accommodation in each of the meteorological offices concerned. As a result, it was decided to mount a trial at Manchester Weather Centre using less-sophisticated sound-proofing equipment than was originally planned. The trial has begun and the outcome is awaited. As in previous years, special forecasts were supplied to the Post Office in connection with a marine information service in the Swansea telephone area in the summer months, and for a ski-report service in the Edinburgh telephone area during the winter.

By local arrangement, the main meteorological office at Preston supplied forecasts for the Lake District National Park Information Service, initially at weekends only, but on a twice-daily basis from Easter. The forecast is recorded by staff of the Information Service and is made available to the public on a Windermere telephone number. This service has proved very popular with climbers and other visitors to the Lake District.

The dissemination via television and radio of routine forecasts and warnings of severe weather continued. In BBC Television a notable event was the introduction of new symbols for the weatherman presentations. The symbols were designed with the general viewer, rather than the specialist, in mind. Considerable publicity was given to them initially at a Press Conference held at the BBC Television Centre, and subsequently in the Radio Times and in most of the national newspapers. The symbols provide a graphic language for the illustration of weather present and future and they enable more information to be conveyed than did those used hitherto. In particular they give some indication of the state of the sky, the presence or absence of clouds being very significant for the man-in-the-street. The time allotted by the BBC for weather presentations, especially at peak viewing times, depends upon audience response, and for this reason the reactions to the new-style presentations are being assessed with a good deal of interest. The new symbols, with explanations, are depicted on the next page. For those with an understanding of fronts and of features of the pressure distribution (anticyclones, depressions, and so on) the presentations continue to include a discussion of the synoptic situation. According to the BBC such viewers are in the minority although they include important groups such as aviators, fishermen, yachtsmen, farmers, teachers and many others with weather-sensitive occupations such as those in the construction and offshore industries.

TABLE SHOWING THE NEW SYMBOLS FOR BBC TELEVISION WEATHER FORECASTS

	<i>Temperature.</i> Red figures on a yellow background give positive temperature in degrees Centigrade. Black figures on a light blue background give freezing temperatures, i.e. below 0°C.
	<i>Sunshine.</i> The yellow symbol represents the sun; the red figures in the centre show a temperature of 25°C.
	<i>Cloud.</i> A white cloud symbol indicates fine-weather clouds that may be thin and patchy.
	A black cloud represents the thicker and more widespread clouds often associated with dull weather.
	<i>Sunny intervals.</i> The sun symbol used in conjunction with a cloud in this way means some sunshine as well, particularly if the white cloud symbol is used.
	<i>Rain.</i> The dark-blue tear-drop symbols beneath the cloud indicate rain.
	<i>Rain showers and sunny intervals.</i> A combination of rain, cloud and sun represents sunny intervals and rain showers.
	<i>Snow.</i> The white snow symbols beneath the cloud indicate snow.
	<i>Sleet.</i> The rain and snow symbols together beneath the cloud indicate sleet.
	<i>Thunderstorm.</i> The symbol of a black cloud with a yellow flash represents the possibility of thunder and lightning.
	<i>Wind speed and direction.</i> The black symbol represents the wind speed and direction, the speed printed in the centre in white is in miles per hour.
FOG	<i>Fog.</i> Fog is not represented by a specific symbol; it is indicated by words on the map in the general areas likely to be affected.

During the summer months the Thursday evening presentation on BBC 1 was extended to include an item on continental holiday weather; a similar extension from October onwards was devoted to the weekend prospects over the United Kingdom. Starting in September, a five-minute period during each Friday's 'Pebble Mill' program in the middle of the day on BBC 1 was devoted to discussion of an item of weather interest by one of the weathermen, items being chosen for their topicality and general interest. Services to independent television companies continued largely unchanged. The BBC CEEFAX and the ITV ORACLE experimental data transmission systems both included weather information provided by the Meteorological Office.

The trial presentations of forecasts on Radio 4 Northern Ireland by staff of the Main Meteorological Office at Aldergrove terminated in February, public reaction not being favourable. The requirement for brief national forecasts and actual weather reports for inclusion in the Radio 4 'Today' program ceased. On Radio 4 Scotland the actual weather reports for a number of locations in Scotland included in the 'Good Morning Scotland' program were replaced by a short forecast for Scotland. Routine forecast services were provided for all 20 BBC local radio stations, and six commercial radio stations contracted for services. A large number of broadcasts and interviews were given by members of the staff, most of them on the subject of current weather.

Services to the Press followed patterns set in previous years, but further changes were made in the Press Forecast Areas to conform with the changes in Scottish local government administrative areas. As usual, many requests were received from the national and provincial Press for special interviews and comment on a wide variety of topics.

Services tailored to meet special requirements were, as in previous years, provided for the British Gas Corporation, the Central Electricity Generating Board, British Rail, London Transport and many smaller concerns. In the context of energy conservation, considerable publicity was given to the week-end temperature forecast service, designed to assist those responsible for the heating of industrial and other premises in winter. As a result, registrations for the 1975/76 winter were more than double those of previous years. Other special services included warnings to highway authorities of road dangers due to weather during the winter months, forecasts for pigeon racing and the notification of dry spells to farmers. The responsibility for the last service was transferred from the Central Forecasting Office at Bracknell to regional forecasting offices so as to permit the inclusion of more detailed local information and to enable the farmer to discuss the situation with a forecaster.

The Weather Centres at London, Glasgow, Manchester, Southampton and Newcastle and the public service office at Watnall, near Nottingham, continued to handle the bulk of the work in the public sector. Excluding weather maps provided for shipping at certain major ports, the total numbers of enquiries dealt with over the past three years were as follows:

	London	Glasgow	Manchester	Southampton	Newcastle	Watnall
1973	309 453	109 941	131 593	96 868	94 658	62 415
1974	313 784	112 293	123 148	97 317	98 223	59 461
1975	311 354	114 974	121 225	102 298	108 147	61 501

Grand totals: 1973, 804 928; 1974, 894 226; 1975, 819 499.

The marine aspects of the work at these offices, in particular the increasingly important offshore work at the London Weather Centre, are dealt with in a separate section of the Report. As usual, there was much variety in the other services provided. To mention but a few, Watnall supplied warnings of strong winds to British Rail in connection with the experimental High Speed Train trials; Glasgow Weather Centre contributed to a 'Mountaineering in Safety' Exhibition and supplied forecasts in connection with the construction of offshore platforms in Loch Fyne; the Southampton office provided a special forecast and warnings service during the construction of a 120-metre chimney at the Fawley refinery; and London Weather Centre supplied special forecasts for the Queen's Birthday Parade and Fly-past.

Over 100 requests for lectures and talks to be given to outside bodies were met voluntarily by members of the staff during the year, while 110 parties of visitors, including a number from overseas, visited the Headquarters and were shown some of the work of the forecasting, telecommunication and computing branches. The keen public interest in the work of the Office continued unabated.

Services for the general public (overseas)

The offices on the Royal Air Force stations in Cyprus, Malta and Gibraltar continued to provide forecasts for the public by means of Press, radio and television. The needs of local government departments, oil-drilling operators and other engineering concerns were also catered for.

Services for marine activities

General services to shipping are provided via BBC Radio and the Post Office coastal radio stations. Every day four bulletins prepared in the Central Forecasting Office are broadcast on Radio 2, and two bulletins on coastal radio, while gale warnings are broadcast as soon as possible after issue. Following discussion and consultation with all interested parties, a number of changes were made in the format and content of the bulletins to improve their value to the user. The most important concerned the coastal station reports included in the bulletins broadcast on Radio 2. Two stations, Wick and Prestwick, were replaced by the two more-exposed stations, Sule Skerry and Malin Head. To overcome the problem of Tiree, a key station, being omitted on those occasions when the bulletins are curtailed, the order of broadcast of the reports was changed to commence with Tiree, rather than with Wick, as previously, and then to proceed clockwise through Sule Skerry, Bell Rock, etc. Further, to meet the special requirements of yachtsmen, a report for Jersey was included in the 0033 and 0633 bulletins; strict limitation on broadcasting time does not permit the inclusion of a Jersey report at any other time of the day.

An additional coastal radio station, Anglesey, was brought into the scheme to improve the coverage over the Irish Sea. Very high frequency (VHF) broadcasts from coastal radio stations were introduced, made simultaneously with the radio-telephonic transmissions. A general synopsis was added to sea area forecasts, and the area covered by Niton Radio was extended to include Thames, Dover, Portland and Wight.

Special marine services provided by the London Weather Centre continued to expand. In addition to routine responsibilities for the Port of London Authority, the Centre provided forecasts for tanker-lightening operations, mostly in the English Channel, and for a wide range of marine activities in the coastal sea areas around the United Kingdom ranging from dredging to the construction of jetties and sewage outfalls.

The greatest demand for increased services at the London Weather Centre came, however, from the offshore industry and this was an area of intense activity during the year. The continued extension of offshore operations from the central North Sea into the even more inhospitable waters east and west of the Shetlands highlighted the importance of accurate and timely weather advice to the industry and emphasized the need for regular reliable observations on which to base this advice. It was quickly realized that the Office would have to adopt a more active and commercial role in its relations with the industry, not only in the promotion of its services, but also in its efforts to ensure that the

industry received the best possible meteorological advice. A much more effective liaison was established with the industry, through representative bodies such as the UK Offshore Operators Association (UKOOA) Oceanographic Committee, of which the Principal Meteorological Officer, London Weather Centre, is a member, and by direct personal contact with senior company officials. Plans were made to base a senior officer in Aberdeen to act as a consultant and to maintain a close liaison with company representatives in eastern Scotland.

Advice concerning the desirable meteorological observing network in the North Sea was provided to the UKOOA Oceanographic Committee, which subsequently identified five or six production platforms as potential environmental data stations. The Office also accepted the responsibility for quality control of all real-time data received from offshore installations and made provision for the routine inspection of these installations by meteorological staff who advise on the siting, operation and maintenance of meteorological equipment.

Specialized forecast services were provided for some 50 offshore installations by a team of five senior forecasters and supporting staff, particular attention being paid to wind and swell. Forecasts and warnings are tailored to meet the requirements of individual operators.

The Office co-operated with the Petroleum Industry Training Board in providing one-day courses for installation managers and their deputies in the use and application of weather forecasts to offshore operations. Training courses at the Meteorological Office College for company-appointed offshore observers were also planned.

Southampton Weather Centre prepared special forecasts for the Royal Ocean Racing Club for the Admiral's Cup races. At the request of the Department of Trade, this Centre also co-operated with Radio Solent in a trial involving the broadcast of warnings of winds of Force 6 and over for the benefit of yachtsmen in the Solent area. The number of enquiries for weather information in connection with yachting and other marine sports remained at a high level. The office at Plymouth provided special forecasts for several major sailing races and championship events including the Royal Ocean Racing Club One-Ton Cup races in Torbay in July.

A ship-routeing service is provided to advise on North Atlantic and North Pacific Ocean passages and to offer advice in regard to the movement of tows. The object of the service for cargo vessels is to select the best course for a ship to steer in order to reach its destination in the shortest time with the least damage to hull and cargo, and with the most economical fuel consumption. The vessel's response to various wave fields is determined by extracting sufficient data from the deck log-books and a ship/wave performance curve is constructed. Wind and sea-wave predictions at intervals of 12 hours for up to 72 hours ahead are supplied to the ship-routeing officers by forecasters of the Central Forecasting Office and this information is used in conjunction with the performance curve to determine the most favourable course for the vessel to follow. Subjective consideration is given also to the loading state of the ship, to surface currents, navigational hazards such as shoals, ice, and to areas of fog. Communication with the vessel is usually by telex before sailing and via predetermined coastal radio stations when the ship is on passage. The provision of routeing advice to tows which do not have too restrictive weather parameters is similar to that for conventional ships but allowance has to be made for the slower speed of the tow and for their reduced manoeuvrability. For tows with limiting weather factors,

which may be wave height or period, amount of heel or wind force, the routeing service advises when and where to seek shelter and when to resume the passage. About 200 conventional routeings were made during the year, and although the service for tows only began in the autumn, requests for this type of routeing service have been increasing considerably.

The Central Forecasting Office (CFO) supplies guidance forecasts and warnings to the forecaster on board the Trawler Support Ship stationed off the Icelandic coast during the winter months from late November until the end of April. The forecaster on the support ship maintains close liaison with the British fishing fleets in the area, issuing local forecasts and warnings of gales, storms and ice accretion.

The Main Meteorological Office at Pitreavie continued to provide a winter forecast service for the benefit of North Sea fishing vessels; forecasts are issued daily from October to March, covering a 72-hour period.

Oil slicks and pollution at sea are emergencies in which CFO plays its part in issuing forecasts and advice on request. Warnings of tropical hurricanes, cyclones and typhoons are issued to Lloyds. CFO works closely with the officers of the Storm Tide Warning Service who are responsible for issuing alerts on occasions when unusually high tides caused by strong winds are liable to cause flooding on the east coast of England.

Services for civil aviation

Meteorological services for civil aviation in the United Kingdom are provided by the Meteorological Office as agent of the Civil Aviation Authority. A detailed discussion of the organization which meets aviation needs is given as a Special Topic earlier in this report. Here, mention is made only of developments taking place during the year. With the increasing interest in North Sea Oil exploration there has been a large expansion in the number of forecasts for helicopters serving the oil rigs. Such operations are potentially hazardous and careful attention has to be paid to details of visibility, cloud height and low level wind. Forecasts have been provided from Heathrow for proving flights of Concorde on routes from London to Bahrain and London to Gander in anticipation of regular services commencing in early 1976.

In international civil aviation affairs the United Kingdom has continued to play a very active part. During January a member of the Office joined the United Kingdom delegation at a meeting of the International Civil Aviation Organization which discussed future plans for meteorological telecommunications for civil aviation in Europe, whilst in March the Office provided a specialist member for a World Meteorological Organization Working Group which considered ways of improving the flight documentation provided to aircrew.

Services for civil aviation (overseas)

Services for civil and general aviation continued to be provided from the offices at the Royal Air Force stations in Cyprus, Malta and Gibraltar in the Mediterranean, at Wildenrath and Gütersloh in Germany, and at Masirah and Salalah in Muscat and Oman.

In Cyprus, the airport at Nicosia has remained closed since July 1974 but civil aviation recommenced instead at Larnaca early in 1975 and traffic gradu-

ally increased during the year. Meteorological support was provided by the office at Episkopi until it closed and then by the office at Akrotiri.

Services for the Royal Air Force

There has been no major change in the organization for meeting the requirements of the Royal Air Force in the United Kingdom during the year, but there has been a decrease in the number of offices following the closure of some operational stations as a result of the Defence Review and other economy measures. Although most of the meteorological offices have multi-role functions, the forecasting services for the Royal Air Force at home continue to be provided by offices which are distributed largely in conformity with the RAF organization. The arrangements are described in detail in the Special Topic on Meteorological Services for Aviation on page 6.

Offices were opened temporarily for short periods at certain locations to provide a service during large-scale exercises and special operations. A forecaster was detached to Barksdale, Louisiana to provide meteorological support for the RAF detachment taking part in a special USAF exercise.

The RAF team which was formed to prepare programmed instruction training packages on meteorology for use at RAF schools has completed its task and this new system of instruction has been introduced at most schools although some meteorological officers still continue to give regular courses of instruction. The Meteorological Office provides technical advice concerning the installation of runway visual range systems at RAF airfields and subsequently calibrates each system every six months.

An amended version of AP 3400/Met O 790, *Meteorological Services for the Royal Air Force*, was printed and distributed.

As a consequence of the effects of the Defence Review on the Near East Air Force (NEAF), plans were made to curtail the meteorological organization in Cyprus and to withdraw completely from Gan in the Indian Ocean. The program is not due for completion until April 1976 but a substantial amount was achieved during 1975. The Chief Meteorological Officer was withdrawn from Headquarters NEAF and the Main Meteorological Office at Episkopi was closed. It was necessary as part of the reorganization to raise the status of the office at Akrotiri aerodrome to a main office but, even so, a considerable reduction in staff in Cyprus was effected. The meteorological teleprinter and facsimile broadcast (call-sign MKS), compiled by the Main Meteorological Office at Episkopi and originally designed to meet extensive United Kingdom needs in the Middle East, ceased on 30 June 1975. United Kingdom requirements continue to be met by the use of existing communication channels.

Subsidiary offices continued to operate on the Royal Air Force stations at Masirah and Salalah in Muscat and Oman. Nearer home the Main Meteorological Offices in Gibraltar and Malta added uneventful years to their long histories whilst in the Federal Republic of Germany the Main Meteorological Office which is located at the Joint (RAF/Army) Headquarters at Rheindahlen continued to support subsidiary offices at the four airfields of Royal Air Force Germany and at the Army Aviation Station, Detmold.

The provision of services to the Royal Air Force overseas involved the continued operation of upper-air stations in Gibraltar, Malta, Masirah, Cyprus and Gan, although the end of the year saw the closure of those in Cyprus and Gan.

Services for the Army and Establishments of the Procurement Executive, Ministry of Defence

The Army and MOD(PE) units continued to call for meteorological support in their planning, development and operational roles.

Forecasting services were provided for Army Aviation at Middle Wallop, Hampshire, and Netheravon on Salisbury Plain and at Detmold in Germany. The post of liaison officer to Headquarters No. 1 (BR) Corps at Bielefeld in Germany was combined with that of officer-in-charge of the Detmold office who visits Bielefeld as required.

Further advice was given on the development and testing of a mobile hydrogen generator for use with the Army Meteorological System (AMETS) which is entering service for measurement and processing of upper-air data for ballistic purposes.

Offices were maintained at the Royal School of Artillery, Larkhill, at the Royal Aircraft Establishment, Aberporth and at the Proof and Experimental Establishments at Shoeburyness, Eskmeals, and Larkhill. The office at Shoeburyness also caters for the meteorological requirements of the Atomic Weapons Research Establishment at Foulness.

Members of the staff of the Office were attached to the Army practice camps at Sennybridge and Otterburn to provide meteorological information for ballistic purposes during exercises on several occasions throughout the year.

Liaison with the Navy Department

The need for the co-ordination of plans to meet the meteorological requirements of defence forces at home and overseas has continued to require close co-operation with the Directorate of Naval Oceanography and Meteorology.

International defence services

The co-ordination of the international meteorological support required by the military forces, and of the study of any associated problems, is undertaken by the various meteorological planning committees of the international defence organizations NATO and CENTO to which the United Kingdom belongs. The Meteorological Office has participated actively in the work of both the meteorological committees during the past year.

Services to the Home Office

The meteorological requirements of the Warning and Monitoring Branch of the Home Office have been kept under review in close working association with that Branch. Detailed plans for meeting these requirements as effectively as possible in an emergency continue to be maintained and tested in regular exercises. Lectures are occasionally given to groups of Home Office Sector Scientists, Chief Warning Officers and members of the Royal Observer Corps who are equipped and trained to make simple meteorological observations in times of emergency.

Services for nuclear establishments

Arrangements for certain Main Meteorological Offices to provide information to nuclear establishments of the United Kingdom Atomic Energy Authority and the Electricity Generating Boards in the event of accidental release of radioactive or toxic material have been reviewed. A computer program for the rapid provision of forecast wind trajectories is being developed.

CLIMATOLOGICAL SERVICES

The collection of climatological observations from all parts of the United Kingdom is the primary task of the Branch. The network of about 650 observing stations which submit climatological returns (see Table IV on page 57) includes over 500 sites which are maintained by voluntary observers and co-operating authorities whom the Office again thanks for excellent work. Without this help, scientific studies in climatology would be severely restricted and services on the scale described below could not be provided. However, it is becoming increasingly difficult to attract people able and willing to make observations every day including weekends, and special attention has been given to this problem during the year. On behalf of the Working Group on United Kingdom Observational Networks, the Branch has made a detailed study of the difficulties which have been experienced and it is hoped that this will lead to more effective measures of support for the network. Digital anemograph logging equipment (DALE) developed by the Operational Instrumentation Branch has now been tested successfully at three Meteorological Office outstations, and it is intended gradually to introduce this equipment into service over the next few years; the use of DALE will eliminate the laborious hand analysis and tabulations of wind records. Plans have also been made for the development of automatic climatological recording equipment (ACRE), which will be especially valuable in areas such as Scotland where network problems are most acute.

As the first stage in the preparation of permanent archives, climatological returns received from the stations in manuscript are transferred to magnetic tape by processer-controlled keying (PCK). Computer methods are then used both to carry out quality control of the data and to produce film from which most of the *Monthly Weather Report* and some other climatological publications can be printed without the need for manual typesetting and subsequent proof-reading. The computer programs for quality control include many checks for internal and time consistency; during the year a measure of areal control has also been introduced by including comparisons with neighbouring stations. A detailed investigation has been carried out in conjunction with the Data Processing Branch to determine whether second (verification) keying is still necessary; although it is clear that this time-consuming and repetitive task cannot be abandoned without unacceptable loss of quality, the study has brought to light several areas where procedural and programming alteration will make the work in the PCK unit devoted to keying climatological data more productive. Studies undertaken jointly with the Systems Development Branch to consider land-line transfer of data between Bracknell and the offices at Edinburgh and Belfast have shown that the quality control of data from Scotland and Northern Ireland could be speeded up in this way, but the expense of installing and operating remote computer terminals would be considerable, and an alternative less costly method of improved data transfer is now being investigated.

The Branch makes direct use of the national climatological archives when providing advice for those who need it. The existence of these records in machineable form (the data bank) has meant that, with the aid of the powerful computing facilities at Bracknell, it is now possible to carry out more detailed investigations for customers; several special programs have been written for this purpose during the year to produce results that could not economically have been obtained by hand analysis methods. However, the specification of climate at a point has

always been a challenge, no matter how close is the network of observations; each site has its own characteristics of soil, aspect, height and so on, and assessment of the effects of these calls for considerable professional judgement. In August a small research group was established within the Branch to study some fundamental aspects of land climatology, and the spatial variability of meteorological elements has been selected as one of the first topics for investigation. Projects of this nature are essentially long-term in character, but the results as they emerge will be of immediate help when providing advice for customers.

The number of climatological enquiries handled at Bracknell, Edinburgh and Belfast increased by nearly 20 per cent over 1974 (see Table XIII on page 62). As in previous years these enquiries covered a very wide range of interests. A substantial number of requests concerned legal and insurance matters, many of these calling for the provision of Certified Statements for civil proceedings or Witness Statements in criminal cases; attendance at Court was sometimes necessary. However, by far the largest proportion of enquiries came from engineers, architects and contractors associated with the building and construction industries. There is a continuing demand for information about extreme wind speeds for the calculation of wind loadings on buildings, bridges and towers, and about temperatures and humidities for the design and operation of heating, ventilating and air-conditioning installations.

The simultaneous occurrence of strong winds and heavy rain is an important factor when considering the installation of heat insulating materials in cavity walls. During the year, a keen interest in this matter was shown by Local Authorities from whom many requests for advice were received. The section for Building Climatology, funded by the Department of the Environment, has also been concerned in 1975 with problems caused by driving rain. A computer model has been devised to estimate the variation in water content of a typical brick wall, taking into account both wind driven rain and evaporation between rain periods. The section has also undertaken studies aimed at achieving a better understanding of the frequency distribution of wind speeds at particular sites, and of speed variations between sites in towns and open country which result from differences of surface roughness and topography.

The study of meteorological conditions along the likely alternative routes for a new Manchester-Sheffield motorway has continued. A two-year period of special observations along the routes was completed in July, and a major report was later submitted to the consulting engineers in charge of the feasibility study. The land climatologist also carried out two major projects using the climatological data bank. The Central Electricity Generating Board requested detailed and long-period climatological statistics against which current weather could be compared as part of their daily estimation of power demand; a special computer program was written to produce the necessary analyses of temperature, wind, cloud and rainfall on a weekly basis over 25 years. The Electrical Research Association, acting for the Department of Energy, commissioned some special computer analyses of wind data to help them assess the potential of wind in the United Kingdom for generating electricity.

Of the enquiries dealt with, by no means all concerned United Kingdom weather; well over 1000 requests referred to the climate in other countries. Most of these came from civil, structural and ventilating engineers who were provided with information and advice in connection with matters as diverse as wind loadings on buildings, radio and television masts in Nigeria, Libya, Iran, Iraq,

Saudi Arabia and the Gulf States, the design of cooling towers in Italy and Turkey, flooding in Romania, and the weathering of cement and window frames in Malaysia and Togo. Requests for assistance also came from research workers in other countries; for example, pressure data for St Helena and Ascension Island were supplied to two American universities in connection with research into the breeding habits of tuna fish.

The land climatologist is a member of several British Standards Institution committees concerned with the establishment of design standards for various structures. During the year he also gave advice to the Ministry of Defence concerning world-wide climatic standards for equipment. The Branch also provided members for two Working Groups of the World Meteorological Organization (WMO), one dealing with the Guide to Climatological Practices, and the other concerned with the Issue of Climatological Data to Users.

Climatological services for Scotland are provided by an office in Edinburgh. During May, this was moved from Palmerston Place to Corstorphine Road, where a new building is shared with the Forestry Commission. Services have been maintained despite the inevitable upheaval of the move and some very difficult working conditions in the new building over a period of months whilst the air-conditioning and forced-ventilation system was being adjusted. The number of enquiries has continued at a high level, though not quite reaching the peak of 1974 when the continuing and exceptional spell of three years' dry weather in eastern Scotland caused particular concern. Many requests for information were received from oil-related industries. The changes in local government organization in Scotland which took effect in May led to a number of problems with the climatological network, and meetings were held with all the new Regional Authorities. The Superintendent continued to serve on a working party on storm sewerage in Scotland; this is due to report early in 1976.

An office in Belfast provides climatological services for Northern Ireland. Despite the continuing unrest, the Senior Meteorological Officer and his staff have again met all commitments. Such sustained effort in these circumstances deserves high commendation, and it is gratifying to record that a letter of appreciation of services rendered has been received from the Department of the Environment for Northern Ireland with whom co-operation is very much a two-way process. The Water Data Unit of the Department has undertaken to process all rainfall-recorder charts from Northern Ireland, using a hand-operated trace-follower which automatically digitizes the trace for analysis by computer; this scheme is now operational, and a start has been made with the backlog of charts awaiting analysis.

The Marine Climatology section has also had a busy year. Work continued on checking ocean current data, and all observations made by United Kingdom ships since 1927 are now on magnetic tape; programs to convert the data into archival form, to sort them and to apply further quality control remain to be written. During the autumn, the Office agreed in principle to take part in a proposed WMO scheme for the international exchange of ocean current data, and offered to act as an international collecting centre for such data from the eastern North Atlantic.

Climatological work on sea-ice has for many years been a responsibility of the Branch. In June, this commitment was broadened to include all aspects of sea-ice work in the Office, including that previously carried out by the Central Forecasting Branch. The new sea-ice section operates seven days a week, and is

located in the Central Forecasting Office. Daily sea-ice charts are issued on facsimile broadcast for mariners, advice on the ice situation is given to the ship routing service and to the Synoptic Climatology Branch, climatological sea-ice charts are published at the end of every month, and articles are prepared for each issue of the *Marine Observer*. In all this work considerable use is now made of satellite pictures on which different types of sea-ice may be identified.

The ocean current and, where applicable, sea-ice sections of six volumes of the Admiralty *Pilot* were revised during the year. The unusually large and steep waves that sometimes occur off south-east Africa were the subject of an article published in 1974 in the *Marine Observer* and written by a member of the Branch. This article aroused particular interest in shipping circles, and was reprinted in *Safety at Sea International*. Following an approach by the International Chamber of Shipping, the WMO has asked all Member States to co-operate by passing any reports of 'freak' waves to a world collecting centre; the Office has agreed to act in this capacity, and will analyse the observations and publish reports in due course. The production of *Marine climatological summaries for the Atlantic Ocean east of 50°W and north of 20°N*, an annual publication, has again been held up. Rewriting the necessary computer programs is unlikely to be completed in 1976.

The number of enquiries concerning marine climatology, ocean currents and sea-ice received during the year was more than double that in 1974 and in answering these considerable use was made of the marine data on magnetic tapes purchased in 1974 from the United States. Once again a large proportion of the requests for information and advice arose from the search for and production of oil and gas in offshore areas, mostly around the United Kingdom but in other parts of the world as well. Advice was given for example about the ocean currents off Greenland to help with assessment of the drift of icebergs in the vicinity of an oil drilling rig, and maximum wind speeds in each month of the year over the southern North Sea were estimated in connection with possible restrictions on the certification of certain of the older gas production platforms in the area. Requests for marine climatological information were also received from many other interests, for example wind data were supplied in connection with the loss of a ship in mistral conditions in the Golfe du Lion, and pressure data for the Atlantic were provided to help with assessment of sea-level changes.

The marine climatologist continued to be considerably involved in matters concerning the offshore industry. He attended six meetings of the Offshore Installations Technical Advisory Committee of the Department of Energy to which he submitted amendments to the meteorological section of the official *Guidance on the design and construction of offshore installations*; these became necessary partly as a result of the work of a sub-group of the European States Working Group on Environmental Matters affecting Offshore Installations, and partly following new work carried out in the Branch using additional information that had recently become available. Advice was also provided concerning the environment section of a draft *Code of practice on fixed offshore structures* being prepared by the British Standards Institution. In addition to preparing papers and giving the talk listed in the Appendices, the marine climatologist continued as a member of the WMO Working Group on Marine Climatology which met in Geneva in January; during this session he also attended a meeting of experts on the Historical Sea Surface Temperature Data project of WMO. In May he represented the WMO at a meeting in Rome of the Inter-Governmental Oceano-

graphic Commission's Working Committee on International Oceanographic Data Exchange.

HYDROMETEOROLOGY

The routine collection and processing of rainfall observations from about 6800 stations and evaporation data from some 60 stations in the United Kingdom has continued. Bracknell has an overall responsibility for this work but the observations in Scotland and Northern Ireland are handled in the first instance by the Edinburgh office and the Belfast office respectively. With the establishment of the Regional Water Authorities (RWAs) in England and Wales, set up by the Water Act 1973, the methods of collection of rainfall observations are changing in some areas. Three RWAs now pass digitized rainfall information to Bracknell by means of a DATEL 200 communication link and another RWA is expected soon to send data on paper tape through the post.

The computer-based operational procedures for the quality control of all rainfall observations for some 6800 stations, the bulk of which observe daily values, have been developed further. The new computer programs not only indicate doubtful values but also make automatic corrections in many cases and print out other observations for subjective scrutiny and manual correction. In all cases the original data are preserved. A special computer program used with a visual display unit (VDU) enables amendments to be written to the rainfall dataset by staff on quality-control work. For the computer stage of the quality-control procedures all observations of daily rainfall for a month for the whole of the United Kingdom can be handled objectively in about 30 minutes. The rainfall observations for a month for a typical Regional Water Authority in England and Wales can be dealt with in 2 or 3 minutes.

Work is well in hand in the preparation of maps of Annual Average Rainfall for the period 1941–70. Rainfall observations are prepared for publication in the *Monthly Weather Report* and in *British Rainfall*. During the year *British Rainfall* for 1968 was published by Her Majesty's Stationery Office, but progress in bringing the *British Rainfall* publications up to date has been regrettably delayed by a dispute in the printing industry.

In view of the requirement for statistical information on short-duration rainfall, work continues on two methods for obtaining such information in digital form for use in computers. The precision encoding and pattern recognition (PEPR) equipment at the Nuclear Physics Laboratory at Oxford University is being used to transfer to digital form on magnetic tape detailed information from a selection of daily autographic rainfall charts recorded over many years: more than 100 000 charts were digitized during 1975. Magnetic-tape event recorders (MTER) are also being employed to provide detailed rainfall information. Rain-gauges with MTER attached can be left unattended in remote areas for two or three months, unlike conventional rain recorders. After some teething troubles, the data retrieval rate from MTER instruments is now over 90 per cent.

Hydrometeorological enquiries covering a wide field were received from the legal profession, universities, a number of commercial concerns, water organizations, consulting engineers, private individuals, and others. The marked increase in enquiries noted in the autumn of 1974 was sustained throughout 1975; the total for the year was 77 per cent greater than for 1974. Enquiries from the

Building Industry increased threefold in 1975 compared with 1974 and mainly concerned claims for time lost through wet weather and rainfall information for use in costing contracts. Following the publication of the work of the Flood Studies Team in March 1975, enquiries concerning storm drainage have continued at a steady rate. The Office has suites of computer programs which enable tabulations to be made of rainfall amounts or intensities in specified durations (1 minute to 25 days) which will be equalled or exceeded for a wide range of 'return' periods, e.g. from as often as twice a year to as seldom as once in 1000 years. There has been an increasing demand for storm profiles which, for any drainage- or catchment-area and return period, give intensities of rainfall at specified durations either side of the peak intensity. Tabulations can be provided at very short notice for any point or area within the United Kingdom. Legal enquiries were mainly concerned with litigation in the Courts and with claims for water damage received by Assurance Firms and Loss Adjusters. There was a marked increase in enquiries in the education category arising from a course in Environmental Control and Public Health instituted by the Open University.

The installation of a visual display unit (VDU) has been of great benefit to the enquiry bureau in dealing with telephone enquiries and has speeded up the answering of written enquiries. Rainfall information for recent years can be displayed for any station simply by entering a few details at the keyboard of the VDU and, if necessary, tabulations can be printed. Observations for the nearest rainfall station to any given National Grid Reference can be readily obtained.

Requests were received from the Central Water Planning Unit for estimates of areal daily rainfall for a large number of catchments for varying periods, including back to 1850 in the case of the Thames at Teddington. Information was supplied for two proposed Water Data Unit publications; *Surface Water United Kingdom 1971-73* and *Water Statistics 1974*. For the first publication, estimates of rainfall, potential and actual evaporation were prepared for 10 areas. For *Water Statistics 1974*, maps of rainfall and potential evaporation 1974 and a map of residual rainfall (rainfall percolating to permanent ground water) were provided for the United Kingdom, along with other material. A map of average annual rainfall for 1941-70 was constructed for the Llyn Padarn (Snowdonia) catchment area in connection with the Dinorwic Pumped Storage Scheme. The enquirer stipulated that all historic rainfall data in the area should be used and that rainfall should be related to altitude and topography. For an area, on the Severn at Bewdley, estimates of areal potential evaporation were required back to 1900. The Anglian Water Authority asked for maps of average annual rainfall and potential evaporation, estimates of average monthly and annual rainfall and evaporation for various areas of the Authority and estimates of monthly actual evaporation, residual rainfall and end-of-month soil moisture deficit for both the whole area and sub-sections of the area. Rainfall intensities for storm durations ranging from 5 to 120 minutes and return periods of once a year to once in 10 years were supplied for Yefren in the Libyan Arab Republic.

Bulletins of *Estimated Soil Moisture Deficit and Potential Evapotranspiration over Great Britain* were issued at frequent intervals. The number of subscribers was maintained despite a substantial increase in price.

The outcome of several years' joint work by the Meteorological Office and the Institute of Hydrology was the publication by the Natural Environment Research Council of the 5-volume *Flood Studies Report*. This *Report* was discussed

at a two-day conference at the Institution of Civil Engineers in London in May 1975. Since the completion of the meteorological contribution (Vol. 2 plus maps in Vol. 5) to the *Flood Studies Report* further computer programs have been written so that nearly all rainfall calculations described in the *Report* can be efficiently and quickly carried out and statistical advice readily provided to engineers, hydrologists and others by the section handling hydrometeorological enquiries.

As highlighted by the *Flood Studies Report*, knowledge or information is still unsatisfactory in some areas and investigations are proceeding into, for example, storm profiles, areal rainfall and return periods of short-duration rainfall. The storm profile work involves investigating sequences of storm events using detailed rainfall information in digital form (PEPR data). More common rainfall events, e.g. events occurring on average 5 to 10 times a year, are also being analysed using digital rainfall data. Design rainfalls for an area are derived from point rainfall statistics using an 'areal reduction factor'; the seasonal and geographical variations of areal reduction factors with different rainfall types are also being investigated. A pilot study, instigated by the National Water Council's Working Party on the Hydraulic Design of Storm Sewers, has started with the aim of determining whether there are preferred directions of movement of rainstorms and if so whether these can be taken into consideration in formulating models for the design of urban and rural drainage systems.

Occasionally the melting of lying snow contributes significantly to floods and for this reason an objective procedure has been developed to estimate the maximum value of the water-equivalent of lying snow for any location in the United Kingdom and for any return period. Use was made of measurements of snow water-equivalent made during the past 10 years. Maps of the persistence of lying snow, the depths of lying snow and the duration of moderate to heavy snowfall over the United Kingdom have been prepared.

Work has continued on a project to assess rainfall deficiency in terms of deficit-duration-frequency and to provide an operational system for monitoring accumulated rainfall over periods from a month to 3 years. To support this project and to meet requirements for very long sequences of data, methods of testing the quality of 18th and 19th century rainfall observations have been studied.

Basic computer programs have been written to assist the soil moisture deficit advisory service. Observational and computed information are obtained on an operational time scale via computer output on microfilm (COM). Comparisons between results obtained from the current operational soil moisture deficit system and the new version under development have been started. Relationships between evaporimeter data and Penman evaporation estimates have led to the development, on an experimental basis, of quality-control procedures for evaporation observations.

The Dee Weather Radar Project, involving co-operation between the Meteorological Office, the Water Research Centre, the Central Water Planning Unit, the Water Data Unit, the Dee and Clwyd River Division of the Welsh National Water Development Authority and Plessey Radar Ltd, continued throughout the year, but there was an appreciable reduction of the Meteorological Office staff effort later in the year. At the beginning of 1975 a real-time processing system came into operation using a PDP 11/40 computer at the Radar Research Station at Llandegla in North Wales. Considerable time was spent in

implementing programs developed for the Meteorological Office by a team at the Royal Radar Establishment to enable radar-derived rainfall to be measured, processed by PDP computer at Llandegla, recorded on magnetic tape and also transmitted in real time from Llandegla to the River Control Centre at Bala and experimentally to the Central Forecasting Office at Bracknell. At the centres remote from the radar site the radar-derived rainfall information has been displayed on a colour television screen and an electronic store at the receiving centres holds data for up to 9 radar-derived rainfall pictures so that they may be reconstituted individually or re-played as a time-lapse sequence. It has been confirmed that the radar measurements of rain falling on subcatchments (of about 100 km²) in the real-time mode differ on average from rain-gauge estimates by about the same amount (i.e. 15–20 per cent) as was found in the earlier off-line experiments using a different processing method.

In the latter part of the year the radar-derived rainfall data were also transmitted to the River Control Centre at Bala in digital form for direct input to a hydrological river-flow model developed for the Water Research Centre by a team at the Institute of Hydrology, assisted by Plessey Radar Ltd. Assessment of the usefulness of the radar-derived rainfall in improving predicted hydrographs at various positions within the Dee river system will be undertaken by hydrologists in consultation with the Meteorological Office. As an aid to the hydrological forecast studies, the Main Meteorological Office at Preston supplied forecasts of rainfall for input to the model.

Investigations were started at Bracknell into the use of quantitative radar observations in forecasting rainfall over small areas (of about 100 km²), and a numerical model employing a grid length of 1 km was developed for estimating rainfall taking account of the orography over North Wales. The model over-estimates rainfall amounts because it calculates the maximum amount of precipitation from a given set of input information, but it may be possible to refine the method to give more realistic results.

A Principal Scientific Officer continued to be attached to the Institute of Hydrology as leader of a team of eight engaged on hydrological, biological and evaporational studies over Thetford Forest. The routine collection of climatic data and rainfall, throughfall and stemflow measurements has been continued to aid in the development of a model for rainfall interception by the forest. More complex versions of the wet- and dry-bulb thermometer interchange system, previously tested in 1974, were set up at two sites at 1 and 4 km from the south-west edge of the forest. During May and June measurements were made at both sites using computer-controlled data-acquisition systems. The aim was to measure the changes in evaporation across the forest from the south-west leading edge, but unfortunately the wind blew from the north-east for most of the time. Usable data did suggest that differences in evaporation are less than 10 per cent.

During August and September micrometeorological data were collected at the main experimental site at Thetford in collaboration with a group from the Atomic Energy Research Establishment, Harwell measuring sulphur dioxide fluxes and a group from Edinburgh University measuring carbon dioxide fluxes. During this period a dew-point hygrometer system for measuring humidity profiles was also successfully tested and this system, together with the carbon dioxide instrumentation, will be used again in 1976.

The Office continued its co-operation in the field of international and national hydrology through the World Meteorological Organization, Unesco, the UK Interdepartmental Committee for International Hydrology and the NERC working party on Hydrology and Hydrogeology in the United Kingdom.

SERVICES FOR AGRICULTURE

Services for agriculture have continued their steady development although the number of staff at headquarters and the four regional offices at Bristol, Cambridge, Edinburgh and Harrogate has remained constant. Following a period of relative stability, several changes of staff have occurred during the last few years including the appointment in 1975 of recently promoted officers to take charge of the agricultural meteorology sections at Edinburgh and Cambridge. Inevitably this has meant a loss of expertise derived from many years of involvement in the subject, but a number of new ideas and methods of analysis are being investigated; these seem likely to lead to further advances in the science of agricultural meteorology.

The effort of staff at headquarters was mainly devoted to advancing the science, but at the same time certain routine services have been maintained and developed and work at the outstations has been supported by the extraction and computer processing of data for their use. As well as maintaining their advisory roles with other disciplines within the Agricultural Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food (MAFF) and the Scottish Agricultural Colleges, staff at the regional offices have continued their own lines of investigation. These are usually closely related to the problems on which they are asked to give meteorological advice.

Co-operative work and discussions have continued with many of the Agricultural Research Council (ARC) Institutes: Central Veterinary Laboratory, Plant Pathology Laboratory, Experimental Husbandry Farms and Experimental Horticultural Stations. Two members of the headquarters staff are associated with the Joint ADAS/ARC Committee on Grassland Manuring. The Bristol office is closely involved in a project in the western Midlands organized by the Permanent Pasture Group at the Grassland Research Institute. A research worker from the Grassland Research Institute has spent several months at headquarters studying the relationship between grass growth and soil and weather conditions, familiarizing himself with the availability of relevant meteorological data and methods of handling it on cosmos, the Meteorological Office computer system.

Following completion in 1974 of the delineation of agroclimatologically homogeneous areas, these areas were used in the *Weekly Weather Notes* for the eight MAFF regions from the beginning of the year. An approach has been made to the Council of Scottish Agricultural Colleges concerning the delineation of agroclimatic areas in Scotland.

The supply of agrometeorological data, including barley-mildew indices, to the regional offices commenced in April. Daily meteorological data are now extracted by cosmos from the synoptic-data bank and transmitted to ADAS offices. Fundamental changes have been made in the procedure regarding the supply of potato blight information. Following work at headquarters high-risk periods are now based on criteria which have been shown to give more satisfactory results than the previous 'Beaumont Periods'. The new system requires

information regarding hourly humidity values in coded form to be transmitted daily by observing stations to Bracknell through the normal teleprinter network. Work is in progress to process data from the synoptic data bank to give an indication of periods of apple-scab infection.

Several outbreaks of swine vesicular disease (which has clinical symptoms similar to those of foot-and-mouth disease) have occurred and staff have frequently been on 'stand-by' for possible deployment to an epidemiological control centre in the event of confirmation of foot-and-mouth disease.

A wide variety of investigations into relations between climate and agriculture and horticulture have been carried out by staff. Examples are: investigations into septoria of wheat, eye-spot disease in winter wheat, and available work-days for various sites in the western Midlands. Because of the high cost of importing cereals and protein for animal feedstuffs there have been requests for information on climatically suitable areas for the growth of maize, oil-seed rape and legumes.

A frost survey at Luddington revealed the difficulties of comparing readings taken at the survey site with corresponding ones at a reference station; an improved accuracy in comparison was achieved using the mean of the differences of minimum temperature between the two stations on radiation nights only.

Studies in plant protection included analyses of gale damage to plastic structures in the Vale of York and of heat losses from plastic and conventional greenhouses in Devon. Trials at Cambridge assessed the effect of shelter upon the growth of French beans.

Work has continued on the search for relationships between certain animal diseases and weather factors. Progress has recently been made in producing an objective method, based on surface wetness, of predicting the emergence dates of the nematode larvae which cause parasitic gastro-enteritis. An investigation is in progress into the systematically poor performance of calves placed in particular pens in a calf house near Harrogate. Measurements have been made of air-renewal rates in beef housing, and some investigations into weather influences on insect populations have been undertaken.

A number of papers were published and over 75 internal memoranda issued. Two bulletins by Mr L. P. Smith on 'Drainage and Climate' and 'The Agricultural Climate of England and Wales' were sent to MAFF for publication. Miss M. G. Roy attended the Seventh International Biometeorological Congress at the University of Maryland and presented a paper on the climatic limitations of intensively managed grassland in the UK and another (prepared jointly with Mr L. P. Smith) on the hay-fever season in London.

OBSERVATIONAL REQUIREMENTS AND PRACTICES

The Branch, of which the Marine Division under the Marine Superintendent is a part, has overall responsibility for arranging that regular meteorological observations of suitable quality are made on land, at sea and in the upper atmosphere in sufficient numbers and with an appropriate distribution in time and space to meet national and international requirements. It specifies how meteorological sensors and observing systems shall be exposed and details the observing techniques to be employed. It arranges for observing stations to be inspected regularly to ensure that approved standards of site, instrumentation and observational procedures are maintained. The Branch establishes, on

behalf of the forecasting, climatological and hydrometeorological branches, requirements for new or improved sensors, observational systems or practices and organizes field trials to determine suitability for operational work, optimum procedures for their routine use and the effect of their introduction on the accuracy and comparability of the basic observational data. It works closely with the Operational Instrumentation Branch on the specification of new sensors or observational systems and on the design of trials to establish the performance of prototypes.

The Branch provides the Chairman and Secretary of an internal working group concerned with reviewing the UK Observational Networks. In the international field the Assistant Director (Observational Practices) serves on the WMO Working Group on the Global Observing System (GOS), whilst senior branch members serve on working groups concerned with radiation measurements and with the requirements, accuracy and quality assurance of observational data.

Observatories

The Observatories at Kew and Lerwick and the Meteorological Office section at Eskdalemuir are important stations in the observing network, providing data of the highest quality.

Kew has continued its studies of the gravimetric rain-gauge and is still engaged in a long-term comparison between the historic recording instruments of various kinds and equivalent modern equipment. The Kew record is of great value in climatological studies and it is important to ensure its homogeneity despite changes in instrumentation. An extensive program of internal renovation of the historic building is in progress.

A very full program of work has continued at Lerwick which includes observations of ozone, noctilucent clouds and aurora, and certain chemical constituents of the air and of rain. There is also a program of solar-radiation observations and upper-air soundings. Preparations were made for the entry of Lerwick into the thunderstorm-location network and this entailed a lengthy program of site calibration.

Trials of new or modified instruments or observing techniques continue to be an important part of the work of the Observatories and provide information on performance under optimum conditions of care and maintenance which allow realistic estimates to be made of the accuracy and fraction of recoverable data to be expected in operational use. During the year there have been tests of new types of thermometer screen and of new and modified rain-gauges. Work has continued on the measurement of wind speed in thermometer screens as part of a study of the accuracy of unventilated psychrometers.

The Observatories continue to attract visitors, some out of general scientific curiosity but often with very specific interests. Lerwick has also provided training in a variety of geophysical skills for the staff of the British Antarctic Survey and for members of various foreign meteorological services.

Surface observations

Several different kinds of surface observations are made to meet particular requirements. For weather analysis and forecasting purposes a network is maintained consisting of observing stations making weather reports at fixed times agreed internationally; these reports from such stations are known as 'synoptic'

reports. It is essential that such reports should be received without delay for use in weather analysis and forecasting. The United Kingdom synoptic reporting network consists of 264 of these stations, of which 77 make hourly reports, and 47 make 3-hourly reports, throughout the 24 hours of every day of the year. The remaining 140 stations report less frequently, some closing at night or at weekends. Meteorological Office staff man 88 synoptic reporting stations, most of which are located at civil and military airfields. The remaining 176 stations are manned by staff of various other authorities and organizations, such as coastguards and lighthouse keepers, or by private individuals; these stations are known as auxiliary reporting stations. Special courses for training auxiliary observers in the making and reporting of weather observations are held at the Meteorological Office College. If it is not possible for an auxiliary observer to attend one of these courses arrangements are made for instruction to be given at a nearby meteorological office, or for a member of the staff of that office to visit the auxiliary reporting station to give instruction on the spot.

There is also a requirement for records of meteorological variables to be maintained over long periods at sites representative of the various types of terrain and urban environment. These 'climatological data' provide information for the long-term averages, extreme values and frequency distribution of meteorological variables and are used in a variety of planning activities notably in agriculture, town planning and industry. It is, of course, important that the exposure of climatological stations should remain substantially unchanged for long periods and this is becoming increasingly difficult to ensure.

Many stations making synoptic reports submit climatological returns as well, usually for several observing hours each day. In the case of a number of key climatological stations manned by Meteorological Office staff these returns cover the whole 24-hour period. About 500 other stations make climatological returns only, usually of data read at 09 GMT though some make returns for additional hours. Most climatological stations are operated by local authorities or similar organizations but a number are still operated by private individuals on a voluntary basis at their own expense. Courses for climatological observers are held at the Meteorological Office College.

In the particular case of rainfall a more extensive network is required to provide the data needed to determine the distribution. This information is of great value for water use, control and planning. Data are received from about 6800 stations most of which measure rainfall only, though a few also measure evaporation. The majority of rainfall stations are maintained by co-operating authorities, usually Regional Water Authorities; the remainder are operated by a variety of other authorities and by private individuals. Though the Meteorological Office operates a relatively small proportion of the total number of rain-gauges it gathers data from all those meeting suitable standards of exposure and equipment and carries out an inspection program to ensure that suitable standards are maintained. In recent years the rate of inspection has fallen well below that considered necessary and attempts are being made to improve matters.

In order to assist the forecasting of weather conditions along major roads a network of 79 stations has been set up providing plain-language reports (PLAINOB). Of these, 51 are at road maintenance depots alongside motorways, 14 are at Automobile Association and Royal Automobile Club offices and 14 are at Fire Stations. Reports are made at approximately three-hourly

intervals during the day throughout the year and are also made during the night in the winter months. A program of inspection of these 'PLAINOB' stations was begun during the year.

Radiation observations

There is a long history of solar and terrestrial surface radiation measurement in the Office, notably at Kew Observatory, but it was not until the 1950s that systematic observations were undertaken at a number of stations. The Meteorological Office network now comprises eight stations in the United Kingdom and four overseas. In addition, measurements were made until June from the Ocean Weather Stations 'I' (59°N 19°W) and 'J' (52½°N 20°W) and since July from the North Atlantic Ocean Station 'L' (57°N 20°W). Global and diffuse solar radiation on a horizontal surface are recorded continuously at eight of these stations and daylight illumination at six. At two stations the intensity of the direct solar beam is also recorded and at one the radiation incident on vertical surfaces having various orientations. At five stations the net flux of solar and terrestrial surface radiation is also measured.

There are also 19 co-operating stations, operated mainly by organizations having an agricultural or hydrological interest, and these provide data, mainly in the form of daily totals, for which the Meteorological Office operates quality-control procedures.

Radiation data from Meteorological Office and co-operating stations are stored on magnetic tape and computer programs have been written for the processing and printing of these data for a variety of purposes. There is an increasing demand for solar-radiation data and the number of enquiries has increased threefold during 1975.

The body of data of assured quality now accumulated is of sufficient length—20 years in some cases—to support both fundamental and applied studies. In some cases these are being undertaken in the universities, but a start has also been made in the Observational Requirements and Practices Branch with the limited staff resources available.

Reliable radiation measurements of suitable accuracy can only be achieved by painstaking daily attention to instruments, by frequent calibration of recording circuits and by frequent comparison of sensors with travelling standards. The travelling standards themselves require regular comparison with the national standard which is embodied in a family of Ångström pyrhelio-meters. The national standard is compared with others in a series of international comparisons which take place every five years. One such intercomparison took place during 1975 at Davos in Switzerland when the UK instrument was found to have retained its calibration to within experimental accuracy.

Runway visual range

At many airfields, both civil and military, observers assess the 'runway visual range' in conditions of poor visibility with the aid of lights at known distances. Although these observations do not form part of the set of data required by meteorologists the Office provides a service of inspection and calibration of the installations for the Civil Aviation Authority and the Royal Air Force. Visits are made twice yearly to 36 civil airports in the UK and to 37 RAF stations at home and abroad.

At a few major airports automatic systems are installed for the estimation of runway visual range but these are not inspected by the Meteorological Office.

Upper-air observations

The normal program of upper-air observations comprises pressure, temperature and humidity soundings by radiosonde at 00 and 12 hours and upper-wind measurement by radar at 00, 06, 12 and 18 hours. At the beginning of the year the network consisted of eight stations in the United Kingdom, two fixed Ocean Weather Stations and five stations overseas. During the year, however, the program was curtailed at various times at the stations in Northern Ireland and Cyprus because of the disturbed conditions there. In June, at the expiry of the International Civil Aviation Organization North Atlantic Ocean Station (NAOS) Agreement, the manning by the United Kingdom of the stations at 59°N 19°W ('I') and 52½°N 20°W ('J') ended. A new Ocean Station ('L') at 57°N 20°W commenced operation in July as part of the World Meteorological Organization's NAOS agreement which had just been drafted (see Marine Division on page 32).

Close liaison continued with the International and Planning Branch in the establishment of stations overseas as part of the UK support for the World Weather Watch program. The latest of these stations is at Mahé in the Seychelles and staff have been trained and are in position and making final preparations for the start of the program.

The performance of high-altitude balloons continued to be satisfactory and their use increased significantly. The performance of the standard neoprene balloon was unchanged but that of the standard natural rubber balloon improved substantially during the second half of the year. Natural rubber balloons are used in nearly all the 06 and 18 hour soundings but the improved performance is not fully reflected in Table V because of the frequent termination of soundings at Long Kesh before balloon-burst as a result of the unsettled situation there.

Thunderstorm location and surveillance

A full program of observations was maintained throughout the year by means of a network of cathode-ray direction-finding (CRDF) stations comprising Shanwell, Long Kesh, Camborne, Hemsby, Gibraltar, Malta, and Cyprus. The area under surveillance extends from 5°N to 70°N and from 40°W to 50°E. In the latter half of the year an enforced reduction in the data from Cyprus probably degraded the performance in the eastern part of the area.

At the end of the year a new CRDF station at Lerwick replaced the station at Long Kesh. This extension to the north is expected to increase the accuracy of reports in the north-west and north-east quadrants of the area. In addition it is believed that low-energy storms to the north of the British Isles, which might otherwise be missed, will be detected.

As part of a wide-ranging study of the Sferic system a comparison was made of the number of storm zones reported by the meteorological visual observing stations ('synoptic network'). Figure 1 shows, for the period May–August 1975 at 09, 12, and 15 GMT, the ratio of the number of storm zones found by the Sferic network to the number of storm zones found by the synoptic network. The ratios are affected by the differing densities of observing stations within the national boundaries and so are given separately for each country examined. It will be seen from the figure that the Sferic network detects more storm zones than does the visual reporting network over all but the most distant European countries. Over sea areas, ship reports of thunderstorms are inevitably so few

that their incidence cannot usefully be compared with that of the Sferic reports. The Sferic system is of course as effective over sea areas as over land areas. It is equally effective at intermediate hours such as 10 or 11 GMT when the number of synoptic reports is greatly diminished. The inclusion of Lerwick should increase the ratios over Scandinavia.

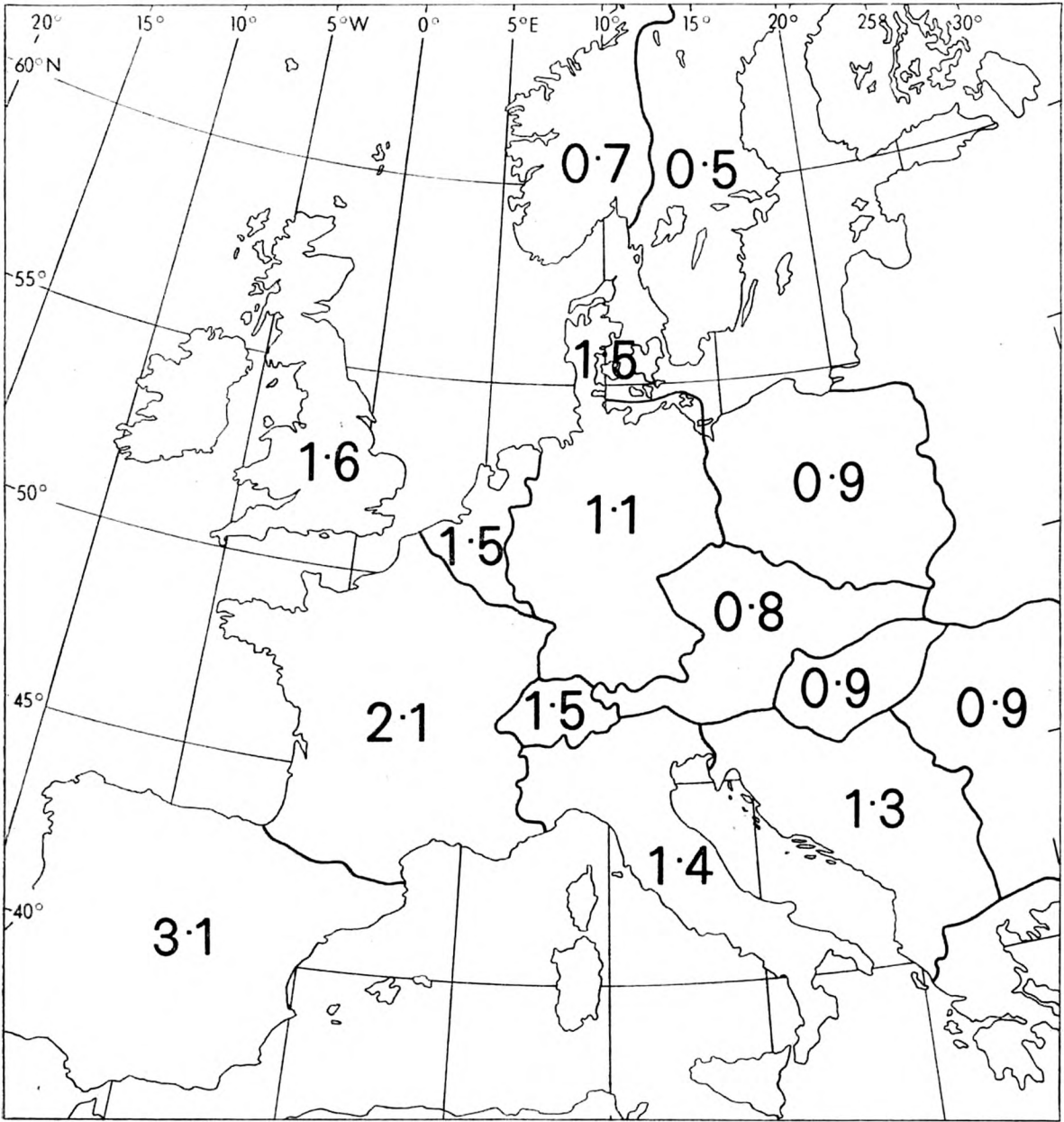


FIGURE 1—RATIO OF THUNDERY ZONES

The ratio of the number of thundery zones located by the atmospherics (Sferic) detection system to the number of like zones reported by the meteorological visual reporting networks of the countries concerned.

Marine Division

Throughout the year the number of Selected Ships recruited has almost balanced the considerable wastage due to ships being sold or laid up for long periods. The number of observations received has, nevertheless, increased since the larger container and bulk-carrier-type vessels spend more time at sea than their predecessors and are therefore able to make a greater number of observations. In spite of retirement and the consequent changes in personnel the Port

Meteorological Office staffs have continued diligently their recruitment of Selected Ships and general liaison work, of mutual benefit, between the Meteorological Office and the various shipping interests. Almost all meteorological work at sea in British merchant ships has always been carried out on a voluntary basis. In recognition and appreciation of their contribution to international meteorology, books were again awarded to the Masters, principal observing officers and senior radio officers who have been responsible for sending in the 100 best meteorological logbooks during the year. Similar awards were made to Masters and officers of vessels on the short sea trades ('Marid' ships) for their contribution in making sea-temperature observations and to trawler skippers and their radio officers who had the best records in making and sending non-instrumental observations from the fishing regions. Barographs were again presented to four ship-masters whose observations over many years have consistently achieved very high standards of excellence.

The policy of installing distant-reading marine meteorological instruments has continued and several newly-built or refurbished ships have been fitted with this equipment, which helps to lighten the tasks of observing officers. Shipowners approached in this connection have all proved very co-operative, in some cases the initiative coming from the shipowners themselves, a situation which favourably reflects the relations between the Meteorological Office and the shipping industry through the medium of the Port Meteorological Officers.

Acknowledgement should once again be made of the valuable service rendered by many Commonwealth and foreign Port Meteorological Officers for their services in the replacement of defective instruments in UK Selected Ships on protracted voyages, and withdrawal of instruments from British vessels which have been sold abroad to foreign interests. The timely intervention of the foreign Port Meteorological Officers has been of considerable assistance as the number of vessels ending their British sea-going career in ports abroad has been increasing considerably.

During the year the Marine Division has been host to visitors from Saudi Arabia and from Argentina. Officials from the meteorological services of these countries have studied our methods of recruiting ships to make meteorological observations, briefing the bridge watchkeeping officers on standards and methods of observing, equipping the vessels with marine meteorological instruments, the routine inspection of ships, and the general administration of the Voluntary Observing Fleet.

As a consequence of the termination of the International Civil Aviation Organization Joint Financing Agreement on North Atlantic Ocean Stations on 30 June this year the UK ceased to operate weather ships on stations 'I' and 'J'. From 1 July 1975 and pending the entry into force of the WMO Agreement for Joint Financing of North Atlantic Ocean Stations (NAOS) (Plate VII), Operating States have agreed to operate the network of ocean weather stations in the central and eastern North Atlantic on an interim basis. The network consists of the following stations:

Station	Position	Operating country
C	52°45'N 35°30'W	Union of Soviet Socialist Republics
L	57°00'N 20°00'W	United Kingdom
R	47°00'N 17°00'W	France
M	66°00'N 02°00'E	Netherlands, Norway/Sweden

The alteration in the UK operating commitment to the NAOS network from two ocean stations to one reduced the UK requirement for weather ships from four to two vessels. Arrangements are being made to refurbish two of the existing four ex 'Castle' class frigates to extend their service to about the end of 1981, subject to the WMO/NAOS Agreement entering into force. These ships were built in 1944 for the Royal Navy and have provided a satisfactory service since their previous conversion to weather ships in 1958/1960 but owing to natural consequence of service and age, repair and maintenance costs continue to mount and the accommodation requires modernization. The ships selected for possible refurbishment are *Weather Adviser* and *Weather Monitor*. The *Weather Reporter* and *Weather Surveyor* will man station 'L' until the refurbished vessels return to service, or the present interim arrangements change. Prior to the termination of the ICAO Agreement all UK weather ships provided communication and navigational facilities for transatlantic aircraft and air-sea rescue equipment was kept in constant readiness. After 1 July all aviation commitments were discontinued although the ships keep a listening watch on the aircraft distress frequency of 121.5 MHz. The weather ships make hourly surface and six-hourly upper-air observations (for heights reached in upper-air ascents see Table V of statistics). The following additional observations were made at regular intervals by British weather ships: solar radiation, sea temperature and salinity to considerable depths, magnetic variation and surface sea-water sampling. The biological sampling program for the Institute for Marine Environmental Research was continued until June. The Longhurst/Hardy plankton recorder was used during this sampling program to determine the vertical distribution of plankton in the upper 500 metres of the ocean at Station 'I'. For this duty a marine biologist from the Institute made several voyages to the station. In association with this investigation into the plankton hauls, water samples for phytoplankton analysis were taken and extra net hauls for analysis of toxic residues in the plankton were made. The Marine Aerosol Sampling Program was concluded during the late summer; this was a project undertaken in co-operation with the Royal Navy (National Gas Turbine Establishment (NGTE), Naval Marine Wing) to obtain and analyse air samples for salt-particle content. The NGTE expressed much satisfaction with the data obtained aboard the weather ships.

The number of marine enquiries has continued to rise and the total for this year has exceeded that of 1974 which was itself a record year. The enquiries were mainly from official organizations, solicitors, insurance companies, shipping interests, universities and industrial firms in the British Isles. However, a large number of enquiries were received from other countries including the USA, France, Holland, Germany, Italy, Sweden, Canada, Liberia, Israel and Greece. The subjects of enquiries were extremely varied, including questions on rollers at St Helena in 1862 (from an American professor), a ship lost in the South Pacific in 1906 and, more commonly, salvage, as in the case of a very large ore-carrier aground on the Casquet Rocks off Guernsey for 3 months. Information was supplied on request to litigants in several court cases, sometimes to both litigants.

The *Marine Observer* was published quarterly as hitherto.

OPERATIONAL INSTRUMENTATION

Demands for new instruments and systems to meet the changing operational needs of the forecasting, climatological and hydrometeorological branches show no sign of easing. Each new requirement is examined in co-operation with the Observational Requirements and Practices Branch, and the most suitable combinations of sensors and observational techniques are chosen.

The Operational Instrumentation Branch carries out any necessary design, development and/or adaptation of equipment and arranges for its assembly into fully proven systems to meet approved applications with the maximum economy and convenience to the user. Much of the work in recent years has been directed to help the human observer wherever possible, to supplement his efforts by the use of semi-automatic or automatic instruments in inconvenient places and at inconvenient times, and to automate the recording of data, thus avoiding subsequent laborious analysis of those data.

The Branch is also responsible for the technical progressing of manufacturing contracts, for acceptance testing and calibration of equipment, for planning and installation in the field and finally for maintenance and any subsequent modification of the equipment throughout its working life.

Two items are worthy of special mention this year: the successful trials of new equipment for determining upper winds, using navigational aids (NAVAID), on ocean weather ships, and the first deliveries in quantity of the new Mk 3 radiosondes at the beginning of the year and of the first computerized ground station towards the end of the year.

The NAVAID windfinding equipment had originally been purchased for use during the GARP Atlantic Tropical Experiment (GATE) in 1974. It was necessary to determine whether the technique could be used operationally on weather ships before two of these vessels underwent a major refurbishing in 1976. A thorough overhaul of the NAVAID equipment began in February and trials were carried out in June and August. During the first of these, some satisfactory upper-wind data were obtained using the LORAN-C navigational system; during the second, data were obtained using both LORAN-C and a combination of OMEGA and VLF (very low frequency) navigational stations. Further development work, involving modification of the US-manufactured sondes, will be required but it has been decided that the present obsolete wind-finding radars can be dispensed with on the refurbished ships.

Flight trials of the production Mk 3 radiosondes were started in February and have proved satisfactory. The first ground station was delivered to Beaufort Park at the end of November for installation prior to an extended period of detailed testing of hardware and software systems in conjunction with actual radiosonde flights; the central calibration plant was due to be delivered to Eastern Road, Bracknell at the turn of the year, in readiness for installation and commissioning.

Co-operative projects: national and international

One of the senior officers of the Branch was a member of the United Kingdom delegation to the Seventh Congress of the World Meteorological Organization in May, and was actively involved in preparations for this in the preceding months. Shortly after this, delegates to the Conference of Commonwealth

Meteorologists visited Beaufort Park when recent major developments in instruments were described and demonstrated.

The main area of international effort continued to be the European COST (Co-operation in Science and Technology) Projects 43 and 72 and several senior officers were involved in the work. In Project 72, which is concerned with the standardization of meteorological instruments in Europe, the sub-group on Automatic Weather Stations has now made arrangements for the holding of a technical conference at Reading University in September 1976 and senior officers will play a major part in its organization. The United Kingdom was also involved in the work of the sub-group on Radiosondes which organized laboratory and field trials at Trappes, near Paris, of a selection of radiosondes and radio-wind devices used by European services. A specification for upper-air balloons was written by the United Kingdom; this should enable the participating countries to purchase balloons giving better and more consistent performance. For Project 43 which is concerned with the development of meteorological/oceanographic data buoys, and with the progressive harmonization of the separate national data-buoy programs, the feasibility of setting up small pilot networks under the joint management of the contributing countries is being examined. This involves many complex issues: financial, legal, organizational and technical.

Construction of the UK national data buoy DB I was completed in September and includes a meteorological sub-system developed and supplied by the Office. The buoy has been deployed a few kilometres off Lowestoft for the winter months and data are being transmitted by a multi-tone frequency-shift keying system (FSK) to a computerized shore station at Lowestoft.

Four small drifting buoys, equipped to measure atmospheric pressure, air and sea temperature and wind speed, were assembled at Beaufort Park by the time of the launch of the United States research satellite NIMBUS 6 in June. Two of these buoys were deployed in the Barents Sea in September, and a further two in the north-eastern Atlantic in October, from the Ministry of Agriculture, Fisheries and Food research vessel *Cirolana*. The positions of the buoys were determined by the satellite and data were transmitted to the Spacecraft Tracking Station in Fairbanks, Alaska and subsequently relayed to the Goddard Space Flight Center in Maryland and the US National Aeronautics and Space Administration's centre in London.

Reliability of the systems after deployment has been disappointing but valuable first experience was gained in the use of satellites to locate and to acquire data from moving platforms.

Two small telemetering buoys, the original prototype OBOE I and an operational version OBOE THAMES, were deployed in the Thames estuary in September for comparison trials. The buoys were moored in relatively shallow water outside the shipping channels but unfortunately capsized during onshore gales. Investigations into future possibilities are continuing.

An officer of the Branch attended the WMO Technical Conference on Automated Meteorological Systems, in Washington in February, and presented two of his own papers and two by colleagues. Another senior officer went to Iran in September as part of a UK team, to carry out a feasibility study on the use of a weather radar to measure precipitation in two mountainous catchments providing a large part of the water supply for Tehran.

The Office has continued to co-operate with the Home Office and the Transport and Road Research Laboratory in trials of visibility sensors which might be used to monitor fog on motorways.

Development, production and evaluation of new instruments and systems

Works services are being carried out for two more Mk 2 automatic Weather Observing Systems (MOWOS) field stations: at the BBC transmitting station at Holme Moss and at the Central Electricity Generating Board station at Bradford West. These installations will bring the total to seven field stations in all; in addition, there are now nine receiving stations in use.

Development of an improved version of the CARD (continuous automatic remote display) system has been largely completed and four systems are being assembled for use at the Army ranges at Otterburn and Sennybridge, and at the RAF ranges at Wainfleet and Theddlethorpe. All four installations will be used operationally, and the last two will also serve to give early warning of adverse weather approaching nearby RAF airfields. The performance of these systems will be monitored to assess their value for more general use.

Trials of the digital anemograph logging equipment (DALE), which were interrupted last year when the company supplying the magnetic-tape deck was closed, have been brought to a successful conclusion. An alternative magnetic-tape deck, using a cartridge system has been found which gives at least as high a rate of data retrieval as the original choice. It has been selected for DALE and as a standard type for future similar applications. Contract action is being taken to obtain replacement data-logging equipments (MODLE) for all radiation-recording stations in the network.

Another system to use the standard cartridge will be the automatic climatological recording equipment (ACRE). A detailed program has been drawn up for the design, development, construction and evaluation of ACRE and for the setting up of an initial network of 10 stations in data sparse-areas.

In order to reach an early decision on a suitable replacement for the existing Mk 3 cloud-base recorders (CBR), trials have been planned to compare a Mk 3 instrument, the latest Mk 5 version (also of the rotating-beam type) and a laser-based CBR. Approval for the use of the last type at civil and military airfields has now been given by the appropriate national safety authorities.

In addition to the more pressing work entailed in meeting existing requirements, the Branch has a wider responsibility to note the emergence of new techniques which could be applied in the field of operational instrumentation and to determine, in conjunction with the Observational Requirements and Practices Branch, whether further studies should be made of a small selection of these.

One such area of applied research is the remote sensing of atmospheric variables in the lowest 1000 metres of the atmosphere. To this end, theoretical studies have been made of several remote-sensing techniques with particular emphasis on acoustic-sounding methods. An officer of the Branch attended a meeting on atmospheric acoustics in Toronto in June. Another current area of interest is in the use of solar cells to power remote automatic equipment, work on which is being planned in conjunction with the Royal Aircraft Establishment, Farnborough

Technical management and services

The Branch continues to liaise closely with user and supply branches in the planning and provision of operational instruments.

The electronic workshop which repairs conventional equipment and constructs prototype equipment for field trials, has been given additional responsibilities: first for the assembly of certain operational systems from manufactured electronic modules, and secondly for making any technical decisions on the repair of devices incorporating advanced technology. Good progress has been made in re-equipping the mechanical workshops with up-to-date machines.

Technical writing activities are going ahead more effectively as a result of the additional effort now available for producing a variety of documents and for supervising work done under contract.

While the effort provided in support of the Dee Weather Radar Project at the Llandegla Research Station was gradually reduced in the early part of the year, plans for an interim operational weather radar network to measure precipitation began to take shape towards the end of the year. It was decided to install an S-band (10-cm) radar, which had formerly been used at Singapore, at Camborne, in Cornwall. The data will be digitized on site and transmitted to the Meteorological Office at Plymouth using a simple colour scale on a television screen to indicate intensity of precipitation; later, data from calibration of rain-gauges will be telemetered to the Camborne installation to make the information more accurate. A second site is being selected on Salisbury Plain, probably at Upavon, for the S-band radar which is due to be returned from Gan early in 1976.

The instruments on the IBA mast at Lichfield have been refurbished, and the obsolete analogue telemetry equipment is being replaced, experimentally, by a MOWOS digital transmission link to ensure that the inherent accuracy of the readings is not degraded during transmission from the mast to the user.

Following acceptance of the Mk IV transmissometer for operational service in monitoring visibility, four of the earlier Mk III instruments have been recalled for overhaul and conversion. It is intended that these will be used on the first four CARD installations.

The bulk of effort on instrument testing continued to be dedicated to the very thorough checking of the initial batches of Mk 3 radiosondes. This is well illustrated by the entries in Table XV. Works services for the new calibration plant are complete, and delivery of the outstanding pressure calibration chambers and controlling computer is expected early in 1976.

Servicing and technical training

The consequences of the Defence cuts announced early in the year required some re-organization in technical support. The Regional Technical Officer (Overseas) who was formerly based at RAF Command Headquarters, Near East Air Force in Cyprus is now based at Beaufort Park. In the coming months, this will provide the necessary close liaison with the staff who are preparing to dismantle equipment at certain overseas stations, starting with Gan.

Other changes are soon to be implemented, in response to increasing and more diversified requirements. A new servicing centre at Kinloss is about to be set up to serve the North of Scotland. Responsibility for technical support at RAF Strike Command has been transferred to the Headquarters Servicing Centre at Bracknell.

The recent innovation whereby designated officers have been made responsible for monitoring all performance reports on selected types of equipment has proved effective; a further development of this scheme is that designated officers for new equipment will henceforth be selected from staff at Beaufort Park to enable close links to be established with staff engaged on the development, installation and modification of equipment.

Although the normal intake of trainee technicians passed through RAF Sealand for basic training followed by the more practical course on operational equipment at Beaufort Park, greater emphasis is having to be given to a series of shorter courses on new equipment, and refresher courses for technicians who were trained in earlier years.

COMPUTING AND DATA PROCESSING

The Data Processing Branch is responsible for operating the coupled IBM 360/195 and 370/158 computer system known as COSMOS, the processer-controlled key-to-disc data-entry system (PCK) and the punched-card unit. It provides the software needed for computer operation, including operation of typewriter and cathode-ray-tube terminals. The Branch is also responsible for general-purpose programs to store, control the quality of and retrieve observational data received from the telecommunication systems, and to produce plotted and line-drawn charts and graphical displays required mostly for day-to-day operational tasks. An Enquiry Bureau maintains liaison with computer users, offering advice as required, and provides a limited service of data extraction from machinable archives.

In the first part of the year the main effort of the Branch was directed towards installing and developing the twin processer system and the expanded terminals system but in the second half of the year emphasis shifted to production of management statistics for monitoring system performance and controlling the use of the computing facilities. In this latter phase special emphasis was placed on optimizing the use of existing equipment and current procedures and the selection of cost-effective solutions to problems falling to the Branch.

The COSMOS Computing Laboratory

Acceptance trials of the 370/158 processer were completed on 10 January and the eight additional disc drives, making twenty in all, were accepted on 27 January. The linking of this second system to the very fast 360/195 computer and the development of operating procedures for the twin system took place over several months. The smaller 370/158 computer, although having only about one-fifth of the power of the 360/195, releases the main processer for the more demanding work such as computations with numerical models of the atmosphere, but when the main 360/195 processer is unserviceable the 370/158 has sufficient power to provide a back-up forecast service. In normal operation the smaller processer provides line-drawing and plotting services, remote-terminals services, undertakes the computation for most of the smaller tasks, and handles all input and output requirements. The two processers are coupled and share the twenty disc drives, the fixed-head disc and the six magnetic-tape drives. Normally all input and output devices are connected to the smaller processer but may be switched to the 360/195 if the 370/158 fails.

Three operating systems are required to operate the coupled twin-processor system; the Asymmetric Multiprocessing System (ASP) to control the flow of work to and from the two processors, the Virtual Storage System (VS2) to control the work done in the 370/158 and the Multiprogramming System with a variable number of tasks (MVT) to supervise the work done in the 360/195. The initial preparation of these operating systems was done in 1974 before delivery of the new equipment but their operational installation and development had to be undertaken at the Meteorological Office in 1975 without interrupting any of the operational work to which the 360/195 was committed. A special 4-disc pack operating system was employed during installation of the eight new drives and the string switching which enables the sharing of all 20 drives between the two processors. For the first four months of the year the ASP, VS2 and MVT systems were developed during those parts of the day when no important operational programs were running. During this period of intensive development and frequent change, all operational work was run on the 360/195 in uncoupled mode to reduce the risk of failures. Also during this period a member of the Operating Systems team was on call at all times to resolve problems arising with the new operating systems. By the end of April, the two processors were running in coupled mode at all times, including the operational forecasting periods, and the number of jobs processed each month had risen to 25 000, from the average of about 17 000 in the last part of 1974. A card reader was moved into the Receipt/Despatch area to allow programmers to enter their own programs and reduce the work load for Branch operations staff.

A telecommunication control unit (TCU) and 13 visual display terminals were installed at various points in the London Road Headquarters building during the first three months of 1975. The new terminals and the existing IBM 2741 typewriter terminals were supported by the time-sharing option operating system (TSO) which has undergone continuous development during the year. Use of the terminals has grown steadily in most of the seventeen branches which use cosmos and four additional terminals are to be attached next year to serve branches at Eastern Road, Shinfield Park, the Meteorological Research Flight, Farnborough and the Principal Forecasting Office at Strike Command Headquarters, High Wycombe. Also the TCU has been used to attach a card-reader and line-printer in the European Centre for Medium-range Weather Forecasts (ECMWF) and there are plans to use the TCU in 1976 for data links to the PDP 11/40 computer in the Systems Development Branch and to a mini-computer which will provide a library accessions service.

Additional automatically plotted charts were produced regularly every 3 hours and twice daily for operational use in CFO and a new library was set up on magnetic disc to make it easier for branches to produce a variety of plotted information of general interest and application.

A second Calcomp 1670 Computer Output on Microfilm (COM) plotter was installed in March. The second plotter together with the second processor, provided the back-up of equipment necessary to ensure a reliable operational service of the smaller line-drawn and plotted charts. The development and testing of the IBM System 7 electronic interface between the telecommunication computers and cosmos (see Section on Meteorological Telecommunications) was delayed during the implementation of the cosmos-coupled processor system but was finally brought into full operation in October when the use of paper tape to transfer telecommunication data to cosmos was relegated to a back-up

role. The System 7 interface provides better data coverage than the paper-tape data previously used and the interface also handles the data faster. The data coverage provided by the telecommunication Main Trunk Circuits continued to improve through the year and tests demonstrated that there would be no significant loss of data if the contents of the four radio-teleprinter (RTT) broadcasts from Moscow, Nairobi, Frankfurt and Dakar were no longer entered into the Synoptic Data Bank. The four RTT broadcasts were relegated to a back-up role in the second half of the year to reduce the time taken to fill the Synoptic Data Bank. The most critical requirement to be based on the Synoptic Data Bank is the plotting of hourly charts for the British Isles area and it is by no means certain that an automated plotting service will achieve the speed and reliability of the present services provided manually by Assistant Scientific Officers.

Investigations were started in the second half of the year, in conjunction with the staff at the Principal Forecast Office at Heathrow, into the possibility of automating a part of the plotting service required at Heathrow. It seems likely that a cost-effective service could be based on existing programs and equipment similar to that installed at Bracknell.

The replacement at Bracknell of paper tape by the System 7 interface as the means of transferring real-time data from the telecommunication computers to COSMOS and the continued demand for more time-critical operations in COSMOS have emphasized the importance of providing ways of monitoring the flow of data at all points in the system. Also, the Central Forecasting Office (CFO) is continuing to develop ways for the forecaster to intervene in the production of automated analyses to improve their quality. To do this effectively, the forecaster needs to know exactly what observations were used by the analysis programs. The programming staff attached to CFO have also made a series of changes to the suite of analysis and forecast programs, to make them easier to operate and to facilitate recovery action if equipment or software failures occur. The arrangements to compute back-up forecasts on the 370/158 in the event of failure of the main 360/195 processor have proved very effective. Data and computed results are stored on discs which are shared by the two processors and if a processor fails during a forecast computation it is possible to use the second processor to complete the computation and output the results without repeating work done before the failure occurred. On occasion a forecast has been started on the 360/195, then continued, at a necessarily slower rate, on the 370/158 and finally completed on the 360/195. This on-site back-up is a great improvement on that previously available at the Rutherford Laboratory, Chilton which required the maintenance of special versions of the analysis, forecast and output programs suited to the Rutherford Laboratory equipment and operating system; in addition, staff had to travel to Chilton, taking data tapes with them.

The IBM 360/195 computer and all peripheral equipment continued to give reliable service throughout the year although a large number of engineering changes to 360/195 channels caused some disruption of work in August and September. There were two serious disc crashes during the year but mechanical damage to the drives was repaired quickly and data were recovered without affecting operational work. The new 370/158 computer also settled down quickly. It has proved very reliable and by the middle of the year it was apparent that the planned reduction in maintenance cover for the main processor and peri-

peripherals could be made without significant risk to operational work. On 1 July maintenance cover on the 360/195 and all peripherals was reduced from 24 to 9 hours per day, saving approximately £60 000 per annum at current rates.

Arising from a staff suggestion, investigations were started into ways of replacing the very expensive pre-printed continuous stationery used on the Calcomp 1136 drum plotters by cheaper individually printed charts produced by Her Majesty's Stationery Office in its printing section at Bracknell. Not only is the scheme likely to reduce running costs, but the system will become much more flexible and should give improved service to CFO.

A second-hand 16-mm Vought camera is being modified in the Operational Instrumentation workshops and will be used in conjunction with the Calcomp 1670 COM equipment to explore the potential for producing line-printer-type output directly on to 16-mm film. The second Calcomp 1670, which was installed primarily to provide equipment back-up for operational purposes, has considerable spare capacity for jobs which are not time-critical. Development of this capacity should delay and perhaps avoid future purchase of additional line-printers and may also reduce output production costs which have risen rapidly owing to increased paper and printing costs.

Considerable effort has gone into the production of management information on the use of computing facilities by user branches. Each year computing branches are required to seek Directorate approval for their proposed use of computing facilities and the Data Processing Branch provides users with information to control individual projects and to help branches to remain within their overall budgets for computing. The Branch also produces for its own purposes management information about the performance of the various components of the cosmos system and its associated off-line equipment. Such information is being applied to improve the overall efficiency of both the equipment and the controlling software (operating systems) and will be used as the basis for the extensive optimization which is planned for 1976. Discussions have taken place with the performance and hardware monitoring section of the Central Computer Agency (CCA) and with IBM and plans have been made for equipment and software monitoring and optimization. IBM and consultants employed through the CCA will take part in this work with the Data Processing Branch, with the object of continuously improving the throughput of work and of minimizing further expenditure on equipment, at least until the time comes for replacement of the main components of cosmos. Depending on the results of this exercise, the study may be extended to individual major projects which are run on COSMOS.

Only small amounts of spare capacity are expected on cosmos but an agreement was reached to provide the European Centre for Medium-range Weather Forecasting (ECMWF) with approximately £150 000 worth of computing services in the next three years. It is of interest that software written by the Data Processing Branch to support visual display terminals under IBM Conversational Remote Job Entry (CRJE) has proved very successful and has been purchased by no fewer than six commercial installations.

Processing of data from the GARP Atlantic Tropical Experiment

The Synoptic Data Bank team continued the work (started in 1974) of collecting and storing synoptic data for the GARP Atlantic Tropical Experiment (GATE). During the first part of the year the final paper tapes containing GATE

data arrived at Bracknell and were transferred to magnetic tape using the PDP 11/40 mini-computer. A total of 51 countries have now sent relevant data. Tests were completed on the method to be used to add these data to the archived data banks, and a procedure has been devised using a visual display unit to correct message formats and telecommunication headings, thereby ensuring successful handling of the data. Processing of the 100 GATE days started in October and is expected to take about six months.

Storage and preparation of data

The intensive efforts to produce and improve the operating systems to drive the dual-processor COSMOS system and the new terminals began to show positive results by the middle of the year and some staff effort became available to review the data-storage and data-preparation work of the Branch. In the past, most observational data were prepared on punched cards or transferred from telecommunication paper tapes to three-quarter-inch KDF9 magnetic tape at 400 bits per inch. KDF9 magnetic tape was also used by computing branches to store their derived results. By 1971 there were 60 million punched cards and over 4000 KDF9 magnetic tapes in store. Since 1971 almost all 'keyed' data have been prepared using the processor-controlled key-to-disc (PCK) system and telecommunication data, and derived results have been stored on half-inch magnetic tape with a packing density four times that of KDF9 tape. In spite of the greatly increased storage capacity of the half-inch tapes, over 13 000 have been brought into use since the installation of the 360/195 in December 1971 and there is urgent need both to reduce the present storage requirements and to control the future demand. The 60 million cards weigh approximately 130 tons and are kept in a partly air-conditioned store remote from the headquarters building. When data are required, the appropriate cards must be selected and brought to the computer area to be read by a card reader attached to COSMOS, after which the cards are returned to store. The data on all 60 million cards could be held on about 300 magnetic tapes occupying about one and a half cubic metres in a store near the computer room but the handling and transcription of such a large number of cards presents a major problem. Transport alone between the store and computer is difficult and an additional card reader has been rented to achieve the target of transcribing to magnetic tape about one million cards per week. However, the project will be cost-effective solely in terms of the released storage space. In parallel with the card-to-magnetic-tape transcription, it is proposed to transfer essential data held on KDF9 magnetic tapes to the higher-density half-inch magnetic tapes, reducing the number of tapes held by a factor of at least three. Furthermore, computing branches are being asked to review regularly their holdings of magnetic tapes and to ensure that only essential data are retained.

As a result of a survey of the PCK installation, approval was obtained for the addition of an extra disc and a line-printer to improve the facilities. Also, a study of the current methods of data presentation, keying and quality control was undertaken jointly with the Climatological Services Branch with the object of improving the throughput of work without reducing the quality of the stored data.

SYSTEMS DEVELOPMENT

The work of the Branch is in small part theoretical—keeping abreast of knowledge, feasibility studies etc.—but for the rest is almost entirely occupied with the practical application of computers and associated devices to meteorological functions. In the past the Office has relied on one, latterly on two (comprising the cosmos system) of the larger, faster main-frame machines that were commercially available to execute the bulk of its computer work. As the work-load grew, so did the size and complexity of the system, to the point where it became almost mandatory to transfer some of it to smaller machines. The advent of the mini-computer, based on miniature integrated-circuit technology, has done much to facilitate this change. Such computers have considerable data-processing power and for certain applications can be more reliable and cost-effective than main-frame machines. They are also more portable and, because of the ease with which a range of devices (including some of the more unusual) can be connected to them, are particularly adapted to the creation of specially tailored, if not novel, systems.

Headquarters mini-computer laboratory

The Digital Equipment Corporation PDP 11/40 installed at Bracknell in the spring of 1974 was intended for multi-branch usage, both operational and experimental. It therefore had a wide initial configuration which has been progressively added to as the number of projects being studied on the system increased. By early 1976 it is expected to comprise 80 K ($K = 1024$) words of memory, two magnetic-disc units, two standard (IBM-compatible) magnetic-tape drives, a teleprinter console, a card reader, a paper-tape reader, an electrostatic printer/plotter, a VDU terminal, a computer-controlled GT40 graphics terminal (incorporating another version of the PDP 11) and two non-standard magnetic-tape drives to read Epsilon and 3M cassettes. There will also be an on-line auto-dialling controller, to enable automatic interrogation of remote devices through the telephone system, and a direct communication link to cosmos. When this expansion is completed the operating software will be extended to provide a real-time, multi-programming capability.

Associated projects

Apart from miscellaneous paper-tape and punched-card conversions, there is a growing amount of routine translation to IBM-compatible tape from Epsilon (10-track, half-inch, 200-bit/inch) and 3M (4-track, quarter-inch, 1600-bit/inch) tape cassettes used to record several varieties of data automatically in the field. A trial is also taking place of data collection through the telephone system from four MOWOS (Meteorological Office weather observing system) automatic stations, under program control. It involves the continual collection, monitoring, storage and display of observations within ten-minute cycles. Later, it is possible that many more MOWOS stations within the United Kingdom will be added, partly to fill the gaps if the number of manned stations continues to decrease, so that a more elaborate network design and dedicated hardware are required.

A scheme to automate the entry and monthly cataloguing of bibliographic material received by the National Meteorological Library (about 1200 papers, books, periodicals etc. per month) is well advanced. The required equipment

(a mini-computer, with magnetic disc and two visual-display keyboard terminals) has been ordered for delivery in mid 1976 and most of the necessary software has already been written and tested on the PDP 11/40. The system will be housed in the Meteorological Office library itself and will be directly connected to cosmos with its more powerful sorting and printing facilities. It will be capable of supporting additional VDUs that may be required, for example, to facilitate rapid remote retrieval of information about publications contained therein.

Another established project is the automatic reading of over a million rainfall charts via the computer-controlled flying-spot scanner at the Nuclear Physics Laboratory, Oxford University, which started over two years ago. These charts, which consist of pen-and-ink traces showing the continuous variations of rainfall over 24-hour periods, are microfilmed at Her Majesty's Stationery Office, Basildon, and are then automatically read and digitized at Oxford. The results (including related statistics) are written to magnetic tape which is subsequently sent to the mini-computer laboratory at Bracknell for checking and correction of any suspect data. An editing system based on the PDP 11 graphics terminal is now in routine operation: this enables any traces read by the flying-spot scanner to be re-created for comparison with the originals, and amended by light-pen if necessary.

The latest project is concerned with a practical study of the processing and display of analogue APT (automatic picture transmission) signals received from observational satellites. The necessary converters (analogue-to-digital and vice versa) have been fitted to the PDP 11 together with a conventional facsimile recorder, to enhance the display possibilities. The arrayed radiance values correspond to pictures of clouds and surface features, both in the visible and the infra-red range of the spectrum. Once digitized and stored in computer memory they can be manipulated and presented in all sorts of ways, and on any map projection and scale. If the study is successful the intention is to develop a separate tailor-made system of satellite-data presentation for use in the Central Forecasting Office.

Allied studies

The various enhancements in the central computer complex (cosmos and Myriad II) have increased the telecommunication and automation possibilities at outstations. Experience on the HQ mini-computer has also made possible a more realistic appraisal of the extra costs of equipment, software, maintenance etc. for such applications. For example, the outcome of a study started in late 1974 of the feasibility of providing more automatic collection and editing of climatological data from the Meteorological Offices at Edinburgh and Belfast was a decision to improve and to persevere with the present postal exchanges with the two sites concerned rather than to embark upon automation. However, other offices, such as the Principal Forecasting Office at Strike Command, have to discharge a much wider range of functions (synoptic plotting, contouring, data display, data collection, message switching etc.) and a similar study, now under way, may show that electronic methods are more worth while in this area. Ultimately a large part of the telecommunication network of the United Kingdom may become a computer-to-computer network.

Early in the year a study was completed of the pros and cons of the micro-filming of old records (charts, log-books, aerological diagrams etc.), more than six million of which are housed in the Meteorological Office Archives. A high proportion of these have to be preserved indefinitely for posterity and for current use. Apart from the more-traditional advantages (durability, compactness, reproducibility etc.) of microforms, more recently there have been advances in methods of retrieval via automatic devices, some controlled by computer. So far no decision has been taken on whether to embark on a mass-filming of these archives. Meanwhile, some fairly long sequences of selected records (comprising Library catalogue sheets, marine logs, monthly rainfall cards, and some rare manuscripts—about 100 000 in all) are being filmed at Her Majesty's Stationery Office, Basildon as a trial exercise.

The machinable data bank

The major proportion of the effort in the Branch still continues to be applied to the build-up on the COSMOS installation of the growing library of data in machinable forms. These, in conjunction with the paper documents referred to above, collectively constitute most of what is known of the history of the weather and climate of the British Isles and of the world's oceans over the last century or more.

Conversion to standard (9-track, 1600-bit/inch) magnetic tape of the many varieties of data from the old media (punched cards, three-quarter-inch magnetic tape, paper tape, analogue traces etc.) still continues and still poses problems of checking, correcting, reformatting etc. Much software has had to be written and this activity will need to continue as new classes of data are added. The software includes two access programs, called GPACCESS (for constant-length) and VACCESS (for variable-length) records, now in general use by most programmers, and one called TALKBACK specially designed for the entry, display and editing of data on VDU keyboard terminals. This enables (FORTRAN) programmers quickly and efficiently to control all the VDU facilities (light-pen, function keys, cursor, reverse images etc.) so as to develop their own data-management schemes.

At present, all the data within the bank are listed annually in a catalogue. This was improved last year by the design of a new data-classification method and by the provision of more basic information about each file of data. Ultimately it is planned that all the relevant information will be available on magnetic discs to improve its retrieval: already master directories comprising details of some 11 000 British rainfall stations, 800 British climatological stations, and about 10 000 world synoptic stations are in this form.

METEOROLOGICAL TELECOMMUNICATIONS

Bracknell Automated Telecommunication System

In 1972 installation of a twin system of Marconi Myriad II computers led to the establishment of an operational data-transmission (2400 bits per second) service with the Washington World Meteorological Centre (WMC). In the following April high-speed connections were established with the Paris and Offenbach regional centres. These high-speed data-transmission connections, which also carried analogue facsimile transmissions, were some of the earliest

parts of the planned new Global Telecommunication System (GTS) of the World Meteorological Organization (WMO) to be implemented. The second phase of the automated system, also based on two Myriad II computers, was formally handed over by the Marconi Company in June 1974 and the following six months were devoted to progressive commissioning of the system, involving facilities and services with both national and international aspects.

During 1975 more and more services have been gradually associated directly with the Phase II system, both in terms of input and output. By the end of the year the data inputs being directly handled by Phase II automation included:

- (a) Inputs at 2400 bits per second from the GTS main trunk segments connected to Washington and to Paris and from the main regional circuit from Offenbach.
- (b) Connections with Oslo and De Bilt at 1200 bits per second.
- (c) Teleprinter-speed (50-baud) connections with Dublin, De Bilt (Netherlands), Reykjavik, Oslo, Rheindahlen (RAF Germany), Cyprus, Malta, Gibraltar, and eleven observational data-collecting centres in the UK.
- (d) Local telecommunication-centre inputs at both high and low speed.
- (e) Inputs, as required for emergency back-up purposes to handle specified regional radio-teleprinter broadcasts from centres such as New York, Nairobi and Moscow.

As regards automated outputs, services at high and medium speed were supplied to the corresponding foreign centres as indicated above. At teleprinter speed, different versions of the UK number one domestic data broadcast have been programmed and introduced, including some which are run continuously instead of stopping as previously for several minutes each hour. Although it has not yet been found practicable to realize the object of providing the UK meteorological offices with data exclusively of their choice as regards content and timing, some headway has been made in this direction. Pre-selection of certain data has enabled the relevant bulletins to reach the forecasting offices earlier and in a more convenient way. Individual output programs have been provided for certain European centres, and for our offices in Cyprus, Malta and Gibraltar; the regional radio-teleprinter broadcast (call-sign GFL) provided by the UK as a WMO commitment, has been placed completely under the control of the automated system.

Progress with the greater spread and penetration of automated services has also meant a reduction in the teleprinter terminal equipment needed at Bracknell, and a reduction of the staff required to man the centre. The recovery of leased equipment and reduced staff requirements have given obvious savings, and fortunately normal staff wastage has avoided any redundancy. The editing staff alone has been reduced from 25 to 15, and the type of work now being undertaken by those remaining has been concentrated on data monitoring and quality control which is an area where human scrutiny and intervention are still needed despite the many checking and control tasks which have been automated. Increased automation and reduced staffing have made it essential to make provision for suitable recovery and re-routing arrangements to be brought into force quickly in the event of outages or breakdowns occurring on key circuits or at centres.

High-speed interface between the Telecommunication Centre and COSMOS

Last year's Report explained the need for a high-speed electronic interface (to be based on an IBM System 7 computer) between the automated complex (AUTOCOM) in the Bracknell Telecommunication Centre and the adjacent Computer Laboratory (COSMOS). There were obvious problems to be solved to achieve this, notably the need for special software and additional special hardware which had to be produced 'in house'. Furthermore an important delaying factor was that of having to develop and test a new interface between two major facilities which were heavily committed to routine operational services, and which were themselves undergoing development at the same time. However, the System 7 interface was finally brought to operational status in October 1975 and the use of punched paper tape, which had been the original interface arrangement between the AUTOCOM and COSMOS, was relegated to a back-up role. The facility of data transfer from COSMOS to the AUTOCOM through the System 7 interface has been virtually completed thus providing a full duplex highway between the telecommunication and data-processing centres.

Enhancement of the Automated Telecommunication System

As explained in last year's Report, the telecommunication automated complex is to be further enhanced by the addition of a twin system of Ferranti Argus 700S computers, mainly to enable the Bracknell Regional Telecommunication Hub (RTH) to fulfil its obligations within the WMO plans for an automated system throughout most of Europe.

During the year specialist staff of the Telecommunications Branch have collaborated with Ministry of Defence (Procurement Executive) engineers and those of Ferranti in advancing the production contract. This has necessitated a number of visits being made to the Ferranti works at Wythenshawe (Manchester), and indeed towards the end of the year a Meteorological Office software specialist was attached to the Ferranti production team. Good progress has been made and at the end of the first 12 months the project is still approximately on schedule. The outlook therefore is that delivery and installation should be achieved by December 1976. A fairly long commissioning period is expected, with introduction to full operational service not taking place before mid 1977.

Analogue Facsimile Services (UK)

Approval was given some three years ago to go ahead with a replacement program by means of which a large number of old analogue facsimile recorders could be 'traded-in' and exchanged for new machines designed to modern standards and having additional facilities, including a capability of operating at 240 rev/min. For various reasons, mainly technical, the exchange program was badly delayed until late 1974 but it has progressed during 1975 and by the end of the year around 90 new machines had been delivered by Messrs Muirhead. The remainder should be delivered during the early months of 1976. These replacement machines are indistinguishable from the current Mufax TR4 Weatherfax Recorder and it is intended to exploit their 240 rev/min capability over the UK national weather facsimile land-line network (MOLFAX), thereby speeding up the service and increasing its traffic capacity.

Procurement of facsimile recorders for satellite cloud pictures

The American ESSA series of satellites provided readout of cloud information in pictorial form by means of a vidicon camera system. Relatively uncomplicated receiving equipment was required to produce cloud pictures from the automatic picture transmission (APT) service. The ESSA series was succeeded by the NOAA satellites, and these introduced the scanning radiometer (SR) mode to provide cloud pictures in both the visible and infra-red ranges of the spectrum. The SR transmission, as recorded on the normal satellite picture recorder, results in narrow pictures with severe distortion occurring towards the edges. There are also differences in the technical characteristics of the transmission of cloud images in the visible and infra-red bands.

Following various investigations concerned with 'stretching' and linearizing the SR cloud pictures, as well as with picture contrast and definition, it was concluded that a satisfactory service for the operational forecaster could be provided by a Mufax TR 4 facsimile recorder suitably modified by Hawker Siddeley Dynamics (HSD). As modified, the recorder would display simultaneously the visible and infra-red cloud pictures side-by-side, each picture 'stretched' by a factor of two, and independently adjusted to give satisfactory contrast and tonal range. Based on trials with an engineering prototype of the HSD-modified recorder, a technical specification was written for a similar machine to be obtained through open tender. The outcome was, as expected, a refinement of the Muirhead-HSD prototype. First deliveries of the new recorder are expected around March 1976.

It was decided that the existing small network (about 7 offices) carrying the satellite cloud picture information should be expanded to almost three times its present size in view of the demonstrated increased value of the cloud pictures to the forecaster, especially with the improved presentation available from the new type of recorder. Action was therefore taken to establish a suitable land-line network, centred on Bracknell, which would distribute the satellite cloud-picture signals to the designated offices.

Main Trunk Circuit facsimile transmissions

It has long been recognized that the store-and-forward process for relaying analogue facsimile transmissions by the magnetic tape method from one centre to another was a rather slow and generally unsatisfactory arrangement. The accumulated delay which occurs when this relay procedure has to be followed by several centres in sequence is not acceptable. At a WMO meeting held in Geneva in December 1974 participants placed on record a request that countries would study the relay problem and introduce a more effective method as early as possible. Certain improvements have been introduced at the Bracknell centre during the past year, but the truly effective change that is required is 'instant replay' instead of the total recording of a chart and rewinding of the magnetic tape having to be completed before the 'replay' or relay can take place.

A digital storage system, microprocessor controlled, has been designed which will enable facsimile signals to be retransmitted within a few seconds of arrival. When implemented this will virtually eliminate the present delay of several minutes which occurs at Bracknell in relaying analogue facsimile transmissions along the main trunk circuit of the GTS.

Coded digital facsimile

The transmission of pictorial information by the analogue facsimile method has long been criticized as being slow, transmitting much redundant information and being incompatible with message switching systems controlled by digital computers. The WMO Commission for Basic Systems (CBS) has set up a new Study Group to investigate how these shortcomings could best be overcome, and particularly to study the use of coded digital facsimile to this end. A successful outcome would enable the GTS main trunk circuit, and regional circuits (the Bracknell RTH is concerned in both) to be operated mainly in the digital mode. With good compression coding the transmission time for pictorial information would be significantly reduced. The amount of compression which can be achieved depends chiefly on the coding used and the complexity of the graphic detail on the chart being transmitted.

Field trials of coded digital-facsimile transmissions have taken place between Washington WMC and Tokyo RTH with somewhat mixed results. It was planned to have similar trials between Washington and the RTHs of Bracknell, Paris and Offenbach utilizing the interconnecting main trunk segments, but for various reasons these did not materialize. However, in readiness for such trials programs were developed at Bracknell to use the System 7 computer (already used for the high-speed interface) to accept, decode and output the coded digital transmissions. Other programs which would enable us to input as well, are under development. Procurement action has been taken to obtain special facsimile machines capable of accepting or providing a digital data stream, so that hard copy can be produced for pictorial readout or scanned for input.

A key meeting of the CBS Study Group on Coded Digital Facsimile was held during the first week of December during which it was agreed *inter alia* that further trials of coded digital facsimile should be undertaken between Washington and Tokyo around March 1976, with provision for the Bracknell and Paris centres to participate if possible.

Ocean Weather Service

Arising from the decision of the International Civil Aviation Organization (ICAO) to withdraw from the North Atlantic Ocean Station (NAOS) scheme at the end of June 1975, a new NAOS scheme under WMO sponsorship was planned to come into force on 1 July and a new telecommunication plan with Bracknell as the sole shore collecting centre was developed at an informal planning meeting held in Geneva in February. The meeting recognized that formal government agreement to the new NAOS scheme might not be reached by 1 July (and that turned out to be the case); nevertheless the participants agreed that should the new ocean stations be manned on 1 July the new telecommunication plan would be implemented. It was also agreed as desirable that radio-teleprinter (RTT) communication should if possible supersede the old morse methods and that trials of RTT communication should be carried out.

The new telecommunication plan came into operation on 1 July, and so far as the Bracknell shore station has been concerned the reception and redistribution of observational reports from Ocean Stations 'C', 'L', 'R' and 'M' have been generally successful. RTT trials between Bracknell and Ocean Stations 'C' and 'R' were carried out at intervals from mid September and later in the year with Ocean Station 'M'. The radio equipment on the British vessels, being

rather old, could not be converted for RTT operation, and so Ocean Station 'L' was omitted from the trials. Results of the trials to date have been rather mixed, with a period of very poor radio propagation during November. So far as the Bracknell shore station was concerned, replacement radio transmitters of modern design and higher power were introduced earlier in the year leading to a marked improvement with morse communication, as well as making provision for RTT working later.

In connection with UK proposals to carry out major refurbishment of two of the present group of British weather ships so as to meet our NAOS commitments to about 1981, much time and effort has been directed to planning improvements of the radiocommunication and associated facilities in these two ships. Because of high inflationary costs it has been necessary to go through the plans a number of times with the object of reducing costs to a minimum consistent with future satisfactory technical performance. A formal decision on the refurbishment program is still awaited.

Satellite ground-station receiving facilities

For some time evidence has been growing that the radio-receiving conditions at the Beaufort Park Experimental Site were deteriorating as a result of increasing levels of electrical and radio interference and this has affected adversely the quality of some of the cloud pictures received in recent months from the NOAA 4 satellite. The receiving equipment at Beaufort Park is also becoming old and exhibiting falling performance. In parallel with the clear evidence of the need for much better facilities for the reception of scanning radiometer (SR) cloud pictures, has come a requirement for other satellite-derived data for research purposes, including Very High Resolution Radiometer (VHRR) pictorial information and later on readout from the geostationary satellite METEOSAT to be provided by the European Space Agency. (For a fuller discussion of these aspects see article on pages 65–74). Possibilities for the Meteorological Office to share the excellent site and facilities of the RAE Farnborough satellite receiving station at Lasham offer a solution to these problems and tests indicate that the quality of SR cloud pictures produced by Lasham are superior to those provided by the Beaufort Park installation.

Financial approval was obtained to use the Lasham station for SR cloud picture information and certain temperature data from the NOAA satellites for one year initially, starting on 1 October. It is hoped that further collaboration with RAE Farnborough will enable our future needs for satellite-data facilities to be provided from the Lasham site at a cost much lower than would arise if new installations at a new site had to be provisioned. Independent satellite-receiving installations connected to our various offices overseas must of course remain.

VAP Project for Iceland

Some reference was made in the Report for 1974 regarding our involvement in a large and technically complex project in the WMO Voluntary Assistance Programme (VAP) concerned with Iceland. The European Regional Telecommunication Plan includes a data-speed connection between the Bracknell RTH and the Reykjavik National Meteorological Centre (NMC). In order to implement this connection it is necessary for the Reykjavik NMC to have a

sophisticated (preferably computer-controlled) message-handling system. The UK has a need to obtain observational data from Iceland and Greenland reliably and speedily both for its own national purposes and for prompt clearance to the GTS. Iceland relies largely upon the UK to provide its requirements for meteorological information, including processed data in both coded and pictorial format. It was agreed between representatives of the UK, Iceland and the WMO Secretariat that the Secretariat would act as the management body for the project while the UK would provide the technical expertise. However, owing to instability of prices due to the inflationary situation it became difficult to stabilize on a system design. Further consultation has therefore taken place to finalize a simpler though still effective design and the outcome is that, subject to certain provisos, contracts will be let to a Logica-IBM partnership to produce the Reykjavik NMC automated-telecommunication system. Technical consultation between Logica and ourselves will continue until the system has been produced in the UK, then dismantled, shipped, re-installed and commissioned in Iceland.

INTERNATIONAL AND PLANNING

The development of meteorology and its applications continues on a broad front, internationally as much as nationally. International co-operation is indispensable for daily operations in many fields and there is a need to share experience for mutual benefit. The World Weather Watch (WWW) of the World Meteorological Organization (WMO) comprises the basic system for observation, collection, storage and distribution of data for all general service purposes; and the Global Atmospheric Research Programme (GARP) organizes a comprehensive attack on the main large-scale problems of meteorology. There are many other research problems and specialized arrangements for specialized services besides these major programs. While most of this work is associated with WMO, there are significant meteorological programs associated with the International Civil Aviation Organization (ICAO), the North Atlantic Treaty Organization (NATO) and in the field of European co-operation. Several Specialized Agencies of the United Nations also have meteorological elements in their programs. The main function of the International and Planning Branch is to handle general international matters, largely as a co-ordinator and as a channel of communication, although ICAO and NATO meteorological questions are handled elsewhere in the Office.

The newest inter-governmental meteorological organization is the European Centre for Medium-range Weather Forecasts, which became an independent entity on 1 November on the entry into force of its Convention, some 8 years from conception of the idea. The headquarters are temporarily in Bracknell and will later move to Shinfield Park, Reading. The United Kingdom is also the third largest financial contributor, so the Office has a large interest. The Director-General is a member of the Council, which governs the Centre and represents all the Member States. During the interim period before the Convention entered into force several working arrangements were made with the Centre; these were confirmed by the Council at its first session in November.

The major WMO event of the year was the Seventh World Meteorological Congress which met in May in Geneva. Preparation of the United Kingdom

brief was therefore a major pre-occupation of the Branch in the previous months. The increasing program of operational hydrology in WMO and the widening involvement of meteorology in such matters of international concern as general environmental questions, world food problems and ocean activities, required a correspondingly widening network of consultation nationally. Besides other government departments, scientific institutes and interested groups in some universities are involved as appropriate.

In June following Congress the quadrennial Conference of Commonwealth Meteorologists was held, this time at the Meteorological Office College, Shinfield Park, with visits to Beaufort Park and the Richardson Wing of Headquarters. These arrangements were welcomed by the 19 representatives of 17 countries, most of whom were the directors of their meteorological services (see Plate I). The Conference provided a forum for a valuable exchange of views, the informal discussions being based in most cases on papers by specialists from the Meteorological Office. The organization of the Conference and secretarial duties for it were undertaken by the International and Planning Branch. The opportunity offered by this Conference and the Congress was taken to discuss some of the Branch activities with overseas meteorologists concerned. In addition the Deputy Director of the Meteorological Service of Zambia visited the Branch in June.

Work later began on the planning and organization of a Technical Conference on Automatic Weather Stations scheduled for September 1976 at Reading University. This Conference is being sponsored by the Council of the European Communities under Project 72 of COST (Co-operation in the field of Science and Technology). COST activities also continued in relation to other meteorological instruments and to ocean data buoys in European waters.

Progress was maintained with the implementation of the World Weather Watch Plan as it affects UK-dependent territory overseas. Despite legal problems in 1974 and early 1975 a new rawinsonde station approached completion on Mahé (Seychelles). Following the training of Seychellois meteorological assistants in upper-air techniques, full operation of the station is due to be achieved during the first quarter of 1976. The new unit, led by two members of staff seconded from the Meteorological Office, is then to be absorbed into the Seychelles Meteorological Service, although still financed by the United Kingdom. Construction work began towards the end of the year of the last of the new WWW upper-air stations, that on St Helena. Its establishment, including training of local staff, should be completed in late 1976 or early 1977. This station will remain under the direct control of the Meteorological Office as there is no local meteorological service on St Helena.

Normal service continued at the three upper-air units established in earlier years, those at Bauerfield (New Hebrides 1972) in conjunction with the French Meteorological Service, and on Tarawa (Gilbert Islands 1973) and Funafuti (Tuvalu, formerly Ellice Islands, 1973) under agency control of the New Zealand Meteorological Service. The Bauerfield station, now a part of the Condominium Meteorological Service with senior staff seconded from the United Kingdom, performed particularly well in securing upper-air data from levels of 30 km and higher on 75 per cent of all balloon flights made. The application of a 'localization' policy in the Gilberts and Tuvalu is expected to result in the replacement of New Zealand and UK expatriates on Tarawa and Funafuti by fully trained indigenous meteorological staff in the early or mid 1980s.

Our WWW activities abroad are also concerned with surface observing stations. The program of 3-hourly observations on St Helena was increased from four to seven daily in September following the recruitment and training in UK of extra local staff. The service at the Royal Society Base on Aldabra, British Indian Ocean Territories (BIOT) increased from one to eight observations daily after the attachment of two meteorological observers from the United Kingdom early in the year. Further consideration was given to the establishment of new observing stations on Farquhar (BIOT) and Coetivy (Seychelles) but, after an exploratory visit to them by the Chief Meteorological Officer of the Seychelles in May, it was decided that the problems were not susceptible of solution at a distance by the United Kingdom, and that progress would have to depend on local government initiative.

As regards helping other countries to implement the World Weather Watch Plan in their territories, the several forms of support to WMO's Voluntary Assistance Programme (VAP) and similar bilateral aid, were continued. Equipment was supplied to meet the needs of Belize (radio facsimile), Sierra Leone (radio teleprinter and facsimile), Somalia (radio transmitter, teleprinter and facsimile) and Botswana (single-side-band radios and generators). At the end of the year further equipment was awaiting despatch to Argentina (radio facsimile), Mauritius (wind-finding radar) and the Maldives (meteorological instruments). Equipment was ordered in support of the Regional Telecommunication Hubs in Nairobi (Kenya) and Kano (Nigeria). A joint support scheme to supply Iceland with a computer-based message-switching system was agreed with Iceland and WMO (VAP Fund): contract action started towards the end of the year. In addition a further cash contribution was made to the VAP Fund. This Fund is used by WMO to help eliminate significant weaknesses in the WWW system which are not being dealt with otherwise. University-level training fellowships in the United Kingdom were also provided as in previous years for overseas meteorologists, to ensure to their services a continued supply of high-level scientific staff.

In the Global Atmospheric Research Programme (GARP) the post-operational phase of the GARP Atlantic Tropical Experiment and the accelerating preparations for the First GARP Global Experiment, scheduled for 1978-79, touched on many parts of the work of the Office, as described elsewhere in this Report. GARP is jointly supported by WMO and the International Council of Scientific Unions (ICSU), but its Secretariat is located with that of WMO in Geneva, and the bulk of the work is done by the meteorological services of Members.

The Director-General, as Permanent Representative of the United Kingdom with WMO, represents not only the United Kingdom itself but also its Dependencies other than Hong Kong and those in the Caribbean which have their own Permanent Representatives. Care is therefore necessary to ensure that on the one hand adequate factual information on meteorological facilities and services is passed to WMO, and that on the other hand relevant information and advice from WMO reaches the local administrations. In the latter case the technical advice of the Meteorological Office is added where it is thought likely to be helpful. In agreement with France the New Hebrides Condominium is included in this arrangement. The British Antarctic Survey, which is concerned with meteorology in the Antarctic, and the Directorate of Naval Oceanography and Meteorology of the Royal Navy are similarly served. The nature of the

WWW requirements for upper-air observations in the Antarctic was discussed with the British Antarctic Survey before they decided on grounds of economy to cease making routine upper-air observations at their stations.

A recent enquiry from WMO sought historical data for an interdisciplinary study of the El Niño phenomenon in the Pacific, an occasional change of ocean currents which has devastating effects on fish-catches there and serious chain effects on world grain supplies. The Office was able to reply that data from British ships' log-books for the area are available back to the 1850s. Other marine questions discussed recently with WMO included the collection in one centre and publishing of records of 'freak' ocean waves. The United Kingdom have accepted this task, and has also expressed interest in taking part in developing a world-wide scheme for collecting ocean current data from weather-reporting ships.

J. K. BANNON
Director of Services

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 THE METEOROLOGICAL OFFICE AND OPERATING ON 31 DECEMBER 1975

	Within UK	Overseas
Principal Forecasting Offices associated with the RAF ...	1	—
Main Meteorological Offices associated with the RAF ...	6	5
Subsidiary offices associated with the RAF	32	5
Observing offices associated with the RAF	7	3
Principal Forecasting Offices associated with civil aviation ...	1	—
Main Meteorological Offices associated with civil aviation ...	3	—
Subsidiary offices associated with civil aviation	11	—
Observing offices associated with civil aviation	7	—
Upper-air observing offices	8	5
Public service offices	6	—
CRDF offices	5	3
Port Meteorological Offices	6	—
Offices associated with the Agricultural Development and Advisory Service (MAFF)	3	—
Other offices	26*	3

*Four of these stations are administered by DR Met O

Notes

A Principal Forecasting Office meets the needs of aircraft flying over 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, which was terminated on 30 June 1975, the United Kingdom operated four Ocean Weather Ships which worked in rotation with two ships from France, one ship from the Netherlands and two ships jointly operated by Norway and Sweden. The British ships served at two of the four ocean weather stations in the eastern North Atlantic; each vessel made, on average, four voyages up to the cessation of the ICAO Agreement and spent an average of 24 days on station during each voyage. Some statistics for this period for the British Ocean Weather Ships are shown below.

Total number of days on station ...							345.6	
Total number of days on passage ...							64.1	
								Station I
								Station J
								<i>Average number per voyage</i>
Aircraft contacted							41	125
Number of aircraft given one or more radar fixes							26	86
Weather messages to aircraft							1	7

From 1 July 1975 and pending the entry into force of a WMO Agreement for Joint Financing of

North Atlantic Ocean Stations (NAOS), operating states have agreed the network of ocean weather stations in the central and eastern North Atlantic on an interim basis. To meet its obligations under this interim Agreement, the United Kingdom is operating two weather ships in conjunction with two ships from France, one from the Netherlands, two jointly operated by Norway and Sweden and five from the USSR. The British ships serve at station L (57°00'N, 20°00'W), one of the four stations in the central and eastern North Atlantic. The French ships serve at station R (47°00'N, 17°00'W), the Dutch and Norwegian ships at station M (66°00'N, 2°00'E), and the ships from the USSR at station C (52°45'N, 35°30'W); each vessel will make on average, eight voyages a year and will spend an average of 24 days on station during each voyage.

Some statistics from 1 July to 31 December 1975 for the British Weather Ships are shown below:

Total number of days on station	...	...	...	183.9
Total number of days on passage	...	...	...	35.6

TABLE III—MERCHANT NAVY SHIPS

A total of 7272 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 1975 the numbers of British ships reporting were:

Selected ships	...	...	...	...	...	...	...	...	...	508
Supplementary ships	...	...	...	...	...	...	...	...	...	36
									including 12 trawlers	
Coasting vessels	...	...	...	...	...	...	...	...	...	49
Lightships	...	...	...	...	...	...	...	...	...	14
Trawlers	...	...	...	...	...	...	...	...	...	15
Auxiliary ships	...	...	...	...	...	...	...	...	...	8
Total	...	...	...	...	...	...	...	...	...	630

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

UK to Australasia	...	...	...	...	...	...	...	...	...	54
UK to Far East	...	...	...	...	...	...	...	...	...	86
UK to Persian Gulf	...	...	...	...	...	...	...	...	...	28
UK to South Africa	...	...	...	...	...	...	...	...	...	48
UK to West Indies	...	...	...	...	...	...	...	...	...	29
UK to Atlantic coast of North America	...	...	...	...	...	...	...	...	...	67
UK to Pacific coast of North America	...	...	...	...	...	...	...	...	...	9
UK to South America	...	...	...	...	...	...	...	...	...	18
UK to European ports	...	...	...	...	...	...	...	...	...	31
UK to Falkland Islands and Antarctica	...	...	...	...	...	...	...	...	...	2
UK to distant-water fishing grounds	...	...	...	...	...	...	...	...	...	20
World-wide tramping	...	...	...	...	...	...	...	...	...	130

During two typical days, one in June, the other in November, the numbers of reports from ships received at Bracknell were as follows:

				Reports	
				June	November
Direct reception from:					
British ships in eastern North Atlantic	...	...	...	112	127
Foreign ships in eastern North Atlantic	...	...	...	85	94
British ships in North Sea	...	...	...	20	9
Foreign ships in North Sea	...	...	...	11	7
British ships in other waters	...	...	...	0	1
Total	...	...	...	228	238

Reception via other European countries:							
Ships in eastern North Atlantic	...	...	...	...	...	291	368
Ships in Mediterranean	...	...	...	...	...	48	66
Ships in North Sea	...	...	...	...	...	88	101
Ships off northern Russia	...	...	...	...	...	24	22
Ships in other waters	...	...	...	...	...	189	139
Ships in Pacific	...	...	...	...	...	0	0
Total	...	...	...	...	...	640	696
Reception via USA and Canada:							
Ships in North Atlantic	...	...	...	...	...	604	624
Ships in North Pacific	...	...	...	...	...	714	622
Ships in other waters	...	...	...	...	...	152	304
Total	...	...	...	...	...	1470	1550

TABLE IV—CLASSIFICATION OF STATIONS RENDERING CLIMATOLOGICAL RETURNS

A large amount of data is obtained for climatological purposes from stations which are not part of the Meteorological Office organization. The following table shows how sources of climatological information in the United Kingdom (including Meteorological Office stations) were distributed on 31 December 1975. The areas and titles of the districts are those used in the *Monthly Weather Report*. The boundaries of districts in Scotland have been changed slightly from those used when preparing the similar table in the *Report* for 1974 to bring them into line with the new Regional boundaries which came into effect in May 1975.

				STATIONS SUPPLYING RETURNS				STATIONS SUPPLYING AUTOGRAPHIC RECORDS			
				<i>Observatories</i>	<i>Synoptic</i>	<i>Agrometeorological</i>	<i>Climatological</i>	<i>Rainfall*</i>	<i>Sunshine</i>	<i>Rainfall</i>	<i>Wind</i>
Scotland, north	...	...	...	1	9	1	35	319	25	10	15
Scotland, east	...	...	...	0	10	9	60	575	49	21	12
Scotland, west	...	...	...	1	14	1	52	532	28	22	19
England, east and north-east	...	...	...	0	9	9	26	598	35	11	14
East Anglia	...	...	...	0	11	15	23	588	32	14	14
Midland Counties	...	...	...	0	12	14	39	1403	52	20	17
England, south-east and central southern (including Greater London)	...	...	...	1	14	17	40	878	60	26	19
England, south-west	...	...	...	0	16	8	33	648	37	5	10
England, north-west	...	...	...	0	5	3	23	504	22	10	13
Isle of Man	...	...	...	0	2	0	1	19	3	1	3
Wales, North	...	...	...	0	3	3	16	294	13	3	4
Wales, South	...	...	...	0	10	9	17	417	22	4	6
Channel Islands	...	...	...	0	2	0	3	20	6	0	1
Northern Ireland	...	...	...	0	11	7	47	295	27	45	10
Total	...	...	...	3	128	96	415	7090	411	192	157

* Includes stations in earlier columns.

TABLE V—HEIGHTS REACHED BY 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 balloon reaching
			<i>100 mb</i> <i>16 000 m</i> <i>(approx.)</i>	<i>50 mb</i> <i>20 000 m</i> <i>(approx.)</i>	<i>30 mb</i> <i>24 000 m</i> <i>(approx.)</i>	<i>10 mb</i> <i>30 000 m</i> <i>(approx.)</i>	<i>10 mb</i> <i>30 000 m</i> <i>(approx.)</i>
Eight stations in the UK	...	5818	94·9	82·7	38·2	16·6	57·0
Five stations overseas	...	2999	97·1	85·5	53·4	27·8	70·3
Four Ocean Weather Ships	...	1090	95·9	81·0	24·3	0·4	—

(b) Observations of wind

		Number of observations	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 UK		... 11 453	88.3	64.9	24.1	8.1	53.3
Five stations overseas		... 6 175	93.2	72.1	33.9	13.7	70.8
Four Ocean Weather Ships		... 2 138	87.4	57.0	15.2	0.6	—

Note: 4 Ocean Weather Ships were used to man 2 stations until 1 July when 2 ships were withdrawn. Subsequently 2 ships were used to man one station. See page 33 for details.

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF Network:
In 1975 61 940

TABLE VII—METEOROLOGICAL COMMUNICATION 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 around 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 (mainly coded messages and information in pictorial format) through the Meteorological Office Telecommunication Centre, Bracknell, for one typical day (24 hours) taken in November 1975 and, for comparison, some corresponding figures are given for one day near the end of 1974.*

				In	Out	Total	Total in 1974
				<i>number of groups in one day</i>			
Coded messages							
Land-line teleprinter and data transmission				908 434	951 511	1 859 945	2 248 486
Radio				208 867	202 891	411 758	467 490

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. These inquiries, most of which refer to current or future weather, are listed below according to the purpose of the inquiry.

							1974	1975
Total number of non-aviation inquiries							1 854 387	1 840 820
Percentage relating to:								
agriculture	...	...	...	...	...	...	12·8	10·4
building	...	...	...	...	...	...	5·9	5·2
commerce, industry	...	...	...	...	...	...	5·2	5·3
holidays	...	...	...	...	...	...	22·5	21·1
marine matters	...	...	...	...	...	...	15·8	14·6
Press	...	...	...	...	...	...	10·3	10·7
public utilities	...	...	...	...	...	...	8·9	9·2
road transport	...	...	...	...	...	...	4·5	8·2
other known purposes	...	...	...	...	...	...	5·9	5·9
unknown purposes	...	...	...	...	...	...	8·2	9·4

TABLE XI—FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC and to most Independent Broadcasting Companies for inclusion in their programs 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 1975.

Area						Dense fog	Mod- erate or heavy snow	Heavy rain	Severe inland gales	Winds in coastal waters
Edinburgh and south-east Scotland	...	...	...	...	...	—	—	—	1	—
Glasgow and south-west Scotland	...	...	...	...	...	1	—	—	1	—
Belfast and Northern Ireland	...	...	...	...	...	—	—	—	2	—
Industrial north-east England	...	...	...	...	...	5	—	—	—	—
Industrial Lancashire and Merseyside	...	...	...	...	...	1	—	1	1	—
Industrial Midlands	...	...	...	...	...	1	2	—	1	—
Bristol and Bath	...	...	...	...	...	—	—	1	—	—
South Wales	...	...	...	...	...	—	—	2	1	—
London and south-east England	...	...	...	...	...	—	—	1	—	2
Plymouth and south-west England	...	...	...	...	...	—	2	1	1	3
Yorkshire	...	...	...	...	...	—	—	—	1	—
Southampton and Portsmouth	...	...	...	...	...	—	—	—	—	—
Total	...	...	...	...	...	8	4	6	9	5

TABLE XII—AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

Information Service Centre	Forecast area	Number of calls	
		1974	1975
Bedford	40 miles radius of Bedford	230 551	250 441
Belfast	Belfast	263 197	275 869
Birmingham	Birmingham	780 740	775 888
Bishop's Stortford	40 miles radius of Bedford	70 729	79 735
Blackburn	Lancashire, Cheshire, Greater Manchester and Merseyside	278 739	314 493
Blackpool	Lancashire, Cheshire, Greater Manchester and Merseyside	195 346	159 737
Bournemouth	South Hampshire	334 127	290 144
Bradford	Leeds, Bradford, Huddersfield	117 591	109 758
Brighton and Hove	Sussex coast	548 923	574 982
Bristol	Bristol	533 117	525 484
Cardiff	Cardiff	523 272	483 203
Canterbury	Kent coast	238 092	259 436
Chelmsford	Essex coast	131 932	128 451
Cheltenham	South-west Midlands	104 039	102 360
Chester	Chester and North Wales coast	163 955	141 324
Colchester	Essex coast	200 347	207 368
Colwyn Bay	Chester and North Wales coast	84 007	78 616
Coventry	Birmingham	175 465	196 027
Derby	Nottingham, Derbyshire, Leicestershire	153 081	149 266
Doncaster	Sheffield, Chesterfield, Doncaster, Barnsley	45 438	43 164
Edinburgh	Edinburgh	347 090	349 051
Exeter	Devon and Cornwall	168 404	167 817
Glasgow	Glasgow	536 530	580 622
Gloucester	South-west Midlands	176 229	164 836
Grimsby	North Lincolnshire and Retford area	50 304	50 063
Guildford	London	116 632	121 766
Hereford	South-west Midlands	90 661	82 801
High Wycombe	Thames Valley	90 661	82 801
High Wycombe	Thames Valley	84 528	98 408
Huddersfield	Leeds, Bradford, Huddersfield	72 649	67 057
Ipswich	Norfolk and Suffolk	162 823	175 717
Leeds	Leeds, Bradford, Huddersfield	313 268	352 277
Leicester	Nottinghamshire, Derbyshire, Leicestershire	229 461	251 836
Lincoln	North Lincolnshire and Retford area	65 435	107 281
Liverpool	Lancashire, Cheshire, Greater Manchester and Merseyside	296 582	286 040
Liverpool	Chester and North Wales coast	79 885	46 763
London	London	2 872 434	3 400 531
London	Essex coast	143 914	142 401
London	Kent coast	176 190	169 187
London	Sussex coast	360 625	343 564
London	Thames Valley	151 412	166 656
London	40 miles radius of Bedford	79 468	96 623
Luton	40 miles radius of Bedford	148 393	154 744
Manchester	Lancashire, Cheshire, Greater Manchester and Merseyside	495 834	533 886
Manchester	Chester and North Wales coast	72 252	82 671
Medway	Kent coast	153 720	178 322
Middlesbrough	North-east England	155 969	163 410
Newcastle	North-east England	324 333	348 781
Norwich	Norfolk and Suffolk	215 067	242 250
Nottingham	Nottinghamshire, Derbyshire, Leicestershire	472 917	481 678
Oxford	Thames Valley	199 749	215 205
Peterborough	40 miles radius of Bedford	76 280	85 088

Information Service Centre	Forecast area	Number of calls	
		1974	1975
Plymouth	Devon and Cornwall	214 392	173 963
Portsmouth	South Hampshire	481 822	391 770
Reading	Thames Valley	278 139	242 399
Sheffield	Sheffield, Chesterfield, Doncaster, Barnsley	285 341	300 629
Southampton	South Hampshire	444 636	450 353
Southend	Essex coast	202 944	227 943
Southport	Lancashire, Cheshire, Greater Manchester and Merseyside	53 668	47 569
Swindon	Bristol	43 977	39 048
Torquay	Devon and Cornwall	123 177	137 130
Tunbridge Wells	London	66 110	71 469
Total		16 255 932	16 935 351

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 in various categories.

		1974	1975
Total number of climatological inquiries	... ..	19 561	23 077
Percentages relating to			
agriculture (farming, forestry, market gardening)	...		9.0
building and design (including siting)	... ..		22.8
commerce (sales, marketing, advertising)	... ..		3.7
drainage	... ..		2.8
education and literature	... ..		4.9
flooding	... ..		0.3
heating and ventilation	... ..		3.1
industrial and manufacturing activities	... ..		4.1
law (damage, accident, insurance)	... ..		12.7
medical and health	... ..		1.0
press and information centres	... ..		3.0
research	... ..		8.3
sport, hobbies, holidays	... ..		1.4
transport and communications	... ..		2.5
water supplies	... ..		8.9
miscellaneous (purpose known)	... ..		4.0
miscellaneous (purpose unknown)	... ..		7.5

TABLE XIV—DATA PROCESSING

- (a) Punched-card installation
 - Number of cards punched by the Meteorological Office installation ... 853 174
 - Number of cards punched elsewhere on behalf of the Meteorological Office 186 686
- (b) Processer-controlled keying system
 - The processer-controlled keying (PCK) system was used for data preparation during 1550 hours.
- (c) Computer installations
 - (1) The 360/195 computer was used for computing during 8442 hours.
 - (2) The 370/158 computer was used for computing during 7173 hours (March–December)

TABLE XV—INSTRUMENT TESTING AND CALIBRATION

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

General meteorological instruments*	...	...	...	...	...	...	...	...	50 573
Balloons ...	...	...	...	...	...	...	...	...	84 713
Radiosonde batteries	...	...	...	...	...	...	...	...	24 921
Radar reflectors...	...	...	...	...	...	...	...	...	54 880
Electrical/electronic instruments and systems	...	...	...	...	...	...	...	...	1 078
Electrical/electronic components†	...	...	...	...	...	...	...	...	631 000
Radiosondes Mk 2 calibrated‡	...	...	...	...	...	...	...	...	16 714
Radiosonde elements Mk 3§	...	...	...	...	...	...	...	...	16 901
Total	...	...	...	...	...	...	...	...	880 780

* Includes calibration of 830 precision aneroid barometers, and certification of 5692 mercury-in-glass thermometers and 1142 electrical resistance thermometers.

† In addition, 2020 radiosondes were recovered after flight and stripped of re-usable components.

‡ Includes AF/RF printed circuit boards, humidity transducers, upper and lower aerial assemblies and other Mk 3 radiosonde components.

§ Includes temperature and pressure elements.

SPECIAL TOPIC—UNITED KINGDOM PARTICIPATION IN INTERNATIONAL
METEOROLOGICAL SATELLITE PROGRAMS

Introduction: The use of satellites in Meteorology

Meteorologists have an almost insatiable appetite for observations, partly to satisfy the ever-growing demand for statistical data on weather and climate, partly to develop and test theories of meteorological processes, but above all to enable them to forecast the weather as best they can. Local forecasts for a few hours ahead require a dense network of observations extending for a few hundred kilometres round the forecast area; forecasts further ahead require observations over a greater area, extending to the whole globe for forecasts beyond a week. From the earliest days of planning for artificial satellites it was realized that they could make a great contribution to the supply of meteorological observations. In fact, the first meteorological satellite was launched in 1960 and has been followed by at least 40 others. The observations they provide could, in principle, be obtained by aircraft and balloons, but at a wholly impracticable cost. In practice, satellites provide the only realistic means of obtaining observations with the required frequency and spacing over most of the earth, and even in those parts that are heavily populated and relatively well-provided with observing stations the complete and uniform coverage of observations given by the satellites can be of great help.

The variety and quality of satellite observations have improved steadily over the years. The earliest observations were pictures from television-type cameras, showing clouds, snow, and ice, as well as surface topography. They were used to identify and locate features in the weather pattern such as tropical storms, fronts, and jet streams and, in the most exacting application, to determine wind speed by following the motion of clouds over short (half-hour) intervals. The television-type cameras have now been replaced by scanning radiometers (SR) which have the advantage that they provide pictures by day and night, using infra-red as well as visible radiation. The infra-red pictures can be used to determine the temperatures of cloud tops and of land and sea surfaces. Rather simple local ground stations are employed to receive such pictures, which are always useful in forecasting and occasionally give vital clues to unsuspected developments.

The other main type of observation is the 'sounding' of the atmosphere from above to determine the vertical distribution of temperature and water vapour. This can be done by radiometers which measure the thermal radiation emitted by the atmosphere at well-defined wavelengths close to the absorption lines of atmospheric gases. If the passband is properly chosen, it can be arranged that most of the radiation measured originates within a fairly narrow band of heights in the atmosphere and indicates the temperature in that band. By using a radiometer with several 'channels' at different wavelengths, temperature can be measured over a range of heights. The instrumental requirements for these measurements are severe because of the need to achieve very narrow passbands and to measure very small energies. The first satellite instruments of this type were flown by the USA in 1969 and they have been followed by several improved versions. The wavelengths used have been mainly in the infra-red absorption

band of carbon dioxide at 15 micrometres but other bands have been used too, notably the 5-millimetre microwave band of oxygen; measurements here have the great advantage of being much less affected by cloud than the infra-red ones.

Many other types of meteorological observation can be made from satellites, but are not yet in routine use. Among them are measurements of the roughness of the sea surface, the moisture of the ground, the concentration of ozone and other minor components of the atmosphere, and the location of areas of heavy rain and of thunderstorms. A particularly important study is that of the radiation budget of the earth. Satellites provide an ideal place from which to measure the incoming radiation from the sun (and its possible variations) and also, by means of radiometers with much broader passbands than those mentioned above, to measure the energy radiated outward from the earth.

These remote-sensing methods cannot yet measure all the required quantities—pressure and wind are notable exceptions—so that many observations from sensors located on the earth or in the atmosphere are still required. The last major use of satellites is in the collection of data from such sensors on automatic stations in inaccessible regions of the earth. For fixed stations it is enough to collect data by a straightforward radio link with the satellite, but for stations on drifting balloons or buoys it is necessary also to locate the station, and several methods of doing this from satellites have been developed successfully.

Two types of satellite orbit have been found most useful for meteorological work. The first is a fairly low (1500-km) orbit with high, near-polar, inclination (80°). From this orbit, whose period is about two hours, every part of the earth's surface can be viewed at least twice each day. The second useful orbit is the geostationary one, at a height of about 36 000 km over the equator. From here a satellite can keep continuous watch on a large part of the earth's surface so that changes in quickly developing weather systems can be followed.

The USA have maintained at least one operational weather satellite (in the TIROS* series) in low polar orbit almost continuously since 1960. In addition six satellites in the NIMBUS series have been used to develop new instruments and techniques. Three geostationary satellites (ATS)* have been used in development work and one is still active. The first of an operational series of geostationary satellites (SMS/GOES)* was launched in 1974, in time to make a very important contribution to the international Atlantic Tropical Experiment (GATE). Data from all these satellites are received at a few central stations, processed and then distributed in various forms over conventional communications links. In addition, some satellites broadcast picture data directly in a form that can be picked up by simple receiving stations within range of the satellite. (This service is known as the Automatic Picture Transmission, or APT, service.) The USSR has launched several low-orbit meteorological satellites but has not distributed the data widely.

It is recognized that satellite observations provided by the USA are already making a considerable contribution to the World Meteorological Organization program known as the World Weather Watch (WWW). The WWW is a composite world-wide system for the acquisition and distribution of meteorological data for both operational and research purposes and includes not only observing systems such as the land-based network of surface and upper-air stations but also

* ATS is Applications Technology Satellite, GOES is Geostationary Operational Environment Satellite, TIROS is Television and Infra-red Observation Satellite and SMS denotes Synchronous Meteorological Satellite.

ship, aircraft and satellite-based observations. The Global Atmospheric Research Programme (GARP) which has been developed by the World Meteorological Organization and the International Council of Scientific Unions, will demand very complete sets of observations during restricted periods and the GARP planners consider it essential for the success of the First GARP Global Experiment (FGGE) due to start in 1978 that there should be complete coverage of the tropical belt, requiring four or five geostationary satellites; the two to be provided by the USA will therefore need supplementing and the European Space Agency (ESA, formerly ESRO), Japan and the USSR have announced plans to do so. Long-term requirements will, of course, have to be determined in the light of results from GARP, but it seems likely that a set of four or five geostationary satellites and a pair of low-polar-orbit ones, making the types of observation outlined earlier, will be necessary and sufficient for WWW purposes.

Meteorological Office activities

Since 1964 the Office has received image data broadcast on the APT service provided by the TIROS and, more recently, the National Oceanic and Atmospheric Administration's NOAA series of US near-polar satellites. The pictures are received at Bracknell and at a number of other suitably equipped Office stations overseas. Six other meteorological services have been provided with APT reception stations under the World Meteorological Organization's Voluntary Assistance Programme. The pictures received at Bracknell are distributed to stations in the UK via a land-line facsimile system. Techniques for improving the ways in which these data are displayed are currently under investigation. After digitization the received data will be processed by computer in an attempt to produce pictures more immediately useful to forecasters both at Bracknell and at other stations. For example, the images could be mapped into a polar stereographic projection on the same scale as meteorological charts. The main Meteorological Office satellite reception facility in the UK has recently been transferred from Bracknell to Lasham. This is the first stage in a program to improve and extend the satellite reception capabilities available to the Office. The Lasham facility is based on an existing station operated by the Royal Aircraft Establishment, Farnborough and will be developed in co-operation with that establishment, as described in the Meteorological Telecommunications section of this *Report*.

At present the Lasham station is equipped to receive VHF transmissions from the NOAA satellites including the SR image data and vertical temperature sounding data. The latter data are being used for research on numerical processing of remote-sounding data.

It is planned that additional equipment will be installed to receive S-band broadcasts from the NOAA spacecraft and, in due course from METEOSAT (the European geostationary satellite), TIROS N and subsequent spacecraft. This will make it possible to receive from the American satellites pictures with better resolution (1 km) than those now received and, using the information in digital form, to estimate sea-surface and cloud-top temperatures. From METEOSAT the station will receive pictures covering the European area every half hour and pictures covering the whole area of the earth visible from the satellite every 3 hours. Unfortunately, the British Isles are so far north that the resolution of the METEOSAT pictures of our area will not be very good (about 10 km).

In the 1960s the Office contributed experiments measuring ozone and oxygen to two British research satellites (ARIEL 2 and 3) and was thus able to build up a group of scientists with experience in satellite instrumentation. The Office has also followed closely the development of temperature-sounding instruments at Oxford and Heriot-Watt Universities for flight on the NIMBUS series of satellites, and the analysis of their data. It was therefore well placed to take part in the two programs described in the following section which are now emerging from their development stages. In each of the projects most of the instrument development and construction is being done outside the Office; the main work of the Office has been in project definition, organization and management, and in preparing to deal with the data when received although, in the TIROS N project, in-house effort has been and will continue to be applied to the radiometric calibration of the instrument.

TIROS N

History. The present low-polar-orbit operational satellites of the USA based on the TIROS M design will continue in operation until 1978 at least. Replacement by the more advanced TIROS N design is planned to occur from 1978 onwards but a period of overlap between the two systems is expected. When the broad specification for the TIROS N satellites was drawn up some few years ago it was decided that the three main components of the payload should be a multi-channel imaging system, a location and data-collection system, and a temperature-sounding system. The temperature sounder was to be based on instruments developed in the NIMBUS program, measuring the radiation emitted by the atmosphere at various well-defined wavelengths in the infra-red. About 18 channels (including water-vapour-sensing and 'window' channels) were required for sounding the troposphere. Fourteen of these, sensitive in the near and middle infra-red and with the wavelength selection done by means of narrow-band interference filters, are grouped in an instrument known as the Basic Sounder Unit (BSU). Four others, operating in the 5-millimetre wavelength region, form the Microwave Sounder Unit (MSU). In addition, it was decided that measurements in three or four channels in the 15-micrometre band of CO₂ should be made using the selective chopping principle, as developed by Oxford and Reading (later Heriot-Watt) Universities in experiments on NIMBUS D, E and F. Selective chopping is a method whereby differing amounts of CO₂ are used, as filters within the instrument, to isolate radiation from near the centres of the atmospheric CO₂ emission lines. The emission observed at the satellite from these narrow wavelength regions originates in the stratosphere and can be used to provide estimates of temperature there. It was agreed that the instruments for these stratospheric measurements should be provided by the Meteorological Office, while the instruments for the tropospheric sounding would be provided by the National Environmental Satellite Service (USA). Preliminary specifications defining the instruments and their interface with the spacecraft were drawn up in May 1972 and have gradually been made more definite since. A formal agreement between the National Oceanic and Atmospheric Administration and the Meteorological Office was signed in the summer of 1974.

A contract for the detailed design and development and subsequent manufacture of flight models of the instrument was placed with Marconi Space and Defence Systems Ltd. In August 1975 the first but incomplete model of the instrument was delivered to the Office for radiometric testing and calibration.

Performance matched the design aim. Work will continue towards meeting the target for delivery of the first flight model which is scheduled to be available in the USA early in 1977.

Requirements. The British contribution to the sounding system is now known as the Stratospheric Sounding Unit (SSU). It is required to make measurements of radiance similar to those provided by the selectively chopped channels of the Oxford/Heriot-Watt instrument on NIMBUS E, that is to say with weighting functions peaking in the 1–20-mb region. (The weighting function indicates what fraction of the radiation leaving the top of the atmosphere has originated from each height region.) In comparison with the NIMBUS E instrument, the SSU has many fewer channels but it is required to make measurements at eight angles across the satellite track instead of only vertically downwards, its accuracy (noise level and systematic errors) must be much improved and above all it must be designed and made as an 'operational' not an experimental instrument, with great emphasis on reliable performance.

Design. The pressure-modulation method of selective chopping (suggested and developed at Oxford University) was adopted for the SSU following a detailed study carried out by the Heriot-Watt group of the techniques which had been used in earlier instruments for NIMBUS D, E and F. The radiation to be measured passes through a cell containing carbon dioxide whose pressure can be varied cyclically (≈ 40 Hz). This varies the strength and width of the CO₂ absorption lines and hence modulates the radiation selectively at the CO₂ absorption wavelengths. It can be shown that the weighting function for the modulated component of radiation passing through such a cell has its peak at a pressure height in the atmosphere proportional to the mean pressure of gas in the cell, so that by using cells filled to different pressures, weighting functions peaking at different heights can be obtained.

Because the wavelength selection and chopping are done by the gas itself, the pressure-modulation system is inherently independent of changes in filters, windows and choppers which affect other systems. The most critical part of the design is the pressure modulation itself. This is done by connecting the absorption cell to the head of a sealed cylinder in which a close-fitting piston oscillates. The clearance between piston and cylinder (0.04 mm) is sufficient to avoid contact, wear and friction but small enough to prevent any serious leakage of gas in the period of one oscillation. The piston is mounted on springs and driven by a moving-coil, loudspeaker-type system at its natural resonant frequency, which is largely determined by the mean gas pressure in the cylinder. The general arrangement of the pressure-modulator cylinder and absorption cell are shown in Figure 2.

The optical system is very simple. A plane mirror inclined at 45° to the optical axis (which is horizontal, along the direction of flight) can be rotated to direct radiation into the system from different fields of view on the earth, across the sub-satellite track, or from space or from a calibrating black-body target in the instrument itself. The radiation passes through the absorption cell, whose front window is the objective lens of the system, and the filter to a field lens and light pipe which condense the radiation on to the detector. The detector is an uncooled pyroelectric one (tri-glycine sulphate) of the type used in the NIMBUS E and F instruments and the electronic design also follows the principles used in those instruments.

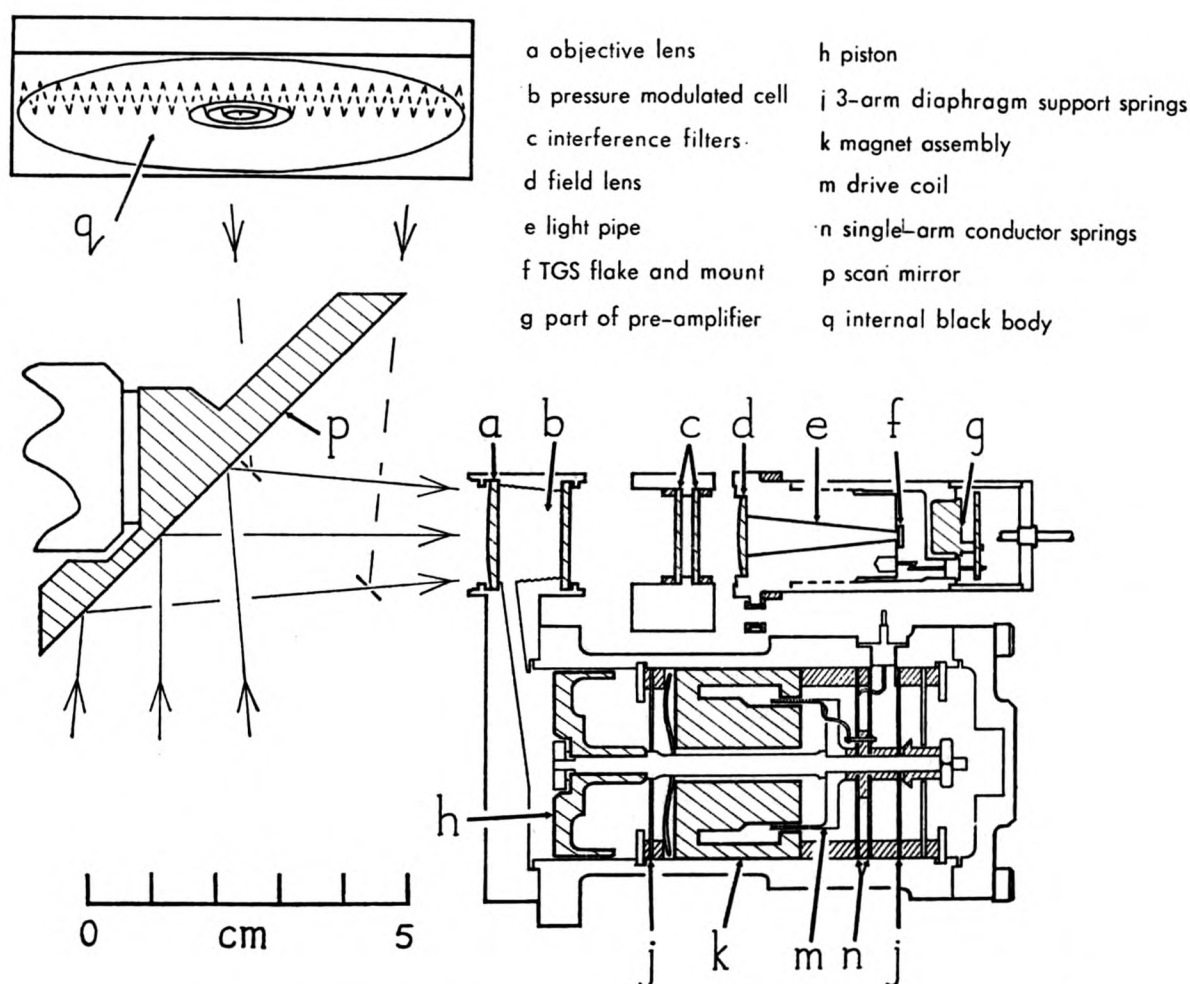


FIGURE 2—LAYOUT OF ONE CHANNEL OF THE SSU RADIOMETER
In practice the scan mirror and black body are shared by three optical channels.

Development. The pressure-modulating system, shown in Figure 2 and Plate II, presented the most difficult problems. Each unit contains 25 ml of CO_2 at a pressure of between 10 and 100 mb, and is required to have a total life of about 5 years. A change of 1 per cent in gas pressure would be serious and a 20 per cent change would probably constitute failure. Water-vapour content must be kept below 0.1 per cent. The materials used, and the method of sealing the system have therefore to be chosen with great care to avoid contamination, leakage or absorption of the CO_2 . Extensive testing was undertaken on two substances—an epoxy used to mount the optics and the polyimide-coated wire of the drive coil—for which insufficient data on CO_2 absorption were available. However, the ultimate test of the design is to monitor a modulator over an extended period. A special life-test model has now been running continuously for six months.

Careful design and testing has also been needed to make sure that the pistons oscillate with constant amplitude and that the electronics handling the signals from the detectors are stable and accurately linear. The detectors themselves—thin flakes of the pyroelectric material tri-glycine sulphate—were at first rather unreliable, but improved manufacturing techniques seem to have surmounted the difficulties.

The components of a single pressure-modulator unit are shown in Plate II together with an assembled unit. Three of these units, with the optical components and detectors are mounted in the 'optics assembly' shown in Plate III

(upper photograph), and this assembly, in turn, is mounted on the main housing which holds the electronics, forming the complete SSU shown in Plate III (lower photograph). The photographs are of the development model, which has been under test since July. It will be followed shortly by the first flight model, which differs only in detail.

Extensive laboratory facilities have been established to permit a full investigation of the radiometric and spectroscopic performance of individual channels and the complete SSU. These facilities comprise a vacuum tank to house the SSU, a variable-temperature target (with an emissivity of 0.999) large enough to fill all eight earth-views and an 8-metre-path gas-cell (for weighting function measurements) together with a data logging system. Digitized data can be recorded serially on magnetic tape, reformed and transcribed to computer-compatible tape by the Office's mini-computer and finally analysed on the COSMOS computer system. A simpler system, without the weighting function facility, is being installed by MSDS Ltd within the clean-room in which the SSUs are assembled.

Future work. Before the launch of the first TIROS N, planned to be early in 1978, the development model will undergo extensive testing to demonstrate that it can survive the severe conditions expected during launch and in orbit. Several flight models will also be completed and tested, both for performance and for ability to withstand their environment; the first will be delivered to the USA early in 1977 for assembly and testing in the complete spacecraft.

Laboratory work will continue on checking the performance of the SSUs and on measuring the transmission properties of CO₂, to improve the accuracy of determination of the weighting functions of the SSU. To check the relation between weighting functions in the laboratory and in the atmosphere a balloon flight of one of the SSU radiometers is being arranged in conjunction with Oxford University and agencies in the USA.

Use of data. The data from a temperature-sounding radiometer consist of a set of radiance measurements made in different spectral intervals and representing a weighted average of the temperatures of different layers of the atmosphere—the weights being determined by the weighting function of each channel. In order to use the data they must be 'inverted' or 'deconvoluted' to obtain estimates of the temperature profile which produced them. The inversion problem is a difficult one and many possible methods of solution have been suggested. No one method is clearly the best in all circumstances; the best method depends, among other things, on the nature of the radiometer data (the number and narrowness of the spectral intervals, the size of the field of view and the noise and other errors in the data), the use to which they are put and the nature and amount of other information which is available about the temperature profiles being observed. To ensure that the Office makes best use of the SSU data and also of data from the rest of the sounding equipment on TIROS N (and, indeed, on other satellites), studies on inversion methods have been undertaken. Data from instruments on the NIMBUS satellites, with weighting functions in the same height range as the SSU, have been used to test various possible schemes for deriving stratospheric temperatures. Comparisons have been made between the radiances observed by the satellite and those computed from conventional meteorological data, which in this case are provided by rocket soundings including some by SKUAS launched from West Geirinish. When TIROS N is launched, it is expected that data from the uppermost channels of the Basic

Sounder Unit and the Microwave Sounder Unit will be needed to supplement the SSU data for the derivation of stratospheric temperatures. Means of obtaining the necessary raw data are under investigation and computer programs are being written to carry out the analysis on an operational basis.

Methods of deriving tropospheric temperatures and humidities, together with cloud height and cover, from radiances observed by the Vertical Temperature Profile Radiometers on the current NOAA operational spacecraft are being investigated.

METEOSAT

History. For a long time European meteorologists and technologists have wished to produce a European contribution to space meteorology. Many projects have been discussed and one, for a satellite very similar to TIROS N, reached a fairly advanced stage of definition. In 1971, however, it was decided that this project represented an unnecessary duplication of American effort and that a far more useful contribution to the world observing system would be a geostationary satellite to provide frequent pictures of clouds and so allow wind velocities to be deduced. This decision, by Directors of Meteorological Services, more or less coincided with a decision by the Council of the European Space Research Organization (ESRO) that they should undertake an 'applications' program with meteorology as one of its three main elements and with a decision by France to attempt to 'Europeanize' her project to develop a geostationary meteorological satellite, METEOSAT. The outcome was that eight of the members of ESRO agreed to develop and launch a satellite based on the French design. The total cost of the project, spread over five years, is about £70 million, the British share being just over one-fifth. The Office took a full part in the discussions which led to the definition and adoption of the METEOSAT program and has continued to play an active role in guiding the development of the project by its representation on the governing body, the Program Board, and also by providing the chairman of the main technical body, the Scientific and Technical Advisory Group.

Outline of project. METEOSAT is intended to be launched by the middle of 1977 and to form one of a chain of four or five (USA, Japan, USSR) similar geostationary satellites which will provide complete coverage of low and middle latitudes. It will be a spinning satellite (100 rev/min) with its axis parallel to that of the earth and its main sensor will be a telescope scanning the earth from west to east by virtue of the spin and from north to south through a mechanism that slowly tilts the telescope system. The telescope will provide a 5000-line picture of the earth's disc at visible wavelengths and a 2500-line one in the infra-red window (11 micrometres) every half hour. The resolution at the sub-satellite point will be about 2.5 and 5 km for the two channels respectively. The pictures will be transmitted at low power and high data rate to a well-equipped central station (near Darmstadt, Federal Republic of Germany). This station, and in particular the part known as the Meteorological Information Extraction Centre (MIEC), will process the data to obtain estimates of sea surface temperature, cloud amount and height and, most difficult, wind velocity, by observing the motion of clouds from one picture to the next. These reduced data will be disseminated by ordinary meteorological telecommunications. In addition, the central station will re-transmit to the satellite a selection of the pictures received, after adding calibration and location data and after suitable changes of format.

These pictures will be broadcast by the satellite (at relatively high power) and can be received by two classes of station known as Primary and Secondary Data Users' Stations (PDUS and SDUS). PDUS will be capable of receiving data at higher rates and with better definition than the much cheaper SDUS. It is expected that pictures received at the PDUS and SDUS will be used qualitatively in forecasting in the same way as APT pictures from polar satellites are now used, but some countries plan to use data received at their PDUS in more quantitative fashion.

The other main function of METEOSAT is to collect and send to the central station data transmitted from 'Data Collection Platforms', probably mainly in remote or inaccessible locations, but also including stations on ships and on buoys or balloons. This system will operate in the 400–460-MHz band and is being designed to be compatible with similar systems in the other geostationary satellites.

Development of satellite. Work on the satellite is directed from an Office established by ESRO in Toulouse. After preliminary studies, a contract was placed with a consortium of European firms in 1974 and work is going ahead as planned to meet the launch date of July 1977. Models of the satellite have been completed and successfully passed tests, and assembly of a flight-standard model is about to begin. The most difficult part of the design is the scanning telescope, a 40-cm mirror instrument capable of tilting smoothly over a range of 18 degrees and using a detector which has to be cooled to 90 K by allowing heat to radiate away to space. Great care is being taken to avoid contamination of the surfaces of the telescope and the radiative cooler because experience with previous satellites has shown that very small amounts of oils, paints or even water, which may diffuse out of the satellite structure and condense on mirrors can produce a very serious loss of performance.

During development the possibility was suggested of adding a third sensor channel, operating at a wavelength of about 6.3 micrometres, to the two (visible and infra-red) originally planned. This can be done with very little disturbance to the existing design and the necessary 'add-on' units are being made, though no final decision has been made whether they should actually be incorporated in the satellite.

Development of ground facilities. METEOSAT will produce very large quantities of data (0.5×10^{10} bits/day), and elaborate ground facilities are needed to extract useful information efficiently. It is intended to do as much as possible of the work at a single central station (at Darmstadt) and to distribute data to individual meteorological services in much-reduced and readily usable forms. The most difficult task is the determination of wind by following the motion of clouds from one picture to another. Whenever possible this will be done automatically by finding, for each small area of picture, the displacement which maximizes the correlation between its cloud pattern and that of the previous picture. The problem is made more difficult because clouds may be present at more than one height, with different wind speeds, and because small movements of the satellite itself may cause an apparent drift of the whole picture; this can be corrected for by observing the apparent motion of suitable geographical features visible in the pictures. Finally, of course, not all clouds move with the wind; they may develop in certain directions or may remain tied to hills or coastlines. For all these reasons it is not expected that a fully automatic system will work in all cases, and arrangements are being made for meteorologists to be

able to monitor the wind-finding process on suitable display consoles and to intervene by using interactive manual methods when appropriate.

To deal with this and all the other data-extraction tasks, a carefully designed computing system is needed. The core of the ground computer complex will be a pair of very powerful computers (ICL 2980) linked to a set of mini-computers and other peripheral devices. Office representatives have played a big part in drawing up specifications and outline designs for this computing complex to ensure that it will meet meteorological needs efficiently and economically.

Summary and conclusions

Satellite observations will play a vital role in the First GARP Global Experiment and in the World Weather Watch program. The satellite system envisaged comprises two components, a set of four or five geostationary satellites above the equator and a smaller number of satellites in fairly low quasi-polar orbits. It is satisfactory that, through the work described above, the Office is making a substantial contribution to both components of the world system. However, the making of observations is not an end in itself, and to get proper benefit from our contribution we must learn to make full use of the data flowing from satellites, not only the data that will come from our own future instruments but also the data available now and in the future from instruments provided by others. A good start has been made, using some of the data available from existing instruments and we are in a strong position to make use of the increased flow of data that will soon come from the station at Lasham and later on from the new instruments in TIROS N and METEOSAT.

PHYSICAL RESEARCH

Cloud physics

The natural processes which control the formation of rain, hail and snow are remarkably complex and are not completely understood. The formation of cloud is caused by cooling of the air which is usually the result of its upward motion and expansion. The pattern of upward air motion controls the shape and structure of the clouds and has a very large influence on the smaller-scale processes which produce the precipitation from it. The air motions in and around clouds are partly driven by large-scale processes in the atmosphere, partly by the irregularity of the earth's surface and partly by the buoyancy of the air when latent heat of condensation is released. The study of these processes is the subject of cloud dynamics.

However, understanding of the air motion in and around clouds is alone not sufficient to interpret and predict the precipitation which falls from them. Condensation of water in clouds takes place as very small droplets or ice crystals some million of which have to combine to form a single raindrop. The study of the processes which make this possible is known as cloud microphysics.

In view of the importance of understanding the factors which control the amount and distribution of rainfall, the Meteorological Office maintains a substantial research effort devoted both to cloud dynamics and to cloud microphysics. Such studies are assuming increasing importance in view of the increasing resources which are being devoted to weather modification by cloud seeding

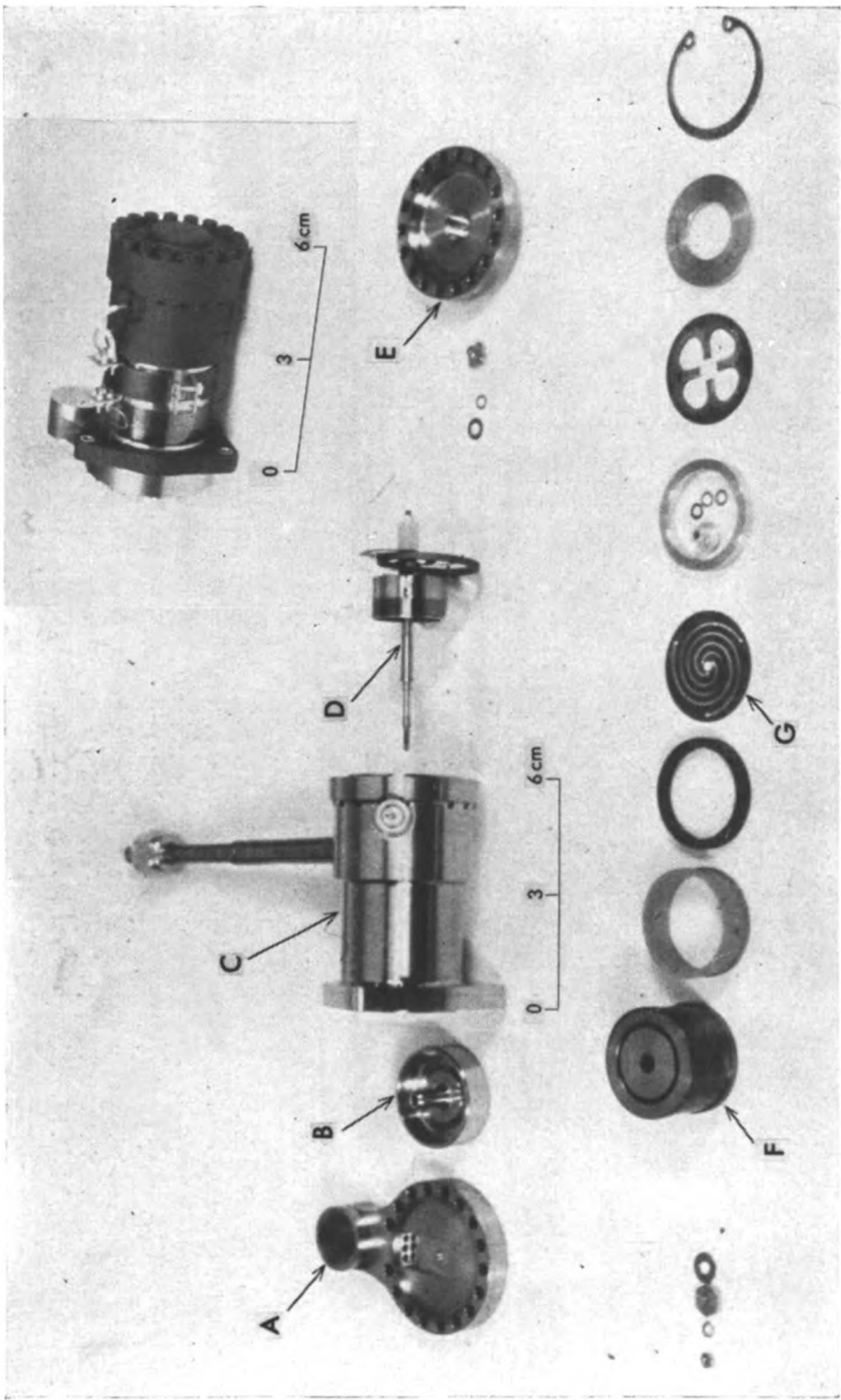


DELEGATES AT THE TENTH CONFERENCE OF COMMONWEALTH METEOROLOGISTS AT SHINFIELD PARK ON 4 JUNE 1975

Standing, left to right: Mr M. E. Mlaki (Tanzania), Mr G. S. Jayamaha (Sri Lanka), Mr Ho Tong Yuen (Malaysia), Mr T. J. Tanner (Seychelles), Dr P. M. A. Bourke (Republic of Ireland, attending as an observer), Mr F. H. Bushby (United Kingdom), Mr G. J. Bell (Hong Kong), Mr N. A. Gbeckor-Kove (Ghana), Mr Ko Ah Guan (Malaysia), Mr R. J. F. Andersson (Botswana), Mr D. E. Jones (United Kingdom), Mr S. N. Gichuiya (Kenya), Mr A. Gilchrist (United Kingdom).

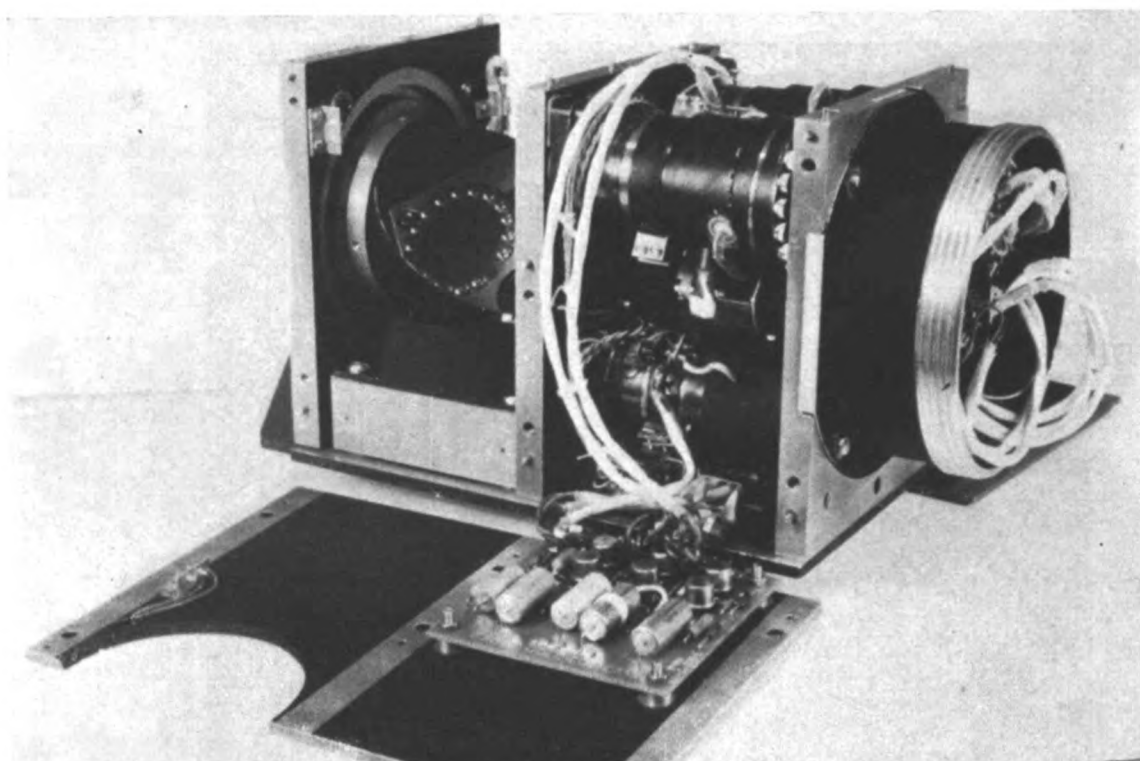
Sitting, left to right: Mr I. W. Lakioni (Malawi), Mr C. E. Berridge (British Caribbean Territories), Mr D. O. Vickers (Jamaica), Dr J. F. de Lisle (New Zealand), Mr J. R. H. Noble (Canada), Dr B. J. Mason (United Kingdom), Mr C. A. Abayomi (Nigeria), Mr I. O. Emore (Nigeria), Mr B. M. Padya (Mauritius), Mr J. H. Catende (Uganda), Mr J. S. Sawyer (United Kingdom).

(See page 100.)

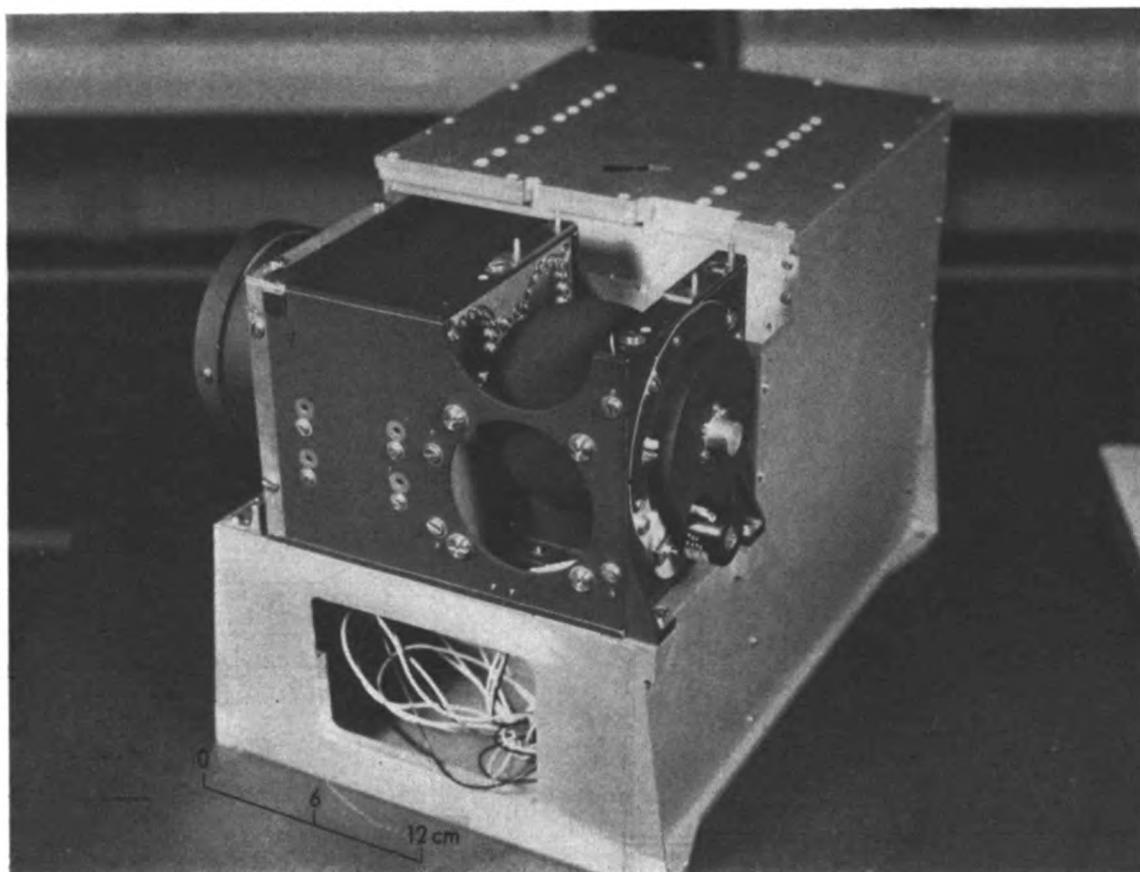


TIROS N STRATOSPHERIC SOUNDING UNIT—COMPONENTS OF A PRESSURE-MODULATED CELL

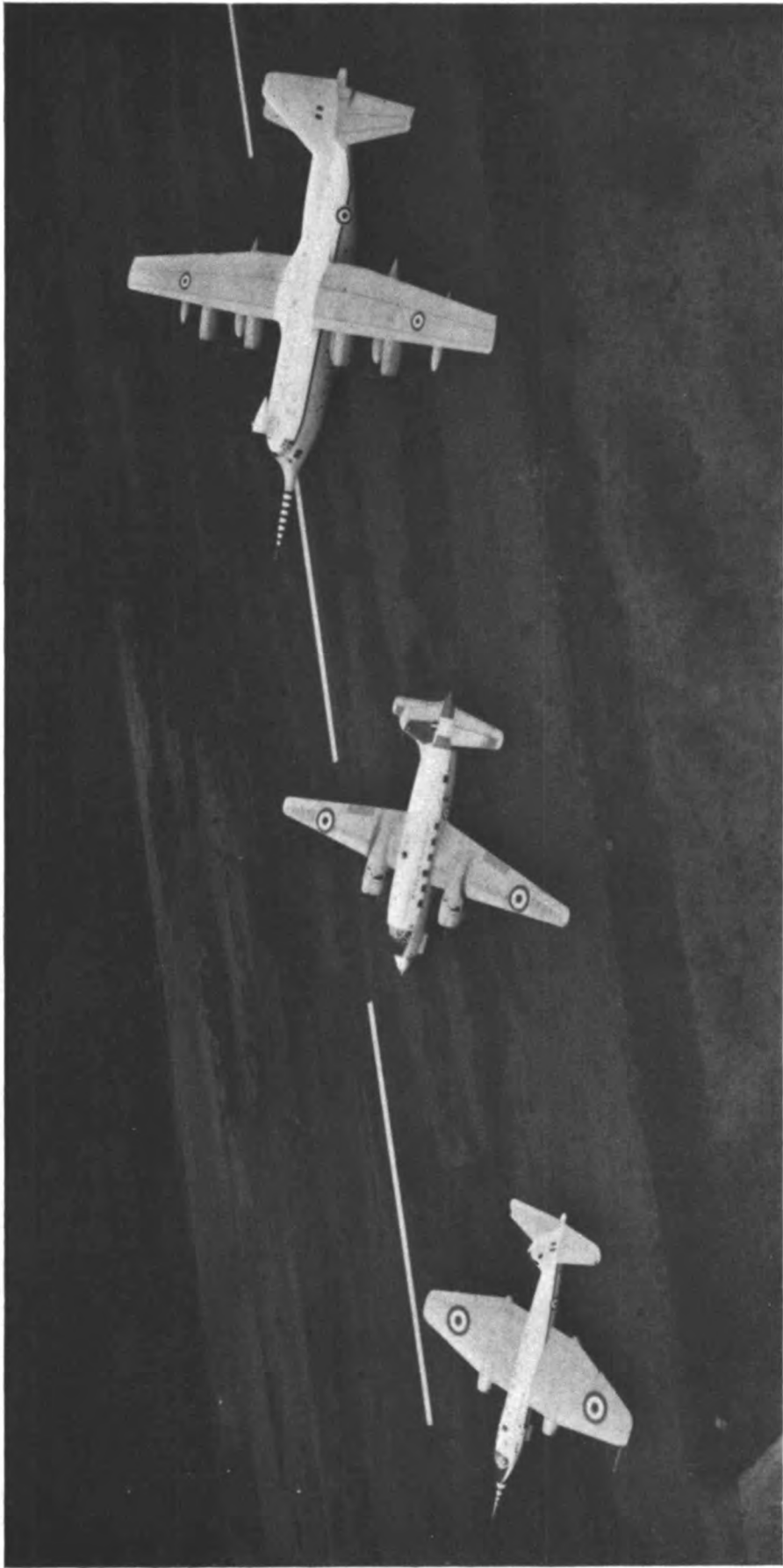
The inset shows a complete unit. The lettered components are: A. Pressure-modulated cell and end flange; B. Piston; C. Cylinder with filling tube attached; D. Coil assembly and conductor spring; E. End flange; F. Magnet; and G. Support spring.
(See page 70.)



TIROS N STRATOSPHERIC SOUNDING UNIT—OPTICS BOX WITH PANELS REMOVED
(See page 70.)



TIROS N STRATOSPHERIC SOUNDING UNIT—COMPLETE ASSEMBLY
The optics box is mounted on an empty development-model electronics structure.
Note. Hole in lower end panel for access—on D1 development model only.
(See page 71.)



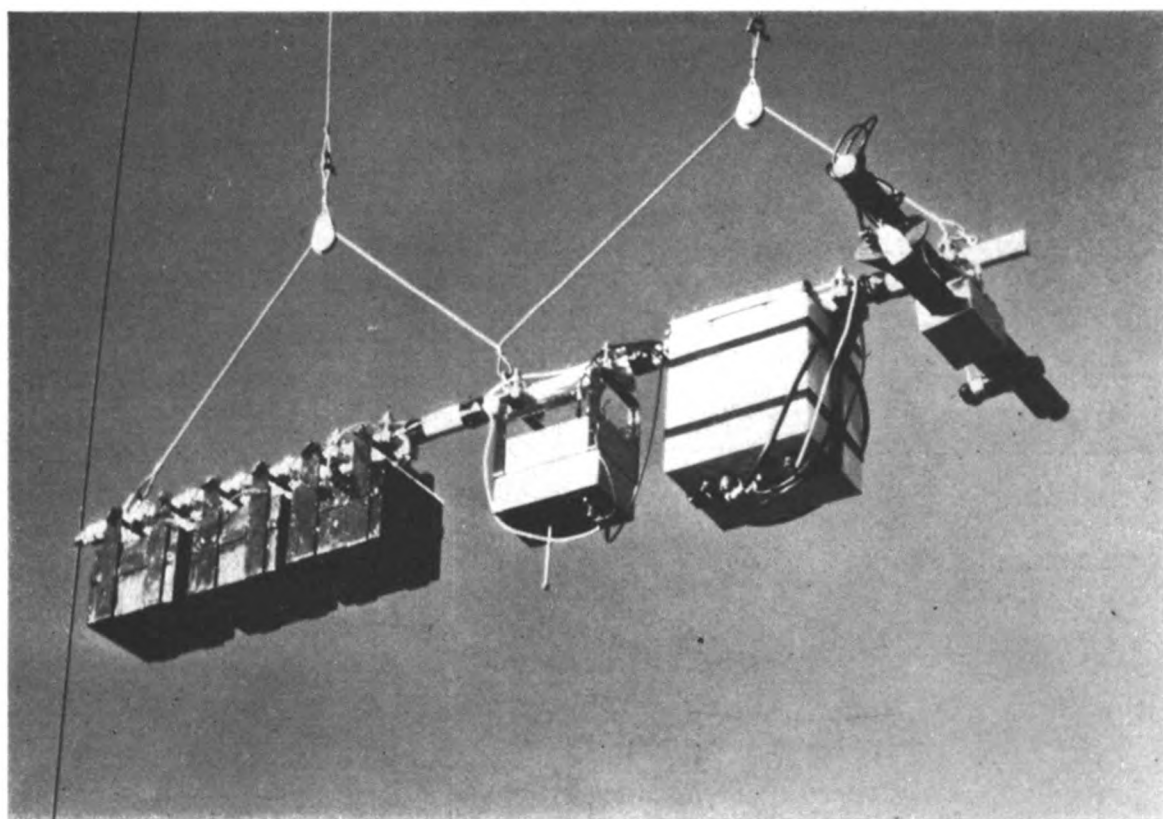
AIRCRAFT OF THE METEOROLOGICAL RESEARCH FLIGHT

Left to right: Canberra, Varsity and Hercules. The Varsity was given up in March 1975 (see pages 81-83).



THE VARSITY OF THE METEOROLOGICAL RESEARCH FLIGHT

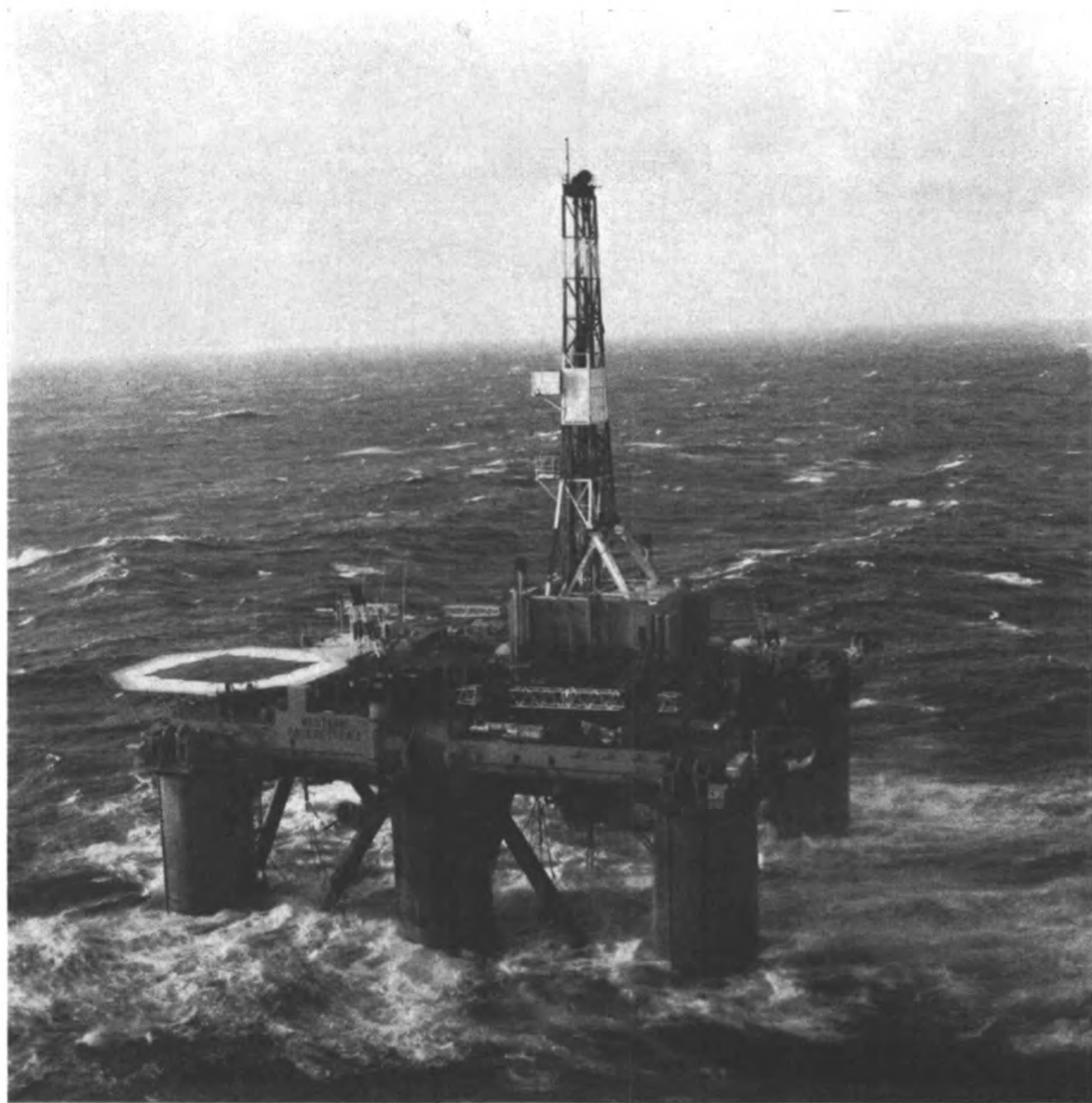
The aircraft, replaced by the Hercules, was given up in March 1975 (See page 81).



KNOLLENBERG PROBE AND TRANSMITTER ON BOOM SUSPENDED FROM BALLOON AT
CARDINGTON

(See page 79.)

PLATE VI



Photograph by courtesy of Western Co. of America Inc.

OIL DRILLING RIG WESTERN PACESETTER I ON LOCATION IN NORTHERN NORTH
SEA



NEW JOINT FINANCING AGREEMENT ON NORTH ATLANTIC OCEAN STATIONS

Sir David Hilyard, K.C.M.G., D.F.C., HM Ambassador and UK Permanent Representative at the UK Mission to the United Nations at Geneva, signing the agreement (subject to ratification) on 12 February 1975.

Seated next to Sir David Hilyard is Dr D. A. Davies, Secretary-General, WMO.

Standing, left to right: Mr Sen Gupta, Personal Assistant to the Secretary-General of WMO, Mr J. J. D. Ashdown of the UK Mission in Geneva, Dr G. K. Weiss of the Operations and Facilities Division of WMO, and Dr K. Langlo, Deputy Secretary-General of WMO. (See page 30.)



Photograph by courtesy of British Aircraft Corporation Ltd.

BRITISH AIRWAYS CONCORDE PHOTOGRAPHED ON TAKE-OFF

in many places in the world. Weather modification has often been attempted on the basis of very inadequate scientific understanding and a proper assessment of the possibilities is badly needed. In addition to laboratory studies of the physical processes involved, the microphysical and dynamical structure of clouds is explored from aircraft of the Meteorological Research Flight and radar is used to examine the cloud structure in three dimensions. These research studies are described in the following paragraphs.

Cloud microphysics

It has long been known that clouds are more likely to produce rain if they contain both ice crystals and water droplets and not water droplets alone. Even down to quite low temperatures most of the initial condensation takes place as water droplets. Hence one of the factors which determine whether clouds rain or not is the number of 'freezing nuclei' present. These nuclei are small particles which allow water droplets to freeze at higher temperatures than they otherwise would, as explained in last year's Report. Considerable uncertainty exists as to the number of freezing nuclei which are present and experiments have been undertaken during the year to improve the techniques of measurements.

One widely used method of counting freezing nuclei in the atmosphere is to draw air through a fine-pore filter and then 'develop' the nuclei on the filter to a size that can be seen. This is done by exposing them to high humidity. Tests of this method have shown that results depend much more than had been thought on the number of nuclei per unit area of filter and suggest that previous measurements may have been underestimating the concentration of nuclei by a factor of at least ten. This has important implications since the number of ice crystals in a cloud often appears to be greater than that expected from the concentration of particles (freezing nuclei) capable of initiating freezing. An alternative explanation of this apparent shortage of freezing nuclei is that in some circumstances droplets when freezing splinter to form more than one ice particle. Experiments have been carried out to test this hypothesis. Recent preliminary results confirm the ice-crystal multiplication when droplets freeze on riming in a narrow range of temperatures near -5°C . However, the degree of multiplication is somewhat less than that found in other laboratories.

One of the major difficulties in research in cloud physics has been that of observing the sizes and distribution of droplets and crystals as they exist in the cloud. Nearly all sampling methods disturb the droplets in the process of collection. For the purpose of overcoming this difficulty the development of a holographic laser system is continuing. The aim is to obtain three-dimensional reproductions of cloud samples with sufficient resolution to allow the size, shape and position of each individual water and ice particle to be determined. A system is now being built so that holograms of cloud droplets can be obtained from an instrument mounted in a special instrument pod near the wing tip of the C-130 Hercules aircraft of the Meteorological Research Flight (MRF).

The holographic system has already shown itself capable of determining the instantaneous position and size of many thousands of droplets from a single exposure. The manual extraction of such a large amount of data from the holograms would be very laborious and time consuming. However, in collaboration with colleagues at the Chemical Defence Establishment, Porton, a means has been devised and tested for automatically analysing the vast amount of data

that this system is capable of yielding. An operational system is being built and will be available for the first flight trials of the aircraft system in 1976.

Cloud dynamics

Hitherto studies of the dynamics of cloud systems have been based mainly either on the use of Doppler radar to measure the velocity of raindrops and snow flakes in cloud, or on the tracking by ground-based radar of small targets dropped by aircraft thereby measuring the detailed structure of the wind. Both systems can be operated only in the neighbourhood of the radar. This places severe limitations on the meteorological systems which can be explored, and makes it difficult to examine rain areas over the ocean where topographic influences are at a minimum.

During 1975 work has been concentrated on a dropsonde system in which the sondes are located by reference to radio-navigational systems. The system can be used from aircraft and will be used in future studies of the dynamical factors controlling the air movement, and temperature and humidity distribution in fronts. It will be possible to deploy the sondes in the areas believed to be most significant irrespective of the location of ground-based radar. The component parts of this dropsonde system which will be mounted on the C-130 aircraft have now been tested in the field and are being manufactured to our detailed specification. The system is such that up to 5 dropsondes may be tracked at any one time, all the necessary tracking and recording equipment being housed in MRF's C-130 aircraft. Ultimately the dropsonde system will, when operated from the aircraft in predetermined flying patterns, be capable of specifying the detailed three-dimensional temperature, humidity and wind structure in an area of several tens of thousands of square kilometres throughout most of the depth of the troposphere.

Meanwhile efforts have been made to account theoretically for the mesoscale-banded structure of frontal precipitation as revealed in past field studies using radar techniques and earlier more primitive dropsondes. The banded structure of frontal precipitation is such that the bands are about 100 km apart and have a typical length of 200–400 km. They tend to be orientated, approximately, parallel to the warm front when ahead of it, perpendicular to the warm front in the warm sector and to a lesser extent parallel to the cold front when behind it.

Work over the past year (in collaboration with Dr Hoskins of Reading University) has shown that many of the features of these rain-bands can be explained in terms of a type of instability in the motion of the atmosphere known as Symmetric Instability. In its simple form, the theory of this instability cannot account for the rain-bands, but by including the effects of latent heat of condensation of water vapour it has been found that areas where the theory predicts instability coincide quite well with those where rain-bands are observed.

Radar meteorology

Study of the modification of rainfall by hilly terrain has continued. Radars at Llandegla in North Wales, Defford in Worcestershire and Castlemartin in South Wales were used intensively for a period of about three months early in the year to obtain data on the effects of the Welsh hills on precipitation. Valuable additional data were made available by the Irish Meteorological Service from their 10-cm radar at Shannon. Radiosonde balloons were flown from Castle-martin and the MRF aircraft was used to obtain more detail of temperature and

humidity on a few occasions. All these observations were combined to give a general picture of the processes at work and to develop and test ideas for predicting the rainfall. These investigations have confirmed the importance of strong low-level wind currents in supplying the moisture which produces the augmented rain over hills which obstruct the flow.

Development of methods of transmitting and displaying information from weather radars continued, in collaboration with staff from the Royal Radar Establishment (RRE) working in the joint Meteorological Office/RRE research unit at Malvern. Data from the radar at Llandegla are now, as a routine, digitized and processed to give estimates of rainfall over 2-km squares. For a period of several months early in the year the Llandegla data were transmitted to the Central Forecasting Office (CFO), Bracknell and displayed there in colour-coded form on a television screen. Several successive pictures (at 15-minute intervals) could be stored and displayed in sequence, so that the movement of rain areas could be followed. Forecasters found the pictures interesting but only limited use could be made of them at CFO because of the rather restricted area covered. A composite picture from several overlapping radars covering a wider area would be of considerable value. The Malvern unit has demonstrated the technical feasibility of producing such composite pictures, and further development work is planned. It is also planned to move the single-radar display to a local forecasting office near a radar site, so that its value in local forecasting can be assessed.

Fog studies

A major study of the physical properties of radiation fog is continuing, making use of the large tethered balloon facilities at Cardington in the winter season. Away from coastal and hilly areas radiation fog is the most commonly occurring type of fog and the practical significance of radiation fog has led on the one hand to the formulation of empirical rules for local forecasting of fog and on the other hand to work, mainly in the USA and France, on methods of fog modification and dispersal. In the UK during the Second World War airfields were kept clear of fog by burning large amounts of paraffin along runways. However, there is a need to place the understanding of fogs on a firmer quantitative physical basis.

In the first phase of the fog project up to the winter of 1974/75 continuous observations were made in a few fogs of wind, temperature, humidity, radiative flux, surface moisture deposition, soil-heat flux, visibility, liquid-water content, droplet-size distribution, condensation-nucleus concentration and the variation of these quantities with height where possible. The results of these observations have been used to develop and test a numerical model of the processes of vertical exchange of heat, water vapour and liquid water. The results are consistent with the view that radiation fog is controlled by a complex interaction between radiative cooling (which encourages fog formation), weak turbulent diffusion (which inhibits fog) and gravitational settling of fog droplets. This latter factor has been neglected in the past and imposes an upper limit to the liquid-water content of the fog.

The main weakness of the first phase is that the observations of drop-size distribution and liquid water content were made only at ground level and it was not possible to monitor (or model) the behaviour and height of the fog top. In the second phase, which commenced at the end of 1975, the interaction of the

wind, temperature and radiation profiles with the drop-size distribution in the vicinity of the fog top is being studied. Specially designed instruments are moved up and down through the fog top. These include a device for measuring drop-size distribution in which droplets drawn through a laser beam are electronically counted and sized according to the amount of light scattered out of the direct beam into a photo-detector formed in an annulus concentric with the beam. The output of this instrument is transmitted to the ground by radio where it is recorded on magnetic tape. (See Plate V, lower photograph.)

Air pollution studies

A great deal of interest has recently centred around the role played by particulate matter in the stratosphere. It has been suggested that particles arising from volcanic eruptions are an important factor in climatic changes because they scatter and absorb incoming solar radiation. Concern has been expressed that the number of such particles may be augmented by human activities, for example by emissions from aircraft and by sulphates formed from sulphur dioxide produced at the ground. An effort has been made to measure directly the absorption of solar energy by particulate matter and gases in the stratosphere with a view to assessing such effects. The sound produced by a chopped solar beam is used as an indicator of absorbed energy. Very sensitive equipment is needed for the purpose. The equipment was flown twice on a balloon launched in France but unfortunately neither flight was successful, through failure of the device which keeps the instrument pointing at the sun.

A careful study was made of the accuracy and representativeness of the measurements of the minor chemical constituents of air and rain which have been made at a few sites for a number of years. The measurements were intended to monitor 'background' pollution at sites remote from strong local sources. The study shows that of the chemical radicals measured, only sulphate is present in sufficient quantity to be reliably estimated by the chemical analysis techniques in use. It is clear that if measurements are to be made to detect possible man-made changes, careful attention will have to be given to the radicals to be measured, the sampling and analysis techniques and the siting of the sampling devices.

The Office has continued to participate in the United Kingdom co-ordinated study of long-range transport of air pollution which is associated with the major investigation by the Organization for Economic Co-operation and Development (OECD) into European sulphur pollution. Over two thousand air trajectories (two each day over 3 years) were determined which represent the passage of air, possibly polluted with sulphur dioxide and sulphates, to one of Europe's most sensitive regions in southern Norway, in order to model the contribution from each of the source areas to that region's sulphur burden. The results of this analysis (which included all the major physical processes such as loss to the ground, washout by rain and chemical conversion in the atmosphere) are broadly confirmed by actual daily measurements taken in southern Norway. Long-range transport appears to provide a significant part of the sulphur deposited on southern Norway, roughly 30 per cent coming from the UK, 10 per cent from the Federal Republic of Germany, and 10 per cent from the German Democratic Republic compared with roughly 17 per cent from Norway itself. There also appears to be some small occasional contribution from North America in trajectories crossing the Atlantic, although this has not been fully confirmed.

A study to determine whether or not the so-called 'high-stack' policy favoured in the UK and in some other countries could be responsible for the very marked increase in acidity of Norway's rivers and lakes in the early 1960s, concluded that it could not; between 1950 and 1970 the continuation of the policy only led to some 5 per cent increase in distant deposition of sulphur attributable to sources in the British Isles.

The atmospheric boundary layer

This year has been a period when large amounts of data collected during major experimental studies made in the preceding two years have been analysed and a start made in trying to interpret them. These experiments, the Global Atmospheric Research Programme Atlantic Tropical Experiment (GATE), the Minnesota Atmospheric Boundary Layer Experiments (MABLE) and the Cardington Atmospheric Boundary Layer Experiment (CABLE) have been described in earlier Reports. All are basically concerned with studying the structure of the lowest kilometre of the atmosphere and the various processes which lead to the evolution and development of the layer. The main problems concern the transport of momentum downward from the atmosphere to the ground and the vertical exchange of heat by turbulent mixing. It is necessary to understand the factors which control the rate at which such transfers take place and the way in which they interact with the vertical profiles of wind and temperature. Already much useful information has been gleaned which is of immediate quantitative value. Other results have proved perplexing and at times contradictory, which only confirms how complex and variable the boundary layer is, and how difficult it is to measure adequately some of its most important properties.

An acoustic sounder has been built and put into operation at Cardington. The sounder emits a series of narrow-beam sound pulses and picks up any echoes from sharp gradients in refractive index in the overlying atmosphere. These gradients may be due to rising thermals, convectively driven turbulence, gravity waves or a marked temperature increase often observed at the top of the boundary layer. The returns, observed by an array of microphones, are displayed to show the variations of temperature-gradient activity with height and time above the sounder. Up to the present one of the principal difficulties has been to deduce the magnitude of the gradients of temperature from the echo intensity with any degree of accuracy. However, the Cardington team have recently compared the small-scale temperature gradients implied by the sounder with those obtained by direct measurements made by a temperature probe on a tethered balloon cable in both unstable and stable conditions. The agreement has proved remarkably good.

Weather ship observations of visibility in strong winds have been used in conjunction with a random-walk turbulence model to estimate spray droplet evaporation rates. Droplet production and evaporation appear to increase very rapidly with wind speed above about 20 m/s; evaporation from spray apparently exceeds that from the sea surface at speeds beyond about 28 m/s and thereafter roughly doubles for each further increment of speed of 3 m/s. The results are rather sensitive, however, to the lower boundary conditions in the calculations.

A comparison has been carried out between winds at Trawsfynydd power station and those at Valley on Anglesey. The power station lies in a mountainous region south of Snowdonia whereas Valley is a well-exposed coastal site only

about 50 km to the north-west. The comparison reveals interesting effects on the Trawsfynydd surface wind which can be linked to local topography. Overall the hills exert a sheltering effect particularly in the stronger wind condition. The most interesting effect is one which is thought to be linked to nearby significant individual hills; there is a tendency for veering and relative strengthening of the surface wind on the leeward side. A possible explanation is that faster-moving air from aloft is brought down to the surface in the lee of a hill.

High atmosphere

The 1974/75 winter Hebrides SKUA meteorological rocket firing campaign which was mentioned in last year's *Report*, terminated in mid February. In all 22 rockets were used and all but 5 provided meteorological data. However the proportion of failures was regarded as unacceptably large. Subsequent investigation and trial firings at Aberporth indicate that the trouble was caused by malfunction in the ejection system for the sonde. It is believed that the slow rate of descent of the spent rocket motor which has been observed on earlier occasions can be attributed to the same malfunction.

The 1974/75 winter campaign was part of an internationally organized investigation of the stratospheric 'winter warming' phenomenon in which rocket stations throughout the northern hemisphere undertook firings (or an increased rate of firings) following the onset of rapid and major temperature increases in the stratosphere. The cause and mechanism of these warmings which affect the stratosphere of the whole of the hemisphere a few times per winter are not fully understood. Our contribution was the provision of 15 complete and 2 partial data sets describing the detailed vertical structure of the atmosphere between about 20 and 60 km. We were able, as a bonus, to obtain 4 of these sets in near time and space coincidence with overpasses of the NIMBUS 5 satellite, thus providing *in situ* measurements for comparison with stratospheric temperatures deduced from radiation measurements made by the Selective Chopper Radiometer aboard that satellite.

Efforts have continued to improve the performance and construction of the rocketsonde itself and to develop a parachute for the effective deployment of the sonde at levels above 65 km. The present parachutes fall too fast.

A paper dealing with the water-vapour content of the stratosphere derived from the measurements of the attenuation of solar infra-red radiation carried out from a SKYLARK rocket launched from Woomera, South Australia was published. The measurements of ozone and molecular oxygen concentration made on the same vehicle continue to give difficulties in analysis. Ozone path totals and vertical concentration profiles have been derived from the descent leg and a comprehensive error analysis has been carried out to determine the limits of confidence of the measurements.

A high-powered dye laser has been in intermittent operation to determine atmospheric scattering profiles in the stratosphere and advantage has been taken of the development of a shorter-wavelength laser to make comparative elastic scattering measurements at two wavelengths. This technique can, in principle, reveal the presence of aerosol layers and delineate regions in which the aerosol mixing ratio is constant with height. Early results are promising. The Junge layer has shown up well and some evidence obtained that the mixing ratio in this layer varies with time. The widely held view that the stratosphere is aerosol-free around 30 km has been shown to be questionable. Less-positive evidence is

accumulating that a shallow aerosol layer exists around 49 km together with an aerosol-free region at about 41 km. However, it is too early to assume that these are permanent features and indeed their existence needs to be verified by further experiments.

No new measurements have been made this year with the equipment to find winds near 90 km in height by radar observations of meteor trails, but a careful theoretical analysis of the whole process of wind-finding has been undertaken, including the interferometric method of determining trail location. It is hoped soon to publish this work, which suggests that many of the difficulties are frequently glossed over.

Ground-based measurements of stratospheric ozone have been made by Dobson spectrophotometers at Bracknell, Lerwick and Gan throughout the year and a new station was opened at Mahé in November as a replacement for that at Gan which will cease to operate in the near future. All results have continued to be submitted to the international ozone data centre. Plans have been made to start similar observations on St Helena in 1976. The observations provide a useful monitoring of the ozone layer in view of the suggestions that the ozone may be depleted by stratospheric pollution from aircraft or the ground.

Satellite projects

Support has continued for two projects, namely the European Space Agency's geostationary satellite, METEOSAT, and the US National Oceanic and Atmospheric Administration's operational near-polar orbiting satellite system, TIROS N. Both these programs and the Office's part in them are described in some detail in the Directorate of Research's Special Topic article on pages 65-74.

Stratospheric analyses

Daily analyses of the stratosphere at the 50-, 20- and 10-mb levels continued throughout the year. The quality of the charts has shown a steady improvement as the experience of those concerned has increased. An exchange of view and methods of procedure with the stratospheric group at the Free University of Berlin became possible as a result of a short attachment by one of the members of the latter group.

A paper on the general features of the stratospheric flow in the 1974/75 winter has been written and submitted for publication and studies have been made of comparisons between the results of SIRS soundings* at 50 mb and those extracted from the 50-mb hand-drawn charts. The differences showed a marked latitudinal variation and were found to vary with the VTPR instrument* in use.

Computer programs have been written to facilitate the production of isentropic charts of the stratosphere which will be used to evaluate daily changes in the vertical velocity field, initially those which occurred during the 1974/75 winter.

Meteorological Research Flight

The Meteorological Research Flight is based at Farnborough and manned by the Royal Air Force. At the end of the year it comprised two aircraft, a Hercules and a Canberra. The Varsity aircraft which had been in use by the Flight for many years was given up in March. The function of the Flight is to carry out meteorological observations for the purpose of atmospheric research.

*Described in the Special Topic report.

A large part of the program is aimed to provide the observations required by other research branches of the Office in the course of their studies of cloud physics, atmospheric turbulence etc. However, studies of some atmospheric phenomena are also carried out by scientists based at Farnborough as part of the establishment of the Flight. The Flight also carries out observations for other government departments and organizations from time to time.

Extensive instrumentation of the Hercules aircraft has continued. In particular, the E290 precipitation radar and its attendant controls, normally used for operational purposes only, have been modified so that control of the radar can be passed to MRF scientists on suitable occasions. The elevation scanning of the radar can now be programmed in the light of the scientific requirements, and the output of the radar, presented on a cathode-ray display similar to that of the pilot, can be photographed by a pair of 16-mm cameras. Provision has been made for an indicator at the first pilot's position such that the aircraft captain is always aware of the radar antenna elevation when control is with the scientist.

The aircraft was detached to Bodø, Norway for two weeks in April/May. During this period flights were carried out over, and to the lee of, the Norwegian mountains to assess the vertical transport of momentum caused by them. For this project, arrangements were made allowing the aircraft to operate both in Sweden and Norway. During the detachment, several flights were also conducted at low level over the northern North Sea to determine the sea-surface temperature structure.

Flights have also been made over the sea nearer home on two of MRF's research projects namely the vertical flux of heat, momentum and water vapour in the boundary layer and the physical and dynamical balance of anticyclonic stratocumulus cloud. Both of these projects involve low-level flying over the sea—sometimes, in the former project, as low as 30 m—and the accurate determination of the various fluxes.

Other new work involving the Hercules includes the assessment of the triggering or enhancement of clear-air turbulence in frontal zones caused by the presence of land, and the collection of air samples in stainless-steel containers in order to determine the concentration of various trace gases, particularly Freon. The analysis of the samples is at present being carried out by the Health Physics Division, Atomic Energy Research Establishment, Harwell.

As mentioned in the section on cloud microphysics, holographic equipment is being fitted to the aircraft to measure cloud droplets. This has involved much design work at MRF and also the construction and fitting out of a special laboratory to test the laser equipment.

The major usage of the Canberra aircraft has been concerned with the installation of the upward- and downward-facing multi-channel radiometers designed and constructed by the Department of Atmospheric Physics, Clarendon Laboratory, Oxford, and the subsequent employment of these instruments to measure the transmissivity of the atmosphere to radiation in various spectral intervals. Following the successful completion of a program of flights over the sea near the UK, the aircraft was detached to Dakar, Senegal for two weeks in October in order to continue the flights under tropical conditions of temperature and humidity. In particular, one object of the detachment was to investigate the radiative properties of the water vapour in very humid atmospheres, and its effect upon the remote determination of sea-surface temperatures from a

satellite. Altogether 13 flights were performed during the detachment, two of which were at night.

Other projects involving the Canberra aircraft include the regular—weekly if possible—sounding of the stratosphere to determine the temporal variation of water vapour and its vertical distribution and, more recently, sampling of air for determination of the Freon (chlorofluoromethane) content.

The Varsity aircraft flew its last experimental mission for MRF on 26 March. Its stay had been extended several times pending the arrival and equipping of the Hercules, but the expense of maintaining an ageing—though still useful—aircraft could not be justified. Up until that time, it had been used extensively on two quite distinct projects, namely the sampling of SO_2 gas at low levels and the investigation of the electrical properties of the atmosphere. The first of these, involving the passing of the outside air through a series of treated filter papers to extract the SO_2 gas has been transferred to the Hercules, but the electrification project, for which sophisticated aircraft-oriented instrumentation is required, cannot so easily be adapted, and work in this field has temporarily ceased.

By far the greatest proportion of MRF ground effort has been concerned with the processing of the data collected by the Hercules aircraft during the multi-national GATE experiment in 1974 during which very extensive data were obtained on the structure of weather systems over the tropical Atlantic. The data are required by one or more of the five international sub-groups, each responsible for one aspect of the experiment, in a preset format after a sophisticated series of quality controls and calibrations have been applied. Progress has been steady but slow, caused firstly by the sheer volume of data collected—the 336 hours of experimental flying yielded more than a thousand million samples of various meteorological parameters—and secondly by the fact that this was the first operational use of the aircraft and there was no previous experience of the new instrumentation. The processing is expected to have been completed by September 1976.

Geophysical fluid dynamics

The high degree of complexity in the atmosphere and the many different physical processes operating in it, tends to obscure some of the fundamental principles which control the large-scale atmospheric motions. The work of the Geophysical Fluid Dynamics laboratory is intended to explore such basic principles which control the motions within rotating fluids of which the atmosphere is one example. Other natural fluid motions in which rotation plays a dominant role are to be found in the atmospheres of the planets, in the oceans and in the interior of the earth. The studies are carried out both by examining in detail the motion of rotating fluids in the laboratory, and also by theoretical mathematical studies. The laboratory systems provide a valuable and severe test of mathematical theory. In the laboratory the experimental conditions can be varied over a wide range and the theories tested thereby in a manner which is not possible if they are applied only to the atmosphere. We cannot change the rate of rotation of the earth to see if a theory continues to apply, but we can change the rotation of the fluid container in the laboratory.

Many features of the large-scale atmospheric circulation can be reproduced in liquid filling a rotating annulus, the inner and outer walls of which are maintained at different temperatures. The transfer of heat by the fluid between

these walls simulates the transport of heat from the equatorial regions towards the poles by the wind systems. The laboratory studies show that several different regimes are possible. The flow may be axisymmetric, it may contain a 'jet stream' with wave-like perturbations or it may be highly irregular. Experimental and theoretical studies have established the conditions under which such regimes are to be expected.

One phenomenon of special interest is known as 'vacillation'. In it a system of wave-like disturbances in the flow undergo a very regular cycle of changes in which their amplitude increases and decreases and their form changes. There are certain similarities with some much less-regular cycles which take place in the atmospheric circulation. The changes which take place in the laboratory fluid during vacillation have been examined by temperature probes placed in the fluid and have shown a remarkable degree of regularity.

Another aspect of the motion in the rotating annulus which has received much study in the year is the effects caused by irregular bottom topography. The use of an axisymmetric sloping bottom surface can be used to simulate the latitudinal variation of the Coriolis parameter on the earth and has provided a means of studying the role of the so-called β -effect under accurately controlled conditions. The disturbance produced by non-symmetric bottom topography in the absence of free baroclinic waves in the fluid is steady and shows a closed horizontal flow pattern centred to one side (the downstream side) of the highest point of the topography. The disturbance amplitude varies with height and is very small indeed in the upper half of the fluid where the general direction of the flow is opposite to that in the lower half. On the other hand when free baroclinic waves are present the topographic disturbance (a) exchanges energy with the dominant free wave as it drifts relative to the topography and (b) extends into the upper half of the fluid. Such effects are clearly relevant to atmospheric behaviour.

Other investigations which have been initiated concern the behaviour of fluid systems when heating and cooling is at the upper surface only, as in the oceans. An experimental system has also been designed in which the fluid motion is driven mechanically rather than thermally. Such a system is in many respects simpler than a thermally driven system, and will make it possible to explore the extent to which aspects of the flow such as vacillation depend on thermal differences.

DYNAMICAL AND SYNOPTIC RESEARCH

Research related to short-range weather forecasting

Currently, routine numerical weather predictions are computed on the basis of representations of the wind, temperature and pressure field at 10 levels in the atmosphere. For forecasts exceeding 36 hours a rectangular array of points is used for the calculations and this covers an octagonal area over most of the hemisphere at 300-km intervals. For shorter-period forecasts a finer grid of 100 km is used over a more limited area.

Efforts have been devoted to studying the operational forecasts and to developing improved techniques. Computational programs have been developed to vary the grid length and the number of levels at which the computation is

performed. Experiments are in progress to determine the effects of changes in the horizontal and vertical resolution on the performance of the forecasts.

An analysis has been made of the success of the numerical model in predicting the movement and development of waves in the flow at mid levels in the atmosphere. As expected this has shown that very long waves are not well handled, by comparison with those that correspond in wavelength to the average depression or anticyclone in middle latitudes. Further investigations are being made by setting up a less complex version of the model, to test its handling of simple atmospheric flow patterns for which there is some theoretical and laboratory understanding. Results so far suggest that errors arising from assumptions at the octagon boundary may be much more significant than had been suspected, and to investigate this further, integrations are being extended to cover the whole of the northern hemisphere.

Various modifications have been tried to improve the representation of physical processes in the 10-level model. The most successful has been the introduction of a procedure to simulate deep convective processes. While having little effect on the isobaric forecasts the scheme results in greatly increased rainfall forecasts in convective situations, especially in summer, and this alteration has now been adopted in the routine forecast calculations. Other changes introduced have been a more realistic handling of the effects of topographic features, alterations to the manner in which exchanges of heat and water vapour between the atmosphere and the underlying surface are introduced, and modifications to the procedure for predicting rain, effective particularly in the early part of the forecast. Experiments are continuing into methods of simulating radiation processes to include both solar and terrestrial radiation. The effect of introducing these effects is likely to be small over short time intervals, but significant when the forecasts run to several days.

Numerical weather predictions provide calculated distributions of pressure, temperature, wind and rainfall. Methods are being explored to improve their utility in regard to the provision of forecasts as required by the public. Worded forecasts are now being printed daily direct from the computer and their quality is being studied. At present the level of phraseology achieved needs further improvement and there are clearly some features, particularly visibility, in which computed forecasts are likely to remain deficient. It is observed also that very intense rainfall is rarely adequately forecast by the model, usually because the rain has been produced by a disturbance of too small a size to be adequately forecast. Attempts are being made to derive statistical relationships involving model parameters which might be used to augment quantitative rainfall forecasts in these situations.

A more direct attempt to study small-scale meteorological systems is being made through a separate model, in which the formulation uses the full basic equations of motion—even sound waves are not excluded. Early experiments with this model have assumed a horizontal grid-length of 10 km, and the vertical resolution allowed for 10 layers between the surface and 4·8 km. Initial experiments have been carried out with a simple version of the model and have attempted to reproduce the structure of sea-breezes over Florida and over the United Kingdom regarding which some data are available. The integrations are promising, though some defects have also been revealed. The program is being extended to accommodate 20 levels in the vertical and a horizontal grid extensive enough to cover the British Isles with a 10-km grid length. Also the predictive

equations are being extended to include more physical processes, and the effects of topography. Integrations carried out with this model will clearly tax the present computer as simulated forecast time and computer time on the IBM 360/195 are likely to be about the same. Experiments are being planned to reproduce lee waves induced by topographic features, and to study the dynamics of cumulus clouds.

The data on which numerical forecasts are based are still for the most part derived from simultaneous observations at standard times. These observations are used to derive computed analyses and there follows an 'initialization' process to derive balanced height and wind fields before commencement of the forecast. Increasing numbers of observations, however, especially those from satellites, are now made at non-standard times and experiments are being made to see if these can be assimilated direct into the forecast procedure. Tests made so far with simulated data have shown that information inserted directly as a correction to the forecast tends to be dispersed and its value diminished. More successful experiments have been made by using statistical procedures to correct the forecast field in the vicinity of new data, and by applying simultaneous corrections to other parameters—for instance when new contour heights are inserted, the wind field in the vicinity is altered accordingly. Research in this area is continuing.

General circulation of the atmosphere

The world-wide circulation of the atmosphere and the climate are determined by physical and dynamical laws which may be expressed mathematically. In principle mathematical integration of the relevant equations could reproduce the observed distribution of winds and weather if the composition of the atmosphere, the energy input from the sun and the state of the earth's surface were specified. However, to do this in practice is extremely difficult because of the enormous complexity of the computations and the need to understand the many processes involved. Nevertheless there is much value in attempting to reproduce the climates of the world by theoretical calculation in this way. Such 'numerical models' of the climate may demonstrate the factors controlling climate and their sensitivity to external influences.

Numerical models which simulate the general circulation of the atmosphere are essentially global weather-forecasting models which create continuously evolving weather situations similar to those of the atmosphere. If the model is run for a long enough time, an estimate of climate (which is the synthesis of weather over a period) can be found. This approach to the simulation of climate, involving its build-up from daily synoptic situations, is adopted because the transient weather systems (depressions and anticyclones etc.) play an essential role in the transport of heat and momentum between latitudes and hence in the processes which determine climate.

The mesh of points over the globe used for calculations in the models is characteristically less than 500 km. Such a fine mesh is needed to achieve a representation of the day-to-day processes which cause the weather. It is also about right for giving a reasonable discrimination in representing the geographical distribution of climates. The relatively fine discrimination of a general-circulation model in both space and time means that climatic integrations require large amounts of computation. Two global models are used in the Meteorological Office for general-circulation and dynamic-climatology studies.

The simpler, which has 5 layers in the vertical and a horizontal mesh size of 330 km, runs at a rate of 5–6 days per hour of central processor time on the IBM 360/195, while for the second which has 11 layers and a horizontal mesh size of about 220 km the rate is about 1 simulated day per hour. The former model has been used in a number of substantial integrations, but the latter is still in a development stage and is being tested mainly in relatively short integrations from real weather situations. Because of its greater vertical resolution the 11-layer model is particularly well suited as a 'test-bed' on which to evaluate schemes for the representation of sub-grid-scale motions in terms of the explicit variables of the model. The inclusion of 3 representative levels within the planetary boundary layer will permit the study of the effects of evaporation and moisture balance at the earth's surface on the larger-scale aspects of climate.

The general-circulation models used so far have been based on finite difference methods in which changes in time are estimated from differences between values on a mesh of grid points. For some time, the possibility of using a finite-element approach has been under consideration. In this, the variables are represented locally by mathematical functions the gradients of which are used in finding the rates of change of the variables. Further substantial progress was made during the year in demonstrating that the method is a serious contender for consideration in future models. Forecasts up to a few days ahead using it have been shown to give results of about the same standard as finite-difference methods using more mesh points, even though features of the method have not yet been optimized.

Typically an estimate of climate is derived from a 'numerical model' by taking the average of pressure, temperature, rainfall etc. as calculated for a period of 30–40 days towards the end of the integration. The results achieved during different integrations with the same numerical model differ because of (a) differences in the condition of the atmosphere at the start of the integration and accidental small errors introduced during the integration, and of (b) systematic differences in the conditions external to the atmosphere which are assumed. Differences of the same nature occur between the same season of different years in the real atmosphere—some inherently accidental and others the result of external influence. Effort has been devoted to evaluating the relative magnitudes of the inherently random and the systematic differences arising from the integrations of the climatic models. It has been demonstrated that the more significant differences between the results from such integrations are substantial and greater than had been previously realized.

Systematic variations arising from sea-surface temperature anomalies have been one of the most rewarding areas for study. In particular the imposition of idealized cold anomalies in the tropical Atlantic has suggested that they may have a substantial effect on West African summer rainfall. There are also strong indications that tropical ocean temperatures have substantial effects on the climate of middle latitudes.

Another important area for sensitivity investigations is in radiative effects on climate. It is widely believed by meteorologists following extensive studies of the atmosphere's radiation budget that cloudiness is a highly significant parameter in determining atmospheric developments and hence climate. A version of the 5-layer model is now available with fully interactive cloud; that is, the cloud amounts which influence the computed radiation exchanges are determined by variables of the model and are not imposed externally. Integrations

in which the formulae for determining the cloud amounts have been varied have shown considerable variation of climate, though, because of the natural variability of the model, it was not possible to assert with confidence that the changes were necessarily significant and were not simply a chance occurrence.

In most numerical simulations of climate it has been assumed that the ocean-surface temperature is known. If one wishes to consider the long-term controls on world climate and climatic fluctuations this is unsatisfactory—the processes which determine the ocean temperature must also be considered. A start has been made on this with a view to extending the modelling of the atmosphere to include the upper mixed layer of the ocean. Taking the surface parameters from an annual general-circulation integration the annual climatological variation of sea-surface temperature and thermocline depth have been calculated making allowance for heat advection by ocean currents. Satisfactory results have been obtained for some areas but in others, particularly in the tropics, the model clearly fails to account for the main oceanic changes.

The 5-level model has also been used in so-called ‘observation-system simulation studies’, the purpose of which is to examine the errors which arise in the specification of the world-wide state of the atmosphere when only a limited network of observations is available. If forecasts are made with somewhat different models these forecasts gradually diverge. These experiments assess how many ‘observations’ are needed to correct one forecast to agree with another on the assumption that the latter is correct. These experiments have confirmed the importance of wind soundings near the equator and surface-pressure observations over the southern oceans in defining the world weather situation. The results have been communicated to the international committee which is planning the First GARP Global Experiment.

Extensive studies have been made of the distribution of non-adiabatic heating of the atmosphere in the 1000–500-mb layer on a daily, pentad, and monthly basis. The geographical distribution of such heating is complicated and major heat sources are chiefly effective in modifying transient air masses whose temperature contrasts sharply with the underlying surface. Nevertheless there is also evidence that in some circumstances large-scale anomalies of sea temperature are capable of intensifying and developing air-temperature anomalies.

The project describing the climatology of the 30-mb level over the northern hemisphere throughout the year was completed and the results are being published as a *Geophysical Memoir*. This includes charts of mean wind, temperature, geopotential and their respective variabilities at all seasons and it also describes the climatology of the quasi-biennial oscillation (QBO) in equatorial stratospheric winds. Further study of the QBO was made and the fact that the tropospheric jet stream appears to be further south in the easterly phase of the QBO for much of the winter and summer was confirmed. It appears, too, from a preliminary study, that the same is true in the southern hemisphere and if so this would mean that the global circulation tends to move southwards in the easterly phase of the QBO.

Further work has shown that it is possible to forecast the phase of the QBO up to two years ahead in some circumstances. This opens the way towards foreshadowing some related circulation changes of importance to climate fluctuations over one or two years ahead.

Possible man-made effects on climate

The special 3-year research program directed by the Committee on Meteorological Effects of Stratospheric Aircraft (COMESA) to investigate possible effects on the human environment arising from projected operations of large fleets of aircraft in the stratosphere was concluded this year and a comprehensive report on this work has been prepared. This program has resulted in considerable advances in our knowledge and understanding of the stratosphere through new measurements of stratospheric composition from aircraft and balloons, new data on basic photochemistry through laboratory studies and improved mathematical models of the complex dynamical and chemical processes that take place. The principal findings of this Committee are that a very large fleet of stratospheric aircraft would be needed to produce a significant effect either on the amount of ozone in the stratosphere or on the climate. Moreover unless the changes were very much larger than predicted it would be extremely difficult to detect them with certainty or assign them to any particular cause against the large natural background variability. Consequently no significant effects are expected from the currently planned operations of the small number of Concorde and other supersonic aircraft expected to be in service during the next one or two decades.

It is recognized, however, that there are still many uncertainties to be resolved before it can be claimed that our knowledge of the atmosphere is sufficient to predict with accuracy all the possible causes and meteorological effects of stratospheric pollution. In addition to emissions from both supersonic and subsonic aircraft flying in the stratosphere, possible chemical sources at the earth's surface which might lead to ozone decrease (such as the release of chlorofluoromethanes or products from increased use of artificial fertilizers) now also appear to require investigation.

The 5-layer model of the atmosphere has been used to assess the probable effect on the world climate of the release of large amounts of waste heat from major centres of nuclear power generation which might be established in the distant future. There has been close co-operation with the International Institute for Applied Systems Analysis, Laxenburg, Austria in these investigations.

Tropical meteorology

During the summer of 1974, the GARP Atlantic Tropical Experiment took place off the West African coast. Many nations took part in this 3-month project, and a vast number of observations were made documenting the tropical atmosphere. To enable scientists to investigate the atmospheric motions which were observed, the data are being collected, checked and assembled in a convenient form. This is a large task which is being shared among five data centres situated in various countries. The UK Meteorological Office accepted responsibility for dealing with 'synoptic-type' data; that is, data describing motions on scales typically hundreds or thousands of kilometres. A 'quick-look' data set has been sent to the two world data centres in Washington and Moscow and also another containing the data collected after the experiment from numerous national meteorological centres on paper tape. These are data sets which have not been fully checked, but which should enable scientists nevertheless to form a good appreciation of the weather situations encountered during the experiment. Many additional observations continue to arrive at Bracknell; some are

from nations which maintained special 'observing platforms' during the experiment, that is, ships or aircraft; others have resulted from the processing of satellite information or from observations collected by commercial aircraft which flew within the area of the experiment. Methods of checking and comparing the data before they are incorporated into a 'final' data set have been devised, and are being tested. During the year, the Meteorological Office team involved in this international task were joined by a Fellow supported by the Natural Environment Research Council.

Investigations of the dynamics of the synoptic weather systems have continued on the basis of the data from the GARP Atlantic Tropical Experiment. The 11-layer numerical model has been used for this purpose and significant improvements have been made over the forecasts prepared during the course of the experiment by means of changes in the treatment of convection and radiative processes.

Research related to long-range forecasting

The regular issue of 30-day forecasts has continued throughout the year. These forecasts are prepared for every calendar month and for each mid-month period and are made available to the Press, television and radio. A detailed document giving not only the 30-day forecast, but also statistics of weather at about 40 places in the British Isles is posted to about 2000 customers who pay a very small fee for this service. The number of customers has shown a modest increase over 1974. The success rate of the forecasts was maintained or slightly improved with three forecasts being assessed as without serious error and several others almost as good.

Although it is not possible to predict day-to-day weather on a monthly time-scale, experimental 7-day forecasts prepared in conjunction with each forecast have usually given useful information for the first week of the period. Techniques are also used regularly to distinguish between the broad character of the weather in the two halves of the month and such information is included in the forecast if noticeable differences between the two halves are expected. In winter the forecasts indicate whether frost, fog, gales and snow are expected to occur more or less frequently than in the 1941-70 period and in summer the number of expected thunderstorms and likely total sunshine hours are related to the same averages.

Research in long-range forecasting remains mainly statistical in character. Perhaps the most significant work this year has been the exploitation of eigenvector techniques. Basically these mathematical techniques break down the highly variable atmospheric patterns into a relatively small number of independent patterns. A particular chart can then be closely represented by about seven of the independent patterns each multiplied by a coefficient and a summation carried out over the seven patterns. Considerable progress has been made in the development of these techniques for forecasting 500-mb anomalies over a fair domain of the northern hemisphere.

Some seasonal (2-month) eigenvector coefficients have been found to have discriminating qualities as early as 5 seasons in advance. For example, in certain parts of the hemisphere it is possible to discriminate in winter (January, February) between the major positive and negative coefficients of certain following pre-winter (November, December) eigenvectors. By matching the current year with historical years in these discriminant regions it appears to be possible to

produce a forecast eigenvector coefficient by analogue. The technique is being tested on independent data for 1975 with encouraging results.

A number of improvements and extensions have been made in the system of cataloguing the daily and monthly weather situations. These catalogues which extend back well into the last century are used in the selection of analogues for the current weather situation and in numerous investigations in which fluctuations in the atmospheric circulation are examined in regard to their interrelations in time and space.

A study was made of the relationship between the cool summers in central England occurring in an even year such as 1974 and the nature of the subsequent winter. This followed the chance discovery of an interesting relationship presumably related to the well-known biennial oscillation that winters in central England after such a summer tended to be extreme, either in a warm or a cold sense. In fact no average winter followed the 19 such summers in the period 1873–1972. Significant differences in surface-pressure patterns were found in summer and the subsequent October and November between those cool even summers followed by a cold winter, and those followed by a mild winter.

Research related to long-range forecasting and climatic change requires a large amount of past meteorological data both as space-time fields and as long time series for individual stations. During the year new data sets of monthly mean sea and air temperatures on a global basis from 1949 to 1969, have been produced from a data set comprising some 8 million marine cards. A further data set of some 32 million marine observations received from US sources has been made available during the year and is being used to extend the monthly series back to the late nineteenth century.

A series of monthly climatological records was also received from US sources and is being used to produce time series of certain elements for over 2000 stations on a global network with records over the period from the 18th century to 1970. Data for 1971–73 have been added to these records and continuous updating from incoming data is planned.

A data set containing monthly mean temperature anomalies over the northern hemisphere 1891–1970 was obtained from the USSR and a method has been devised for producing simulated monthly charts of 500 mb and 1000–500-mb thickness for the northern hemisphere 1891–1944 from these data and from surface pressure data.

Because of the unique nature of our data bank and its relative ease of access, due to the standard formats employed, parts of it remain in constant demand from other national meteorological services and universities all over the world. In 1975 sales or exchanges were completed or in hand with countries including the USA, Canada, USSR, Spain, Poland, France and Switzerland.

Climatic change

In view of the recent sequence of mild winters in Europe a comparative study of the circulation changes between the 1960s and 1970s was carried out and the results presented at the international conference on climatic change in Norwich in August. The main findings were that in the 1970s the Arctic had warmed slightly and the area of snow and ice in the northern hemisphere had decreased. At the same time the pressure gradient between the Arctic and the sub-tropical anticyclones had increased, partly on account of lower pressure in

the Arctic but also due to a small mean displacement northwards of the sub-tropical high in the Atlantic sector. At the same time, however, a cooling of about 0.2 degC was detected in the latitude band 40°–60°N in the 1970s compared with the 1960s.

The relation between the meridional thermal gradient and the zonal westerlies has been the subject of study. Although an increased temperature difference between equator and pole is necessarily accompanied by a greater increase of the westerlies with height, there is no evidence that an increased meridional thermal gradient leads to increased westerlies at the surface. Although some interesting correlations were found in particular sectors of the hemisphere, they did not support the idea of a simple cause-and-effect relationship. The zonal surface westerlies appear to be rather insensitive to the meridional thermal gradient over the hemisphere as a whole and do not closely mirror the seasonal changes in polewards transfer of sensible heat.

A study of rainfall in the West African marginal rainfall areas for the period since 1855 showed that the longer periods of marked rainfall deficit have occurred at roughly 30-year intervals. A longer period of about 60 years was also indicated, with very severe droughts in 1910 to 1914 and probably in the years around 1860. There are significant relations between the rainfall of this area and pressure and flow patterns at the surface and at upper levels over the North Atlantic and western Europe both at the height of the rainy season itself and also in the precursor months April and May.

The Meteorological Office is co-operating with the Climatological Research Unit at the University of East Anglia in a study of rainfall fluctuations in the British Isles with a view to ascertaining the extent to which they may be predictable by statistical methods. The study will include the establishment of a number of homogeneous long-period records of rainfall back to at least 1830 and the study of interrelationships with other aspects of the European climate.

There has been renewed interest in a number of scientific and popular journals in apparent relationships between weather fluctuations and various indices of solar activity. A number of studies have been carried out with a view to clarifying these elusive relationships. Although some apparently significant correlations have been achieved, solar relationships can only explain at most a small part of the variance in meteorological and crop-yield series and have little or no predictive value. There are also disturbing indications that the solar series and terrestrial series do not maintain a constant phase relationship.

Special investigations

The development of Concorde has posed many questions relating to meteorological conditions in the stratosphere and the route-proving flights carried out during the year revealed that certain atmospheric conditions could affect the operation of the auto-pilot. The Office participated in a special series of flights based at Kuala Lumpur to study the problem and many hours of flight data were analysed to try to identify the meteorological conditions and the likely location in which the difficulties might be encountered. Work was completed on the analysis of flight data to estimate the probability of encountering severe and sudden changes in temperature which might affect the engine performance and the results were reported to the Airworthiness Division of the Civil Aviation Authority.

Clear-air turbulence (CAT) is still a cause for concern in aviation circles and an investigation to determine the best meteorological index for forecasting CAT has been completed. This was based on a large number of reports of CAT obtained from pilots during a few days in the spring of 1972 and the indices were obtained from the 10-level model used in routine forecasting. The results showed some promise and plans are being prepared for a new series of observations in the spring of 1976.

A problem of increasing concern to airlines is the occurrence of large wind shears in the lowest 100 metres of the atmosphere. On approaches to airports aircraft have experienced difficulties which have been attributed either to changes with height of the mean wind speed or to large predominantly horizontal wind shears on the glide slope. Data on both types of wind shear are being assembled and analysed.

Analysis of photographs and observations of radar echoes from storms in the Gan and Singapore areas has continued throughout the year with a view to providing estimates of the probability of aircraft encounters with cumulonimbus clouds at various heights in the tropics. Work has also been started on a project to find the best meteorological index for predicting severe thunderstorms in the south of England.

Other limited investigations have included the preparation of reports on weather in the sea areas around the British Isles in connection with helicopter operations, advice on problems in air pollution, anomalous radio propagation and storm tide surges and the preparation of appreciations of the weather at aerodromes and on air routes.

A small team helps and encourages investigations carried out at outstations mainly in relation to problems involving local weather. Computer services for the provision of data and various forms of analysis as well as guidance and detailed constructive criticism have been supplied to investigators.

GENERAL ACTIVITIES OF THE RESEARCH DIRECTORATE

The Meteorological Office continued to work closely with a number of national and international bodies which are concerned with meteorological research. The Office provides representatives on a number of research-oriented committees of the Royal Society, the Natural Environment Research Council and the Science Research Council. In the international field, scientists from the Office serve on several working groups of the World Meteorological Organization and of the International Association of Meteorology and Atmospheric Physics.

Dr R. J. Murgatroyd attended hearings held by the US Federal Aviation Authority in Washington on 14 and in New York on 18 April in order to give evidence on the effect on the ozone layer of proposed flights by the Concorde aircraft. He also gave testimony on 21 May to the Congressional Committee on the Environment in regard to the possible effects of more general human activities on stratospheric ozone.

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

The Committee also advises on a number of small university research projects which are directly supported by the Meteorological Office; these number five in addition to five placed through the Gassiot Committee of the Royal Society.

During the year five members of university staffs worked in the Office as consultants for short periods. Also one research scientist from overseas carried out research in the Meteorological Office for an extended period during which he was supported by his home institution.

LIBRARY, PUBLICATIONS, ARCHIVES AND CARTOGRAPHIC SECTION

The National Meteorological Library forms part of the Meteorological Office Headquarters at Bracknell. It is used mainly by staff of the Office, but also meets a large demand for its services from universities, schools, commercial and industrial firms, and the general public.

The number of items classified and catalogued (which includes all relevant journal articles) reached a new record. The number of loans showed little change from recent years, but a reader/printer for microfiche and microfilm was acquired to meet an increasing demand for use of these media. Some figures representative of the work of the Library are given in Table XVI on page 98.

Students from library schools have visited the Library, in groups or as individuals, in the course of their practical work. Staff of the Office have continued to participate in the facilities offered by the Association of Special Libraries and Information Bureaux (ASLIB) and the Circle of State Librarians.

Collaboration continued during the year with the Systems Development Branch in their investigation into possible automated systems for cataloguing and other library work. In order that any future computerized cataloguing system should be able to operate as easily as possible using standard keyboards only, a change was made on 1 June in the method of transliterating Cyrillic alphabets into Roman characters. The ISO/R9 system previously employed was replaced by the joint system of the British Permanent Committee on Geographical Names (PCGN) and the US Board on Geographical Names (BGN); the PCGN system is now used for all cataloguing work and in all publications.

The Editing Section remained responsible for the preparation for printing of most official publications of the Office and co-operated closely with Her Majesty's Stationery Office (HMSO) in the maintenance of publishing standards. It also produced the 'proceedings' of the COVOS/COMESA Anglo-French symposium held at Oxford on the effects of stratospheric aircraft.

Works published during the year are listed in Appendix III; these include the *Meteorological Magazine*, a monthly journal containing short scientific articles, reviews, and items of interest to meteorologists everywhere.

The Cartographic Section prepares diagrams for Meteorological Office publications, for internal memoranda, and for papers contributed to scientific journals 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. The preparation of data-entry

forms, exhibition displays, lecture and training viewfoils and slides is undertaken together with the reprographic action necessary for printing these and other miscellaneous items.

Some statistics showing the extent of the work carried out by the Cartographic Section are given in Table XVI.

PROFESSIONAL TRAINING

Policy on both professional and management training of staff is determined by the Meteorological Office Training Board under the chairmanship of the Director-General. Professional training of staff is done almost entirely within the Office, either at the Meteorological Office College, Shinfield Park, near Reading or the Technical Training School at Beaufort Park, near Bracknell.

The number of students on courses at the College was maintained at a high level, and for two short periods during the year residential accommodation at the College was insufficient and some students had to live out. The Scientific Officer Course for graduates with high honours, which started in the autumn had 21 students, with one each from Malaysia and Cyprus. The course is intended for those going initially into pure and applied research, but because course members are expected to play a leading part in the operational, consultative and administrative work of the Office as their careers develop, some course members spend a period in operational forecasting when the course has finished. The Applied Meteorology Course was instituted in 1973 for promotees and new entrants with graduate qualifications and/or Higher National Certificate. Members will spend much of their career in applied meteorology, including forecasting. This course was well supported, with 32 students including one from Libya.

On the Initial Forecasting Course there were 42 students and it is thought to be the biggest IFC ever to have been run by the Meteorological Office. The basic qualifications for this course are 'A' level in Mathematics and Physics, for, although the minimum qualification for recruitment direct into the SO grade is HNC, a number of promotees to SO still have only the 'A' level qualifications.

The Initial Forecasting Course is not only a complete course in its own right but also forms an integral part of the Sandwich Course in meteorology which leads to an honours B.Sc. degree of the University of Reading. The Sandwich Course extends over three and a half years and attendance at the University alternates with periods of training in the Meteorological Office. The Sandwich Course is particularly attractive to overseas meteorological services for it provides professional training in the practical aspects of weather forecasting as well as the university meteorological degree studies. The first two students have now successfully completed the course, one with first class honours. Several overseas students who are registered at the Geophysics Department of Reading University attended the IFC as part of their preliminary studies for their M.Sc. degrees.

The Meteorological Office Training Board decided that developments in meteorology as a science and as a profession were advancing so rapidly that

forecasting staff should have further training or refresher courses at intervals of 5 to 10 years. The courses involved are:

- (a) The Advanced Forecasting Course, which prepares the forecaster for a more responsible role than he has been following since his first forecasting course;
- (b) the Extension Course. This is a refresher course which also includes some basic statistics to enable a forecaster to conduct minor research investigations into the weather at his own station or local area; and
- (c) the Senior Meteorologist's Course, which gives more experienced meteorologists a broad view of meteorology and the Meteorological Office.

The instructor staff at the College was increased by one Principal Scientific Officer to ensure that the standard of instruction was maintained at the highest level.

Courses for Assistant Scientific Officers changed little this year. There are courses for those going into synoptic work and for those who are to work in research or Headquarters Branches and need a course in basic meteorology. The course for officers newly promoted to the Scientific Officer grade in a supervisory role, which was inaugurated in 1973, is now well established in the College curriculum. More specialized courses include the Meteorological Statistics Course, the Tropical Meteorology Course and the Mediterranean Meteorology Course and these have continued to be well attended. A number of one-week courses have been provided for Air Traffic Controllers required to make weather observations at aerodromes, and for observers who are not members of the Meteorological Office but who, coming from many walks of life, man the Auxiliary Reporting Climatological Stations. Enquiries concerning courses should be addressed to the Principal, Meteorological Office College, Shinfield Park, Reading RG2 9AU. At the request of Marine Exploration Limited, the training of ships' officers in the making of observations was carried out on board three of their ships and an observing course was run for the company at Cowes, Isle of Wight, by a member of the College staff. College staff co-operated with the Royal Society by attending boards to select two meteorologists to serve on the island of Aldabra, and one was trained in observing at the College.

The College has continued to be used by a number of outside organizations for meetings and conferences, and this included a two-week conference in September by the European Centre for Medium Range Weather Forecasts.

A number of special courses were arranged for students sponsored by overseas governments or by WMO under VAP or UNDP funds. There was an increase in the demand by overseas governments for meteorological technicians to be trained to various levels in handling mechanical, electrical or electronic equipment, and in the maintenance of meteorological instruments. These programs were arranged with the Technical Training School at Beaufort Park, and use was made of the Training Services Agency Skillcentre in Cardiff for training in some basic skills.

Radio (Met) Technicians are largely recruited from the ASO grade. Trainees are given a 6-month basic electronics course at RAF Sealand and a further 6-month course at the Meteorological Office School of Technical Training at Beaufort Park, which is concerned with the theory and operation of all electronic and electrical equipment used by the Office. A further 5 months

of an RMT's training are taken up by practical training in the field. During the year courses were given on 13 types of instrument and were attended by MOD (Navy) personnel and overseas students as well as Meteorological Office Servicing Organization staff.

A small radiosonde and radiowind training school is maintained at Beaufort Park and here 13 members of the staff received training in techniques for using the radiosonde and the Cossor wind-finding radar. A further member of the staff, destined for the new World Weather Watch upper-air station at Mahé, Seychelles, was trained in basic radiosonde techniques and radiowind techniques using the Plessey WF3 radar.

Table XVII contains further details of courses completed in 1975 at the three Meteorological Office training establishments. The overseas students were sponsored by their own governments, by WMO, or by British Technical Assistance. In addition to those listed in the table, one overseas student sponsored by the United Kingdom under the Voluntary Assistance Program of WMO successfully completed his Ph.D. studies at Reading University and another his Sandwich Course studies. Six continue to study on the Sandwich Course and four continue with higher degree studies. There was one award under the program in 1975 and this was for higher degree studies at Reading University.

The number of staff given release for part-time study, mainly at technical colleges was 268 during the year and in addition 26 members of staff are taking Open University courses and receiving assistance under the further education scheme. Twelve members of staff have been given either full-time release with pay for university studies or to attend Sandwich Courses, and four have taken advantage of a scheme under which scientists can continue to work in the Office while studying for a Ph.D. under the joint supervision of the Office and a co-operating university.

J. S. SAWYER
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY, ARCHIVES AND CARTOGRAPHIC SECTION

Library

Publications received:									
Daily weather reports	...	...	...	...	...	...	...	...	12 815
Books, journals etc.	...	...	...	...	...	...	...	...	7 621
Slides and photographs	...	...	...	...	...	...	...	...	436
Individual books, pamphlets, articles etc. classified and catalogued	...	...	...	...	...	...	...	...	9 411
Publications lent (excluding internal 48-hour loans):									
Daily weather reports	...	...	...	...	...	...	...	...	10 359
Books, journals etc.	...	...	...	...	...	...	...	...	16 774
Slides and photographs	...	...	...	...	...	...	...	...	7 761
Number of exchange agreements	...	...	...	...	...	...	...	...	372
Number of pages translated by library translators	...	...	...	...	...	...	...	...	1 117
Russian 751, German 275, French 91									
Number of pages translated by freelance translators	...	...	...	...	...	...	...	...	156
French 59, Japanese 48, Russian 25, Hungarian 10, Italian 6, Czech 5, German 3									

Archives

Number of loans	2 132
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Cartographic Section

Number of diagrams, maps and charts completed during year	2 932
Number of reprographic jobs during year	...	...	...	...	...	...	...	371

TABLE XVII—TRAINING

The following figures give details of courses completed during 1975 at the Meteorological Office training establishments at Shinfield Park and Beaufort Park.

	Number of courses	Length of course in weeks	Number of students
Scientific Officers	1	26	23
Applied Meteorology	1	22	36
Initial Forecasting	1	18	42
Advanced Forecasting	4	7	30
Extension Course	3	4	27
Senior Meteorologists	2	3	48
Meteorological Statistics	1	4	7
Tropical Meteorology	2	3	19
Mediterranean Meteorology	2	3	3
SO (Supervisors)	5	4	47
Auxiliary and Co-operating Observers	8	1	106
Basic Meteorology (Assistant Level)	2	4	16
Initial Assistant	10	4	93
Advanced Assistant	5	6	46
Air Traffic Control Officers	2	1	11
Meteorology for Technicians	2	2	20
Radiosonde (Initial)	4	9	12
Radiosonde (Refresher)	1	4	1
Electronics	1	18	6
Technical Updating	12	2	47
Total			640

INTERNATIONAL CO-OPERATION

At the Seventh World Meteorological Congress (Geneva, 28 April to 23 May) the Director-General, Dr B. J. Mason, led the United Kingdom delegation, which included Mr H. E. Davies, Secretary of the Office, Mr G. J. Day and Mr D. G. Harley, Assistant Director (International and Planning) as well as Captain R. K. Alcock, RN, Director of Naval Oceanography and Meteorology, Mr O. Gibb, Director of the Central Water Planning Unit, Reading, and others. The Congress amended the WMO* Convention to cover operational hydrology and other activities related to meteorology, and decided the WMO program and budget for 1976–79. New programs approved include an agrometeorological program in aid of food production and a study to design a major experiment aimed at obtaining scientifically convincing answers concerning the feasibility of precipitation enhancement.

The 10th Commonwealth Meteorologists' Conference was held at the Meteorological Office College from 3 to 6 June. There were 19 participants from 17 countries overseas. Dr B. J. Mason and Mr J. S. Sawyer, Director of Research, between them chaired the informal sessions in which a number of Office staff took part. Participants also visited the operational areas of the Richardson Wing, and saw the latest activities in instrument development at Beaufort Park.

The Council of the European Centre for Medium-range Weather Forecasts (ECMWF) met in London, 4–6 November, immediately after its Convention came into force. Dr B. J. Mason with Mr A. Thorp (Finance, Ministry of Defence), represented UK, supported by Mr D. G. Harley, and others. Dr Mason also attended the previous Interim Committee session in Brussels in February. Mr F. H. Bushby, Deputy Director (Dynamical Research) took part in the Interim Scientific Advisory Committee meeting in June, and Mr E. Slater in the Finance Committee session in London in October. A planning meeting in London in June, on the Centre's data and telecommunication requirements, was attended by Mr G. A. Corby, Deputy Director (Communications and Computing), Mr G. R. R. Benwell, Assistant Director (Central Forecasting) and Dr R. L. Wiley, and a scientific seminar organized by the Centre at Shinfield Park in July was attended by Mr C. D. Hall, Dr J. R. Raftery and Dr D. A. Forrester.

The other European meteorological projects under the scheme for co-operation in science and technology (COST) are developed through a technical committee on oceanography and meteorology. Mr M. J. Blackwell, Assistant Director (Operational Instrumentation) and Mr G. A. Clift between them attended five meetings of the committee or its sub-groups in Brussels or in Petten, the Netherlands. Mr J. E. Wright took part in radiosonde laboratory trials near Paris in January, and Mr K. J. T. Sands in the program committee planning a conference on automatic weather stations to be held in Reading in 1976.

The growing importance of meteorological satellites calls for much international co-ordination and planning. The development of the Meteorological Satellite program of the European Space Agency required meetings of the

*A list of abbreviations used in this section, and their meaning, is given on page 107.

Program Board in Paris in January, February, June, September and November attended by Dr Mason and Dr K. H. Stewart, Deputy Director (Physical Research). Dr Mason took part in meetings of Directors of the meteorological services of the States involved in June, September and November. Dr Stewart attended eight meetings in France, and Mr D. E. Miller two in Darmstadt, on the scientific and technical aspects of the program. The development in the UK of the stratospheric sounding unit for the American TIROS-N satellite program was reviewed at meetings in Washington, DC in February and July, and at Bracknell in November, where Mr G. P. Carruthers and other staff of the High Atmosphere Branch took part. On more general aspects of meteorological satellites, Dr N. E. Rider, Assistant Director (High Atmosphere), attended the WMO 5th co-ordination meeting on geo-stationary satellites in Geneva in April, and Mr B. R. May attended meetings advising on the co-ordination in Europe of reception and evaluation of information from satellites, in Rome in February, and Sweden in September.

Activities in connection with the Global Atmospheric Research Programme continued at a high level. In the post-operational phase of the GARP Atlantic Tropical Experiment an informal meeting on data management in Geneva in January was attended by Mr E. A. Spackman and a meeting in Bracknell in February on the Synoptic Scale sub-program was attended by Mr A. Gilchrist, Assistant Director (Dynamical Climatology) and Mr Spackman. Dr B. J. Mason as Chairman and Mr F. H. Bushby attended the 7th Session of the Tropical Experiment Board, in Geneva in February. Mr J. S. Sawyer took part in the 11th Session in Tokyo in October of the Joint Organizing Committee (JOC) for GARP and Mr Bushby took part in meetings of the JOC Working Group on Numerical Weather Experimentation, in Washington in April, Reading in August and Paris in November.

Mr G. A. Corby represented the United Kingdom at the Second Session of the WMO Intergovernmental Panel for the First GARP Global Experiment (FGGE) in Geneva in September. There were other meetings on special aspects of FGGE. Mr E. J. Bell, Assistant Director (Telecommunications) went to a planning meeting on data management in Washington in April. Dr N. E. Rider consulted with the Joint Planning Staff in Geneva in April and took part in a meeting on planning tropical observing systems in Washington in July, and Mr G. J. Day, Assistant Director (Observational Requirements and Practices) attended a similar meeting on drifting ocean buoys at Shinfield Park, also in July.

Dr B. J. Mason also attended the 5th informal meeting of Directors of European Meteorological Services, held in Rome on 12 and 13 March. By invitation he took part in the Nobel Symposium at Spatind, Norway from 8 to 12 September, whose theme was 'The impact of space science and applications satellites on mankind'.

A scientific Symposium on Long-term Climatic Fluctuations, sponsored jointly by WMO and the International Association of Meteorology and Atmospheric Physics, was held at the University of East Anglia, Norwich, from 18 to 23 August. Mr J. S. Sawyer, Mr R. A. S. Ratcliffe, Assistant Director (Synoptic Climatology), Mr A. Gilchrist, Assistant Director (Dynamical Climatology) took part together with six of their staff.

In anticipation of the new North Atlantic Ocean Station scheme being implemented on 1 July 1975, new telecommunication arrangements were

developed at a meeting in Geneva in February. Mr E. J. Bell represented the United Kingdom. From 9 to 11 June, representatives of the governments which had been represented at the 1974 Conference which prepared the agreement met in Geneva to consider the situation on ratification, and further action. Mr. N. Bradbury, Deputy Director (Observations) represented the United Kingdom.

Mr Bradbury also represented the United Kingdom at the 4th joint session of the WMO Executive Committee Panel on Meteorological Aspects of Ocean Affairs with the Intergovernmental Oceanographic Commission's Working Committee for IGOSS (Integrated Global Ocean Station System) in Paris in February. Mr H. C. Shellard, of the Climatological Services Branch represented WMO at the meeting in Rome in May of the IOC Working Committee on International Oceanographic Data Exchange, and Mr G. J. Day was invited by WMO to join a sub-group of experts on IGOSS Basic Observational Network Design meeting in Paris in December. Mr R. A. S. Ratcliffe was invited by WMO to become a member of the Advisory Committee on Oceanic Meteorological Research, and took part in its session in Geneva in November.

Other WMO meetings, or joint WMO meetings with other international bodies, in which Meteorological Office staff took part, were as follows:

<i>Subject</i>	<i>Place and date</i>	<i>Attended by</i>
CMM Working Group on Marine Climatology	Geneva January	Mr H. C. Shellard (Met O 3)
WMO/CoSAMC Working Group on Climatic Fluctuations and Man	Geneva January	Mr M. K. Miles (Met O 13)
Bilateral UK/Republic of Ireland Co-ordination Meeting on Telecommunications Facilities between Bracknell RTH and Dublin NMC	Dublin January Bracknell March	Mr E. J. Bell, Assistant Director (Telecommunications) Mr D. McNaughton Mr R. J. Sowden Mr R. Ross (Met O 5) Mr C. E. Goodison (Met O 5)
Informal Planning Meetings USA, UK, France, Germany on Main Trunk Circuit Transmissions	Paris February	
WMO/IAMAP Symposium on Education and Training in Meteorology and Meteorological Aspects of Environmental Problems	Caracas, Venezuela February	Mr D. E. Jones, Assistant Director (Professional Training)
WMO Technical Conference on Automated Meteorological Systems	Washington, D.C. February	Mr D. J. Painting (Met O 16)
7th Session of GATE Tropical Experiment Board	Bracknell February	Mr D. E. Parker (Met O 20)
2nd Meeting of Informal Advisory Group for GATE Synoptic Scale Program	Bracknell February	Mr D. E. Parker Mr S. F. G. Farmer (Met O 20)
4th Session of EC Panel of Experts on Meteorology and Economic and Social Development	Tunis March	Dr P. G. F. Caton (Met O 3)
CAeM Working Group on Briefing and Documentation Practices	Geneva March	Mr C. H. Hinkel (Met O 7)
WMO IPM on the VAP Project for Telecommunications Automation within the Reykjavik NMC	London March Geneva September	Mr E. J. Bell, Assistant Director (Telecommunications) Mr C. E. Goodison Mr J. D. Lunn (Met O 5) Mr E. J. Bell

<i>Subject</i>	<i>Place and date</i>	<i>Attended by</i>
IUGG—XVIth General Assembly	Grenoble, France August/September	Mr F. H. Bushby, Deputy Director (Dynamical Research) Dr R. J. Murgatroyd (Met O 20) Mr P. Graystone, Assistant Director (Forecasting Research) Mr P. Goldsmith, Assistant Director (Cloud Physics) Miss M. J. Atkins (Met O 11) Dr R. Hide (Head of Met O 21) Mr D. E. Miller (Met O 19) Dr R. J. Murgatroyd (Met O 20)
WMO/CAS Working Group on Stratospheric and Mesospheric Problems	Geneva September	
RA VI Working Group on Collection of Observational Reports from Ships by Coastal Radio Stations	Geneva October	Mr D. McNaughton (Met O 5)
4th International Comparison of Regional Working Standard Pyrheliometers	Davos, Switzerland October	Mr H. E. Painter (Met O 1)
Advisory Committee on Oceanic Atmospheric Research	Geneva November	Mr R. A. S. Ratcliffe, Assistant Director (Synoptic Climatology)
JOC Study Group Conference on Four Dimensional Data Assimilation	Paris November	Mr R. Dixon (Met O 11) Mr A. Lorenc (Met O 20)
UNEP/WMO Meeting on Weather Modification	Geneva November	Mr P. Goldsmith, Assistant Director (Cloud Physics)
CBS Study Group on Coded Digital and Analogue Facsimile	Geneva December	Mr E. J. Bell, Assistant Director (Telecommunications) Mr C. E. Goodison (Met O 5)

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

<i>Subject</i>	<i>Place and date</i>	<i>Attended by</i>
Air Force Technical Applications Center Meeting	Patrick AFB, Florida January December	Dr F. B. Smith, Assistant Director (Boundary Layer)
Study Group II meeting NATO MCMG, Working Groups on Plans and Communications	Brussels January	Mr C. E. Goodison (Met O 5)
46th Australian and New Zealand Academies of Sciences Congress	Canberra January	Dr R. J. Murgatroyd (Met O 20)
Mariner, Jupiter, Saturn Science Team Meetings	Pasadena, Calif. January March May July September December	Dr G. E. Hunt (Met O 20)
Tenth Meeting of ICAO MOTNE Regional Planning Group	Paris February	Mr J. E. Skilling (Met O 7)
AMS—Third Symposium on Meteorological Observations and Instrumentation	Washington, D.C. February	Mr A. H. Hooper (Met O 1)
NATO Science Committee	Brussels February	Mr J. S. Sawyer, Director of Research

<i>Subject</i>	<i>Place and date</i>	<i>Attended by</i>
4th CIAP Conference	Boston, Mass. February	Dr R. J. Murgatroyd (Met O 20) Dr A. F. Tuck (Met O 20)
Meeting at AFCRL to discuss the Minnesota Experiment	Boston, Mass. March	Dr S. J. Caughey (Cardington)
16th Radar Meteorology Conference	Houston, Texas April	Dr T. W. Harrold (Malvern)
41st Meeting of NATO Meteorological Working Groups on Plans and Communications	Amsterdam April	Mr J. C. Gordon (Met O 6) Mr C. E. Goodison (Met O 5)
AFCENT Meteorological Committee—23rd Meeting	Berchtesgaden April	Mr W. G. Durbin (Met O 6) Mr G. A. Cowling (Met O 6)
Energy and Climate Meeting	Laxenberg, Austria April	Mr. A. Gilchrist, Assistant Director (Dynamical Climatology)
Anglo-French Committee on Engine Emissions	Paris April	Dr R. J. Murgatroyd (Met O 20)
Federal Aircraft Authority Hearings on Concorde's Environmental Impact Statement	Washington, D.C. and New York April	Dr R. J. Murgatroyd (Met O 20)
European Space Agency Solar System Working Group	Paris April	Dr G. E. Hunt (Met O 20)
International Astronomical Union Symposium on 'Jupiter, the Giant Planet'	Tucson, Arizona May	Dr R. Hide (Met O 21) Dr G. E. Hunt (Met O 20)
Joint Meeting of NATO Panels X and XII	Brussels May	Mr M. J. O. Dutton (Met O 9)
Conference on Mesoscale Modelling	Las Vegas, Nevada May	Dr M. C. Tapp (Met O 11)
ICSU Committee on Space Research (COSPAR)	Varna, Bulgaria May/June	Dr N. E. Rider, Assistant Director (High Atmosphere)
NATO Co-ordination Group for Tactical Weather Network—20th Meeting	Rheindahlen May	Mr E. Cayhill (Met O 6) Mr N. Holdsworth (Met O 6) Mr C. Alderson (Met O 6) Mr P. G. Rackliff (Met O 6)
NATO Co-ordination Meeting for International Exercise	London May The Hague, The Netherlands December	
Mountain Wave Investigation and Sea Surface Temperature Survey	Bodø, Norway May	Meteorological Research Flight
Meetings of the A B C A Armies Quadrupartite Working Group on Meteorology	Ottawa May	Mr G. F. W. Clapp (Met O 6)
Meetings on Long Range Transport of Air Pollution Experiment	Cardington, Beds. May Oslo August	Dr F. B. Smith, Assistant Director (Boundary Layer)
Congressional Environmental Subcommittee	Washington, D.C. May	Dr R. J. Murgatroyd (Met O 20)
Inter Micro '75 Conference	London June	Mr R. Bexon (Porton)
Working Group on JONSIS	De Bilt, The Netherlands June	Mr M. J. Blackwell, Assistant Director (Operational Instrumentation)
Third Workshop in Atmospheric Acoustics	Toronto June	Mr H. A. Douglas (Met O 16)
NATO MCMG 32nd Meeting	Brussels June	Mr E. Evans, Assistant Director (Defence Services) Mr J. C. Gordon (Met O 6) Mr C. E. Goodison (Met O 5)

<i>Subject</i>	<i>Place and date</i>	<i>Attended by</i>
NATO MCMG Working Groups on Plans and Communications Study Group I Meeting	Oslo June Bracknell July	Mr C. E. Goodison (Met O 5)
7th International Biometeorological Congress	Washington, D.C. August	Miss M. G. Roy (Met O 8)
Consultant on use of weather radar to measure precipitation	Tehran Sept./Oct.	Dr T. W. Harrold (Met O 16)
4th International Conference on Wind Effects on Buildings and Structures	London September	Dr P. G. F. Caton (Met O 3)
European Research Office Panel on Mesometeorology	Garmisch September	Dr P. W. White (Met O 11)
NATO Advanced Study Institute 'Modelling and Prediction of the Upper Layers of the Ocean'	Urbino, Italy September	Dr J. F. B. Mitchell (Met O 20)
Meteorological Panel (Panel XII) of NATO Group AC/225 12th Meeting	Fort Monmouth, N.J. September	Mr G. F. W. Clapp (Met O 6)
CENTO Meteorological Co-ordination Conference	Ankara September	Mr E. H. C. Donophy (Met O 6)
NATO/CCMS Meeting on Air Pollution Modeling	Frankfurt September	Dr F. B. Smith, Assistant Director (Boundary Layer)
NATO MCMG 42nd Meeting of the Working Groups on Plans and Communications	Bruges October	Mr G. A. Cowling (Met O 6) Mr C. E. Goodison (Met O 5)
Meeting on Liaison and Planning for JASIN 1978	Hamburg October	Dr N. Thompson (Porton)
Investigation of the radiative properties of the water vapour dimer at low levels and also of cirrus cloud	Dakar October	Meteorological Research Flight
10th International Aerosol Conference	London October	Mr P. Goldsmith, Assistant Director (Cloud Physics)
Commissioning of Ozone Spectrophotometer	Mahé, Seychelles Oct./Nov.	Mr J. H. Convery (Met O 19)
7th International Laser Radar Conference	San Francisco November	Dr R. E. W. Pettifer (Met O 19)
IBM OS Guide Group	Dublin November	Mr D. S. Gill (Met O 12)
AMS Fourth Conference on 'Probability and Statistics in Atmospheric Science'	Tallahassee, Fla November	Mr A. F. Jenkinson (Met O 13)
Australian Meteorological Society Conference on 'Climatic Change'	Melbourne December	Mr R. A. S. Ratcliffe, Assistant Director (Synoptic Climatology)
Symposium on 'Weather Radar and Water Management'	Chester, Malvern and Bala December	Dr B. J. Mason, Director-General Mr J. K. Bannon, Director of Services Mr R. Murray, Assistant Director (Agriculture and Hydrometeorology)
Discussions at Environmental Protection Agency on Closure Techniques	Raleigh, N. Car. December	Dr T. W. Harrold (Met O 16) Mr C. G. Collier (Met O 8)
2nd International Symposium on Computing Methods in Applied Sciences and Engineering	Versailles December	Dr F. B. Smith, Assistant Director (Boundary Layer) Mr A. Gilchrist, Assistant Director (Dynamic Climatology)

The following staff were released by the Office during 1975 for service with international and other organizations:

<i>Subject</i>	<i>Place and date</i>	<i>Attended by</i>
Dr D. M. BurrIDGE	Principal Scientific Officer	ECMWF, Bracknell
Mr R. L. Newson	Principal Scientific Officer	ECMWF, Bracknell
Miss J. Charlewood	Scientific Officer	ECMWF, Bracknell
Mr C. F. Neave	Senior Scientific Officer	Fiji
Mr E. L. Evans	Senior Scientific Officer	Fiji
Mr L. P. Stevens	Senior Scientific Officer	Antigua
Mr W. M. Longworth	Higher Scientific Officer	Seychelles
Mr C. W. Brookes	Telecommunications Technical Officer III	Seychelles
Mr J. Hayhurst	Scientific Officer	New Hebrides
Mr R. C. Wilderspin	Assistant Scientific Officer	Royal Society, Aldabra

Staff returning from international and other secondment appointments were:

Dr K. A. Browning	Senior Principal Scientific Officer	NCAR, USA
Mr D. J. Clarke	Principal Scientific Officer	ECMWF
Mr A. S. Russell	Senior Scientific Officer	Fiji
Mr D. J. Skelly	Senior Scientific Officer	Fiji
Mr P. F. McAllen	Senior Scientific Officer	Antigua
Mr S. I. Nute	Senior Scientific Officer	Antigua
Mr K. E. Woodley	Higher Scientific Officer	WMO, Geneva
Mr S. W. Francis	Higher Scientific Officer	Kenya
Mr J. G. R. Kidd	Higher Scientific Officer	Kenya
Mr B. Dyson	Higher Scientific Officer	Kenya
Mr P. J. Fisher	Assistant Scientific Officer	British Antarctic Survey

LIST OF ABBREVIATIONS USED IN THIS SECTION

ABCA	— America, Britain, Canada and Australia
AFB	— Air Force Base
AFCENT	— Allied Forces Central Europe
AFCRL	— Air Force Cambridge (Massachusetts) Research Laboratories
AMS	— American Meteorological Society
CAeM	— Commission for Aeronautical Meteorology
CBS	— Commission for Basic Systems
CCMS	— Committee on the Challenges of Modern Society
CENTO	— Central Treaty Organization
CIAP	— Climatic Impact Assessment Program
CMM	— Commission for Marine Meteorology
CoSAMC	— Commission for Special Application of Meteorology and Climatology
COSPAR	— Committee for Space Research
EC	— Executive Committee
ECMWF	— European Centre for Medium-range Weather Forecasts
GARP	— Global Atmospheric Research Program
GATE	— GARP Atlantic Tropical Experiment
IAMAP	— International Association of Meteorology and Atmospheric Physics
ICAO	— International Civil Aviation Organization
ICSU	— International Council of Scientific Unions
IPM	— Informal Planning Meeting
JASIN	— Joint Air-Sea Interaction
JONSIS	— Joint North Sea Information Systems
MCMG	— Military Committee Meteorological Group
MOTNE	— Meteorological Operational Telecommunication Network, Europe
NATO	— North Atlantic Treaty Organization
NCAR	— National Center for Atmospheric Research
NMC	— National Meteorological Center
RTH	— Regional Telecommunication Hub
VAP	— Voluntary Assistance Program
WMO	— World Meteorological Organization
WWW	— World Weather Watch

STAFF

GENERAL

The names of the Principal Officers of the Meteorological Office are listed on pages xi–xiii and the organization of the Office is shown in the diagram on page xiv. At the end of 1975 the total number of posts of all grades was 3504, a decrease of 144 over the year. The actual strength at the end of the year was made up as follows:

Deputy Secretary ...	...	...	...	...	...	...	...	1
Under Secretary ...	...	...	...	...	...	...	...	2
Science Group								
Chief Scientific Officer ...	...	...	...	...	...	...	...	1
Deputy Chief Scientific Officer ...	...	...	...	...	...	...	...	6
Senior Principal Scientific Officer	...	...	...	...	...	...	...	25
Principal Scientific Officers	...	...	...	...	...	...	...	111
Senior Scientific Officers ...	...	...	...	...	...	...	...	291
Higher Scientific Officers	...	...	...	...	...	...	...	523
Scientific Officers ...	...	...	...	...	...	...	...	513
Assistant Scientific Officers	...	...	...	...	...	...	...	1009
Administration Group								
Assistant Secretary	...	...	...	...	...	...	...	1
Principal ...	...	...	...	...	...	...	...	1
Executive Grades ...	...	...	...	...	...	...	...	30
Clerical Grades ...	...	...	...	...	...	...	...	151
Marine Staff								
Marine Superintendent ...	...	...	...	...	...	...	...	1
Nautical Officer Grades ...	...	...	...	...	...	...	...	11
Ocean Weather Ships and Base								
Officers and non-industrial grades	...	...	...	...	...	...	...	58
Crew and industrial grades	...	...	...	...	...	...	...	59
Professional Engineer Staff								
Superintending Engineer	...	...	...	...	...	...	...	1
Principal Professional and Technology Officer	...	...	...	...	...	...	...	1
Professional and Technology Officer Grade I ...	...	...	...	...	...	...	...	3
Professional and Technology Officer Grade II	...	...	...	...	...	...	...	4
Professional and Technology Officer Grade III	...	...	...	...	...	...	...	3
Professional and Technology Officer Grade IV	...	...	...	...	...	...	...	6
Technical and Signals Grades	...	...	...	...	...	...	...	289
Typing and miscellaneous non-industrial grades ...	...	...	...	...	...	...	...	137
Industrial employees	...	...	...	...	...	...	...	102
Locally entered staff and employees overseas	...	...	...	...	...	...	...	126

The year 1975 was a year of increasingly high unemployment generally and this was reflected in the increased number of applications for posts at all levels and a decrease in staff turnover.

The number of competitions for Assistant Scientific Officer vacancies was reduced to three, no new applications being accepted after the end of July. One competition was held for the recruitment of graduate staff and the number of applications showed an increase of over 30 per cent on last year. Sixteen graduates and 97 Assistant Scientific Officers joined during the year as well as one Nautical Officer, one Cartographic Draughtsman and one Drawing Office Assistant.

Casually employed staff included three Nautical Officers, one Scientific Officer and 10 college-based Sandwich Course students receiving industrial training in the Office. Four undergraduates were employed during the summer vacation and two postgraduate students and five vacation consultants spent short periods in the research branches.

HONOURS AND DISTINCTIONS

The Director-General was awarded the Symons Gold Medal of the Royal Meteorological Society, received an Honorary Doctorate of Science at the University of Strathclyde, and was elected a Fellow of the American Meteorological Society.

Dr K. A. Browning was elected a Fellow of the American Meteorological Society.

Dr R. Hide was awarded the Charles Chree Medal and Prize of the Physical Society.

The L. G. Groves Memorial Prize for Meteorology was awarded to Dr R. J. Murgatroyd and Mr J. M. Nicholls received the Meteorological Observer's Award.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

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APPENDIX II

A SELECTION OF LECTURES AND BROADCASTS GIVEN BY MEMBERS OF STAFF

ADAMS, R. J., Ph.D.

Shelter. *Agricultural Development and Advisory Service, Regional Vegetables Group (Eastern Division), Cambridge.* 21 October.

ARMOUR, D. G.

Agrometeorology. *Largs and District Young Farmers' Club.* 15 December.

ATKINS, MARGARET J., B.Sc.

The value of satellite vertical temperature profile radiometer (VTPR) data in numerical weather prediction. *General Assembly of the International Union of Geodesy and Geophysics, Grenoble.* 30 August.

BENNETTS, D. A., Ph.D.

Project Scillonia and rainband modelling. *Royal Meteorological Society meeting on 'Fronts', London.* 19 November.

Numerical modelling of cumulonimbus clouds. *Department of Geophysics, University of Reading.* 5 December.

BEST, K. E.

The making of a weather forecast. *Welsh Centre of the Royal Meteorological Society, Gwent College of Technology, Newport.* 11 November.

Meteorology for Yacht Masters Certificate. *National Sailing Centre, Cowes.* 12–14 December.

BORRETT, P. D., B.Sc.

Meteorological use of computers. *Sheffield Regional Centre for Science and Technology.* 15 May.

BROWN, A. A.

Meteorology. *Geographical Society, University of Birmingham.* 20 November.

BROWNING, K. A., Ph.D., D.I.C.

The structure and environment of severe local storms. *Royal Meteorological Society, London.* 11 October.

Atmospheric fronts: their mesoscale structure and associated rainfall. *Royal Meteorological Society, London.* 19 November.

BURRIDGE, D. M., Ph.D.

Semi-implicit methods in numerical weather prediction. *Scientific Advisory Committee of the Interim Committee of the European Centre for Medium-range Weather Forecasts, Reading.* 15 January.

The use of semi-implicit methods in solving the hyperbolic equations of numerical weather prediction. *Computational Physics Conference, University of Strathclyde.* 27 August.

BUSHBY, F. H., B.Sc., A.R.C.S.

Recent developments in numerical weather prediction. *Atmospheric Physics Seminar, Clarendon Laboratory, Oxford.* 27 November.

CLAPP, G. F. W.

Operational use of weather. *Royal Military College of Science, Shrivenham.* 9 July.

COLLIER, C. G., B.Sc., A.R.C.S.

Rainfall measurement by radar. *Symposium on Weather Radar and Water Management, Chester and Malvern.* 16 December.

CRADDOCK, J. M., M.A.

The evidence for climatic change in the last 1000 years. *Geographical Society of the University of Bristol.* 17 January.

Statistical problems in forecasting. *Royal Statistical Society, London.* 4 February.

CREASE, B. C.

Role of satellites in meteorology today. *Cambridge College of Art and Technology.* 30 October.

CULLEN, M. J. P., Ph.D.

Finite elements in non-linear evolutionary processes. *Course on Finite Elements in Fluid Flow, University of Southampton*. 19 December.

DEEKS, P. H. G.

Meteorology for Yacht Masters Certificate. *Adult Education Centre, Kingston-upon-Thames*. 13 January.

Climatology. *Cement and Concrete Association, Slough*, 5 November.

Use of weather statistics in the building industry. *Cement and Concrete Association, Slough*. 4 December.

DIXON, R., B.Sc.

An operational hemispherical functional (polynomial) analysis system. *Joint Organizing Committee for GARP Study Conference, Paris*. 17 November.

FORSDYKE, D., B.Sc.

Shelter for glasshouses. *Agricultural Development and Advisory Service Glasshouse Group, London*. 25 February.

FRANCIS, P. E., Ph.D.

Weather forecasting and agriculture. *Edinburgh Agricultural Economic Discussion Circle*. 1 December.

FREEMAN, M. H., O.B.E., M.Sc.

Recent advances in weather forecasting. *The Geographical Association, Guildford*. 4 February.

GADD, A. J., Ph.D.

Operational Numerical Weather Prediction. *British Association for the Advancement of Science, University of Surrey, Guildford*. 29 August.

The operational forecasting of fronts with the 10-level model. *Royal Meteorological Society, London*. 19 November.

GEORGE, D. J.

Lectures to the Royal Meteorological Society and 'Mountain Weather' Field Study Course, Betws-y-Coed, Gwynedd. 23–30 July.

Lecture to London Mountaineering Club on 'Mountain Weather'. 17 January.

GILCHRIST, A., M.A.

Sensitivity experiments with the Meteorological Office general circulation model. *International Institute for Applied Systems Analysis Informal Conference on Waste Heat and Meteorological Effects, Vienna*. 29 April.

Discussion on general circulation modelling. *Conference of Commonwealth Meteorologists, Reading*, 4 June.

The effects of a cold Atlantic on West African rainfall. *WMO/IAMAP Symposium on Long-Term Climatic Fluctuations and the Future of our Climate, Norwich*. 21 August.

Modelling climate by numerical models. *British Association for the Advancement of Science, University of Surrey, Guildford*. 29 August.

The UK Meteorological Office general circulation model. *European Centre for Medium-range Weather Forecasts seminar on the Scientific Foundation for Medium-range Weather Forecasts, Bracknell*. 11 September.

Modelling the climate numerically. *Department of Mathematics, University of Bristol*. 4 November.

General circulation models with examples taken from the Meteorological Office model. *Institut de Recherche d'Informatique et d'Automatique, 2nd International Colloquium on Numerical Methods for Science and Technology, Paris*. 17 December.

GOLDSMITH, P., M.A.

Inadvertent weather modification. *University of Reading*. 20 February.

Advertent weather modification. *University of Reading*. 27 February.

The scavenging of aerosols by precipitation over the oceans. *General Assembly of the International Union of Geodesy and Geophysics, Grenoble*. 5 September.

Stratospheric ozone and Freons. *10th International Aerosol Conference, London*. 1 October.

Wash out. *Royal Society Study Group on Pollution in the Atmosphere, London*. 10 December.

GRANT, D. R., B.Sc. and McKELLAR, H. A.

General Meteorology. *Phone-in program, BBC 4, Scotland*. 16 January.

GRANT, J. R., B.Sc.

Meteorology. *Private Pilots Course, Coventry Technical College series of lectures*. January and February.

GRAYSTONE, P., B.A.

Tropical analyses and forecasts by numerical methods during the GARP Atlantic Tropical Experiment. *General Assembly of the International Union of Geodesy and Geophysics, Grenoble*. 29 August.

Use of computers in modern weather forecasting. *British Computer Society, Kingston-upon-Thames*. 19 November.

Weather prediction by numerical methods. *Hydraulics Research Station, Wallingford*. 10 December.

HARROLD, T. W., Ph.D., D.I.C.

The measurement and forecasting of rainfall using radar data. *University of Wales Institute of Science and Technology symposium on Radar and the Measurement of Rainfall, Cardiff*. 12 February.

Measurement of rainfall by radar. *Conference of Commonwealth Meteorologists, Reading*. 5 June.

Rainfall forecasts in the United Kingdom using radar data. *Symposium on Weather Radar and Water Management, Chester and Malvern*. 16 December.

HIDE, R., Sc.D., F.R.S.

Motions in planetary atmospheres.

Geophysics Department, University of Reading. 20 February.

Astronomical Society, University of Leicester. 24 February.

Royal Meteorological Society (Presidential Address), London. 16 April.

Physics Department, University of Birmingham. 22 October.

Topographic effects in rotating fluids and core-mantle coupling.

Euromech 56, University College, London. 17 April.

Meeting of European Geological Societies, University of Reading. 10 September.

Jupiter's magnetism. *International Astronomical Union symposium on 'Jupiter, the Giant Planet', University of Arizona, Tucson, Arizona*. 21 May.

Rotation of Jupiter's atmosphere. *Joint Royal Astronomical Society and Royal Meteorological Society Meeting on Rotation of Planetary Atmospheres, London*. 28 November.

Dynamics of rotating fluids. *Department of Physics, Imperial College of Science and Technology, London*. 10 and 17 December.

HOPKINS, J. S., B.Sc.

Acquisition and interpretation of wind data for design purposes. *Royal Meteorological Society Discussion Meeting, London*. 15 January.

Meteorological aspects of wind loading of structures. *Polytechnic of the South Bank, London*. 17 April.

HOUGHTON, D. M., M.Sc., D.I.C.

Weather forecasting applied to small boat operators. *Royal Institution of Navigation, London*. 20 January.

Forecasting for Olympic racing. *Royal Yachting Association, Olympic Symposium, Oxford*. 1 February.

Weather forecasting for coastal cruising. *Cruising Association, Little Ship Club, London*. 12 February.

Careers in meteorology. *Phone-in broadcast, London Broadcasting Company*. 3 May.

Applying the weather forecast to offshore racing. *Royal Ocean Racing Club, London*. 5 and 19 June.

Background to the weather forecast. *Southall College of Technology*. 30 October.

Understanding the wind. *Chichester Yacht Club*. 1 November.

HUGHES, I. G.

Meteorology for nuclear fallout prediction and Civil Defence. *Home Office Defence College, Easingwold, N. Yorks*. 9 April and 17 September.

HULL, O. M.

Meteorology for yachtsmen. *First half of a course of 20 lectures, Inner London Education Authority, Frobisher Adult Education Institute*. 24 September to 31 December.

HUNT, G. E., Ph.D., F.I.M.A.

Radiation and clouds in the general circulation of the atmosphere. *Department of Meteorology, University of California and Los Angeles*. 9 January.

- Weather and climate on the planets. *Institute of Physics (Midland Branch), University of Warwick, Coventry.* 4 February.
- Planetary atmospheres. *Three lectures to M.Sc. students, Department of Geophysics, University of Reading.* February.
- The structure and composition of the atmosphere and clouds of Venus. *Royal Astronomical Society/Royal Meteorological Society/Geological Society meeting on Venus and Mercury, London.* 11 April.
- The atmosphere of Jupiter. *Imperial College Chemical Society, London.* 29 April.
- Motions and morphology of clouds in the atmosphere of Jupiter. *International Astronomical Union symposium on 'Jupiter, the Giant Planet', University of Arizona, Tucson.* 21 May.
- Studies of the sensitivity of the earth's radiation budget to changes in cloudiness. *National Center for Atmospheric Research Workshop on the Effect of Cloudiness on Climatic Change, Boulder, Colorado.* 15 July.
- The role of cirrus clouds as a climatic variable as identified by some numerical experiments. *WMO/IAMAP Symposium on Long Term Climatic Fluctuations in Climate and the Future of our Climate, Norwich.* 21 August.
- Contribution to BBC TV program 'Sky at Night' concerning satellites of Jupiter. 27 August.
- The atmosphere of Jupiter and its satellites. *British Interplanetary Society, London.* 16 October.
- Studies of the role of radiation and clouds in the general circulation of the atmosphere. *University of Exeter.* 17 October.
- Contribution to BBC TV program 'Sky at Night' concerning Venera 9 landing on Venus. 22 October.
- Contribution to BBC TV program 'Sky at Night' concerning rocks of Venus. 12 November.
- Planetary meteorology and atmospheric radiative transfer. *Three lectures to M.Sc. students, Department of Physics, Imperial College of Science and Technology, London.* November/December.
- The use of space shuttle for planetary studies. *Royal Astronomical Society/Institute of Physics Meeting, London.* 12 December.

JACKSON, M. C., M.Sc.

- Weather science and weather forecasting. *Royal Meteorological Society Course, Nettlcombe Court, Williton, Somerset.* 13–20 August.

JAMES, D. G., Ph.D.

- The Meteorological Research Flight contribution to the GARP Atlantic Tropical Experiment. *Royal Meteorological Society, London.* 21 May.

JENKINSON, A. F., I.S.O., M.A.

- Rainfall/flood studies. *Institution of Civil Engineers conference on flood studies, London.* 7 May.
- Some quasi-periodic changes in rainfall in Africa and Europe. *WMO/IAMAP symposium on Long-term Climatic Fluctuations and the Future of our Climate, Norwich.* 21 August.
- Extreme rainfall estimation. *Institution of Civil Engineers/Institution of Water Engineers and Scientists/Royal Meteorological Society Scottish symposium on Flood Studies Report, Edinburgh.* 17 October.

- Extreme value analysis in meteorology. *American Meteorological Society 4th Conference on Probability and Statistics in Atmospheric Science, Tallahassee, Florida.* 19 November.

JOHNSON, G. C.

- Meteorology and mountaineering. *Course of four lectures at Mountain Expedition Training Centre, London Borough of Brent.* 12 February to 14 May.

JONES, D. E., M.Sc., D.I.C., A.R.C.S.

- An objective analysis scheme for GATE data. *Royal Meteorological Society, London* 21 May.
- Mathematical problems of meteorological data analysis and initialisation. *British Association for the Advancement of Science, University of Surrey, Guildford.* 29 August.
- The UK Meteorological Office objective analysis scheme for GATE. *Joint Organizing Committee for GARP Study Group Conference on Four-dimensional Data Assimilation, Paris.* 18 November.

JONES, M. V., B.Sc.

- The use of computers in weather forecasting. *Lanchester Polytechnic, Rugby.* 20 January.

KEERS, J. F., B.Sc.

Meteorological aspects of drainage design. *Planning and Transport Research and Computation Co. Ltd, courses on drainage design, London*. 12 May and 3 November.

The variability of precipitation and evaporation. *International Hydrological Decade Conference at the Institution of Civil Engineers, London*. 19 February.

LEACH, H., B.Sc.

Topographic effects in a baroclinic fluid. *Geophysics Department, University of Reading*. 10 February.

Thermal convection in a rotating fluid annulus: some effects due to bottom topography. *Euromech 56, University College, London*. 17 April.

LORENC, A. C., B.A.

Results of some experiments assimilating observations from a simulation of the FGGE observing system into a global general circulation model. *Joint Organizing Committee for GARP Study Group Conference on Four-dimensional Data Assimilation, Paris*. 20 November.

MCCASKILL, J. R., B.A.

Clouds and weather signs and The weather forecaster at work. *Weekend School Adult College, Grantley Hall, Ripon*. 12 and 13 July.

MCILVEEN, W. A., Ph.D.

Computers and weather prediction. *British Computer Society, Wolverhampton Branch*. 5 February.

McKELLAR, H. A.

Mountain weather. *Scottish Ski Club, Glasgow*. 6 February.

MASON, B. J., C.B., D.Sc., F.R.S.

Recent developments in forecasting of weather and climate. *The Hugh MacMillan Memorial Lecture of the Institution of Engineers and Shipbuilders in Scotland, Glasgow*. 25 March.

The prediction of weather and climate. *British Association for the Advancement of Science, Guildford*. 22 August.

The numerical prediction of weather and climate. *Mathematics Department, Imperial College, London*. 9 October.

The use of satellites in the exploration of the atmosphere. *Physical Society of the University of Reading*. 27 November.

An integrated weather network. *Water Research Centre and Royal Radar Establishment Symposium at RRE Malvern*. 17 December.

MASON, P. J., Ph.D.

Sloping convection in a container with sloping end-walls. *Euromech 56, University College, London*. 17 April.

MILES, M. K., M.Sc., A.R.C.S.

North Atlantic circulation and associated temperature gradients. *WMO/IAMAP symposium on Long-term Climatic Fluctuations and the Future of our Climate, Norwich*. 21 August.

MURGATROYD, R. J., O.B.E., Ph.D., C.Eng., M.I.E.E.

Recent studies of possible effects on the atmosphere due to increased flying in the stratosphere. *46th Australian and New Zealand Academies of Sciences Congress, Canberra*. 23 January.

Description of the UK COMESA programme. *4th Climatic Impact Assessment Programme Conference, Boston, Mass*. 4 February.

Stratospheric pollution. *Conference of Commonwealth Meteorologists, Reading*. 6 June.

Transport processes in the stratosphere and their significance in stratospheric pollution problems. *The Royal Society Study Group on Pollution in the Atmosphere, London*. 16 September.

Modelling of the stratosphere. *Le Centre National d'Études Spatiales et Techniques, Paris*. 10 December.

OGDEN, R. J., B.Sc.

Climatology for the offshore industry. *Symposium on Climatology for the Public Benefit, Association of British Climatologists, Oxford*. 5 January.

North Sea weather in relation to offshore operations. *Petroleum Exploration Society of Great Britain, London*. 7 January.

Climatology. *Domestic Heating Society, London*. 11 February.

Meteorology in the service of agriculture. *Canterbury Farmers Club and East Kent Chamber of Agriculture, Canterbury*. 17 February.

Meteorology and some applications to engineering. *Institution of General Technical Engineers, London*. 7 March.

Meteorology for agriculture. *National Farmers Union, Staplehurst, Kent*. 17 March.

Weather and the community. *National Trust, Reading*. 7 April.

Meteorology—physics in action. *Institute of Physics, Guildford*. 15 October.

Weather and air photography. *Royal Photographic Society, London*. 10 December.

PAINTING, D. J., B.Sc.

Electronics in meteorological instrumentation. *Society of Electronic and Radio Technicians (South-west Region), Bristol*. 25 September.

PARDOE, C. W., B.Sc.

The nature of orographic rain. *University of Wales Institute of Science and Technology symposium on 'Radar and the Measurement of Rainfall', Cardiff*. 12 February.

PETTIFER, R. E. W., Ph.D.

High altitude laser radar techniques. *Heriot-Watt University, Edinburgh*. 3 February.

Elastic and inelastic scattering studies of the stratosphere using laser radar. *Inter-Union Commission on Radio Meteorology, Bournemouth*. 16 May.

Physics in weather forecasting. *Junior British Association, Belfast*. 26 September.

PLUMB, R. A., Ph.D.

Momentum transport by the thermal tide in the stratosphere of Venus. *British Theoretical Mechanics Colloquium, Manchester*. 10 April.

Dynamics of the stratosphere of Venus. *Joint meeting of the Royal Meteorological Society/Royal Astronomical Society/Geological Society on 'Various aspects of the Planets Venus and Mercury', London*. 11 April.

High Taylor number thermal convection in a rotating fluid annulus subject to a horizontal temperature gradient: spectral characteristics of nonaxisymmetric flow regimes. *Euromech 56, University College, London*. 17 April.

The stability of bounded wave motion. *Department of Geophysics, University of Reading*. 24 October.

The stability of Rossby waves. *University College, London*. 6 November.

Dynamics of the Venus 4-day rotation. *Joint Royal Astronomical Society/Royal Meteorological Society/Institute of Physics meeting on 'The Rotation of Planetary Atmospheres', London*. 28 November.

RATCLIFFE, R. A. S., M.A.

BBC-2 'News Extra'. Interview on recent mild weather and prospects. 7 January.

Objective methods of long-range forecasting. *Geophysics Department, University of Reading*. 16 May.

Participation in 'Start the Week' with Richard Baker, BBC Radio 4. 18 August.

Some aspects of the climate of the northern hemisphere in recent years. *WMO/IAMAP symposium on Long-term Climatic Fluctuations and the Future of our Climate, Norwich*. 21 August.

Climatic fluctuations past and present. *Worthing Science Society*. 1 October.

Can short-term climatic fluctuations be forecast? *Australian Royal Meteorological Society conference on Climatic Change, Melbourne*. 10 December.

ROACH, W. T., Ph.D., D.I.C.,

Project Scillonia and rainband modelling. *Royal Meteorological Society meeting on 'Fronts', London*. 19 November.

ROWNTREE, P. R., Ph.D.

Use of GATE data in numerical modelling. *Royal Meteorological Society meeting on 'The GARP Atlantic Tropical Experiment', London*. 21 May.

Results of GATE. *Conference of Commonwealth Meteorologists, Reading*. 4 June.

- Thermal and orographic forcing of the northern hemisphere winter circulation in a numerical model. *WMO/IAMAP Symposium on Long-term Climatic Fluctuations and the Future of our Climate, Norwich*. 21 August.
- The relative importance of tropical thermal, extra-tropical thermal and orographic forcing in a general circulation model. *Department of Geophysics, University of Reading*. 21 November.
- ROY, MARJORY G., M.Sc.
 Soil moisture deficits. *Farmers' Study Group, Thame, Oxon*. 12 February.
 Climatic and other limitations to the seasonal production of intensively managed grassland in the United Kingdom. *Seventh International Biometeorological Congress, Washington, D.C.* 25 August.
 Hay fever in London: relationship between the summer disease severity and late spring temperatures (Text by L. P. Smith, B.A. and Marjory G. Roy, M.Sc.). *Seventh International Biometeorological Congress, Washington, D.C.* 28 August.
- SAWYER, J. S., M.A., F.R.S.
 Some aspects of air pollution on a global and continental scale. *Clean Air Society, London*. 30 April.
- SCOTT, J.
 Forecasting for the general public. *Scottish Centre of the Royal Meteorological Society, Edinburgh*. 28 February.
- SHELLARD, H. C., I.S.O., B.Sc.
 Extreme wind speeds over the United Kingdom offshore areas. *Seminar on Fluid Loading of Offshore Structures, National Physical Laboratory, Teddington*. 23 September.
- SIMS, F. P.
 Weather and agriculture. *National Farmers Union, Bridge Yate, Avon*. 28 January.
 Shelter and glasshouses. *Horticultural Advisory Officers' Conference, Babbacombe, Torquay*. 5 February.
 Shelter for glasshouses. *Fuel Efficiency Conference, Trowbridge, Wilts*. 12 February.
 Weather and agriculture. *North Cornwall Grassland Society, Camelford*. 14 February.
 Weather and agriculture. *West Cornwall Grassland Society, Marazion*. 17 February.
 Measurement of climatic environment in and around buildings. *West Midlands Land Service Conference, Harper Adams Agricultural College, Newport, Salop*. 16 July.
 Shelter for glasshouses. *Horticultural Conference, Ellbridge Experimental Horticultural Station, Cornwall*. 12 November.
- SINGLETON, F., B.Sc.
 Lectures on weather and sailing given to courses at the National Sailing Centre, Cowes. 14–22 June and 12–14 December.
 Lecture to the Cruising Association, London. 30 December.
- SMITH, C. V., M.A., B.Sc.
 Weather, climate and livestock production. *Agricultural Development and Advisory Service Livestock Conference, London*. 5 May.
- SMITH, F. B., Ph.D.
 The structure of the atmosphere and dispersion of pollutants. *University of Surrey, Guildford*. 6, 13, 20 February.
 The boundary layer, its basic structure and its variations under the influence of external boundary conditions. *Institute of Mathematics and its Applications Symposium on Kinetics of the Atmosphere, Leeds*. 12 March.
 Long-range transport of air pollution.
Organization for Economic Co-operation and Development Project meeting, Cardington. 29 May.
British Council Course on Pollution, Imperial College of Science and Technology, London. 15 July.
Warren Spring Laboratory, Stevenage. 19 November.
- SMITH, K. C.
 Weather and agriculture. *South Beaufort Young Farmers' Club, Doynton, Avon*. 25 November.
- SMITH, L. P., B.A.
 The interpretation of the physical environment in relation to plant growth: a consideration of basic principles. *Association of Applied Biologists, Bath*. 16 September.
 Drainage and Climate. *Conference of the West Midlands Drainage Officers, Buxton*. 28 October.

SPALDING, T. R., B.Sc.

Mountain weather. *Course of lectures to Royal Meteorological Society Field Study Course, Betws-y-Coed, Gwynedd*. 23–30 July.

STARR, J. R., Ph.D.

Clouds, rain and rain-making. *Physical Society, University of Bristol*. 30 January.

Physics of rain, snow and hail.

Physical Society, University of Warwick, Coventry. 3 March.

Physics Society, University of Bath. 18 March.

Physics Society, University of Surrey, Guildford. 20 November.

STEVENS, L. P. and RIGDEN, H. L.

General Meteorology for seamen. *Royal Naval Reserve Merchant Navy Acquaint Course, HMS Wessex, Southampton*. 8 April and 8 October.

TAPP, M. G., Ph.D.

A non-hydrostatic meso-scale model. *Conference on meso-scale modelling, Las Vegas*. 9 May.

THOMPSON, N., Ph.D.

Meteorological measurements from HMS *Hecla* during GATE. *Hydrographer's Winter Conference, Hydrographic Department, Taunton*. 8 January.

Boundary layer measurements during GATE. *Colloquium, Chemical Defence Establishment, Porton*. 24 January.

Measurements of marine boundary-layer structure by tethered balloons. *Department of Geophysics, University of Reading*. 7 March.

Measurements of turbulence in the planetary boundary layer. *GATE discussion meeting, Royal Meteorological Society, London*. 21 May.

Chemical threat to civilian populations. *Advanced Course for Local Authority Scientific Advisers, Home Defence College, Easingwold, N. Yorks*. 31 October.

TUCK, A. F., Ph.D.

Chemical modelling of perturbations due to NO_x emissions. *4th Climatic Impact Assessment Programme Conference, Boston, Mass*. 6 February.

Contribution to BBC Radio 4 program 'PM' concerning Freons reducing ozone. 13 June.

WHITE, P. W., Ph.D.

Meso-scale modelling in the UK Meteorological Office. *European Research Office, Meso-meteorological Advisory Panel, London*. 5 February.

Finite difference methods in numerical weather prediction. *Mathematics Department, City of Leicester Polytechnic*. 26 February.

A non-hydrostatic meso-scale model. *European Research Office Panel on meso-meteorology, Garmisch-Partenkirchen, Germany*. 2 October.

WICKHAM, P. G., M.A.

Numerical weather prediction. *Mathematics Department, Polytechnic of Central London*. 19 November.

APPENDIX III

PUBLICATIONS

The publications prepared by the Meteorological Office are generally issued by Her Majesty's Stationery Office as official publications. Catalogues listing all the publications which may be purchased through the sales offices or usual agents of Her Majesty's Stationery Office, or direct from the Meteorological Office at Bracknell, are sent free to any applicant.

The following publications have been issued:

PERIODICALS

Annual Report on the Meteorological Office 1974.

Daily Aerological Record containing information in respect of meteorological conditions in the upper air for the British Isles.

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

Monthly Summary of the Daily Weather Report.

Monthly Weather Survey and Prospects, a monthly publication containing climatological data for the United Kingdom, the weather of the past month, a general survey and inference, and weather prospects for the coming month in the United Kingdom; a supplementary document, containing survey, inference and prospects only, is published in mid month.

Estimated Soil Moisture Deficit and Potential Evapotranspiration 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.

Sea Ice Charts (daily).

Monthly (coloured) *Ice Maps* (to September 1975).

Meteorological Magazine (monthly).

Monthly Weather Report (to February 1975).

Marine Observer (quarterly).

Marine climatological summaries for the Atlantic Ocean east of 50°W and north of 20°N—1967.

OCCASIONAL

Weather in Home Waters, Vol. II—The waters around the British Isles and the Baltic,
Part I.

Abbreviated weather reports.

Guide to plotting procedures.

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