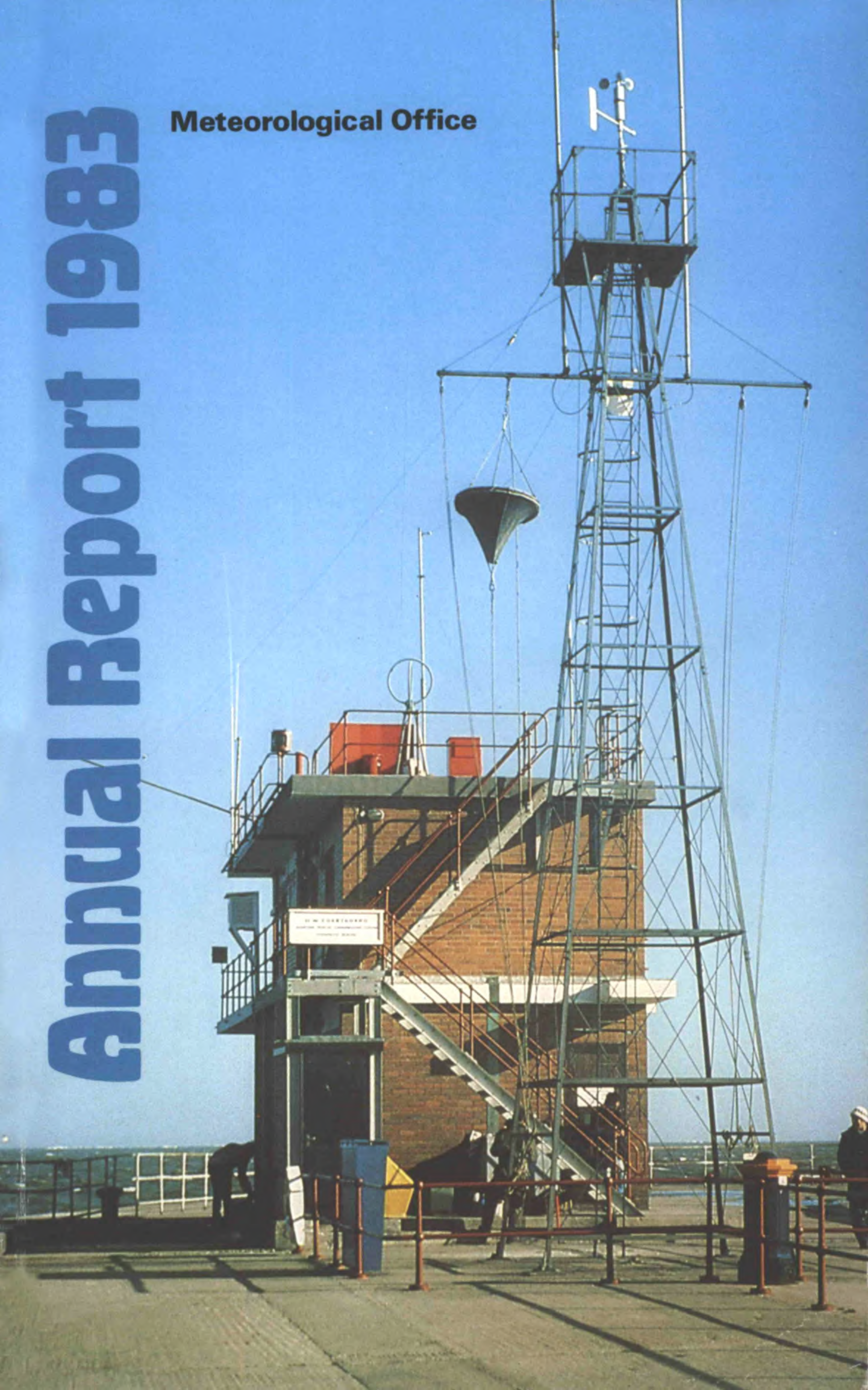
# Meteorological Office

# Annual Report 1983



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# ANNUAL REPORT
## ON THE
# METEOROLOGICAL OFFICE
# 1983

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

*LONDON*
HER MAJESTY'S STATIONERY OFFICE

U.D.C.
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*Cover photograph: The Coastguard station at Gorleston, which served as an auxiliary reporting station for The Meteorological Office until October 1981.*

## FOREWORD BY THE DIRECTOR-GENERAL

During the year the Resource Control Review undertaken by the Government's Rayner organization was published. It is gratifying to note that the Review was able to report—'The UK undoubtedly has in the Meteorological Office a centre of excellence of which she can be proud'. It was further pointed out that this is achieved at one of the lowest costs per head of population for meteorological services in countries of the developed world. The Review looked into the whole of the Office's activities and made a number of suggestions and proposals which are now being considered by appropriate bodies within the Office and within the Ministry of Defence.

Important conclusions of the Report are firstly, that the Meteorological Office should continue to be responsible for providing the general public with a free service of weather information and forecasts financed through general taxation; secondly, that because the armed forces are the Office's largest 'customer', the Meteorological Office is appropriately placed within the Ministry of Defence and should continue to be part of that Ministry and thirdly, that the Meteorological Office should continue to explore ways of marketing and selling specialized meteorological and climatological services and should look into new organizational ways of furthering commercial activities, possibly through the establishment of private venture companies.

About half of the resources of the Office go into the activities of data acquisition and analysis, the production of forecasts through the use of several numerical models which are run on the central computer, and receiving and transmitting these products world wide. These activities are central to all the main services which are provided—to defence, to civil aviation, to industry and commerce, and to the public at large: they would still be required if only one of them were served. An important matter of policy is how the costs of these central overhead activities should be attributed to each of the Office's main customers. This policy question was raised by the Resource Control Review, but was not answered by it. An agreed solution is urgently required.

A large part of the Review is concerned with suggestions regarding the future stance to be taken by the Office with respect to commercial activities. A lot of attention will be given to this area by the Office's senior management in the coming months, in particular to the relation between the free public service on the one hand and repayment services on the other. Attention is also being given to a further question raised as a result of the Resource Control Review—that of the extent to which restrictions need to be placed on the general accessibility of data and forecast products generated by meteorological services in order that the Meteorological Office can itself recoup some of the costs of producing the information.

At the beginning of 1983 the fine-mesh version of the 15-level forecasting model on the new Cyber 205 computer became operational, supporting the coarser-mesh global 15-level model which became operational a few months earlier. With these new models a significant improvement in forecasts has been evident. Many of the statistics employed to assess forecast skill show that forecast errors in 1983 were the smallest on record. The global version of the model has proved particularly valuable in the medium-range period (3 to 5 days ahead). Very good warning has been provided of the rapid development and movement of the winter storms. Impressive too was the forecast at the end of August which correctly predicted the breakdown of the long, settled spell of summer weather 5 or 6 days in advance.

Increasing emphasis is being given to bringing the benefits of automation to the outstations. Numerical model forecast products are disseminated through minicomputer systems known as OASYS (Outstation Automation System). A third OASYS was installed during the year at London Weather Centre, the other two being at Heathrow Airport and at Headquarters Strike Command (HQSTC). As a first step towards replacing the slow broadcast of meteorological data to the smaller forecast offices supporting Royal Air Force operations, the OASYS at HQSTC, which is itself linked to Bracknell, has been connected to remote outstation terminals (ROASTS) in the forecast offices at RAF Lyneham and RAF Honington. The trials of these equipments are designed to test a prototype Defence Operational Meteorological Information Network for Outstations (DOMINO) whose purpose is to improve the speed and flexibility of response to the operational needs of the Royal Air Force.

Automation is also being developed in many other activities. Word processors have been installed in the main typing pool, and are to be introduced into the Central Forecasting Office and London Weather Centre for compiling forecast material. Plans have been drawn up to install terminals connected to the central computers at the climatological units at Edinburgh and Belfast, and at meteorological units at the regional centres of the MAFF agricultural advisory service. The first stage of the computer-based Management Accounting and Information System also became operational in April.

The program for the introduction of new technology into Meteorological Office communications and observational systems made significant progress in 1983. Twenty Synoptic Automatic Weather Stations (SAWS), 30 Digital Anemograph Logging Equipments (DALE), 10 Meteorological Observing Systems for Ships (MOSS), 20 Mk 5B Wind Systems and 25 JASMIN stores and displays for weather radar data were delivered, and many were installed and became operational. Collection of ship reports via the INMARSAT satellite started in February and some 1500 reports per month are now received in this way, with a significant reduction in the cost of each report.

The Office continued to provide for defence needs for meteorological support in the South Atlantic. Mobile Meteorological Units (MMUs) on Ascension Island and at RAF Stanley in East Falkland were manned by Office staff holding Civil Class commissions and serving in uniform as part of the RAF operations staffs at both locations. The Unit on Ascension Island will revert to civilian status in 1984 but that at Stanley will continue as a military one, at least until the new strategic airfield is completed.

Following the decision of the Council of the International Civil Aviation

Organization (ICAO) to implement the planned new World Area Forecasting System for Civil Aviation, with Bracknell and Washington as World Centres, much detailed planning has taken place throughout the year both in house and in conjunction with the neighbouring Regional Centres in Europe at Frankfurt and Paris, and with Washington. It is aimed to begin implementation of the system in Europe and North America early in 1984 but it may be many months before full implementation is achieved world wide. Meanwhile, with the agreement of the Civil Aviation Authority (CAA), global grid-point data are being provided directly from the central computer complex at Bracknell to a limited number of air operators through the airlines' own communication system.

In its continuing search for economy in the provision of services for civil aviation, the CAA sought our co-operation in transferring the forecasting task undertaken at Gatwick to the Principal Forecasting Office (PFO) at Heathrow. This was completed by 1 October. While this enabled a small staff saving to be made, delays in making alternative arrangements for the issue of meteorological flight documentation have held up further staff economies at both Gatwick and Heathrow. The introduction during June of new low-level weather and wind forecast charts for flights made at levels below 12 000 ft over the UK and the nearby continent was intended both to improve the information for pilots flying at low levels and to reduce the demands made from the general aviation section for personal consultations with the forecasters.

In July the 12-month running total revenue from the offshore industry for services provided from London Weather Centre exceeded £1 million for the first time. Thirty-four per cent of this income came from overseas companies. The demand for forecasters to be provided offshore on rigs, platforms and vessels of various kinds increased markedly and on several occasions staff were deployed offshore concurrently on four different projects. One contract gained in competitive tender was for the setting up of an on-the-spot forecasting service at the Sullom Voe oil terminal in the Shetland Islands.

Presentation of weather information through the media continues to be a growth industry. During the year both of the new early morning TV programs began taking services from London Weather Centre, the material being presented by the channel's own weathermen. Three more regional IBA TV stations elected during the year to use local Meteorological Office staff and material in the production of live weather presentations and a further ten local radio stations began taking live broadcasts from regional Weather Centres or having scripts prepared at them. A significant effort is being devoted within the Office to the development of new forms of weather presentations. These involve animation of satellite and radar display sequences and of the output of numerical weather prediction models.

I now turn to a few items of particular interest in the Office's Research Program.

An issue of considerable current importance, both to scientists and the public at large, is the problem of 'acid rain'. The Office has been very active in investigating this problem since 1971 and its work, set out in context, is the subject of our Research Special Topic on page 76. An important contribution has involved the use of the instrumented Hercules aircraft in collaboration with the Central Electricity Research Laboratories, to study the physical and chemical properties of a power station plume in order to enhance our understanding of the transport of pollutants under different meteorological conditions.

In dynamical research, accessibility to the computing power of the Cyber 205 has enabled significant progress to be made. Further improvements have been made to the operational forecasting model. The new mesoscale model covering the British Isles with a 10 km grid has been run regularly on an experimental basis; operational trials with this model are planned to begin in 1985. In climate modelling it has been possible to make multi-year runs (up to 8 years long) to examine climatic effects and their variation from year to year. In particular, numerical experiments have been carried out to examine the atmospheric response to anomalies of sea surface temperature in the Pacific Ocean of which the largest are associated with the El Niño phenomenon.

The work described in the preceding paragraphs demonstrates the wide variety of tasks undertaken by the Meteorological Office. Despite a reduction in manpower, achieved through increased efficiency brought about by automation, the range of the Office's responsibilities, especially in the provision of services to specialized customers, has continued to expand.

During the short time I have been in post as Director-General since taking over from Sir John Mason on 1 October 1983, I have been much impressed by the degree of dedication, loyalty and professionalism which is shown by the staff of the Office and I look forward with enthusiasm to the challenges of the next few years.

J. T. HOUGHTON

*February 1984*
*Meteorological Office*
*Bracknell, Berkshire*

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## APPENDICES

# FUNCTIONS OF
# THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Ministry of Defence and is administered by the Air Force Department. The Director-General is responsible to the Secretary of State for Defence through the Minister of State for Defence Procurement.

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; provision of basic meteorological information for use by the Royal Navy; and liaison with the Director of Naval Oceanography and Meteorology.

(b) The provision of meteorological services to other government departments, public corporations, local authorities, the Press, television, radio, industry and the general public.

(c) The organization of meteorological observations, including observations of radiation, atmospheric electricity and ozone, in the United Kingdom and at certain stations overseas.

(d) The collection, distribution and publication of meteorological information from all parts of the world.

(e) The maintenance of the observatory at Lerwick.

(f) The provision of professional training in meteorology.

(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 the Meteorological Services in western Europe in the co-ordination of their programs.

# 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 meteorological services and research.

(c) To ensure the maintenance of adequate contact between the Meteorological Office and those who use its services.

Membership as at 31 December 1983:

Chairman: Sir Peter Swinnerton-Dyer, Bt, F.R.S.

Members: Professor A. H. Bunting, C.M.G.
Professor H. Charnock, F.R.S.
Professor P. H. Fowler, D.Sc., F.R.S.
Mr J. Miller, F.I.O.B.
Mr J. McHugh
Mr G. Williams
*Dr J. T. Houghton, C.B.E., F.R.S. (Director-General, Meteorological Office)
*Mr D. C. Humphreys, C.M.G. (Deputy Under-Secretary of State (Air))
*Air Vice-Marshal J. W. Price (Assistant Chief of the Air Staff (Operations)); alternate, Group Captain D. N. Galpin
*Captain D. C. Blacker, B.Sc., R.N. (Director of Naval Oceanography and Meteorology)
*Mr A. White (Representative Civil Aviation Authority); alternate for research meetings, Mr J. C. Morrall

Secretary: *Mr F. R. Howell, M.B.E., F.C.I.S. (Secretary, Meteorological Office)

**ex officio*

The Committee met four times in 1983. One quarterly meeting was devoted to the research program.

# PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

## DIRECTOR-GENERAL

J. T. Houghton, C.B.E., D.Phil., F.R.S.

## DEPUTY TO THE DIRECTOR-GENERAL

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

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| INTERNATIONAL AND PLANNING<br>Assistant Director | G. J. Day, B.Sc. |

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| Chief Meteorological Officer,<br>H.Q. Strike Command | D. Forsdyke, B.Sc. |
| PUBLIC SERVICES<br>Assistant Director | R. M. Morris, B.Sc. |
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| SYSTEMS DEVELOPMENT<br>Assistant Director | P. Ryder, Ph.D. |

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| Boundary Layer Research | |
| Assistant Director | D. J. Carson, Ph.D. |
| Special Post | F. B. Smith, Ph.D. |
| Meteorological Research Flight | |
| Assistant Director | C. J. Readings, Ph.D., D.I.C., A.R.C.S. |
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| Assistant Director | P. Jonas, Ph.D., D.I.C. |
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| SATELLITE METEOROLOGY | |
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| PERSONNEL MANAGEMENT | |
| Assistant Director | D. M. Houghton, M.Sc., D.I.C. |

# METEOROLOGICAL OFFICE ORGANIZATION

(at 31 December 1983)

- Director-General
  - Director of Research
    - Deputy Director (Physical Research)
      - Met O 14 (Boundary Layer Research)
      - Met O 15 (Cloud Physics)
      - Met O 19 (Satellite Meteorology)
      - Met O 21 (Geophysical Fluid Dynamics)
      - Meteorological Research Flight
      - Radar Research Laboratory
    - Deputy Director (Dynamical Research)
      - Met O 9 (Special Investigations)
      - Met O 11 (Forecasting Research)
      - Met O 13 (Synoptic Climatology)
      - Met O 18 (Library and Publications)
      - Met O 20 (Dynamical Climatology)
      - Met O College (Professional Training)
  - Secretary
    - Met O 4 (Supply, Finance, Secretariat Office Services)
    - Met O 10 (Personnel Management)
  - Director of Services
    - Deputy Director (Forecasting Services)
      - Met O 2 (Central Forecasting)
      - Met O 6 (Defence Services)
      - Met O 7 (Public Services)
    - Deputy Director (Communications and Computing)
      - Met O 5 (Telecommunications)
      - Met O 12 (Data Processing)
      - Met O 22 (Systems Development)
    - Deputy Director (Observational Services)
      - Met O 1 (Observational Requirements and Practices)
      - Met O 3 (Climatological Services)
      - Met O 8 (Agriculture and Hydrometeorology)
      - Met O 16 (Operational Instrumentation)
    - Met O 17 (International and Planning)

# DIRECTORATE OF SERVICES

## SPECIAL TOPIC—MARINE METEOROLOGY

### INTRODUCTION

The origins of marine meteorology go back beyond the time when Lieutenant Matthew Fontaine Maury of the United States Navy first realized the commercial and scientific value of weather information collected from ships, but to him must go the credit of publishing the first sailing directions, and wind and current charts for the benefit of mariners. As a result of this initiative, the US Government invited representatives from ten European countries to meet Lieutenant Maury at the Brussels international Maritime Conference of August and September 1853, for discussions on a universal system of meteorological observations at sea.

During 1854, Captain Robert FitzRoy (later Vice-Admiral) was appointed head of the Meteorological Department of the Board of Trade, and operations started early in 1855. By the month of May in the same year, FitzRoy had already recruited 50 merchant ships and 30 warships. Sets of tested instruments and meteorological logbooks were provided on loan to willing shipmasters at a total cost per ship of £11, and the first observing fleet was born. In due course, Parliament voted an initial sum of £3200 for this new work. In 1861 Admiral FitzRoy introduced the first British storm warning service for shipping, which used only land-based observations. Gale warning cones were also introduced at this time, as well as the publication of the first newspaper forecasts in August 1861. It was FitzRoy himself who applied the word 'forecast' to weather; and indeed it is clear that he was the prime mover in setting up the early Meteorological Office which was primarily intended for the benefit of marine safety.

It was not until 1912 that ships were able to telegraph their coded observations regularly for the forecaster's use and, for a short while after the First World War, ships were encouraged to exchange messages in code for mutual benefit. Weather bulletins for shipping were started soon afterwards and as early as 1924 they were being transmitted in six parts from three radio stations; Valentia for the western area, Niton for the southern area and Cullercoats for the eastern. Since then, except for a break during the Second World War, radio weather bulletins have been maintained continuously.

### OBSERVATIONS ON AND OVER THE OCEANS

*The Voluntary Observing Fleet (VOF)*

The great importance of meteorological observations from ships at sea becomes apparent when it is noted that almost three-quarters of the earth's surface is covered by the oceans. These observations have been undertaken voluntarily by Masters and Officers of merchant ships since 1855, and their importance remains undiminished despite the increasing sophistication of satellite data acquisition.

In the early days, observations were made every four hours aboard ships although nowadays they are required to be made at the main synoptic hours of 00, 06, 12 and 18 GMT. In addition to most of the elements required today, these early observations contained unusual items such as the specific gravity of the sea, temperatures at depth as well as at the sea surface, the temperature of rain, descriptions of hailstones, sightings of driftwood and tidal stream observations. Today some of these more detailed and localized observations are undertaken by specialist weather or research ships.

The voluntary observing ships of all nations are divided into three main classes—selected, supplementary and auxiliary ships. Selected ships make the most comprehensive observations of the three, being equipped with precision aneroid barometer, barograph, two screens (each with dry- and wet-bulb thermometers) and sea temperature bucket and thermometer; additionally, wind speed and direction are estimated from visual observations. The other two classes of ship have a reduced quota of instruments and observe correspondingly fewer elements. In addition to general meteorological observations, VOF ships are encouraged to make sea surface current observations whenever possible, and the advent of satellite navigational aids has allowed a ship's position to be fixed with greater frequency and accuracy, thus resulting in improved current data.

In addition to the prompt transmission of ships' observations to forecast offices, either via coastal radio stations or satellite, meteorological logbooks from the British VOF are sent to Bracknell where they undergo quality control before the meteorological data are included in the Meteorological Office marine climatological data bank. Part of the contents of ships' logbooks which are forwarded to Bracknell is made up of reports of phenomena. These reports are very varied, and can include such items as a recording of noctilucent cloud or aurora, a note of the ship passing through discoloured sea, sightings of spectacular revolving wheels of bioluminescence, encounters with whales, dolphins and flying fish, the landing of insects and migratory or passage birds on the ship, or even, as was reported recently, a plague of poisonous moths on a ship anchored off the Venezuelan coast. Whenever practicable, these reports are forwarded, with collected specimens, to appropriate experts for identification and comment.

Incentives to officers to continue their valuable voluntary marine observing were originally in the shape of gifts of current and pilot charts which included printed articles on meteorology and allied marine topics. From January 1924 these awards were superseded by a monthly journal called the *Marine Observer* which became a quarterly publication nine years later and has thus continued since. A large part of the journal is devoted to reporting the ships' phenomena records, together with any expert analyses which can be made available.

After assessment by Master Mariners of the Marine Branch, ships' meteorological logbooks are considered for 'Excellent' Awards; their quality determines which Masters, Principal Observing Officers and Radio Officers receive annual book presentations. Four awards, taking the form of inscribed barographs, for long and meritorious voluntary work at sea have also been presented to dedicated Masters of merchant ships by the Director-General annually since 1948.

Out of a grand total for the world's VOF of about 7500 ships, the British fleet consists of 420 of which over 400 are selected ships. Although this number is considerably smaller than the highest achieved in the 1960s, when there were almost 600 selected ships, the decline seems now to be halted, and has never been as severe as the general reduction of ships in our merchant navy brought about by the depressed state of world trade.

The maintenance of a backbone of keen observers on ships has been achieved by the Port Meteorological Officers' persistent efforts in recruiting many more diverse ship types. This has been aided by technological advances in maritime communications which are leading to the improved and more timely use of ships' synoptic data.

*The Ocean Weather Ship service*

In 1939, when transatlantic flights of passenger and freight carrying aircraft became a commercial proposition, it became clear that more detailed weather information was necessary than could be obtained from ships' voluntary observations alone. In that year the French and the Germans each had one ship making special surface and upper-air observations in the Atlantic. This type of operation increased in importance during the 1939–45 war, when the allied navies established a chain of small naval ships, mostly corvettes, as weather ships for the benefit of the numerous military aircraft crossing the ocean during that period.

After the war, the World Meteorological Organization (WMO) and the International Civil Aviation Organization (ICAO) agreed in 1947 to the establishment of 13 weather stations in the North Atlantic, 8 operated by the USA and 5 by European countries. The advantages of having frequent and regular reports of the upper air from fixed points in the ocean were obvious, and the regular surface observations augmented merchant ship observations by filling in the unavoidable gaps in the network. The need for economies has resulted in a gradual reduction over the years in the number of weather stations in the North Atlantic, down to ten in 1949, nine in 1954 and then to four in 1975. The original Flower Class corvettes introduced as Meteorological Office weather ships in 1947 were replaced in the early 1960s by four converted frigates, based at a new dock in Greenock. In 1977, the number of ships manning the one remaining UK station was reduced to two, these ships being refurbished and renamed *Admiral FitzRoy* and *Admiral Beaufort*.

In the interests of further economy, these two ships were finally withdrawn because of their age, the strenuous nature of their operations, and soaring maintenance costs, and were replaced at the beginning of 1982 by a single chartered large trawler, the *Starella*, converted and fitted with sophisticated equipment for making regular meteorological observations at the surface and in the upper air, and for their automatic transmission by Telex-over-Radio. *Starella* has a crew of 20, including 7 Meteorological Office staff, and operates at station 'L' at position 57°00′N, 20°00′W in conjunction with the Dutch weather ship *Cumulus*. The UK ship spends 30 days on station followed by 20 days in port, usually at her home base of Fleetwood, from where her in-port administration is handled by the OWS officer of the Meteorological Office. The three other Atlantic stations are manned by weather ships from France, Norway and the USSR.

*Ship communications for meteorological observations*

Until recently, meteorological and oceanographic observations from ships at sea have been sent to the national meteorological services by conventional radio methods. Many countries, including the UK, operate an arrangement whereby observations are accepted through nominated Coast Radio Stations (CRS) at no cost to the originating vessel, payment being made instead by the receiving meteorological service. Reports are normally sent direct from the CRS to the appropriate National Meteorological Centre (NMC) (e.g. Bracknell) for local and domestic use and also for international distribution on the WMO Global Telecommunication System (GTS).

Within the last year or two, satellite communication facilities provided by INMARSAT, the International Maritime Satellite Organization, have been instrumented for use by ships at sea and a growing number of ships in the VOF are transmitting their observations via the INMARSAT system. INMARSAT effectively extends to ships at sea the modern and reliable telecommunication services available on land. Using a special 2-digit address code a suitably equipped ship can send its weather report directly by satellite link and an INMARSAT Coast Earth Station (CES) to the associated NMC. Bracknell is served in this way by the CES operated by British Telecom at Goonhilly in Cornwall, which can be contacted directly by ships anywhere in the Atlantic (North or South). The ship to NMC communication is rapid, reliable and free from the vagaries of radio propagation conditions. Furthermore the tariffs, which are based on the time taken to transmit the message, compare very favourably with those for transmission by traditional radio methods. At the end of 1983, rather more than 10 per cent of the total number of observations received at Bracknell from merchant ships were arriving in this way. WMO is co-ordinating action to ensure that meteorological services world-wide derive maximum benefit from the new opportunities for both collection and dissemination of marine meteorological information provided by the INMARSAT system.

A system designed solely for prompt collection of ships' weather reports via satellite, (unlike INMARSAT which caters for a wide range of telecommunication requirements), is the Meteorological Office Observing System for ships (MOSS). It is intended for operational use on ships in the VOF and utilizes the data collection capabilities of geostationary meteorological satellites. Weather observations entered manually into the on-board equipment are automatically transmitted to the satellite at predetermined times and subsequently relayed to the ground control station. From there they are passed to a convenient meteorological centre for distribution via the GTS. In the case of a MOSS-equipped ship on the eastern North Atlantic, for example, the report will normally go via the Meteosat satellite to the European Space Operations Centre at Darmstadt in West Germany for insertion on to the GTS at the nearby centre of Offenbach. The system has proved effective, reliable and cheap. It has the particular advantage that the transmission is initiated automatically and does not require a Radio Officer to be on duty at the time.

*Buoys and marine automatic weather stations*

In addition to the observations which are provided by ships (VOF and OWS) and the data available from satellite and aircraft surveillance there is a need for measurements from a variety of other ocean data acquisition systems (ODAS). This need may stem from specific, local requirements such as forecasting for the offshore hydrocarbon recovery industry or from the wider demands for global network information. It may be met in a variety of ways which are often dictated by the availability of suitable platforms upon which the observational equipment can be mounted. Over the past ten years a series of complementary approaches to these demands for marine observations have been developed. These have resulted in the deployment of a range of automatic and semi-automatic marine observing systems, all based upon a standard electronics package and employing the same meteorological sensors but all adapted to the specific platforms available. Such automatic systems have been deployed on moored buoys, drifting buoys, fixed navigation towers, offshore islands, oil platforms and light-vessels.

A wide variety of telecommunications systems are employed with these weather stations. On the oil platforms they rely largely on telephone lines terminated by modems through which the data pass. The inshore buoys and offshore islands rely on VHF radio links to shore stations which are linked in turn by telephone lines to various locations equipped with data 'phones and teleprinters. Buoys more than 30 miles from shore rely on satellite communications, or in some cases HF radio links. Both the geostationary satellite, Meteosat, and the polar orbiting satellites (NOAA 7 and 8) are used. Normally data are transferred through Meteosat and the polar orbiters are used to provide a check that the buoy is still in position. In the case of the freely drifting buoys both data and position are obtained through the NOAA satellites. Most of these marine observing systems report at three-hourly intervals, timed at the 'synoptic' hours 00 GMT, 03 GMT, 06 GMT etc., although some have a facility which enables them to be interrogated at will from the base (shore) station or from more distant locations equipped with data 'phones and teleprinters.

The present network of marine observing systems includes three oil/gas recovery platforms in the North Sea (Beryl A, Piper A and Amoco 49/27A) which are all fully interactive systems collecting basic data (pressure, temperature, wind and humidity) automatically, and permitting an operator on the platform to add to this basic information his own estimates of such variables as cloud, visibility and weather. There are three inshore systems; the 3 m diameter toroidal buoy moored in Lyme Bay and two stations on the uninhabited islands Muckle Holm and Sule Skerry (Plate I). These are all fully automatic battery-powered units; the Sule Skerry system incorporates a microprocessor in its shore station located at Wideford Hill, Orkney but the other two, whose shore stations are at Portland and Sullom Voe respectively, do not have this facility. There are also two open ocean, moored buoys currently operating in the network. ODAS 20 is moored about 150 miles south-west of Land's End and is a fully automatic observing system which reports through Meteosat with a position check made periodically through the polar orbiting satellites. ODAS 451 is moored about 350 miles west of the Faeroe Islands and reports by HF radio to Reykjavik, Iceland, and also through the polar orbiting satellites to a data read-out station in Oslo.

Although some of the systems described have been set up specifically to meet the Meteorological Office local user needs, there is a wider, international requirement for this type of data and in Europe the COST 43 Project aims to establish an experimental network of ODAS through fostering bilateral and multilateral co-operative programs under the aegis of the International Agreement which governs the Project. Four different international programs have been, or are being, undertaken within this framework over the past six years. A joint experiment on the efficacy of different sensor suites, buoy hulls and HF transmission systems was mounted with a Norwegian laboratory in 1978/79, and the present ODAS 451 is a joint venture between the United Kingdom, Norway and Iceland. In the realm of drifting buoys, the Office is involved in two joint projects. Six buoys owned by the Institut für Meereskunde, Kiel and equipped with pressure sensors provided by the Office were deployed in the autumn of 1983 in the North Atlantic. These buoys drifted eastwards across the Atlantic and reported surface pressure and sea surface temperature in near real time through the polar orbiting satellites. The same system will be used in a larger joint project now being planned under the aegis of COST 43 in co-operation with the French, Norwegian, Irish and Icelandic meteorological services. This project, due to begin buoy deployments in early 1986 is intended to keep an operational network of drifting buoys in part of the eastern North Atlantic for about three years in the first instance.

Further international co-operation will be fostered to assist with the overall objective of establishing and maintaining appropriate contributions to the Global Observing System of the WMO.

*Observations from commercial aircraft over the oceans*

A further contribution to the observational data base over the oceans is provided by observations from commercial aircraft which are added to the position reports required under International Civil Aviation Organization regulations. In this connection a new facility was developed as one of the Special Observing Systems for the Global Weather Experiment of 1979. This prototype Aircraft to Satellite Data Relay system (ASDAR) was developed for the US National Oceanic and Atmospheric Administration and 17 units were made and flown on aircraft of a number of countries.

The prototype ASDAR provided observations of position, altitude, wind speed and direction and air temperature which were extracted automatically from the aircraft Flight Data Acquisition Unit every 7.5 minutes and transmitted through the nearest geostationary meteorological satellite in bulletins of eight observations every hour. These data proved highly useful and gave a detailed picture of the atmosphere at aircraft cruising level.

The original ASDAR was not designed for quantity production and in response to developing interest in operational applications of the device, a Consortium of eight Meteorological Services has been set up to fund the development of a unit suitable for production. The development of the new unit will be completed in September 1985 when flight trials on six units will have concluded and necessary certification with the satellite operators, and the UK Civil Aviation Authority and USA Federal Aviation Authority will have been obtained. The first production units are expected to go into service early in 1986.

*Satellite observations over the oceans*
Sensors on both geostationary and polar orbiting satellites have the particular advantage of being able to view large areas of the atmosphere and earth's surface not readily accessible to other observing systems. This advantage in terms of coverage is particularly valuable over the oceans. Winds derived from cloud movement and temperature profiles derived from radiances have made a considerable improvement to our data base. Even though the accuracy of these quantities is in general less than that obtained from surface based systems, there are sufficient of these data to make a significant improvement to analyses over ocean areas.

### ANALYSIS AND FORECASTING MODELS FOR SEA STATE AND SWELL

Before the advent of powerful computer technology, the accepted means of forecasting ocean waves was by the use of empirical wave growth curves, the wave height and period being deduced from the expected wind speed, duration and fetch. The numerical models now in use by the Office incorporate physical principles such as wave growth, interaction and dissipation, the advection of swell energy and, in the higher resolution version, depth dependent processes such as refraction and bottom friction. The basis of the model is a discrete directional wave energy spectrum (14 frequencies and 16 directions) which is determined by the surface wind fields forecast by the numerical weather prediction model. The information required on height and period can then be obtained by calculating the appropriate statistical moment of the energy spectrum.

The current operational forecasting services for ocean waves are based on the products of three numerical models which are run on the CDC Cyber 205 computer twice a day following the integrations of the atmospheric prediction models. The coarse-mesh version produces forecasts up to 48 hours ahead for areas of the North Atlantic and North Pacific Oceans to the north of 18°N with a grid length of approximately 150 km. The two fine-mesh models make forecasts for up to 36 hours. One covers the continental shelf and north-eastern Atlantic with a resolution of 25 km and the other the Mediterranean Sea with a resolution of 50 km. The coarse-mesh model provides boundary values for the fine-mesh continental shelf model. Thus swell forming in the Atlantic is taken into account by the continental shelf model and advected onward.

Before running each forecast a 12-hour 'hindcast' is performed. This is essentially a repeat of the first 12 hours of the previous integration but this time using wind fields that are updated with recent observations. This forecast–hindcast cycle ensures that the starting point of each ocean wave forecasting sequence is the best possible description of the initial situation within the limits of the numerical simulation technique. These hindcast fields are retained in an archive which dates back to 1978 and have been used, for example, to provide supplementary estimates of wave energy resources off the Hebrides. The accuracy of forecasts and hindcasts is assessed by the routine gathering of wave data from the limited number of fixed observing stations, e.g. weather ships and offshore oil and gas production platforms.

The coarse-mesh products are mainly used in forecasting for shipping. Other users of forecast wave data from the fine-mesh model are those Water Authorities with responsibility for aspects of coastal defence. At present four such Authorities receive forecast wind and wave information. This service was initiated following the Portland flooding of February 1979 and usually runs from September to April. During these months another numerical oceanographic forecast model is also run operationally for the Storm Tide Warning Service. This model covers a similar area to that of the fine-mesh continental shelf wave model. By transforming the wind information into data on surface shearing stress the model is able to calculate the height and rate of progression of any 'storm surge'—the raising of sea level due to atmospheric forcing. The astronomical tidal effect is also simulated in the model.

## Marine forecasting services

*Services for the shipping and fishing industry*

Forecasts for shipping have been undertaken by the Meteorological Office for well over a century. The first direct weather forecasts to mariners took the form of visual gale-warning signals introduced at ports in the British Isles in 1861 and, with only minor modifications, this system is still in use today. Weather bulletins covering the sea areas around the British Isles and the eastern North Atlantic Ocean are broadcast regularly by a variety of means. They are prepared in the Central Forecasting Office, (CFO) at Bracknell where forecasters maintain a 24 hours a day watch on the weather.

For the familiar sea areas, Viking, Forties, Cromarty, Forth, Tyne etc., weather bulletins covering wind direction and speed, weather and visibility are issued four times a day. A statement of the gale warnings in force, a general synopsis of expected developments over the next 24 hours and a series of latest reports from around the British Isles are also included. Gale warnings are kept under constant review and may be issued, amended or cancelled at any time. They are broadcast on BBC Radio 4 and by coastal radio stations at the first available opportunity. For some years, the British Telecom coast radio station at Cullercoats has been transmitting gale warnings and forecasts in the radio teletype mode on an experimental basis. During the past year this system, now known as NAVTEX, has become operational and extended to sea forecast areas to the west of the United Kingdom by transmission from Portpatrick coast radio station. In the near future, Land's End coast radio station will be similarly involved.

The Atlantic Weather Bulletin for Shipping is broadcast twice daily by HF radio telegraphy from the British Telecom coast radio station at Portishead. Its purpose is to give mariners information about the weather existing and expected in the eastern North Atlantic out to 40°W.

Nearer home, a forecast for inshore waters up to 12 nautical miles off the coast of Great Britain is issued twice daily and broadcast by the BBC. Many local radio stations located around the United Kingdom broadcast small craft warnings issued by the Office during the period from April to October. Warnings are issued when winds of force 6 or more are expected within the next 12 hours for local inshore waters up to 5 nautical miles from the coast.

The Central Forecasting Office (CFO) at Bracknell prepares for transmission by radio facsimile a number of weather charts which are of value to mariners. These include surface analyses and 24-hour prognostic charts transmitted four times a day, 48- and 72-hour surface prognostic charts once a day, North Atlantic wave analysis and 24 and 48-hour prognoses twice a day and a sea ice chart once a day. In general, these cover the greater part of the North Atlantic Ocean, though the precise areas vary from chart to chart.

The sea ice charts cover the North Atlantic Ocean, the Baltic, the Barents Sea, the Greenland Sea, Baffin Bay and Hudson Bay and are prepared by a special section in the CFO using information obtained from a variety of sources. The charts give 5-day mean sea temperature isotherms as well as showing sea ice conditions. A chart is also available which shows the ice conditions in the seas of the northern hemisphere at the end of each month. Sea surface isotherms are plotted and isopleths of accumulated air temperature below freezing give an indication of the severity of the season.

In addition to the standard services, many of which are provided free in compliance with the International Convention for the Safety of Life at Sea (1974), specialized forecasts can also be provided to suit the requirements of individual customers.

*The Ship Routeing Service*

The Meteorological Office Ship Routeing Service was set up experimentally in 1968, specifically to provide advice to Shipmasters on passages across the North Atlantic. There was close collaboration with three well-known British shipping companies, and the successful link with the Cunard Line continues to this day. World-wide ship routeing is now available to ships of any type and any nation. The Ship Routeing Officers (Master Mariners) are located in the CFO and are thus able to obtain current and projected weather information without delay in order to follow their clients' needs closely. All the Meteorological Office's resources are therefore continuously available including warnings, ice and fog information, satellite imagery and computer outputs.

Forecast wave height and direction fields are used in conjunction with the ship's performance curve to evaluate several projected alternatives of course and distance over 12-hour periods to form a 'time-front'. Successive 12-hour steps generate a least-time track for the complete sea passage, producing the theoretical course which the ship would be advised to follow. However, other considerations such as navigational hazards, areas of fog or ice and the Master's particular requirements must be taken into account. Requested criteria for the routeing service may include one or several of the following: fuel economy, ship and/or cargo damage avoidance, special maintenance programs and towage conditions. On completion of the voyage, 'hindcast' charts are available to the client, showing comparisons of actual weather experienced with probable conditions that might have been encountered on an alternative (usually the shortest) route.

In the 15 years since the commencement of the Ship Routeing Service, advice has been provided for more than 5000 passages of ships, tows and oil platforms, and the annual receipts cover in full the staff costs of those directly involved, plus a significant contribution towards overheads.

*The Storm Tide Warning Service*

The Storm Tide Warning Service (STWS) was originally established in September 1953 as a result of the tidal flooding disaster earlier that year. On the night of 31 January 1953, severe northerly gales in the North Sea caused the tides to be much higher than predicted in the tide-tables; 300 people were drowned and 160 000 acres were flooded on the east coast of England. Although responsibility for issuing tidal flood warnings lies with the Ministry of Agriculture, Fisheries and Food, the STWS provides the up-to-date information on the effect of the weather on tidal levels.

The staff of the STWS monitor the tides recorded at 12 tide gauges, at Stornoway and at various places on the east coast of Britain round to Newhaven. Since the winter of 1978–79, a mathematical model originally devised by the Institute of Oceanographic Sciences has been run on the Meteorological Office computer to supplement the empirical equations previously used to forecast the meteorological effects on tides. Forecasts and warnings are passed routinely to all the east coast Water Authorities. In addition model forecasts are supplied to west coast Water Authorities, which have been increasingly concerned about tidal floods on their coasts, particularly around the Bristol Channel and the north-east part of the Irish Sea.

*Marine forecasting service to the offshore industry*

Ever since the first drilling in the UK sector of the North Sea took place in winter 1964 in the Dogger Bank area, the Meteorological Office has provided forecast services to the offshore industry, primarily through the London Weather Centre.

As the offshore industry's forecasting requirements have developed over the years, so also has the service provided by the London Weather Centre to meet those needs. The North Sea was originally a relatively poorly known area as far as meteorology was concerned, and even less was known about forecasting the state of the sea. Techniques to handle this problem advanced rapidly as observational data became available from the rigs themselves. The original forecast aid for wave height and period was a series of graphs produced by Darbyshire and Draper (National Institute of Oceanography). However, useful as they were, the graphs were found to underestimate waves in the northern North Sea and overestimate them in the southern North sea. As more data became available it became apparent that techniques of forecasting swell, as well as those for taking into account the topography of the sea bottom were needed.

The latest and most significant development for inshore forecasting to the offshore industry has been the introduction of direct computer printout of winds from the atmospheric model and the development of the fine-mesh sea/swell computer models. They have made a significant improvement in the accuracy of forecasting wind and waves, and are particularly useful in depicting the trends (i.e. increase or decrease) of high seas. The computer model products are now used as the basis for all forecasts to the offshore industry. A further advantage of the numerical guidance from computer models has been the possibility of providing forecast wave information in spectral form. This is of particular use to companies in determining more precisely the anticipated behaviour of structures when, for example, the swell is close to the resonant period.

The form of service provided to the offshore industry has also developed over the years to meet the changing needs of operators. The London Weather Centre has become the operational centre of the service to the offshore industry and is responsible for all the forecasts issued. These are sent via the standard medium of telex and always deal with specific sites rather than general areas. This is because it has been found that conditions can vary considerably over relatively short distances in the North Sea.

The standard package consists of forecasts for two periods of 12 hours followed by two periods of 24 hours and an outlook for the following 48 hours. If required, the outlook period can be extended for a further two days. In addition to the standard telex service, issued twice daily, a full back-up service of updated forecasts and flash warnings at any time is provided.

To improve the value to customers of the telex forecast service, two additional facilities are provided. First, a 24-hour consultancy service with the forecaster on the Oil Bench at London Weather Centre is available. Any recipient of the forecast may telephone for clarification and he is always accorded a high priority. Second, the Meteorological Office at Dyce Airport, Aberdeen, maintains a personal contact with customers as well as conducting a daily briefing on the forecast for onshore managers. This assists not only in the day-to-day decision-taking within the company but also in the deployment of costly resources in the coming week.

For most applications, this comprehensive service is sufficient; however, in more recent years, there has been an increasing requirement from offshore companies to supply forecasters on site to deal solely with the weather-sensitive activities of a single project. This is particularly the case with expensive construction projects such as the concrete Ninian platform which was constructed in Loch Kishorn in 1978. It has become apparent that the loss of even one day's production of oil caused by the absence of an adequate forecasting service is a great many times the cost of providing the service.

### Marine data archive

Since the middle of the last century the Meteorological Office has built up an archive of weather logbooks from British-owned merchant ships. During the post-war years many of these data were transferred to computer compatible form, first on to punched card and then on to magnetic tape as part of a general policy to generate computer archives. Although world-wide in nature the value of this archive was limited in that it was merely a subset of the totality of observations made by ships of all nations all over the world. There were also problems in the early years of computer archiving because of the poor format of the data and their unknown quality.

The other major maritime nations of the world had similar collections of data from their respective merchant fleets and, until 1961, little or no effort was made to pool these sources of data. In 1964, under the provisions of a WMO Resolution, responsibility for data from the oceans of the world from 1961 onwards was divided between the countries as shown in Figure 1. Under the terms of this Resolution each country recovers the weather logbooks used on board its ships and transfers them to magnetic tape in an agreed format. The observations are then separated by that country into sets corresponding to the areas on Figure 1 and passed to the appropriate responsible country.

In addition to archiving in computer form the British historic marine data from 1854 onwards the Meteorological Office has obtained other historic

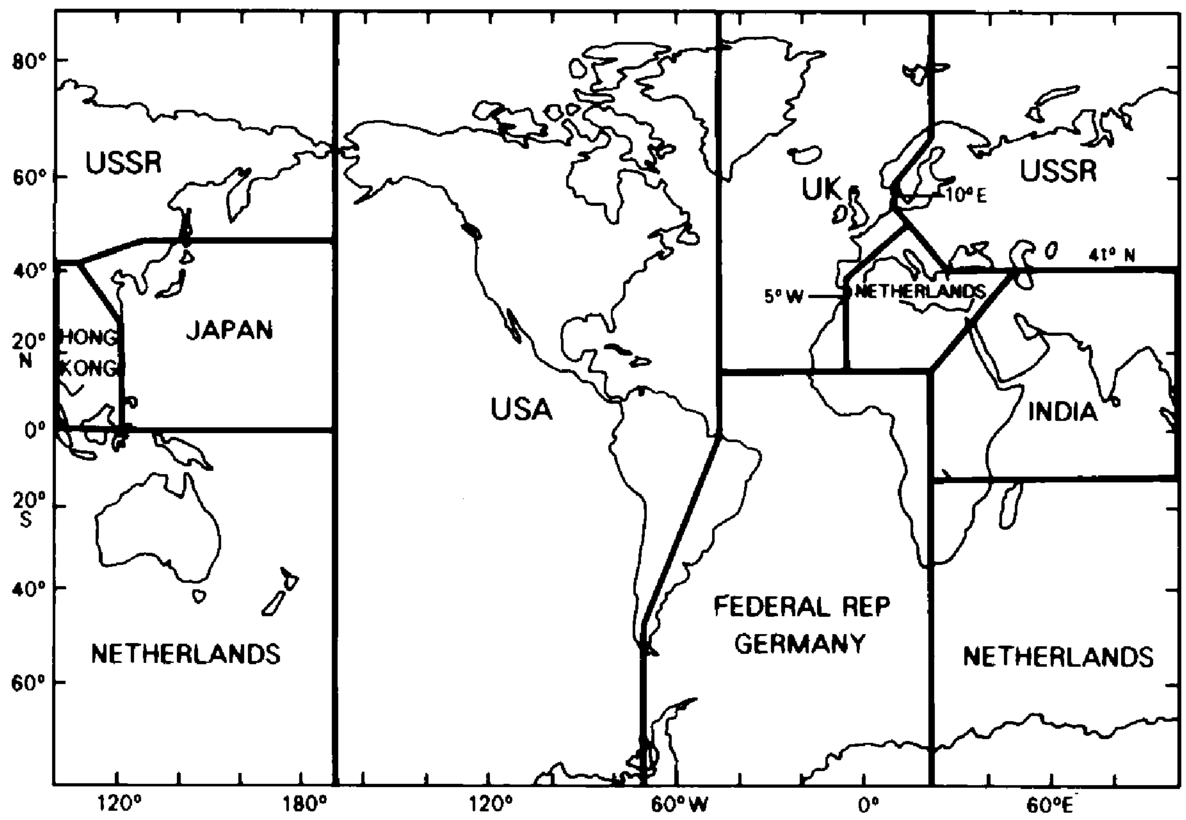



Figure 1—Marine data—areas of responsibility

data sets on magnetic tape, notably one from the United States of America and one from Germany. After merging all these data into a world-wide data set and incorporating the data from the United Kingdom area of responsibility, it was necessary to carry out fairly comprehensive quality control checks in order to ensure that the data archived were as reliable as possible and free from duplicate observations. Much time and effort has gone into developing the software necessary to achieve a convenient data format and to undertake the quality control work.

The data bank so developed proved adequate for many enquiries relating to the North Atlantic Ocean and British home waters. However, as the offshore industry began to explore further afield, and as the shipping industry became aware of the capacity of the Meteorological Office to answer enquiries at short notice, the need to improve the density of observations on a world-wide basis was realized. As a consequence a series of bilateral exchanges was agreed with the result that all data from 1961 onwards for the areas of responsibility of other nations have now been included in the marine archive held on COSMOS. Notable omissions from this exchange program so far include the Indian Ocean area where data have been promised from 1961 to 1967 but not yet received, and the USSR.

Although the largest constituent of the Main Marine Databank is the collection of observations from merchant ships there are a number of subsidiary data sets which have been created and included in the Main Databank using a common format. These other data sets are from the ocean weather stations (OWS) in the North Atlantic, from light-vessels (LV) in the North Sea and around British coasts, comprising 23 British and 4 Dutch vessels, and from 17 oil production platforms (OPP). The data from the OWS and LV are valuable because it is possible to use them for time series analyses and the data, particularly from the OWS, are of high quality. However, data from the OPP continue to give concern because the quality is often unsatisfactory for climatological use.

The Main Marine Databank is now nearly completely global in scope containing approximately 53 million observations on 77 high-density magnetic tapes. It is a direct access data set and so, in principle, data for a given location and time can be extracted directly by using comprehensive indexes rather than a sequential search. The formatting has been designed to permit easy transfer to a suitable mass storage device when one becomes available.

The Meteorological Office is also the World Data Centre, under the auspices of WMO, for ocean current observations derived from the drift of ships. Recently a new archive was created to hold all the ocean current data already available in the Meteorological Office and software was developed to incorporate contributions from other countries. However, the data exchange has not proved as successful as that relating to the 1964 WMO Resolution and data have been received from only 5 countries to date. The major use of this data set is in the revision of *Admiralty Pilots*, many of which were originally based on very inadequate ocean current data samples.

Each responsible country under the provisions of the 1964 WMO Resolution is required to summarize the data from its area on an annual and decadal time scale. Because of high printing costs it was agreed in 1981 by the WMO Commission for Maritime Meteorology (CMM) to discontinue the production of printed summaries on an annual basis. CMM did, however, agree that such summaries should continue to be available on magnetic tape. The Meteorological Office has continued to produce annual summaries but has effected the necessary economy by using microfiche printed direct from computer. Copies of the microfiche can be provided quite cheaply on request.

*Marine enquiry bureau service*

Based on the comprehensive marine data bank described above this service is provided to answer enquiries relating to the design, planning and post-operational phases of marine projects. The enquiry bureau is manned by a team of experienced climatologists and meteorologists supported by a small team of programmers who have developed a good deal of the standard software used and have written specialized programs to service individual customer requirements. Maximum use is made of modern computer techniques, such as graphical output on film and microfiche as well as on paper.

At the design stage the engineer is concerned to establish the extremes of weather which his structure may experience and the design necessary to withstand those extremes. The item being designed can vary from a small construction such as a fire escape bolted to the deck of an oil platform at one extreme to a major work such as the platform itself or a large harbour defence wall at the other. The consequences of under-design can often be serious in terms of loss of life, although the financial penalties tend to be linked rather more with the size and cost of the construction. Over-design may not be important with small components but can be very expensive with large structures. An example, frequently quoted, is that one extra metre of rig leg length can add £1 million to the cost. In the majority of cases winds and waves are the parameters which most affect design but data for other meteorological variables are also sometimes requested. Extremes are estimated by fitting an appropriate function, such as the Weibull distribution, to the available data and extrapolating to the required return period. This technique must be used with great care and with full knowledge of the limitations of the data.

Meteorological Office advice is often sought when planning weather sensitive marine projects. Enquiries vary in scope from requests for climatological information from students engaged on field studies or amateur yachtsmen planning voyages to those from marine contractors trying to establish the viability of a particular operation. The majority of enquiries fall into the last category and often involve an estimate based on past records of the probable amount of unproductive time which could occur. The contractor will base his estimate of completion date and costs upon the climatological data provided. By so doing he will hope both to avoid penalties for contractual delay and to minimize costs due to having equipment lying idle. A large tug or dredger which is confined to harbour by bad weather can cost £15 000 to £20 000 per day. It is therefore important that an appropriate amount is included in the tender to cover the probability of such delays.

Inevitably, contractual disputes occur both in marine construction and ship operations. Often, these involve structural damage, cargo loss or damage, or delay beyond contractual completion date attributed, at least in part, to adverse weather. Many disputes are settled out of court by mutual agreement after considering all the facts. On those occasions when this proves impossible, a certified statement may be requested by a court or arbitration tribunal. In a small proportion of such cases further explanation may be necessary and a marine climatologist may attend the hearing as an expert witness.

In addition to the types of enquiry mentioned above, large investigations may be carried out such as the assessment of the offshore wind energy resources. A limited program of investigation and development is also mounted in support of enquiry work. An example of such work is the wave climate synthesis project undertaken jointly with the National Maritime Institute (NMI) Ltd. The Meteorological Office provided data from merchant ships and expert advice on their quality while NMI provided a computer model to convert sparse visual estimates of wave height and the more prolific estimates of wind speed into a useful wave climatology. The Meteorological Office and NMI Ltd have now set up a joint commercial venture to market this wave climatology service and can, as a joint operation, reply to an enquiry for any location in the world within 48 hours.

## OTHER WORK OF THE DIRECTORATE OF SERVICES

### Forecasting Services

*Central forecasting*

The Central Forecasting Office (CFO) maintains a continuous operation throughout the 24 hours on each day of the year. Internationally, CFO is a Regional Meteorological Centre within the World Weather Watch of the World Meteorological Organization and, as such, issues analyses, forecasts and advice to a number of National Meteorological Centres in Europe for an area of responsibility covering a large part of the North Atlantic and western Europe. In addition to the more traditional advice in chart form, there has been a steady increase in the transmission of machinable data in the form of coded bulletins. This was extended considerably in 1983 by the introduction of a new series of bulletins (including rainfall data) directly from the new 15-level fine-mesh forecasting model. These bulletins are disseminated twice daily to 13 countries within Europe, from Romania to Iceland.

At the national level, CFO's main role is to provide an overall framework of guidance for the forecasting undertaken at the Meteorological Office outstations. This ensures consistency in the forecasts made for the general public of the broad evolution of the weather, while allowing outstation forecasters the freedom to take account of local weather effects within their areas of responsibility. The guidance material for periods of up to 5 days ahead takes the form of charts and text, which are updated every 6 hours, or more frequently if occasion arises. In addition, the Senior Forecaster in CFO retains a direct influence on forecasts for the media through regular telephone conferences with the forecasters at the London Weather Centre responsible for the weather broadcasts on television and radio and by issuing forecasts covering the whole of the United Kingdom to the Press Association four times a day.

Central to CFO's role is the need for the forecaster to consider and interpret large volumes of forecast information generated by numerical models of the atmosphere on the fastest available computers. There are severe time constraints, but a numerical forecast covering Europe and the North Atlantic for up to 36 hours ahead is available from the fine-mesh model within 3 hours of observation time. This is followed by a run of the global model which provides numerical weather predictions for up to 6 days ahead. These are made twice a day and are based upon numerical analyses made every 6 hours. The analyses are monitored and quality controlled by forecasters who correct or reject spurious data and, where appropriate, introduce simulated data to assist the analysis process.

Forecasters must consider the latest available numerical forecast in the light of earlier numerical model runs and additional information on horizontal and vertical scales smaller than those resolved by the models from conventional weather observations and from sources such as radar and satellite pictures. Despite the significant advances in the accuracy of numerical models, which give generally good guidance on the broad-scale weather developments, the additional information can often be crucial, especially in forecasting the weather in detail for the first 24 hours ahead.

At longer time scales, owing to improvements in numerical modelling, much more reliance can now be placed on the medium-range guidance at least for periods up to 5 days. Interpretation of the model output by a skilled forecaster is still necessary, however. In CFO account is taken of numerical forecasts made in the USA, the Federal Republic of Germany and the European Centre for Medium Range Weather Forecasts as well as those provided by the global model of the Meteorological Office. The medium-range forecasts have proved valuable in the provision of repayment services and the global coverage of the model output has enabled the CFO to respond to requests for forecasts for distant parts of the globe. For example, forecasts of wind and temperature for aircraft operations in the South Atlantic were provided routinely throughout the year in support of services provided by staff of the Defence Services Branch.

The issue of forecasts and warnings for ships at sea was another important task carried out in CFO. Routine forecasts covered an area from the coasts of Europe westwards to 40°W and northwards to include the waters around Iceland. In addition, the advent of the global model allowed advice and forecasts to be given for shipping over all the oceans of the world, both through the specialist Ship Routeing Service located in CFO and for individual customers, often by radio telephone. The CFO forecasters also provided data and advice to the Storm Tide Warning Service (STWS) which provided warning on occasions when tidal and atmospheric conditions combined to cause tidal surges. In April 1983 STWS became an integral part of the Central Forecasting Branch. Details of these many services for marine interests are included in the Special Topic of the Directorate of Services—Marine Meteorology.

A team of specialist aviation forecasters in CFO prepared material for the flight documentation supplied to civil aviation throughout Europe for westbound flights across the North Atlantic. While most wind and temperature information was supplied directly from the numerical model, subjective amendment was carried out for important features such as jet streams and clear air turbulence. Special forecasts were also provided for Concorde operations, using the improved output from the new model which, in contrast to its predecessor, comfortably embraces the flight levels, up to 55 000 feet, of the supersonic airliner.

Within the Central Forecasting Branch there is a section responsible for the maintenance and development of the operational numerical forecast suite and of the products made available through the Outstation Automated Systems (OASYS). Following the introduction of the 15-level numerical weather prediction model in September 1982, there was intensive activity throughout 1983 to improve the efficiency of the operational system and the quality of the numerical forecasts. In collaboration with the Forecasting Research and Data Processing Branches, the computational efficiencies of individual computer programs and of the operational system as a whole were investigated, and significant savings of Cyber 205 computer time were achieved. Many of the operational tasks concerned with the output of model results in chart or digital from were transferred to the IBM 3081 computer, thus achieving a better use of total computing resources.

Another major organizational consideration was the provision of back-up for the 15-level numerical model for use when the Cyber 205 is inoperative. For the fine-mesh version of the model it became clear that the most effective method of producing back-up was to run the formerly operational 10-level model on the IBM 3081. Although, inevitably, 10-level model products are of lesser quality this alternative is superior to others in that the normal operational schedules can still be met. That is to say, the 36-hour numerical forecasts based on midnight and midday observations required in meeting CFO's Regional Meteorological Centre responsibilities can be made available in the Central Forecasting Office at 0300 and 1500 GMT respectively. For the global version of the 15-level model, back-up to cover Cyber 205 breakdowns of up to about 12 hours' duration was obtained from longer-period forecasts previously completed. The necessary chart and digital information required for this was produced as routine and was thus always available for back-up when occasion arose. For the rare instances of longer breakdowns, plans were made for back-up to be available in future in the form of digital data issued from the alternative World Area Forecast Centre in Washington D.C.

Changes were introduced in the operational analysis and forecasting system to improve the quality of 15-level model results. Special efforts were made to ensure that the preparation of observational and intervention data for input to the operational system is carried out in a consistent and effective manner, and programs were modified to process new forms of data and increased volumes of existing forms of data which became available. In collaboration with the Forecasting Research Branch a number of shortcomings in the data assimilation and forecast models were remedied, one important benefit being that smoothing was no longer required before charts were produced for users. Case studies were carried out, usually as a result of questions raised by the duty forecasters monitoring the numerical products, to clarify the roles of observational and intervention data, and of the objective analysis procedures, in circumstances where the forecast model showed particular sensitivity to details of the initial conditions.

Facilities for the objective evaluation of numerical forecasts were further extended, and the results obtained were monitored in relation to changes in the operational system. The information made available for evaluation included verification statistics, error maps and systematic trends in variables during forecasts.

The numerical model used for operational prediction of waves and swell on the sea surface was compared with two other wave models in an international project using carefully chosen wind fields, with special emphasis on prediction for the North Sea. Continuing research of this kind is expected to lead to improvements in the scientific formulation of the wave model. At the same time considerable effort was devoted to the best use of available wind data, to extension of the region of coverage to meet new requirements, e.g. for ship-routeing purposes, to verification and to archiving of wave model results. See also this year's Special Topic of the Services Directorate.

Progress was made with several aspects of forecasting office automation. A steady program of development of applications software for the minicomputer systems at three major outstations has been maintained. Grid-point information from the 15-level model is now available to each OASYS in digital form, and this has opened up a new range of possibilities for locally derived output products. In CFO the facilities available for interactive monitoring of observations and analyses were further extended to meet the requirements of global data assimilation, and to increase the effectiveness of the limited amounts of time available to forecasters to prepare their intervention data. Increased effort was also devoted to the graphical display of charts and vertical profiles on visual display units in CFO, but in this aspect of the work the hardware currently available imposes significant constraints.

There was a marked growth in activity related to the provision of both numerical model and satellite imagery data for display on television. Techniques for processing the data to obtain suitable formats and for the transfer of information to computers used by television companies were further developed in the light of the variety of requirements being defined. Of great importance are the techniques which must be developed for modification of products by forecasters before transmission to television users, so that the information presented to the public will be fully consistent with guidance issued by the Meteorological Office in other ways. This work has resulted in higher priority being given to the upgrading of the interactive graphical display facilities in the CFO.

*Services for industry, commerce and the general public*

Forecast services for the general public, industry and commerce are provided from a network of public service offices around the United Kingdom. Nine of these offices are dedicated Weather Centres located in or near city centres whilst others are multi-functional offices located on civil or military aviation airfields. Reorganization of Defence support services has caused changes to the public service in some areas. The Main Meteorological Office (MMO) at RAF Pitreavie ceased its public service commitments to Fife, Edinburgh and the Lothians and this responsibility was taken up by the Aberdeen Airport Office and Glasgow Weather Centre. The MMO at RAF Bawtry was relieved of its responsibility for supporting Defence needs in November and it is planned to move the office to Leeds in early summer 1984. Reorganization of Defence services at the Honington MMO has led to the need for a Weather Centre to be established in Norwich to serve commerce, industry and the general public in East Anglia, which is expected to open early in 1984. Plans to rationalize services to the public and civil aviation in south-west Scotland, which began in 1982, are referred to in the section on services to civil aviation.

Public service offices have continued their efforts to extend their repayment services. New technology is being introduced as quickly as possible to allow expansion of services without incurring the need for extra staff. In 1983, an Outstation Automation System (OASYS) was brought into operation at London Weather Centre (LWC). This is a twin computer system linked to the central computer resources (COSMOS) at Bracknell. Many of the routine tasks such as plotting and preparing lists of data, previously undertaken by support staff, are already being handled by the system. It also enables the forecaster to recall and display data in various formats at his work position as soon as they are available. Work is continuing on further exploitation of this system. A word processor was acquired by London Weather Centre and most letters, reports and invoices are already being handled using this equipment. Plans are in hand to extend the use of word processors more widely in forecasting offices.

General forecasts are prepared for dissemination by the media (television, radio and the press) at no direct cost to the general public. Regional forecasts, updated several times daily, are available on the British Telecom Weatherline service and on Videotex systems at a relatively low cost to the public. All Weather Centres and other designated Offices also provide a wide range of dedicated forecast services either on a contractual or consultancy basis for a range of weather-sensitive activities. These include transport, construction, agriculture, power, offshore industries and also leisure activities. These specialized forecasts are usually issued in a format designed to meet the specific requirements of the customer and are communicated by telex or document facsimile. Consultancy services give access to a forecaster, as and when required, by an ex-directory telephone number. This is a particularly useful service to those clients whose work is weather-dependent but provides scope for flexibility in planning.

The year 1983 was a particularly busy one for development of services for radio and television. The Office is now in a position to offer a very comprehensive selection of pictorial satellite imagery and forecast weather parameters suitable for graphical animation on television. The data are assembled on COSMOS and are available for digital transmission to television studios. During the year discussions on the display of animated products took place with the BBC and seven of the IBA regional TV companies and also with two companies considering broadcasting to Europe.

The BBC altered the structure of their early evening programs in October, omitting the live presentation by the Weatherman. The program uses some of the newer style of presentations and the Weatherman is involved in the production of the program and the preparation of the scripts. Channel 4 TV continued their experiment with a new style of presentation. The sequence of the charts on which those forecasts are based is sent by document facsimile from London Weather Centre. This presentation is limited in its scope but shows the possibilities for future development, given an extended range of forecast products and the facility for digital transmission. Both the BBC and TV-am breakfast television programs are provided with weather forecast material by the Office and under the terms of negotiated contracts their presenters have the facility to discuss the weather situation with the forecasters at London Weather Centre. There were a number of changes in presentation of weather on regional television during the year. BBC Wales withdrew the live presentation at the time of the introduction of the new '60-minutes' program on national television. However, live presentations were introduced by Yorkshire TV, Tyne-Tees TV and HTV (West) using forecasters from Bawtry, Newcastle Weather Centre and Bristol Weather Centre respectively. This means that almost all television regions, other than north-west England, are served by live forecast presentations on at least one TV channel. Whether or not the presenters are members of the Office, they are supplied with weather information and guidance from the nearest Meteorological Office Weather Centre.

The steady expansion of live radio broadcasts from local and regional BBC and IBA stations has continued. By the end of 1983 no fewer than 43 radio stations were carrying live broadcasts made by members of the Office. Most other local radio stations use scripts prepared at the nearest public service office. Apart from the introduction of planned new stations further growth of services for local radio is likely to be limited by financial considerations.

The upsurge in interest by the media has called for a continual process of training, auditioning and selection of staff for the specialized broadcasting duties. Relevant lectures and training sessions have been added to the basic forecasting courses undertaken at the Meteorological Office College. In the autumn, the first special three-day course on presentation techniques took place at the College.

In addition to the routine broadcasts on radio and television already described, Office staff were involved in many other programs during 1983. The retirement of the former Director-General and the appointment of the new one, the announcement of the designation of CFO at Bracknell as a World Aviation Forecast Centre, the release of the report of the Resource Control Review on the Meteorological Office and the exceptional weather of the summer prompted a larger than normal number of requests for interviews. A list of the main broadcasts is incorporated in Appendix II of this Report. Jim Bacon, one of the BBC Weatherman team, again presented the weather feature in the 'Travel' program on BBC 2 during the summer and the duty Weatherman also featured regularly in the BBC 1 'Holiday' series in July. The year 1983 also saw the retirement of the senior Weatherman, Jack Scott, after 12 years of continual presentation on BBC television. Mr Scott immediately took up new duties as the weather presenter on Thames Television, with backing, under contract, of the London Weather Centre.

The amount of weather information provided to Prestel and Teletext grew steadily in 1983. The number of Prestel users continued to increase steadily during the year, although numbers are still well below the original predictions. The majority of users are still in the commercial rather than the domestic field although the proportions are becoming more even. Prestel offers a comprehensive selection of forecasts, weather reports and weather statistics for the United Kingdom and abroad as well as some services for specialized activities such as general aviation. During 1983, 5-day outlooks and forecasts for the sailing community were introduced and both proved very popular. Various trials were held during the year to test the interest of the users and identify the services most needed. A major development was the introduction of a service through Prestel for the home computer user. This allows software to be disseminated which can provide much enhanced graphics using the microcomputer displays. The Office has already tested this concept and is considering the best way to exploit the facility both in-house and for services to customers.

It is considered that the next major development on Prestel will be the introduction of Specialist User Group Services, some using Closed User Group concepts. The Meteorological Office has played a leading role in the Department of Industry sponsored home user project, 'Club 403', based on an area in the West Midlands. This trial has given the Office a good opportunity to assess the public reaction to alternative styles of presentation. The Office has also been involved in discussions with other interested groups, particularly general aviation, agriculture and road users. It is expected that at least one of these services will be introduced operationally early in 1984.

The Office continues to provide national weather forecasts for display on CEEFAX and ORACLE (the BBC and IBA Teletext systems respectively) and ORACLE also receives a regional service for most areas. Consideration is being given to providing this information automatically to the IBA using one of the facilities of the Prestel service.

There has been little change to the Weatherline service during 1983 despite efforts to persuade British Telecom to extend the service to remaining areas of the Country. A new forecast covering the coast and inshore waters of Devon and Cornwall was introduced in August fulfilling one long-recognized gap in the service. In 1983 the number of calls to Weatherline totalled 24 434 088, a figure similar to the 1982 total of 25 510 988. In an effort to establish the effectiveness of advertising for Weatherline, the Office combined with British Telecom to advertise the service in Ulster, through local commercial radio. The initial returns show that there has been a substantial increase in the number of calls, more than enough to cover the cost of advertising.

The number of enquiries to the Weather Centres again decreased. This is a result of the restriction of casual telephone access to Weather Centres and other public service offices. During periods of staff shortage answer-sets were installed at Glasgow and Nottingham Weather Centres and callers were advised by recorded message of alternative sources of weather information, such as Weatherline, Teletext, Prestel and local radio broadcasts. Seekers of specialist advice were asked to contact an administration number.

The use of consultancy services by commercial callers has already been mentioned but many other services tailored to the needs of a particular industry are provided routinely. One of the most important of these, in terms of weather sensitivity and the national interest, is that provided to the offshore industry. This is described more fully in the section on 'Services for marine activities' (page 22). The gas and electricity industries are also major users of specialist meteorological information and a dialogue is maintained with both corporations on the scope for improvement in meeting their operational requirements. The year 1983 was a mixed year in this respect. The CEGB decided to take a more detailed service which was designed to meet the needs of a new computer model; this service was introduced at the beginning of October. By contrast, in an effort to reduce costs British Gas decided to reduce their comprehensive national service despite acknowledging that the service is very cost-effective to the Corporation's operational activities.

Two particular services of note were introduced in 1983. From June to early August, several centres provided weather forecasts to the Hay Fever and Pollen Bureau. These forecasts were used by the Bureau to calculate the likely level of pollen count at selected sites around the country for the following day. The pollen count data were distributed by the Bureau to the media. The other service was introduced for Marks and Spencers food division. In order to assist the company with planning its supply of food stocks for Saturdays, weekend forecasts of appropriate weather factors are supplied on Tuesdays and updated daily. This is a market which offers considerable scope for the Office and opportunities for the retailer.

During 1983 the Meteorological Office participated in a number of exhibitions, the design and construction of the stands being sponsored for the most part by the Central Office of Information (COI) and the MOD Directorate of Promotions and Facilities (MOD(DPF)). The major exhibitions included the Bath and West Show (Shepton Mallet), the Royal Show (Stoneleigh), Offshore 83 (Aberdeen) and the International Boat Show (Southampton). There were also first visits to Building West (Bristol), the Royal Ulster Agricultural Show (Belfast) and the Royal Highland Show (Edinburgh). The Office was involved in two Energy Managers' Exhibitions, one in Basingstoke and one at Crawley, both sponsored by British Gas. The Steeple Cup, for the best stand under 30 foot frontage at the Bath and West Show, was awarded to the Office. The main purpose of these exhibitions is to promote services to commerce and industry and also to provide opportunities to develop better public relations. Advice was also given to a number of

Meteorological Office stations mounting static displays dealing with aspects of the work of the Office.

The Office also took part in the Annual Meeting of the British Association for the Advancement of Science held at Sussex University. The stand, for this show, was prepared and erected by the Meteorological Office Cartographic Section. Two seminars were organized as part of the Mason Conferences, run in conjunction with this meeting and the theme was focused upon the needs of Industry and Commerce and how the Office could meet these needs. The seminars were attended by invited speakers from industry as well as speakers from within the Office.

Members of the Public Services Branch replied to hundreds of letters received during the year and escorted organized parties from a wide variety of backgrounds around the operational part of the Meteorological Office Headquarters. Members of staff at Bracknell and elsewhere gave a number of talks to interested clubs, societies and educational establishments.

Summing up, 1983 has been a year of modest growth in the supply of specialized services to industry and commerce. There was a significant expansion in the supply of weather information to the media. The expansion of services has been limited by restriction on staff resources and it is the advent of new technology, especially in the field of communications, that now seems likely to allow a further expansion. Free public access to forecasters by telephone has become increasingly restricted but, to offset this, plans have been made for more information to be provided through television, Teletext, and Viewdata. The Office is alert to the potential for wider dissemination of weather information through the development of cable television and direct broadcasting by satellite.

*Services for marine activities*

Services to shipping via BBC Radio, British Telecom, International Coast Radio Stations and our international radio teleprinter and radio-facsimile broadcasts were given throughout the year.

During April the broadcast in radio teletype from Cullercoats Coast Radio Station of weather forecasts and gale warnings for all North Sea, English Channel and adjacent coastal sea areas from Fair Isle to Plymouth, was given the acronym 'Navtex' and made operational after being experimental for some years. The Navtex mode of transmission was extended to Portpatrick Coast Radio Station on 1 October, whence forecasts and gale warnings for sea areas adjacent to the west coast of the UK from Fair Isle to Lundy were transmitted in radio teletype.

Buchan Radio, a new Coast Radio Station remotely controlled from Stonehaven Radio, Grimsby Radio, a new Coast Radio Station remotely controlled from Humber Radio, Pendennis Radio, a new Coast Radio Station remotely controlled by Land's End Radio and Cardigan Radio, a new Coast Radio Station remotely controlled by Anglesey Radio, were established by British Telecom International during the year and commenced transmitting the appropriate gale warnings and forecasts for sea areas in VHF mode. To give a more even distribution of station reports from locations around the UK coast, weather reports from the Butt of Lewis were included in the BBC Radio 4 transmission from 1 August. On the same day reports from the Goeree Light Tower automatic weather station, formerly included in the station reports broadcast after the Shipping Forecast on BBC Radio 4, ceased.

The Central Forecasting Office (CFO) issued forecasts and guidance advice in emergencies involving oil slicks and pollution at sea. The Storm Tide Warning Service, which as explained in the Special Topic article on Marine Meteorology (page 9), is primarily concerned with coastal flooding, also issued alerts on occasions when unusually low tides caused by strong winds put ships at risk of grounding in the shallower waters.

Forecasts for ships of the Royal Navy were supplied by the Pitreavie and Plymouth Meteorological Offices, and the Aberporth Meteorological Office provided support for Royal Navy ships undergoing trials in Cardigan Bay, as well as answering many general marine enquiries. The main Meteorological Office at Pitreavie provided a winter forecasting service from October to April for the benefit of North Sea fishing vessels. The Meteorological Office in Gibraltar supplied a number of forecasts to vessels of the Royal Navy and Royal Fleet Auxiliary. Royal Air Force marine craft at home and abroad were provided with forecasts by the nearest meteorological office and the office at Akrotiri in Cyprus gave forecasts for Royal Corps of Transport vessels operating from Akrotiri mole.

During the year the offshore oil and gas industries made increasing demands on the forecasting services of the Meteorological Office. During the 1982/83 winter, demand was particularly high, and record numbers of forecast services were provided. Demand has been shaped by the general levels of activity in the North Sea and UK continental shelf areas and also by an increasing awareness of both the value of forecast services as well as the improvements to the service which have been introduced over the past 18 months. Much of the credit for this increased awareness comes from the quality of the services themselves, but is also due to the continued effective liaison and follow-up mounted by staff at London Weather Centre and Aberdeen.

To meet the expected increase in demand for services, greater resources were committed during the year and were also organized more effectively. Forecast products from the Meteorological Office's new 15-level atmospheric model, and from the fine-mesh sea state model were received earlier and with greater resolution than before. Forecasters took advantage of the greater accuracy of the new models to provide site-specific forecasts for up to 90 locations at any time on a twice-a-day basis. To provide the forecasters with a better and more cost-effective support, an OASYS minicomputer system was installed at London Weather Centre during March. This dual-processor system, similar to those at Heathrow and Strike Command, High Wycombe, was linked to the telecommunication system at Bracknell by a new high-speed X25 data link. This enabled the system to take over the functions of automatic chart plotting and the rapid dissemination of fine-mesh forecast products. In addition, visual display units in the Forecast Room provide instant access, in a number of graphical formats, to the latest observational data, including those from rigs and platforms in the North Sea. Two CHEETAH telex terminals were also installed in March, completing a phase in the automation of the Telex Room. Using the concurrent receipt, despatch and word-processing facilities of these terminals, a higher volume of traffic has been possible with greater reliability than ever before. Finally, a coherent program of training of offshore forecasters was initiated, designed to give forecasters a good grounding in both theoretical and practical offshore forecasting, with on-the-job experience at London and Aberdeen, as well as the mandatory safety and survival courses at the Robert Gordons Institute of Technology in Aberdeen.

The most popular forecast service used by the offshore industry has been the twice-a-day telex forecast for up to five days ahead. This enables companies both to plan resource deployments (tugs, support vessels, divers on station, etc.) for the coming week and also to make decisions regarding their day-to-day weather-sensitive activities. The service is complemented both with a daily briefing of marine personnel and a 24-hour consultancy service for up-to-the-minute advice. Briefings and local forecasting advice were provided for Aberdeen-based companies by forecasters at Dyce Meteorological Office, and by forecasters at Kirkwall in the Orkneys and Lerwick in the Shetland Islands for the oil tanker loading operations at Flotta and Sullom Voe respectively. The consultancy service was provided by the Offshore Bench at London Weather Centre. Finally, revised forecasts were provided by the London Weather Centre if it was deemed necessary by the duty forecasters and, for sudden, dramatic meteorological developments such as occur several times each winter, a special 'alert warning' service was provided to alert operators to sudden changes in weather conditions in the shortest possible time.

In addition to shore-based forecasting services, the Meteorological Office was required to provide a record number of forecasters on site at locations in the North Sea. During the early part of the year, four sites were being served concurrently, requiring ten meteorologists to provide continuous uninterrupted cover. This season was characterized by long-term involvements with the BP Buchan Production Platform (six months), the DB100 Barge in the Brae Field, working for Marathon (nine months) and the construction and tow-out phases of the Phillips Maureen Platform (four months)—the largest platform of its kind ever built. The long-term contracts proved a notable achievement for the Meteorological Office, and were a reflection and recognition of the quality of service provided, the accuracy of the forecasts and the commitment and involvement of the personnel involved. Staff and equipment were also provided for short-term detachments throughout the year at very short notice—on occasions less than 12 hours. The high level of offshore placements produced an increase on last year of 63 per cent in the number of man-days spent forecasting offshore.

Revenue from offshore work increased by 15 per cent over the previous year, and overseas offshore earnings were up by 6 per cent. In July, the 12-month running total of revenues from the offshore industry rose above one million pounds. Offshore earnings now account for about 70 per cent of all revenues earned by the London Weather Centre.

The Meteorological Office also continued to give technical advice to the offshore industry through its representation on a number of committees. The Principal Meteorological Officer at London Weather Centre is the meteorological adviser to the Oceanographic Committee of the United Kingdom Offshore Operators' Association (UKOOA) and the Office also provided a permanent adviser to the Oceanographic and Metorological Sub-Committee of the International Exploration and Production Forum.

The ship routeing service is now marketed under the name Metroute, and continues to advise on North Atlantic and North Pacific passages. Advice is also offered on the movement of tows and salvage operations, and to vessels on other international voyages on request. Extensive advertising in marine orientated publications led to a continuous flow of new enquiries, including a recent one from the Shipping Corporation of India. The voyage assessment service, supporting investigations into ships' performance in relation to actual weather experienced, attracted considerable attention from shipowners and charterers. This service is seen as good value in assisting clients to resolve claims concerning voyage delays due to slow speeds, deviations to avoid foul weather and other factors.

*Services for civil aviation*

Services for civil aviation are provided by the Meteorological Office as an agent of the Civil Aviation Authority (CAA) which, for the purposes of the International Civil Aviation Organization (ICAO), is the meteorological authority for the United Kingdom (UK). The Meteorological Office provides professional advice to the CAA and services to civil aviation on a repayment basis. The CAA recovers the costs of these services as part of the *en route* charges levied on aircraft using the navigational services within the UK airspace.

The organization of meteorological services for civil aviation is centred on the Principal Forecast Office (PFO) at Heathrow Airport London, which is designated by ICAO as the Area Forecast Centre (AFC) responsible for the provision of forecast information for all flights from Europe to North America. Computer output from Bracknell, modified with regard to the detailed structure and position of jet streams by a team of specialist upper-air forecasters at the Central Forecasting Office (CFO), is passed to Heathrow. With the addition of charts of significant weather, prepared by the aviation forecaster at Heathrow, these upper-air charts are distributed throughout Europe by radio and landline facsimile. Within the UK the charts are distributed by the landline Civil Aviation Meteorological Facsimile broadcast (CAMFAX), together with a selection of charts which are required from other AFCs. The charts are copied as necessary at the airfields to provide flight documentation. Until June the forecasters at Heathrow also produced significant-weather charts covering Europe and the Mediterranean area for flights from the UK above 5000 ft as a special requirement for certain airlines. These charts were broadcast on CAMFAX together with wind charts produced at Bracknell, covering the same area. This requirement was withdrawn and both sets of charts have been replaced by the Frankfurt AFC charts for flights within Europe. At the same time a new low-level weather chart prepared at Heathrow was introduced, together with a wind chart, produced at Bracknell, covering the British Isles and the very near continent.

This centralized service just described is adequate to satisfy the needs of most commercial air transport carriers with aircraft which fly at high levels, but there is a growing category of civil flying, known broadly as 'general aviation', with different needs. This second category covers a number of fashionable leisure activities including club flying, gliding, hang-gliding, microlight flying, hot-air ballooning and parachuting as well as business flights for executives, air taxis, helicopters, crop spraying and aerial survey work. Services provided for general aviation flights demand considerably more of the forecasters' time than services provided for scheduled commercial flights on account of their more weather-sensitive nature.

The introduction during June of the new low-level weather and wind forecast charts for flights made at levels below 12 000 ft over the UK and nearby continent was intended both to better inform the pilots flying at low levels and reduce the demands made from the general aviation sector for personal consultations with the forecasters. The full effect of the new charts awaits their more widespread distribution through the dedicated civil aviation facsimile network (CAMFAX) or through the public telephone network by means of document facsimile transmission (DOCFAX).

It is still necessary to prepare individual forecasts for flights from the less well-equipped airfields. Main Meteorological Offices (MMO) at Manchester Airport, Prestwick, Aldergrove and Cardiff Weather Centre are all involved in supplying this service with some dependent forecasting offices at other civil airports and a number of forecast offices at RAF stations. Many general aviation forecast enquiries are handled by telephone, especially from pilots not having direct access to the CAMFAX or DOCFAX products. In an attempt to satisfy most of these enquiries the CAA introduced an automatic telephone answering service—the General Aviation Visual Flight Forecast Service (GAVFFS)—about ten years ago. This service is essentially intended to advise a pilot whether conditions are likely to be favourable or unfavourable for flying and forecaster advice should only be sought for more detailed information if necessary. To reduce further the time spent on dealing with forecast enquiries plans were made for the GAVFFS to be expanded and modified to meet more fully the needs of the general aviation pilot. The new streamlined service is expected to be available in late 1984 or 1985. In the meantime the Office began to provide a general aviation service on Prestel, the British Telecom Viewdata service, on an experimental basis.

Following the decision of the Council of the ICAO to implement the planned new World Area Forecasting System for Civil Aviation, with Bracknell and Washington as World Centres, much detailed planning has taken place throughout the year both in-house and in conjunction with the neighbouring Regional Centres in Europe at Frankfurt and Paris and with Washington. It is aimed to begin implementation of the system in Europe and North America early in 1984 but it may be many months before full implementation is achieved world-wide. Meanwhile global grid-point data are being provided directly from the COSMOS computer complex at Bracknell to a limited number of air operators through the airlines' own communications systems. Such data were supplied to British Airways and Scandinavian Airlines System (SAS) for computer flight planning throughout the year. The supply of the same data directly to the large communications and flight planning organization, Société Internationale de Télécommunications Aéronautiques (SITA) began in the late summer. Considerable interest continues to be shown in the ability of the Office to provide these data and representatives of several large international airlines, including American based companies, and flight planning organizations have visited or contacted the Office during the year to discuss the possibility of future reception of these data.

A very important aspect of the Office's work for civil aviation is the supply of warnings of weather conditions which could affect the safety of aircraft, either in flight or on the ground. In-flight warnings of certain significant weather phenomena (SIGMETS) are prepared at Heathrow and Prestwick for the London and Scottish Flight Information Regions (FIRs) respectively, and, also at Heathrow, for the Shanwick Oceanic Control Area. Specialized SIGMET warnings are prepared for supersonic civil aircraft within the above areas. All relevant SIGMET information is available with pre-flight documentation and is brought to the attention of aircrews in flight by way of the Air Traffic Control services. Warnings are issued to aerodrome authorities when weather conditions likely to affect ground operations are expected. Accurate warnings of commencement, duration and intensity of snowfall with relevant surface wind and temperature predictions are vital if the costly equipment and materials used in aerodrome snow and ice clearance are to be used effectively and economically, because the financial penalties to operators of aircraft forced to divert to other airfields can be large.

Every hour, minimum pressure values for each of 20 Altimeter Setting Regions (ASRs) over and around the United Kingdom are prepared in CFO. These are used mainly to ensure the safe clearance of high ground but, over the sea, low-flying aircraft and helicopters use ASR values to maintain safe vertical separation.

At aerodromes, weather observations are of great importance and Meteorological Aviation Reports (METARs) are made, normally every half hour during the period of airfield operation. At airports without Meteorological Office staff, observations are made by Air Traffic Control (ATC) personnel who have been specially trained for this purpose. Courses, consisting of one week at the Meteorological Office College at Shinfield Park followed by one week at an aerodrome observing office, are organized for sponsored ATC staff on a repayment basis. In most instances, METAR reports are transmitted to the CAA message-switching computer at Heathrow, from which they are retransmitted nationally and internationally by way of the Operational Meteorological (OPMET) teleprinter channels and the Meteorological Operational Teleprinter Network, Europe (MOTNE), respectively. Aerodrome landing forecasts (TAFs) are provided on a routine basis for all the major airfields and these are similarly exchanged between offices. Together with area forecast charts, low-level charts or individual route forecasts; those data make up the weather documentation provided to departing aircrew.

In its continuing search for economy in the provision of services for civil aviation, the CAA sought the Office's co-operation in transferring the forecasting task undertaken at Gatwick to the PFO at Heathrow. This was completed by 1 October. While this enabled a small staff saving to be made, delays by the CAA in making alternative arrangements for the issue of meteorological flight documentation have held up further staff economies at both Gatwick and Heathrow. Following a feasibility study initiated by the Office in co-operation with the CAA, plans were accepted during the year for the amalgamation of the three forecasting offices in south-west Scotland at Prestwick Airport, Glasgow Airport and the Glasgow Weather Centre into a single regional office located centrally in Glasgow. This will allow better and more economical use to be made of the resources in this area.

Developments in the field of the new technology have been adapted to the observing task. Following a joint study between the Office and the CAA a partial automation trial has been set up at Stansted. All the instrumented data, such as runway visual range, pressure, temperature, wind speed and direction, along with those such as weather, visibility, cloud base and amount requiring manual input, are automatically coded into a METAR and into formats suitable for ATC, and displayed on VDUs. After scrutiny, the message is automatically transmitted to the CAA's message-switching computer.

One of the tasks of the Civil Aviation Branch is to provide, on request from the Accidents Investigation Branch (AIB) of the Department of Transport, detailed weather information which may be relevant to an aircraft accident. The normal requirement is for copies of actual weather reports, relevant forecast and warnings, and a résumé of the general weather situation. Occasionally, climatological data, such as hourly rainfall are also required. Investigations assisted in 1983 ranged from a crop spraying incident to a fatal helicopter accident near the Isles of Scilly.

The National Gliding Championship at Booker in May was provided with forecast services.

Two members of the Office's scientific staff, based at the CAA HQ contributed to the examining function of the Directorate of Flight Crew Licensing. As a service to training establishmetns, occasional bulletins were issued during the year, drawing attention to common errors made by candidates. Advice on the content, form, and style of future examinations was given to the Working Group on Senior Licence Examinations. Work continued on the revision of the meteorology section of the Air Traffic Control training manual.

*Services for civil aviation and the general public (overseas)*

Services for civil aviation were provided from the meteorological offices at Royal Air Force Gibraltar, Gutersloh and Wildenrath. At Gibraltar meteorological services were also provided for the general public through the media of Press, radio and television, and for various civil departments and commercial concerns in accordance with charging policies for similar services in the United Kingdom. Services to the public from the Main Meteorological Office at Royal Air Force Akrotiri in Cyprus were limited to forecasts broadcast by the British Forces Broadcasting Services (BFBS). A similar service for BFBS in Germany was provided by the meteorological office at Royal Air Force Wildenrath. Close contacts were maintained with the Cyprus Government Meteorological Service.

*Services for the Royal Air Force*

Senior officers of the Meteorological Office fill the posts of Chief Meteorological Officer on the Air Staffs at Headquarters Strike Command (HQSTC) and at Headquarters Royal Air Force Germany (HQRAFG). They are responsible for the provision of meteorological services to meet the requirements of the Commands and act as meteorological advisers to the Commanders. Meteorological services for the Royal Air Force in the United Kingdom, including the Royal Air Force units at the MOD(PE) airfields at RAE Farnborough, RAE Bedford and the Aeroplane and Armament Experimental Establishment at Boscombe Down, are provided by offices organized partly in conformity with the Royal Air Force command and control organization.

The Principal Forecasting Office (PFO) at HQSTC, continuously manned by senior forecasting staff, exercises technical control over the output from the subsidiary forecast offices at all the airfields under Strike Command, in RAF Germany and at several airfields under Support Command. The forecast products from the PFO are used by the subsidiary offices to assist in meeting the requirements of military aircraft operating in widely differing roles through personal briefing and through the provision of flight forecast documentation. With the aim of achieving greater efficiency and flexibility in responding to the Royal Air Force requirement a computer system, linked to the central computer resources at Bracknell and known as the Outstation Automation System (OASYS), became operational in the PFO at HQSTC in 1982. Work continued on the development of the system and its extension to remote outstation automated terminals (ROASTS) with the aim of improving the efficiency and flexibility of support for the Royal Air Force by replacing the slow broadcast of meteorological data to forecast offices supporting Royal Air Force operations with a fast computer-based demand system under the control of the outstation forecaster. A trial of a prototype Defence Operational Meteorological Information System (DOMINO) commenced at Lyneham and Honington in September.

Main Meteorological Offices (MMOs), manned 24 hours a day, are located at some Royal Air Force Group Headquarters and at Maritime Air Region Headquarters. The location of the MMOs within separate regions of the United Kingdom allows expertise in regional meteorology to be applied to services for Defence and also for civil and general aviation, industry and commerce and for the general public. Changes are taking place as the result of a joint study with the Air Force Department on the future role of the MMOs in relation to the needs of the Royal Air Force. Following the move of HQ No. 1 Group to Upavon in November the MMO at RAF Bawtry was relieved of its defence responsibilities prior to its planned closure. Support for meteorological offices at RAF aerodromes in Lincolnshire and Yorkshire is now provided solely from the PFO at HQSTC and the office at RAF Coningsby which has been strengthened to take on a number of residual defence commitments.

The major part of the support provided routinely for the subsidiary offices by the PFO at HQSTC is in the form of a comprehensive program of analyses and forecasts in chart form which are transmitted by facsimile and designed to cover most of the operational requirements of the Royal Air Force in the United Kingdom and in Germany. Additional facsimile products are broadcast to selected offices by the MMO at Headquarters No. 1 Group Royal Air Force. A dedicated teleprinter broadcast from the PFO to the subsidiary offices contains observational and forecast data relevant to the various tasks. The dedicated facsimile and teleprinter broadcasts provide the main source of data for direct briefing and for the preparation of forecast documentation. The powerful processing and communications computer systems at Bracknell enable major support to be provided directly to offices serving the the Royal Air Force in the United Kingdom and overseas through the automated selection and transmission of large amounts of data and of various forecast fields for up to five days ahead.

Defence requirements for meteorological support in the Mediterranean were provided by the MMOs at Royal Air Force Gibraltar, Royal Air Force Akrotiri and by an observing office at Paphos in Cyprus. At Gibraltar the radiosonde unit maintained a routine program of radiosonde and radar wind observations whilst staff of the observing office at Paphos undertook a routine program of pilot balloon ascents. The requirements of British forces in Germany for meteorological support were provided by subsidiary forecast offices at the Royal Air Force stations at Wildenrath, Gutersloh, Brüggen and Laarbruch and at the Army Air Corps Airfield at Detmold whence support was provided to HQ1(BR) Corps at Bielefeld and to the Corps in the field. In addition to technical support from the PFO at HQSTC, host nation support was also received from the German Military Geophysical Office (GMGO) at Traben-Trarbach.

The staffs of the meteorological offices at the Royal Air Force airfields in Germany were fully involved in NATO evaluation exercises during the year and invariably achieved high markings. Staff from the Gutersloh office were deployed in the field in support of off-base Harrier operations on a number of occasions.

The VOLMET voice broadcast of plain language reports from a selection of Royal Air Force, USAF and civil airfields moved in late autumn from the London Military Air Traffic Control Centre at West Drayton to HQ(N)1Gp at Royal Air Force Upavon. Data for the broadcast were processed and supplied directly by automated means from the Communications Centre at Bracknell.

The Office contributed to the training of military aircrew by the provision of lectures in meteorology and tutorial assistance, mainly at the Support Command training airfields where potential aircrew receive their first experience of support for their tasks from Meteorological Office staff.

*Services for operations in the South Atlantic*

Direct meteorological support for Royal Air Force and Army operations in the South Atlantic continued to be provided by Strike Command Mobile Meteorological Units (MMUs) at Wideawake airfield on Ascension Island and at Stanley airfield in the Falklands. Both units were manned by Meteorological Office staff holding Civil Class reserve commissions and serving in uniforms as part of the operations staff at both locations. Some of their technical support was provided by PFO HQSTC and invaluable support was also provided direct by the Central Forecasting Office (CFO) at Bracknell in the form of grid-point data from the output of the 15-level global model.

An indication of the additional, and now routinely established, workload in response to South Atlantic needs for meteorological support is provided by a comparision of the number of briefings and forecasts issued for aviation at overseas stations (Table IX) in 1982, which did not include the work of the MMUs in the South Atlantic, with the totals for 1983 which included briefings and forecasts issued by the MMUs. An increase of nearly 30 per cent is evident.

Plans were made for a Main Meteorological Office for the South Atlantic to be opened at Mount Pleasant when the Falkland Islands Strategic Airfield (FISA) becomes operational. A civilian-manned MMO is expected to replace the present MMU at RAF Stanley as the centre for the provision of meteorological support in the Falklands and will also have wider responsibilities for meteorological support throughout the South Atlantic.

*Services for the Army Air Corps*
Meteorological services for the Army Air Corps were provided by subsidiary forecast offices at Netheravon and Middle Wallop in the United Kingdom and at Detmold in Germany where the Senior Meteorological Officer also acts as the Staff Meteorological Officer for the Headquarters of 1(BR) Corps at Bielefeld. He and his staff supported Army deployments in the field throughout the year.

*Other services for the Army and Establishments of the Ministry of Defence Procurement Executive*
Meteorological offices were maintained at the Royal School of Artillery, Larkhill, at the Royal Aircraft Establishment (RAE) Aberporth and at the Proof and Experimental Establishments (P & EE) at Shoeburyness, Eskmeals and Pendine. The office at Larkhill also provided meteorological support for the Chemical Defence Establishment (CDE) at Porton Down and for RAE and P & EE units located at the ranges on Salisbury Plain. At Aberporth there was a very significant increase in demand for meteorological services during the spring and early summer, arising from an upsurge in the number of guided weapon trials in support of the Falklands Task Force. Staff were attached to the rocket range at South Uist in the Hebrides to provide assistance for a program of missile firings during the summer. Also supported were special National Air Traffic Services (NATS) trials concerned with precision altimetry and aircraft separation. The Shoeburyness office continued to support the Atomic Weapons Research Establishment and the Royal Armaments Research and Development Eastablishment at Foulness Island.

Meteorological Office support was provided for the Royal Artillery practice camps at Sennybridge, Otterburn and Okehampton during several periods throughout the year. Forecasts were also provided for parachute dropping zones throughout the United Kingdom. Several Defence establishments were supplied with meteorological data and advice connected with the development of weapons and military equipment. Joint trials for the assessment of explosive sound propagation and focusing were held at Porton Down in the spring and Shoeburyness in the autumn. Defence Services Branch HQ staff, scientists from Salford University and staff from the meteorological office, Larkhill participated in the trials with logistic support at Porton provided by CDE. Similar joint support was given to an acoustic survey of a Royal Artillery firing position at Sennybridge. Trials directed towards improving wind-finding techniques in the lowest levels of the atmosphere were conducted at Larkhill and Eskmeals.

*Liaison with the Royal Navy*
Close co-operation in Defence matters was maintained with the Directorate of Naval Oceanography and Meteorology (DNOM), mainly through the post of Naval Liaison Officer (NLO) in the Headquarters of the Meteorological Office at Bracknell. Co-operation in the organization and development of national and NATO meteorological support between the Meteorological Office and the Royal Navy ensures an efficient across-the-board response to United Kingdom Defence requirements for meteorological support for land, sea and air forces both nationally and within NATO.

*International Defence Services*

The Meteorological Office participated actively, on behalf of the United Kingdom, in the work of a number of NATO groups concerned with the co-ordination of meteorological support for military and civil defence needs and also contributed to studies associated with that support. The co-ordination of Meteorological Office activity in NATO exercises is centred in the Defence Services branch, working closely with DNOM through the Naval Liaison Officer (NLO). The national and NATO roles of the Meteorological Office in transition to war and in war are kept under constant review and a member of the Defence Services Branch represents the Meteorological Office on the Air Force Department Steering Committee for WINTEX-CIMEX exercises. The Defence Services Branch played a full part in the NATO biennial Command Post Exercise WINTEX/CIMEX 83 in late February and early March. Other Headquarters Branches and certain outstations were also involved.

The Meteorological Office provided a Principal Scientific Officer, holding a Civil Class Commission in the rank of Group Captain, for the post of Chief Meteorological Officer on the staff of the Supreme Allied Commander at SHAPE. The Office also contributed one forecaster and one assistant to the staff of the NATO Allied Meteorological Office in the Joint Operations Centre at Maastricht in Holland.

*Services to the Home Office*

Detailed planning to meet the meteorological requirements of the United Kingdom Warning and Monitoring Organization (UKWMO) continued throughout the year. Forecasters were provided for the meteorological cells in the five Sector Controls during the annual international exercise held in March and for the national exercise in October. The Meteorological Office also supplied the charts and data for the exercise weather to be used by all nations planning to participate in the 1984 NATO Civil Defence exercise INTEX 84. Lectures on the Meteorological Office organization related to fall-out monitoring were given to UKWMO Sector Control staff, warning officers and the Royal Observer Corps.

*Services for nuclear establishments*

Arrangements for MMOs to supply information to nuclear establishments of the United Kingdom Atomic Energy Authority, British Nuclear Fuels Ltd, AWRE and the Electricity Generating Boards in the event of the accidental release of radioactive or toxic material, were kept under review and frequently exercised. Similar arrangements cover emergencies which could arise in the transport of radioactive material or which might involve nuclear submarines in port.

## Climatological Services

The fundamental role of this Branch is the maintenance of archives of data both from the United Kingdom Climatological Network and from ships sailing in all the oceans of the world. Routine publications are produced summarizing these data for general and some special applications and enquiry bureau services are maintained providing data, advice and consultancies for a wide range of customers both in the private and the public sectors. There has been little change in the total number of enquiries, and Table XIII provides a detailed breakdown of the various types of enquiry handled this year both by this Branch and that concerned with Agricultural and Hydrometeorological Services. Revenue earned by the Climatological Services Branch has increased by over 60 per cent from that in 1982 to well over £300 000.

*Climatological data*

The numbers and geographical distributions of the various types of station supplying data for climatological purposes are summarized in Table IV. The Meteorological Office continues to be indebted to the very many co-operating observers for the provision of much valuable information which could not be obtained economically in any other way. However, the continuing decline in the number of voluntary observers is a cause for some concern; a net loss of 15 such observers was recorded during the year.

The major task of controlling the quality of climatological data is undertaken partly by use of computer techniques and partly subjectively. Computer checks are made on the raw data for internal inconsistencies, impossible values and, where possible, sequential consistency. After initial queries have been resolved, further programs compare data from all climatological stations on an areal basis and corrections are made where necessary. Queries raised at each stage of the programs are referred to staff at Bracknell (for England and Wales), Edinburgh (for Scotland) and Belfast (for Northern Ireland). Quality control of climatological data is necessary to maintain the archive to a high standard and it is especially important in answering the many enquiries of a legal or insurance nature. After observations have been quality controlled the data are stored in the computer archive from which printed copies on microfiche are made available for use by enquiry bureau staff.

The procedures for the automatic capture of both daily and hourly climatological data received at Bracknell from synoptic stations via the operational telecommunications network have been developed further to minimize data loss. A list of observing practices for every station has been prepared giving details of every element measured at each observing hour for each day of the week. This list is used by a program which monitors the weather messages received and which, in the event of missing data, sends messages back down the telecommunications channels to the relevant stations.

Work has started on improving the machinable archive of climatological daily data (mostly for the period 1930 to 1970). This has involved the bringing together of several sets of data so that they will become much easier to use. The opportunity is being taken to carry out some quality control of the data with the object of removing the gross errors. The archive of hourly anemograph data on microfiche has been extended backwards in time to 1970 and work has begun on extending the archive of anemograph data on magnetic tape back to 1960.

*Land climatology*

Many thousands of climatological enquiries have continued to be received with the emphasis on those for building and construction work as well as for insurance and legal purposes. Staff attended court as expert witnesses on a few occasions to give evidence.

A number of consultancies were provided with members of the Branch calling upon the resources and expertise available in other specialist Branches as necessary. A notable feature was the increase in the number of requests for advice concerning the planning of road construction schemes. The Department of Transport sought the opinion of the Land Climatologist on the scientific validity of two reports from private consultants relating to meteorological aspects of the M40 Oxford to Warwick extension. Following this consultation the Land Climatologist gave evidence at the public enquiry.

Other major projects involved advice to RAE Farnborough relating to the behaviour of piezo-electric crystals at low humidities, the provision of data for an EEC contract for the production of a wind energy atlas for Europe and the organization of a routine service for a client concerned with the forward buying of commodities. Members of the Branch attended various British Standards Institute Committees connected with building, construction and other design matters.

A large quantity of climatological data was sold to the Science and Engineering Research Council for use by universities working on SERC funded projects. Following negotiations with South West Universities Regional Computing Centre it was agreed that the Centre should hold, on a trial basis, climatological data primarily for use by university researchers working on non-funded projects or by teaching staff. Arrangements with the Centre are such that use of the data on funded projects or for work on contract will be conditional upon the payment to the Meteorological Office of a suitable fee as a contribution to the archiving and quality control costs incurred in the compilation of the data banks.

*Building and construction climatology*

This unit works mainly in collaboration with other Government Departments, notably the Building Research Establishment (BRE), but also provides services for commercial concerns. Information was provided to the Transport and Road Research Laboratory regarding prolonged cold spells in order to assess the susceptibility of roads in different parts of the country to frost heave. Analyses of relevance to the calculation of heat loss from buildings were provided for use in a Meteorological Data Handbook for Designers to be published by the Department of Energy. Studies were undertaken for BRE relating to weather interference with outdoor construction operations and the assessment of building exposure using an index of wind-driven rain.

The promotion and improvement of Meteorological Office services for the construction industry continued. Links with several professional bodies were strengthened and presentations of the services available were made to regional groups of the Royal Town Planning Institute, the Landscape Institute, The Society of Surveying Technicians and the Chartered Institute of Building.

*Marine climatology*

A steady flow of enquiries was received regarding the design, planning and implementation of marine projects, and a stable combination of both large and small projects was achieved. Strenuous efforts were made during the year to increase the amount of enquiry work and, hence, the revenue. Worthy of note was a joint venture set up between the Meteorological Office and

National Maritime Institute Ltd (NMI) to market a wave climatology computer program developed as a co-operative project.

After the production of an initial report relating to the offshore wind energy resource there were further discussions with the various interested parties. A new area of work for the unit was for the commercial fishing industry for which several investigations were performed during the year. Contact was maintained with the Department of Energy regarding advice connected with matters of safety offshore.

The global archive of surface marine meteorological data was augmented by the inclusion of all available data from the areas of responsibility of the Federal Republic of Germany and Japan. The global archive of surface ocean current data measured from the drift of ships was also completed during the year. Marine climatological summaries for the North Atlantic were produced, on microfiche, for each year from 1961 to 1970 inclusive.

*Investigations and development*

A statistical model which generates a time sequence of mean hourly wind speed was developed within the Branch and was tested against independent data. It was found to perform satisfactorily in its simulation of monthly and annual extremes, in the proportion of time that wind speeds exceeded a given threshold and in the shape of the general distribution of wind speed.

The investigation into relationships between topography and climate continued using a topographic data set of spot heights on a half-kilometre grid. A study of minimum temperatures showed that important parameters were found to be the differences in height between the station, the lowest point within 3 km and the average height over a radius of 10 km.

A study was made comparing the mean daily temperature computed conventionally as the average of the daily maximum and minimum values to the average of the 24 hourly values. Differences were found to be around 0.3 °C or less. At some automatic weather stations maximum and minimum temperatures relate not to the extreme values recorded by continuously operated thermometers but to the highest and lowest of the hourly observations. An investigation into the differences between these two types of values was carried out and, again, differences were found to be around 0.3 °C.

Preliminary work on the preparation of climatological statistics from the period 1951 to 1980 was completed. Tabulated data relating to averages and extremes will shortly be available on microfiche.

Computer programs to produce Fisher–Tippett extreme value analyses of any type of suitable data were developed. These produce a graph of the data, the best fitting line and a table of the ranked data.

Programs were developed to produce customized products to meet the requirements of individual customers. These are for use in the supply of routine monthly, weekly or daily data as well as for single, one-off analyses to meet a particular customer's need.

*Publications*

Publication continued of the *Monthly Weather Report* which summarizes observations for most of the stations in the climatological network. In order to overcome delays at the printer's a change in procedure was introduced whereby the front, descriptive, page of the report is now produced within the Meteorological Office as camera-ready copy. The backlog of printing was eliminated as a result.

The revised version of the volume for Africa of *Tables of temperature, relative humidity, precipitation and sunshine for the world* was published during the year. This is the third volume of the series, first published in 1958, to be revised. Pressure of other work is expected to preclude revision of the volumes for Central and South America, Asia, Australasia and the Pacific for the foreseeable future.

The production of the regional *Climatological Memoranda* continued with the publication of volumes for the Midlands, Thames Valley, London, Lancashire, Cheshire and the Isle of Man.

### *Services in Scotland and Northern Ireland*

Offices in Edinburgh and in Belfast continued to provide services specifically for Scotland and Northern Ireland respectively. The important role played by these offices is the injection of local knowledge into both the quality control of data and the provision of enquiry bureau services. Close liaison was maintained with the staff at Headquarters in Bracknell, particularly those responsible for the computer archive. With the co-operation of the Systems Development Branch a case was made for the introduction of computer terminals in both these offices.

## SERVICES FOR HYDROMETEOROLOGY

The hydrometeorological services provided by the Meteorological Office depend upon the ready availability of good quality data held in computer data banks in a form suitable for processing to meet the many varied requirements of both customers and the Office. The system relies upon the co-operation of water and other authorities throughout the United Kingdom, who operate most of the network of around 6000 rain-gauging stations, for the supply of basic data.

At the 1982 annual meeting between the Meteorological Office and the National Water Council (NWC) the recommendations of a working party, set up to review rainfall measurements in England and Wales, were accepted. The Meteorological Office was required to liaise with each water authority separately to bring about a reduction in the network of manually read daily rainfall gauges. The procedures for this reduction nevertheless ensured that gauges of greatest importance to the water authorities, Meteorological Office and Institute of Hydrology were retained, but allowed for the shutdown of gauges in densely gauged areas and of gauges from which experience showed that there was difficulty in obtaining regular, reliable observations. In 1983 the reduction in gauges began in the North West Water Authority area, agreement was reached on the reduced rain-gauge networks in the Welsh and Severn-Trent Water Authority areas and detailed discussions were set in train with the seven remaining water authorities.

The routine collection of observations of daily rainfall accumulation was continued. Further improvements to the quality control of gauge data were investigated. These mainly turned on the use of radar observations to help resolve dubious gauge observations when the 'near-neighbour' quality control method failed (typically in showery conditions). The meteorological offices at Belfast and Edinburgh continued to collect and monitor rainfall observations from Northern Ireland and Scotland respectively. The data bank of hourly rainfall accumulations provided by recording gauges of various kinds was maintained. Procedures designed to use radar data to correct gross errors of timing and amount in hourly rainfalls were also investigated.

The Meteorological Office computerized index of rainfall stations, Rainmaster, was maintained and used as the control data set for most of the data entry into the computerized archives. Copies of the index were provided to water authorities and to certain Weather Centres to help them determine the availability of data for members of the public. Liaison on the index continued with the Institute of Hydrology.

The publications *Monthly and annual totals of rainfall for the United Kingdom* for 1978 and 1979 were issued and good progress was made on the preparation of the issues for 1980 and 1981. These publications serve as a convenient national summary for official purposes and were exchanged with a large number of meteorological services in other countries. They were sold in the United Kingdom to university and other specialist libraries and also to members of the public.

The number of rainfall enquiries increased by 7 per cent compared with 1982, the result of concern over the wet spring and heavy, isolated storms during the dry summer. Enquiries were received from a variety of sources including the building industries, the legal profession, municipal and consulting engineers, water authorities and educational institutions, and covered a wide spectrum of interests. In order to answer these enquiries a considerable amount of rainfall data was written into the microfiche archive held in the enquiry section. The archive contains all available monthly, daily and hourly rainfall values since 1961.

Assessments of total area rainfall, month by month, for approximately 900 catchment areas in Great Britain were completed up to the end of 1981, together with an account of the rainfall, evaporation and soil moisture deficit during 1981. These items were prepared for eventual inclusion in the Institute of Hydrology publications *Water data 1981* and *Surface Water: United Kingdom 1981–1983*.

Estimates were made on a routine weekly basis of average values of components of the soil water balance for 40 × 40 km squares covering England, Wales and Scotland by the Meteorological Office Rainfall and Evaporation Calculation System (MORECS). The number of customers for the weekly MORECS bulletin was about 140, a small increase over earlier years which resulted from the discontinuation of the Estimated Soil Moisture Deficit (ESMD) bulletin during 1983. Progress was made on the MORECS archive of evaporation and soil moisture deficit data from 1961 onwards.

In the area of research and development a 'Flood Studies' analysis was carried out jointly with the Jersey Meteorological Office to provide information on extreme rainfall in the Channel Islands. Other work concerned the confidence limits of estimates of extreme point rainfalls and the statistics of heavy rainfalls over small areas, rather than at points.

Further effort was put into the assessment of the usefulness of radar observations as an addition to historic rainfall data from relatively dense gauge networks. Investigations were made of the possible benefit of radar to improve the areal average rainfall used in MORECS and several different methods of combining radar and gauge observations were compared. Radar data from Hameldon Hill and Camborne were used, together with gauge data, to draw more general conclusions concerning the extent to which estimates of surface rainfall might be improved by combining the results of the two observing systems. An additional interest was in data quality control and the use of radar observations to detect errors in gauge observations. Radar, with its wide geographical and continuous time coverage, can be expected to yield useful information on the statistics of extreme areal rainfalls and to lead to analogous information to that on point rainfalls contained in the Flood Studies Report. Work began on analysing radar data for this purpose.

In 1983 staff took part in meetings to publicize the rainfall information available in the United Kingdom and the outcome of their studies. There was the usual collaboration with the WMO Commission for Hydrology. The Branch explained its work to visiting scientists from abroad and undertook the training of some people from the Third World.

## SERVICES FOR AGRICULTURE

Support for the agriculture industry in England and Wales was provided primarily by teams of two or three agrometeorologists located at regional headquarters of the Agricultural Development and Advisory Service (ADAS) of the Ministry of Agriculture, Fisheries and Food (MAFF). A reorganization of this support was completed in the spring with the opening of an agrometeorological unit at the regional headquarters in Trawsgoed (Aberystwyth). All six ADAS regions are now served in this way. Staff worked closely with ADAS advisers on the diversity of agricultural problems on which weather makes some impact. There is no equivalent scheme for the extension services in Scotland and Northern Ireland, but agrometeorological data were supplied on request by the climatological units of the Meteorological Offices in Edinburgh and Belfast.

A small Headquarters unit provided direct support for the regional staff, principally by extracting from the extensive computer-based data sets a variety of data and products required at the outstations. The Bracknell unit also produced a range of routine information, including bulletins on the development of plant diseases in response to weather, summaries of recent meteorological data of value for field operations, and estimates of soil moisture deficit and irrigation need. These were distributed widely, principally to the extension services, but also to a number of institutes and commercial users.

With some enquiries a rapid and adequate reply was possible from the application of meteorological principles and knowledge and from the results of many studies carried out within the Agriculture Section in the last three decades. On other occasions it was necessary to institute an investigation to obtain the required answers. Much of the work of this nature was carried out in conjunction with ADAS staff, but some collaborative studies involved other organizations and institutes. The year saw activity over a wide spread of agricultural topics. Demands for our services continued at a high level.

The importance of grass to British agricultural production continued to justify substantial effort on topics connected with this crop. An EEC-sponsored investigation of the potential for field hay-drying in north-west Europe approached completion at the end of the year. A second study, also sponsored by the EEC, on variations in grass production in response to weather was continued in collaboration with the Grassland Research Institute. These projects involved the construction and quality control of meteorological data sets for a number of European countries. The data sets followed the format of the UK Agricultural Data Set which was completed in 1982 and which has found frequent use since. Work was initiated on the effects of weather on the nutritional value of grass, a subject of considerable importance in the timing of hay and silage-making for optimal quality. The year also saw the introduction of routine weekly issues of '*T*-sum' (accumulated temperature) data for the whole of Britain. This information was used widely by farmers to time the first application of fertilizer in the new year. A member of staff returned during the year from the Grassland Research Institute where he had carried out a successful program of field and laboratory experiments on hay-drying.

The effects of the wet spring and very dry summer highlighted the importance of soil moisture in agriculture. The weekly bulletins produced by the Meteorological Office Rainfall and Evaporation Calculation System (MORECS) again provided a valuable service. A method was devised to incorporate its results into a simple system of irrigation scheduling designed for running on on-farm microcomputers. An adapted version of MORECS was run during the summer to support an experiment in the east Midlands on the response of barley to irrigation. Another version was used regularly to provide comprehensive information on the long-term irrigation needs for proposed cropping rotations on individual farms. MORECS calculations were also applied, in conjunction with models of moisture flow in soils, to estimate from climatological data the probable frequency with which fieldwork might be carried out in different parts of the country without seriously damaging soil structure.

The unusually wet spring also led to local outbreaks of Potato Blight earlier than predicted by the existing weather based models used to produce daily bulletins on expected disease development. This led to further studies and a revised scheme for blight prediction. Tests were also made of a prototype operational scheme for Fireblight prediction. Following the successful completion of trials of the Crop Disease Environment Monitor (CDEM) (see page 49), ADAS purchased 11 commercially-produced versions. Studies were initiated to consider how to combine the information from the CDEM network with information provided by the synoptic network for crop protection purposes. The weather-based scheme for forecasting the development of pea moth and cut-worm was operated again this year and studies were initiated to extend the scheme to other insect pests such as frit fly and codling moth. Work on the problem of timely spraying against pests and diseases was complemented by other work on the frequency of occasions suitable for the application of a number of different pesticides.

Several studies were made in connection with the development and growth of cereals. These included experiments in the Northern Region of ADAS on the effects of shelter on yield, and the deployment of automatic weather stations in cereal experiments in the Eastern Region. A photosynthesis model of wheat growth and cereal yield underwent further development. The model provided the primary input for further studies which it is hoped will lead to an operational system for the prediction of the national cereal yields.

There were numerous studies during the year on different aspects of animal health. Several concerned the monitoring of internal and external environments of animal and poultry houses. There was considerable involvement with automatically controlled systems of natural ventilation which save on energy costs. Recommendations were made on new standards for air hygiene and air quality in intensive livestock units. Aspects of the spread of certain diseases by the airborne route again received attention. Two past outbreaks of foot-and-mouth disease (FMD) were studied in detail, in the one case to determine why the spread of disease was so limited on that occasion, and in the other, to relate the probability of infection to herd size and the magnitude of the disease challenge. The latter study led to the development of sounder procedures for selecting the order of inspection of livestock units by veterinarians in the vicinity of any outbreak of the disease. Improvements were also made in methods of estimating the dilution of airborne virus concentration during travel over land or sea. This work gave an improved basis for advice by the agrometeorologists to cover any future outbreak of FMD in the UK. Studies were made of past outbreaks of Newcastle disease and Aujeszky's disease. The results provided some support for an airborne pathway for the spread of these diseases. Methods for forecasting the emergence of the larvae which cause parasitic gastro-enteritis in lambs were tested in conjunction with the Central Veterinary Laboratory. A number of farms in south-east England participated in successful final tests of a weather forecasting schemes for reducing the number of deaths in young lambs attributable to exposure (wind chill).

The nuisance from farm odours led to work on probable odour strengths in the vicinity of livestock units, and a start to the country-wide assessment of the problems in the vicinity of idealized sources.

The nuisance from smoke and smuts that arose from straw-burning in 1983 was the subject of an inquiry within MAFF. The notes contributed by the Meteorological Office on 'Weather and Straw-burning' carried the recommendation that the agro-meteorologists' understanding of airborne dispersion should be applied routinely to the products of straw-burning.

A proposed new area of investigation, the study of weather effects on weeds and the efficiency of weed control methods, was explored with the Weed Research Organization. Two of the more unusual studies carried out during the year concerned the use of wind power to supplement electrical power in the pumping of excess drainage flows, and protection against frost by the airflow produced by large propellers.

The potential of land for crop production is closely dependent on local meteorological conditions. Contributions to the MAFF Working Group concerned with land classification culminated in the detailed mapping over England and Wales of relevant derived meteorological quantities.

The current replacement of the ADAS computer and terminal system, and the increasing purchase of viewdata (Prestel) sets by the public at large together provide the opportunity to disseminate, far more widely than in the past, a variety of agrometeorological information. A considerable effort was expended during the year on devising schemes to improve links between the main computer system at Bracknell, the new ADAS system and the regional agrometeorologists. Parallel studies considered the much improved agrometeorological data bases and input and output facilities that will be required on COSMOS to cope with the likely future increase in demand from ADAS and those members of the public with farming interests. Steps were also taken to improve the sources of data available for agrometeorological purposes. Some of the synoptic automatic weather stations to be installed by the Meterological Office in many parts of the United Kingdom will carry specialized agrometeorological sensors (for example, surface wetness detectors, as used in CDEM) in those areas where arable and horticultural crops are grown widely. Consideration was also given to possible uses of radar rainfall and meteorological satellite data in agriculture. A special synthetic agricultural data set, for those variables used in evapotranspiration calculations, was created for over 100 stations for a recent 20-year period. The data set is based on the standard Agrometeorological Data Set but is distinguished by the additional use of objective interpolation procedures to provide estimates for all missing data.

Members of staff again participated in numerous demonstrations and exhibitions, and presented lectures to a variety of institutes and organizations.

There was further co-operation with several international agencies. Two members of staff attended the Eighth Session of the Commission for Agricultural Meteorology (a WMO body); one was elected to the President's Advisory Group and the other to the chairmanship of a working group which is studying agrometeorological aspects of operational crop protection.

## Observational Requirements and Practices

The Branch, of which the Marine Division under the Marine Superintendent is a part, is responsible for arranging that regular meteorological observations of suitable quality are made on land, at sea and in the upper atmosphere at enough locations to meet national and international requirements. It approves suitable sites for observing stations, specifies how meteorological sensors and observing systems shall be exposed, states the observing techniques to be employed and implements World Meteorological Organization (WMO) coding procedures at United Kingdom stations. Observing stations are inspected regularly, as recommended by WMO, 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 observational systems, sensors, or practices. It liaises closely with these Branches to substantiate the utility of data from requested systems, and then with the Operational Instrumentation Branch on their specification, on the design of trials to establish the performance of prototypes and the suitability of the systems for operational use. The output from newly acquired operational instrumentation is assessed to determine the optimum procedures for its use and the effect of its introduction on the accuracy and comparability of the basic observational data.

*Surface observations*

The networks of land and sea stations, manned and automatic, needed to satisfy observational requirements are continuously reviewed by the internal Working Group on United Kingdom Observational Networks and a new policy document on climatological networks was issued during the year. A Study Group on the United Kingdom Meteorological Observing Network Strategy is producing plans for the integrated evolution of networks over the next 20 years.

A fairly uniform network of observing stations is maintained for weather analysis and forecasting purposes. At fixed times these stations make weather reports, known as 'synoptic' reports, which are transmitted to forecasting centres without delay in an internationally agreed meteorological code. At the end of 1983 the United Kingdom synoptic reporting network consisted of 262 manned stations on land, of which 82 made hourly reports and 46 made 3-hourly reports every day. The remaining 134 stations reported less frequently, many closing at night or at weekends and public holidays. Meteorological Office staff manned 83 of these synoptic reporting stations, most of which were located at civil and military airfields. Fourteen stations included in the network were manned by DNOM and USAF personnel and at the remaining 165 stations, known as auxiliary reporting stations, weather observations were made by coastguards, aviation staff, lighthouse keepers and a number of private individuals. Special instruction for such observers in the making and reporting of weather observations was given either on station or at the Meteorological Office College. In addition, 67 non-Meteorological Office stations provided regular plain language reports of current weather near major roads to assist the Office in its forecasting role for transport.

Automatic stations are being used increasingly to supplement the networks, although at the moment measurements are limited to pressure, temperature, humidity, rainfall and wind. By the end of the year the new Synoptic Automatic Weather Stations (SAWS) had been installed at 13 sites, adding to the existing 12 older automatic stations. Planning continued for the acquisition and installation of a further 40 SAWS. The output from the SAWS has proved highly reliable.

Automatic systems are deployed also at 10 locations in the seas around the United Kingdom, both in support of general forecasting requirements and of specialized services such as those to the offshore industry. Fully automated weather stations, which transmit a wide range of atmospheric data to mainland collecting centres, are installed at very remote locations such as fixed buoys in the east Atlantic and uninhabited islands. Semi-automated weather stations are installed at locations such as North Sea oil rigs, where manual insertion of observed cloud, visibility and weather into the transmitted message is possible. These reports are of paramount importance to the forecasting of North Sea weather. The Branch maintained its efforts to obtain regular, good quality manned observations from company personnel on board oil and gas platforms and rigs; two members of the Branch visited offshore installations advising on siting of instruments, giving instruction in observing and reporting, and carrying out inspections.

In order to assess climatic trends there is a requirement for records of meteorological variables to be maintained over long periods at sites which are representative of various types of terrain and urban environment. For such climatological records to be of value it is important that the exposure of the instruments at the stations are to a common standard and that the sites of such stations remain substantially unchanged with time. This is difficult to ensure as the demand on land for development purposes increases near many of the stations; however, it has been possible to select 21 stations where little change of site or exposure is expected and these are known as Reference Climatological Stations.

Many stations making synoptic reports also submit climatological returns. By the use of a code called the National Climatological Message (NCM), climatological data from stations which also make synoptic reports are fed directly into the computer based climatological archive from the telecommunications channels. At 76 stations manned by Meteorological Office staff and at 87 auxiliary stations these NCM returns covered the whole 24-hour period. About 490 stations, which usually make meteorological observations only once daily, continued to submit monthly manuscript climatological returns. Most of these stations were operated by local, regional or national authorities, but a number were still operated by individuals on a voluntary basis. During the year 19 observers who have provided climatological returns of a high quality over 15 years were rewarded through the new book award scheme.

A more extensive network is required to determine rainfall distribution for application to the use, control and planning of water resources. About 6000 stations provided data, these being listed by area in Table IV. Many of these stations measured rainfall only, and were mostly maintained by co-operating authorities, usually Regional Water Authorities. The Meteorological Office collected data from those rain-gauges which complied with the accepted standards of exposure and type of equipment and rainfall stations were regularly inspected. Plans for a reduction (by about a third) in the number of stations from which data are required are being implemented by several Water Authorities, as explained on page 36.

*Upper-air observations*

Upper-air observations are made at eight stations in the United Kingdom in accordance with the standard program of complete soundings (pressure, temperature, humidity and wind) at 00 GMT and 12 GMT and wind-only soundings at 06 GMT and 18 GMT. These stations use the Mk 3 radiosonde. A similar program is carried out at Gibraltar but the instrument used there is the Grawsonde M60. The *Starella's* upper-air program when manning either Ocean Weather Ship station 'L' (57°00′N, 20°00′W) or 'M' (66°00′N, 02°00′E) is four complete soundings per day using the American VIZ radiosonde modified so that upper winds can be determined from NAVAID radio transmissions.

During the year the major manufacturer of radiosonde balloons in the United Kingdom withdrew from the market. Alternative balloons, mostly manufactured overseas, were tested to establish their performance in both summer and winter environments. Replacement balloons have already been used on the operational upper-air program and marked disparities between day and night time burst heights have occurred. These factors preclude a realistic appraisal of the overall performance figures (see Table V).

An extensive review of requirements for upper-air observations, including the observing network density, the frequency of observations, the altitude to be attained and the amount of detail to be provided, was begun. The meteorological requirements of the international community, the Meteorological Office itself, and specialist users within the United Kingdom were all included in this study.

*Radiation observations and investigations*

With the installation of solar radiation sensors at the new observing office at Aviemore, in the Cairngorms, the recent phase of expansion of the solar radiation network at Meteorological Office stations was completed. This was funded in part by the Commission of European Communities (CEC). The work of the whole network comprising 21 co-operating stations as well as 14 Meteorological Office stations, is monitored by the National Radiation Centre (NRC) at Beaufort Park and inspection visits are made regularly by NRC staff.

All Meteorological Office stations record the levels of both global and diffuse short-wave radiation on a horizontal surface while additional variables, such as the magnitude of the direct solar beam and irradiances on vertical surfaces, are measured at a limited number of sites. All data are recorded at one-minute intervals on magnetic tapes which are processed centrally at Bracknell. Most co-operating stations supply only daily totals of global radiation but six stations also send in hourly totals.

The future evolution of both the radiation measuring networks and the sunshine recording network were examined in detail during the year; the recommendations from the study pointed to an increase in the network of global radiation measurements, mainly through measurements on SAWS, and a corresponding decrease in the sunshine network.

The NRC is now equipped to measure atmospheric turbidity using a sun photometer which samples the direct solar irradiance in four narrow (5–10 nm) spectral bands defined by interference filters. The recalibration of a similar instrument used at Eskdalemuir Observatory highlighted some problems with the use of sunphotometers and investigations have begun.

A further responsibility of the NRC is the maintenance of the radiation standards used for the testing of network pyranometers and for the calibration, as a repayment service, of instruments sent to the Meteorological Office. The calibration of the standards themselves requires long periods of clear skies and was undertaken at RAF Akrotiri in Cyprus in August both for the Kipp CM11 and Eppley standards.

A study was completed, partially funded from a CEC solar energy contract, concerning the estimation of hourly solar radiation from the extensive network of sunshine recorders. Maps of estimated mean hourly global and direct irradiation were prepared from the results, incorporating the relatively poorly distributed measurements of irradiation. Under the same contract liaison continued with other groups investigating the radiation received on inclined surfaces.

The introduction of a more efficient method of archiving the radiation network measurements, and of disseminating radiation data to customers on repayment, is nearing completion. Over 250 enquiries were received, principally from universities and architectural firms, requesting various types of solar radiation data.

*Observatories*
The Branch maintains the Observatory at Lerwick and a section at the NERC Observatory at Eskdalemuir. Both these stations maintain 24-hour synoptic observations and are Reference Climatological Stations. Lerwick is also a radiosonde station, and forms part of the thunderstorm locating network; additional measurements are made of ozone, atmospheric potential gradient, air to earth current and atmospheric pollution. Eskdalemuir is part of the global network of Background Atmospheric Pollution Monitoring stations; in addition to pollution, measurements include those of evaporation and atmospheric potential gradient.

*Thunderstorm location*
The program for locating thunderstorms over western Europe and the east Atlantic continued throughout the year. Hourly observations between 06 GMT and 21 GMT are made by four stations in the United Kingdom, and at Gibraltar, and processed in real time at Beaufort Park for international dissemination (see Table VI). The locations of the storms, accurate to a half degree in latitude and longitude, are also archived on magnetic tape. There is now a very considerable amount of data available for research purposes.

*User trials*
Data from an automatic weather station (designed by Heriot-Watt University) operating on the summit of Cairngorm during 1983 were compared with other high-level observations on the mountain. A report upon the utility of the data in the preparation of winter-time forecasts for the Scottish Highlands was produced in collaboration with forecasting staff at the Glasgow Weather Centre.

A boundary-layer radiosonde of American design was operated by local staff first at Bedford and then at Lossiemouth. Detailed profiles of temperature and humidity in conditions associated with the formation and dissipation of fog and haar were obtained. The extent to which such data might improve the forecasting of fog was examined. Further trials with a modified radiosonde which carries a pressure sensor to determine altitude more accurately are planned.

A program of more than one hundred comparison flights between the radiosondes of the United Kingdom (Mk3 radiosonde), of Finland (RS 80) and of West Germany (M 60) was undertaken. The Finnish system, loaned to us by the British Antarctic Survey prior to despatch to Halley Bay, makes use of the radio transmissions of the world-wide OMEGA navigation network to determine the horizontal displacement of the ascending radiosondes. The trials provide the first extensive comparison in the British Isles between winds derived in this way and winds derived by radar tracking. Figure 2 presents the results for one ascent made during the storm in early September which caused extensive damage in the south and west of England. The radar data are averaged over an interval of about one minute and so provide considerably more detail than do the OMEGA data which have to be smoothed over more than two minutes to overcome the effect of weak signals. When allowance is made for this difference it can be seen that agreement between the two sets of results is generally good, with a worst discrepancy of about five knots in wind speed.

Work was completed upon a new technique for the automatic selection of significant levels from the very many provided in the output of an upper-air sounding. Although inevitably falling somewhat short of the selection provided by a trained human analyst, the technique devised provides an improvement over present machine methods with only a negligible increase in the total number of levels chosen.

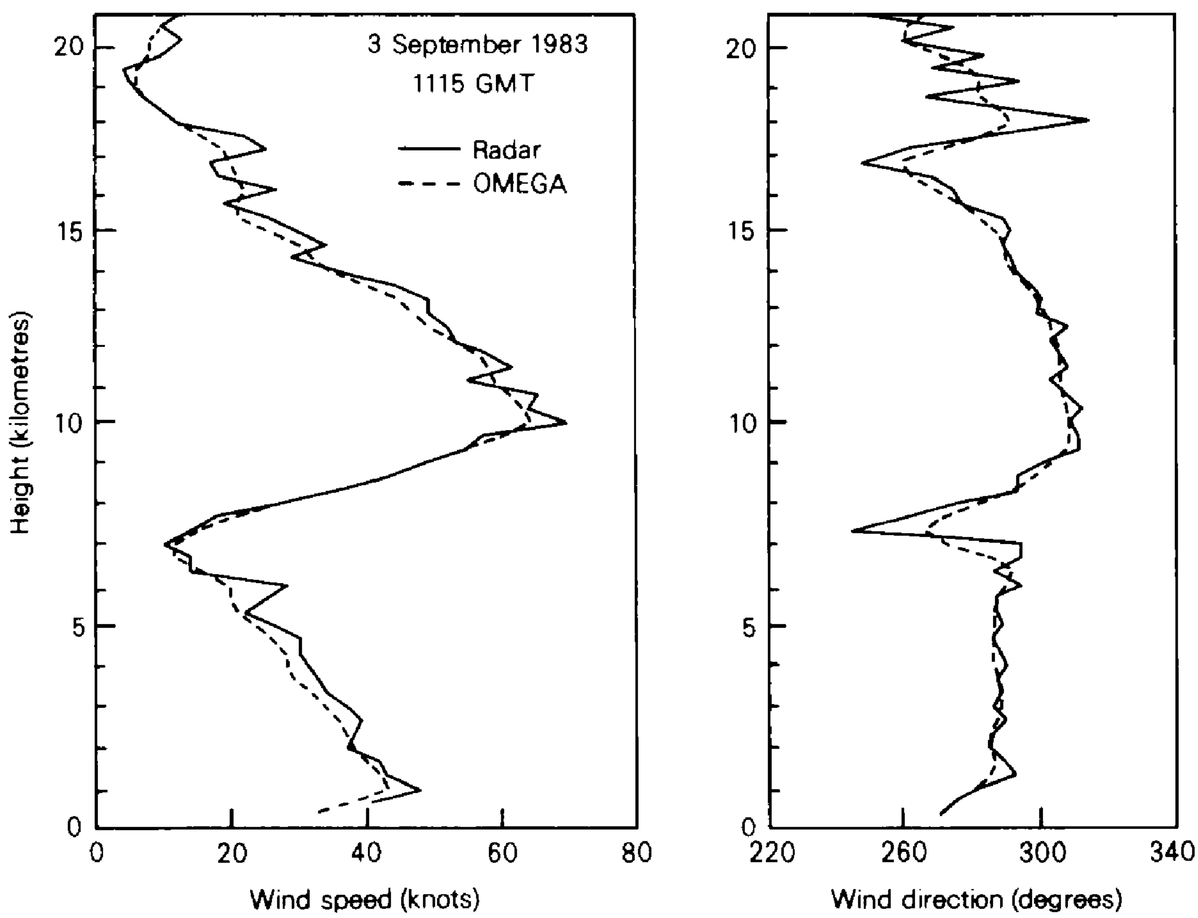



Figure 2—Comparison of winds derived by the Vaisala RS 80 radiosonde using the OMEGA navigation network, with one-minute winds from standard Meteorological Office wind-finding radar

*Quality evaluation*

Regular analyses of the reports received every twelve hours from the upper-air stations of the northern hemisphere were made and a report for 1982 was provided to the World Meteorological Organization. The results for United Kingdom stations led to a tightening of on-site quality evaluation at our own stations.

A scheme for automatically monitoring the quality of surface data was extended to 27 automatic weather stations in the United Kingdom or adjacent sea areas, to 31 offshore platforms and drilling rigs, and to 126 manned stations. The schemes provides a routine evaluation of the quality of instrumental output enabling faults to be seen and remedied readily.

*International matters*
The Assistant Director (Observational Requirements and Practices) was a member of the WMO Working Group on the Global Observing System (WGGOS), and of the WGGOS Study Group on Optimized Observing Systems which is actively developing plans for the evolution of global systems over the next 20 years. He was also a delegate to the WMO Commission for Basic Systems, and during 1983 acted as a technical adviser to the United Kingdom delegation at the ninth Congress of WMO. Senior Branch members served on the WMO Advisory Working Group on Upper Air Technology and on international working groups concerned with radiation measurements; one officer acted as the Rapporteur (to WMO) on the compatibility of data from different upper-air measurement systems. The Marine Superintendent served on the WMO Commission for Marine Meteorology.

*Marine Division*
*The Voluntary Observing Fleet.* The numerical strength of the Voluntary Observing Fleet remained almost static throughout the year. Although the continued recession in world trade still has a considerable impact on the British merchant and fishing fleets, the continuing efforts of the Port Meteorological Officers have ensured that the number of withdrawals has been equalled by the number of recruitments. These Officers are established at the major ports of London, Liverpool, Southampton, Hull, Middlesbrough, Glasgow and Cardiff and, under the guidance of the Marine Superintendent, are responsible for maintaining the numbers of a variety of ships ranging from very large oil tankers and passenger vessels to coastal traders and trawlers which are prepared to make voluntary surface meteorological observations and are collectively known as the Voluntary Observing Fleet (VOF). Most of the older, conventional ships of the British merchant fleet have now been replaced by fast modern vessels which spend less time in port and are thus at sea for a greater proportion of the year. As a result, the number of observations received continued to increase.

Apart from a few special purpose Ocean Weather Ships and research vessels, meteorological work at sea in British merchant ships has always been carried out on a voluntary basis and it is gratifying to note that the standard of observing was well maintained throughout the year. The policy of appointing Port Meteorological Officers who are Master Mariners with considerable experience of voluntary observing at sea contributes significantly to the high standard of observations received from officers of the VOF. The installation of distant reading equipment on a number of merchant ships under construction, in order to ease the workload of observing officers, continued with the whole-hearted support and co-operation of ship owners. Once again, acknowledgement must be made to the many Commonwealth and foreign Port Meteorological Officers for their valuable services and assistance in the replacement of defective instruments in British observing ships on protracted voyages, and the withdrawal of instruments and publications from British ships which were sold or ended their career abroad.

As in previous years, 'Excellent' Awards in the form of books were made to the shipmasters, principal observing officers and radio officers who were responsible for submitting the 100 best meteorological logbooks for the year. Similar awards were made to masters and officers on short sea trades for their contribution in making sea temperature observations. Long service awards in the form of inscribed barographs were made to four shipmasters in recognition of their valuable voluntary meteorological observing over many years during their career at sea.

The *Marine Observer,* a quarterly journal of maritime meteorology, was published as in previous years. The purpose of the journal is to stimulate the interest of mariners in meteorological observing and a considerable proportion of each edition is devoted to observations of phenomena made by voluntary marine observers.

Marine enquiries, principally from shipping interests, solicitors, universities and individual firms continued at a high level.

*The Ocean Weather Ship Service.* Under the North Atlantic Ocean Station (NAOS) scheme the United Kingdom continued to operate an Ocean Weather Ship on station 'L' situated at 57°00'N, 20°00'W. The UK ship *Starella,* a converted trawler, on charter to the Meteorological Office, continued to operate in conjunction with the Netherlands weather ship *Cumulus* on station 'L' which was thus manned continuously throughout the year. In addition, the *Starella* relieved the Norwegian weather ship *Polarfront* on station 'M' situated at 66°00'N, 2°00'E for 10 days during October to enable the *Polarfront* to have her annual overhaul.

The weather ship made hourly surface and six-hourly upper-air observations (for heights reached in upper-air ascents see Table V on page 70) throughout the year. Sea and swell records were made using the Tucker shipborne wave recorder and, in addition, sea water temperature and salinity readings, collection of rain water samples for analysis by the International Atomic Energy Agency and collection of sea water samples on passage to and from station for monitoring radioactive content were undertaken at regular intervals. A plankton recorder was towed on a number of voyages to and from station on behalf of the Institute for Marine Environmental Research.

## Operational Instrumentation

This Branch is responsible for the installation and maintenance of all instrumentation needed to meet the operational requirements of the Office. Arrangements are made for new equipment to be developed as and when necessary and technical advice is provided for procurement purposes. In addition, common services such as engineering drawing, mechanical and electronic workshops, technical writing, test and calibration of instruments, photography and technical training are provided and the Office Museum is maintained. The Branch is active in relevant international co-operative activities including the European Co-operation in Science and Technology (COST) Project 43 and the WMO Commission on Instruments and Methods of Observation (CIMO) of which a senior member of the Branch is the Vice-President.

The Branch co-operates closely with the Observational Requirements and Practices Branch to assist them in their task of defining the requirements of the user Branches, and then attempts to meet these requirements by the most cost-effective method. Preference is given to the use of commercially available solutions rather than in-house design and development. Once the solution to a problem has been found and tested successfully in field prototype form, the Branch provides technical assistance to the equipment supply Branch in the procurement of appropriate quantities of production units. Functionally, the Branch is divided into two parts: 20 per cent of the total manpower form two design and development (D & D) groups; the other 80 per cent form a service, maintenance and support group.

*Design and development*

The sensor development group have continued to make progress in the work on sensors for use in hostile environments. The Rosemount orthogonal (differential pressure) wind sensor which was deployed at Great Dun Fell over the 1982/83 winter proved extremely successful, remaining ice-free and reporting valid wind speed and direction in conditions of extreme ice accretion. An idea to solve the problem of air temperature measurement in similar severe conditions was evaluated during the same trial. The technique used is to mount a bead thermistor at the extremity of a long flexible rod and the natural vibration of the rod is used to prevent ice build-up at the thermometer element (see Plate II). The thermistor is unshielded and preliminary results from the trial at Great Dun Fell and in subsequent field trials at Beaufort Park suggest that errors of measurement should be less than $\pm 2$ °C at all times but better than $\pm 1$ °C in most situations.

The construction of WMO specification reference psychrometers was completed and evaluation of these instruments commenced towards the end of the year. An investigation was also started into methods of improving the accuracy of humidity measurement on the Mk 3 radiosonde.

The 'weighing tipping bucket' rain-gauge was further developed and a prototype system put into the field for operational evaluation. This system, which measures rate and amount of rainfall, incorporates a data processing unit developed from a commercial microcomputer. The microcomputer software algorithms are now sufficiently specified to enable an 'intelligent' interface to be constructed (either in-house or by a licensed manufacturer) for a pre-production model.

The four Continuous Automatic Remote Display (CARD) systems at RAF and Army ranges have given good service throughout the year. Data from one of them (at Otterburn, connected to Pitreavie) were accepted for wider dissemination in the national broadcasts of synoptic data. The interface for Cloud Base Recorder data was finally completed and installed in the CARD equipments for operational trials during the autumn.

As a contribution to an important co-operative project with the Civil Aviation Authority a semi-automatic observing system was developed and installed for trials at Stansted Airport. The system provides all the required Air Traffic Control weather displays with combined inputs from automatic sensors and visually observed data entered by the meteorological observer. Automatic coding of METAR reports is also carried out.

A significant amount of effort was expended on activities aimed at providing the meteorological instrumentation required in both the short and long term in the South Atlantic.

Some unexpected difficulties and the higher priority of other work have delayed progress on the Automatic Climatological Recording Equipment (ACRE) project. However, procurement action is now under way. Involvement with the Crop Disease Environment Monitor (CDEM) was completed this year when the first of the production equipments ordered by the Agricultural Development and Advisory Service (ADAS) were delivered and put through acceptance tests. This enabled the design engineers to complete the handbook material and test specifications so that future equipments can be delivered directly by the manufacturer. The Treasury obtains a royalty on every system sold.

The Section working on marine systems had a particularly successful year. The meteorological buoy, ODAS 20, (a temporary replacement for the large data buoy DB1 in the south-west Channel approaches) was deployed on schedule in April and despite some teething troubles with sensors and the communication system, gave good service. The longest period out of operational service occurred in September after a severe storm damaged one of the power supply units. However, communication was maintained with the buoy throughout. The joint Norway/UK/Iceland buoy (ODAS 451) was redeployed in the spring following an electronics failure late in 1982. Thereafter some 80 per cent of transmitted data were received via the HF and satellite channels up to the end of the two-year experimental period which ended in November. Plans to keep this important co-operative venture (a COST-43 project) alive for a further operational period were under discussion late in the year.

A new joint project was initiated this year with the Institut für Meereskunde, Kiel and the Irish Meteorological Service. The two meteorological services supplied surface pressure sensors which were fitted to six drifting buoys purchased by the Kiel group and deployed by them in the mid-Atlantic in September. These buoys then provided surface pressures and sea surface temperatures in real time at the synoptic hours as they drifted eastwards. Further co-operation with Kiel was arranged which resulted in their lending a drifting buoy equipped with a pressure sensor to the Branch. This buoy was secured adjacent to the ODAS in Lyme Bay so that comparison data between the two buoys and the land station at the Royal Naval Air Station at Portland could be obtained. The experiment will continue into next year.

A report was received from MEL, a Division of Philips Electronic and Associated Industries Ltd, which considered the manufacturing work and costs associated with the conversion of the Mk 3 radiosonde to 400 MHz operation. Discussions and studies on the specific conclusions of the report and on the wider issues of how to maintain a cost-effective radiosonde capability were carried on throughout the year.

The major project to develop and procure an operational replacement for the obsolete Cathode Ray Direction Finding (CRDF) System made good progress this year. The new system which, like CRDF, will locate the source of lightning flashes over ranges of several thousand kilometres is in two parts, a control station and a network of unmanned outstations. The control station is designed around a commercial minicomputer and a series of peripheral devices which together will support a very complex and sophisticated set of software. The contract for this part of the system was let late last year and all the hardware has now been procured by the contractor who is using it to produce the software. The preparation by the contractor of the necessary procurement specification was completed in the autumn. Software implementation then began. The development of the outstation has been undertaken in-house and the design and construction of the prototype hardware was completed. Considerable time was required to produce all the necessary descriptive and specification documents but this was completed in July and the case for financial approval was submitted and approved. Contract action began in September when the request for tender invitations to be issued was passed to MOD(PE). The software for the outstation is being written in-house and steady progress was made. Introduction of the system is scheduled for mid-1985.

*Support services and maintenance*
The continuing program to equip the Office with a wider range and greater quantity of automated observing systems generated a major proportion of the workload in support of the Procurement Branch (Met O 4). Contracts for 22 Mk 5 Wind Systems, 25 'JASMIN' video stores and their associated displays for use with the quantitative weather radars, 10 MOSS (Meteorological Observers' System for Ships), and 41 DALE (Digital Anemograph Logging Equipment) equipments were completed this year. Procurement action was intiated or continued for 11 short base-line transmissometers, 10 ACRE (Automatic Climatological Recording Equipment) a further 30 SAWS (Synoptic Automatic Weather Stations), and a replacement for the existing Magnetic Tape Event Recorder (MTER) for recording rainfall. Deliveries of the 20 laser cloud-base recorders (LCBR) now on order began early in the year but were stopped when significant manufacturing and design weaknesses were revealed by acceptance tests. All the equipments were then withdrawn by the manufacturer who has had to undertake extensive redesign. Delivery of the first redesigned units is expected early in 1984. Progress on the refurbishment of the Cossor windfinding radars made only slow progress because of difficulties associated with the provision of adequate drawings, but these have now been overcome.

The post-design services group (PDS) undertook a wide variety of work of which a special feature was the design of modifications to protect our automatic systems from the effects of nearby lightning strikes. There was a much greater incidence of this type of damage this year than we have encountered before and modifications had to be devised for several operational systems. Work on the nature of faults which have occurred on the high power rotating joints in the Cossor 353D windfinding radars resulted in several units being successfully repaired and returned to service.

The electronic workshop has again been loaded fully this year. This small unit provides a specialist repair and construction facility to enable the life of obsolete equipment to be extended cost-effectively and to allow the economic production of prototype electronic circuitry in support of the design and development groups and PDS. Significant improvements to the facility have included the successful completion of a subsidiary workshop adjacent to the main stores at the Western Road site and the establishment of a repair facility for the tape recorders used extensively in the Mk 3 radiosonde ground stations. The additional workshop allows heavy equipment such as facsimile recorders and cloud base recorders to be repaired at the stores without having to be transported to Beaufort Park. The tape recorder repair facility, which could not be obtained from the manufacturer, will avoid re-equipment costs of the order of hundreds of thousands of pounds. The mechanical workshops had a busy year and handled over 350 jobs.

Services to 21 Branches and sections were rendered by the Engineering Drawing Office and Photographic group during the year. The photographer undertook 548 assignments, of which 54 involved location work. The great majority of the drawing work was carried out by external contractors under the supervision of the engineering design services staff.

As a consequence of the completion of several equipment procurement contracts the two installation teams undertook between them the installation and commissioning of 10 SAWS, 6 SAWS polling units, 30 DALE equipments and 1 Meteorological Office Data Logging Equipment (MODLE 3) as well as a large number of individual, smaller equipments such as digital thermometers and wind measurement instruments.

The elderly 3 cm weather radar on top of the British Telecom (BT) tower in London was found to be causing radio interference with a new BT microwave link and could not be economically modified to overcome the problem. The equipment was therefore switched off in April and is being dismantled and removed from the tower by the installation staff. This radar facility will be replaced by the 5.6 cm Chenies weather radar when it comes into service in 1984. A 3 cm radar at Manchester Weather Centre was also switched off and decommissioned on 1 October 1983 because its function has been taken over by the automatic weather radar facility at Hameldon Hill. The equipment was dismantled and recovered as spares to support the remaining units of this type at Newcastle and Akrotiri, Cyprus.

The totals of instruments, electronic systems and radiosonde components tested or calibrated during the year are shown in Table XV. The numbers in the 'Tested' column are mainly a reflection of the rate of supply of items. On the other hand, the calibration totals give an indication of the workload in the section and show a significant increase over last year in all cases. In spite of this increase, further reorganization and increased flexibility in the use of resources allowed a net reduction of four in the number of staff employed on this work. A special, urgent program of tests of radiosonde balloons from overseas manufacturers had to be mounted when our principal supplier, the only one in the UK capable of meeting our specifications in full, went out of the balloon manufacturing business at short notice. A longer series of evaluations began in the second half of the year and will continue through the winter into next year. Steady progress was made towards our objective of bringing all our test and calibration procedures and their associated documentation up to the requirements of Defence Standard 05-55. The test rig used to check and calibrate wind vanes was completely modernized this year by the introduction of an electronic angle position indicator. The old equipment had been in service for 20 years.

In consequence of cost benefit studies carried out last year, the Meteorological Maintenance Organization (Met O MO) assumed responsibility in April for the maintenance of the Automatic Message Preparation Equipment (AUTOPREP) and the Phase III message switching enhancement in the Meteorological Telecommunication Centre (Met TC). In addition, Met O MO assumed responsibility for 10 new SAWS and their 7 associated polling units, 30 new DALE installations, the MODLE 3 at Aviemore, and many new minor installations such as rain-gauges and wind sensors. Against this must be set the reductions in load due to the decommissioning of the weather radars at London and Manchester and a small reduction in the numbers of facsimile equipments in use. These changes represent a geographical redistribution of the Met O MO workload which gave rise to the need to reappraise the distribution of resources. As a result, a new area maintenance centre was opened this year at Kinloss, Morayshire. Compensatory reductions in resources were made in the staff levels at the area maintenance centres at Birmingham and Shanwell.

The School of Technical Training (MOSTT) ran courses on behalf of the Meteorological Office College and details are given in Table XVII. A feature of the training load undertaken this year was the number of overseas students who attended courses specially run for them or who were given 'on the job' training. Two such students worked in the Branch laboratories this year and made some very useful contributions to the output of the sections in which they assisted.

The North West Weather Radar Project, in which the Branch participated along with the North West Water Authority and the Meteorological Office Radar Research Laboratory, reached the end of its development phase when all the outstanding reports on the research sub-projects were published late in the year. The system, which has functioned with better than a 98 per cent reliability throughout the year, is now regarded as operational. The London Weather Radar Project which began last year as a co-operative venture between the Office, the GLC, Thames Water and Southern Water made very good progress. Early in the year a tender was accepted from Plessey Radar Ltd for an improved version of their type 45C radar and the necessary support hardware. The manufacture of the system went smoothly and successful system tests were held at the factory at the end of the year. The new accommodation for the system at Chenies, near Rickmansworth, was completed and handed over by the contractor in the second half of the year so that the way is clear for system trials, installation and commissioning to be undertaken in early 1984.

Preliminary discussions have taken place with water authorities and other Government Departments with the aim of establishing consortia which will finance and procure quantitative weather radar systems in Northern Ireland, South Wales and south-west England, and Scotland. To provide a national framework for this activity and a consolidated, professional view of the cost benefits of quantitative weather radar, the National Water Council/ Meteorological Office Joint Working Group presented in June its report on National Weather Radar Coverage (over England and Wales) to the Directors of Operations of the Water Industry and to the Directorate of the Meteorological Office. After approval by these Directorates the report was submitted by them to their respective Ministries (MAFF and MOD) for endorsement.

*International co-operation*

A senior member of the Branch served on the WMO Commission on Instruments and Methods of Observation (CIMO) and is the Vice-President and a member of its Advisory Working Group. Another senior member served on the CIMO Working Group on Surface Instruments. After a meeting of this Working Group an information paper was prepared on the characteristics and performance of instruments needed for the automatic acquisition of meteorological measurements. A senior member of the Branch was also Chairman of the European COST 43 Project which is aimed at establishing an experimental network of real-time ocean data acquisition systems (ODAS) around the European continental shelf. The COST-43 Management Committee organized a major international seminar on ODAS technology at the European Centre for Medium Range Weather Forecasts in June. From this emerged a proposal for a joint venture to deploy an operational network of drifting buoys in the eastern North Atlantic, and a member of the Branch took part in a subsequent planning meeting at which support for this concept was pledged in principle by the meteorological services of France, Ireland, Norway, Iceland and the United Kingdom.

## Computing and Data Processing

Following major enhancements in the previous two years to COSMOS, by which name the Office central computing facility is known, 1983 was a period of consolidation and development as far as large processors were concerned, though there were several changes in ancillary equipment. The possession by the Office of modern computers of great processing power and advanced design, together with the experience gained in their use, have made COSMOS an establishment of some standing in the computing world, both at home and internationally. During the year there were wide contacts with other computing centres, especially those in process of installing Cyber 205 computers. The Office was represented at a meeting of meteorological centres equipped with this very fast machine, held in order to exchange experience and ideas. Establishments represented included the National Meteorological Center and the Goddard Space Flight Center, Washington, the Geophysical Fluid Dynamics Laboratory, Princeton, and the Fleet Numeric Weather Center, Monterey. The Office also hosted a conference of managers of data-processing establishments equipped with large IBM computers.

### *The Central computing facility*

At the heart of COSMOS are three powerful processors. Two of these are IBM machines, the 370/158 which has a central processing speed of the order of one million instructions per second, and the 3081, about ten times as fast. As well as doing substantial amounts of processing in their own right, these act as front-end machines to the third machine, the CDC Cyber 205, which is about 30 times faster than the 3081. Use of the Cyber 205 increased steadily during the year, though it is becoming apparent that release of the full power of its central processor is seriously impeded by lack of sufficient storage space. The IBM 3081, installed at the end of 1982, gave very good service from the start and, compared with the 360/195, has achieved an impressive increase in throughput. The Cyber 205, as was to be expected of a new machine of advanced design, did not reach the same high level of reliability, and there were interruptions for major engineering changes during the year. These changes, however, were implemented in a planned program which permitted routine forecasting to continue and, taken as a whole over the year, performance and reliability of the Cyber were good. The IBM 370/158 while still giving useful service is nearing the end of its planned life, and studies were undertaken to formulate a specification for its replacement.

High-speed storage devices form an essential part of any modern computing installation, and a major change was the installation of high-density fixed discs. Their total capacity is 15 gigabytes, making it possible to transfer to these devices all information required for fast access. Though some mountable units have been retained as back up, the manually intensive task of mounting discs has now almost been eliminated, with the number of support staff reduced accordingly. The medium for long-term storage, however, continues to be magnetic tape and the library of such material has increased steadily. Here too, economies in storage and handling are being made by recording new and existing data at higher densities.

*Systems support*

The function of the small systems group in the Data Processing Branch is to liaise with manufacturers, software specialists and users. This year in particular the group has worked closely with Control Data Ltd (CDL) in the task of establishing links between the Cyber 205 and the two front-end machines. Normally the 370/158 is used to transfer programs and data to, and receive output from, the Cyber; faults in the software linking the two machines observed during routine operation were recorded and analysed for corrective action. By the second half of the year the link between the Cyber 205 and the IBM 370/158 was considered acceptable for full operational use. The IBM 3081 was also linked to the Cyber 205, though use of this connection is still restricted, particularly when the IBM machine carries a full workload. Communication between two high-speed processors of different design is a complex undertaking and, though responsibility for linking the Cyber to the IBM machines rested with CDL, the experience gained by the involvement of the systems team is likely to prove useful when it becomes necessary to establish links between COSMOS and other internal computers.

Now that the Office has in the IBM 3081 a computer powerful enough to support a large terminal system, the first stage of a project to modernize and expand the network was implemented. Use of the terminal facilities increased rapidly, partly because of improvements in the supporting software but primarily because a rapid response time is now provided. By the end of the year the frequency of terminal operation by users had reached nearly 17 000 per month—over three times the 1982 figure. The COSMOS network was extended further to additional external establishments, some of these being customers for meteorological products. They included the Société Internationale de Télécommunications Aéronautiques (SITA), an international agency which is handling flight-planning information for civil aviation. Provision was made also to supply meteorological data to television companies direct from COSMOS.

*Support for computer-based applications*

Small groups in the Data Processing Branch are established to provide services or to write software which have a general application in the Office. A major commitment is training of programming staff; nearly all of this is now conducted internally, either at courses arranged by the Meteorological Office College or at local seminars. Technical guides to help programmers to make the best use of the COSMOS system are constantly revised in line with new developments, and general assistance is provided in computing techniques. This year in particular, detailed guidance was given to enable users to adapt to the use of the new direct-access storage devices, and the improved terminal facilities. Another group provides the software needed for line-drawing and plotting devices. Much of their work is concerned with the output of actual and forecast charts for operational use, the schedule for which has had to be considerably amended since the new forecast suite was first introduced the previous year. Processing of meteorological data is another service provided for users. A complex suite of programs is maintained to produce, and provide access to, the synoptic data bank, which comprises quality-controlled data, processed directly from bulletins received in COSMOS from the Meteorological Telecommunications Centre and held on-line. Because of the need for access to real-time data by an increasing number of users, the data bank is now duplicated, and observations for the last five days are stored. The extension of forecasting to the southern hemisphere, where conventional reports are relatively sparse, has required more effort to be given to checking and storage of aircraft messages and satellite observations.

*Data entry*

For some years a keying establishment has existed to transcribe climatological data entered by observers on prepared forms. These observations have been keyed manually for recording on magnetic tape and subsequent processing but this process is increasingly being automated. Where climatological returns on hand-written forms continue to be necessary, the intention in the future is to process them by means of an Optical Character Reader (OCR), procurement of which is now in hand. A gradual reduction in the establishment of this section has already been achieved, and this process is likely to continue. A small group will still be needed to transcribe certain data such as ships' logbooks, to incorporate corrections, and to handle new material (other than climatological data) which is found to be unsuitable for processing by OCR equipment.

## Systems Development

The introduction and further development of automated systems continued to dominate the activities of the Systems Development Branch. High priority was given to projects which take the benefits of such systems into the outfield. This work has been sustained by the continuing program of installation and development of Outstation Automation Systems (OASYS). Increased efficiency was also sought through the automation of services provided at Headquarters, where the combination of modern hardware and software has enabled a considerable expansion of general-purpose computing tasks based on the central data-processing complex, COSMOS.

*Automation of outstation functions*

The third minicomputer-based OASYS became operational at London Weather Centre in March. The design closely follows that of the systems installed in the Principal Forecasting Offices at London (Heathrow) Airport and Headquarters RAF Strike Command in 1981 and 1982 respectively. During the year the on-line storage capacity available to each system's dual PDP 11/60 processors was increased by the addition of a semiconductor memory module which simulates a very rapid access disk. The enhancement allows more tasks to be completed in a given period.

Each OASYS is connected by a medium-speed line to the Meteorological Telecommunication Centre at Bracknell. The introduction of new telecommunication protocols (CCITT recommendation X25) at terminating interfaces on these lines has allowed a greater variety of data types to be carried. Hitherto the links have been used to maintain an up-to-date store of meteorological observations in OASYS which can be displayed in the form of plotted charts or as a sequence on a graphics visual display unit. During the year numerical model forecast data were disseminated by this method too. A typical example of the charts generated on a matrix printer attached to OASYS from such data is shown in Figure 3.

It is technically feasible to attach remote terminals to an OASYS. This raises the possibility of providing main and subsidiary forecasting offices with rapid access to stored information on demand at relatively low cost. So-called Remote Outstation Automation System Terminals (ROASTs), consisting of a simple visual display unit and a matrix printer capable of producing text and graphics, linked to the OASYS at Headquarters, RAF Strike Command, were installed in forecasting offices at RAF Lyneham and RAF Honington during the year. A six-month evaluation trial began during the autumn.

The Fleet Weather and Oceanographic Centre at Northwood is also to be equipped with a facility modelled closely on OASYS, known as the Fleet Meteorological Computer. The system is being constructed, initially at Bracknell, by Royal Navy personnel with assistance from Meteorological Office staff. The necessary hardware was delivered and software development begun.

*Development of computer-based applications*

It has been apparent for some years that the lack of interactive access to COSMOS was a bar to progress in many applications. Consequently following the acquisition of the IBM 3081 (see section on computing and data processing), a start was made on the expansion of terminal-based services. Some 30 monochrome and 8 colour VDUs and 3 printers were installed in the Headquarters building during the year. Plans to increase the number of terminals at other sites in the Bracknell area are well advanced; proposals have been made to install COSMOS terminals at offices providing climatological services at Edinburgh and Belfast, and it is hoped to link Regional Headquarters in the Agricultural Development and Advisory Service to COSMOS in a similar manner.

Despite the progress made in recent years in numerical weather prediction, the need for human intervention and interpretation remains undiminished. Indeed it has become even more important to extract as much useful information as possible from remote-sensing weather radar and satellite-based observing systems to sustain and complement such numerical methods. The time-critical nature of the processes involved requires presentation of data in a manner which facilitates rapid but well-informed judgement. At present forecasters responsible for this are presented with a mixture of charts, diagrams, and images on TV monitors. It is likely that the optimum configuration will be one in which human intelligence and judgement interact

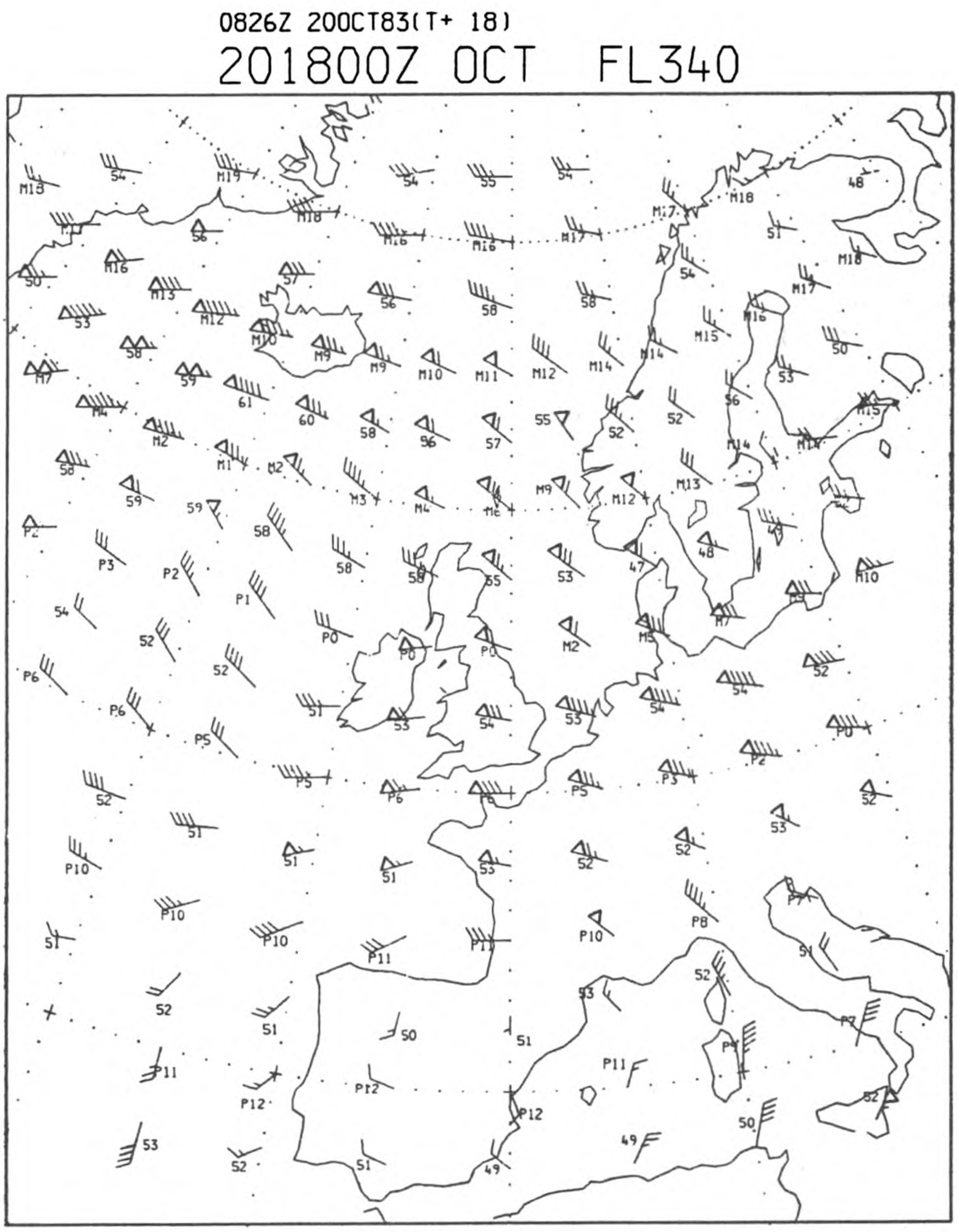



Figure 3—A forecast chart produced on the OASYS at Headquarters Strike Command

Winds are depicted at each grid point, with temperatures (negative) and *D*-values (differences between actual height above mean sea level of a particular pressure surface and the height of the same pressure surface in the ICAO Standard Atmosphere) being given for alternate rows of grid points.

with a powerful data processor and display system capable of integrating a wide range of inputs in a common format. A proposal to purchase and develop such a system within the Meteorological Office has been made and approved. Procurement is scheduled for next year.

During the year a restructuring of routine data-archiving methods enabled the Systems Development Branch to provide a sound basic service to users whilst a number of long-standing requirements for additional facilities were tackled. Archives containing land surface, marine, upper-air and radiation data, and supporting software, were handed over to users for maintenance and further development. A start was made on the construction of new catalogues of observing sites and machinable data.

The Branch continued to provide a general-purpose facility for data transcription and text processing, based on its minicomputer laboratory. Word processors were introduced into the Headquarters typing pool during the year. At present many forecasts are produced in manuscript form for transmission to a range of customers via telex for example. Equipment to automate this text preparation and dissemination was purchased and will be brought into use during 1984 in the Central Forecasting Office.

The computer-based Management Accounting and Information System (MAIS) became operational at the beginning of the financial year. MAIS is based on a proprietary data-base management system and provides a method of recording and reporting the commitment of resources to the activities of the Meteorological Office. Manpower represents almost two-thirds of total costs so attention was initially centred on the commitment of staff time to tasks and a new reporting scheme came into operation at the beginning of April. Analyses based on these data became available during the summer. The Memorandum Operating and Trading Account for 1983/84 will be prepared from them. Estimates of annual expenditure on meteorological equipment were introduced into MAIS and a subsystem to record details of procurement transactions was brought into use in the second half of the year.

## METEOROLOGICAL TELECOMMUNICATIONS

The Telecommunications Branch is responsible for the provision of telecommunications support to the whole of the Office, and for the operation of the Meteorological Telecommunication Centre (Met TC) at Bracknell. An efficient communications system is essential to operational meteorology and, as the observing and forecasting capabilities develop so the communications requirements become more demanding. The strategy adopted to meet those requirements involves the maximum utilization of modern telecommunications techniques consistent with the need for every stage of development to be cost effective. The year 1983 has not seen any major changes in the telecommunications facilities in the Office but there has been steady progress with the development of existing systems to improve their capabilities and operational efficiency, coupled with extensive planning and preparation for the introduction of new systems in the near future.

The Met TC plays a key role in the collection and dissemination of meteorological information both nationally and internationally. Information in a variety of formats and numeric code forms is received, stored, and distributed. Figure 4 shows the principal types of data handled and the main sources and recipients of the information.

International exchanges of data are effected over landline and satellite circuits operating at speeds in the range 1200 to 9600 bits per second (bps). These are controlled by the Ferranti Argus 700S computer system which was first brought into service in 1980 and which continued to provide very high service availability—over 99.7 per cent throughout the year. Data received from all parts of the world via the WMO Global Telecommunications System (GTS) are passed to the main data-processing computers (COSMOS) at Bracknell, to the European Centre for Medium Range Weather Forecasts (ECMWF) at Shinfield Park and to a number of European National Meteorological Centres. As a Regional Telecommunication Hub (RTH) on the Main

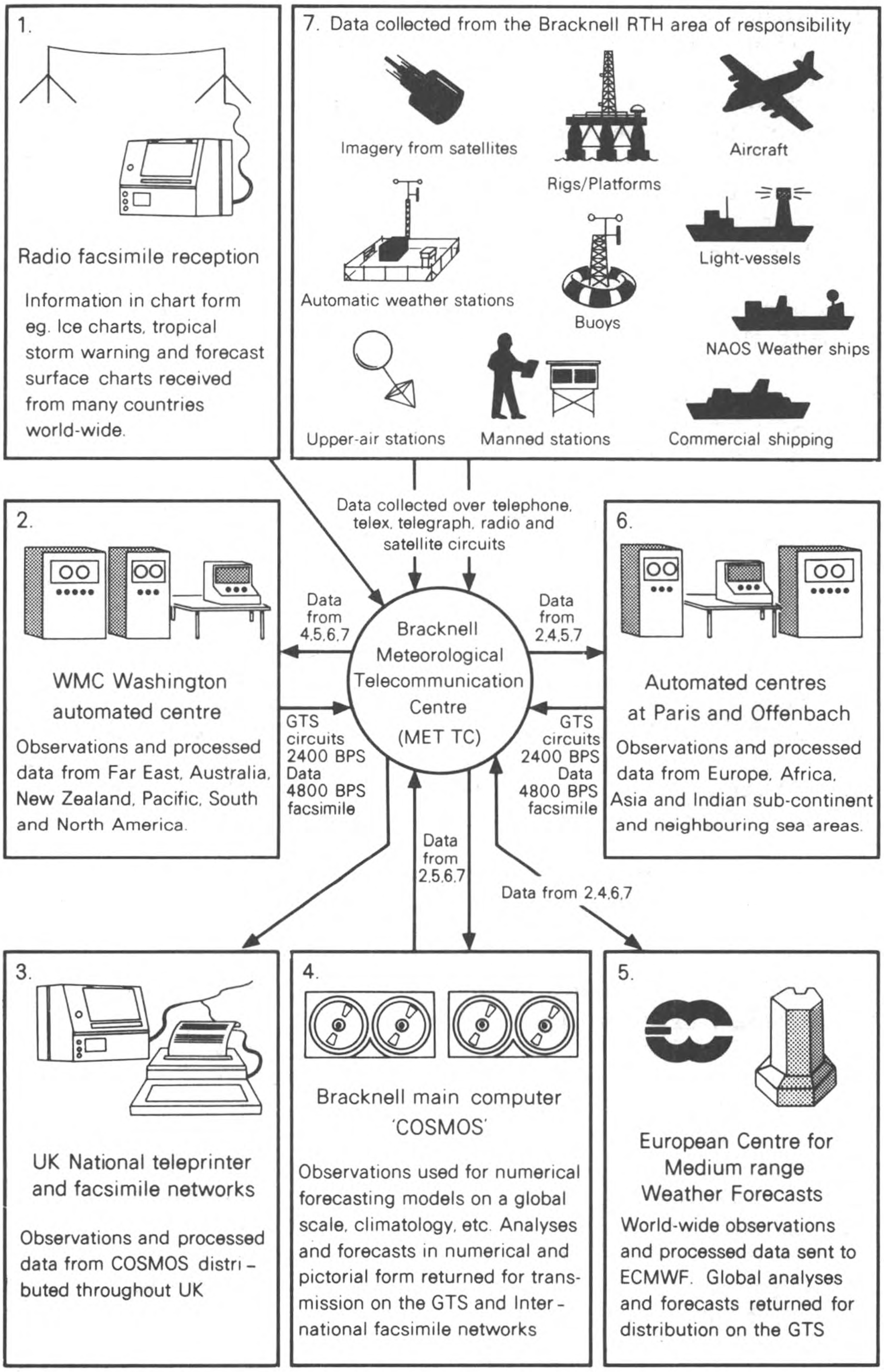



**Figure 4—The principal types of data handled by Bracknell Meteorological Telecommunication Centre**

Trunk Circuit (MTC) of the GTS, Bracknell Met TC links Europe and North America and injects into the global system observational data from the United Kingdom, Republic of Ireland, Greenland, Iceland, the Netherlands, ships at sea including the Ocean Weather Ships of the North Atlantic Ocean Station network, and aircraft operating over the eastern North Atlantic.

In February British Telecom (BT) brought their Coast Earth Station for the INMARSAT maritime satellite communications system into service. Suitably equipped ships are now able to send their observations direct to Bracknell using a specially provided service indicator for the address. There has been a steady growth in the number of reports collected in this way, from about 200 in February to around 1500 in September. The reliability of communication and ease of use compared with the older form of radio communication through BT Coast Radio Stations has meant that many of these reports are additional to those that would have been received using the older methods. Costs per message are lower using satellite communication links and the system is being used increasingly for the transmission of Ship Routeing Service messages. Studies are being made of the possible uses of other INMARSAT facilities under development by BT.

The Ferranti Argus 700S computers also control distribution of data at 4800 bps to the OASYS minicomputer systems at the Principal Forecasting Offices at Heathrow Airport and at Headquarters RAF Strike Command. The OASYS at London Weather Centre receives data via a Ferranti Argus 700G computer using new methods of data link control to provide protection against transmission errors. The same computer also provides link control functions for the 9600 bps link between the 700S main system and the data-processing computers in COSMOS. Additionally it supports the 4800 bps link to ECMWF and the special 2400 bps link to Washington that was developed towards the end of the year for the exchange of binary data. This latter link will be used to receive World Area Forecast System (WAFS) grid-point data from Washington for use if the WAFS products from Bracknell are not available.

Collection from and distribution of data to outstations in the United Kingdom continued over the teleprinter networks supported by the Marconi Myriad, Phase II, message-switching system. The main MCC A/MCC B 100 baud broadcasts which reach many stations have given reliable service throughout the year. The inclusion of radar rainfall displays in simple pictorial format on the MCC A broadcast has been well received by outstation forecasters. The displays, originated by the Meteorological Office Radar Research Laboratory at Malvern, are broadcast at hourly intervals.

The MOLFAX landline facsimile network has continued as the main method of supplying information in pictorial form to UK outstations. The broadcast program has again been radically changed, this time to include a number of output products from the new fine-mesh numerical model. The regular transmission of plotted charts, tephigrams, etc., has been maintained but new techniques for handling some of these products have been under development during the year. They are described in a subsequent paragraph.

Facsimile services by landline and via the GFE radio broadcast to provide distribution of the Bracknell/Heathrow Area Forecast Centre products have been maintained. The GFE program also includes analyses and forecast charts of interest to the maritime community and is often received by ships at sea. A second radio-facsimile broadcast, GFA, provides products of more general meteorological interest. Members of the Branch have spent much effort this year in planning new schedules for these services to support the new Area Forecast System arrangements to be introduced in Europe in 1984.

The Ferranti 'Telex Manager' microcomputer-based data preparation system installed last year has proved very efficient at handling messages through the public telex network and to a number of telegraph lines which require special formats or procedures. Many messages are now routed automatically between the telex network, the Automated Telecommunication Complex (AUTOCOM) and COSMOS. Towards the end of the year trials demonstrated the feasibility of linking word-processor terminals to the Telex Manager (TM) to provide a means of connecting these terminals to the TM supported networks. It is planned to install terminals in the Central Forecasting Office (CFO), thus enabling forecasters to take advantage of the word-processing facilities when compiling certain forecasts, and providing a speedy and flexible means of despatching them to different recipients over telex and other links.

*Developments in automation in the Met TC*

Work on the contract for AUTOCOM Phase IV, the message-switching system to replace the ageing Marconi Myriad AUTOCOM Phase II system, continued throughout the year. Close liaison has been maintained with the contractors, Systems Designers Ltd, to ensure that the detailed design and capabilities of the new system are closely in accord with requirements. The system hardware, comprising five Tandem NON-STOP processors, was delivered to the contractors early in the year and brought into operation for software development during August. Familiarization training for engineering staff who will be supporting the system was begun. The completed Phase IV system is due for delivery by the contractors in late 1984. Important features of the system will be the facilities for program development, the potential for enhancement and further expansion and the provision of an easily accessed data base. The latter will allow data request/reply facilities to be established for users at home and overseas.

The 'in-house' software development of the AUTOFAX (digital facsimile) computer system continued throughout the year, culminating with the quasi-operational use of AUTOFAX for certain charts disseminated over the MOLFAX network. The charts are produced in digital form in COSMOS and passed via a 9600 bps link to AUTOFAX, a Ferranti Argus 700GX computer, which stores them for subsequent transmission to the network through a digital-to-analogue converter and in accordance with a programmed schedule. Full operational implementation, which will ultimately extend to all facsimile transmissions originated within the Met TC, awaits delivery of a second AUTOFAX computer early in 1984.

*Satellite imagery*

Satellite imagery, received from the RAE ground station at Lasham and processed by the computer-controlled AUTOSAT system, is supplied to the Central Forecasting Office Bracknell and to many other UK locations over the SATFAX facsimile network. At the end of the year the network was being extended to serve a further 12 outstations, bringing the total to 42 altogether. It was also undergoing some reconfiguration to ensure that, of the three AUTOSAT output programs available to outstations (a third having been added during the year), each outstation receives the one best suited to its needs.

The main sources of imagery received during 1983 were the US polar-orbiting satellites NOAA-7 and NOAA-8 and the European geostationary meteorological satellite Meteosat-2, with a small number of images from the US geostationary GOES-East. New software introduced on AUTOSAT included some to combine Meteosat infra-red images for adjacent areas to allow users of the image display system in CFO to follow the movement of weather systems across the Atlantic and Europe more easily than before.

Plans were made in collaboration with RAE and MOD (Navy) to install BT Megastream (2 Mbps) links for the transmission of high-resolution digital satellite imagery from Lasham to Farnborough, Bracknell and Northwood. The Network has been designed with an expansion capability, and to provide a data-transfer facility between any of the four locations. It is planned to be available by mid-1984 although real-time operation between Lasham and Bracknell will not begin until some time later. A Study Group has been set up to make recommendations concerning enhancement or replacement of the PDP 11/60 AUTOSAT computer to handle the greatly increased volume of data the new link from Lasham will provide.

### International and Planning

Ever since governmental organizations attempted to provide a meteorological service to user groups, the successful development and application of meteorology has depended on international co-operation in making observations promptly available from a wide area. This has involved the detailed organization of reporting codes—in effect a common language—of reporting schedules, of observing standards and of telecommunication protocols and schedules. With the introduction into operational service of numerical weather prediction models covering the whole globe by the UK and some other countries, this world-wide co-operation has assumed even greater importance and represents, in troubled times, a remarkable example of friendly and effective co-operation between nations.

The focal point of co-operation is the World Meteorological Organization (WMO), a specialized agency of the United Nations which was founded in 1947 as a successor to the non-governmental International Meteorological Organization (IMO). WMO has its headquarters in Geneva and its present membership comprises 170 states and territories. The governing body of WMO is the Congress, composed of Permanent Representatives of Members, which meets every four years. The Ninth Congress met in Geneva from 2 to 27 May and was attended by the Director-General who was assisted by the Assistant Director (International and Planning), the Assistant Director (Observational Requirements and Practices) and Mr M. W. Stubbs. The Congress defines the policies to be followed in the following Quadrennium and develops a Programme and Budget in some detail. Ninth Congress agreed on a Budget of near-zero real growth and defined a Programme which represents a sensible compromise between the need to continue essential routine activities and the desire to explore new possibilities. The Congress appointed Dr Godwin Obasi (Nigeria) as the new Secretary-General to succeed Dr Aksel Wiin-Nielsen (Denmark) on 1 January 1984.

Between Congresses, the work of WMO is supervised by an Executive Council (EC) (renamed by Ninth Congress) which meets annually. The EC comprises 10 ex-officio members (the President and 3 Vice-Presidents of WMO and the 6 Presidents of Regional Associations) and 25 members, who must be Directors of Meteorological Services, elected by Congress to represent the international meteorological community rather than their countries. Sir John Mason was elected a member and attended the 35th Executive Council which met between 30 May and 3 June 1983 immediately following the Congress. Sir John was assisted by the Assistant Director (International and Planning) and Mr M. W. Stubbs.

Matters of interest in particular geographical areas are co-ordinated by six Regional Associations. The United Kingdom is a member of two Regional Associations, Regional Association I (Africa) by virtue of the operation of a meteorological station on St Helena, and Regional Association VI (Europe). Neither met during the year but the Office co-operated in many activities at working level in both Regions. In the case of Regional Association I in particular, the Office took advantage of its operation of an advanced, automated Regional Telecommunication Hub to take part in special campaigns to monitor the flow of data through the Global Telecommunication System and took several initiatives to identify some of the reasons for the serious shortage of data both within and from Africa.

Scientific and technical matters are co-ordinated by the 8 Technical Commissions each of which specializes in a particular aspect of meteorology and hydrology. Again, the Office took part in many interactions at working level especially in the Commission for Aeronautical Meteorology which is now developing arrangements for the new World Area Forecast System (WAFS) agreed with the International Civil Aviation Organization (ICAO). The UK will provide a World Area Forecast Centre (WAFC) and a Regional Area Forecast Centre (RAFC) in the new system. During the year the Commission for Basic Systems (CBS) met in Washington from 31 January to 11 February and the Commission for Agricultural Meteorology (CAgM) met in Geneva from 21 February to 4 March. CBS was attended by the Director of Services who was assisted by the Assistant Director (Observational Requirements and Practices), by the Assistant Director (Telecommunications) and by Miss M. Atkins. CAgM was attended by the Assistant Director (Agriculture and Hydrology) who was assisted by Dr N. Thompson.

The meteorological aspects of other international activities are dealt with through such organizations as the ICAO and the North Atlantic Treaty Organization (NATO). The International Council of Scientific Unions, in which scientists participate as individuals rather than as representatives of scientific bodies, is responsible together with WMO for the Global Atmospheric Research Programme (GARP) of which the World Climate Research Programme (WCRP) is an important part. The WCRP is the research component of the World Climate Programme (WCP) of which other components are the World Climate Data Programme and the World Climate Impact Programme. Dr J. T. Houghton (Director-General from 1 October 1983) is Chairman of the Joint Scientific Committee for the WCRP.

Within Europe the UK continues to be a member of the European Centre for Medium Range Weather Forecasts (ECMWF) which has its Headquarters at Shinfield Park, Reading, adjacent to the Meteorological Office College. The Centre has a staff of 145 drawn from its 17 member countries and has the task of developing numerical weather prediction methods for the period 10–12 days ahead. The Director-General is a member of the ECMWF Council which meets twice a year and the Office is represented on the Centre's Finance Committee—of which the Assistant Director (International and Planning) is Chairman—and on the Technical Advisory Committee. The Scientific Advisory Committee comprises scientists chosen for their individual expertise in relevant fields; Mr F. H. Bushby (Director of Services) is a member and was elected Chairman during this year.

British contributions to Antarctic Meteorology are the responsibility of the British Antarctic Survey (BAS) which maintains a program of surface and upper-air observations at some of its bases. The Meteorological Office supports the operations of BAS World Weather Watch (WWW) stations by providing consumables and some equipment; the level of this support is reviewed from time to time in the light of changing circumstances. As a result of policy decisions taken during 1982 the Office is assisting BAS in re-equipping the upper-air station at Halley Bay (badly damaged by fire during 1981) and will concentrate its efforts on providing support for that station in the future. Because of the nature of the Antarctic Treaty which governs activities in Antarctica, Antarctica does not constitute a WMO Region. However, essential co-ordination of arrangements for meteorological observations and communications is accomplished by a WMO EC Panel on Antarctic Meteorology of which the Assistant Director (International and Planning) is Chairman. The Panel arranged an expert meeting on Antarctic Telecommunications in Geneva in June. The meeting produced a very useful set of proposals which were examined by the Consultative Committee of Signatories to the Antarctic Treaty which met in Canberra (Australia) in September.

The United Kingdom also participates in two programs of the European Co-operation on Science and Technology (COST). COST Project 43 is concerned with the implementation, by concerted action, of a network of fixed data gathering buoys in European waters and COST Project 72 is currently concerned with the development of international procedures, codes and communications protocols by which the data from radars measuring precipitation can be communicated across national boundaries and assembled nationally into useful composite displays. The Assistant Director (Operational Instrumentation) is the Chairman of the Management Committee for COST 43 and Mr C. G. Collier of the Meteorological Office Radar Research Laboratory is active in COST 72 and a related activity sponsored by the WMO Regional Association VI.

A new meteorological initiative took place in the Consortium of Meteorolo-ical Services which had been set up to develop for production an Aircraft to Satellite Data Relay System (ASDAR). ASDAR is a means to extract, from the flight data systems of wide-bodied civil aircraft, information on wind speed and direction, air temperature, position and height which can then be relayed via geostationary meteorological satellites to collecting stations within the WWW. A prototype system, developed in the USA, was used in the Global Weather Experiment and found to have considerable potential as a component of the WWW. However, a commercial unit was not available and a Consortium was formed by the Meteorological Services of Australia, Canada, the Federal Republic of Germany, the Netherlands, New Zealand, Saudia Arabia, the UK and the USA to arrange for the development of a unit suitable for production. The Assistant Director (International and Planning) is the Chairman of the Programme Board of the Consortium. After a great deal of detailed negotiation a contract was signed on 13 September by the Secretary-General of WMO on behalf of the Consortium, with GEC McMichael Ltd of Slough. The contract calls for the development of a unit, suitable for production, and for its certification with the UK Civil Aviation Authority and the USA Federal Aviation Authority and with satellite operators. The contract will run for 24 months and 6 units will be produced of which 3 will be deployed for evaluation on UK based aircraft and 3 on aircraft based in the USA. Planning for the operational exploitation of the device will proceed in the interim in WMO and operational use is expected to begin early in 1986. As part of a program to interest aircraft operators in the use of the device the Assistant Director (International and Planning) addressed a meeting of the Airlines Electronic Engineering Committee (AEEC) in Washington between 11 and 13 October.

It is customary for the UK to host a meeting of Directors of Commonwealth Meteorological Services during the period immediately following WMO Congresses. The first such meeting, then of Empire Meteorologists, took place in 1929. The 1983 Conference took place at the Meteorological Office College from 6 to 9 June and was attended by 19 delegates. Attention is concentrated on scientific and technical matters of mutual concern and is less concerned with institutional matters than many WMO meetings. On this occasion the Conference decided that increased co-operation between Commonwealth Meteorological Services would be beneficial and further decided that sessions half-way between Congresses would be more useful than in the year of Congress. Accordingly the next Conference will be in 1985.

The Meteorological Office Programme Board, formerly the Programme Review Committee, which comprises the Senior Directorate of the Office, keeps under review the progress of the Meteorological Office Programmes and the direction and distribution of effort. The International and Planning Branch provides the Secretariat for the Programme Board which met in April and November. During the year, the manual assembly of management information on a wide range of projects and activities, which had been conducted during several previous years, to assist the Progamme Board in making its decisions, ceased and the Branch co-operated actively in the development of the computer based Management Information and Accounting System (MAIS) which is to provide a wide range of timely information, tailored both to the needs of the Board and of managers at a variety of levels.

Appendix III (page 174) lists the meetings of WMO and other meteorological bodies in which Meteorological Office staff participated, together with other visits abroad.

F. H. Bushby
*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—NUMBER OF OFFICES OF VARIOUS TYPES STAFFED BY THE METEOROLOGICAL OFFICE AND OPERATING ON 31 DECEMBER 1983

| | Within UK | Overseas |
|---|---|---|
| Principal Forecasting Offices associated with the RAF | 1 | — |
| Main Meteorological Offices associated with the RAF | 4 | 2 |
| Subsidiary offices associated with the RAF | 31 | 4 |
| Subsidiary offices associated with the Army | 3 | 1 |
| Subsidiary offices associated with MOD(PE) | 3 | — |
| Observing offices associated with the RAF | 4 | 1 |
| Observing offices associated with MOD(PE) | 1 | — |
| Principal Forecasting Offices associated with civil aviation | 1 | — |
| Main Meteorological Offices associated with civil aviation | 3 | — |
| Subsidiary offices associated with civil aviation | 5 | — |
| Observing offices associated with civil aviaton | 11 | — |
| Upper-air observing offices | 8 | 1 |
| Main Meteorological Offices associated with public services* | 3 | — |
| Subsidiary offices associated with public services* | 6 | — |
| CRDF offices | 4 | 1 |
| Port Meteorological Offices | 7 | — |
| Offices associated with the Agricultural Development and Advisory Service (MAFF) | 6 | — |
| Other offices | 16 | — |

*Also known as Weather Centres (see page 18)

*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 public services and normally supervises the work of subsidiary offices.

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

Many civil aviation offices perform public service tasks and vice versa.

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 the United Kingdom obligations under the WMO Agreement for the Joint Financing of the North Atlantic Ocean Stations (NAOS), the Office operated one ocean weather ship. This was employed to man Ocean Station 'L' (57°00'N, 20°00'W), one of the four stations of the network, together with the Netherlandish ocean weather ship, each ship spending an average 30 and 26 days respectively on station each voyage. The station was manned for a total of 203.7 days by the UK ocean weather ship in 1983 and on passage for 35.7 days. Two ships from France, one from Norway and five ships from the USSR served at the other three stations.

## TABLE III—MERCHANT SHIPS AND SEA STATIONS

A total of about 7517 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, 'auxiliary ships', platforms rigs and buoys also make and transmit meteorological observations.

On 31 December 1983 the numbers of British ships reporting were:

| | |
|---|---|
| Selected ships | 416 |
| Supplementary ships (including 2 trawlers) | 10 |
| Coasting vessels | 58 |
| Lightships (including 1 light-tower) | 13 |
| Auxiliary ships | 6 |
| Total | 87 |

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

| | |
|---|---|
| UK to Australasia | 14 |
| UK to Far East | 29 |
| UK to Persian Gulf | 11 |
| UK to South Africa | 17 |
| UK to West Indies | 10 |
| UK to Atlantic coast of North America | 40 |
| UK to Pacific coast of North America | 4 |
| UK to South America | 4 |
| UK to European ports | 99 |
| UK to Falkland Islands and Antarctica | 5 |
| UK to distant-water fishing grounds | 3 |
| World-wide trading | 190 |

During a typical five-day period in June, the average daily numbers of reports from ships and sea stations received at Bracknell were as follows:

| | Reports | |
|---|---|---|
| | 1982 | 1983 |
| Direct reception from: | | |
| British ships | 179 | 169 |
| Foreign ships | 74 | 133 |
| Rigs, Platforms, Buoys | 86 | 87 |
| Total | 339 | 389 |
| | | |
| Total number of reports received by geographical location: | | |
| Eastern North Atlantic | 756 | 893 |
| Western North Atlantic | 580 | 541 |
| Mediterranean | 98 | 118 |
| North Sea | 279 | 312 |
| Arctic Ocean | 69 | 98 |
| North Pacific | 776 | 919 |
| All other waters | 532 | 512 |
| Total | 3090 | 3393 |

## TABLE IV—CLASSIFICATION OF STATIONS SUPPLYING CLIMATOLOGICAL INFORMATION

For climatological purposes, data are obtained not only from official sources but also from very many stations which are not part of the Meteorological Office. This table shows the distribution on 31 December 1983 of stations which supply climatological information, classified under the following headings:

Met O Synoptic — stations manned by professional meteorologists.
Auxiliary Synoptic — stations manned by non-Meteorological Office staff whose observations are used primarily in weather forecasting.
Climatological — stations run by individuals or organizations co-operating voluntarily with the Meteorological Office and fulfilling the minimum requirements of reporting extreme temperatures and rainfall.
Agrometeorological — climatological stations at establishments primarily concerned with agriculture.
Holiday Resorts — stations participating in a scheme whereby information is sent daily to the Meteorological Office for communication to the Press.

The areas and titles of the districts are those used in the *Monthly Weather Report*.

| | STATIONS SUPPLYING RETURNS | | | | | | STATIONS SUPPLYING AUTOGRAPHIC RECORDS OR MAGNETIC TAPE OUTPUT | | |
|---|---|---|---|---|---|---|---|---|---|
| | *Met O Synoptic* | *Auxiliary Synoptic* | *Climatological* | *Agrometeorological* | *Holiday Resorts* | *Rainfall** | *Sunshine* | *Rainfall* | *Wind* |
| Scotland, north .. .. .. .. .. | 8 | 9 | 34 | 0 | 0 | 332 | 23 | 15 | 16 |
| Scotland, east .. .. .. .. .. | 6 | 6 | 42 | 10 | 2 | 450 | 33 | 22 | 14 |
| Scotland, west .. .. .. .. .. | 6 | 6 | 49 | 2 | 0 | 484 | 24 | 24 | 17 |
| England, east and north-east .. .. | 7 | 4 | 17 | 7 | 4 | 515 | 26 | 16 | 15 |
| East Anglia .. .. .. .. .. .. | 9 | 0 | 17 | 14 | 3 | 445 | 29 | 24 | 11 |
| Midland Counties .. .. .. .. | 6 | 6 | 31 | 17 | 0 | 939 | 39 | 25 | 18 |
| England, south-east and central southern .. .. .. .. .. .. | 10 | 6 | 23 | 19 | 13 | 739 | 56 | 28 | 27 |
| England, south-west .. .. .. .. | 8 | 9 | 24 | 6 | 11 | 570 | 37 | 19 | 13 |
| England, north-west .. .. .. .. | 6 | 4 | 13 | 1 | 2 | 417 | 17 | 23 | 13 |
| Isle of Man .. .. .. .. .. .. | 1 | 1 | 0 | 0 | 1 | 18 | 3 | 1 | 3 |
| Wales, North .. .. .. .. .. | 1 | 4 | 14 | 2 | 2 | 248 | 11 | 5 | 4 |
| Wales, South .. .. .. .. .. | 2 | 5 | 10 | 5 | 1 | 285 | 13 | 15 | 5 |
| Channel Islands .. .. .. .. .. | 2 | 0 | 1 | 0 | 2 | 17 | 15 | 2 | 2 |
| Northern Ireland .. .. .. .. .. | 2 | 6 | 45 | 9 | 0 | 273 | 26 | 50 | 10 |
| Total .. .. .. .. .. .. | 74 | 66 | 320 | 92 | 41 | 5732 | 352 | 269 | 168 |

*Includes stations in earlier columns.

## TABLE V—HEIGHTS REACHED IN UPPER-AIR ASCENTS

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

| | Number of Observations | Percentage of all balloons reaching | | | | Percentage of largest balloons reaching |
|---|---|---|---|---|---|---|
| | | 100 mb (≈16 km) | 50 mb (≈20 km) | 30 mb (≈24 km) | 10 mb (≈30 km) | 10 mb (≈30 km) |
| (a) *Temperature, pressure and humidity:* | | | | | | |
| Eight stations in the UK | 5788 | 93.3 | 85.3 | 68.4 | 21.2 | 45.8 |
| One station overseas .. .. | 728 | 97.8 | 87.2 | 72.7 | 22.4 | 27.0 |
| One Ocean Weather Ship | 844 | 86.6 | 72.6 | 58.4 | 19.3 | — |
| (b) *Wind:* | | | | | | |
| Eight stations in the UK | 11 557 | 91.5 | 73.5 | 42.8 | 10.3 | 44.3 |
| One station overseas .. .. | 1459 | 92.8 | 72.0 | 45.5 | 9.9 | 24.9 |
| One Ocean Weather Ship | 837 | 83.5 | 70.0 | 55.7 | 17.8 | — |

## TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network in 1983 .. .. .. 22 780

## TABLE VII—METEOROLOGICAL COMMUNICATION TRAFFIC

National and international exchanges of meteorological information are effected over land-line, satellite and radio links. Observational and processed data provided by major analysis and forecast centres and carried in coded messages constitute the greater part of the traffic. Although there are wide variations in message length there are on average about 620 characters per message. Exchanges of pictorial information, principally analyses and forecast charts, are made by facsimile. Analogue transmission methods are still used for radio facsimile and the majority of land-line facsimile broadcasts but digital transmission over multiplexed links has been introduced on some of the main international connections of the Global Telecommunication System.

The following figures are taken from an analysis of the traffic handled by the Meteorological Telecommunication Centre, Bracknell, on a typical day (24 hours) in November 1983. Corresponding totals for 1982 are also shown.

| | *Number of messages/products in one day* | | | |
|---|---|---|---|---|
| | In | Out | Total | Total in 1982 |
| Coded messages: | | | | |
| Land-line teleprinter and data transmission | 20 495 | 134 745 | 155 240 | 140 200 |
| Radio transmission .. .. .. .. .. .. | 196 | 3432 | 3628 | 3319 |
| Facsimile products (pictorial format): | | | | |
| Land-line transmission .. .. .. .. .. .. | 265 | 1150 | 1415 | 1338 |
| Radio transmission .. .. .. .. .. .. | 31 | 141 | 172 | 163 |

*Notes*

The increase in the total for land-line teleprinter and data transmission messages is mainly due to the introduction of the OASYS minicomputer system at London Weather Centre together with an increase of traffic for the OASYS minicomputers at RAF HQ Strike Command and London (Heathrow) Airport.

## TABLE VIII—SPECIAL SEASONAL FORECASTS

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

| | Year | Number of customers | Year | Number of customers |
|---|---|---|---|---|
| Consultancy services to farmers and growers .. .. .. .. .. .. | 1982 | 212 | 1983 | 233 |
| Week-end temperature forecasts (a winter service primarily for industrialists) .. .. .. .. .. | 1982/83 | 86 | 1983/84 | 77 |
| Winter road danger warnings (primarily for local authorities) .. .. .. .. | 1982/83 | 300 | 1983/84 | 319 |
| Consultancy or forecast services (concerning road conditions) .. .. | 1982/83 | 129 | 1983/84 | 130 |

## TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office, acting as a Regional Meteorological Centre of the World Weather Watch, is mainly concerned with the analysis of the weather situation and with the issue of forecast charts for the guidance of other offices including the two Principal Forecasting Offices which serve civil aviation from London/Heathrow Airport and military aviation from the Headquarters of RAF Strike Command. The Central Forecasting Office also has a commitment to civil aviation in the provision of wind and temperature charts for use with the significant weather charts produced by the Principal Forecasting Office at Heathrow and for the transmission of grid-point data direct to outside civil aviation organizations including British Airways, Scandinavian Airline System, SITA, the CAA APOLLO computer unit and Eurocontrol Maastricht.

The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings that took place during 1982 and 1983. These do not include warnings and routine general forecasts.

| | 1982 | 1983 |
|---|---|---|
| Number of meteorological briefings for | | |
| aviation in the UK .. .. .. .. .. .. .. .. | 363 354 | 328 733 |
| aviation at overseas stations .. .. .. .. .. .. .. | 35 358 | 45 312 |
| Number of aviation forecasts issued for | | |
| aviation in the UK .. .. .. .. .. .. .. .. | 1 790 458 | 1 836 274 |
| aviation at overseas stations .. .. .. .. .. .. .. | 155 337 | 237 625 |

## TABLE X—NON-AVIATION ENQUIRIES

Non-aviation enquiries are handled by eight Weather Centres, in London, Manchester, Glasgow, Southampton, Newcastle, Nottingham, Bristol and Cardiff and the forecast unit at Lerwick Observatory. The function of these offices 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 questions for forecasts and other weather information from the general public, Press, public corporations, commercial firms, etc. These enquiries, most of which refer to current or future weather, are listed below according to the purpose of the enquiry.

| | 1982 | 1983 |
|---|---|---|
| Total number of non-aviation enquiries | 1 838 079 | 1 655 146 |
| Percentage relating to: | | |
| agriculture | 14.3 | 13.1 |
| building | 4.3 | 3.9 |
| commerce, industry | 5.6 | 7.3 |
| holidays | 15.5 | 14.9 |
| marine matters | 10.8 | 12.0 |
| Press | 13.9 | 16.4 |
| public utilities | 10.7 | 10.7 |
| road transport | 5.2 | 4.1 |
| other known purposes | 8.4 | 8.0 |
| unknown purposes | 11.3 | 9.7 |

## 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 for which FLASH messages are broadcast and the number issued in 1983.

| | Dense fog | Moderate or heavy snow | Heavy rain | Glazed frost and icy roads | Severe inland gales | Blizzard |
|---|---|---|---|---|---|---|
| Edinburgh and south-east Scotland | — | — | — | — | 1 | — |
| Glasgow and south-west Scotland | — | — | — | — | — | — |
| Belfast and Northern Ireland | — | — | — | 1 | 3 | — |
| Industrial north-east England | — | — | — | — | 5 | — |
| Industrial Lancashire and Merseyside | — | — | 1 | — | 3 | — |
| Industrial Midlands | — | — | — | — | — | — |
| Bristol and Bath | — | — | 1 | — | — | — |
| South Wales | — | — | — | — | — | — |
| London and south-east England | — | — | 1 | — | 3 | — |
| Plymouth and south-west England | — | — | 1 | — | 3 | — |
| Yorkshire | — | — | — | — | 1 | — |
| Southampton and Portsmouth | — | — | — | — | — | — |
| Warnings covering more than one area or blizzards outside industrial areas | — | 8 | 2 | 1 | 16 | — |
| Totals | 0 | 8 | 6 | 2 | 35 | 0 |

TABLE XII—'WEATHERLINE' FORECASTS

| Information Service Centre | Forecast area | Number of calls 1982 | 1983 |
|---|---|---|---|
| Aberdeen | Aberdeen and Grampian | 57 200 | 91 987 |
| Bangor, N.I. | Northern Ireland | 17 366 | 21 449 |
| Bedford | Herts, Beds and inland Essex | 294 295 | 284 058 |
| Belfast | Northern Ireland | 380 546 | 480 380 |
| Birmingham | Birmingham and Warwickshire | 1 172 966 | 1 020 425 |
| Bishops Stortford | Herts, Beds and inland Essex | 123 252 | 140 334 |
| Blackburn | North-west England | 348 984 | 330 902 |
| Blackpool | North-west England | 211 762 | 190 068 |
| Bournemouth | Dorset and Hampshire coast and Isle of Wight | 496 308 | 585 592 |
| Bradford | West Yorkshire | 190 093 | 184 146 |
| Brighton | Sussex and South Kent coast | 763 417 | 773 986 |
| Bristol | Somerset and Avon | 776 799 | 759 813 |
| Cambridge | Herts, Beds and inland Essex | 220 855 | 204 752* |
| Cardiff | Glamorgan and Gwent | 760 848 | 649 719 |
| Canterbury | North Kent and Essex coasts | 397 663 | 377 696† |
| Chelmsford | North Kent and Essex coasts | 169 177 | 172 812 |
| Cheltenham | South-west Midlands | 174 814 | 152 544 |
| Chester | Anglesey and North Wales coast | 161 314 | 148 965 |
| Colchester | North Kent and Essex coasts | 333 366 | 265 293 |
| Colwyn Bay | Anglesey and North Wales coast | 130 572 | 129 093 |
| Coventry | Birmingham and Warwickshire | 272 064 | 190 061 |
| Derby | East Midlands | 203 775 | 189 535 |
| Doncaster | South Yorkshire and Peak District | 78 560 | 75 277 |
| Dundee | Dundee, Fife and Tayside | 63 472 | 142 802 |
| Edinburgh | Edinburgh and Lothian | 371 015 | 335 122 |
| Exeter | Devon and Cornwall | 480 853 | 446 572 |
| Glasgow | Glasgow and district | 811 071 | 748 384 |
| Gloucester | South-west Midlands | 259 230 | 238 938 |
| Grimsby | Lincolnshire and Humberside | 94 561 | 93 449 |
| Guildford | London | 214 751 | 188 079 |
| Hastings | Sussex and South Kent coast | 162 926 | 190 315 |
| Hereford | South-west Midlands | 136 239 | 114 124 |
| High Wycombe | Oxfordshire, Buckinghamshire and Berkshire | 240 307 | 234 141 |
| Huddersfield | West Yorkshire | 112 268 | 119 858 |
| Ipswich | East Anglia | 300 718 | 293 893 |
| Leeds | West Yorkshire | 452 643 | 500 596 |
| Leicester | East Midlands | 349 073 | 349 524 |
| Lincoln | Lincolnshire and Humberside | 231 801 | 249 316 |
| Liverpool | North-west England | 355 064 | 323 081 |
| Liverpool | Anglesey and North Wales coast | 48 433 | 48 378 |
| London | London | 3 915 905 | 3 440 119 |
| London | North Kent and Essex coast | 252 411 | 241 962 |
| London | Sussex and South Kent coast | 311 000 | 344 189 |
| London | Oxfordshire, Buckinghamshire and Berkshire | 272 171 | 197 269 |
| London | Herts, Beds and inland Essex | 140 660 | 190 612 |
| London | North Downs and Weald | 5 202 | 15 111 |
| Lowestoft | East Anglia | 52 499 | 58 735 |
| Luton | Herts, Beds and inland Essex | 328 927 | 301 217 |
| Manchester | North-west England | 789 745 | 808 195 |
| Manchester | Anglesey and North Wales coast | 72 415 | 71 667 |
| Mansfield | East Midlands | 0 | 2 197 |
| Medway | North Kent and Essex coast | 293 480 | 238 555 |
| Middlesbrough | North-east England | 260 586 | 260 436 |
| Milton Keynes | Herts, Beds and inland Essex | 73 836 | 66 136 |
| Newcastle | North-east England | 559 178 | 583 454 |
| Newport, Gwent | Glamorgan and Gwent | 156 175 | 134 170 |

| Information Service Centre | Forecast Area | Number of calls 1982 | 1983 |
|---|---|---|---|
| Northampton | East Midlands | 138 386 | 117 890 |
| Norwich | East Anglia | 424 137 | 440 742 |
| Nottingham | East Midlands | 543 099 | 585 457 |
| Oxford | Oxfordshire, Buckinghamshire and Berkshire | 404 446 | 453 685 |
| Peterborough | East Anglia | 128 769 | 121 962 |
| Plymouth | Devon and Cornwall | 722 466 | 714 364 |
| Portsmouth | Dorset and Hampshire coast and Isle of Wight | 555 666 | 500 473 |
| Reading | Oxfordshire, Buckinghamshire and Berkshire | 706 364 | 500 716 |
| Sheffield | South Yorkshire and Peak District | 508 303 | 556 990 |
| Southampton | Dorset and Hampshire coast and Isle of Wight | 782 434 | 757 320 |
| Southend | North Kent and Essex coasts | 289 287 | 275 256 |
| Southport | North-west England | 61 972 | 60 321 |
| Swansea | Glamorgan and Gwent | 0 | 3 522 |
| Swindon | Avon and Somerset | 69 308 | 59 217 |
| Torquay | Devon and Cornwall | 139 680 | 166 210 |
| Tunbridge Wells | London | 132 060 | 130 480 |
| Total | | 25 510 988 | 24 434 088 |

*Also includes forecasts for East Anglia
†Also includes forecasts for Sussex and South Kent coast

## TABLE XIII—CLIMATOLOGICAL ENQUIRIES

Met O 3, Met O 8, Edinburgh and Belfast receive a number of enquiries relating to past weather, to climatology and to the application of meteorological data to agriculture. The following figures give the total number of enquiries and the percentages of this number in various categories.

| | 1982 | 1983 |
|---|---|---|
| Total number of climatological enquiries | 44 540 | 43 714 |
| Percentages relating to: | | |
| agriculture (farming, forestry and market gardening) | | 16.5 |
| building and design (including siting) | | 12.9 |
| commerce (sales, marketing, advertising) | | 10.0 |
| drainage | | 1.8 |
| education and literature | | 6.2 |
| flooding | | 0.1 |
| heating and ventilation | | 3.7 |
| industrial and manufacturing activities | | 1.3 |
| law (damage, accident, insurance) | | 12.5 |
| medical and health | | 0.5 |
| Press and information centres | | 2.9 |
| research | | 3.8 |
| sports, hobbies, holidays | | 0.9 |
| transport and communications | | 0.7 |
| water supplies | | 5.8 |
| miscellaneous (purpose known) | | 12.1 |
| miscellaneous (purpose unknown) | | 8.2 |

TABLE XIV—DATA PROCESSING

| | 1982 | 1983 |
|---|---|---|
| Computer installations: | | |
| Number of tasks run on the 360/195 computer | 240 000 | — |
| Number of tasks run on the 3081 computer | 52 000 | 455 000 |
| Number of tasks run on the 370/158 computer | 199 000 | 145 000 |
| Number of tasks run on the Cyber 205 computer | 92 000 | 101 000 |
| Number of tasks run on the terminal system | 59 000 | 147 000 |
| Processor-controlled keying systems: | | |
| Number of characters keyed at Bracknell | 60 300 000 | 46 000 000 |
| Number of characters keyed at Devizes | 8 500 000 | — |
| Punched-card installation: | | |
| Number of computer cards punched | 204 000 | 155 000 |

TABLE XV—INSTRUMENT TESTING, CALIBRATION AND ACCEPTANCE

| | Tests | Calibrations |
|---|---|---|
| General meteorological instruments: | | |
| Wind measuring | 390 | 782 |
| Pressure measuring | 501 | 934 |
| Humidity measuring | 58 | 7 |
| Precipitation measuring | 449 | 76 |
| Radiation measuring | 0 | 260 |
| Sunshine recording | 55 | — |
| Temperature measuring | 33 | 3822 |
| Pilot/cloud-base balloons | 6400 | — |
| Miscellaneous | 7689 | — |
| Electrical/electronic instruments: | | |
| Instruments and systems | 946 | — |
| Instrument calibrations | — | 353 |
| Components | 4942 | — |
| Radiosonde instruments: | | |
| Components accepted | 116 943 | — |
| Humidity elements skinned and seasoned | 1000 | — |
| Pressure elements | — | 7200 |
| Reference elements | — | 6900 |
| Temperature elements | — | 19 500 |
| Balloons | 29 966 | — |
| Radar reflectors | 15 800 | — |
| Parachutes | 7890 | — |
| String unwinders | 2855 | — |
| Recovered radiosonde transmitters | 1973 | — |

# DIRECTORATE OF RESEARCH

## SPECIAL TOPIC—METEOROLOGICAL ASPECTS OF ACID RAIN

*Introduction*

Photochemically-derived oxidants associated with the products of combustion are sometimes believed to damage the environment. Ozone, for example, is suspected to be a major cause of tree damage in parts of central Europe. Acid precipitation, resulting from $SO_2$, $NO_x$ and their derivatives, is potentially harmful to some soils and freshwater ecosystems.

The link between acid rain and fish kill was first postulated by Odén (1968) from his observations in Scandinavia. This initiated collaborative programs of research, and intergovernmental discussions and agreements, in order to understand and control the damage. As Table 1 shows, the UK has been in a somewhat vulnerable position having, in 1978 (the last year for which national emissions are available), the highest sulphur dioxide emissions in western Europe. The UK also lies upwind of much of the rest of Europe. Note, however, that the emissions per head of population in the UK are well down on those of many east European countries, our $NO_x$ emissions are only half those of West Germany, and that for several reasons our $SO_2$ emissions have dropped substantially from 5.83 million tonnes in 1971 to an estimated 4.00 Mt in 1982 (see Table 2). Also during this decade emissions of carbon monoxide and hydrocarbons have increased whilst those of $NO_x$ have remained rather steady.

TABLE 1—EMISSION FIGURES FOR EUROPE IN 1978

| | Sulphur dioxide $SO_2$ | | Nitrogen oxides $NO_x$ as $NO_2$ | | Non-methane hydrocarbons NMHC | |
|---|---|---|---|---|---|---|
| | Total Emissions Mt/year | Emissions per head t/year | Total Emissions Mt/year | Emissions per head t/year | Total Emissions Mt/year | Emissions per head t/year |
| D.D.R. | 4.0 | 0.24 | 0.68 | 0.04 | 0.68 | 0.04 |
| Czech. | 3.0 | 0.20 | 0.60 | 0.04 | 0.60 | 0.04 |
| F.R.G. | 3.6 | 0.06 | 3.35 | 0.055 | 2.45 | 0.04 |
| U.K. | 5.0 | 0.09 | 1.73 | 0.03 | 1.16 | 0.02 |
| France | 3.6 | 0.07 | 1.65 | 0.03 | 2.00 | 0.04 |
| Norway | 0.15 | 0.04 | 0.11 | 0.03 | 0.17 | 0.04 |
| Europe | 58.4 | — | 21.3 | — | 20.6 | — |

TABLE 2—EMISSION FIGURES FOR THE UNITED KINGDOM 1971–82 (Mt/year)
(WARREN SPRING LABORATORY DATA)

| | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | 1981 | 1982 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SO_2$ | 5.83 | 5.64 | 5.80 | 5.35 | 5.13 | 4.98 | 4.98 | 5.02 | 5.34 | 4.67 | 4.23 | 4.00 |
| $NO_x$ [$NO_2$] | — | 1.73 | 1.85 | 1.72 | 1.70 | 1.74 | 1.77 | 1.80 | 1.89 | 1.79 | 1.71 | 1.67 |
| CO | — | 7.86 | 8.30 | 8.07 | 7.80 | 8.06 | 8.27 | 8.62 | 8.79 | 8.86 | 8.62 | 8.84 |
| HC [methane] | — | 2.40 | 2.60 | 2.73 | 2.77 | 2.93 | 3.04 | 3.16 | 3.36 | 3.37 | 3.36 | 3.29 |
| HCl | — | — | — | — | — | — | — | — | — | — | — | 0.23–0.68 |
| $NH_3$ | — | — | — | — | — | — | — | — | — | — | — | ~0.3 |

Nevertheless there is considerable pressure to reduce emissions of $SO_2$ and $NO_x$ which in the former case would probably entail the introduction of flue gas desulphurization to existing and future fossil-fuel power stations (which now emit about two-thirds of all the $SO_2$). This would be a disruptive, expensive procedure adding something like 15 per cent to our electricity bills. The waste slurry would also have to be disposed of, and this could itself create significant environmental problems.

A very important question that is being currently debated is whether if emissions were reduced by $X$ per cent, say, would the depositions in the sensitive areas be reduced by $X$ per cent or is there an inherent non-proportionality in the whole process? If the answer were that the depositions would be reduced by only some small fraction of $X$ per cent on the sensitive areas of Europe, then costly desulphurization could hardly be justified. We cannot go into details in this review; suffice it to say the evidence is confusing. Long-term model deposition fields applied to Europe and the USA when compared with 'observed' fields support proportionality. Considerations of air chemistry on the other hand suggest short-term depositions may on occasions be strongly non-proportional.

The Meteorological Office has played an active role in the study of this problem of acid rain, performing theoretical research and carrying out fundamental experimental work since 1971. Its voice has been heard in the various collaborative programs and in numerous scientific conferences, most recently for example at a Discussion Meeting on Acid Rain at the Royal Society, 5–7 September 1983, at which a review paper was presented (Goldsmith *et al.*, 1984).

Finally in this Introduction, two points should be made. Firstly it seems that the tree damage in Germany and elsewhere in central Europe, probably involving ozone, may be largely a regional problem, even though $NO_x$, the precursor of ozone, is a rather long-lived species. Ozone is generated within polluted atmospheres in the presence of sunlight, conditions which are typical of large stagnant summer anticyclones with very low advecting windspeeds. The problem is complex, intriguing, but as yet inadequately understood.

Secondly it is desirable to attempt a definition of 'acid rain', especially since in popular parlance it appears to mean any material due to human activities that falls out of the atmosphere! Marsh (1984) has defined it simply as precipitation with a pH less than 5.0. More complex, but perhaps less practical, definitions could be given; for example, relating it to the inherent pH of the soil on which the precipitation is falling.

*Ecological concerns*

Although outside the area of the Office's expertise, some discussion of ecological effects is appropriate since we are dealing with a highly complex interrelated set of problems. Some brief discussion of the effects is also desirable to complete the picture for the reader. The details, still subject to continuing research, are drawn from many sources; for example *Acid rain, a review of the phenomenon in the EEC and Europe* by Environmental Resources Ltd (1983).

Soil is usually layered into horizons each havings its own pH, soil type, humus content and ionic character. These horizons are modified in time by water pathways, the rate of weathering of rock and ionic exchange, the uptake of minerals by plants and by the action of micro-organisms and burrowing creatures. Acid rain plays an important role in this modification, but it is almost certainly a role with a very long time-scale. Sulphate ultimately leaches out of the soil on a time-scale which is usually long compared to that of a single episode of rain and enters rivers and lakes. Nitrate and cations on the other hand are largely modified by the soil and its micro-organisms. If the reserve of available calcium in the soil is exhausted by the acid in the rain, which may be the case for some poor soils, cationic exchange may then release toxic aluminium ions, and those of other metals. Consequently the pH and ionic character of water entering streams is virtually uncorrelated with that of the rain, except in the rare situation where there is so little soil that the run-off is almost completely over bare clean rock. Thus although flushes of highly acidic stream water containing toxic aluminium, resulting in substantial fish kills, do occur, especially in spring and in autumn in mountainous areas, these are not directly related to single episodes of acid rain. The spring flush is usually associated with the rapid release of acid species during snow melt whereas the autumn flush is due to the wash-off of dry deposition accumulated during prolonged dry periods in summer. Whereas the low pH may be corrected by systematically adding lime to the waters, the release of aluminium could not. In so far as this may be important it is therefore clear that no simple solution exists for the recipients of acid rain.

Significant reductions in fish populations have now been noted in southern Scandinavia, Scotland, Wales, the Adirondack mountains of north-eastern USA and in parts of Canada, all areas with shallow soils and quartz-bearing bedrocks. Coniferous plantations may accentuate the problem locally but are not the prime cause. Trees not only enhance the local capture of reactive acidifying gases and aerosols from the air, but on harvesting remove essential cations from the environment making it more susceptible to acid rain. They also effectively concentrate the acidic components by removing water through enhanced evaporation.

*Early history*

Systematic measurements of the chemical composition of precipitation began in the middle of the last century, for agricultural purposes (Lawes *et al.* 1861). At about the same time the first Chief Alkali Inspector analysed many samples of air and rain in the UK and Germany; the results were published in his remarkably far-sighted book (Smith 1872). During the next 80 years or so, measurements were made for a variety of purposes, mainly by research groups, but data records and interest were sporadic.

*Collaborative studies*

(a) *European Atmospheric Chemistry Network (EACN)*

This network started from an earlier Swedish network in 1955 by Egnér, Rossby and Eriksson (see Egnér *et al.* 1955) whose interests were respectively agricultural, meteorological and geochemical. This network provided the Meteorological Office's first involvement in the field by administering the UK's 10 air and rain monthly sampling stations as part of its contribution to the International Geophysical Year 1957–58. Interest again declined after the initial data were analysed, until Odén (1968) pointed out that the observations showed precipitation in northern Europe and Scandinavia to be acid, and that the causes and consequences should be investigated. The Office's contribution to EACN was reduced to 3 stations in 1966 which have continued until the present. One of the stations, Eskdalemuir, also reports to the Background Atmospheric Pollution Monitoring Network (BAPMoN) which is a world-wide operation of more recent vintage co-ordinated by WMO.

(b) *The OECD program*

Following proposals submitted by the Scandinavian Council for Applied Research (NORDFORSK) to the OECD (The Organization for Economic Co-operation and Development) in May 1970, ten member countries in western Europe including the UK agreed in April 1972 to participate in a co-operative technical program to measure the long-range transport of air pollutants (LRTAP). The objective was to determine the relative importance of local and distant sources of sulphur to regional air pollution and acid precipitation. A network of 56 stations monitoring pH and concentrations of sulphur dioxide and sulphate in air and precipitation on a daily basis was established, co-ordinated by the Norwegian Institute for Air Research (NILU). Estimates of sulphur emissions were made and models simulating the advection, diffusion, chemical transformation and ultimate deposition were developed and run operationally. The Meteorological Office collaborated fully; for example, it made the first detailed S(sulphur) emission survey for the UK resolved on 20×20 km squares, it mounted the first air-sampling program using an aircraft which helped to establish some of the basic transformation and deposition parameters required by the models, and it was the first in modelling the origins of sulphur deposited on the sensitive areas of southern Norway. Some of these aspects will be referred to in more detail later.

The results of the LRTAP program which finished in 1976 were published in an OECD Report (1979). They confirmed the importance of long-range transport, they established in broad terms the contribution each European country makes through its emissions to the long-term deposition within every other country, and pointed to the importance in certain remote regions of the contribution of so-called 'background' concentrations unidentified by the model, and presumably coming from natural and artificial sources outside Europe.

(c) *The EMEP program*

The second program, starting in 1977, brought in many of the east European countries, including the USSR, recognizing the truly international character of the problem, the need to extend and improve the data input, and the need to involve all the emitters if reductions in emissions were to be achieved. The program was mounted jointly under the auspices of UNECE, UNEP and WMO (Eliassen and Saltbones 1982), and called EMEP (the European Monitoring and Evaluation Programme). It has three centres, the Chemical Co-ordinating Centre at NILU, responsible for the monitoring program, and two Meteorological Synthesizing Centres responsible for modelling work, one in Oslo and the other in Moscow. The Meteorological Office has a commitment to collaborate in basic research matters with the Norwegian

MSC. Model development and further flight programs have been our main contributions and these will be referred to later.
The objectives of EMEP are similar to those of LRTAP but in addition include some of the other major constituents in acid rain. The program is now completing its second phase and details of the third phase will be developed and agreed at meetings in late 1983 and early 1984.

(d) *The American/Canadian programs*
Although the purpose of this review is to highlight the work going on in Europe and the contribution of the Meteorological Office to this work, it would be inappropriate not to refer, however briefly, to the considerable effort going on in the USA and Canada. Similar monitoring and modelling programs have been under way there since about 1977 and are now being co-ordinated following the Memorandum of Intent on Transboundary Air Pollution agreed by the two countries in 1980. Many different models are being developed and tested, some highly complex, and a very ambitious and costly program of monitoring, using ground stations and aircraft, is being established.

(e) *The Meteorological Office/CERL Collaborative Plume Study*
The Meteorological Office and the Central Electricity Research Laboratory have been collaborating for several years on a study of the behaviour of pollutants emitted from Eggborough Power Station in South Yorkshire. The study brings together three important facilities: the highly-instrumented Meteorological Research Flight (MRF) Hercules aircraft, the ability to assess the concentration of inert tracers injected into the plume out to distances of several hundred kilometres, and the facility for forecasting the most probable position of the plume using the output of the Office's numerical weather forecasting program. The objectives of the study are:

(i) to enumerate the vertical and horizontal transfer and dispersion processes,

(ii) to clarify the physical and chemical transformations affecting the pollutants in clear air, cloud and precipitation, and

(iii) to determine atmospheric budgets of these pollutants around the British Isles as derived from both artificial and natural sources.

*Emissions*
Table 2 summarizes the emissions of $SO_2$ between 1971 and 1982 within the UK. During that time there was an overall drop of about 30 per cent but power station emissions have remained fairly static and now constitute roughly two-thirds of the total. Figure 5 shows the spatial distribution of the emissions in 1982.
European emissions of sulphur have shown a monotonic fourfold increase from 1900 to 1980:

| Year | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 | 1980 |
|---|---|---|---|---|---|---|---|---|---|
| $SO_2$ emissions (Mt/year) | 16 | 22 | 22 | 25 | 25 | 25 | 32 | 52 | 61 |

and these figures embody a twofold increase from 1955 to 1975. The spatial

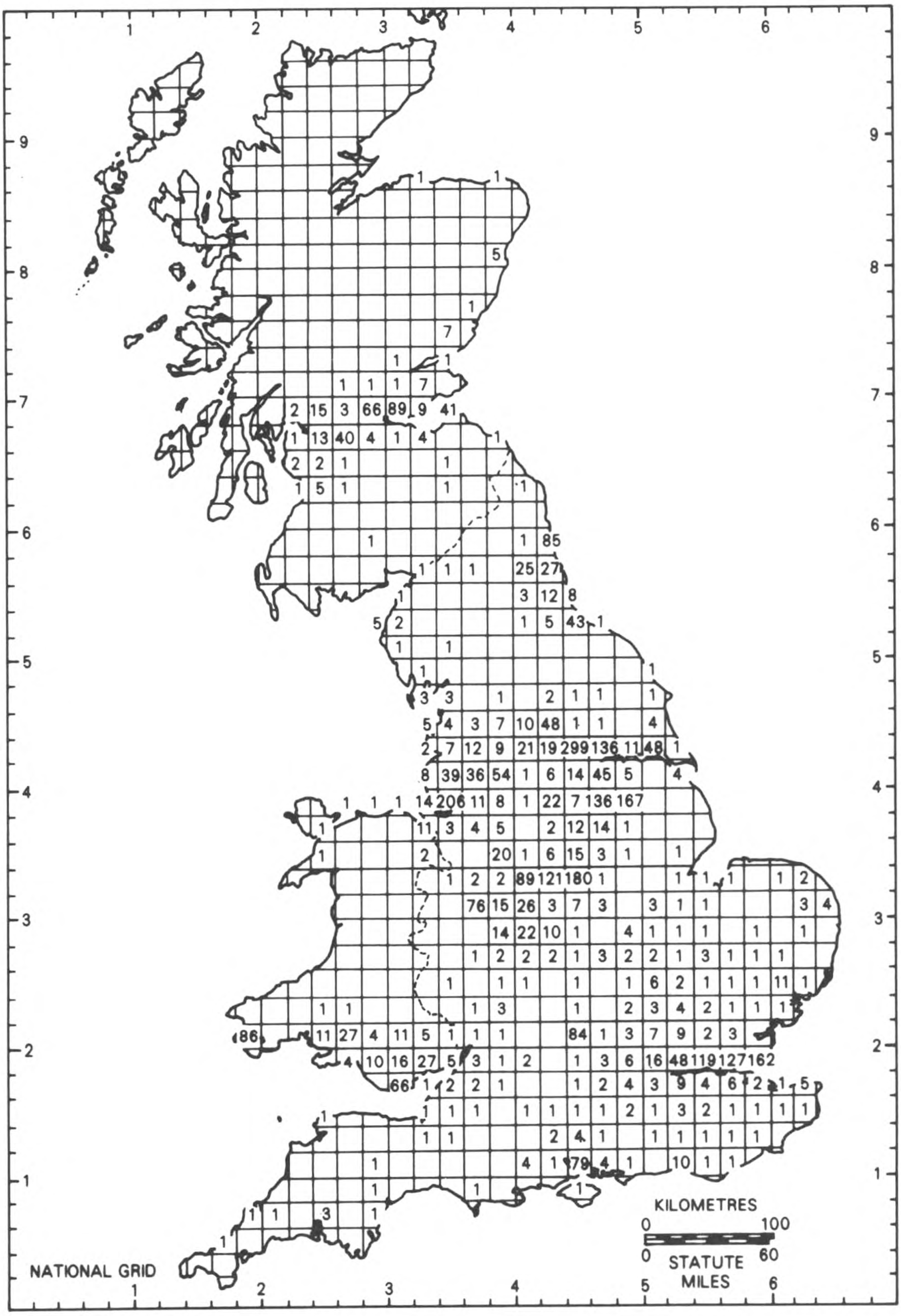



Figure 5—Distribution of emission of $SO_2$ within the United Kingdom in 1982 (Warren Spring Laboratory data)

Units: $10^3$ tonnes. Grid squares: 20 km × 20 km.

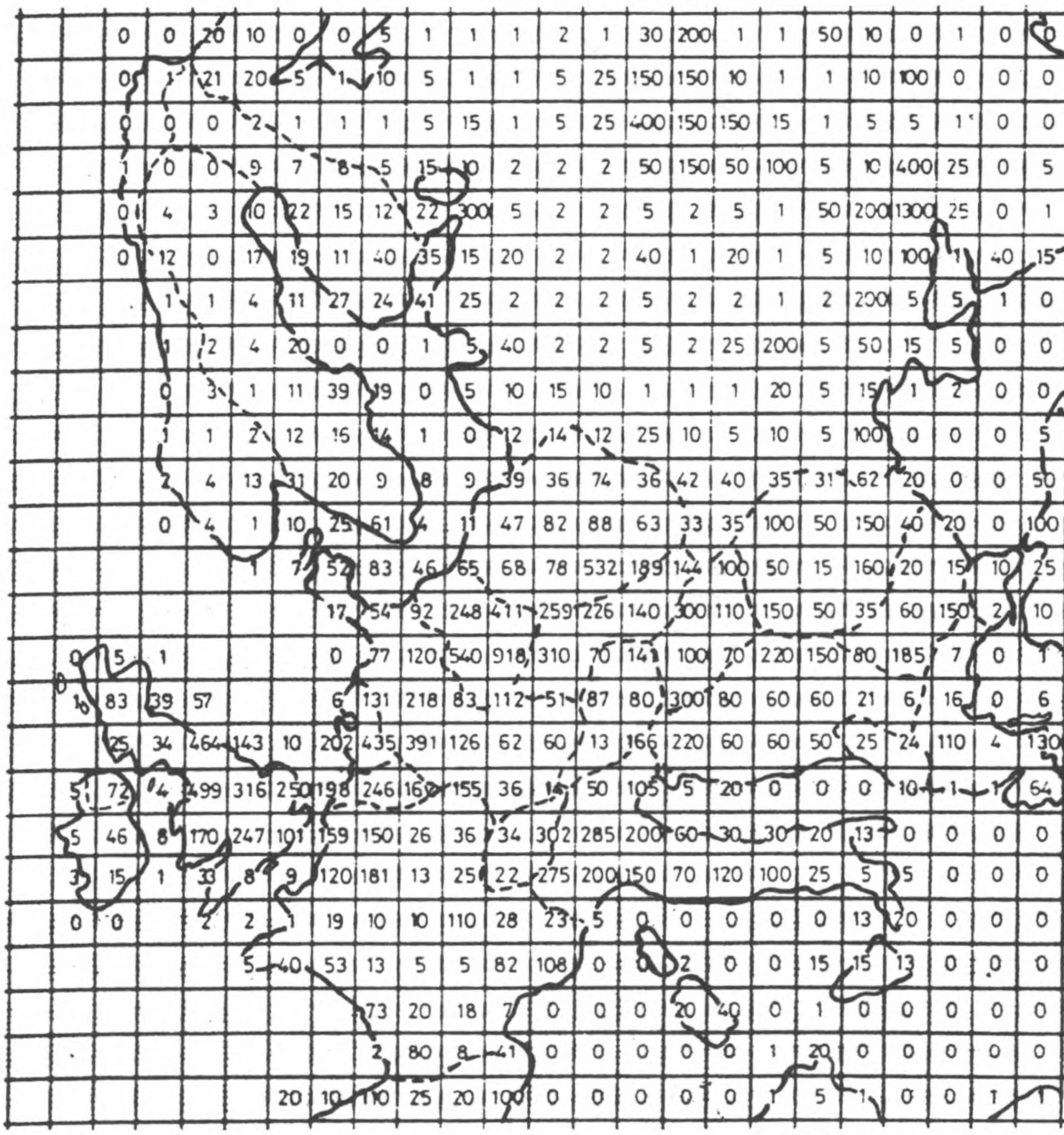


Figure 6—European Monitoring and Evaluation Programme (EMEP) emission data for 1978 in part of the 150 km × 150 km grid network

Unit: $10^3$ tonnes sulphur equivalent per year.

distribution for 1978 has been prepared in connection with EMEP by Dovland and Saltbones (1979), for 150 km grid squares, as shown in Figure 6. National emission figures are uncertain to within 10–15 per cent at best and are much more uncertain in some countries, mainly east European. The general upward trend shown by these figures is not typical of every country, as is shown in Figure 7 which gives the national trends from 1972 to 1982.

Emissions from natural sources are estimated to be some 10 per cent of the total for Europe, i.e. some 3 Mt of sulphur. Background air coming into Europe from the Atlantic carries some further sulphate at a typical sulphur equivalent concentration of 0.2–1 $\mu$g m$^{-3}$. This constitutes only some 5 per cent of the available airborne sulphur for deposition within Europe, although in more remote areas, like northern Scandinavia, this background contribution can be dominant.

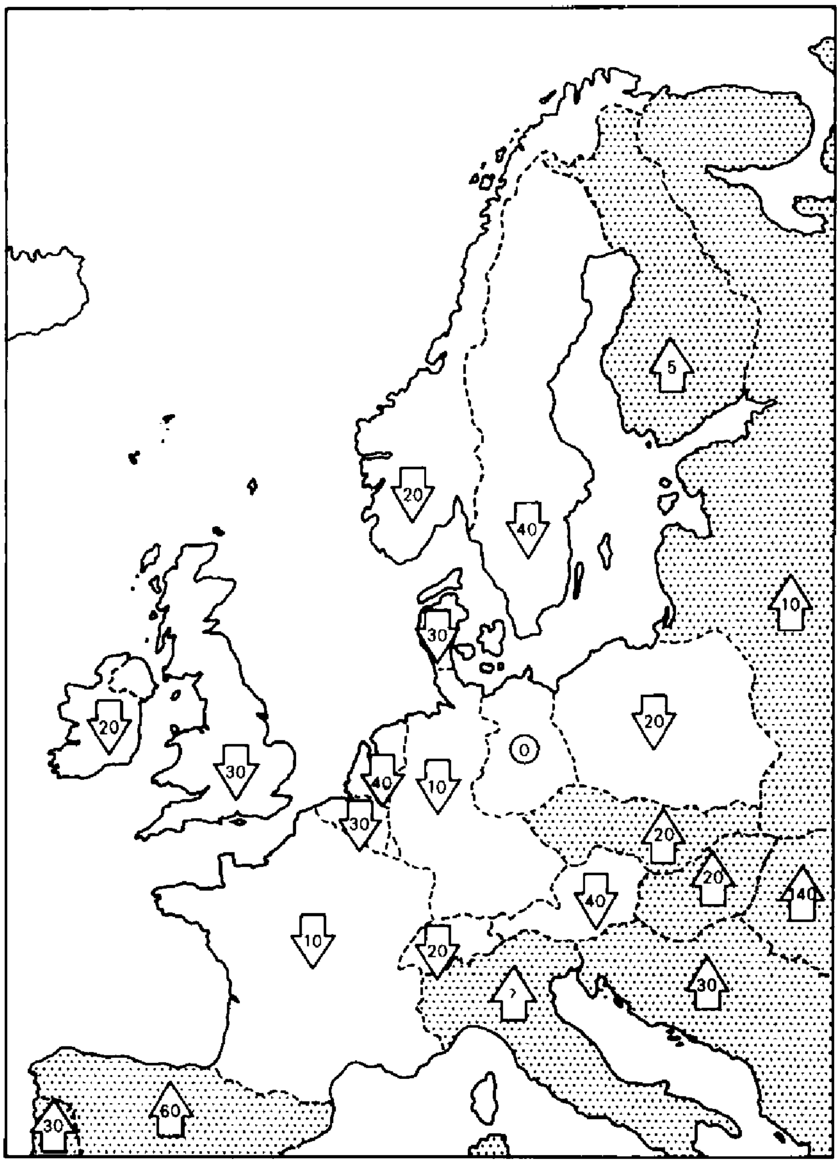



Figure 7—Percentage changes in estimated national $SO_2$ emissions 1972–82

Estimated uncertainties range from 5 per cent in the north and west to 50 per cent in the east and south. Estimates of increase for Italy range from 0 per cent to 60 per cent. Estimates of overall European changes vary from 0 per cent to an increase of 20 per cent.

Since 1973 fifteen OECD monitoring stations (which later became EMEP stations) have consistently reported data. All are in western and northern Europe. The average concentrations of sulphate in precipitation and in air at these stations remained rather steady until about 1980 when there is a suggestion of a significant fall especially in the former, reflecting perhaps the influence of the world-wide economic recession. Whilst these trends are not totally in line with trends in emissions in western and northern Europe, they indicate some positive response, albeit confused by uncertainties in the accuracy of the data, by year-to-year variations in trajectory climatology and by trends in other parts of Europe.

Estimates of $NO_x$ emissions within the UK, although subject to some uncertainty, have shown a different pattern since 1972 (see Table 2), almost steady until 1975, then increasing from 1.7 Mt to 1.9 Mt in 1979 and then falling again to 1.67 Mt in 1982 (expressed as $NO_2$). Over much of Europe, $NO_x$ and non-methane hydrocarbon (NMHC) emissions are both typically about 0.03–0.04 tonnes per year per head of population (see Table 1). Exceptions are 0.055 t/year $NO_2$ per head for West Germany and 0.02 t/year NMHC per head for the UK. Methane is by far the most abundant hydrocarbon in the atmosphere. It originates mainly from natural sources and is chemically very stable (life-time 5–10 years). Non-methane hydrocarbons on the other hand are largely of industrial origin and are more important in the transformation processes leading to acid rain. It has been tentatively suggested that control of their emissions might be a more cost-effective way of controlling acid rain formation.

*Meteorology of long-range transport—physical aspects*

The atmosphere's boundary layer is characterized by the effect the underlying surface has on the air's velocity, temperature, turbulence structure, and so on, in its vicinity. In particular, differences in temperature between the air and the surface have a profound effect on the dynamic stability and depth of the layer. Consequently, over land they both tend to exhibit marked diurnal changes. These changes have important consequences for the long-range transport of pollution. Figure 8 illustrates the various processes affecting the pollution and all of these are to a greater or lesser degree affected by the stability and depth of the boundary layer. Some points to note are:

(i) Associated turbulence will diffuse pollutants through the layer; some will be absorbed and deposited at the surface provided the near-surface layers of the air are not too stable.

(ii) The same mixing will drive and maintain chemical reactions between the various chemical species, both anthropogenic and natural.

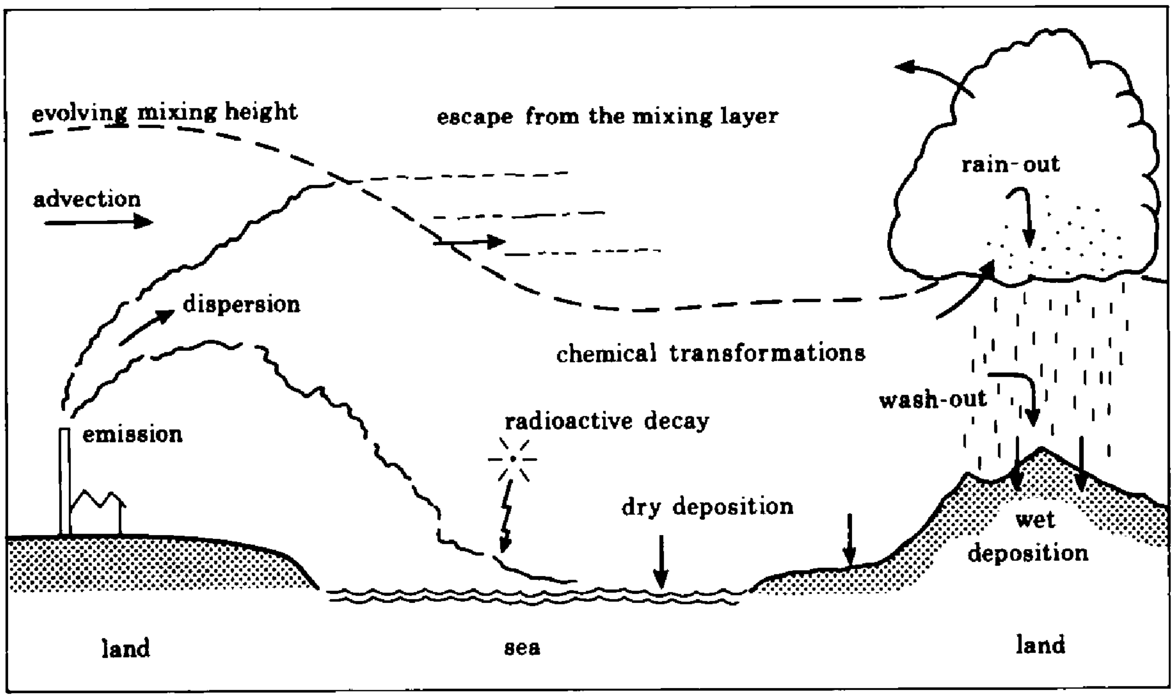



Figure 8—Processes involved in the deposition of atmospheric pollutants

(iii) The wind can vary in a rather complex way in the boundary layer in response to its depth, stability, past history and the underlying surface roughness. Determination of the travel of pollution is consequently difficult in many circumstances.

(iv) Cloud and rain which can remove pollution to the underlying surface can be very dependent on the state of the layer.

Clearly a very great deal could be said about these factors here, but instead we will concentrate on just a few points of particular relevance to the problem of modelling the transport and deposition processes. It may suffice to say for the rest that the structure and behaviour of the boundary layer has been, and continues to be, a matter of dedicated study within the Boundary Layer Research Branch both at Bracknell and at Cardington.

(a) *Dry deposition*

Dry deposition is the name given to the uptake of airborne gases and particulates by the underlying surface as a result of absorption, diffusion, adhesion, impaction and sedimentation—that is, by all processes excluding the intervention of precipitation. Normally the uptake is assumed to depend linearly on the airborne concentration. The coefficient of proportionality (with dimensions of velocity, and hence called the deposition velocity $v_d$) depends on the physical and chemical nature of the surface, the wind speed and the intensity of turbulence, the nature of the pollutant and the height at which the concentration is measured.

Most reactive gases have deposition velocities in the range of 0.2–2 cm $s^{-1}$ during the day, the exact value depending on the nature of the surface. $SO_2$, for example, has an average $v_d = 0.8$ cm $s^{-1}$. The deposition velocity of particles depends very much on their size; very small particles (diameter $d$ less than 0.1 $\mu$m) deposit by Brownian diffusion and have $v_d$ in the range 0.02–0.2 cm $s^{-1}$, small particles ($0.1 < d < 1 \mu$m) suffer from having no efficient deposition processes and have $0.01 < v_d < 0.05$ cm $s^{-1}$ whereas for larger particles ($d > 1$ $\mu$m) the value of $v_d$ increases rapidly with $d$ as impaction and sedimentation become important from about 0.02 cm $s^{-1}$ ($d = 1$ $\mu$m) to 1 cm $s^{-1}$ ($d \approx 3$ $\mu$m) to 10 cm $s^{-1}$ ($d = 10$ $\mu$m). The rate of dry deposition of pollution reaching the sensitive areas of Europe from the main source areas (typically about 1000 km away) turns out to be remarkably insensitive to the exact value of $v_d$ for any of the reactive gases. This is because at this range there is a rough balance between the amount remaining in the atmosphere (and hence the near-surface concentration $C_0$) and $v_d$, so that $C_0 \propto v_d^{-1}$.

(b) *Wet deposition*

Wet deposition is that part of the loss of airborne pollution to the surface arising from processes involving precipitation. In general wet deposition is less important than dry deposition over much of the industrialized central parts of Europe, but is more important in the more remote areas, especially where the rainfall is heavy as it is over the Norwegian and Scottish mountains. These areas are of course the areas of particular ecological sensitivity.

The process of wet deposition involves aspects which are either imperfectly understood or difficult to parametrize. Nevertheless, from a modelling point of view, the long-term wet depositions are often derived satisfactorily given the rainfall distribution, reflecting the basic fact that precipitation generally appears to be very efficient at removing $SO_2$, sulphate and the derivatives of NO from the air.

However, the agreement between model output and actual deposition may not be so good in just those mountainous areas of greatest concern. The effects of mountains on cloud character, rainfall frequency and intensity are known in general terms but in insufficient detail to determine their influence on the removal of pollutants. Moreover, a monitoring station's rainfall and pollutant concentrations may not be representative of a mountainous region, which makes model validation difficult. Canadian studies (Hopkinson and Dublin 1981) point to different removal efficiencies associated with rain and snow, and the dependence of the latter on temperature and snowflake size. A particular problem arises with low-level orographic clouds as their role and frequency within polluted boundary layers over mountainous areas are still not fully understood. Such clouds are called feeder clouds when they enhance any precipitation falling through them from clouds at higher levels. The tendency for low-level boundary-layer air to seek trajectories round mountains and through gaps, and thereby avoid to some extent the potential or actual areas of feeder clouds and higher precipitation, may result in apparently non-linear links in the coarse-grid models between removal in rain and concentrations within the boundary layer. Modelling of wet deposition may also be in error owing to spatial and temporal smoothing of rainfall data from widely separated meteorological observing stations when these data are interpolated to the model trajectory.

Some of the pollution drawn into precipitating cloud may escape into the surrounding relatively stable air above the boundary layer, and be temporarily 'lost', whereas much will be removed by rain-out, that is by incorporation into the growing raindrops within the cloud. Some may also be incorporated into the falling drops below cloud—a process called washout—or may be lost back into the air by desorption or evaporation.

(c) *Occult deposition*

Wind blown fogs, intercepted by trees and vegetation, can be the cause of considerable deposition of water and pollution. The process has been called occult (or 'hidden') deposition because of the difficulty of modelling it. Its importance to the total deposition of sulphur, for example, has recently been assessed to be generally small but can exceed 20 per cent in some limited, mainly mountainous, areas. It is well known that the frequency of 'damp' fogs tends to increase with surface elevation. But proximity of the sea, the extent and nature of the mountains, etc., are all factors of importance. Whilst radiation fogs are commonest in very light winds, other forms of fog occur in wind, and the deposition rate clearly increases with wind speed.

Damage to trees in central Europe, discussed earlier, is most frequently observed on ridge-tops where occult deposition is likely to be important. This suggests that whilst ozone may be the major cause of the damage, some synergistic effect with fog-borne sulphate may also be important.

(d) *Episodes*

The development of models capable of dealing with single-event depositions especially of episodic proportions, is a formidable problem. Two kinds of episodes, sometimes related, can be identified: episodes in terms of deposition and episodes in terms of concentration.

The importance of these kinds of episode is a matter of continuing research and debate. So far no important ecological damage has been identified as being dependent on single events. As already noted soils and freshwaters appear to depend on longer-term average depositions. However, research has not exhausted all the ecological possibilities. Furthermore, even the long-term average depositions are largely made up of contributions from relatively few large episodic depositions.

Considering deposition-episodes first, episode-days have been defined by Smith and Hunt (1978) as those days with the highest wet-depositions which, when summed, make up 30 per cent of the annual wet deposition total. The number of episode-days, taken as a percentage of the total number of wet days, defines the 'episodicity'. A station is described as highly episodic if the episodicity is less than 5 per cent and unepisodic if greater than 10 per cent. Figure 9 shows the episodic character of Goonhilly (Cornwall) in 1980 (Irwin 1982). In terms of sulphate, nitrate and hydrogen ions the station is highly episodic, 30 per cent of the total deposited $H^+$ ions being deposited in only about 5 or 6 days per year.

Smith (1983) has defined episodes in concentration (that is, concentrations in precipitation) as days when the concentration exceeds three times the long-term mean. Smith notes that these days occur in a very limited number of meteorological situations, principally, for deposition in northern Europe, when an active front draws into itself heavily polluted air from a stagnant anticyclone covering the industrialized areas of central Europe.

(e) *Chimney heights*

A popular belief has grown up in this subject that recent ecological damage is the result of the 'high-stack' policy of the UK and some other industrialized countries. This is largely nonsense. High stacks have had tremendous benefits; they have substantially contributed to the elimination of the health-damaging smogs that used to plague our urban areas. By emitting pollution at high level they considerably reduce local surface concentrations and depositions. It is true that this does mean that more remains in the air to travel to greater distances but the enhancement has been estimated by the Meteorological Office to be only some 10 per cent. Fisher (1984) has recently confirmed this using his long-range transport model in which he shows that the contours of total-sulphur deposition over Europe arising from UK sources are pushed out further by the use of high stacks by only some 20–40 km.

*Meteorology of long-range transport—chemical transformation aspects*

Two gases are produced during fossil fuel burning which may be transformed under atmospheric conditions to produce strong acids in rain. They are nitric oxide, NO, and sulphur dioxide, $SO_2$, which can be the precursors of nitric and sulphuric acids respectively. Coal burning produces hydrogen chloride, HCl, which can in addition form a third strong acid, hydrochloric, by direct dissociation in the aqueous phase. It may well be that more attention should be paid than hitherto to the role of HCl in determining the acidity of rainfall. For $SO_2$ and NO the possible transformations by chemical reaction must be considered.

$SO_2$ dissolves physically in water; from this state, the bisulphite, $HSO_3^-$, and sulphite, $SO_3^{2-}$, anions may be formed. In the presence of other species,

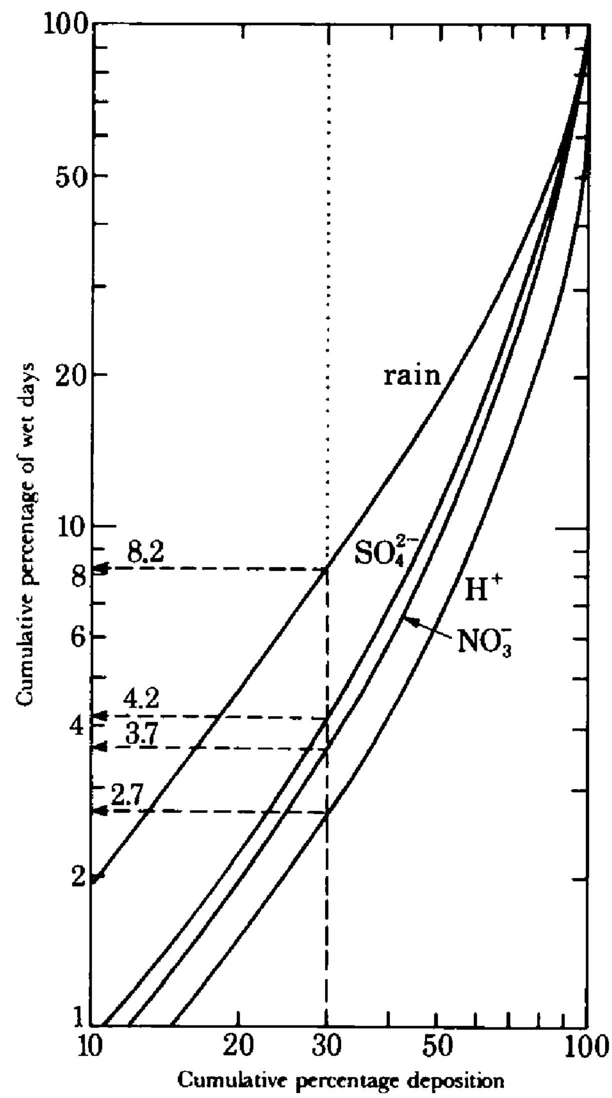


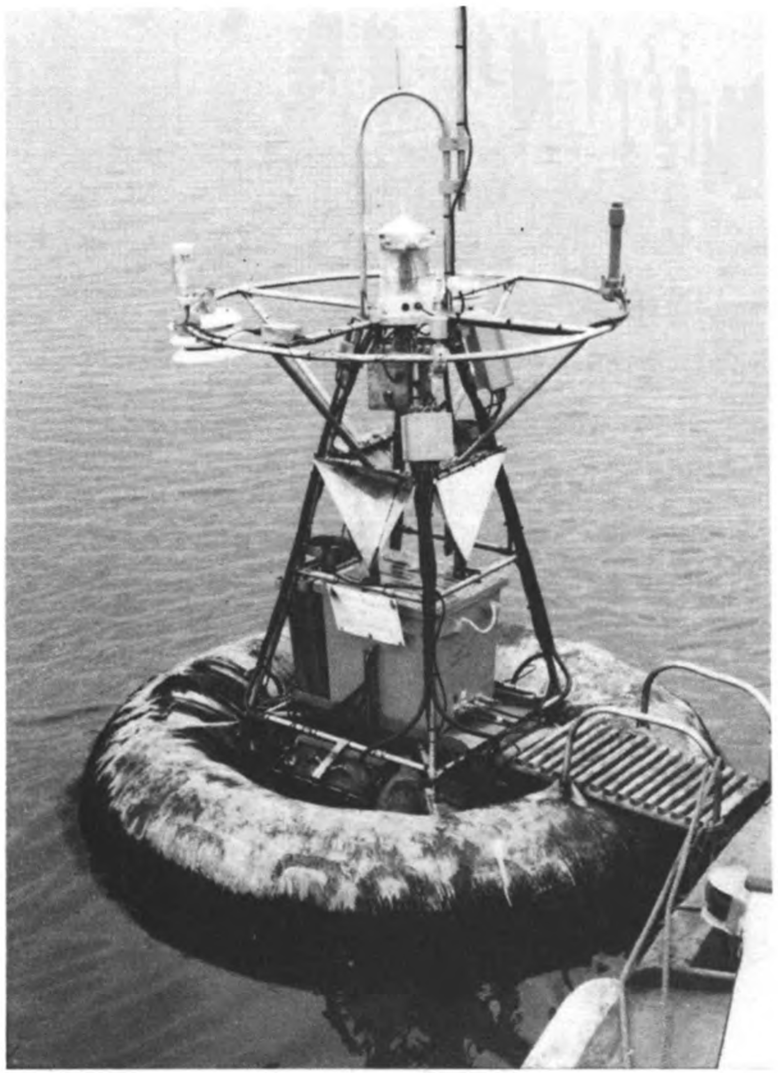

Figure 9—Daily measurements of the amount and composition of precipitation made at Goonhilly by Warren Spring Laboratory (Irwin 1982)

Rainfall, sulphate, nitrate and hydrogen ions are progressively more episodic.

the $SO_3^{2-}$ may undergo oxidation to sulphate, $SO_4^{2-}$. The rate at which this occurs depends upon the concentrations of $O_3$, $H_2O_2$, $NH_3$ and $H^+$ among others. Another way in which sulphate may enter precipitation is if some previous physico-chemical processes have produced an aerosol, whose particles contain the anion, and which have then acted as condensation nuclei for water droplet growth or been captured by a cloud droplet by some other physical process such as Brownian capture or impaction. Such sulphate aerosol may have been formed in two ways, from evaporation of a precursor cloud droplet, or via gas-to-particle conversion by means of homogeneous gas-phase photochemistry.

In the case of nitric oxide, conversion to a soluble form (nitric acid vapour, $HNO_3$, or dinitrogen pentoxide, $N_2O_5$) must occur, probably in the gas phase, before incorporation into aqueous droplets can take place. The driving force for the photochemistry is sunlight and most of the chemical reactions are temperature dependent, so that diurnal and seasonal variations in oxi-

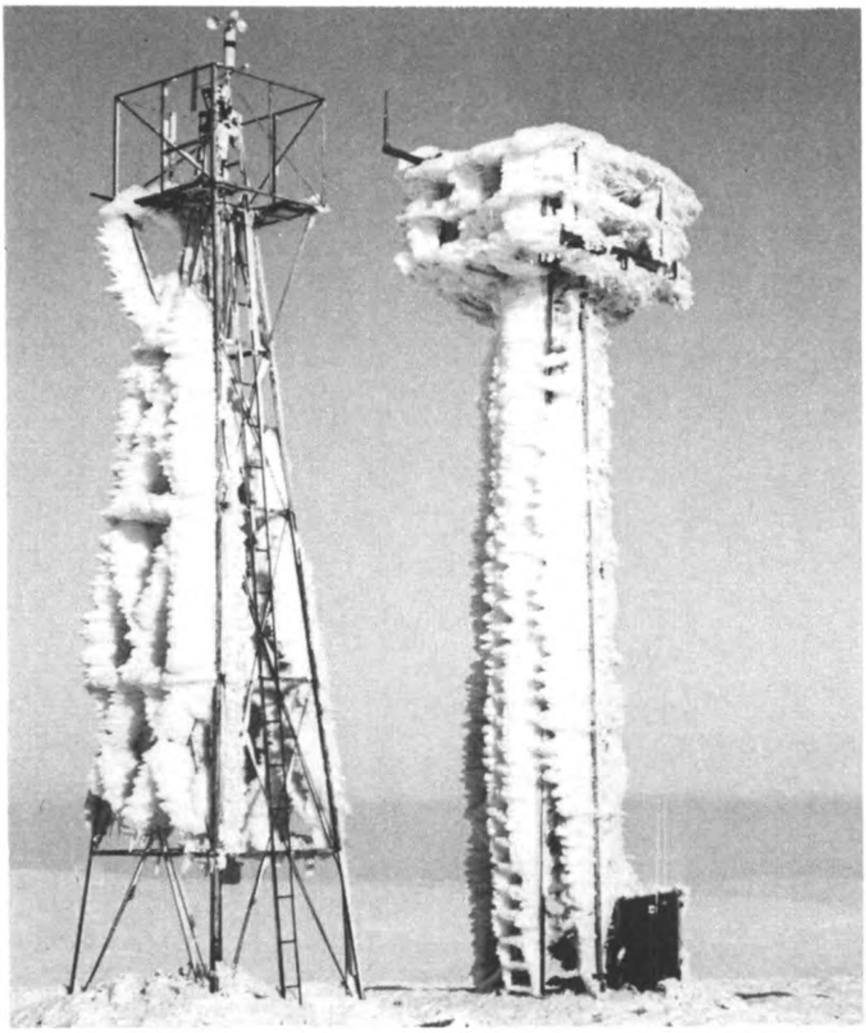
PLATE I

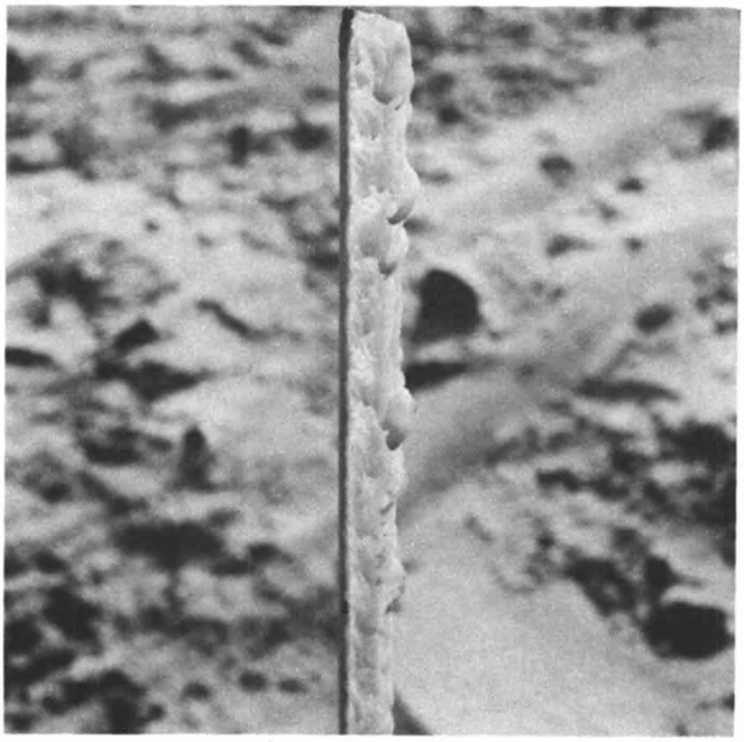


Automatic Weather Stations

The 3 m diameter data buoy, ODAS 2, pictured after a year in the sea, and the Automatic Weather Station on the uninhabited island of Sule Skerry. (See page 5.)

PLATE II





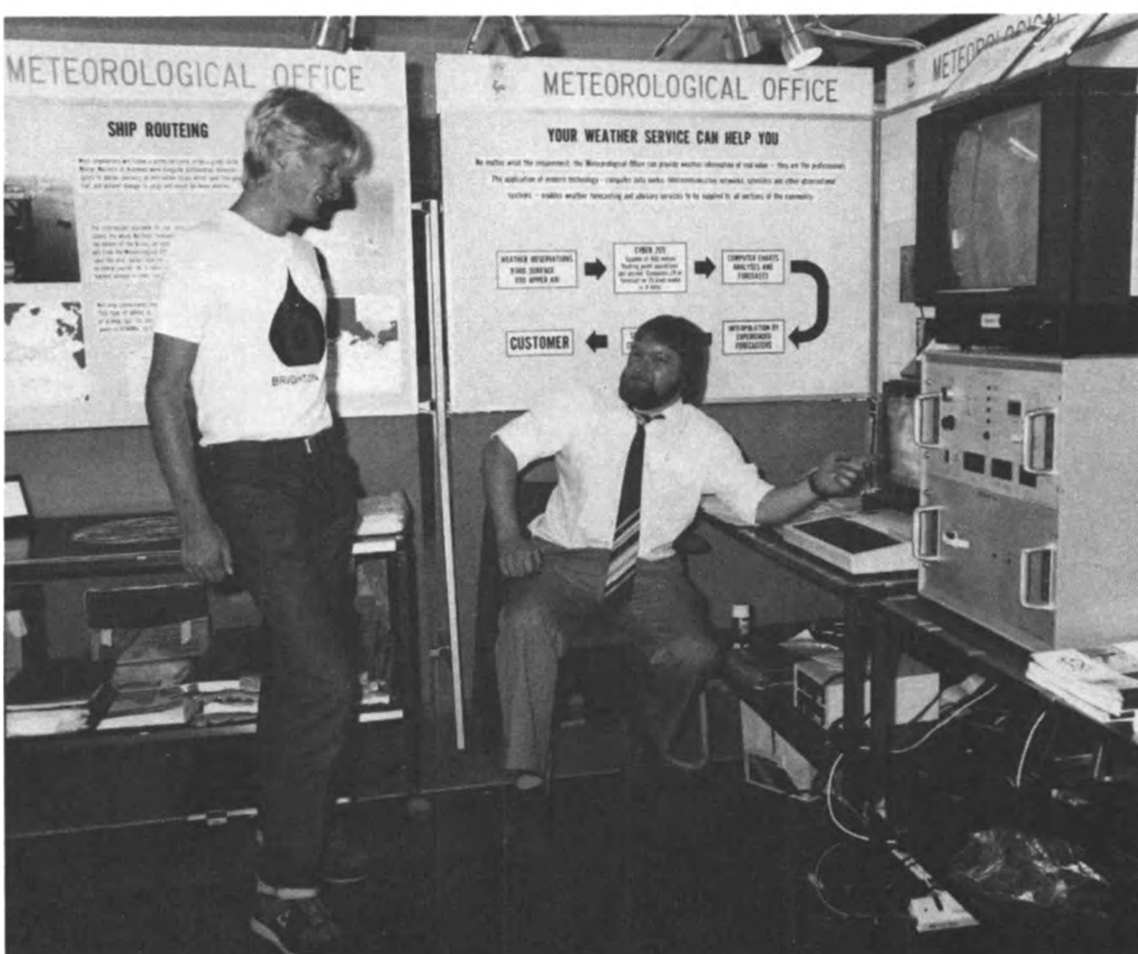
## Rime ice accretion at Great Dun Fell

The cup anemometer (upper left) has been cleared of ice. The lower picture is a close-up of a bead thermistor on a flexible rod. Rime ice builds up on the rod but is shaken free of the thermistor by the natural vibration of the system. (See page 49.)


Royal Bath and West Show, Shepton Mallet, 1–4 June 1983

The Meteorological Office was awarded the Steeple Challenge Trophy for the best stand in the show with a frontage of 30 ft or less. Mr Ted Young (right) received the Trophy on behalf of the Office from the Lord-Lieutenant of Somerset, Lt.-Col. G. W. F. Luttrell, M.C.

PLATE IV


**British Association for the Advancement of Science Annual Meeting, University of Sussex, 22–26 August 1983**

The Meteorological Office stand was manned throughout the week, mainly by Headquarters staff.

dation rates may be expected. A key quantity of interest is the rate-determining step in the sequence of elementary processes in which the primary species, $SO_2$ and NO, are oxidised to the strong acid anion. The rate-determining step may be generalized, and the law of mass action applied to obtain the rate of reaction:

$$A + B \rightarrow C + D$$

$$-d[A]/dt = -d[B]/dt = d[C]/dt = d[D]/dt = k[A].[B]$$

(where [A] represents the concentration of constituent A).

Suppose now that B is $SO_2$, and A is the oxidant responsible for the rate determining step—probably OH in the gas phase. The concentration of OH is determined by its production rate and its loss rate. The former depends principally on the intensity of sunlight, the latter mainly on other molecules (e.g. CO, $CH_4$, $NO_2$ etc.) *provided* the $SO_2$ plume has been diluted. [A] is then little affected by [B]. In this case

$$-d[SO_2]/dt = k_1[SO_2]$$

and if the supply of $SO_2$ is halved, the rate of production of $SO_4^{2-}$ will be halved. The oxidation of NO is a different matter. Here the principal reaction is:

$$NO + O_3 \rightarrow NO_2 + O_2$$

and because this reaction is a major loss mechanism for tropospheric ozone the rate of loss of NO is not proportional to changes in [NO].

A further complication is that to some extent [NO] and $[SO_2]$ are correlated in the atmosphere by virtue of both being produced by fossil fuel combustion, and this may cause non-proportionalities as the $NO \rightarrow NO_2$ reaction consumes ozone otherwise destined to participate in the $SO_2 \rightarrow SO_4^{2-}$ reaction.

*Measurements*

(a) *Airborne measurements*

Recent flights by the Meteorological Office's C-130 Hercules aircraft, which has been equipped with instruments built by the Central Electricity Generating Board Research Laboratories (CERL) at Leatherhead, have made experimental measurements relevant to the transformation of $SO_2$ and NO. The work has been submitted for publication (Cocks *et al.* 1983, Bamber *et al.* 1984). On flights over the North Sea on 28 and 29 January 1981 this aircraft was used to measure $O_3$, $NO_x$ and $SO_2$, and display their concentrations in real time, together with that of sulphur hexafluoride which had been injected as an inert tracer into the emission stack of Eggborough Power Station (53°24′N, 1°6′W). During the flights, the boundary layer was about 400 m deep, and contained stratiform cloud with a liquid water content of 0.2–0.6 g $m^{-3}$ and a mean droplet diameter of about 6 $\mu$m. The insolation, integrated over the solar spectrum, was about 15 per cent of the clear air maximum expected for the time and place.

Ground-based measurements indicated that the Eggborough plume was mixed vertically in the boundary layer within about 20 km of the source. The labelled plume was detected at 105 km from the source on 28 January and at 650 km from the source, near the Danish coast, on the 29th. These positions corresponded to plume travel times of about 5 hours from 0900 GMT and 24 hours from 1200 GMT on 28 January, respectively, and were the result of south-westerly winds with mean speeds of 5–10 m $s^{-1}$.

Measurements of $[NO_2]/[NO]$, and $[O_3]$ and the $SF_6$ tracer along the cross plume traverses at 105 km and 650 km are shown in Figures 10(a) and (b). The tracer identifies the centre of the plume; in that region, the ozone is depleted as a consequence of

$$NO + O_3 \rightarrow NO_2 + O_2$$

However, the central $[NO_2]/[NO]$ ratio is not accordingly elevated. The measurements show that less than half of the primary NO has been oxidized in much of the plume, and less than one-third at the plume centre after 24 hours of travel, 650 km from source. Ozone is depleted in the plume by the above reaction, and it is clear that mixing of the plume with ambient air, which could replenish the ozone to a volume fraction* concentration of about $20 \times 10^{-9}$, is in fact rate limiting. Since the supply of oxidant is being depleted, it follows from the general arguments given earlier that, for this plume, reductions in NO emissions will not cause proportional reductions in $NO_2$ loads at these distances.

The depletion of ozone in the plume centre also has implications for the oxidation of $SO_2$, for which the rate determining step in the gas phase is believed to be reaction with OH. The oxidizing hydroxyl radicals are produced through photochemistry initiated by ozone, and hence the non-proportionality argument also applies to gas phase oxidation of $SO_2$. If, as seems likely, the oxidizing species in the aqueous phase is either ozone or hydrogen peroxide, the aqueous phase oxidation of $SO_2$ to $SO_4^{2-}$ will also be slow, because $H_2O_2$ originates in the gas phase via ozone-induced photochemistry and, as indicated, $O_3$ is depleted.

Thus, if the conditions in which plumes mix slowly with ambient air are common occurrences, the oxidation rates will be slow because of a shortage of oxidant. In turn, this is a circumstance in which non-proportionality between emissions and depositions may be expected.

Measurements during a flight by the Hercules aircraft round Great Britain at 150 metres altitude in an anticyclonic easterly flow on 21 July 1982 showed a very low background influx of $SO_2$ coming from over the North Sea. However, four plumes were resolved off the Welsh coast (Figure 11) and the $SO_2$, $SO_4^{2-}$ and $O_3$ content measured. At the same time, an instrumented Jetstream aircraft, leased by CERL from the Cranfield Institute of Technology, was used to measure $SO_2$, $SO_4^{2-}$, $O_3$, NO and $NO_2$ upwind (eastward) of Wales. The integrated upwind source of $SO_2$ was estimated to be 118 tonnes per hour (t $h^{-1}$) sulphur equivalent. At the Jetstream flight track the fluxes of $SO_2$ and $SO_4^{2-}$ were estimated to be 83 t $h^{-1}$ and 6 t $h^{-1}$ sulphur equivalent respectively. At the Hercules flight track the estimated fluxes of $SO_2$ and $SO_4^{2-}$ were 24 t $h^{-1}$ and 18 t $h^{-1}$ respectively.

There was obviously a high loss rate (27%/hour) during the 4¾-hour long passage over Wales, which can be accounted for by an oxidation rate of 4%/hour and a dry deposition velocity of 5 cm $s^{-1}$. The oxidation rate can range from 4% to 29%, depending on assumptions about deposition by direct impact of cloud droplets on the Welsh hills (Bamber *et al.* 1984).

*The volume fraction (or mole fraction) of a component in a mixture is found by dividing the volume of that component at the total pressure and the temperature of the mixture by the volume of the mixture at the same pressure and temperature.

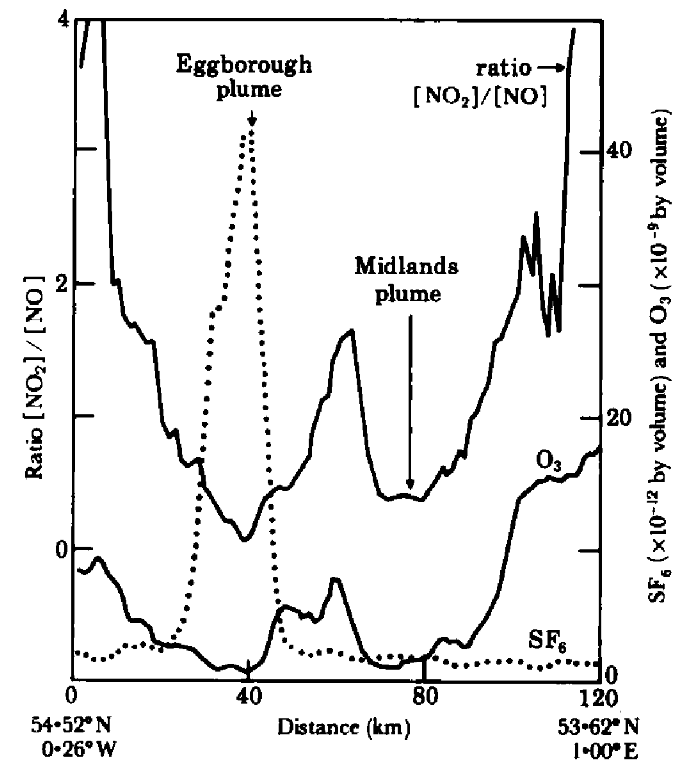



Figure 10(a)—Cross-plume profile at a height of 150 m on 28 January 1981, 105 km from Eggborough power station

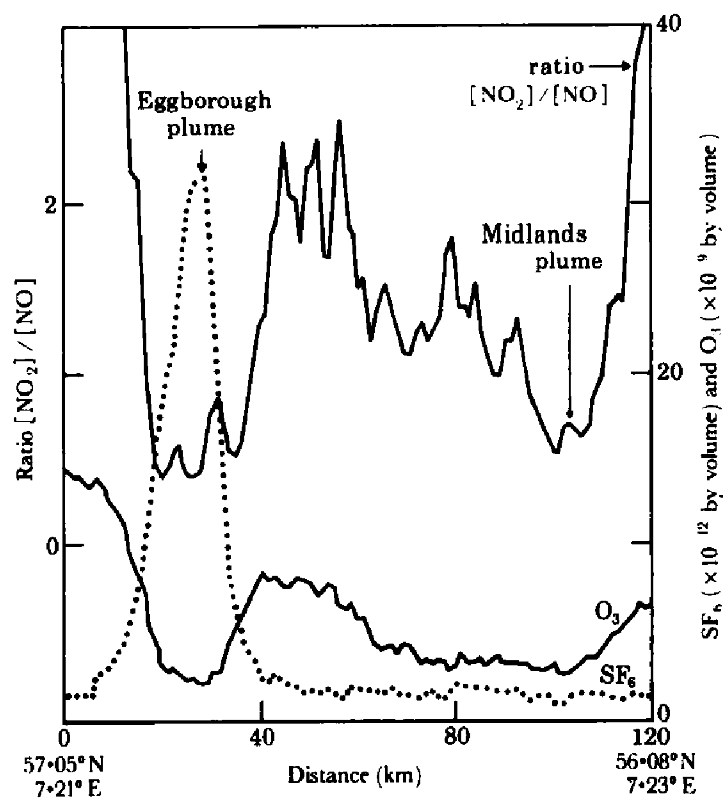



Figure 10(b)—Cross-plume profile at a height of 150 m on 29 January 1981, 650 km from Eggborough power station

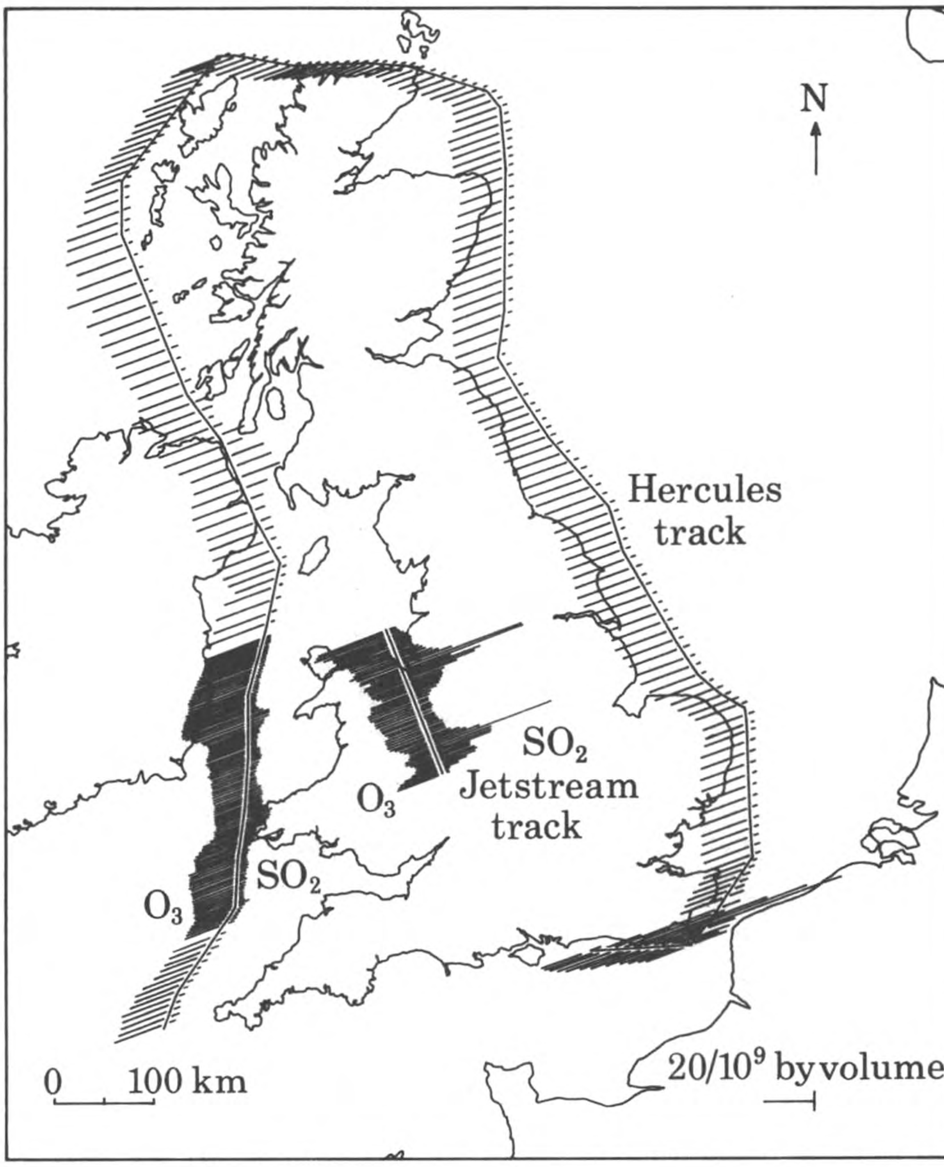



Figure 11—Airborne pollution measurements, 21 July 1982
The Hercules aircraft of the Meteorological Research Flight circumnavigated Great Britain in a counter-clockwise direction at an altitude of 150 m, while the leg flown by the Jetstream aircraft from the west Midlands to the Mersey estuary was at 400 m. In this region the amounts of $SO_2$ and $O_3$ are shown on an identical scale by the lines at an angle to the aircraft tracks. The angle corresponds to the wind direction (roughly 070°) in the region of the main plumes; the $SO_2$ values are the lines on the east side of the tracks and the $O_3$ values are those to the west.

Satellite pictures for the day in question showed a near-stationary stratocumulus deck over Wales, not advected with the 9 m $s^{-1}$ mean wind in the boundary layer, which was capped with a strong inversion at an average height of 1200 m. Thus, in the clear air boundary layer between the sources and the Jetstream track, the oxidation rate was 2%/hour and the dry deposition velocity 2 cm $s^{-1}$. In the boundary layer with stratiform, wave-like cloud over Wales, the minimum oxidation rate was 4%/hour and the equivalent deposition velocity 5 cm $s^{-1}$. The maximum oxidation rate was 29%/hour.

The stratiform cloud thus has a high oxidation rate associated with it; the high apparent dry deposition velocity may speculatively be associated with the impaction of droplets on the Welsh hills and is consistent with the terminal velocity of drizzle-sized drops. Rainfall was reported for 21 July of 1.1, 0.4 and 0.2 mm at 3 of about 550 sites in central and South Wales, the remainder giving zero returns. However, few of these rain-gauges are near the hill tops.

It thus seems clear that, on this occasion, a near-stationary layer of stratiform cloud over Wales, with wave-like characteristics, gave an oxidation rate of $SO_2$ to $SO_4^{2-}$ of 4–29%/hour, and was associated with an overall loss rate of $SO_2$ of 27%/hour.

These two flights illustrate how different the fates of power station plumes can be, depending upon the detailed interplay of cloud physics, boundary-layer dynamics, radiation and chemistry. They also demonstrate the value of airborne investigation, which permits experimental observation of the basic physical processes in a way denied to ground-based observation.

(b) *Ground-based measurements*

The EMEP measurements are made daily. Analytic techniques are periodically checked by the Chemical Co-ordinating Centre which submits specially prepared artificial samples to the National Laboratories. Results indicate that biases do exist but that these are becoming less significant as methods improve. Sampling techniques have not been scrutinized to the same extent. 'Wet-only' collectors (i.e. open only during precipitation) are being used increasingly to reduce contamination from dry deposition in between rain events.

EACN stations collect air and precipitation samples on a monthly basis. Their data form the longest available run of measurements of precipitation composition. The techniques used for judging the composition of air have been critically examined by Brownscombe *et al.* (1974).

Permanently open collectors have operated continuously at three Meteorological Office EACN sites at Bracknell, Lerwick and Eskdalemuir. Since 1973 additional automatic wet-only collectors and standard meteorological rain-gauges have been added. Examination of the records from the three sites indicates a need for careful quality control, especially for data prior to 1973. Sodium contamination from soda glass wool filters has been a major cause of error.

Another study considered the reproducibility of the data by comparing results from nearby identical collectors (8 m apart at Bracknell, 300 m apart at Lerwick). Correlations were generally good, the variability of a species being about 20 per cent at Bracknell. Nevertheless, tests to see whether the two sets of data came from the same population revealed that for some ions (including sulphate) they did not, implying systematic differences. Slanina *et al.* (1979) and Granat (1977) have made similar shorter-term tests on other EACN data.

Comparison of the wet-only and permanently open collectors showed the latter consistently collected more $SO_4^{2-}$, and possibly more $NO_3^-$, $Cl^-$ and $NH_4^+$ at Lerwick and Eskdalemuir due to dry deposition (although the different materials used in the manufacture of the collector may also have contributed), but the extent of this effect is hard to quantify, especially for other stations.

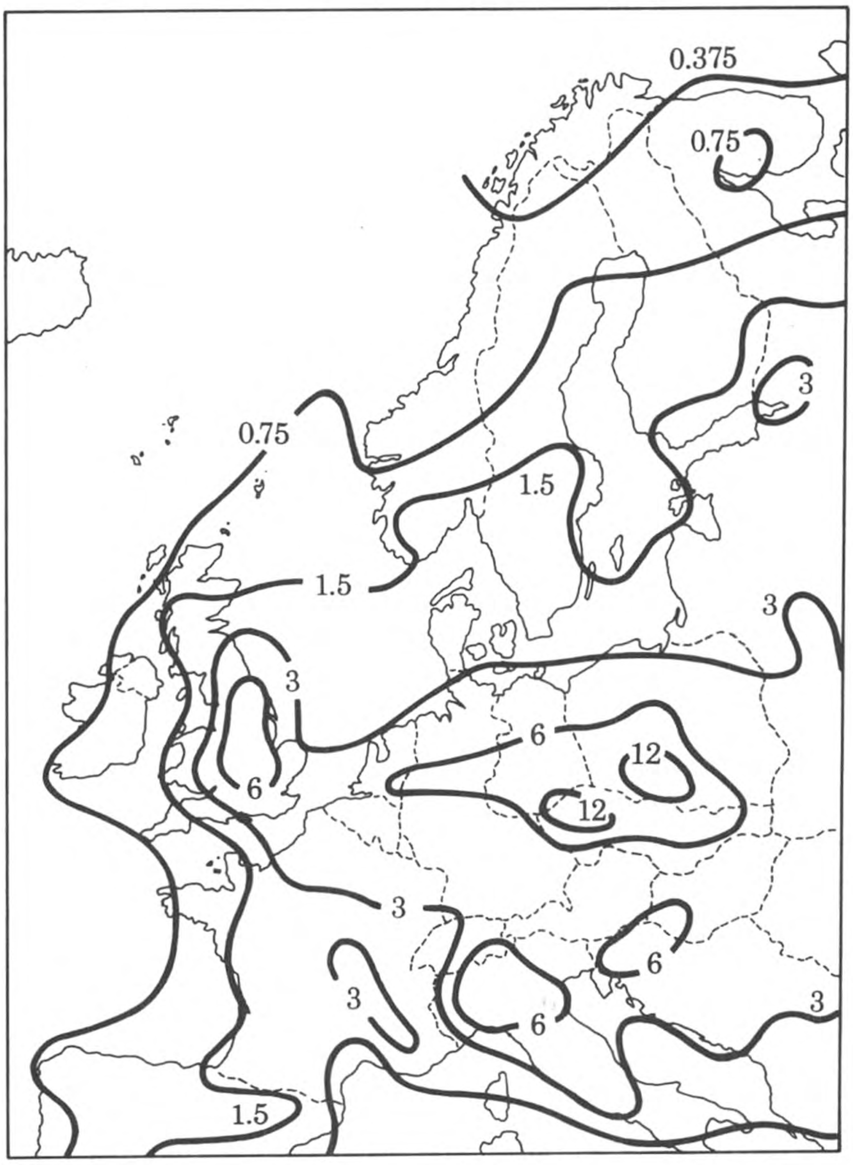



Figure 12—Total sulphur depositions per unit area ($g\ m^{-2}$ per year) from the EMEP model for a two-year period (1978–79)

*Modelling*

Models simulating the fate of pollution in the atmosphere can be subdivided in a variety of ways which can only be touched on very briefly here, but are described in greater detail by Pasquill and Smith (1983). Three of the ways are as follows:

(a) *Statistical models*

These are models that use statistics of wind, boundary layer depths and precipitation. Resulting deposition fields may have validity but only over long times ($\geqslant 1$ year). The models are simple and very economical to run. Deposition fields for man-made sulphur oxides have been shown by Smith (1983), Fisher (1984) and others to be in surprisingly good agreement with 'observed' fields for both Europe and North America. Best agreement is obtained when the sporadic nature of rainfall is recognized and incorporated using statistical techniques described, for example, by Smith (1981).

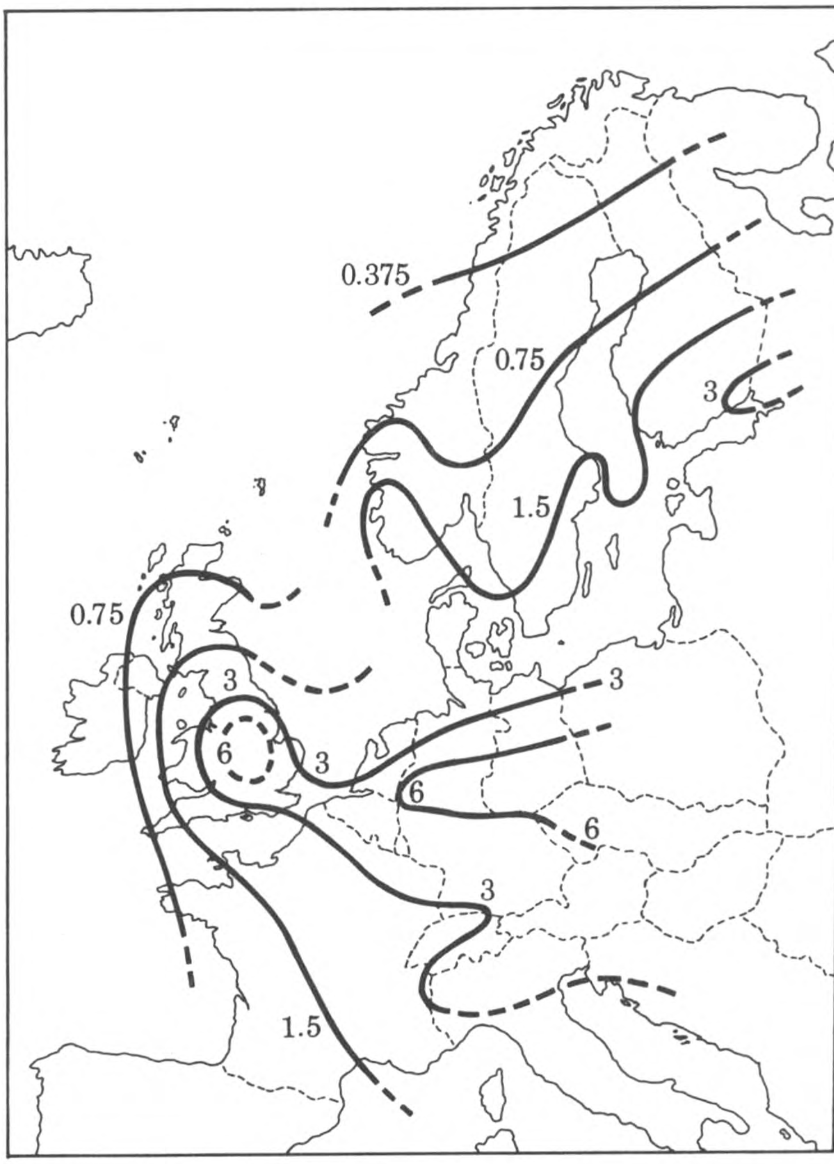



Figure 13—Total sulphur depositions (g $m^{-2}$ per year) implied by interpolation between measurements made at the EMEP network of monitoring stations over the two-year period 1978–79

(b) *Operational models*

These are models that use real hour-by-hour meteorological data, but owing to the limitations of these data and the rather sparse observing network still require the use of much parametrization and have validity over rather long times ($\geqslant$several months). The models used in EMEP are of this type. Figures 12 and 13 show the model-predicted and 'observed' total deposition of sulphur across Europe for 1978–79. The agreement is basically good.

(c) *Complex models*

Complex models are being developed for long-range transport simulations in several places, including the Meteorological Office. They are essentially mesoscale models taking into account topography and the three-dimensional equations of motion. In some cases they will rely on the output of numerical weather prediction models; in others they will require considerable non-standard meteorological data. All need a highly sophisticated computer facility. Their intended uses range from aiding field experiments (as in the Meteorological Office/CERL Plume Study), to testing the validity of simpler models, to providing valuable data in the case of an accidental release of hazardous material into the air. At present no evidence is available as to how successful such models will be in simulating short-period events.

The prediction of total deposition has already been mentioned. The EMEP model is also capable of showing how much the emissions in one country contribute to the depositions in another.

Figure 14 shows this pictorially. The size of the circle within each country is proportional to the average deposition of sulphur per square metre per

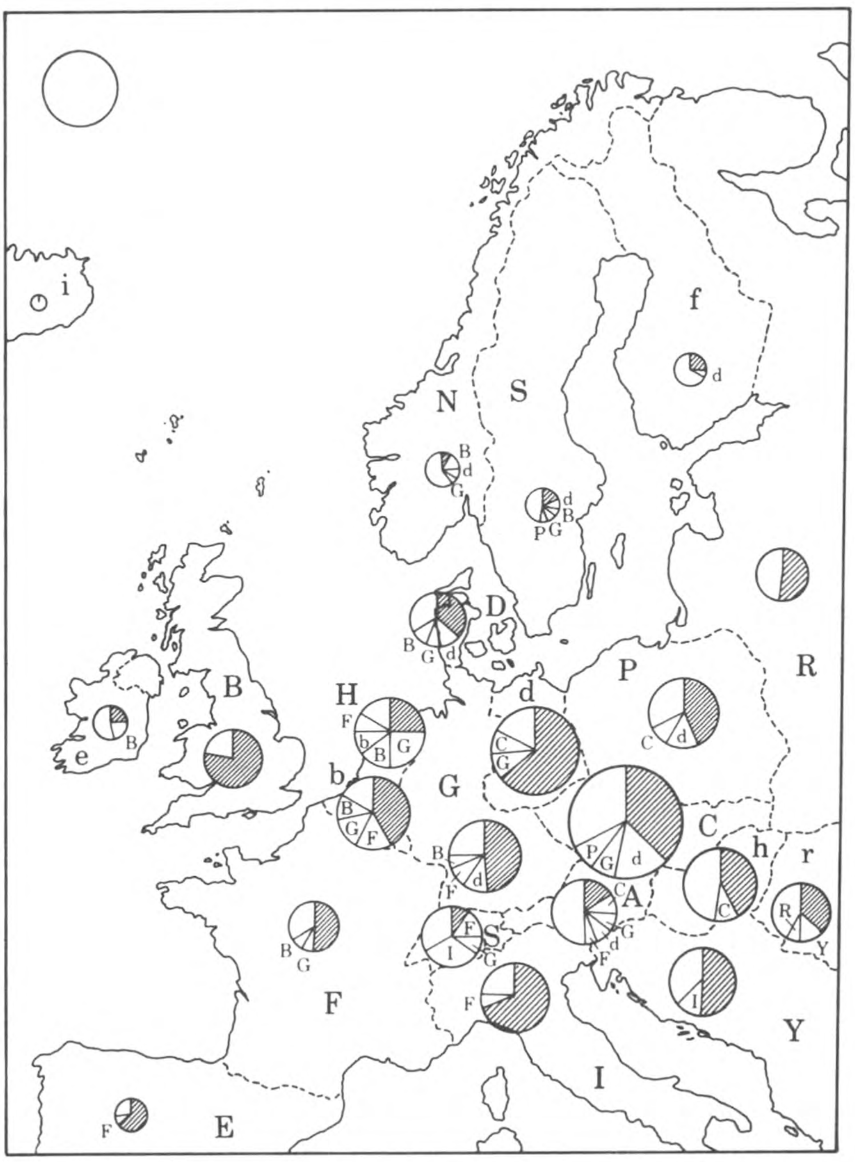



Figure 14—Total sulphur depositions within European countries as implied by the results of the EMEP MSC-W Lagrangian trajectory model

Depositions are in g $m^{-2}$ per year. The circle in the top left-hand corner represents an area equivalent to a sulphur deposition of 5 g $m^{-2}$ per year (wet + dry). The shaded areas denote the contribution from emissions within the same country; other sources greater than 20° are labelled.

year. The shaded part represents the deposition arising from internal emissions; other segments are labelled with the letter of the country of origin. The unlabelled segment includes contributions smaller than a 20° segment, or from other unspecified, perhaps external, sources. It is interesting to note that Czechoslovakia receives over 12 times as much as Norway, and that although Britain contributes more than any other country to Norway's deposition, it only amounts on average to a sulphur equivalent of about 0.15 g $m^{-2}$ per year, albeit this contribution is concentrated in the southern part of the country.

*The future*

The Meteorological Office has an important role to play in the future of the study of acid rain, through continued theoretical and experimental research, and perhaps ultimately in consultation regarding procedures for emission modification or control.

Nevertheless, other actions may well require a meteorological input. Three examples are:

(i) The reduction of other components in the pollution mix which may be indicated by air-chemistry modelling to be a highly cost-effective strategy.

(ii) Increasing still further effective source heights with a view to maximizing the insulation of the pollution from ground-deposition processes, especially in the sensitive areas of Europe.

(iii) Emission control. It is possible that oil-fired power stations could change over to more expensive low-sulphur fuel oil, and coal-fired stations run at low output, whenever forecast trajectories indicated travel of the plumes to Scandinavia, especially if wet-removal was expected on arrival. A pilot study in 1974 indicated a potential 45 per cent success rate. Ten years later the quality of weather forecasts has improved significantly. A further study is now being pursued using the output from the fine-mesh 15-layer model to see if a higher, acceptable level of success can now be achieved.

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# OTHER WORK OF THE DIRECTORATE OF RESEARCH

## Physical Research

### *Cloud physics*

The presence of water, in its three phases, has important effects on the chemical and physical processes which occur in the atmosphere, so studies of clouds and precipitation are relevant to many activities of the Meteorological Office. Aspects in which cloud physics research is directly important are the problems of forecasting heavy rain or fog while the effects of clouds on the radiative balance of the atmosphere ensure that even large-scale atmospheric motions are sensitive to the formation and dissipation of clouds. A combined observational and numerical approach has been adopted to clarify the underlying physical processes so that advice can be given both on the solution of these meterological problems and on various practical problems including the maximum precipitation rates to be expected in particular situations and the factors determining the icing potential of supercooled clouds.

During the year extensive use has been made of the instrumented C-130 Hercules aircraft of the Meteorological Research Flight (MRF) which has been equipped to make measurements of a range of cloud properties. Improvement of the instrumentation is a continuing process and a new droplet-sizing instrument has been obtained and tested during the past few months. The development of techniques for measuring air temperature in cloud and total water content is being undertaken while methods of providing real-time displays of droplet and ice crystal size distributions are being investigated. The latter development will facilitate the control of experimental flights, ensuring that data are obtained in optimum conditions. In order that maximum use of the aircraft observations may be made, numerical models are being developed to interpret observations of cloud processes ranging from the organization of clouds on scales of tens of kilometres to mixing processes on scales of metres or less.

During December 1982 an experiment was undertaken to measure the structure of rainbands associated with an intense cold front over the North Atlantic. Sondes were dropped from the aircraft to measure the structure of the atmosphere along two vertical planes orientated perpendicular to the surface front. Additional measurements of cloud structure were subsequently obtained at two levels. Analysis of the observations has revealed the presence of a narrow cloud band along the line of the surface front having wider, parallel, cloud bands on either side. The results from a detailed analysis are being used to discriminate between different theories for the formation of cloud bands in frontal regions. The data set obtained during this experiment is more complete than those obtained in earlier investigations; the observations along parallel lines enabling variations in the atmospheric structure along the direction of the surface front to be ascertained. It was hoped that data from additional case studies would be obtained during a detachment of the aircraft to RAF Machrihanish during April 1983, the base being chosen to maximize the time available for experimental flights. The unusual atmospheric circulation during that period, however, prevented a suitable front occurring although a number of flights in connection with other projects were very successful.

Theoretical studies of frontal circulations have suggested that banded cloud structure may be influenced by smaller-scale convection. Small-scale convective cells have also been observed in flights through frontal cloud bands. Substantial progress has been made towards the development of a two-dimensional numerical model capable of representing these effects explicitly. Numerical schemes have been developed which adequately handle clouds which are poorly resolved by the computational grid.

A numerical model of deep convective cloud is being used to investigate factors influencing rainfall. Integrations of the model have, however, demonstrated some sensitivity of the predicted rainfall to the representation of microphysical processes in the clouds. A scheme for representing snow formation in the model, which at present includes only rain and hail, is being developed. In both these aspects of model development observations of the evolution of precipitation obtained using the C-130 aircraft in uniform precipitation are being used to test the numerical schemes. The variety of models used by different research groups has resulted in WMO co-ordinating a Workshop to compare them. While possible experiments are still being planned it is expected that integrations obtained for a range of conditions will be compared with those obtained using different models with similar initial data and also with observations.

Integrations of the cumulonimbus model are being used to assist in the interpretation of observations of vigorous convective cloud made by the

Rutherford Appleton Laboratory using a 10 cm dual polarization radar. The radar can discriminate between regions of large drops, small drops and ice throughout the clouds. Data obtained using the radar are being compared with model predictions to explain the glaciation mechanisms in these clouds. Aircraft observations obtained in less vigorous convective clouds during the 1981 KONTUR (KONvektion und Turbulenz) experiment are also being compared with model simulations with similar objectives. The intense storms accompanied by large hail which were observed over much of southern England on 5 June 1983 are also being investigated using the numerical model. The observed wind shear and low-level flow of moist air are believed to be crucial for the generation of such storms and model integrations will test this hypothesis. It is also hoped to investigate the growth of large hail in the simulated clouds.

Observations of the structure of isolated moderate cumulus clouds have been made on several occasions including during the Machrihanish detachment. The data include measurements of drop size distributions and of the air flow. Analysis of these observations has shown that while air is entrained principally into the top of developing clouds some is also entrained at the edges of the clouds. The predictions of numerical models of the effects of entrainment on the droplet size distribution are being compared with the observations in an attempt to explain the observed droplet growth rate in these clouds. In some of the observed clouds significant numbers of ice crystals were found and data on their distribution obtained using an aircraft-mounted holographic camera system are being used to help understand the mechanisms for ice crystal formation in clouds.

Experiments using a model of radiation fog development have demonstrated generally good agreement between the predicted occurrence of fog using empirical forecasting models and the numerical simulations. The detailed predictions of the numerical model are also in reasonable agreement with observations of radiation fog made at Cardington several years ago except that the model does not reproduce the large temperature gradients often observed close to the ground. The model has been used to assess the sensitivity of fog formation to the properties of the underlying surface, for example, soil type and degree of saturation with the aim of providing guidance to forecasters for whom forecasting fog is both an important, and a difficult, problem.

Several flights have been made with the instrumented aircraft through stratocumulus clouds to determine their structure in order that the processes influencing the development of these clouds might be evaluated. It has been shown that the formation of cloud may cause stratification of a previously well mixed atmospheric boundary layer. This process has not previously been considered in models of the boundary layer although it profoundly influences cloud evolution. It has also been shown that water loss by precipitation is an important contribution to the vertical flux of water through the boundary layer. A detailed analysis of the aircraft observations also reveals the presence of organized convective motion within these clouds driven by cooling at the cloud top. This organized motion is the dominant transport process in stratocumulus. The aircraft measurement program is being extended to include nocturnal stratocumulus in order that the effects of solar radiation on cloud evolution may also be assessed.

*The atmospheric boundary layer*

The atmospheric boundary layer is that part of the atmosphere influenced directly by the underlying surface and may vary in depth from a few tens of metres in stable conditions to perhaps a few kilometres in very unstable conditions. The Boundary Layer Research Branch (which includes the Meteorological Research Unit at Cardington, Bedfordshire) has continued to pursue a varied and balanced program of observational, theoretical and numerical studies of selected, important boundary-layer issues.

Several studies of the mean structural and turbulent characteristics of boundary layers over relatively simple terrain have benefited directly from data collected at Cardington, often with support from the Royal Aircraft Establishment (RAE) tethered-balloon facility based there. In particular, further investigations of the subsidence inversions, which generally cap the daytime, convectively unstable, boundary layer, have been made with a Lyman-Alpha humidity probe modified to include an anemometer. There is often a layer about 100 m thick with a total velocity excess of 3–5 m $s^{-1}$ relative to the air immediately above and below it, the depth and strength of this 'jet' depending on the intensity of the inversion. One hypothesis is that these 'jets' are the direct cause of the distinctive, thin, dry layers which have also now been observed on several occasions at the inversion, the dry air being advected outwards from the centre of associated anticyclones. No evidence has been found to support alternative suggestions that the dry layers are formed *in situ*. If valid, the mechanisms envisaged could be important for the clearance of stratus. However, further work is needed to test the currently favoured hypothesis.

Our recent studies of the atmospheric boundary layer over the sea have concentrated largely on analyses of data collected in previous years using the instrumented MRF Hercules aircraft, in particular, data from the KONTUR Experiment, a study of convective boundary layers, which took place in the German Bight in autumn 1981. Observations from intercomparison flights, in which the Hercules and the German Falcon aircraft flew in close formation, have been processed and exchanged with collaborating scientists at the Max-Planck Institut für Meteorologie, Hamburg. On the whole, the two data sets are in reasonably good agreement. However, there are some important and interesting differences, for example in the temperature spectra, that need to be resolved and which are being investigated further. Data from flights when cloud streets were reported show evidence of weak, two-dimensional circulations in the form of roll vortices parallel to the streets and with their longitudinal axes approximately along the mean-wind direction. Such roll vortices can have a marked influence on turbulent transport in the boundary layer and so complementary two-dimensional numerical modelling studies have been done to investigate, in particular, the influence of clouds and cloud-top radiational cooling on the dynamics and physical properties of the rolls. Results show that, although small clouds have little effect on the dynamics of the roll motions, they do have a marked influence on the entrainment of the overlying statically stable air into the boundary layer, and on the consequent boundary-layer growth.

Despite its important and diverse applications, our knowledge of turbulent flows over hilly terrain is extremely limited and extensive observational and theoretical work still remains to be done. For several years our philosophy has been to extend this knowledge gradually through a series of experiments conducted at sites carefully selected so as to afford data which could be interpreted with reasonable confidence in the context of well-defined, if simplified, topographic features. In keeping with this general philosophy, a further successful four-week field experiment was conducted in the Sirhowy Valley, South Wales, in June. The two previous visits to the same site, in 1980 and 1981, had provided data for near-neutral and slightly unstable (daytime) conditions. However, topographical influences on the mean flow and the turbulence are often much more pronounced when the flow is stably stratified. The aim of the most recent experiment was to obtain a high-quality data set to provide a sound basis for subsequent scientific analysis of the mean flow and the turbulent characteristics in stable flows over a nearly two-dimensional, ridge-valley system.

Before the field phase considerable effort on design, construction and testing produced a prototype of a new turbulence probe for making fast-response measurements from the tethering cable of a kite balloon. On previous occasions the balloons used had been too small to climb above the very turbulent air in the valley, which resulted in measurements, highly contaminated by balloon-cable motions, being made at relatively low levels only. The much larger balloon (five times the volume of the previous balloon) used this year was flown with ease into the calmer air above the valley, enabling measurements to be made with the turbulence probe on a cable with limited motion and at levels up to 2.5 times the height of the surrounding valley sides. The support of the RAE Balloon Unit was invaluable to the whole operation. All equipment, including the new turbulence probe, worked well and a great deal of worthwhile data was gathered. A valuable scientific outcome is expected. The results of the previous Sirhowy Valley experiments were described in a scientific paper.

Data from the more recent (September 1982) experiment conducted at the nearly circular hill, Blashaval, on North Uist have also been analysed and used to assess various conflicting theories for the airflow over isolated, three-dimensional hills. Results confirm that simple essentially inviscid theories can provide useful predictions of the speed-up of the mean flow over terrain with moderate slopes. However, turbulence measurements in the summit region indicate that the existing theories do not describe adequately how to match the disturbed turbulence remote from the surface to the equilibrium turbulence occurring very close to the surface. This is an important issue, for example, in determining the net drag caused by hills, and needs to be resolved.

The Branch is engaged in developing a variety of numerical models in addition to those used for boundary-layer flows over complex terrain. The two-dimensional modelling of horizontal roll vortices has been mentioned already. Another particularly important development is a three-dimensional 'large-eddy' model in which the eddies larger than a certain size are represented explicitly through the model's finite difference scheme, whereas smaller scale eddies have to be parametrized. Testing of the model has been restricted so far to laboratory flows but the results have been most encouraging and application to atmospheric boundary-layer flows is imminent.

The boundary layer is also the layer that supports most of man's activities and its turbulent character governs the transport, dispersion and deposition of most airborne pollutants. A wide range of spatial scales is involved in dispersion of atmospheric pollution and the calculation of the concentrations of pollutants within a few kilometres of a source (short-range) requires different considerations from those used over several hundred kilometres (long-range). An increasingly important function of the Meteorological Office is to provide advice on problems of atmospheric dispersion at all ranges.

Although various aspects of the study of long-range transport of atmospheric pollution continue to receive our attention, the most topical pressing concern is the so called 'acid-rain' problem. Our particular contributions to that study are discussed fully elsewhere in this Report, within the more general context of the special topic 'Meteorological aspects of acid rain'.

At present there is no practicable method of forecasting the medium-range transport and dispersion of pollutants over realistic, complex topography. With this aim in mind a version of the three-dimensional, mesoscale model developed in the Forecasting Research Branch has been made available to the Boundary Layer Branch. In due course it is hoped that a suitably adapted version of this model will constitute a powerful new tool, not only for forecasting the transport of pollutants on specific occasions but also for assessing the suitability of sites for the installation of potential polluting industrial plant.

Some further short-range dispersion trials were carried out during the Sirhowy Valley Experiment in June using harmless, dry-cleaning fluids as a tracer and 'Porton' diffusive sampling badges as detectors. The trials embraced a good range of flow conditions: two releases were performed from the summit ridge in cross-valley flow, two on the valley floor in calm and along-valley flow, and two in the base of the recirculating eddy on the lee slope of the valley. Preliminary analysis of the data indicates the importance of the recirculating eddy which often extends across the windward side of the valley, and the generally marked variability of wind in the valley. Here again the experimental efforts have been complemented strongly by theoretical studies. In particular, the so-called 'random-walk technique' has been extended significantly to be applicable to general inhomogeneous turbulence. Numerical models of airflow over simple orography have also been used in conjunction with the random-walk technique to interpret the results of earlier short-range dispersion experiments carried out on the slopes of Blashaval, North Uist, in 1982. Initial results suggest that although the distortion of the mean flow by the hill may carry a low-level plume quickly down to the surface, local concentrations within the plume will, in neutral and unstable conditions, tend to be reduced by enhanced crosswind motions and to some extent by increased turbulent mixing in the vertical.

*Meteorological Research Flight*

The Meteorological Research Flight (MRF) of the Meteorological Office is located at the Royal Aircraft Establishment (RAE), Farnborough. It now operates a single Royal Air Force aircraft, namely a Hercules C-130, the Canberra having been withdrawn in 1981. Flight crews are provided by the RAF but most of the aircraft maintenance is carried out by RAE personnel.

MRF is responsible for scientific instrumentation installed in the aircraft. The Hercules is extensively instrumented to carry out studies of the lower levels of the atmosphere having in addition to the more traditional sensors (for wind, temperature, humidity etc.), radiometers, equipment for studying cloud structure, a drop-sonde system and an extensive chemical sampling capability. It is used as a research facility by several research Branches of the Meteorological Office (notably Boundary Layer, Cloud Physics and Satellite Meteorology) as well as by universities and other research groups. In addition, studies of some atmospheric processes, notably radiative transfer and mountain waves, are carried out by scientists based at Farnborough as part of the establishment of MRF. Some of the work involves detaching the aircraft from Farnborough and this year there were two namely CAME (see Satellite Meteorology) and NARTHEX (based on Machrihanish, see Cloud Physics and Atmospheric Chemistry).

The instrumentation of MRF aircraft has always been subject to continual review as new requirements generated by evolving research interests have to be reconciled with the need to maintain existing instruments. Thus the past year has seen the installation of an integrating nephelometer (intended to measure scattering by aerosol), more reliable pressure transducers and a further probe for measuring cloud droplets as well as new power sources. Work has started on a multi-channel radiometer due to be installed in 1984 (see below) and there are also plans to fit OMEGA navigation equipment. However the bulk of the effort, over and above that needed for routine maintenance, has been devoted to the design and development of a new data recording system based on microprocessors. This will replace the existing system which is now over ten years old and no longer capable of meeting requirements. The new system will include several novel facilities including automatic test equipment, a quick-look system and a real-time display as well as the basic data gathering facility. It should be available in 1984.

Within MRF itself research effort now concentrates almost exclusively on radiative studies. Basic to this is the provision of radiometers, notably the multi-channel radiometer referred to above. This is based on an instrument previously used in the Canberra and originally built by the Atmospheric Physics Department, Oxford University, as the prototype for a satellite experiment. The modified radiometer will be able to measure radiances in 16 narrow spectral intervals lying in the region 1–16 $\mu$m. The narrow field of view can be scanned from zenith position and in 15° steps from nadir to nadir minus 60°. Three groups are involved, namely MRF, Oxford University and the Rutherford Appleton Laboratory. Among the problems the radiometer will be applied to are the role clouds play in radiation budgets, and the validation of satellite retrievals.

Over the past two years the Hercules aircraft has been making measurements of broad-band fluxes of both visible and infra-red radiation between the surface and 10 km altitude in cloud-free conditions. These data are being used to assess radiative schemes such as that used in the Meteorological Office's 11-level model. In addition, on occasions when the atmosphere is relatively polluted, aerosol characteristics are being recorded in order to see how radiative structure is related to the presence of aerosol. Those studies have revealed heating rates as large as 6 °C per day sustained for several hours, and albedos of about 0.7, somewhat larger than expected. This work is being carried out in collaboration with the University of Manchester Institute of Science and Technology which makes detailed measurements of aerosol characteristics at ground level. Efforts are also being made to improve the aerosol sampling capability of the Hercules, notably by the installation of an integrating nephelometer.

Studies are also carried out in cloudy air. This work has recently been extended to study broken cloud fields and already initial analyses of albedos on occasions of low solar elevation have revealed a consistently non-linear relation between albedo and cloud cover. This may be contrasted with the usual linear assumption. Measurements have also been made in layer ice clouds where an attempt is being made to relate the infra-red broad-band fluxes to cloud structure. Initial analyses show that emissivity is more closely related to total particle cross-sections than to total particle mass.

The analysis of observations of cloud sheets made using the multi-channel radiometer mounted on the Canberra aircraft before it was withdrawn, has been completed. These measurements were made in narrow spectral intervals (1–2 $\mu$m) and when combined with information on cloud characteristics, especially on occasions when microphysical measurements were made concurrently within cloud by the Hercules, provide valuable insights into the radiative characteristics of layer clouds. Thus in many instances it has proved possible to use reflected radiances to distinguish between ice and water clouds, as the ratios of the energy reflected at different wavelengths differ markedly. Several theoretical models have proved capable of predicting reflectivities above water layer clouds but only those which do not assume that cirrus cloud particles are spherical can handle ice clouds — the Monte Carlo multiple scattering model developed in house has proved particularly effective.

The Canberra also completed a series of observations of water vapour in the lower stratosphere before it was withdrawn, covering the period 1974–80 — a manually operated hygrometer (i.e. a Dobson–Brewer) being used to measure humidity mixing ratios. The most striking feature to emerge from these observations was the enhanced variability observed between 45°N and 50°N compared to those at higher latitudes. This would seem to imply that there is a source of stratospheric water vapour south of 45°N, perhaps the subtropical jet stream. Between 60°N and 65°N mean levels of stratospheric water vapour decreased, implying the presence of a sink nearer the pole. There was also an increased probability of observing very high humidities (i.e. $>10$ mg kg$^{-1}$) further north, but the origin of these events is still not clear. The sudden stratospheric warming in February 1979 was generally associated with warmer and moister conditions at higher latitudes compared to other Februarys.

An analysis of data obtained from flights in stably stratified conditions over mountainous areas of the British Isles is almost complete. This has shown that resonant lee-wave disturbances are common and that they can produce vertical fluxes of horizontal momentum comparable in magnitude with surface fluxes and on occasion with fluxes measured over larger mountains. The characteristic wavelengths and variations in amplitude with height are well predicted by simple linear theory, given vertical profiles of wind and stability. However, non-linear theory is needed to produce quantitative predictions of amplitudes and momentum flux. There is also some evidence that, in addition to the lee-wave modes, longer wavelength hydrostatic mountain waves are present, which may be important, particularly in the generation of orographic cirrus cloud.

*Atmospheric chemistry*

The abundance of certain trace chemical species in the atmosphere may influence the general atmospheric circulation and climate through effects on the radiation balance. The effects of species with so-called anthropogenic sources, e.g. sulphur dioxide produced by burning fossil fuels, cannot be fully understood until more is known of the complex interactions involving both the dynamically determined transport processes and the chemical transformations which may occur. The chemical transformations may involve many species with both natural and anthropogenic sources and may be influenced by photochemical effects. A particular aspect of the interaction between meteorology and chemistry has been described in the Special Topic on 'Meteorological aspects of acid rain' but a number of other problems are also being investigated.

In order that long-term atmospheric trends can be detected at an early stage a program of monitoring certain key species is being undertaken. Samples of rainwater collected in special gauges at three sites are analysed by the Laboratory of the Government Chemist. Data from these measurements are exchanged as a contribution to the Background Air Pollution Monitoring Network organized by the World Meteorological Organization (WMO). The problem of maintaining the integrity of such measurements over a long period of time is, however, causing some concern. As a contribution to the WMO sponsored Ozone Monitoring Programme the Meteorological Office undertakes measurements of the total abundance of ozone in an atmospheric column at Bracknell, Lerwick and St. Helena. Routine calibration of the instruments is necessary at about three-year intervals and during the year the instrument at Lerwick was checked, modified and recalibrated. A similar instrument at Mahé, although not operated by the Office, has also been calibrated for WMO.

Progress has been made towards the development of instruments for measuring trace constituents of the upper atmosphere on an occasional basis. An instrument to measure the concentrations of several species by the absorption of solar radiation has been designed. It is expected that this instrument will be used initially for ground-based measurements but that later it will be mounted on an aircraft so that measurements may be made at many locations. A prototype balloon-borne stratospheric grab sampler will be flown shortly. The device collects samples for subsequent analysis on the ground and recent developments have been concerned with preserving the integrity of the sample. An attempt was made during May to measure directly the absorption due to the dust cloud injected into the stratosphere by the eruption of the El Chichon volcano. Although the experimental balloon payload was successfully recovered after a launch from Aire sur l'Adour (France) a fault with the instrument prevented useful measurements from being made.

In order to examine the interaction between the chemistry of the various trace species and atmospheric dynamics it has been necessary to develop a numerical model in which the chemical evolution equations are integrated along the trajectories of air parcels. The isentropic trajectories are derived from the results of an analysis of satellite observations of the stratosphere. Preliminary results obtained using this powerful technique suggest that the depletion rate of ozone may be more rapid than previously suggested in certain circumstances although the sensitivity of these results to the presence of different species has still to be estimated. The representation of the chemical evolution of the constituents in the model was developed using a model of the photochemistry of an atmospheric column. The earlier model has been used to calculate the diurnal variation of some trace species in response to the changes in incoming solar radiation. The results show that composition is strongly height dependent. While earlier experiments with this model concerned the distribution of ozone, data for other species are being extracted for comparison with observations.

The numerical experiments have demonstrated the necessity of making global scale measurements of some trace species if their distribution is to be adequately described. Future satellites will carry instruments to make such measurements and the Office is represented on the scientific team for the Halogen Occultation Experiment. This experiment is to be flown on the Upper Atmosphere Research Satellite which is due to be launched in 1988.

In addition to the atmospheric chemistry studies associated with the acidity of rainfall, measurements of the concentration of trace species in the troposphere and lower stratosphere are being undertaken using the instrumented Hercules aircraft of the Meteorological Research Flight. The instrumentation enables the concentrations of some species to be measured in flight while other species are measured after the flight by chemical analysis of samples of air taken at various times along the flight path. During a detachment of the aircraft to RAF Machrihanish during April many measurements of trace species concentration were made in a variety of situations. The low tropopause height during this period enabled flights to be made into the lower stratosphere and measurements around atmospheric jet streams are being analysed to understand the processes by which the exchanges of air between the troposphere and stratosphere occur. It is believed that 'folds' in the tropopause near such jet streams allow the exchange of air and this hypothesis is being tested. Other flights were designed to investigate the vertical profiles of different species from low levels to the lower stratosphere in order that the factors controlling their distribution could be assessed. The results suggest that OH was produced in the troposphere following the injection of ozone associated with a cut-off depression. The production of OH was accompanied by a decrease in the hydrocarbons present. Further analysis of the observations made during this period is continuing.

*Satellite meteorology*

The highlight of the year was the decision to proceed with the Meteosat Operational Programme which was reached at a Conference of Plenipotentiaries held in Geneva in May. The plans call for three operational satellites, similar to the current experimental Meteosat but with some improvements and longer design life. Meteorological coverage is expected to be provided under this program from 1987 to 1995 by Meteosat in geostationary orbit above the Greenwich Meridian. Staff from the Office played a significant role in the working groups which paved the way for the decision to proceed.

A small computer system was installed in March to convert raw sounding data from the US polar-orbiting satellites (TIROS-N) into profiles of temperature and humidity. Data for an area within about 3000 km are received at Lasham and transmitted to Bracknell for processing. Meteorologically useful profiles, with a horizontal spacing generally better than 100 km, are then available within 40 minutes of observation. By October the system was working very much as planned. A comparison between a conventional analysis of 1000–500 mb thickness, Figure 15, and the corresponding analysis based on satellite data alone, Figure 16, shows the general agreement but also clearly indicates the additional detail provided over the Atlantic by the satellite data. The system has been set up using software kindly provided by the US National Oceanic and Atmospheric Administration (NOAA) as a basis for the method of retrieving meteorological parameters.

A major line of research during the year has been directed towards making better use of the sounding data from satellites. The sensing technique used is not capable of penetrating most clouds. As a result, methods of allowing for cloud in partly cloudy areas are crucial to obtaining the maximum geographical coverage. Various improvements to present operational cloud-clearing schemes have been considered. Work also started on a new scheme for retrieving humidity profiles and some fundamental research was undertaken which may form a basis for moving to improved operational methods of retrieving meteorological data from sounding information. A number of case studies were undertaken before it became possible to acquire sounding data in real time. The results of these studies were presented to an international liaison group interested in the TIROS Operational Vertical Sounder (TOVS) in September.

Discussions with NOAA's National Environmental Satellite and Data Information Service (NOAA/NESDIS) have resulted in a proposal to fly an Advanced Microwave Sounding Unit (AMSU) on TIROS-N from the late 1980s. The AMSU has the particular merit that it can make measurements through cloud. It has been agreed in principle that the Office should contribute the section of AMSU principally concerned with measuring water vapour and liquid water. By the end of the year contracts had been awarded to Industry and to the Rutherford Appleton Laboratory for preliminary studies.

In March an experiment was conducted to compare microwave brightness temperature measurements with *in situ* measurements of temperature and humidity over a wide range of atmospheric conditions. The US National Aeronautics and Space Administration provided a Convair 990 aircraft which carried a radiometer similar to that proposed as the Office's contribution to AMSU. The Meteorological Research Flight Hercules C-130 made the *in situ* measurements, using 29 dropsondes and 5 aircraft profiles co-located with radiometer data. The results are still being analysed but the intention is to demonstrate the effects of high water vapour content, rainfall and other disturbances on the accuracy of humidity profiles based on microwave radiometer data. The experiment, called CAME, was conducted in the triangle between Gander, Bermuda and Barbados with a spur down to 5°N.

Stratospheric Sounding Units (SSUs) continue to be supplied to NOAA/NESDIS for the US TIROS-N series of satellites. An SSU was launched on NOAA-E in March. On achieving orbit the satellite was found to be tumbling. Despite considerable concern, the satellite was brought under control within a few weeks and entered service as NOAA-8, to replace NOAA-6 whose imaging system had an intermittent fault. The performance of the SSU on NOAA-8 is not quite as good as the one on NOAA-6, however. The heights

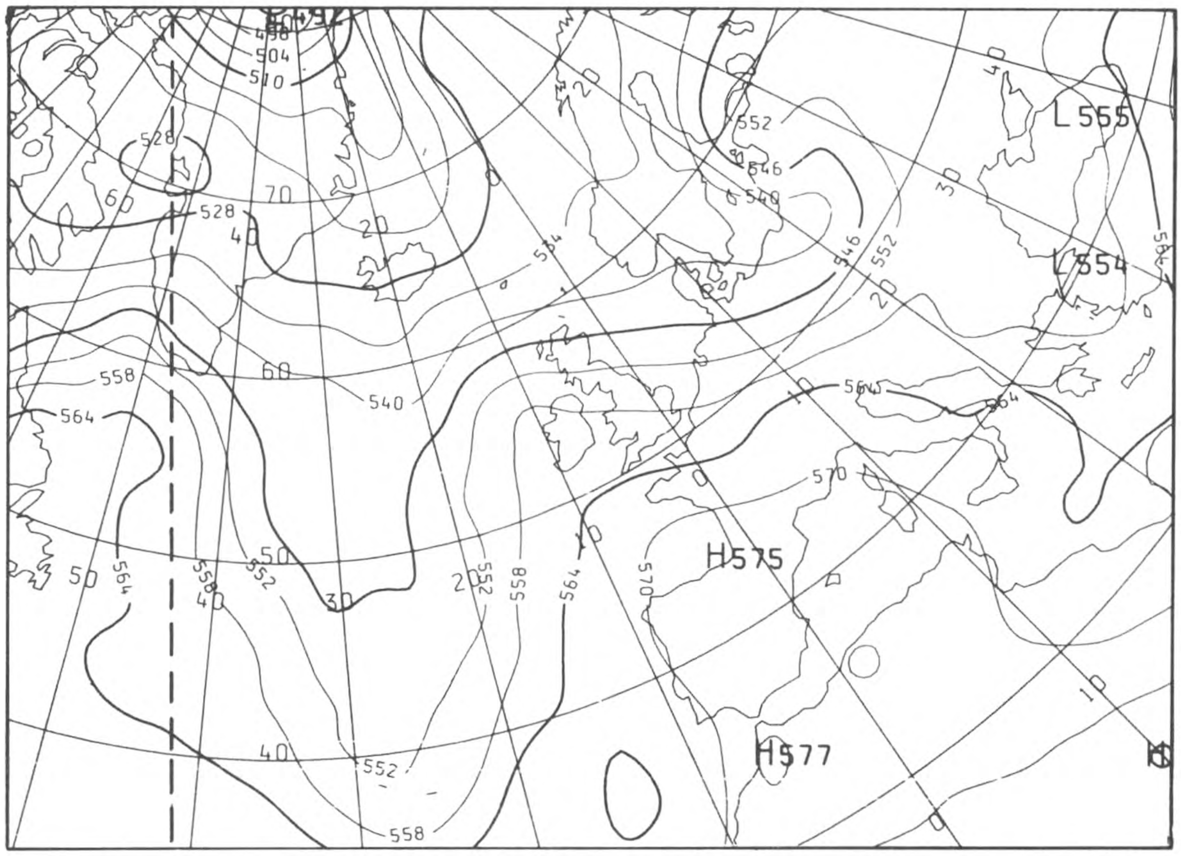


Figure 15—A working chart from the Central Forecasting Office for 00 GMT on 23 September 1983

The isopleths are the 1000–500 mb thickness analysis derived from routinely available meteorological observations, including a few satellite data. The patterns show a deep trough at 30°W. The analysis made 24 hours later shows that this trough developed into a closed circulation at about 45°N.

at which the SSU measures stratospheric temperature are drifting slowly but it is nevertheless expected that the instrument will remain useful for its design life of two years. One channel of the SSU on NOAA-7 has drifted so far that it cannot be used. Because suitable corrective action was not taken during the channel's active period NOAA's archive will have to be recalculated. The underlying problem seems to be a change in the gas content of some of the pressure-modulated cells of the SSUs and the possibility of remedial action on the unflown SSUs is being considered.

Under a Memorandum of Understanding with the Rutherford Appleton Laboratory the Office is making a contribution towards the Along Track Scanning Radiometer (ATSR) which is to be flown on the European Remote Sensing Satellite (ERS-1). ATSR is designed to make more accurate measurements of sea surface temperature by providing better corrections for the errors introduced by the atmosphere. The Office's design for the focal plane assembly, essentially the detectors and associated optics, is largely complete.

International liaison continues to be a major feature of satellite meteorology and a number of topics deserve mention in addition to the Meteosat Operational Programme. Representatives have regularly attended meetings of a number of groups under the auspices of the European Space Agency.

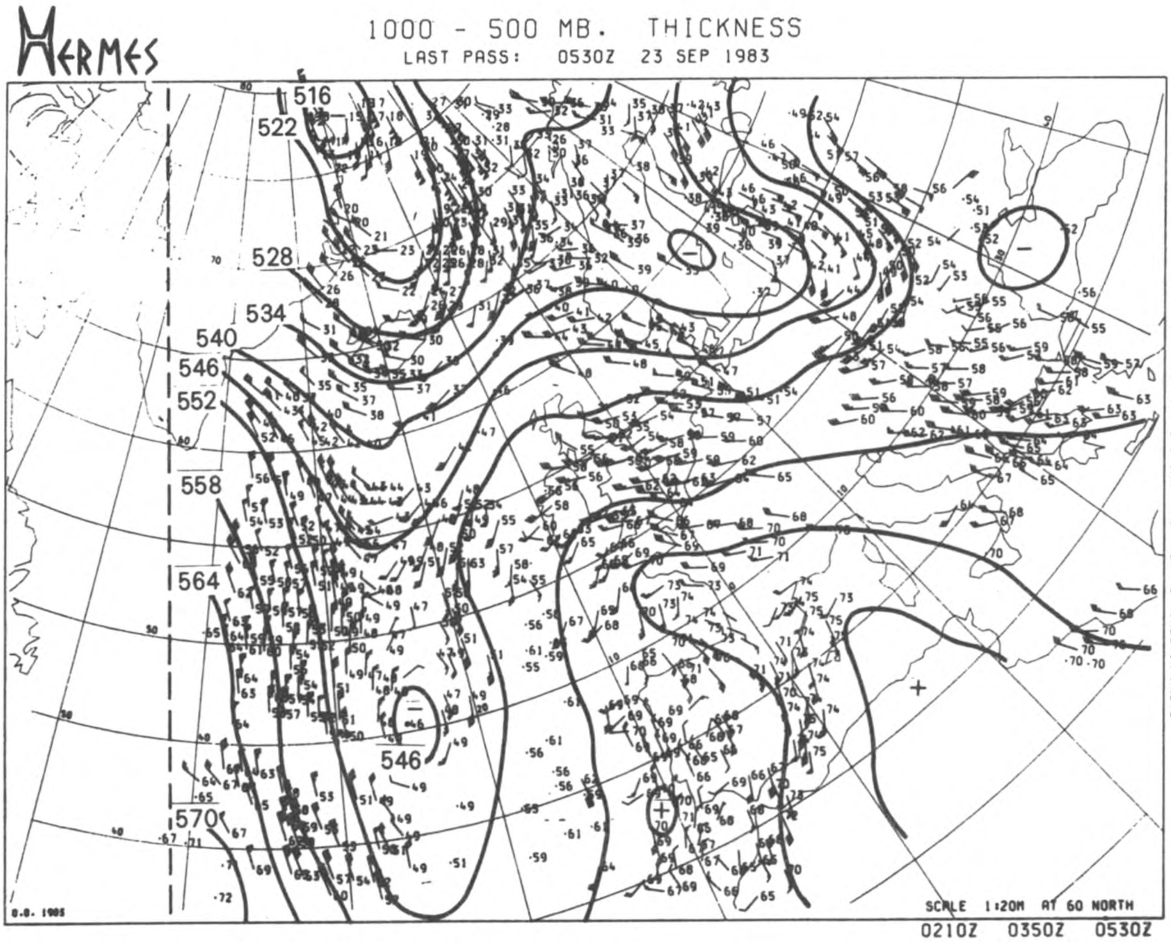


Figure 16—This chart shows observations from the HERMES system, derived from satellite data alone, giving the individual 1000–500 mb thickness values (last two digits of value in decametres), the derived thermal wind vectors and the thickness isopleths.

The data were obtained from three passes of the NOAA-7 satellite a few hours after the time of the chart shown in Figure 15. The density of observations is such that a closed circulation is already clearly visible at 45°N, 25°W. The patterns over the rest of the chart are broadly similar to those in Figure 15, taking into account the small time difference.

Among these are the expert group on the ERS-1 Active Microwave Instrument, the algorithm development group for that instrument, the ERS-1 data team, Program Boards for Meteorology, and the Meteosat Operations Advisory Group. Such liaison is essential to make progress on major international projects. The extent of the Office's involvement can be gauged from the appropriate entries in Appendix III. The future provision and funding of civilian polar-orbiters for meteorological use has also been under discussion.

An experiment to test the feasibility of direct reception of high resolution digital data from TIROS-N satellites was conducted. The results indicated that this approach would probably be effective. However, recent developments in telecommunications now offer the possibility of implementing a wide-band link from Lasham to Bracknell capable of handling high-resolution digital imagery. Taking into account wider MOD interests it was decided to go ahead with improving the link from Lasham. Another experiment was being organized towards the end of the year. This is for the low-cost reception and display of Meteosat imagery as retransmitted in analogue form. The system is portable and so, when fully developed, will be suitable for use at exhibitions and selected outstations as the need arises.

*The Short Period Weather Forecasting Pilot Project*
The ability to analyse cloud and precipitation patterns has been greatly improved by new methods of processing, transmitting and displaying radar and satellite imagery. These improvements are expected to lead to increased accuracy and detail in local forecasts of precipitation for periods of 0 to 6 hours ahead and in some cases up to 12 hours ahead. The Short Period Weather Forecasting Pilot Project which began at the Meteorological Office Radar Research Laboratory in Malvern in 1978 is aimed at developing the necessary observational and analysis facilities and optimizing their effect on the forecasting capability of the Meteorological Office.

The embryonic network of weather radars which has been in use since 1979 consists of radars at Camborne (Cornwall), Upavon (Wiltshire), Clee Hill (Shropshire) and Hameldon Hill (Lancashire). They provide qualitative coverage over a large part of England and Wales. A further radar covering London and south-east England is under construction and will be operational next year. Rainfall data from individual radars are sent digitally at 15-minute intervals to a number of forecasting offices and Water Authorities. The data are in the form of rainfall patterns and in some cases accumulations over river subcatchments. In addition, data are sent to the Meteorological Office Radar Research Laboratory at Malvern where a composite display is generated automatically within about 5 minutes of data time and retransmitted to a few forecasting offices. The rainfall data can be displayed on a colour television monitor as a matrix of 5 km squares based on the National Grid. Facilities exist for action replay of sequences of pictures.

The main source of satellite data in the Pilot Project is the half-hourly imagery from the geostationary satellite, Meteosat. Visible, infra-red and water vapour imagery are received digitally by means of a Primary Data User Station (PDUS) at Malvern. The resulting pictures are automatically remapped to a National Grid projection identical to that of the radar data and displayed within about 20 minutes of nominal data time. These cloud pictures are of interest in their own right; however, procedures are also being developed to analyse the cloud data in terms of precipitation to extend the analysis beyond the area covered by the radar network. There is no simple relationship between cloud imagery and surface precipitation and the procedures being developed involve some subjective interpretation by a meteorologist.

The rainfall information which is derived from radar and satellite is useful because it is in the form of detailed fields and when used in conjunction with other observations it constitutes a very helpful analysis tool for the local forecaster. However, one of the difficulties with the rainfall fields derived from radar and satellite is that most of the sources of error are physical in nature rather than due to straightforward instrumental errors. That is to say, the instruments do not measure the wanted parameter exactly. A good knowledge of the general meteorological situation is needed in order to correct for these errors and this calls for the development of analysis procedures whereby the radar and satellite data can be compared with other forms of meteorological data. These procedures must be carried out quickly if the resulting analyses are to be available promptly enough to be useful and to this end an advanced man–computer interactive video display system is being developed. The interactive display system, known as FRONTIERS, was delivered by a contractor, Logica Ltd, during the year. In addition to its role in enabling the forecaster to analyse and control the quality of the rainfall information from radars and satellite, FRONTIERS is designed to enable extrapolation forecasts to be made for the period 0 to 6 hours ahead using computerized rain cell identification. These forecasts are expected to be best over the first 2 or 3 hours and as such should complement those likely to be provided by the mesoscale numerical model discussed elsewhere in this Report. Trials of the FRONTIERS interactive display system have been started using a special team of forecasters to operate it. Procedures for quantitatively assessing the performance of the system have been developed and demonstration trials are planned for 1984.

The Pilot Project will have reached a satisfactory conclusion in a year or two if, as is planned, the radar and the analysis system are put on an operational footing. In the meantime the unedited radar network data are being disseminated as nearly as possible on a regular basis in parallel with the continuing development work. During this year, for example, bright-band detection and correction software, and ground clutter cancellation hardware have been developed, although neither has yet been implemented. Archiving procedures have continued to be improved. New user display systems have been specified and developed; one of them is a low cost system based on a microcomputer. Various software has been written to link the Network, PDUS and FRONTIERS computer system and also to provide products for the COST-72 European Weather Radar Network Project. Rain-gauge calibration procedures at two of the radar sites have been improved and assessed; in particular work carried out as part of the North West Weather Radar Project has shown that the accuracies being achieved in the real-time system are comparable with those achieved off-line in the earlier Dee Weather Radar Project. During the latter part of the year one of the radars (Clee Hill) has been rehoused in a new radome on a tall pedestal; this will minimize earlier difficulties with radome-attenuation effects and will provide improved coverage over parts of Wales. Radar network and satellite data acquired as part of the Pilot Project are also being used, together with supplementary radiosonde ascents from Malvern and other, operational, stations in the UK, for studies of the structure and evolution of mesoscale weather systems. These studies are leading to the development of conceptual models which help the forecaster to understand and interpret the new forms of data. One particularly interesting study has shed light on the nature of mesoscale convective complexes, a kind of weather system producing extensive thundery rain which is not easy to forecast by conventional means.

Finally, and most important, liaison continues to be actively maintained with operational users of the radar and satellite data, thus providing useful feedback. For example a recently completed trial at an aviation forecast office showed that the forecasters 'found the information invaluable for analysis while the ability to (action) replay stored data has given much greater impact to their verbal briefings'.

*Geophysical fluid dynamics*

The high degree of complexity of the atmosphere tends to obscure the fundamental factors that control large-scale atmospheric motions. The main work of the Geophysical Fluid Dynamics Laboratory is intended to explore basic dynamical processes in rotating fluids, of which the earth's atmosphere is but one example. Other natural fluid systems in which rotation plays a dominant role are the oceans, the liquid core of the earth (where the earth's magnetism originates) and the atmospheres of other planets.

Co-ordinated studies of dynamical processes in rotating fluids are carried out using several methods. These comprise: (a) the detailed examination of flows in laboratory systems, (b) computer simulations of these flows and (c) the mathematical analysis of a variety of related but simpler systems. The laboratory studies suggest new ideas and lines of theoretical research, while the combination of laboratory measurements and computer simulations provides amongst other things a unique opportunity to subject numerical models to tests of performance that are much more stringent than those possible in corresponding numerical work on atmospheric motions. In the laboratory the external conditions can be varied over a wide range and meteorological theories thereby tested in a manner which is not possible if they are applied only to the atmosphere. One cannot for example change the rate of rotation of the earth to see if a theory continues to apply, but one can change the rate of rotation of the fluid container in the laboratory.

Many features of the large-scale atmospheric circulation can be reproduced in liquid filling a rotating annular tank, 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 regular wave-like perturbations or it may be highly irregular. The regular wave-like perturbations may be either steady, shape preserving waves or 'vacillating' waves whose amplitude or shape varies periodically. Laboratory studies have established the external conditions under which such regimes are to be expected. 'Intransitive' behaviour of the system, where more than one equilibrium state can occur for the same external conditions, greatly complicates these studies and has implications for climatological investigations. The progression from axisymmetric through regular wave-like patterns to highly irregular patterns is now known to be typical of the behaviour of many dynamical systems and is the subject of a considerable amount of mathematical research in institutions around the world.

An important adjunct to these investigations is the development and exploitation of advanced laboratory and numerical techniques. Equipment for determining flow velocities throughout the fluid from TV images of the motion of neutrally buoyant particles is now significantly extending the range of diagnostic techniques available for laboratory studies. For example, it is now possible to make detailed investigations of energy transformations in time-varying flows.

The computer model which is used to simulate the laboratory flows has such a fine resolution that the only sub-gridscale processes present are molecular viscosity and thermal conductivity. It produces the same qualitative flow phenomena as seen in the laboratory, although appreciable differences have been found in the external conditions under which certain types of flow — such as amplitude vacillation — occur. Quantitative comparisons of laboratory measurements and numerical simulations of steady waves have given good results. These comparative studies, both qualitative and quantitative, have implications for attempts to model the more complex flows found in the atmosphere.

The combined laboratory plus numerical approach also assists in the development of a soundly based theory of atmospheric predictability (which is a major goal of the work). For example, the occurrence of the regular-wave regime in the annulus system is of major theoretical significance and has not yet been fully explained. The very existence of such waves shows that non-linear processes can promote order rather than disorder in the flow, and implies that theories of atmospheric predictability based on traditional turbulence concepts may be unduly pessimistic. Laboratory experiments are providing considerable insight into the ordering influence of non-linearity and numerical simulations give valuable data for testing of theoretical models and hypotheses.

Wave motions of the same general type as those generated in the 'thermally driven' annulus can also be produced in a mechanically driven system consisting of two immiscible layers of fluid in a rotating tank with a lid which rotates faster or slower than the tank. In some respects the mechanically driven system roughly corresponds to the wind-driven circulation of the oceans. Experiments with two-layer mechanically driven systems have clarified a number of important questions concerning non-linear interactions of baroclinic flow. Our latest work in this area is with numerical models and aims to elucidate the different balances in steady and vacillating flows.

The high resolution pictures of the atmospheres of Jupiter and Saturn, obtained by Voyager 1 and 2 space probes, confirm that Jupiter's Great Red Spot and other dynamically similar, although smaller, features are very stable eddies embedded in regions of highly sheared flow. The baroclinic hypothesis as to the nature of the eddies, introduced recently by the Branch, has received additional striking support with the discovery of a stable, azimuthally localized baroclinic eddy during laboratory and numerical studies of thermal convection in systems subject to internal heating. Further investigations into the mechanism behind this phenomenon may provide considerable insight into the isolated nature of the Great Red Spot and other atmospheric eddies.

Studies of the origin of planetary magnetic fields and the structure of planetary interiors have continued. We have investigated non-linear magnetohydrodynamic waves in rotating fluids and developed further theorems in electrodynamics, encouraged by the highly successful application of one such theorem to the problem of probing planetary interiors using magnetic data. Papers have been completed and published concerning potential vorticity mixing and atmospheric super-rotation and on angular momentum fluctuations of the earth's atmosphere, length of day changes and polar motion. The many ramifications of the latter work (which includes the demonstration that atmospheric excitation makes a major contribution to the generation of the Chandlerian wobble and the elucidation of a pronounced fluctuation in the atmospheric general circulation on a time-scale of about seven weeks) in geodesy and solid earth geophysics as well as in meteorology are now being pursued by groups in several countries including a special working group set up by the International Union of Geodesy and Geophysics.

## Dynamical and Synoptic Research

*Research related to numerical forecasting models*

Work under this heading is divided between development of improvements to the new operational numerical weather forecasting system introduced in September 1982, and on proposed extensions to the system planned for the next few years. Particular items under the latter heading are the introduction of an analysis system using the 75 km grid of the fine-mesh model, and the development of a mesoscale forecasting system using a 10 km grid over the British Isles to a standard where it will be available for operational use in 1985.

Now that the new data assimilation scheme has been brought into operational use, efforts have been directed to developing and testing modifications both to improve the quality of the analyses (which are made every six hours) and to reduce the computer time used. Thus the rate at which observed data are assimilated into the model has been studied. In the original scheme, differences between observed values and model 'first-guess' values based on the forecast for the same time were calculated and the model values corrected towards the observed values at each time-step over the whole six-hour period. This correction was calculated as a fixed fraction of the difference between observed and model values. Since the six-hour period is not symmetrical about the time of observation but ends at it, there is a danger that the model will fit the observations at too early a time. The scheme was therefore modified to use a correction with a fraction of the difference between observed and model fields that varied with time. When incorporating such increments into the model, there is a tendency to generate high-frequency noise as well as to correct the model values. This was originally corrected by adding an extra term to the equations which damped the vertically averaged divergence. Though the highest frequencies of gravity waves are associated with a distribution of divergence that is independent of height, it was found that spurious waves were also excited in the assimilation with divergence that changed sign in the vertical. An additional modification was developed that damped the complete divergence field. These two modifications together were found to result in considerable improvements in the analysis. The tropical wind fields were much smoother and more realistic and some spurious features near steep mountains such as the Andes were removed or reduced. At the same time the average error in fitting the observations was also reduced. The changes were therefore included operationally.

A major difficulty in analysis schemes is always the incompleteness of the data coverage. This means that the maximum amount of information has to be extracted from each observation and, in particular, pressure and temperature observations have to be used to give information about the winds and vice versa. In the new analysis scheme this is done by using the geostrophic relation to deduce wind increments from pressure increments and the hydrostatic relation to deduce temperature increments from pressure increments. Further experiments have led to improvements in the techniques for incorporating these increments into the assimilation.

Another difficulty in the analysis scheme occurs in the neighbourhood of mountains. Observed surface data at a station level have to be used to modify model surface values in the neighbourhood, which may be at widely varying heights above sea level. The most promising solution to this problem at present has been found to be the use of sigma (pressure normalized by surface pressure) rather than pressure coordinates in this part of the analysis. Such usage, however, has disadvantages when dealing with surfaces well away from the boundary layer. It may be that a hybrid sigma and pressure coordinate system would be even more effective and work is continuing to that end. A number of other proposed modifications to the analysis scheme have been tested, but found not to have clearly beneficial effects. The procedure for testing such modifications has become more important as the general standard of analyses has increased and potential improvements become more subtle. Facilities have been developed to allow detailed diagnostic case studies to be carried out. It is now possible to calculate basic and derived fields and cross-sections and display them in detail for selected areas from any of the analyses, the forecast first guess, or, for comparison from the analysis made at ECMWF for medium-range forecasting purposes. Cases have already been found where differences in four-day forecasts for the United Kingdom issued by different centres can be traced back to differences in the analyses of particular variables over the Pacific.

The operational forecasting system includes a fine-mesh model with a 75 km grid as well as a global model with a grid-length of 150 km. At present the initial data for the fine-mesh model are derived by interpolation from the analyses prepared for the global model. This means that extra detail in the data that could have been resolved by the fine-mesh model will be missed; satellite-derived temperature fields are but one example. A computer program to allow a fine-mesh limited area version of the assimilation to be carried out has been written. Considerable testing of this will be required before deciding how best to include it in the operational schedule.

It is necessary also to assess the possible effect of new sources of data independently of the assimilation scheme. This is because the techniques of assimilation may not yet be adequate to obtain full benefit from the data. Therefore alternative methods of analysing data using spline functions are being studied in conjunction with a CASE student at the Royal Military College of Science.

Although it is hoped that the use of an assimilation scheme in which the model smoothly adjusts to input data will automatically produce fields consistent with the model formulation (in particular with pressure and wind fields in approximate geostrophic balance outside the tropics), it has been found in a number of case studies that there are on occasion large apparent differences between the analysed winds and the implied geostrophic wind. In several cases, these occasions have been related to forecasts of a lower standard than normal. As a tool for investigating these cases, a normal mode initialization scheme has been developed. This is a method of deriving a balanced wind and pressure field from initially unbalanced data. Though it could be used directly in the analysis procedure, it is more likely to be useful as a diagnostic tool in determining what influence particular observations, or particular parts of the analysis procedure, have had on the forecasts.

The beginning of the year saw the operational introduction of a computationally efficient global version of the 15-level coarse-mesh forecasting model. This replaced an earlier version of the model whose integration area covered the region of the earth north of 30°S. The model has a horizontal resolution of approximately 150 km and is used in the Central Forecasting Office to provide forecasts for up to 6 days ahead. Great care was taken to ensure that this version of the model runs efficiently on the CYBER 205 computer and much work during the year has gone towards consolidating this effort. For example, much of the economy in memory and computer time was achieved through changes to the method of applying the zonal filter necessary to retain computational stability near the poles. In essence this involved switching from filtering the tendencies to filtering the model's prognostic fields. This had led to roughnesses developing in the forecast height fields above 500 mb. The cause was traced to a property of potential temperature, a prognostic field, which was filtered along the model's terrain following sigma coordinates. At upper levels this variable changes quickly with height and its variation along a sigma level is thus strongly influenced by the orography of the model. A hybrid scheme which filters a combination of temperature and potential temperature, changing from potential temperature at the surface to temperature at upper levels, has partially solved this problem.

Other investigations of deficiencies in the model are continuing. There is a known tendency for the central pressure of continental depressions to be held too deep during the later part of their life cycle. This is thought to be caused by a poor treatment of the momentum transfer between the free atmosphere and the surface layers in the model. Tests where the surface friction was enhanced by relating it to orographic height have met with only partial success and further work is necessary.

In order to separate the effects of modelling errors in large-scale forecasts from those of errors in the initial data a project is being carried out in which analyses produced by the Meteorological Office data assimilation system and ECMWF's are used as initial data for forecasts run with the two centres' models.

Development of the operational limited area fine-mesh forecasting model has also continued. This model has a horizontal grid-length of 75 km and covers an area consisting of the North Atlantic and western Europe. It is used mainly to predict the detailed weather, in particular the rainfall, in the region of the British Isles for periods up to 36 hours ahead. During the winter months there were several occasions when this model became unstable and had to be rerun using a reduced time-step. These cases were characterized by areas of strong wind flow close to the southern tip of Greenland. Tests showed that this problem was related to the approximate form of the Fourier chopping procedure designed to maintain stability at high latitudes by removing high wave number components from the model's prognostic fields. The nature of the Fourier Transform is unsuited to the limited domain of the fine-mesh model and it appears that the approximations which were necessary to implement this filter could lead on some occasions to an unstable amplification of the short waves due to an aliasing of unresolved wave numbers with those waves sensitive to the steep Greenland orography. An alternative method of filtering has been developed which uses a local multi-point approximation to the Fourier Transform and is therefore better suited to the non-cyclic nature of a limited domain. This filter, which damps the amplitude of all the unstable wave numbers by an amount which ensures stability, has been tested successfully on these cases and has been introduced into the operational model.

A unified version of the global and fine-mesh models has also been completed. This is based on the efficient global model program code and ensures that improvements in formulation can be easily promulgated through all versions of the model. The economic use of computer memory employed in this program has allowed a version of the fine-mesh model to be run experimentally with a 50 km horizontal grid-length. This takes 35 minutes to complete a 36-hour forecast, as compared with 10 minutes for the 75 km version, on the Cyber 205 computer. This higher resolution version of the fine-mesh model will be used for case study investigations of occasions of severe weather. These are often associated with meteorological features whose horizontal dimensions are no greater than a few hundred kilometres. Forecasts with this increased resolution will play an important role in assessing the proposed fine-mesh analyses when these become available.

Other aspects of the fine-mesh model have received attention. Modifications to the lateral boundary conditions were found to be necessary in order to control small but misleading fluctuations in the surface pressure during a forecast. The operational schedule requires the global model to be run later than the fine-mesh model in order to allow time for observations from distant parts of the globe to be received for the global analysis. Consequently the lateral boundary values were taken from a global forecast starting 12 hours earlier and not from a current analysis as is required for consistency. This procedure has now been changed so that an extra hemispheric forecast is run from the same initial time as the fine-mesh model in order to provide more consistent boundary values.

The quality of precipitation forecasts has generally improved over the past year; this is particularly true of frontal rainbands which are now more coherent than at the time of the model's introduction. Much of this can be attributed to the smoother nature of the fine-mesh forecasts as a consequence of the revised boundary updating procedure and the improvements to the analysis scheme. One aspect of the precipitation forecasts, however, which caused some problems, is a tendency for the model to predict erroneously small amounts of convective rainfall when in reality the weather remains dry. At present such rainfall can be generated whenever convective cloud forms in the model. This is clearly wrong as can be seen on any day of fair-weather cumulus. A reformulation of the convection scheme has, therefore, been necessary. Tests are now taking place of changes which prevent precipitation forming until a critical cloud depth has been reached. A revised method of calculating the effects of the evaporation of the rain falling through the relatively dry air below the base of the convective cloud is also being tested.

A full interactive radiation scheme has been developed for use in all forecast models. The scheme uses predicted humidities and inferred cloud amounts to calculate the reflection, absorption and emission of solar and infra-red radiation. At present climatological distributions of cloud and humidity are used in the radiation calculation. Because of limitations imposed by the current size of computer memory, however, this scheme is only being considered for the fine-mesh model. It is expected to provide improved surface temperature forecasts and enable forecasts of cloud amounts which are not available currently.

An important part of the research plan has taken the form of detailed case studies. Some of the results that have been obtained by comparing forecasts made in the Meteorological Office with forecasts made at ECMWF have been described already. As a more ambitious experiment in this direction, the GARP Working Group on Numerical Experimentation has recently organized an international experiment to compare seven-day forecasts using the models of a number of research centres. These forecasts were all run from the same initial conditions (the ECMWF FGGE IIIb analysis for midday on 21 January 1979, during the first Special Observing Period). All the models made similar serious errors early in the forecast, of which the most likely explanation is that the initial analysis contained substantial errors despite the sophisticated analysis scheme and the unprecendented quantity of data. To investigate this further, a set of forecasts is being prepared using the current operational Meteorological Office model to be run from alternative analyses for the same time.

The new operational forecasting system provides forecasts using a 75 km grid over Europe and the North Atlantic. Though this provides a reasonable amount of detail over the United Kingdom, it is not possible to provide forecast guidance on all the scales required by users or to take advantage of the high-resolution data available from the surface stations, the radar network or satellite imagery. A mesoscale model, which will ultimately cover the British Isles with a 10 km grid, is therefore being developed to meet this need. At present a restricted area is being used, covering England and Wales. Expansion to the full area awaits enhancement of the Cyber 205 computer. The prototype forecast suite has been assembled and several case studies run with encouraging results. The model has 16 levels in the vertical, the lowest being at 10 m and the highest near the tropopause at 12 km. The first stage of the forecast process is to run the operational fine-mesh forecast, modified to produce values of its main variables over an area somewhat larger than the British Isles every three hours. These data are interpolated horizontally and vertically on to the mesoscale grid to initialize the model and provide boundary conditions. These fields also provide a first guess for objective analyses of surface temperature, humidity, wind and visibility, cloud base and amount, and rainfall rate observations. The analyses are used to adjust all variables in the boundary layer and to specify the cloud and humidity distributions. The forecast is currently run for 12 hours from these initial conditions with 3-hourly output. Several parts of the forecast model have been improved during the year. A representation of turbulent diffusion using an explicit prediction of turbulent kinetic energy was incorporated and resulted in a time saving as well as a more realistic representation of the boundary layer. In addition, this will allow regions of turbulence in the free atmosphere to be predicted. A more complete treatment of the surface radiation balance, including the effect of clouds, has been inserted. An extra term was added to the upper boundary condition to prevent unrealistic large changes in the mean pressure of the model. A deep convection scheme has been designed and tested independently of the model with encouraging results. Testing inside the model is at an advanced stage. Several new output facilities have been added to the suite. Most notable is that for viewing model fields on a colour graphics VDU before deciding which ones to make hard copy of. An option to output information for a limited number of points every time-step has also proved valuable, particularly in showing temperature variations and the predicted rainfall intensity. Recently, work has started on using the colour graphics VDU to permit interaction with the analyses used in the preparation of initial data for the forecast.

The problem of evaluating the forecasts made by such a model is not trivial. Much more detail is produced than by the fine-mesh model, for instance, perturbations to the wind field caused by sea-breezes or mountains. There are insufficient data in the conventional network to check all this. Thus it is necessary to compare time series at individual points as well as maps at fixed times, and to make full use of radar and satellite information.

The research described so far is based on constructing large computer models of the atmosphere, and verifying the results using real data. Though a considerable degree of success has been achieved, particularly on the large scale, persistent faults have been noted. An example of this is poor performance in predicting the onset or renewal of blocking patterns in the upper air which determine major changes in weather types. Another is the poor handling of organized convectively driven rainfall areas, which are often associated with the heaviest rainfall in the spring and summer. The general standard of rainfall forecasts still falls short of the standard of pressure and wind forecasts. Experiments have shown that it is difficult to make major changes to model predictions by making changes to the formulation of the type discussed earlier in this report. It is therefore necessary to consider more fundamental changes, but not so large as to affect the many correct aspects of current model performance.

Recent developments in the mathematical theory of numerical models suggest that existing techniques will predict smooth regions of the flow successfully but are not guaranteed to handle singular regions correctly. An example of a situation which may be mishandled is the occlusion process in the life cycle of a depression, which depends on correctly representing the frontal dynamics. In particular cases it may be necessary to predict singular regions correctly in order to predict the evolution of the large-scale flow; these will be the most difficult cases to forecast.

Several research projects are therefore in progress which examine the dynamics of singular regions in the atmosphere and test whether current numerical techniques are sufficient to handle them. The first example studied is the hydraulic jump, which may be associated with strong mountain winds or the sea-breeze front. It has been found that conventional finite difference schemes that conserve momentum will model these correctly, provided that the artificial diffusion used to capture the jump is not too scale-selective. This suggests that the highly scale-selective schemes used in the operational models may no longer be appropriate when the grid-length is substantially reduced.

The second case studied is a two-dimensional model of frontogenesis. Conventional schemes appear to be unable to propagate a discontinuity into the interior of the flow, because any air originally in contact with the ground has to remain there. This suggests that the occlusion process, where a warm air mass is undercut by cold air, may be mishandled. It has been found that an alternative scheme for representing the sub-grid-scale dynamics based on the geostrophic momentum approximation can predict discontinuities propagating in to the interior. This work is being extended to three-dimensional models in order to see if the life cycle of depressions can be better represented.

The third case studied is the dynamics of three-dimensional turbulence. It is known that such turbulence is highly intermittent and its structure is strongly influenced by large-scale effects, for instance, rotation or stratification. At present its effects are represented in models by horizontal eddy viscosity. It is hoped that, by constructing accurate models to illustrate the small-scale dynamics involved, better representations can be designed.

*General circulation of the atmosphere*

An understanding of the physical basis of the general circulation of the atmosphere and the development of methods to simulate it accurately using numerical models can be expected to have major influences on improving both long and short period weather forecasting. It is also central to a worthwhile assessment of the degree of future climatic change due to natural or man-made factors. Work in this area has continued to receive a high priority. Data obtained during the 1979 international global observing experiment form the most comprehensive archive for research on the general circulation of the atmosphere that has so far been produced. However, in several respects, the global circulation during the year of the experiment was not typical and consequently there is much to be gained by comparing these observations with the less comprehensive sets available for other years. Examples illustrating the range of aspects examined using the 1979 data are monthly mean maps and zonal averages of basic quantities such as wind and temperature, derived quantities such as horizontal divergence, standing and transient eddy variances and covariances, heat, moisture and momentum fluxes and budget calculation. Filters suitable for separating transient eddies into different time scales have also been useful; for example, the variance of the 500 mb height field following the application of a band-pass time filter to select disturbances with periods of 2–6 days is being used as an indication of the storm tracks; fluxes of heat and momentum are being related to these tracks. Another aspect being studied is the feasibility of completing atmospheric regional energy budgets sufficiently accurately to derive oceanic fluxes as a residue. As well as using the observational data to study the general circulation, investigations are being made of the impact that various observing systems have on our ability to perform accurate analyses of weather systems and of the global atmosphere. This question is likely to have an important influence on the design of the future global weather observing network taking into account the costs and scientific value of setting up and maintaining various satellite and aircraft borne and surface based observing instruments.

Numerical simulations of the general circulation have been made using the 11-layer model. The computer program has been written so that several different resolutions on a latitude/longitude grid can be used. Those in use during the year are $2° \times 3°$, $2\frac{1}{2}° \times 3\frac{3}{4}°$ and $5° \times 7\frac{1}{2}°$; the second of these has been the one most frequently adopted since it provides a sufficiently fine resolution for the representation of the principal aspects of the atmospheric motion without involving unacceptable amounts of computing time. The computer programs have been developed during the year to enable the model to be run with greater ease and efficiency. Output from the model is automatically archived on magnetic tape and a wide variety of diagnostic quantities can be recorded during the progress of the model run.

Much of the development work on the model has been concerned with the techniques for representing sub-grid-scale physical processes. Several integrations have been performed using interactive model-generated cloud radiation, with a view to examining the sensitivity of the model's radiation balance to prescribed cloud properties. The main shortcoming apparent in these simulations using an interactive cloud scheme is the tendency for the lower atmosphere to cool excessively leading to the production of spurious low-level cloud over the oceans. Detailed comparisons of the long-wave radiation scheme used in the model with other methods of parametrizing this aspect of the physics have been made in order to understand and correct a significant underestimate of the downward long-wave fluxes in clear skies. Improvements have been obtained by revising the infra-red spectral bands and their relative weighting in the calculation of the atmospheric emissivities. Also under investigation is the treatment of the water vapour continuum and the sensitivity of the model to prescribed short-wave properties of model-generated clouds.

Alternative formulations of evaporation from land surfaces and of sub-surface hydrological processes are being examined. In view of the known sensitivity of climate simulations to these processes close attention has been given to methods of describing them more accurately. A scheme based on that employed operationally by the Agriculture and Hydrometeorology Branch of the Meteorological Office for predicting evaporation and soil moisture deficits over the United Kingdom has produced promising results. In co-operation with the University of Liverpool, a global soils and vegetation data set has been compiled on a 1° resolution grid. It will be used to study the sensitivity of the model to geographical perturbations of land surface albedo and soil moisture availability.

Work is also proceeding on developing improvements to the parametrization of deep convection. The same parametrization was adopted for the operational forecasting model and assessment of the shortcomings of the scheme has been aided by comments and criticisms by senior forecasters in the Central Forecasting Office. Aspects to be considered are a revised treatment of evaporation of rainfall below convective cloud, the inhibition of precipitation from shallow clouds especially where the aerosol distribution is likely to be of a continental type, and the inclusion of a representation of downdraughts.

A first multi-annual cycle integration of the 11-layer model on the Cyber 205 computer of more than 8 simulated years has been completed. One aspect that has been studied is the surprisingly large interannual variability in the tropical rainfall, especially over Australia, and also in the upper tropospheric flow. This feature of the model arises despite the imposition of the same seasonally varying forcing (incoming solar radiation and imposed sea-surface temperatures) from one year to the next. It may be due in part to the retention of knowledge about the previous year in the soil moisture deficits in various parts of the world. However, replacing the soil moisture in the model by that for a year earlier made little difference to simulation and more investigation of the results is required. A second multi-annual cycle run of the model has now been started containing a number of changes and improvements to the formulation. The results of these integrations are being carefully compared with analyses of observations during the 1979 global experiment and during other years.

A notable feature of the global atmospheric circulation worthy of close study is the Asian monsoon. Although in long simulations the model is capable of reproducing the monsoon with considerable realism, forecasts of the timing of the onset starting from a week or so beforehand are disappointing. Also, simulations lack important details, such as the development of monsoon 'breaks'. A number of short forecasts have been run to test the sensitivity of the model's simulation of the monsoon onset to the representation of physical processes such as evaporation, radiation and diffusion. Some improvements were obtained with modified formulations of the parametrizations. Studies of the characteristics of the monsoon from observed data are concentrating on the years 1979 and 1983. In both years the monsoon was late by some two weeks or so, but in 1979 the onset was much sharper with a well defined break in mid-July.

*The global climate*

Major modification to the global climate arising, for example, from changes in atmospheric composition will inevitably also have an impact on the ocean circulation, on the sea surface temperature and on the extent of sea ice. These will in turn affect the atmosphere. Ideally, climate change studies should be carried out using a fully interactive atmosphere-ocean-sea ice model with an absence of external constraints that may force the model towards a predetermined climatic state. The difficulties in implementing such a system successfully arise from the present inadequate understanding and representations of the various physical processes involved. For example, as discussed in the previous section, defects in the present cloud and radiation scheme cause spurious cooling at low levels, and this might lead in extended climate integrations to unrealistic amounts of sea ice. Again, a parametrization of sea ice that failed to take into account the leads within the ice field and the breaking off of icebergs at the edges of the ice sheet will fail to provide an appropriate transfer of heat between ocean and atmosphere because of the higher insulating properties of solid ice. At present, therefore, most investigations concentrate on the sensitivity to fairly small changes from present conditions. This has been the approach in the studies performed so far into the effects on the global climate of an increase in carbon dioxide concentration.

The first phase of experiments on the effects on the earth's climate of a carbon dioxide increase is now almost complete. They have included increasing concentrations by factors of two and four and increasing sea surface temperatures uniformly and as a function of latitude together with consistent changes in the sea ice extent. The experiments were carried out using the 5-layer model. The experiments were described in the Special Topic in the 1982 Annual Report of the Meteorological Office. More recently the changes induced in the hydrological cycle have been closely examined. The results suggest that increases in precipitation are governed largely by the rises in sea surface temperature. These precipitation increases are statistically significant in the middle and higher latitudes along the model's depression belt, particularly in winter, and along the eastern coasts of the subtropical continents in summer. Statistically significant drier regions are mainly confined to the subtropics and to middle latitudes in summer.

Experiments have been performed with the model to assess the importance of representing the detailed nature of sea ice. In the northern polar region the sea ice tends to be compact while the divergence of the southern ice sheet from the Antarctic continental land mass causes it to fracture and break up leaving large areas of open water. The method of parametrization in the model is more representative of the compact Arctic ice. In order to assess the impact of greater heat transfers through broken ice, the edge of the Antarctic sea ice field in the model was moved several degrees towards the pole. The results of the experimental runs indicated that the Antarctic polar trough becomes deeper and is shifted poleward, there is a warming of the atmosphere over Antarctica and the circumpolar tropospheric westerlies decrease over the latitudinal zone from which the ice was removed.

Considerable progress is now being made in the development of models to simulate the ocean circulation. A 6-layer baroclinic dynamical model with a latitude/longitude grid mesh and a representation of the bottom topography is being used at present. Comparisons have been made of parallel runs of the model with differing resolutions ($5° \times 7\frac{1}{2}°$ and $2\frac{1}{2} \times 3\frac{3}{4}°$). The higher resolution gave larger mass transports for ocean gyres, principally because of a better representation of the relatively narrow currents on the western boundaries of the main ocean basins. In co-operation with the University of Oxford a finer mesh version of the model (with a $1° \times 1°$ mesh) is being used for testing the influence that the bottom topography has on the Gulf Stream. The layers of the ocean near the sea surface are well mixed by turbulent motion. Using a simple model, an assessment has been made of the relative importance of wind generated mixing and mixing due to turbulence set up by shears in the ocean currents; the latter seems to be important only during the 12 hours or so following a major wind shift. Because of a lack of data on wind speed variance, parametrization of the mixed layer by flux gradient relationships using stability dependent diffusion coefficients is being investigated.

The importance to the global climate of the presence of ice has necessitated the development of a parametrization that represents the build up and melting of sea ice. This has recently been extended to include a simple representation of the formation of leads through which large amounts of heat and moisture are released into the atmosphere. Preparations are being made for running the full ocean model, including the sea ice parametrization, for long periods non-interactively using atmospheric forcing derived from the 11-layer model. As a first step towards running a fully interactive atmosphere/ocean model, the atmospheric model has been coupled to a single-slab mixed-layer ocean model. This replaces the ocean by a single equivalent layer that can respond interactively with the atmospheric simulations by storing or exchanging heat. The effects of heat transfer within the ocean by currents can be included in a simple way by imposing heating or cooling related to the observed geographical distribution of the net annual heat flux necessary to maintain the same seasonal cycle of sea surface temperatures from year to year. More elaborate interactive experiments await the development of more efficient codes for the ocean model.

*Dynamics of the middle atmosphere*

The middle atmosphere is the region above the tropopause extending from a level of about 10 km to 80 km above the earth's surface, including both the stratosphere and the mesosphere. The air motions at these levels are an intrinsic part of the general circulation of the atmosphere. The origins of many of the disturbances to the airflow in the stratosphere can be traced to the troposphere and there is evidence that some aspects of the middle atmospheric circulation can have an impact on tropospheric weather systems. Much of the interest in the dynamics of the stratosphere and mesosphere is, however, concerned with the presence of radiatively active trace gases, such as ozone, and dust particles whose transport by the air motions and whose chemical reactions in the presence of sunlight can play a significant role in controlling the earth's climate through their impact on the radiation balance.

A numerical model of the stratosphere and mesosphere is being used to investigate the dynamical processes of the region. The model has 32 levels between about 10 km (300 mb) and about 80 km above the earth's surface. Lower boundary conditions are derived from tropospheric data. Most of the early experiments with the model used a low-resolution grid mesh with 16 points around each line of latitude and 36 points along the meridians from north to south poles. The relatively coarse grid around lines of latitude was considered adequate because large-scale waves dominate the stratospheric flow. A useful diagnostic quantity for examining the nature of the flow predicted by the model is the so-called Ertel potential vorticity, since it is conserved following fluid parcels in the absence of diabatic and frictional effects. It was noted that, when wave amplitudes become large, fields of Ertel potential vorticity were distorted into long strings in an unrealistic manner. Further tests suggested that this behaviour is symptomatic of low-resolution models and that finer meshes are essential in order to represent such situations satisfactorily. Versions of the model with 36 points and with 72 points around lines of latitude gave improved simulations of the major stratospheric warming event in February 1979 during which the middle atmospheric circulation became highly distorted. The experiments, however, highlighted the need for an improved method of relating winds to the geopotentials in the intitial data. A new scheme is being developed using the linear balance equation outside the tropics and deriving the vorticity by interpolation within the tropical zone. In order to facilitate experiments using a high-resolution grid mesh, the model has been extensively reformulated so that it can run efficiently on the Cyber 205 computer. Computing speeds 30 times those achievable on the IBM 3081 are being obtained and still greater speeds are expected following further refinements to the code. A scheme for solar radiation heating and long-wave cooling has been incorporated into this version of the model and a facility to output a wide variety of diagnostic quantities has been provided.

As well as being used for the simulation of observed events, the model has proved valuable in investigating theoretical ideas concerning the nature of stratospheric disturbances. It has been demonstrated that local disturbances of appropriate scale propagate upwards and downstream as wave-trains of Rossby waves. The waves disperse as they move away from their source and the varying degree of refraction of the wave components means that the upper atmosphere responds on a larger scale than that of the principal scale of the original disturbance. Stratospheric warmings can be profitably interpreted in terms of such wave-trains, allowing the connection of warmings to the growth of particular features in the troposphere to be more firmly established. As a further aid in investigating these phenomena, a linear steady-state primitive equation model has been developed. An upper boundary condition that allows wave energy to pass out of the top of the model domain without reflection is necessary to simulate the direction of wave propagation correctly. This model is being used to examine the structure of downstream Rossby wave-trains for varying distributions of the zonal wind.

Observations of the middle atmosphere have been available over a period of five years from the Meteorological Office's Stratospheric Sounding Units (SSUs) installed on board the American NOAA satellites. Analyses of the data are performed each day for 5 layers between 10 mb and 1 mb and are distributed on a routine basis to about 25 research centres both in this country and overseas. The data provide an exceptionally valuable archive enabling studies to be made of interhemispheric and interannual variations of the middle atmospheric circulation. During the year a new satellite, NOAA-E, was launched to take over from NOAA-A which was coming to the end of its life. This satellite, together with NOAA-C (launched in 1981) will now provide the observational data until 1984 when a further replacement satellite is planned. A considerable amount of programming effort is required in support of the acquisition of the data and the subsequent analyses, particularly prior to the launch of a new satellite. In order to simplify the procedures and to make them more reliable, an automatic system has been devised for accumulating the data directly into COSMOS, as they are transmitted across a transatlantic link, instead of first storing them on magnetic tape.

The analyses of SSU data have been used in studies of large-scale disturbances in the stratosphere of both hemispheres. It is considered that the 1979 stratospheric warming can be viewed as a downstream wave-train generated by the growth of anticyclonic vorticity over western Europe. In the southern hemisphere winter (July) the wave-trains typically differ from those in the northern hemisphere in having phases almost independent of height, though in the late winter of 1981 (August) the southern polar vortex became highly distorted in a way that resembled features of the northern hemisphere winter. Major warmings apparently occur preferentially in the northern hemisphere because cross-polar flow steers the wave-trains towards the pole; southern hemispheric flow tends to be zonal.

### *Synoptic climatology*

The Synoptic Climatology Branch studies the behaviour of the atmosphere on time-scales ranging from 10 days to decades and develops improved methods of long-range forecasting.

Archives are maintained of data from climatological stations throughout the world and new data are added following careful quality control. Many gaps exist in past records and reliable information to fill them is sought, often by consulting other meteorological services and institutions. From the data available daily temperature and rainfall series for 10 districts covering the United Kingdom from 1951 have recently been constructed and are being used to study 'spells' of weather in different parts of the United Kingdom.

Spectral analysis of daily central England temperature shows that there is a tendency for variations to occur on time-scales near 8–10 months and also around 40–60 days. An investigation started this year to determine the extent to which these local variations reflect much larger-scale processes in the atmosphere and oceans.

A world-wide network of upper-air soundings began to operate in 1948 but available compilations of observations contain many errors and uncertainties, sufficient to confuse or obscure small variations in climate that may have taken place. A more reliable data set for the entire globe has been created by requesting mean monthly upper-air data from the countries of origin for 200 selected stations, together with supplementary information such as the instruments used and the launching sites. Monthly or daily data from about 175 of these stations have been received and subjected to quality control. The data are particularly valuable for investigating temperature trends in tropical regions. The influence of the atmospheric phenomenon called the Southern Oscillation is clearly shown in the tropical observations, but up to at least August 1983 there was no tropical tropospheric cooling attributable to the March 1982 eruption of the volcano El Chichon in Southern Mexico. A temporary tropospheric cooling around 1965 which has been attributed to the March 1963 Agung eruption was shown to have begun before the eruption; other comparable coolings were not associated with volcanic eruptions. The data showed a warming trend of about 0.1 °C per decade in the tropical lower troposphere, consistent with a similar trend at the surface over tropical land since 1950. Any corresponding trend in the tropical upper troposphere is thought to be masked by changes in radiosonde instrumentation.

Some of the extra-tropical upper-air stations are being used to study trends of temperature differences between the upper troposphere and the lower stratosphere. Increasing atmospheric carbon dioxide is likely to result in warming in the troposphere and cooling in the stratosphere, rendering the temperature difference a sensitive indicator. Archived polar-orbiting and geostationary Meteosat satellite data have been compared, and detailed statistics on the effects of viewing angle on apparent cloudiness have been tabulated. The cloud estimates from the polar-orbiting satellites revealed a dramatic increase in deep convection over the central equatorial Pacific in association with the 1982–3 El Niño/Southern Oscillation episode*. The data are being used to provide world-wide estimates of cloud cover and other parameters to define the albedo and components of the radiation balance of the earth, for use in numerical modelling experiments.

*El Niño—The Child—is the name given to a relatively warm southward current that flows along the coast of Ecuador and Peru at the Christmas season; every few years it is much warmer than usual, and it is these major warm episodes that are now usually referred to by meteorologists by the term El Niño. The Southern Oscillation is a broad-scale fluctuation of pressure, temperature and rainfall over the tropical Pacific and Indian Oceans. The two phenomena are now known to be related.

Substantial long-term changes in regional and global sea surface temperature continue to be indicated by a study of an updated and improved historical sea surface temperature data base. A global warming of about 0.6 °C between about 1910 and 1950 appears to arise partly from a sudden warming of about 0.3 °C in the early 1940s when there was an abnormally long El Niño/Southern Oscillation episode. Since 1960 there has been pronounced cooling in the middle and higher latitudes of the northern hemisphere partly offset by warming in the tropical and subtropical southern hemisphere. Investigation continues into the influence of progressive changes in measurement methods on sea surface temperature estimates.

A historical marine air temperature data base for 1854 to 1981 has been created and quality controlled. These data show global interannual and long-term temperature variations in phase with those of sea surface temperature, and of similar or slightly larger amplitude. The 19th century marine air data, however, appear unexpectedly warm; the reasons for this are as yet unclear. On time scales of 2–3 years, El Niño/Southern Oscillation episodes originating in the tropical Pacific appear to dominate variations of global marine air temperature and global sea surface temperature, with the variations of marine air temperature being the larger with a typical magnitude of 0.6–0.8 °C.

Monthly air temperature averages over northern hemisphere oceans have been combined with published monthly, mainly land, northern hemisphere air temperatures to give the closest approximation yet achieved to a true northern hemisphere surface air temperature time series. It indicates a warming of about 0.6 °C between about 1910 and the 1940s and a cooling of 0.3 °C thereafter to around 1970. A recent slight warming cannot yet be interpreted as part of a longer trend.

The patterns of sea surface temperature and lower tropospheric circulation variations that accompany each phase of El Niño and the Southern Oscillation are being studied as part of a broader investigation into the influence of tropical sea surface temperature variations on the atmospheric circulation. A general circulation model was used several years ago to show that variations of sea surface temperature in the tropical north-east Pacific may affect weather patterns in the North Atlantic in winter. An analysis of surface pressure and sea surface temperature data collected since 1890 seems to support this idea.

In addition to directly observed data, archives of the objectively analysed grid-point data produced by the Central Forecasting Office are also maintained and derived quantities such as the mean westerly momentum and horizontal and vertical fluxes of heat and momentum are calculated from analyses stored in the European Centre for Medium Range Weather Forecasts (ECMWF). The ECMWF archives have been used, not only in routine monitoring and discussion of many world-wide meteorological events, but also in the analysis of blocking anticyclones which have affected the North Atlantic. Study of the fluxes of vorticity resulting from transient weather systems support the hypothesis that the blocking anticyclones are maintained by these transient systems (mainly depressions) which skirt them.

The major effects on the tropical tropospheric flow associated with enhanced heating by the central and eastern equatorial Pacific Ocean were reproduced in a simple mathematical model of tropical forcing.

*Research related to long-range forecasting*

The experimental long-range forecasts have preserved continuity with those issued to the public until December 1980, but the procedures have been streamlined and automated as much as possible. The forecasts are prepared by a small group of scientists who attempt to combine the results of a number of statistical techniques with their own insights based on extensive experience of atmospheric behaviour. A method based on multivariate analysis has become the most prominent forecasting procedure. It uses a variety of statistical approaches to construct forecasts of surface circulation patterns from several types of data including surface pressure, air temperature and sea temperature from much of the northern hemisphere; several of the older statistical methods are effectively incorporated in this more general technique. Tests of the multivariate method on independent data show that the method has some predictive skill. Revisions are being made to incorporate the results of recent research into sea surface temperature and atmospheric variations. A revised computer-based analogue technique was brought into use; this method was the mainstay of long-range forecasting for a long period and so provides a standard against which newer statistical or dynamical techniques can be compared. Information from medium-range numerical forecasts is regularly considered when preparing the forecasts.

One function of the long-range forecasting experiment is to maintain awareness of practical problems that have to be solved if regular long-range forecasts are to be of maximum possible benefit to potential customers. Thus it has been found helpful to prepare the monthly forecasts as two half-monthly forecasts which may be markedly different. The forecast for the first half month is now influenced appreciably by medium-range numerical forecasts. The experimental forecasts are sent by telex to a limited selection of commercial users in order to maintain contact with users' views and requirements. The forecasts continue to be assessed for their accuracy and this year improvements to the methods of assessment have been introduced.

Two general circulation models (GCMs) of the atmosphere are being used experimentally for long range forecasting. One model extends over the northern hemisphere and has 5 data levels in the vertical; the other is global with eleven levels, and is a version of the current operational forecasting model. Starting from operational global analyses, 30-day dynamical forecasts can be made in near-real time using the 11-level model. At least one forecast has been run for each month in the last year.

General circulation models provide deterministic forecasts of atmospheric processes from the largest quasi-stationary planetary scales, to the relatively high frequency, synoptic scale, baroclinic waves. However, inaccuracy in either the initial conditions, or model specification, introduces forecast errors which grow with time, and by about day 10 of the forecast, little skill in forecasting daily atmospheric fields is apparent, on average. On the other hand, this growth in error is predominantly associated with baroclinic cyclone waves and does not necessarily affect the lowest frequency components of the flow. To show this, forecast fields from the 5-level model have been averaged over 15-day periods before verifying against real data. On average, these forecast fields show skill up to the 16–30 day period.

Another technique which attempts to extend dynamical predictability beyond 10 days is the process of ensemble forecasting. An ensemble forecast consists of the set of forecasts made from initial conditions which differ in detail but are similar in their large-scale features; for example, the state of the atmosphere on successive days. An important question being studied is whether there is any correlation between the skill of the average of the ensemble, and the spread of the individual forecasts.

A difficulty with dynamically based long-range forecasts is that the model climatology is, in general, not the same as the observed climatology; i.e. part of the forecast error may be due to systematic biases. The influence of such biases on the forecast assessment can be partially mitigated by using verification diagnostics based on anomaly fields, defined as differences of either model or observed fields from their respective climatology. Of course the non-linearity of the equations of motion ensures that such biases cannot be wholly removed. When integrating general circulation models for forecasting purposes it is important that not only the initial conditions but also the sea surface temperatures (SSTs) be known as accurately as possible. The SSTs are not forecast by the model during an integration and must be specified externally. Results from a number of 5-level model runs show that there can be significant improvement in the skill of a dynamical long range forecast if observed rather than climatological tropical SSTs are specified.

Perhaps the best known example of circumstances where SSTs deviate substantially from their climatological average is the 'El Niño' episode during which parts of the east and central tropical Pacific Ocean can warm to as much as 6 °C above normal. During the winter of 1982/83 there was a strong El Niño and the weather of many areas of the world was dramatically different from normal with severe droughts in some areas of the world, and severe flooding in other areas. The 11-level model has been used to try and assess the sensitivity of the winter atmospheric circulation to SST anomalies in the tropical Pacific Ocean, and a number of experiments have been run with SST anomalies in different regions of the tropical Pacific. Long integrations, of several hundred days, are necessary to obtain statistically significant results. It is found that if the tropical east Pacific is anomalously warm, the mid-latitude jet stream extends across from the west and central Pacific to the North American continent. Associated with this extension of the jet stream, synoptic scale depressions propagate across the east Pacific, leading to stormy weather over the west coast of the USA. The model does not, on the other hand, show large significant atmospheric anomalies to the east of North America. In contrast, however, a relatively weak positive SST anomaly in the tropical west Pacific appears to generate a strong mid-latitude response over the Pacific, North America and the Atlantic. It is possible that these experiments, which are continuing, may help to explain why winters during which El Niño episodes are in progress have markedly different atmospheric anomaly patterns.

Other integrations are under way which test the sensitivity of the general circulation to mid-latitude SST anomalies off the Newfoundland coast. A set of 5-level model integrations for early winter has shown that to the north of the SST anomaly and extending downstream over the British Isles the intensity of the synoptic-scale waves is larger for a warm anomaly than for a cold anomaly.

*Special investigations*

Many requests for meteorological advice are received which require more than the routine extraction of data or the straightforward application of meteorological theory. Unless they are so specialized as to require the attention of one of the main research Branches, they are usually handled in the Special Investigations Branch, which has considerable expertise in assembling fact and theory from diverse sources and applying the results to practical problems. Mostly, the problems arise from the needs of aviation either directly in relation to aircraft operations in bad weather, or indirectly through the development of techniques for forecasting parameters required by aviation.

*Forecasting techniques*

The numerical forecasting models now in operational use are capable of providing more detailed information, particularly about conditions close to the earth's surface and in the lower troposphere where many of the problems are encountered, than has been available in the past. As a result, the emphasis of work related to aviation has been shifting to the development of forecasting techniques based on the output of the operational numerical model and its interpretation in terms of local weather. These investigations are also of value in assessing and improving the operational forecasting model. For example, it was shown that the model's handling of tropical upper-wind observations and of temperatures in the lowest layer of the atmosphere was suspect, and that the influence of land-sea differences and orography on forecast precipitation appeared excessive and too small respectively. These defects have been or are being remedied by the Forecasting Research Branch.

Statistical techniques are being applied to data from the forecast model to develop forecasts of probability of precipitation (mainly for agriculture) and surface temperature (mainly for the power industry).

Significant-weather charts, which indicate areas where clear air turbulence, icing and thunderstorms are likely to occur, are supplied to aircraft in flight documentation. At present, they are prepared by a forecaster, but it has been recommended by the International Civil Aviation Organization (ICAO) that they should be generated as numerical model output. Numerical forecasts of a probability of encounter with at least moderate clear air turbulence per 100 km of flight are now produced operationally by the 15-level model. The development of a technique to delineate from numerical forecasts areas of deep convection (particularly severe convection) is well advanced.

In forecasting upper winds for aviation a parameter of particular interest is the 'equivalent headwind', the average headwind experienced by an aircraft along its particular route. In flight planning, airlines use wind forecasts to choose routes with, other circumstances permitting, the lowest possible value of equivalent headwind. A scheme for monitoring errors in this quantity in forecasts by the new 15-level model has been developed; it uses winds measured by aircraft equipped with the Aircraft Inertial Data Systems (AIDS) to determine the true equivalent headwinds along their routes. Climatologies of equivalent headwind have also been sold to some airlines.

The development of local forecasting techniques is being advanced by the introduction of automation at outstations. This allows more effective use to be made of various kinds of synoptic and satellite information. Also the local structure of the atmospheric boundary layer can be measured by relatively inexpensive mini-sondes and acoustic sounding techniques. Data from these sources are being monitored and methods developed for using the information to improve forecasts. Part of the program is carried out by outstation staff themselves, helped and encouraged by a small team at HQ. Computer services for the provision of data and guidance on methods of analysis and interpretation are given. Similar services are provided for student projects at the Meteorological Office College. This team is also developing mesoscale analysis techniques to improve the local forecasting of fog, showers, stratocumulus and surface temperatures.

Particular emphasis is being given at present to the improvement of fog and haze forecasting at outstations. A questionnaire to outstation forecasters confirmed the relevance of boundary layer structure observations, satellite pictures and statistical aids to local forecasting and revealed an increasing user interest in visibilities in the range 1–10 km.

In this connection field projects have been carried out at RAE Bedford and Lossiemouth to obtain observations of boundary layer structure in fog and haar. The analysis of the data is in progress. Techniques are being developed to give forecasters objective visibility predictions based on current observations and other relevent parameters. Improved climatologies of visibilities in the range 1–10 km for individual stations have been distributed.

*Aviation climatology*

The increasing use of helicopters in bad weather has led to a need for better information on the probability of encountering severe icing or heavy snow. This is being met by a program of observations from the MRF aircraft and by preparing a climatology of icing conditions. A most important source of data for the latter is a unique set of cloud observations obtained on nearly 20 000 aircraft reconnaissance flights made during and after World War II. The observations were put into machinable form before processing.

Aviation authorities have long been concerned about the effect of low-level wind variations (now referred to as 'windshear') on the handling of large jet aircraft. As a result of studies in the Branch, a windshear alerting service is now in operation at Heathrow and its extension to other airports is under consideration. A related problem is the fact that the wind supplied by air traffic control to aircraft about to land or take-off is based on an anemometer which may be unrepresentative of the wind experienced by an aircraft flying up to 3 km away. Automatic digital logging equipment was attached to the two Heathrow anemometers (3.2 km apart) for one year to investigate the frequency distribution of wind differences. In addition, a study of the mode of presentation of wind speed and direction to air traffic control has led to recommendations to output an average wind for air traffic control (ATC) use which will be considered by the Windshear Committee of the Civil Aviation Authority.

There is a steady demand for climatological data. A recent example was the speedy preparation of a climatic brief for the Task Force operations in the South Atlantic. Advice and information is also being given for the preparation of a MOD Environmental Handbook for Defence Equipment. Additionally, demand for climatological data tailored for aviation needs remains high.

*Non-aviation work*

Advice is given to firms in the chemical industry in forecasting the spread of chimney plumes and to help them plan emergency action in the event of a serious leakage of dangerous contaminant. Enquiries concerning the spread of radioactive material under particular circumstances also arise from time to time. An improved method of categorizing atmospheric stability in terms of routine meteorological observations is being developed in collaboration with the Boundary Layer Research Branch.

The processing of field data obtained from the site of a proposed nuclear power station at Torness in Scotland during the last two years has been completed and a report written for the South of Scotland Electricity Board. Because this is a coastal site with high ground not far inland, there are special problems in assessing the dispersion climatology of material accidentally released which require special investigation.

Radio meteorological enquiries are also handled, and are principally concerned with the effects of precipitation and evaporation ducting on microwave communication links.

## Library and Publications

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

The Library has probably the most comprehensive holdings in its field in the world and is being increasingly called on by overseas institutions for assistance. The bibliographic data base built up since late 1971 by the entries into the Meteorological Office Library Accessions and Retrieval System (MOLARS) now contains 120 000 items and an agreement has been made with the European Space Agency for this to be available under licence on their on-line Information Retrieval Service. The development of this facility should be of much help to European institutions and a promising source of revenue to the Office.

With the gradual demise of national daily weather reports (DWRs) in hard copy, there is less demand for this material and a major rearrangement of the Library has been carried out. Holdings of DWRs have been moved out of the main library and the space thus made available used to hold longer runs of meteorological journals, which continue to increase in number and content, and material from international organizations such as WMO, ESA and ECMWF.

Liaison with UK library services, particularly those in MOD, and with meteorological libraries overseas continued to help keep our collection up to date and allowed us to give assistance to smaller Commonwealth countries. The original diagrams, prepared in the Office in 1883, of the pressure waves from the Krakatoa eruption were loaned to the Natural History Museum for their Krakatoa Centenary display.

Plans for a small extension to the Library have been agreed but await availability of the necessary finance.

While accessions remained at much the same level, loans increased by some 8 per cent with outside loans, mainly through the British Library inter-library lending voucher scheme, making up about one-sixth of the total. The expected increase in the use of microfiche took place with the Office expanding its publishing in this medium and the Library making copies in the form of fiche of material otherwise unavailable for lending.

Enquiries covered their usual wide range: geographically, from early meteorological records from the Caribbean, through the climate of the salt marshes of southern England and the effect of climate on turtles in northern Greece, to the rainfall of Nepal; and, historically, from the first mention of seaweed as a forecasting aid (1597) to weather on election days and the effects of El Niño and the eruption of El Chichon. Visitors using the Library numbered about 600 and included some from USA, Australia, Syria and the Netherlands.

The visual aids collection continues to increase and the obtaining of video recording and viewing facilities will allow expansion in this medium. Improved equipment was obtained for use in the various lecture rooms. Requests for loans of visual aid materials and use of facilities continue to increase.

Meteorological observations in manuscript and other original documents and records are kept, in accordance with the Public Records Act 1958 and the Public Records (Scotland) Act 1937, in special repositories (archives) in Bracknell, Edinburgh and Belfast. The material in these archives is consulted by many researchers from both inside and outside the Office.

The archives at Bracknell came under the control of the Librarian during the year. The possibility of including lists of the holdings of this repository and of those at Belfast and Edinburgh on the MOLARS data base is under consideration. A proper reading room with viewing facilities for microfilm and microfiche is now available at Eastern Road, Bracknell.

A reorganization within the Branch has resulted in the formation of an integrated Publications Section, containing specialist groups dealing with editing, cartography and graphics, distribution, and matters concerning Crown copyright. The Section handles most official publications of the Meteorological Office, of which an increasing number are prepared as camera-ready copy 'in house', printed using facilities provided by the Ministry of Defence, and sold direct to the public, either by post from Headquarters or across the counter at Weather Centres. Major works, such as the *Annual Report*, handbooks and the monthly *Meteorological Magazine* are passed to Her Majesty's Stationery Office (HMSO), with which the Section has close contacts. A summary of Meteorological Office titles in both categories, published during 1983, appears as Appendix IV.

The Section also prepares artwork for internal memoranda and for papers contributed to scientific journals by members of staff, produces a wide variety of charts, diagrams and forms, and deals with exhibition displays, viewfoils and other lecture aids, as required by other Branches of the Office.

Distributions include the dispatch to outstations of scientific journals, textbooks, works of reference and technical forms, as well as a variety of administrative material. Copies of departmental publications, other than those intended solely for internal use, are sent regularly to Chadwyck Healey Ltd, of Cambridge, for inclusion in the Catalogue of British Official Publications (not published by HMSO).

Close liaison with the Copyright Section of HMSO on matters concerning the use of Crown copyright material by outside publishers has continued.

The number of enquiries has remained at an average of about ten a month.

Statistics on the work of the Library and Publications Section are given in Table XVI (page 141).

## Professional Training

### *Introduction*

Since 1971 Professional Training in the Office has been centred on the Meteorological Office College at the former Headquarters of Royal Air Force Flying Command at Shinfield Park, near Reading. The College is residential and this has proved advantageous in raising standards and keeping pace with changes in the science and operation of meteorology. The training of technicians in the maintenance of electronic meteorological equipment is centred on a School of Technical Training which is based at Beaufort Park, near Bracknell, but which uses the facilities at Shinfield Park when they are more appropriate. The numbers trained this year are shown in Table XVII. When places are available most courses are open, on repayment, to students nominated by other meteorological services. In the 12 years 1972 to 1983, 774 overseas students were trained. They came from 76 different countries and territories.

In addition many of the Office's scientific staff improve their academic qualifications with official help. The numbers receiving support in 1983 are shown in Table XVII. At the highest level, at any one time, a few members of the staff are usually working towards a PhD under supervision shared with a co-operating university.

Training in the Office is directed by the Training Board under the chairmanship of the Director-General. An Assistant Director is responsible for Professional Training. He is also the Principal of the College and Secretary to the Board. Details of each course are given in the College brochure which is available on request from the Principal, Meteorological Office College, Shinfield Park, near Reading, RG2 9AU.

The aim of the training is to enable people to learn the skills they need to carry out their duties effectively. These skills include those of observing, plotting, learning codes, the art of communicating weather information to others, the ability to form a scientifically based judgement or of being able, without fail, to repair equipment in a remote location with whatever facilities are available. Forecasters, for example, are taught by fellow forecasters and learn that their product is their opinion in the mind of their client. All students are encouraged to see their work as part of a team effort. Residential training fosters this team concept and enhances the sharing of experience. It also allows courses to be short, intense and economical. It generates a sense of corporate identity.

In general, courses are run at Shinfield Park only when there is a large body of staff with common training needs. Where a job requires skills and knowledge not used widely in the Office, they are acquired by private study, by attendance at outside courses or by on-the-job training. As the size of the group needing a set of skills increases, however, changes are made to existing courses or new courses are devised. In general there is continuing discussion between the training staff and other members of the Office to monitor and clarify training needs and to look to the future.

*Professional training of entrants with good honours degrees*
Soon after entry, most of these young scientists or mathematicians take the 25-week Scientific Officers' Course. Part of the course is concerned with the science of meteorology and its translation into practice in the Meteorological Office, but members also hear and discuss talks by experts on more general matters such as government finance, security and defence. The course allows members' potential to be assessed and advice to be given to management on their most appropriate area of work. After the course, members attend the Advanced Lectures component of subsequent SO Courses for a further two years. They then receive no further formal professional training, but continue to develop their professionalism through colloquia on research and meteorological services topics in Headquarters, conferences and meetings of learned societies and relevant lectures at other institutions, including universities. They soon find themselves attending such events as contributors. A few return to Shinfield Park for specialist courses open to all grades.

*Professional training of other graduate recruits and existing staff of similar standing*
At different times in their careers these members of the staff may serve either as forecasters or as support scientists. The training for the two groups is slightly different, although staff may be switched from one pattern of jobs to the other during their careers and appropriate retraining is then arranged.

Support scientists take the 14-week Applied Meteorology Course soon after entry. Most return later for the Initial Programmers' Course and then, after six to nine months' experience of using the computer, return to the COSMOS Programmers' Course. Sometimes success at this stage is linked to promotion to Higher Scientific Officer. HSOs of some five years' experience take the Extension Course and after another five the Further Extension Course. These courses bring their members up to date in areas of meteorology which have developed significantly since their earlier courses. During the year the Training Board reaffirmed its decision that individuals should continue to have such in-service courses at intervals of about five years.

HSOs who are promoted to Senior Scientific Officer take the three week Senior Meteorologists' Course which is designed to fit the senior officers for broader responsibilities. Many of the speakers are Assistant Directors and there are always visitors from outside government. As the Office's areas of interest evolve, so does the content of this course. SSOs who are in the grade for many years return at approximately five-yearly intervals.

For 13 weeks new entrant Forecasters follow the same basic Applied Meteorology Course as Support Scientists. Then they form into a separate group and concentrate on forecasting techniques and practices. Next they work in forecasting offices for three months training on the job. The new Forecaster remains under supervision during the next two to three years, after which he returns for the seven week Advanced Forecasting Course. This fits him to understand and forecast developments on longer time and space scales and is also followed by three months on-the-job training.

Subsequently Forecasters join Support Scientists on the Extension, Further Extension and Senior Meteorologists' Courses. Occasionally, three week

Advanced Forecasting (Refresher) Courses are run for staff who have not been actively forecasting for some years.

A newly entered Assistant Scientific Officer whose first post is to be in Headquarters or in assisting research at outstations follows the four week Assistants' Basic Meteorology Course. It provides a background in the subject of meteorology along with improved facility in skills, such as data handling which are needed in most Branches. It does not attempt to cover skills needed only in a few Branches. These are taught on-the-job later.

Assistants who are destined to work in synoptic meteorology follow a different route. Their four week initial course introduces them to the skills they need for supervised work in a forecasting or observing office. They then continue their training on-the-job until they are capable of filling a rostered post. After about three years they take the second College component of their initial training, the four week Advanced Synoptic Assistants' Course, a more basic performance as observers of the weather which widens their knowledge of meteorology and practices within the Office in order to fit them for a wider range of work. It is intended to extend this pattern to ensure that they too receive appropriate in-service courses at five yearly intervals. Extending and updating is the main purpose of the four week Scientific Officers' (Supervisors) Course for existing supervisors of ASOs. This comes some years after the three week Initial Supervisors' Course which helps them acquire management skills peculiar to the Office, in particular the problems of small groups working rosters in remote locations. (General management training is arranged through the Ministry of Defence.)

Many of the observations of weather in the United Kingdom are made by people who are not members of the Office. Those who observe primarily for synoptic meteorology join a one week Auxiliary Observers' Course on which they improve their skills in observing, recording and coding. Those who observe primarily for climatological purposes, follow a one week Co-operating Observers' Course which emphasizes observing, recording, the uses to which observations are put and the importance of quality control of data. Sometimes these courses concentrate a particular group, such as agrometeorological observers, together. Observers for aviation purposes spend one week at Shinfield Park, learning the aviation weather observation code, the skills of observing and recording. They then undergo one week of training on-the-job at an aerodrome under the supervision of professional observers. This is particularly important because it allows observations to be practised at night.

Technicians are mostly recruited from amongst existing Assistant Scientific Officers. Their training reflects the variety and complexity of electronic equipment in or entering service. It includes over a year of formal instruction. Recently the first half has been carried out at the Army School of Electronic Engineering at Arborfield. During the year the Army found they were unable to continue this arrangement and the 1983 course began instead at the Reading College of Technology. Specific instruction on meteorological equipment is carried out by full-time instructors from the School of Technical Training. Throughout, the technicians live at the Meteorological Office College and much of the second half of their instruction is also carried out there.

On the telecommunications side, an Assistant Signals Officer devotes approximately half his time to training, primarily of members of the communications grades who work in the Meteorological Telecommunication Centre at Bracknell. As well as training for new entrants, one week continuation courses are provided as necessary to improve signals practices and basic keyboard skills. Specialized training is arranged when new equipment and new procedures are introduced. Most of this takes place in a specially equipped Training Room in the Richardson Wing of the Headquarters, but some staff attend courses run by equipment manufacturers or by other specialists, including those provided by the Ministry of Defence ADP Training Centre at Blandford.

In general, staff at all levels receive specialist training when a viable group exists which justifies the effort. Otherwise it is carried out on-the-job or by attendance at local Colleges. Training in radio sounding, for example, has for some years been carried out entirely on-the-job because viable groups cannot be gathered together. On the other hand the training of computer programmers has become an established feature of the Calendar of the College at Shinfield Park. Programming is undertaken by staff at every grade from ASO to SSO (and sometimes above). Training is given around the time that staff are posted into computing work. It takes place partly at the College, where the Initial Programmers' Course runs for four weeks and makes use of the PDP 11/34 computer with a Remote Job Entry facility linking it directly to COSMOS at Bracknell. This initial instruction is followed by six to nine months' on-the-job training and then a two week COSMOS Programmers' Course for those whose work is primarily oriented to this central system. Specialized instruction on these courses is given by Data Processing staff, who have also arranged a series of specialist seminars in computer topics to provide more advanced training during the year.

Other subjects in which short courses are available as necessary are Mediterranean Meteorology (three weeks), Tropical Meteorology (three weeks), Meteorological Statistics (four weeks) and an Introduction to Meteorology for Non-meteorological Staff (one week).

One week courses in Defence Meteorology for Forecasters entering that field are run in co-operation with officers of all three fighting services and the UK Warning and Monitoring Organization. Three courses have been held at the Royal Air Force College, Cranwell, this year. Emphasis is put on meeting the specialized needs of each RAF command and on practising techniques of presentation and briefing which match the needs.

## 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 provided representatives on a number of research-oriented committees of the Royal Society, the Natural Environment Research Council and the Science and Engineering 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.

Support for research in Universities was provided through the Gassiot Grants Committee which met once, in April, and recommended the award of 9 grants totalling £50 000. Nine research students provided a valuable link with university research by carrying out a part of their work in the Office under the Co-operative Awards in Science and Engineering (CASE) scheme. Several members of university staffs worked in the Office as consultants for short periods, and there were numerous visits from overseas scientists.

P. Goldsmith
*Director of Research*

# STATISTICS OF THE RESEARCH DIRECTORATE

## TABLE XVI—LIBRARY, ARCHIVES AND CARTOGRAPHIC SECTION

| | |
|---|---|
| *Library* | |
| Publications recived: | |
| Books, journals, etc. | 7880 |
| Daily weather reports | 7853 |
| Films, slides and photographs | 2954 |
| Individual books, pamphlets, articles, etc. classified and catalogued | 11 170 |
| Publications lent: | |
| Books, journals, etc. | 18 587 |
| Daily weather reports | 4218 |
| Films, slides and photographs (440 occasions) | 9404 |
| Number of exchange agreements | 1090 |
| Number of pages translated by MOD translators | 605 |
| *Archives* | |
| Documents received from Headquarters Branches: | |
| Charts for permanent retention | 28 000 |
| Charts for limited retention | 30 000 |
| Ships' logbooks | 880 |
| Rainfall cards for 1980 (number of stations) | 4620 |
| Documents received from outstations: | |
| Daily Registers | 1050 |
| Autographic charts (station-months) | 2500 |
| Enquiries dealt with: | |
| Loans to Headquarters Branches | 196 |
| *Cartographic Section* | |
| Number of diagrams, maps and charts completed during 1983 | 3787 |
| Number of reprographic jobs during 1983 | 586 |

## TABLE XVII—TRAINING

The following figures give details of courses completed during 1983 at the Meteorological Office training establishments at Shinfield Park and Beaufort Park.

| | Number of courses | Length in weeks | Met. O. staff | Others | Total |
|---|---|---|---|---|---|
| Scientific Officers Part II (1982) | 1 | 6 | 14 | 2 | 16 |
| Scientific Officers Part I (1983) | 1 | 15 | 11 | 2 | 13 |
| Applied Meteorology Part II (1982) (Forecasters) | 1 | 8 | 20 | 10 | 30 |
| Applied Meteorology (Prep) (1983) | 1 | 3 | 15 | 7 | 22 |
| Applied Meteorology Part I (1983) | 1 | 10 | 23 | 10 | 33 |
| Applied Meteorology Part II (1983) (Support Scientists) | 1 | 1 | 6 | 0 | 6 |

TABLE XVII (*continued*)

| | Number of courses | Length in weeks | Met. O. staff | Others | Total |
|---|---|---|---|---|---|
| Initial Forecasting (Prep) .. .. | 2 | 2 | 9 | 7 | 16 |
| Initial Forecasting .. .. .. | 2 | 16 | 27 | 8 | 35 |
| Advanced Forecasting .. .. .. | 2 | 7 | 17 | 3 | 20 |
| Extension Course .. .. .. | 2 | 4 | 17 | 5 | 22 |
| Further Extension Course .. .. | 1 | 3 | 11 | 1 | 12 |
| Senior Meteorologists .. .. .. | 1 | 3 | 8 | 1 | 9 |
| Meteorological Statistics .. .. | 1 | 4 | 3 | 3 | 6 |
| Tropical/Mediterranean Meteorology .. .. .. .. .. .. | 1 | 3 | 0 | 4 | 4 |
| Initial Programmers .. .. .. | 3 | 4 | 23 | 1 | 24 |
| COSMOS Programmers .. .. | 2 | 2 | 13 | 0 | 13 |
| Basic Assistants .. .. .. .. | 1 | 4 | 10 | 0 | 10 |
| Initial Assistants .. .. .. .. | 5 | 4 | 79 | 2 | 81 |
| Advanced Assistants .. .. .. | 7 | 4 | 60 | 5 | 65 |
| Extension Assistants .. .. .. | Nil | | | | |
| Station Supervisors .. .. .. | 1 | 4 | 8 | 1 | 9 |
| Initial Supervisors .. .. .. | 2 | 3 | 20 | 1 | 21 |
| Auxiliary Observers .. .. .. | 4 | 1 | 58 | 0 | 58 |
| Co-operating Observers .. .. | 5 | 1 | 56 | 0 | 56 |
| Air Traffic Control Observers | 4 | 1 | 40 | 0 | 40 |
| Instrument Maintenance .. .. | 1 | 6 | 0 | 9 | 9 |
| CDC Cyber Course .. .. .. | 1 | 2 | 4 | 10 | 14 |
| Management, Scientific and Technical .. .. .. .. .. .. | 1 | 0.6 | 21 | 0 | 21 |
| Introduction to Meteorology for Non-Met. Staff .. .. .. | 1 | 1 | 9 | 0 | 9 |
| ASO to R(M)T Conversion (1982) | 1 | 56 | 9 | 0 | 9 |
| Digital Anemograph Logging Equipment (DALE) .. .. .. .. | 2 | 1.2 | 10 | 0 | 10 |
| Digital Anemograph Logging Equipping Course for Trainee R(M)Ts | 1 | 1.6 | 10 | 0 | 10 |
| Mk 1 Wind System/GEC Telemetry | 2 | 0.8 | 21 | 0 | 21 |
| Synoptic Automatic Weather Station (SAWS) .. .. .. .. .. | 1 | 1.0 | 8 | 0 | 8 |
| Higher Level Maintenance Course for Windfinding Radars .. .. | 1 | 1.0 | 10 | 0 | 10 |
| Data Print-out Unit for MOWFR4 | 1 | 1.6 | 5 | 0 | 5 |
| OBOE Automatic Weather Station (2 courses) .. .. .. .. .. | 2 | 1.6 | 15 | 0 | 15 |
| Cossor Windfinding Radar .. .. | 1 | 3.8 | 9 | 0 | 9 |
| Mk IV Wind System .. .. .. | 2 | 0.7 | 16 | 7 | 23 |
| Cross-wind Resolver .. .. .. | 1 | 0.5 | 9 | 0 | 9 |
| Temperature Bridges and Indicators .. .. .. .. .. .. | 1 | 0.5 | 9 | 0 | 9 |
| Cloud Base Recorders Mk 3A and 3B .. .. .. .. .. .. .. | 1 | 1.8 | 9 | 1 | 10 |
| Facisimle Transmitter K150 .. .. | 2 | 0.6 | 9 | 7 | 16 |
| Facsimile Recorder TR4 .. .. | 2 | 2.0 | 9 | 7 | 16 |
| Satellite Facsimile Recorder Mk IVa and IVc .. .. .. .. .. .. | 2 | 1.6 | 9 | 7 | 16 |
| Speech + Duplex .. .. .. .. | 1 | 0.4 | 9 | 0 | 9 |
| Plessey Windfinding Radar WF3 | 1 | 4.4 | 0 | 7 | 7 |
| Instrument Maintenance Course | 1 | 2.0 | 0 | 9 | 9 |
| Totals .. .. .. .. .. | | | 758 | 137 | 895 |

TABLE XVII (*continued*)

Students from the following territories attended courses which terminated during 1983.

| | Number of Students |
|---|---|
| Abu Dhabi | 1 |
| Bahamas | 1 |
| Bahrain | 2 |
| Belgium | 2 |
| Botswana | 2 |
| Cyprus | 2 |
| Finland | 1 |
| Gambia | 1 |
| Germany | 4 |
| Gibraltar | 1 |
| Guernsey | 1 |
| Hong Kong | 10 |
| Territories served by International Aeradio Ltd | 7 |
| Jersey | 2 |
| Lebanon | 2 |
| Libya | 2 |
| Malawi | 1 |
| Malaysia | 4 |
| Malta | 2 |
| Netherlands | 4 |
| Pakistan | 1 |
| Switzerland | 2 |
| Tanzania | 2 |
| Zimbabwe | 4 |

Training in the United Kingdom during 1983 under the Voluntary Co-operation Programme of the World Meteorological Organization

| Institute | Training | Duration | Country |
|---|---|---|---|
| University of Reading | BSc Meteorology | 4 Years | Tanzania |
| University of Reading | BSc Meteorology | 4 Years | Netherlands Antilles |
| Herriot-Watt University | MSc Computer Science | 1 Year | Uganda |
| University of Reading | MSc Meteorology | 2 Years | Tanzania |
| University of Reading | MSc Meteorology | 2 Years | Ghana |
| University of Reading | MSc Meteorology | 2 Years | Costa Rica |
| University of Reading | Agro-Meteorology | 6 Months | Niger |
| Reading College of Technology and Meteorological Office | Basic Electronics | 2 Years | Seychelles |
| Reading College of Technology and Meteorological Office | Basic Electronics | 2 Years | Jamaica |
| Reading College of Technology and Meteorological Office | Basic Electronics | 2 Years | Zimbabwe |
| Reading College of Technology and Meteorological Office | Basic Electronics | 2 Years | Kenya (3) |
| Reading College of Technology and Meteorological Office | Basic Electronics | 2 Yeras | Zambia (2) |

TABLE XVII (*continued*)

| Institute | Training | Duration | Country |
|---|---|---|---|
| Reading College of Technology and Meteorological Office | Basic Electronics | 2 Years | Botswana |
| Reading College of Technology and Meteorological Office | Basic Electronics | 2 Years | Tanzania |
| Farnborough College of Technology and Meteorological Office | IMC | 4 Months | Kenya |
| Farnborough College of Technology and Meteorological office | IMC | 4 Months | Bahamas |
| Farnborough College of Technology and Meteorological Office | IMC | 4 Months | Tanzania (2) |
| Meteorological Office | EC | 1 Month | Pakistan |
| Meteorological Office | OJT | 1 Month | Iraq |
| Meteorological Office | IFC + OJT | 9 Months | Zimbabwe |

IMC = Instrument Maintenance Course
EC = Extension Course for Higher Scientific Officers
OJT = Training on the job

External training—academic year 1982/83

| | Number of students |
|---|---|
| Full time | |
| First Degree | 6 |
| Part time | |
| Higher Degree | 3 |
| First Degree | 0 |
| Block release HNC | 28 |
| Other HNC/HTEC | 22 |
| ONC/A-level | 36 |
| O-level | 5 |
| Miscellaneous | 6 |
| Day release (under 18 years) | 1 |
| Further education | |
| Open University | 24 |
| Science and mathematics | 17 |
| Others | 2 |
| Field study courses | 2 |

# ADMINISTRATION

## Personnel Management

The Personnel Management Branch (Met O 10) is responsible for the full range of personnel services affecting careers of Meteorological Office staff from recruitment to retirement. The age group which joined the Office during the rapid expansion in the 1940s is now reaching retirement age and, despite the imposed reduction in total staff numbers, there was still a requirement during 1983 for substantial recruitment in the lowest grades to keep operational posts filled. As in the previous year, the response to the Assistant Scientific Officer (ASO) vacancy advertisements was almost overwhelming; some 2500 initial enquiries resulted in 1500 applications, of which 277 were selected for interview in Scotland, Northern Ireland, and at Manchester and Bracknell. By the end of the year 85 new ASOs had been appointed. At graduate level, from over 850 applicants, 11 were appointed in the Civil Service Commission Band 1 and 16 in Band 2.

As a consequence of the peak number of retirements, the total number of vacancies to be filled by promotion was greater than in recent years, and promotion boards in 1983 were fully occupied with longer lists of candidates.

Difficulties were experienced in maintaining the level of expertise in operational posts at outstations because of the high level of retirements, imposed cuts in staff numbers, and the additional requirement to provide services in the South Atlantic. The latter imposed a considerable strain also on officers of the Mobile Meteorological Unit.

Career Interviews were maintained at levels set in recent years, and staff of all grades took the opportunity to discuss career options and preferences with career officers. The training program for officers new to staff reporting duties was maintained, and two conferences for senior staff allowed more experienced line managers to discuss the problems of staff appraisal and personnel management.

*International co-operation*

The following staff were released by the Office during 1983 for service with international and other organizations:

| | | |
|---|---|---|
| Dr R. W. Riddaway | PSO | European Centre for Medium Range Weather Forecasts |
| Mr S. Lefevre | SO | European Centre for Medium Range Weather Forecasts |
| Mr R. J. Purser | SSO | University of Wisconsin, USA |
| Mr P. J. R. Smith | TTO II | Pan Am World Services Inc. |
| Mr N. Nesbitt | TTO II | Pan Am World Services Inc. |

Staff returning from international and other secondment appointments were:

| | | |
|---|---|---|
| Mr C. A. Brimacombe | HSO | European Space Agency |
| Mr R. R. Warner | HSO | European Space Agency |
| Mr M. J. Crisford | SO | International Aeradio Ltd |

| | | |
|---|---|---|
| Mr A. Darlington | SO | International Aeradio Ltd |
| Mr D. Ireland | HSO | International Aeradio Ltd |
| Mr K. F. Silvester | SO | World Meteorological Organization |
| Mr R. P. Rumney | HSO | Grassland Research Institute |
| Mr B. J. Mott | TTO III | Government of Vanuatu |
| Mrs R. Shambrook | HG Carto D'woman | European Centre for Medium Range Weather Forecasts |

*Staff numbers*

At the end of the year 1983 the total number of posts, of all grades, was 2773, a decrease of 42 over the year. The actual strength at the end of the year was:

| | |
|---|---|
| Deputy Secretary | 1 |
| Under Secretary | 1 |
| Science Group | |
| Chief Scientific Officer | 2 |
| Deputy Chief Scientific Officer | 6 |
| Senior Principal Scientific Officer | 26 |
| Principal Scientific Officer | 108 |
| Senior Scientific Officer | 279 |
| Higher Scientific Officer | 492 |
| Scientific Officer | 448 |
| Assistant Scientific Officer | 743 |
| Administrative Group | |
| Assistant Secretary | 1 |
| Principal | 1 |
| Senior Executive Officer | 3 |
| Higher Executive Officer | 9 |
| Executive Officer | 16 |
| Clerical Officer | 46 |
| Clerical Assistant | 68 |
| Professional and Technology Group (including Marine Superintendent staff) | |
| Superintending Engineer | 1 |
| Prinicipal Professional and Technology Officer | 3 |
| Professional and Technology Officer Grade I | 5 |
| Professional and Technology Officer Grade II | 17 |
| Professional and Technology Officer Grade III | 4 |
| Professional and Technology Officer Grade IV | 3 |
| Telecommunications Staff | |
| Telecommunications Technical Officer Grade A | 1 |
| Telecommunications Technical Officer Grade I | 8 |
| Telecommunications Technical Officer Grade II | 27 |
| Telecommunications Technical Officer Grade III | 63 |
| Radio (Meteorological) Technician | 37 |
| Signals grades | 49* |
| Teleprinter grades | 63 |
| Typing and miscellaneous non-industrial grades | 135* |
| Security officers | 11 |
| Ocean Weather Service | 2 |

| | |
|---|---|
| Industrial employees ... ... ... ... ... ... ... | 50 |
| Locally entered staff and employees overseas ... ... ... ... | 52 |

* Rationalization of grouping gives different totals from 1982. Combined total 1982 = 190. Combined total 1983 = 184.

## EQUIPMENT

In the light of one of the recommendations of the Resource Control Review carried out in 1982, the decision was made to withdraw from a plan to link Meteorological Office stores to the RAF stores accounting data processing system based at Hendon. To facilitate development of an in-house computerized system, the Meteorological Office supply Branch has adopted the Procurement Executive stores accounting procedures, one of the effects of which will be to phase out accountability for low-value equipment. The advent of the Management Accounting and Information System (MAIS) has led to the need for equipment expenditure to be more closely monitored. Consequently, a comprehensive record of equipment contracts is being built up progressively within the computer data base.

## FINANCE

Except for services provided by the Property Services Agency (PSA) on an allied service basis, the cost of the Meteorological Office is borne on Defence Votes to which all receipts from repayment services are also credited. This year has seen the introduction of the Property Repayment System (PRS) by the PSA. This has meant the Headquarters buildings of the Meteorological Office together with certain outstations in the Civil estate being charged a rent related to commercial practice. This has eliminated another item of capitation rate costing and in some cases the resultant reduction in the cost attributable to the Meteorological Office has been considerable. Other outstations are included in the Defence estate and as such are not included in the PRS.

The Finance section of the Secretary's department has continued the financial control of cash expenditure and receipts accounting. Publication of the report of the Resource Control Review, which recommends *inter alia* the introduction of Responsibility Budgets, has given greater impetus to the introduction of the Management Accounting and Information System (MAIS) on the computerized Integrated Database Management System. The new Staff Time Analysis was introduced in April and now covers all Headquarters and outstations of the Meteorological Office in a standard format. As the data base is built up it is expected that this will greatly facilitate the introduction of the proposed Responsibility Budget.

The following tables are drawn directly from the Memorandum Operating and Trading Account (MTA). They differ from the Voted figures of expenditure and receipts which are contained in the Annual Statement of Defence Estimates. This is because the figures in the tables include costs which are not included in Voted figures, such as pension and gratuities provision, notional insurance provision, interest on capital and depreciation. By the same token, the capital cost of major items of expenditure, such as computers, are excluded from the figures in the tables although they appear in Voted expenditure in the year of acquisition.

The tables include figures for the previous year 1981/82, for comparison, shown on the same basis as the current year figures. Charges for repayment work were raised by 9 per cent on 1 January 1983. It had been hoped to hold the increase in charges below that figure but an increase (to 24 per cent) at the direction of the Treasury in the provision made for pensions and gratuities made this impossible and vitiated the improvement which might have followed the reduced level of staff pay awards.

F. R. Howell
*Secretary*
*Meteorological Office*

STATEMENT OF THE COST OF METEOROLOGICAL SERVICES FOR THE YEAR ENDED 31 MARCH 1983

| | 1982/83 | | 1981/82 | |
|---|---|---|---|---|
| | £000 | £000 | £000 | £000 |
| Total meteorological servies (cost accounted) | | 55 684 | | 52 309 |
| Receipts | | | | |
| Training and secondments | 274 | | 187 | |
| Exchequer Depts | 817 | | 784 | |
| Non Exchequer bodies | 14 566 | | 14 097 | |
| Industry & Commerce | 1680 | | 1539 | |
| General public | 83 | | 73 | |
| | | 17 420 | | 16 680 |
| Net Expenditure | | | | |
| Defence | 19 887 | | 18 833 | |
| Civil | 17 048 | | 15 189 | |
| International | 921 | | 1221 | |
| Exchequer Departments | 408 | | 386 | |
| | | 38 264 | | 35 629 |

METEOROLOGICAL OFFICE RECEIPTS 1982/83 (CASH RECOVERABLE)

| | 1982/83 | 1981/82 |
|---|---|---|
| | £000 | £000 |
| Services to: | | |
| Ministry of Agriculture, Fisheries and Food | 656 | 512 |
| Other Exchequer Departments (Department of Environment etc) | 137 | 249 |
| Civil Aviation Authority | 13 304 | 12 820 |
| National Environment Research Council | 1 | — |
| Other Non-Exchequer Departments | 79 | 31 |
| EEC | 222 | 97 |
| Public Authorities etc. | 202 | 372 |
| Meteorological Office College (training of meteorologists) | 209 | 112 |
| Secondments to outside bodies | 65 | 75 |
| Comprehensive forecasting for the offshore oil industry | 1077 | 998 |
| Forecasting services tailored to meet users special needs | | |
| Ship Routeing Service | 106 | 114 |
| Gas Boards | 152 | 167 |
| Central Electricity Generating Board | 174 | 158 |
| British Rail | 23 | 22 |
| Independent Broadcasting Authority | 127 | 76 |
| British Broadcasting Corporation | 105 | 79 |
| Press | 54 | 51 |
| Other customers' special services | 494 | 469 |
| Automatic Telephone Weather Services (British Telecom) | 233 | 278 |
| | 17 420 | 16 680 |

STATEMENT OF OPERATING EXPENSES FOR THE METEOROLOGICAL

| (1) Expenditure | (2) Defence Services £000 | (3) Exchequer Departments non-repayment £000 |
|---|---|---|
| Customer activity costs | | |
| Direct labour | 2696 | 47 |
| Other direct costs | 193 | 4 |
| Indirect costs | | |
| Labour | 3579 | 78 |
| Others | 1343 | 24 |
| North Atlantic Ocean Stations (NAOS) receipts | | |
| Depreciation | 137 | 1 |
| General Meteorological Office Costs | | |
| Research | 3217 | 56 |
| Observations<br>Telecommunications<br>Computing | 4768 | 118 |
| General services | | |
| Central Forecasting Office<br>Technical Support<br>Maintenance<br>Training<br>Administration and Personnel<br>Others | 3395 | 69 |
| Total Meteorological Office management costs | 19 328 | 397 |
| Full cost items | | |
| Share of MOD HQ costs<br>Insurance<br>Interest on capital<br>Fixed<br>Working | 559 | 11 |
| Total Meteorological Office full costs | 19 887 | 408 |

OFFICE FOR THE YEAR ENDED 31 MARCH 1983

| (4) Public Services | (5) International | (6) CAA | (7) 1982/83 Total | (8) 1981/82 Total |
|---|---|---|---|---|
| £000 | £000 | £000 | £000 | £000 |
| 2860 | 382 | 2108 | 8093 | 8676 |
| 221 | 5 | | 423 | 282 |
| 2297 | 49 | 2185 | 8188 | 8116 |
| 1047 | 1221 | 482 | 4117 | 3485 |
| | (1192) | | (1192) | (2578) |
| 60 | 77 | 56 | 331 | 708 |
| 3128 | 63 | 1718 | 8182 | 7828 |
| | | | 9382 | 8555 |
| 6970 | | 3770 | 4903 | 4542 |
| | | | 1341 | 1358 |
| | | | 1342 | 1305 |
| | | | 2648 | 2414 |
| 3982 | 287 | 2624 | 1680 | 1545 |
| | | | 1137 | 979 |
| | | | 2479 | 2407 |
| | | | 1071 | 1376 |
| 20 565 | 892 | 12 943 | 54 125 | 50 998 |
| | | | 466 | 541 |
| | | | 69 | 55 |
| 599 | 29 | 361 | | |
| | | | 830 | 525 |
| | | | 194 | 190 |
| 21 164 | 921 | 13 304 | 55 684 | 52 309 |

## STAFF HONOURS AND AWARDS

Mr C. W. G. Gazzard was awarded the British Empire Medal in the 1983 New Year's Honours.

Mr N. Coupe, Mr A. Stranney, Mr J. Whiteside and Mr G. Bain were each awarded the Imperial Service Medal. The medals were presented to them by the Director-General.

# APPENDIX I

## BOOKS OR PAPERS BY MEMBERS OF THE STAFF

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WARNER, R. R.; The meteorological product: analysis. Paris, European Space Agency, *ESA Bull,* No. 35, 1983, 30-33.

WHITTAKER, A. E.; The quasi-stationary buoy—a neglected concept. *Weather,* **38**, 1983, 162-169.

# APPENDIX II

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

ADAMS, R. J.

Sources of weather data. *Lecture to Agriculture and Related Industries Study Group of Operational Research Society, University of Reading.* 5 May.

Climatological services. *Annual Meeting of the British Association for the Advancement of Science, University of Sussex, Brighton.* 25 August.

Services supplied by the Meteorological Office Climatological Branches. *Association of British Climatologists, Portsmouth Polytechnic.* 23 September.

Weather, climate and the British way of life. *Series of 10 lectures, Department of Educational Studies, University of Surrey.* September-December.

ALLARDICE, J. G.

Weather forecasts and forecasters. *Scottish Television.* 28 July.

BACON, J.

The problems of delivering forecasts to the public on radio and TV. *Royal Meteorological Society.* December.

BALLARD, S. P.

The study of three-dimensional turbulence using vortex methods. *Mathematical Physics Colloquium, Atomic Weapons Research Establishment, Aldermaston.* 18 October.

BANNISTER, J. E.

Forecasting for hot air balloons. *Balloon Symposium Conference at Birmingham Airport.* 22 October.

BECKLEY, R.

Lecture. *Institute of Groundsmanship.* 2 November.

BELL, R. S.

Weather forecast modelling on the Cyber 205. *Control Data Supercomputer Seminar, Nice.* April.

BENNETTS, D. A.

The NAVAID dropsonde. *Royal Meteorological Society, Mesoscale Sub-group.* May.

BENTLEY, A. N.

The development of a meteorological buoy—ODAS 20. *COST-43 Seminar on ODAS Technology, Reading.* 15 June.

BIBB, M. J.

The problems and uses of weather forecasting. *Thorn/EMI Science and Engineering Society, Wells.* 16 March.

BROMLEY, R. A.

Modern methods of weather prediction. *Institution of Electrical Engineers, University of Aston, Birmingham.* 6 December.

BROOMFIELD, C. S.

Discussion on new edition of *Observers' handbook. Thames Valley Radio (Radio 210).* 24 March.

BROWN, A. A.

Lecture. *Institute of Mechanical Engineers, Birmingham.* 2 December.

BROWN, D. W.
Ten lectures on oceans and weather. *Workers' Educational Association, Wanborough, Wiltshire.* September-November.
Weather and weather forecasting. *Half-day School for Workers' Educational Association, Warminster, Wiltshire.* 19 March.

BROWNING, K. A.
The use of radar and satellite data in nowcasting. *Inaugural Lecture, Royal Meteorological Society, West Midlands Branch.* 27 January.
Line convection at active cold fronts. *Atmospheric Physics Group, Imperial College, London.* 10 March.
A radar and satellite based system for very-short-range forecasting. *Annual Special Topic Lecture, Edinburgh.* 6 April.
Six lectures on mesoscale structure and mechanisms of frontal precipitation systems. *Course on Mesoscale Meteorology, Pinnarpsbaden, Sweden.* 2-9 June.
An integrated radar-satellite nowcasting system in the UK. *Academy of Meteorological Science, Beijing, China.* 25 October.
*Nanjing Institute of Meteorology, China.* 1 November.
Frontal precipitation and air motion as observed by radar. *Academy of Meteorological Science, Beijing, China.* 25 October.
Severe convective weather as observed by radar and satellite. *Academy of Meteorological Science, Beijing, China.* 26 October.
Developments in very-short-range forecasting. *Discussion Meeting, Royal Meteorological Society, London.* 14 December.

BROWNSCOMBE, J. L.
Weather and the farmer. *Agricultural Training Board, Tenterden Group.* 21 June.
Solar tides in the stratosphere derived from SSU data. *Discussion Meeting on the Structure and Dynamics of the Middle Atmosphere, Royal Astronomical Society, Institute of Physics and Royal Meteorological Society, London.* 14 October.

BRUCE, W. J.
Year of the observer. *'Nationwide', BBC Television.* 21 March.
Record April rainfall. *'News at One', BBC Television.* 16 May.
Weather presentations. *BBC Television, South West.* 18–29 July.
A question of weather.
*Royal Meteorological Society, East Midland Branch, Loughborough University.* 29 November.
*British Association of Young Scientists, University of Bristol.* 22 December.

BUTLER, A. P.
Hydrometeorological services of Met O 8. *Joint Regional Meeting, Royal Town Planners' Institute and Landscape Gardeners' Institute.* 27 January.
Flood studies and MORECS. *Ministry of Agriculture, Fisheries and Food, Northallerton.* 29 June.
Availability of hydrometeorological data in Met O 8. *Association of British Climatologists, Portsmouth Polytechnic.* 23 September.
Design rainfall for large roofed areas. *Seminar on Drainage Design, Institute of Public Health Engineering, Brunel University.* 29 September.

CALLEN, N. S.
Boundary layer modelling. *British Association for the Advancement of Science, Bracknell.* 22 August.

CARPENTER, K. M.
Combined use of radar and meteorological satellites for weather forecasting in the UK. *Symposium of the Kring Voor Remote Sensing on Remote Sensing by Meteo-satellites, Amsterdam.* 17 March.
Progress and status of the FRONTIERS Project. *WMO Workshop on Very Short Range Forecasting: Systems Research Aspects, Boulder, Colorado.* 15–17 August.

CARSON, D. J.
A two-dimensional numerical study of boundary-layer rolls using KONTUR data. *Seminar on KONTUR Results, Hamburg.* 31 October.

CATTLE, H.
The simulation of the climate of the Mediterranean region by atmospheric general circulation models. *NATO Workshop on Atmospheric and Oceanic Circulation in the Mediterranean Basin, Centro Recherche Energia Ambiente, Santa Teresa, Italy.* 12 September.
Representation of surface heat exchange in the region of the ice margin in an atmospheric general circulation model. *MIZEK Modelling Workshop, Lake Morey, Vermont.* 19 October.
Meteorological data assimilation systems as a source of wind field analysis for ocean studies. *Workshop on Interim Ocean Surface Wind Data Sets, University of Wisconsin, Madison.* 26 October.

CAUDWELL, W. J.
Presentation of the work of the Marine Climatology Section applicable to offshore survey work. *Kalanos Conference, Gatwick.* 14 April.
Presentation of the work of the Marine Climatology Section and its applications to the offshore industry. *The Eleventh World Petroleum Congress.* 1 September.

CAUGHEY, S. J.
Gale warnings and the shipping forecast. *Royal Ulster Yachting Association, Belfast.* 19 January.
Turbulence and waves in stable layers. *International Conference on Turbulence in Stable Flows, Pembroke College, Cambridge.* 14–16 March.
Climatological differences between the Belfast (Harbour) and Belfast (International) Airports. *'Counterpoint', Ulster Television.* May.
Exceptional rain in the Mountains of Mourne. *Irish Meteorological Society, Dublin.* 24 September.
Convective boundary layers. *Baltimore, USA.* 31 October—4 November.
Acoustic sounding of the atmosphere. *Physics Department, University College, Galway.* 1 December.
The climate of Northern Ireland. *Irish Astronomical Society.* 13 December.

CHRISTIE, W. S.
Offshore observing. *Scottish Offshore Training Association (SCOTA), Aberdeen.* 24 February.

COCHRANE, J.
Work of the agrometeorologist. *British Association of Seed Analysts, East Anglian Region, Braintree.* 8 March.
Agrometeorology. *Walton Agricultural Discussion Society, Walton.* 12 December.

COCKRELL, P. R.
A new general-purpose method for large-volume production of contour charts. *Meeting of the UK Chapter of the European Association for Computer Graphics, York.* 29 March.

CRABTREE, J.
Studies of plume transport and dispersion over the North Sea. *Commonwealth Meteorologists' Conference, Meteorological Office College, Reading.* 7 June.

CULLEN, M. J. P.
Properies of the solutions to the quasi-geostrophic and semi-geostrophic equations. *Royal Meteorological Society, Dynamic Specialist Group, Imperial College, London.* 26 April.
Atmospheric fronts as a solution of Lagrangian conservation laws. *AMS/SIAM Summer Seminar, La Jolla, California.* 27 June.
Predictability of semi-geostrophic fronts. *IAMAP Symposium on Mesoscale Predictability, Hamburg.* 24 August.
Some aspects of solutions of non-linear partial differential equations relevant to meteorology. *ECMWF Seminar, Reading.* 7–8 September.

Cumming, H.
Forecasting for the offshore industry. *Royal Meteorological Society.* 14 December.
Cumming, H. and Patterson D. C.
Observing and reporting North Sea weather. *Scottish Offshore Training Association (SCOTA).* 24 February and 27 April.

Dancey, D. W. G.
A course in elementary meteorology. *Workers' Educational Association, Newbury, Berkshire.* September-November.
Dent, L.
Modern forecasting methods.
*British Aerospace, Woodford.* 7 March.
*British Gas Seafarers' Association.* 16 November.
Dickinson, A.
The UK Meteorological Office computer system. *Computer representatives' meeting, ECMWF, Reading.* 18 May.
The influence of model and analysis deficiencies on forecast errors. *IAMAP—WMO Symposium, Paris.* 2 September.
Super computers and their role in numerical weather forecasting. *Central Electricity Generating Board Headquarters, London.* 24 November.
Donophy, E. H. C.
Modern methods of weather forecasting. *Institution of Electrical Engineers (Student Branch).* 16 November.
Douglas, H. A.
Selection of Bracknell as a World Forecast Centre. *BBC World Service.* 17 January.
Downes, C. R.
The work of the Voluntary Observing Fleet of the Meteorological Office. *Seminar at Institute of Oceanographic Sciences, Wormley, Surrey.* 14 June.

Eccleston, A. J.
Radar and satellite data for short-period forecasting. *Plymouth Polytechnic.* 7 March.
Radar and satellite based system for very-short-range forecasting. *University of Birmingham.* 25 May.
Looking forward—the FRONTIERS Project. *Mason Conference, British Association for the Advancement of Science, University of Sussex, Brighton.* 25 August.
Real-time use of Meteosat imagery for precipitation forecasting. *Meteosat Scientific User Meeting, Clermont-Ferrand, France.* 30 November-2 December.
Ephraums, J. J.
Applications of ODAS data in wave modelling. *COST-43 Seminar on ODAS Technology, Reading.* June.

Farmer, S. F. G.
Advice to industry on the meteorological aspects of air pollution. *Royal Town Planning Institute and Landscape Institute Symposium, Reading.* 27 January.
Findlater, J.
Mesoscale fog studies. *Royal Town Planning Institute and Landscape Institute Symposium, Reading.* 27 January.
Numerical forecasting in the tropics. *Commonwealth Meteorologists' Conference, Meteorological Office College, Reading.* 6 June.
Folland, C. K.
The historical sea surface temperature data set and grid-point surface pressure archive. *Summer Meeting of the Association of British Climatologists, Portsmouth Polytechnic.* 23 September.

FOOT, J. S.
Measurement of near infra-red reflection and transmission of sunlight by clouds. *IAMAP Meeting during IUGG 18th General Assembly, Hamburg.* August.

FOREMAN, S. J.
Numerical weather models and the impact of computer technology. *CDC Seminar on Environmental Information Systems Technology, Hornbaek, Denmark.* 10 May.
The numerical weather prediction model of the Meteorological Office. *Sixth Conference on Numerical Weather Prediction, Omaha, USA.* 7 June.
Forecast errors—model or analysis?
*National Meteorological Center, Washington, USA,* 10 June.
*Geophysical Fluid Dynamics Laboratory, Princeton, USA.* 13 June.
*Goddard Laboratory for Atmospheric Sciences, Greenbelt, USA.* 15 June.

GADD, A. J.
Recent developments in weather forecasting. *Sidcup Literary and Scientific Society.* November.

GALLOWAY, W.
Clouds. *BBC Wales 'AM'.* 29 November.

GEORGE, D. J.
Mountain weather. *Mountain Rescue Team, St Athan.* 7 July.
Weather services to farmers. *Chepstow Young Farmers' Club.* 9 November.

GLOSTER, J.
The airborne spread of foot-and-mouth disease and Newcastle disease. *Royal Society Discussion Meeting on Airborne Spread of Diseases, London.* 2 February.

GOLDING, B.
Results frtom the Meteorological Office mesoscale model. *Royal Meteorological Society Discussion Meeting, Imperial College, London.* 14 December.
Impact of convection schemes in mesoscale models. *ECMWF Workshop on Convection in Large-scale Numerical Models, Reading.* 29 November.

GOLDSMITH, P.
Atmospheric transport and transformation. *Royal Society Acid Rain Discussion Meeting, London.* 5 September.
Status of weather modification. *Royal Meteorological Society, Midland Branch, Nottingham.* 18 October.

GRANT, A. L. M.
The current status of analysis and interpretation of data from the Hercules aircraft of the Meteorological Research Flight. *Seminar on KONTUR Results, Hamburg.* 31 October.

GRANTHAM, R.
Lecture. *Ripon Sailing Club.* 9 November.

GREGSON, J.
Work of the Meteorological Office. *Local radio, 'West Sound'.* 2 March.
Work of the Meteorological Office. *Ayr Archeological and Natural History Society.* 10 November.

HIDE, R.
Predictability of rotating fluid systems. *Workshop on Atmosphere Predictability, La Jolla, California.* 1 February.
Giant planets. *Keynote Address at Inaugural Conference of New Zealand Institute of Physics, Auckland.* 12 May.
Rotating fluids in geophysics and planetary physics. *Union Lecture, International Union of Geodesy and Geophysics, General Assembly, Hamburg.* 22 August.

Planetary atmospheres. *Special Meeting of the Royal Meteorological Society.* 19 October.
Magnetic methods for probing planetary interiors. *Royal Astronomical Society, London.* 11 November.
Magnetic analogue of Ertel's potential vorticity theorem. *Royal Astronomical Society, London.* 25 November.

HILL, F. F.
Weather analysis and forecasting since the 1850s. *Association for Science Education, Worcestershire Branch, Malvern College.* 3 February.

HOUGH, M. N.
Urban climate and its biological consequences. *Institute of Biology, Durham.* 19 March.
The influence of weather on cereal growth. *ADAS Agronomists' Conference, Newmarket.* 10 May.

HOUGHTON, D. M.
One-day teach-in on coastal meteorology. *British America's Cup Team, Nassau, Bahamas.* 13 February.
Wind strategy. *Hurst Sailing Association, Hurst.* 9 March.
Using the wind to win. *Royal Yachting Association Training Weekend, Rutland.* 27 March.
Coastal winds for the sailor. *Royal Meteorological Society, Bracknell.* 8 October.
Observed local behaviour of coastal winds. *University of Reading, Department of Meteorology.* 18 November.

HOUGHTON, J. T.
Satellite meteorology. *Royal Meteorological Society Anniversary.* 19 October.
Reply to toast. *50th Anniversary Meeting, British Interplanetary Society.* 22 October.

HUME, C. J.
Weather and agriculture. *Guildford Young Farmers' Club.* 8 April.

JENKINS, G. J.
Weather forecasting. *Royal Meteorological Society Field Study Course, Nettlecombe, Somerset.* 23–31 August.

JONAS, P. R.
Experiments using the Meteorological Office cumulonimbus model. *International Cloud Modelling Workshop, Aspen, Colorado.* 3–7 October.
Instrumental developments in cloud physics. *Royal Meteorological Society Meeting, London.* 11 November.

JONES, D. E.
Modern methods of weather prediction.
*Institute of Electrical Engineers, Rugby.* 14 March.
*Institute of Electrical Engineers, Thurso.* 26 April.
*Institute of Electrical Engineers, Aberdeen.* 27 April.
*Institute of Electrical Engineers, Dundee.* 28 April.
El Niño and related weather over the globe. *Radio interview, BBC Radio 4, 'World at One'.* 14 July.
El Niño and UK weather. *Radio interview, BBC World Service.* 22 July.
The interest in observing temperature in the 17th century. *Radio interview, BBC Radio 4, 'The World this Weekend',* July.
*Contribution to live studio broadcast 'Friday Live', Tyne-Tees Television.* 9 September.
The collection of current global data (in the Meteorological Office). *Summer Meeting of the Association of British Climatologists, Portsmouth Polytechnic.* 22 September.

Fluctuations and trends in temperature in the tropical troposphere. *Climate Diagnostics Workshop, Toronto, Canada.* October.

JONES, D. W.

Two lectures: (1) A humidity sensor for Automatic Weather Stations, (2) A method for the automatic selection of upper-air 'significant levels' from radiosonde data. *WMO/AMS/CMOS 5th Symposium on Meteorological Observations and Instrumentation, Toronto, Canada.* 12 April.

KELLY, R. D.

The work of the Aviemore meteorological office. *Lecture to the Chinese Nature Conservation Delegation and to the Directorate of the Nature Conservancy Council, Aviemore.* 2 June.

KING, J. C.

Modelling the development of large eddies in the stable atmospheric boundary layer. *IMA Conference on Models of Turbulence and Diffusion in Stably Stratified Regions of the Natural Environment, University of Cambridge.* 15 March.

LANDON, F.

Observing the weather. *Royal Meteorological Society Meeting on Meteorology for Amateurs, London.* 23 April.

LANGLEY, D. E.

Defence meteorology course. *RAF Cranwell.* 21 November.

LAWSON, J. B.

Two lectures: (1) Basic meteorology, (2) Effects of weather on nuclear fallout. *UKWMO Scientific Advisers' Conference, Home Defence College, Easingwold.* 22 January.

The role of the meteorologist in UKWMO. *ROC Chief Observers' Conference, Stoke Rochford, Grantham.* 24 April.

LORENC, A.

On the accuracy of general circulation statistics calculated from RGGE data—a comparison of results from two sets of analyses.

*IAMAP-WMO Symposium, Paris.* 29 August.

*National Meteorological Center, Washington, USA.* 18 October.

Numerical weather prediction research at the UK Meteorological Office—analysis aspects. *US Air Force Geophysical Laboratory, Boston, USA.* 25 October.

LUNNON, R. W.

Intercomparison of cloud coverage derived from geostationary and polar-orbiter satellite data. *IAMAP Symposium, IUGG Assembly, Hamburg.* 23 August.

Atmospheric effects on running. *Royal Meteorological Society Discussion Meeting on Weather and Outdoor Activities, Bracknell.* 8 October.

MCCALLUM, E.

Four lectures on meteorology for yachtsmen. *Hurst Further Education Centre, Tadley.* January.

Ten weekly lectures on introducing meteorology. *Hurst Further Education Centre, Tadley.* September—November.

MCCASKILL, J. R.

Meteorological services for industry. *Midlands Area Floor Covering Trades Association.* 15 March.

MCGINNIGLE, J. B.

Annual lecture. *Cement and Concrete Association.* September.

MACKIE, G. V.

Marine meteorology. *Royal Institute of Navigation, Humber Branch, Hull.* 26 May.

McMahon, B. B.

Intercomparison of $NO_2$ absorption in twilight sky spectra. *International Workshop on Atmospheric Spectroscopy, Chilton, Oxfordshire.* 19–21 July.

McNeil, J. B.

Radiation fog and drainage winds at Aldergrove. *Irish Meteorological Society, Dublin.* 24 September.

Mansfield, D. A.

Predictability of the quasi-stationary flow in the atmosphere and its dependence on anomalous boundary forcing. *WMO-IAMAP Symposium, Paris.* 1 September.

Maryon, R. H.

Short-range dispersion experiments made in hilly terrain. *Euromech Colloquium, 'Air-flows over coasts and hills and the effects upon pollution and human activity', Delphi.* 13 September.

Mason, Sir John

Review of the Meteorological Office during Sir John Mason's period of office. *Institution of Professional Civil Servants, Meteorological Office Branch Annual General Meeting, Reading.* 16 February.

The effects of an increase of carbon dioxide in the atmosphere. *Irish Meteorological Society.* 30 March.

Numerical modelling of the global climate with the aid of giant computers. *Royal Society of Edinburgh.* 11 April.

Address at opening of the COST-43 Seminar 1983. *European Centre for Medium Range Weather Forecasts, Reading.* 14 June.

Recent developments in global weather forecasting. *Oxford University Scientific Society.* 14 October.

Cloud physics and dynamics. *Royal Meteorological Society, Centenary of 'Royal' Meeting.* 19 October.

Mason, P. J.

Studies of flow over hills. *DFVLR, Obersassenhofen, West Germany.* 17 January.

A two-dimensional numerical study of horizontal roll vertices in the planetary boundary layer. *Department of Meteorology, University of Munich.* 19 January.

Trailing vortices induced by surface-mounted obstacles. *Department of Meteorology, University of Reading.* 20 May.

Description of the Sirhowy Valley Experiment. *Broadcast on BBC Radio 4, 'Today'.* 20 June.

Large-eddy modelling. *Royal Meteorological Society Dynamical Specialist Group meeting on 'Atmospheric turbulence modelling', European Centre for Medium Range Weather Forecasts, Reading.* 27 October.

Minhinick, J. H.

GCE O-level Meteorology Course, series of lectures. *Frogmore Further Education College.* Commenced 21 September.

Mitchell, J. F. B.

The seasonal response of a general circulation model to changes in $CO_2$ and sea temperatures. *Royal Meteorological Society, London.* 19 January.

Modelling the effect of $CO_2$ increase on climate. *Royal Institute of Chemistry.* 4 May.

$CO_2$ experiments with prescribed changes in sea surface temperature. *18th IUGG General Assembly, Hamburg.* 18 August.

The response of the climate to changes in $CO_2$ and to sea surface temperature anomalies. *Applied Mathematics Course, University of Southampton.* 24 October.

Energy and our future environment. *Department of Energy meeting on the effects of pollutants on global climate, London.* 8 November.

Climate modelling research. *University of Cambridge Archimedean Society, Bracknell.* 23 November.

MONK, G.
Weather for balloonists. *North West Region, British Balloonists' Club, Mere, Cheshire.* 15 February.

MORGAN, J.
Discussion of Meteosat operational program.*BBC Radio 4, 'Today'.* 8 March.

MORRIS, R. M.
Lecture. *Round Table, Henley.* 10 March.
Lecture. *Silcoates School.* 22 April.
Uses of satellites in offshore weather forecasting. *University of Dundee.* 5-8 July.
Accuracy of weather forecasts.
*BBC Radio 2.* 17 August.
*BBC Breakfast TV.* 19 August.
*British Association for the Advancement of Science, University of Sussex, Brighton.* 23-25 August.
Talkback. *BBC Radio 4.* 20 September.
Seminar on Offshore Safety and Communications. *Leith Nautical College.* 26-28 October.
Documentary on weather forecasting. *BBC Radio 4.* November.
Forecasting for industry, commerce and the general public. *Royal Meteorological Society Sixth Form Lectures.* 18 and 25 November.

NASH, J.
Stratospheric temperature tides. *Second Workshop on Data Comparison and Derived Dynamical Quantities during Northern Hemisphere Winters (1978-82), Department of Atmospheric Physics, University of Oxford.* 13 April.

NICHOLLS, S.
The dynamics of stratocumulus: comparisons between a mixed layer model and aircraft observations. *IAMAP Meeting, Hamburg.* 15-26 August.

O'NEILL, A.
The response of the upper atmosphere to local disturbances in the troposphere.
*University of Oxford.* 24 February.
*18th IUGG General Assembly, Hamburg.* 24 August.
The propagation of local disturbances from the troposphere into the stratosphere. *Fourth American Meteorological Society Conference on the Meteorology of the Upper Atmosphere, Boston, Massachusetts.* 22 March.
Downstream wavetrains in the stratosphere. *Royal Meteorological Society Dynamical Specialist Group Meeting on Teleconnections, University of Cambridge.* 29 June.
Aspects of the stratospheric circulation in the southern hemisphere. *Royal Meteorological Society Summer Meeting, University of Cambridge.* 22 July.

PAINTING, D. J.
An automatic weather station for oil platforms. *COST-43 Seminar on ODAS Technology, Reading.* 15 June.
Synoptic Automatic Weather Stations. *Conference of Directors of Commonwealth Meteorological Services, Reading.* 6 June.
Developments in operational meteorological instruments. *Royal Meteorological Society.* 16 November.

PALMER, T. N.
The role of non-linear wave interactions in preconditioning the stratospheric circumpolar flow. *University of Reading.* 18 February.

Properties of the Eliassen–Palm flux for planetary scale motions. *Royal Meteorological Society, Imperial College, London.* 20 April.
General circulation model studies of the atmospheric response to different phases of the El Niño. *University of Cambridge.* 29 June.
Breaking planetary waves in the stratosphere. *IUGG Assembly, Hamburg.* 22 August.
Response of a general circulation model to sea surface temperature anomalies in the tropical east and west Pacific. *WMO–IAMAP Symposium, Paris.* 2 September.

PARKER, D. E.
Fluctuations and trends in temperature in the tropical troposphere. *IUGG Assembly, Hamburg.* 23 August.
Archiving and interpretation of global climate data in the Meteorological Office: upper-air station data and the historical marine air temperature archive. *Summer Meeting of the Association of British Climatologists, Portsmouth Polytechnic.* 22 September.
Drought in Africa. *Radio interview, BBC World Service.* 27 September.

PARTINGTON, S. J. G.
The climate of Northern Ireland. *The Astronomical Society, Armagh.* 8 December.

PATTERSON, D. C.
North Sea weather. *'Jimmy Mack Show', BBC Radio Scotland.* 10 January.
Weather forecasting. *Physics Society, University of Aberdeen.* 8 February.
Work of the Aberdeen meteorological office. *Grampian TV.* 8 March.
Weather and weather forecasting. *Banchory Field Club, Aberdeen.* 8 March.
Meteorological Office computer. *North East Scotland Research Group, BP, Aberdeen.* 13 April.
The atmosphere. *First year students, North of Scotland College of Agriculture.* 19 October.
Forecasting for the oil industry. *British Petroleum Radio Network, CCTV, broadcasting to company's North Sea platforms.* November.

PATTERSON, D. C. AND BUCHANAN, P.
Observing and reporting North Sea weather. *Scottish Offshore Training Association.* 30 November.

PEARSON, R. A.
Data storage retrieval and processing facilities at Bracknell. *World Meteorological Organization RA I Training Seminar Algiers.* 5–9 December.

PETTIFER, R. E. W.
Some applications of optical remote sensing to meteorology. *ISPRA Course on Optical Methods for Remote Sensing of Air Pollution, Milan.* 13 April.
Two lectures: (1) Aspects of the instrumentation, deployment and performance of 2–5 m diameter wave-following meteorological data buoys, (2) COST-43, a co-operative European ODAS experiment. *MTS/NDBC Symposium on Data Buoy Technology, New Orleans, USA.* 29 April.
The cost of soundings. *Conference of Directors of Commonwealth Meteorological Services, Reading.* 7 June.
COST-43, a review of the past, a look to the future. *COST-43 Seminar on ADAS Technology, Reading.* 16 June.
Automatic observing systems in the Meteorological Office. *Institution of Electrical Engineers, Reading.* 3 November.
Developments in operational meteorological instruments. *Royal Meteorological Society.* 16 November.

PONTING, J. F.
Automated quality control procedures suitable for Ocean Data Acquisition Systems (ODAS) data. *COST-43 Seminar, European Centre for Medium Range Weather Forecasts, Reading.* 14–16 June.

PORTER, M. R.
Project Scillonia. *Department of Meteorology, University of Edinburgh.* 1 December.

POTHECARY, I. J. W.
Meteorological support during the Falklands conflict. *AGARD Symposium, NASA Langley Research Center, Hampton, Virginia, USA.* 19 October.
Meteorological support during the Falkland Islands operations. *American Meteorological Society, District of Columbia Chapter, USA.* 20 October.
Weather during the Falklands conflict. *Royal Aeronautical Society, RAF Halton Branch.* 17 November.

READ, P. L.
Long-lived eddies on Jupiter and Saturn—a laboratory analogue. *University of Oxford.* 27 October.

ROE, C. P.
Weather and agriculture. *Oxford Young Farmers' Club, Oxford.* 9 March.

ROSS, G.
An experiment in forecasting probability of precipitation. *Workshop on Probability Forecasting, Government Camp, Oregon, USA.* 12–14 October.

ROWNTREE, P. R.
Land surface processes in climate models—parametrization and model sensitivity. *Fourth Session of the Joint Scientific Committee for the World Climate Research Programme, Venice.* 1 March.
Climate modelling. *Course on Understanding Climate, University of East Anglia.* 16 June.
The quasi-stationary flow in the tropics in general circulation models. *IAMAP-WMO Symposium on the maintenance of the quasi-stationary components of the flow in the atmospheric models, Paris.* 31 August.
Parametrization of surface processes in general circulation models and related experiments. *Course on the climatological aspects of desertification: facts, theories and methods, Erice, Sicily.* 15 October.
Sensitivity of global simulations to convective formulations. *ECMWF Workshop on Convection in Large-scale Numerical Models, Reading.* 29 November.

ROY. M. G.
The history of the Ben Nevis observations. *Royal Meteorological Society, Scottish Centre, Meeting on Mountain Weather, Fort William.* 24 June.

SHEARMAN, R. J.
Presentation of the Meteorological Office contribution to the Wave Climate Synthesis Project. *National Maritime Institute Ltd.* 10 May.

SHUTTS, G. J.
Angular momentum coordinates as a relative of the semi-geostrophic transformation. *Royal Meteorological Society Specialist Dynamical Group, Imperial College, London.* 20 April.

SILLS, A.
Propagation and prediction of explosive noise. *P & EE and AWRE staff, New Ranges, P & EE Shoeburyness.* 1 September.

SINGLETON, F.
Meteorology—a historical review. *Royal Society of Chemists, Essex Branch.* 15 June.
The Meteorological Office climatological archives. *Association of British Climatologists, Portsmouth Polytechnic.* 22 September.

SLINGO, A.

Clouds and radiation in the Meteorological Office 11-layer general circulation model. *Royal Meteorological Society Discussion Meeting on Cloud Climatology and Climate, Imperial College, London.* 16 March.

Cloud-radiation studies with the Meteorological Office general circulation model. *18th IUGG General Assembly, Hamburg.* 23 August.

Radiation and clouds in the Meteorological Office climate model. *University of Oxford.* 13 October.

SMITH, C. V.

Airborne infection and livestock disease control: a meteorological appreciation. *Royal Society Discussion Meeting, London.* 1–2 February.

Two lectures: (1) Applications of climatological data in agriculture, (2) Applications of climatological data in hydrology. *International Climatologists' Course, University of East Anglia.* 2 June.

Agricultural meteorology in the UK. *Commonwealth Meteorologists' Conference, University of Reading.* 7 June.

The information and advice available from the national weather service. *European Weed Research Society, University of Oxford.* 13–15 December.

Weather services for the water industry. *Mason Conference, British Association for the Advancement of Science, University of Sussex, Brighton.* 25 August.

SMITH, F. B.

Meteorological factors influencing the dispersion of airborne diseases. *Royal Society Discussion Meeting, 'The Aerial Transmission of Disease', London.* 1 February.

Diffusion of pollutants in the atmosphere. *A series of nine lectures to MSc Course, University of Surrey, Guildford.* 3, 10, 17 February.

Long-range air pollution. *Association of British Climatologists, Royal Meteorological Society, University of Birmingham.* 12 March.

Conditions pertaining to high acid concentrations in rain. *International Conference on Acid Precipitation—Origin and Effects, organized by Verein Deutscher Ingenieure Kommission Reinhaltung der Luft, Lindau.* 7 June.

SMITH, R. N. B.

A 1½ order turbulence closure scheme for a mesoscale model. *Royal Meteorological Society Dynamics Specialist Group, European Centre for Medium Range Weather Forecasts, Reading.* 27 October.

SMYTHE, P. O.

Poor visibility and low cloud at Aldergrove. *Irish Meteorological Society, Dublin.* 24 September.

SPACKMAN, E. A.

Climatological regions of the UK using statistical methods. *Agrometeorological Group, Royal Meteorological Society, Rothamsted.* 2 February.

Models using weather data for decision making by farmers. *Agriculture Group, Operational Research Society, Reading.* 5 May.

The frequency of occasions suitable for crop spraying based on chemical-dependent meteorological criteria. *Association of Applied Biologists, Oxford.* 14 December.

SPARKS, W. R.

Potato blight prediction. *ADAS Plant Pathologists Technical Conference, Malvern.* 23 February.

How weather can be monitored in the field. *University of Reading.* 5 May.

STARR, J. R.

Weather and the farmer. *National Farmers' Union, Petworth.* 4 January.

Weather in agriculture.

*Ciba-Geigy Training Conference, Whittlesford.* 27 January.

*Penshurst Farmers' Discussion Group.* 15 February.

*Agricultural Training Board, Rochester.* 30 March.

Flukes, frosts, crops and calves. *British Association Youth Section (Crawley), East Grinstead.* 9 February.
Weather and viticulture. *South-east Vine Growers, Efford.* 17 February.
Meteorological aspects of irrigation planning.
*South-east Region Agricultural Advisory Offices, Guildford.* 22 February.
*Sparsholt College of Agriculture, Winchester.* 11 March.
Clouds, rain and rainmaking.
*British Association Youth Section, Basingstoke.* 1 March.
*St Mark's School, Hounslow.* 10 March.
Agricultural meteorology in Wales.
*Interview on BBC Radio Wales, 'AM'.* 12 April.
*Interview on BBC Radio Wales, 'Points North'.* 25 April.
Agricultural meteorology. *Interviews with HTV Wales and BBC Wales at Welsh Plant Breeding Station Open Day, Aberystwyth.* 17 and 18 May.
Aberystwyth sunshine. *Interview for BBC Radio Wales, 'AM'.* 16 June.
Hurricanes, tornadoes and floods. *International Energy Action, Coleford.* 20 July.
The agricultural effects of the drought. *Interview for BBC Radio Wales, 'AM'.* 22 August.
Weather on the farm.
*Llangwyryfon Discussion Group.* 9 November.
*Aberaeron Discussion Group.* 13 December.
Weather in your garden, *Llanilar County Primary School, Dyfed.* 12 October.
Services for agriculture. *Third Year Agricultural Students, University College of North Wales, Bangor.* 31 October.
A dyma rhagolygon y tywydd! *Clwb Ieunctid, Llanilar, Dyfed.* 3 November.
Farming weather. *Wenvoe Farmers' Discussion Group, Cardiff.* 14 November.

STUBBS, W.
The work of the Meteorological Office. *St. Mary's Open Circle Fellowship, Maidenhead.* 1 February.
The shipping forecast—its preparation and its use. *The Pirates Cruising Club, Ewell.* 3 February.
Meteorology and sailing. *Datchet Water Sailing Club, Datchet.* 13 April.
The Meteorological Office. *Cox Green Wives' Group, Maidenhead.* 13 June.

SWINBANK, R.
Angular momentum in numerical models of the atmosphere. *Royal Astronomical Society/Royal Meteorological Society meeting on short-period fluctuations in the rotation of the earth and their excitation by meteorological and other geophysical processes.* 13 May.
The impact of FGGE on southern hemispheric meteorology. *Royal Meteorological Society Summer Meeting, University of Cambridge.* 22 July.

TEMPERTON, C.
Fast Fourier transforms for numerical weather prediction models on vector computers. *First International Colloquium on Vector and Parallel Methods in Scientific Computation, Paris.* 18 March.
Fast Fourier transform packages for CRAY-1 and Cyber 205. *NAG Seminar on Mathematical Software for Vector and Parallel Processors, London.* 8 June.
Fast Fourier transforms on the Cyber 205. *NATO Advanced Research Workshop on High-speed Computation, Julich, West Germany.* 22 June.

THOMPSON, N.
Weather and agriculture. *National Farmers' Union, Sevenoaks Branch.* 15 February.
Meteorological services to agriculture. *Mason Conference, British Association for the Advancement of Science, University of Sussex, Brighton.* 25 August.

TUCK, A. F.
Vertical profiles of tropospheric gases. *CACGP Meeting, Oxford.* 29 August–2 September.

VAUGHAN, G.
Air sampling flights around the British Isles at 500 ft. *CACGP Meeting, Oxford.* 29 August–2 September.

WASS, S. N.
Glasshouse heating. *ADAS Farm Mechanization Advisers' Conference, Cardington.* 15 February.
Meteorological information available for fireblight prediction. *Fireblight Workshop, East Malling Research Station. 8 March.*

WHITE, A. A.
Combined numerical and experimental studies of baroclinic waves in a rotating annulus system. *American Meteorological Society Conference on Waves and Stability, Boston, Massachusetts.* 22 March.
Approximating the Navier–Stokes equations—a case study using a quasi-geostrophic model. *American Meteorological Society Conference on Waves and Stability, Boston, Massachusetts.* 25 March.
Translation operations, non-Doppler effects and changes of apparent vertical. *Royal Meteorological Society, London.* 20 April.
Atmospheric angular momentum fluctuations, length-of-day changes and polar motion. *Royal Astronomical Society, London.* 13 May.
Analytical model of finite amplitude baroclinic waves. *University College, London.* 20 May.

WHITE, P. A.
The offshore wind energy resource around the United Kingdom. *International Symposium on Offshore Wind Energy Systems, Royal Aeronautical Society, London.* 21 October.

WHYMAN, R. D.
The climate of Kent. *Department of Geography, Kent County Council.* 18 October.

WICKHAM, P. G.
Five lectures on forecasting methods. *Course for MSc Students, Department of Meteorology, University of Reading.* February–March.

WOODROFFE, A.
The problems of the senior forecaster today. *Royal Meteorological Society.* December.

## APPENDIX III

## INTERNATIONAL MEETINGS ATTENDED BY MEMBERS OF THE STAFF

The more important meetings are discussed in the report of the International and Planning Branch on pages 63-66. Attendances at WMO meetings, or joint WMO meetings with other international bodies, were as follows:

| *Title* | *Place and date* | *Attended by* |
|---|---|---|
| CIMO working group on instruments and methods of observation for surface data | Geneva<br>January | Mr D. J. Painting (Met O 16) |
| Commission for Basic Systems—8th session | Geneva<br>January/February | Mr F. H. Bushby, Director of Services<br>Mr A. I. Johnson, AD Met O(TC)*<br>Mr J. M. Nicholls, AD Met O(OP)<br>Miss M. J. Atkins (Met O 2) |
| Commission for Agricultural Meteorology—8th session | Geneva<br>February/March | Mr C. V. Smith, AD Met O(AH)<br>Dr N. Thompson (Met O 8) |
| Expert meeting on NAOS Operation | Geneva<br>March | Dr D. N. Axford, DD Met O(O)*<br>Captain G. V. Mackie, Marine Superintendent |
| CAeM working group on the provision of meteorological information required before and during flight (PROMET) | Geneva<br>March | Mr K. Pollard (Met O 7) |
| Expert meeting on integrated system study observing system experiments | Geneva<br>March | Mr A. Gilchrist, DD Met O(D) |
| Fourth session of the WMO/ICSU Joint Scientific Committee | Venice<br>March | Dr P. R. Rowntree (Met O 20) |
| Informal planning meeting of major donor members to the VCP | Geneva<br>April | Mr M. W. Stubbs (Met O 17) |
| Informal co-ordination meeting on the use of INMARSAT | Geneva<br>April | Mr A. I. Johnson, AD Met O(TC) |
| Fifth Symposium on meteorological observations and instrumentation | Toronto<br>April | Mr D. W. Jones (Met O 16) |
| Ninth World Meteorological Congress | Geneva<br>May | Sir John Mason, Director-General<br>Mr G. J. Day, AD Met O(IP)<br>Mr J. M. Nicholls, AD Met O(OP)<br>Mr M. W. Stubbs (Met O 17) |
| Executive Council—Thirty-fifth session | Geneva<br>May/June | Sir John Mason, Director-General<br>Mr G. J. Day, AD Met O(IP) |
| North Atlantic Ocean Stations—8th session of the Board | Geneva<br>June/July | Dr D. N. Axford, DD Met O(O)<br>Captain G. V. Mackie, Marine Superintendent<br>Mr J. R. Hughes (Met O 4) |
| Implementation/co-ordination meeting on upgrading of the operation of the Main Trunk Circuit | Geneva<br>June | Mr R. J. Sowden (Met O 5) |
| Intercomparison of radiation codes for climate modelling WMO/IAMAP Radiation Commission | Paris<br>June | Mr R. C. Wilderspin (Met O 20) |

*The full titles of the Deputy Directors (DDs) and the Assistant Directors (ADs) are given on pages x-xii. Other abbreviations are explained in Appendix V (pages 186-188).

| *Title* | *Place and date* | *Attended by* |
|---|---|---|
| Workshop on very short-range forecasting system (research aspects) | Boulder, CO August | Dr K. M. Carpenter (Met O RRL) |
| International meeting on satellite measured earth radiation budget and climate change signals | Igls, Austria August/September | Mr R. W. Lunnon (Met O 13) |
| IAMAP/WMO symposium on the maintenance of the quasi-stationary components of the flow in the atmosphere and in atmospheric models | Paris August/September | Dr P. R. Rowntree (Met O 20)<br>Mr A. Lorenc (Met O 11)<br>Dr A. Dickinson (Met O 11)<br>Mr J. Turner (Met O 2)<br>Mr R. Dumelow (Met O 11)<br>Dr T. N. Palmer (Met O 13)<br>Dr D. A. Mansfield (Met O 13) |
| RA VI working group on regional procedures for the transmission of digitized meteorological radar data over the GTS | Bratislava, Czechoslovakia September | Mr C. G. Collier (Met O RRL) |
| CBS working group on the GOS—study group on study area—optimized observing system—1st session | Geneva September | Mr J. M. Nicholls, AD Met O(OP) |
| Meeting of experts on the WMO wave programme | Geneva September | Dr P. E. Francis (Met O 2) |
| Planning meeting for international cloud modelling workshop | Aspen, CO October | Dr P. R. Jonas, AD Met O (CP) |
| WMO meeting of experts on climatic situations and the drought in Africa | Geneva October | Dr J. F. B. Mitchell (Met O 20) |
| JSC working group on numerical experimentation—5th session | Journet, France November | Mr A. Gilchrist, DD Met O(D) |
| CCl working group meeting on climate data management | Geneva November | Mr P. F. Abbott (Met O 3) |
| International organizing committee for radiosonde comparison | Geneva November/ December | Mr A. H. Hooper (Met O 1)<br>Dr J. Nash (Met O 1) |
| EC working group on long-term planning—1st session | Geneva November/ December | Mr G. J. Day, AD Met O (IP) |
| Joint CAS/JSC meeting of experts on atmospheric boundary-layer parametrization over oceans and its role in climate prediction | Reading December | Dr D. J. Carson, AD Met O(BL)<br>Dr H. Cattle (Met O 20)<br>Dr A. Slingo (Met O 20) |
| CAS working group on cloud physics and weather modification | Geneva December | Mr P. Goldsmith, Director of Research |
| RA I regional training seminar on archiving, storage, quality control and retrieval functions of NMCs in Africa | Algiers December | Mr R. A. Pearson (Met O 22) |
| European monitoring and evaluation programme review meeting | Friedrichshafen, December | Dr F. B. Smith (Met O 14) |

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

| *Subject/purpose* | *Place and date* | *Attended by* |
|---|---|---|
| Meteosat Operational Programme Working Group | Paris January | Mr D. E. Miller, DD Met O(P)<br>Mr J. Morgan (Met O 19) |

| *Title* | *Place and date* | *Attended by* |
|---|---|---|
| ESA Scientific and Technical Advisory Group to Meteorological Satellite Programme Board | Paris<br>January | Mr D. E. Miller, DD Met O(P) |
| ESA working group on atmospheric instrumentation definition activities | Paris<br>January, May | Mr D. E. Miller, DD Met O(P) |
| Meteosat Operational Programme Working Group, technical subgroup | Paris<br>January | Mr J. Morgan (Met O 19) |
| AAFCE Tactical Evaluation meeting | Ramstein, Germany (F.R.)<br>January | Mr D. G. Strachan (Met O 6) |
| Discussions of details of large-eddy modelling techniques | Oberpfaffenhofen, Germany (F.R.)<br>January | Dr P. J. Mason (Met O 14) |
| World Area Forecast System, implementation in Europe | Offenbach<br>February | Mr K. Pollard (Met O 7)<br>Mr R. J. Sowden (Met O 5) |
| Royal Society discussion meeting—the aerial transmission of disease | London<br>February | Dr F. B. Smith (Met O 14) |
| EEC meeting, Solar Energy R & D Programme, Wind Atlas for EEC | Brussels<br>February | Dr R. J. Adams (Met O 3) |
| Workshop on observing system experiments | Washington, DC<br>February | Mr A. Lorenc (Met O 11) |
| Seminar on data-assimilation methods | Washington, DC<br>February | Mr A. Lorenc (Met O 11) |
| Co-operative study of the impact of FGGE data on NWP systems | Washington, DC<br>February | Mr A. Lorenc (Met O 11) |
| Meteosat Operational Programme Working Group | Paris<br>February | Mr J. Morgan (Met O 19) |
| Meteosat Operational Programme potential participants | Paris<br>February | Mr J. Morgan (Met O 19) |
| Meteosat Operations Advisory Group | Darmstadt<br>February, May, September, December | Mr J. Morgan (Met O 19) |
| ESA Programme Board Meteorology | Paris<br>February | Mr J. Morgan (Met O 19) |
| ESA ERS-1 AMI team | Taunton<br>February | Mr D. Offiler (Met O 19) |
| ECMWF Technical Advisory Committee—sub-group | Reading<br>February | Dr W. A. McIlveen (Met O 22) |
| Guide on the Automation of Data Processing Centres | Geneva<br>February/March | Mr M. W. Stubbs (Met O 17) |
| Discussions with US Weather Service, computer manufacturers and MIT conference | Washington, DC<br>Minneapolis, MN<br>Boston, MA<br>March | Mr F. H. Bushby, Director of Services |
| Eighth ECODU Executive Symposium | Nice<br>March | Mr F. H. Bushby, Director of Services |
| ECMWF Technical Advisory Committee—5th session | Reading<br>March | Mr D. H. Johnson, DD Met O(F)<br>Dr R. L. Wiley, AD Met O(SM) |
| ESA Intergovernmental meeting | Paris<br>March | Sir John Mason, Director-General<br>Mr D. E. Miller, DD Met O(P)<br>Mr J. Morgan (Met O 19) |
| ECMWF Finance Committee 29th and 30th sessions | Reading<br>March, September | Mr G. J. Day, AD Met O(IP)<br>Mr M. W. Stubbs (Met O 17)<br>Mr J. E. NcNulty (Met O 4) |
| Meteorological panel for the North Sea and adjoining waters—5th meeting | Hamburg<br>March | Mr R. M. Morris, AD Met O(PS)<br>Mr F. Hayes (Met O 7) |

| Title | Place and date | Attended by |
| --- | --- | --- |
| NATO MCMG working group on weather plans and weather communications—57th meeting | London<br>March | Mr C. E. Goodison (Met O 5)<br>Dr J. I. Gibbs (Met O 6) |
| Meeting of COST senior officials juridicial and financial sub-group | Brussels<br>March | Dr R. E. W. Pettifer, AD Met O(OI) |
| IMA Conference on models of turbulence and diffusion in stably stratified regions of the natural environment | Cambridge<br>March | Dr D. J. Carson, AD Met O(BL)<br>Dr F. B. Smith (Met O 14)<br>Dr P. J. Mason (Met O 14)<br>Dr J. C. King (Met O 14)<br>Dr A. J. Lapworth (Met O 14)<br>Mr D. J. Thomson (Met O 14) |
| Remote sensing by meteorological satellites | Amsterdam<br>March | Dr K. M. Carpenter (Met O RRL) |
| Discussions with Météorologie Nationale | Trappes, France<br>March | Dr G. J. Jenkins (Met O 1) |
| Use of UK model products by Scandinavian Airlines System | Copenhagen<br>March | Dr R. A. Bromley (Met O 2)<br>Mrs A. L. Bedford (Met O 2)<br>Mr M. Phillips (Met O 12) |
| First international colloquium on vector and parallel methods on scientific computation | Paris<br>March | Mr C. Temperton (Met O 11) |
| Discussions on joint project using drifting buoys in the Atlantic | Keil, Germany (F.R.)<br>March | Dr R. E. W. Pettifer, AD Met O(OI) |
| ESA ERS-1 data team | Paris<br>March | Mr J. Morgan (Met O 19) |
| Pre-launch testing of SSU F6 on NOAA E (NOAA 8) | Vandenburgh Air Force Base, CA<br>March | Mr B. Tonkinson (Met O 19) |
| Discussions on microwave radiometry with NOAA/NESDIS | Washington, DC<br>March | Dr D. R. Pick (Met O 19) |
| Symposium on climate and the biosphere | Osnabruck, Germany (F.R.)<br>March | Dr J. F. B. Mitchell (Met O 20) |
| American Meteorological Society—4th conference on meteorology of the upper atmosphere | Boston, MA<br>March | Dr A. O'Neill (Met O 20) |
| AMS—4th conference on atmospheric and oceanic waves and stability | Boston, MA<br>March | Dr A. A. White (Met O 21) |
| Euro-graphics Conference | York<br>March | Mr P. R. Cockrell (Met O 22) |
| ECMWF Council—17th session | Reading<br>April | Sir John Mason, Director-General<br>Mr G. J. Day, AD Met O(IP) |
| Meeting of Directors of European meteorological services | Helsinki<br>April | Sir John Mason, Director-General |
| Aircraft to Satellite Data Relay System meetings | Geneva<br>April, July, August, September | Mr G. J. Day, AD Met O(IP) |
| ECODU Conference | Nice<br>April | Dr S. R. Mattingly (Met O 12)<br>Mrs A. M. Foreman (Met O 12)<br>Mr R. S. Bell (Met O 2) |
| IBM Users Group | Noordwykerhout, Holland<br>April | Mr M. A. Phillips (Met O 12) |
| Environmental sub-committee of the EEC Committee on research and development (CREST) | Brussels<br>April | Mr A. Gilchrist, DD Met O(D) |

| *Subject/purpose* | *Place and date* | *Attended by* |
|---|---|---|
| Second Workshop on data comparison and derived dynamical quantities during northern hemisphere winters (1978–1982) | Oxford<br>April | Dr J. Nash (Met O 1)<br>Dr A. O'Neill (Met O 20) |
| NATO AFCENT Meteorological Committee | Rheindahlen, Germany (F.R.)<br>April | Mr P. Menmuir (Met O 6)<br>Mr D. G. Strachan (Met O 6)<br>Mr M. G. Waller (Met O 6) |
| ESA ERS-1 AMI team | Munich<br>April | Mr D. Offiler (Met O 19) |
| ESA Programme Board Meteorology | Paris<br>April | Dr R. L. Wiley, AD Met O(SM) |
| Visit to National Data Buoy Centre. MTS/NDAC Symposium on buoy technology | Bay St Louis, MS, New Orleans, LA<br>April | Dr R. E. W. Pettifer, AD Met O(OI) |
| International Conference on long-range transportation models for photo-chemical oxidants and their precursors | Raleigh, NC<br>April | Dr F. B. Smith (Met O 14) |
| Discussions on COST 72 radar projects and COST 43 buoy projects | Dublin<br>April | Dr R. E. W. Pettifer, AD Met O(OI) |
| Remote sensing sub-group of working group on technology set up by Versailles Summit on economic growth and employment | Paris<br>April | Dr R. L. Wiley, AD Met O(SM) |
| The Weather Channel. A dedicated cable TV system | Atlanta, GA<br>May | Mr R. M. Morris, AD Met O(PS) |
| Meeting to discuss the exchange of radar data between the UK and French Meteorological Services | Paris<br>May | Mr C. G. Collier (Met O RRL) |
| Intercomparison of wave models | De Bilt<br>May | Dr P. E. Francis (Met O 2) |
| EEC Meeting, solar energy R & D programme, Wind Atlas for EEC | Risø, Denmark<br>May | Dr R. J. Adams (Met O 3) |
| CDC Seminar on environmental information systems technology | Hornbaek, Denmark<br>May | Mr S. Foreman (Met O 11) |
| Lecturer at course on mesoscale meteorology | Pinnarpsbaden, Sweden<br>May/June | Dr K. A. Browning (Met O RRL) |
| Conference of Commonwealth Meteorologists | Reading<br>June | Sir John Mason, Director-General<br>Mr F. H. Bushby, Director of Services<br>Mr P. Goldsmith, Director of Research<br>Mr D. E. Miller, DD Met O(P)<br>Dr M. J. P. Cullen, AD Met O(FR)<br>Mr G. J. Day, AD Met O(IP)<br>Mr C. R. Flood, AD Met O(CF)<br>Dr P. Ryder, AD Met O(SD)<br>Dr R. E. W. Pettifer, AD Met O(OI)<br>Dr A. J. Gadd (Met O 2)<br>Mr R. J. Sowden (Met O 5)<br>Mr J. Findlater (Met O 9)<br>Mr J. Crabtree (Met O 14)<br>Mr D. J. Painting (Met O 16)<br>Mr M. W. Stubbs (Met O 17) |

| *Subject/purpose* | *Place and date* | *Attended by* |
|---|---|---|
| COST 43 Seminar on data buoy technology | Reading<br>June | Sir John Mason, Director-General<br>Dr R. E. W. Pettifer, AD Met O(OI)<br>Mr J. M. Nicholls, AD Met O(OP)<br>Dr G. J. Jenkins (Met O 1)<br>Mr J. F. Ponting (Met O 1)<br>Mr D. J. Painting (Met O 16)<br>Mr A. N. Bentley (Met O 16)<br>Mr J. Bedford Smith (Met O 16)<br>Mr J. Hardie (Met O 16) |
| Advisory Committee of the EEC for Programme Management, Climatology | Brussels<br>June | Mr A. Gilchrist, DD Met O(D) |
| Meeting of the COST 72 co-ordinating committee, exchange of radar data throughout western Europe | Brussels<br>June, November | Mr C. G. Collier (Met O RRL) |
| International Maritime Organisation (IMO) 4th session of the Maritime Safety Committee | London<br>June | Captain G. V. Mackie, Marine Superintendent |
| Sixth American Meteorological Society Conference on numerical weather prediction | Omaha, NE<br>June | Mr R. S. Bell (Met O 2)<br>Mr S. Foreman (Met O 11) |
| NATO Group of experts on fallout warning exercises | Oslo<br>June | Mr P. G. Rackliff (Met O 6) |
| Inspection/liaison visits HQ RAF Germany, HQ1 (BR) Corps, RAF Brüggen, Gutersloh, Laarbruch, Wildenrath and AAC Detmold | Germany (F.R.)<br>June | Mr I. J. W. Pothecary, AD Met O(DS) |
| Visit to Geophysical Fluid Dynamics Laboratory and seminar on operational model | Princeton, NJ<br>June | Mr S. Foreman (Met O 11) |
| Visit to NMC, GLAS and seminars on operational model | Washington, DC<br>June | Mr S. Foreman (Met O 11) |
| NATO advanced research workshop on high-speed computation | Jülich, Germany (F.R.)<br>June | Mr C. Temperton (Met O 11) |
| International conference on acid precipitation—origin and effects | Lindau, Germany (F.R.)<br>June | Dr F. B. Smith (Met O 14) |
| COST 43 Management Committee and regional sub-group meetings | Reading<br>June | Dr R. E. W. Pettifer, AD Met O(OI)<br>Mr D. J. Painting (Met O 16) |
| ESA ERS-1 data team | Frascati, Italy<br>June | Mr J. Morgan (Met O 19) |
| ESA ERS-1 AMI team | Hamburg<br>June | Mr D. Offiler (Met O 19) |
| Scientific and technical advisory group to ESA. Programme Board Meteorology | Paris<br>June | Dr R. L. Wiley, AD Met O(SM)<br>Mr J. Morgan (Met O 19) |
| ESA Programme Board Meteorology | Paris<br>June, November | Dr R. L. Wiley, AD Met O(SM)<br>Mr J. Morgan (Met O 19) |
| ESA Programme Board Operational Meteorology | Paris<br>June, November | Dr R. L. Wiley, AD Met O(SM)<br>Mr J. Morgan (Met O 19) |
| Large scale computations | San Diego, CA<br>June/July | Dr M. J.P. Cullen, AD Met O(FR) |
| Work on the WMO Wave Programme | Geneva<br>June/July | Dr P. E. Francis (Met O 2) |
| NATO 40th MCMG Meeting | Brussels<br>June/July | Mr I. J. W. Pothecary, AD Met O(DS) |

| *Subject/purpose* | *Place and date* | *Attended by* |
|---|---|---|
| UARS principal investigators meeting | Washington, DC July | Dr A. F. Tuck (Met O 15) |
| International workshop on atmospheric spectroscopy | Chilton July | Dr E. L. Simmons (Met O 15)<br>Mr N. C. Atkinson (Met O 15)<br>Mr B. B. McMahon (Met O 15) |
| Visit to US National Meteorological Center for discussion of World Area Forecast System, implementation plans | Washington, DC July | Mr R. J. Sowden (Met O 5)<br>Dr A. J. Gadd (Met O 2) |
| Inspection/liaison visit RAF Akrotiri | Cyprus July | Mr A. Lambley (Met O 6) |
| Demonstration of computer graphics facility | Milan July | Dr B. J. Conway (Met O 22) |
| HALOE science team meeting | Mainz, Germany (F.R.) August | Dr A. F. Tuck (Met O 15) |
| Eighteenth IUGG General Assembly | Hamburg August | Dr R. Hide (Met O 21)<br>Dr D. A. Bennetts (Met O College)<br>Dr J. S. Foot (MRF)<br>Mr R. W. Lunnon (Met O 13)<br>Mr C. A. Nash (Met O 15)<br>Mr S. Nicholls (Met O 15)<br>Dr T. N. Palmer (Met O 13)<br>Mr D. E. Parker (Met O 13)<br>Dr J. F. B. Mitchell (Met O 20)<br>Dr A. O'Neill (Met O 20)<br>Dr A. Slingo (Met O 20)<br>Dr M. J. P. Cullen, AD Met O(FR) |
| BAAS, Application of meteorological services to industry and commerce | Brighton August | Captain G. V. Mackie, Marine Superintendent |
| US Army meso-meteorology Advisory Panel | Saulgau, Germany (F.R.) August | Dr P. W. White, AD Met O(DC) |
| Oceans '83 conference and exhibition | San Francisco, CA August/September | Mr R. J. Shearman (Met O 3) |
| Calibration of pyranometers | Akrotiri, Cyprus August/September | Mr J. H. Seymour (Met O 1) |
| CACGP Conference on tropospheric chemistry | Oxford August/September | Mr P. Goldsmith, Director of Research<br>Dr P. R. Jonas, AD Met O(CP)<br>Dr B. A. Callander (Met O 14)<br>Mr J. Crabtree (Met O 14)<br>Mr M. Kitchen (MRF)<br>Mr R. C. Pallister (Met O 15)<br>Dr A. F. Tuck (Met O 15)<br>Dr G. Vaughan (Met O 15) |
| ECMWF Scientific Advisory Committee—11th session | Reading September | Mr F. H. Bushby, Director of Services |
| ECMWF Technical Advisory Committee—6th session | Reading September | Mr F. H. Bushby, Director of Services<br>Mr D. H. Johnson, DD Met O(F)<br>Dr P. Ryder, AD Met O(SD)<br>Mr G. J. Day, AD Met O(IP) |
| ECODU Conference | Dusseldorf September | Dr W. A. McIlveen (Met O 12)<br>Dr S. R. Mattingly (Met O 12) |
| IBM Users Group | Oxford September | Mr M. Boyd (Met O 12) |
| Olivetti computer aided design | Ivrea, Italy September | Mr G. A. Unwin (Met O 12) |

| *Subject/purpose* | *Place and date* | *Attended by* |
|---|---|---|
| Advisory Committee of the EEC Second Climatology Research Programme | Brussels September | Mr A. Gilchrist, DD Met O(D) |
| Royal Society Discussion meeting on acid rain | London September | Mr P. Goldsmith, Director of Research<br>Dr F. B. Smith (Met O 14) |
| IMO, 26th session of the sub-committee on radio communications | London September | Captain G. V. Mackie, Marine Superintendent |
| Intercomparison of wave models | Hamburg September | Dr P. E. Francis (Met O 2)<br>Mr J. J. Ephraums (Met O 2) |
| Second international meeting of statistical climatology | Lisbon September | Mr R. C. Tabony (Met O 3) |
| Offshore Europe '83 | Aberdeen September | Mr W. D. Caudwell (Met O 3)<br>Mrs C. Boyack (Met O 3) |
| NATO 20th Army Armaments Group Panel XII Meteorology | Brussels September | Mr P. G. Rackliff (Met O 6) |
| NATO 25th SHAPE Meteorological Committee | Mons, Belgium September | Dr J. I. Gibbs (Met O 6)<br>Mr D. Forsdyke (Met O 6) |
| Seminar on numerical methods for weather prediction | Reading September | Mrs S. P. Ballard (Met O 11)<br>Mr R. T. H. Barnes (Met O 11)<br>Mr I. S. Cook (Met O 11)<br>Mr A. D. Darlington (Met O 11)<br>Mr R. K. Dumelow (Met O 11)<br>Mr S. Foreman (Met O 11)<br>Dr T. B. Fugard (Met O 11)<br>Dr B. Golding (Met O 11)<br>Mr W. H. Hand (Met O 11)<br>Mr A. G. Higgins (Met O 11)<br>Mr C. T. Little (Met O 11)<br>Mr C. A. Parrett (Met O 11)<br>Mr D. R. Roskilly (Met O 11)<br>Mr R. N. B. Smith (Met O 11)<br>Mr C. Temperton (Met O 11)<br>Mr M. Young (Met O 11) |
| Fourth symposium on turbulent shear flow | Karlsruhe, Germany (F.R.) September | Mr N. S. Callen (Met O 14) |
| Euromech colloquium on airflows over coasts and hills and effects on pollution and human activity | Delphi, Greece September | Mr R. H. Maryon (Met O 14) |
| NATO/CCMS conference on air pollution modelling and its applications | Copenhagen September | Mr D. J. Thomson (Met O 14) |
| COST 43 working group on North Atlantic drifting buoy project | De Bilt September | Mr D. J. Painting (Met O 16) |
| Discussions on advanced microwave sounding unit | Washington, DC Los Angeles, CA September | Dr D. R. Pick (Met O 19) |
| TOVS Study Conference | Igls, Austria September | Dr J. R. Eyre (Met O 19) |
| ESA ERS-1 AMI team | Bracknell September | Mr D. Offiler (Met O 19) |
| NATO workshop on the atmospheric and oceanic circulation in the Mediterranean Basin | La Spezia, Italy September | Dr H. Cattle (Met O 20) |
| SEAS anniversary meeting | Oxford September | Dr P. Ryder, AD Met O(SD)<br>Dr A. P. Cluley (Met O 22) |
| Chemistry of multiphase atmospheric systems | Corfu, Greece September/ October | Dr G. Vaughan (Met O 15) |

| *Subject/purpose* | *Place and date* | *Attended by* |
|---|---|---|
| Meteorological Users of CYBER 205 USA National Meteorological Centre | Camp Springs, MD October | Mr F. H. Bushby, Director of Services<br>Mrs A. M. Foreman (Met O 12)<br>Dr P. Ryder, AD Met O(SD) |
| World Area Forecast System, Implementation in Europe | Bracknell October | Mr K. Bryant (Met O 7)<br>Mr K. Pollard (Met O 7)<br>Mr R J. Sowden (Met O 5) |
| Aeronautical Radio Incorporated (ARINC) meeting and liaison visit to National Meteorological Service | Washington, DC October | Mr G. J. Day, AD Met O(IP) |
| NATO MCMG working group on weather plans and weather communications 58th meeting | Oslo October | Dr J. I. Gibbs (Met O 6)<br>Mr C. E. Goodison (Met O 5) |
| Workshop on probability forecasting | Corvallis, OR October | Mr G. H. Ross (Met O 9) |
| IMO, 28th session of the sub-committee on Safety of Navigation | London October | Captain G. V. Mackie, Marine Superintendent |
| Visit to Geophysics Laboratory—Workshop on numerical prediction | Boston, MA October | Mr A. Lorenc (Met O 11) |
| ESA—Earth Observation Advisory Committee | Paris October | Dr J. T. Houghton, Director-General |
| European working group on limited area models—5th meeting | De Bilt October | Miss M. J. Atkins (Met O 2)<br>Mr R. N. B. Smith (Met O 11) |
| NATO Civil Defence Committee working group exercise on fallout warning exercises | London October | Mr P. G. Rackliff (Met O 6) |
| NATO AGARD symposium | Langley, VA October | Mr I. J. W. Pothecary, AD Met O(DS) |
| Meteorological support to ATOC | Messtetten, Germany (F.R.) October | Mr P. Menmuir (Met O 6) |
| Visits to OJCS Washington, HQ Air Weather Service, Global Weather Centre Offut AFB, Atmospheric Sciences Laboratory US Army, White Sands | United States of America October | Mr I. J. W. Pothecary, AD Met O(DS) |
| Liaison visit, 1 (BR) Corps Bielefeld | Germany (F.R.) October | Mr K. R. Ingamells (Met O 6) |
| Visit to NMC—seminar and discussions on data assimilation methods | Washington, DC October | Mr A. Lorenc (Met O 11) |
| Visit to Geophysical Fluid Dynamics Laboratory—seminar and discussions on data assimilation methods | Princeton, NJ October | Mr A. Lorenc (Met O 11) |
| Visit to CDC and Cray Research Incorporated to discuss super computer developments | Minneapolis, MN October | Dr P. Ryder, AD Met O(SD) |
| Visit to National Weather Service to discuss methods of disseminating meteorological data | Washington, DC October | Dr P. Ryder, AD Met O(SD) |
| AGARD Development and use of numerical and factual data-bases | London October | Mr P. R. Cockrell (Met O 22)<br>Mr R. A. Pearson (Met O 22) |
| Eighth Global Diagnostic Workshop | Toronto October | Mr D. E. Jones, AD Met O(SC) |
| ESA ERS-1 data team | Oslo October | Mr J. Morgan (Met O 19) |
| Scientific and Technical Advisory Group to ESA Programme Board Meteorology | Paris October | Mr J. Morgan (Met O 19) |

| *Subject/purpose* | *Place and date* | *Attended by* |
|---|---|---|
| Course on climatological aspects of desertification: facts, theories and methods | Erice, Sicily October | Dr P. R. Rowntree (Met O 20)<br>Dr C. C. Heasman (Met O 20) |
| MIZEX modelling workshop | Lake Morey, VT October | Dr H. Cattle (Met O 20) |
| Workshop on interim ocean surface wind data sets | Madison, WI October | Dr H. Cattle (Met O 20) |
| Visit to various IBM sites in eastern USA to discuss powerful new computers, networking and imaging methods | United States of America October | Dr P. Ryder, AD Met O(SD) |
| Visit to Atmospheric Environment Service to discuss methods of disseminating meteorological data | Toronto October/ November | Dr P. Ryder, AD Met O(SD) |
| Lectures on nowcasting and mesoscale meteorology | Beijing, China October/ November | Dr K. A. Browning (Met O RRL) |
| ICAO METAG—8th meeting | Paris October/ November | Mr K. Pollard (Met O 7) |
| Seminar on KONTUR results | Hamburg October/ November | Dr D. J. Carson, AD Met O(BL)<br>Mr A. L. M. Grant (Met O 14) |
| Inspection and calibration of Dobson Spectrophotometer: inspection rawinsonde station | Mahé, Seychelles November | Mr J. M. Regan (Met O 15)<br>Mr P. Collins (Met O 16) |
| ECMWF Council—18th session | Reading November | Dr J. T. Houghton, Director-General<br>Mr F. H. Bushby, Director of Services<br>Mr G. J. Day, AD Met O(IP) |
| European working group on observing system experiments | Paris November | Mr A. Gilchrist, DD Met O(D) |
| IMO, 13th session of the Assembly | London November | Captain G. V. Mackie, Marine Superintendent |
| ESA ERS-1 AMI team | The Hague November | Mr D. Offiler (Met O 19) |
| Work on the Guide on the Global Data-processing System | Geneva November | Mr M. W. Stubss (Met O 17) |
| Work on job re-classification in WMO Secretariat | Geneva November/ December | Mr M. W. Stubbs (Met O 17) |
| ACEWEX and Co-ordination Group for TWN | Traben-Trarbach, Germany (F.R.) November/ December | Mr D. G. Strachan (Met O 6) |
| Workshop on convection in large scale numerical models | Reading November/ December | Dr B. Golding (Met O 11)<br>Dr P. R. Rowntree (Met O 20)<br>Dr A. Slingo (Met O 20) |
| Meeting of experts to plan the pilot Atmospheric-Hydrological Experiment | Geneva November/ December | Dr J. F. B. Mitchell (Met O 20) |
| COST 43 Management sub-group meeting | Brussels December | Mr D. J. Painting (Met O 16) |
| COST 43 Management Committee | Brussels December | Dr R. E. W. Pettifer, AD Met O(OI)<br>Mr D. J. Painting (Met O 16) |
| Fifth session of CCCO | Abingdon December | Dr J. T. Houghton, Director-General |

# APPENDIX IV

# PUBLICATIONS

Publications issued by the Meteorological Office appear either in the form of official Government publications, obtainable through the sales office or usual agents of Her Majesty's Stationery Office, or (more commonly nowadays) as departmental publications which may be obtained directly from the Meteorological Office. Catalogues of both these classes are obtainable free on request.

The titles which follow are those that were completed during 1983; an asterisk indicates that the publication concerned was handled by HMSO. The final numbers within brackets are International Standard Book Numbers (ISBN), which provide positive identification of those items that bear them.

## PERIODICAL

Annual

*Annual Report on the Meteorological Office* 1982 (0 11 400345 9)*
*Annual Weather Summary* (London)
*Annual Weather Summary* (Southampton)
*Marine climatological summaries for the Atlantic Ocean E of 50°W, N of 20°N* (microfiche), 1964 (0 86180 104 0), 1965 (0 86180 105 9), 1966 (0 86180 106 7), 1967 (0 86180 116 4), 1968 (0 86180 120 2), 1969 (0 86180 121 0), 1970 (0 86180 083 4)
*Meteorological Office Almanack* 1984 (Leaflet No. 11)
*Monthly and annual totals of rainfall for the United Kingdom* 1978 (0 86180 143 1)
*Monthly ice charts* 1982 (0 86180 083 4)
*Monthly Weather Report*, annual summary, 1981 (0 11 726692 2)
*Snow survey of Great Britain*, 1981/82 (0 86180 078 8)
*Meteorological Office Calendar* 1984

Quarterly

*Marine Observer**
*Stratospheric charts for the Northern Hemisphere* (microfiche), 1982 1st quarter (0 86180 118 0)
*Stratospheric charts for the Southern Hemisphere* (microfiche), 1981 1st quarter (0 86180 093 1)

Monthly

*Anomaly maps* (London Weather Centre)
*Builders' Inclement Weather Summary* (Nottingham Weather Centre)
*Daily Weather Summary* (Bristol)
*Daily Weather Summary* (Cumbria)
*Daily Weather Summary* (Newcastle and NE England)
*Daily Windspeed Summary* (Bristol)
*Degree days* (Heathrow)
*Full tabulation of anemograms* (London Weather Centre)
*Lincoln Weather Diary* (Nottingham Weather Centre)
*Meteorological Magazine**
*Monthly analysis of rainfall during the working day* (Manchester Weather Centre)
*Monthly Supplement to the Daily Weather Summary* (Newcastle and NE England)
*Monthly Weather Report* (October 1981 to November 1982)*
*Monthly Weather Summary* (Central southern England)
*Monthly Weather Summary* (London)
*Monthly Weather Summary* (Southampton)
*Monthly Weather Summary* (Southern Sussex)
*Monthly Weather Summary* (UK)
*Rainfall analysis* (London Weather Centre)

*Relative humidity and vapour pressure at Abbotsinch*
*Sunshine tabulation* (London Weather Centre)
*Temperature at Abbotsinch*
*Watnall Weather Diary* (Nottingham Weather Centre)
*Watnall Weather Summary* (Nottingham Weather Centre)

Fortnightly
*Meteorological Office Rainfall and Evaporation Calculation System (MORECS)*

Weekly
*Daily Weather Summary* (Manchester)
*Degree days* (Heathrow), weekly edition
*Soil temperatures* (St James's Park)
*Ice Charts* (scale 1:10 million), North Atlantic (Wednesdays only)

Daily
*Daily Remarks* (London Weather Centre)
*Daily Weather Summary* (London Weather Centre)
*Shipping Chart and Forecast* (Glasgow Weather Centre)

SERIAL

Climatological Memorandum No. 130, *The climate of Great Britain: Lancashire, Cheshire and the Isle of Man* (0 86180 102 4)
Climatological Memorandum No. 132, *The climate of Great Britain: The Midlands* (0 86180 077 X)
Climatological Memorandum No. 135, *The climate of Great Britain: London* (0 86180 107 5)
Climatological Memorandum No. 143, *The climate of Northern Ireland* (0 86180 080 X)
Scientific Paper No. 40: *The Meteorological Office GATE modelling experiment* (0 11 400342 4)*

OCCASIONAL

*A brief introduction to the United Kingdom Mark 3 radiosonde system* (1983 edition) (0 86180 125 3)
*Climatological Services—Scotland* (revision)
Leaflet No. 3: *Weather bulletins, gale warnings and services for the shipping and fishing industries* (0 86180 126 1)
Leaflet No. 5: *Making weather observations* (0 86180 081 8)
Leaflet No. 12: *Publications* (0 86180 144 X)
*Observer's Handbook*, 4th edition (0 11 400329 7)*
*Services for agriculture—Wales*

# APPENDIX V

## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AAFCE | Allied Air Forces Central Europe |
| ACE | Allied Command Europe |
| ACEWEX | Allied Command Europe Weather Exchange |
| ACRE | Automatic Climatological Recording Equipment |
| ADAS | Agricultural Development and Advisory Service |
| AFCENT | Allied Forces Central Europe |
| AGARD | Advisory Group for Aerospace Research and Development (NATO) |
| AIDS | Aircraft Integrated Data System |
| AMI | Active Microwave Instrument |
| ASAP | Automated Shipboard Aerological Programme |
| ASDAR | Aircraft to Satellite Data Relay |
| ATOC | Air Tasking Operations Centre |
| AUTOCOM | Automated Telecommunication Complex |
| AUTOPREP | Automatic Message Preparation Equipment |
| AUTOSAT | Automatic Satellite Imagery Handling System |
| BAAS | British Association for the Advancement of Science |
| CAA | Civil Aviation Authority |
| CACGP | Commission on Atmospheric Chemistry and Global Pollution |
| CAeM | Commission for Aeronautical Meteorology (WMO) |
| CBS | Commission for Basic Systems (WMO) |
| CCCO | Committee on Climatic Changes and the Ocean |
| CCl | Commission for Climatology (WMO) |
| CCMS | Committee on the Challenge of Modern Society |
| CDC | Control Data Corporation |
| CDEM | Crop Disease Environment Monitor |
| CFO | Central Forecasting Office |
| CIMO | Commission for Instruments and Methods of Observation (WMO) |
| CMM | Commission for Maritime Meteorology (WMO) |
| COSMOS | Meteorological Office computing system |
| COSPAR | Committee on Space Research (ICSU) |
| COST | European Co-operation in Science and Technology |
| DALE | Digital Anemograph Logging Equipment |
| EC | Executive Council (WMO) |
| ECMWF | European Centre for Medium Range Weather Forecasts |
| ECODU | European Control Data Users |
| EEC | European Economic Community |
| EMEP | European Monitoring and Evaluation Programme |
| EPPO | European and Mediterranean Plant Protection Organization |
| ESA | European Space Agency |
| EUMETSAT | European Meteorological Satellite System |
| FAO | Food and Agriculture Organization (United Nations) |

| | |
|---|---|
| GLAS | Goddard Laboratory for Atmospheric Sciences |
| GOS | Global Observing System (WMO) |
| GTS | Global Telecommunication System (WMO) |
| HALOE | Halogen Occultation Experiment |
| HELIMET | Provision of meteorological services to helicopter operations (ICAO) |
| IAMAP | International Association of Meteorology and Atmospheric Physics (IUGG) |
| IASH | International Association of Scientific Hydrology (IUGG) |
| IBM | International Business Machines Ltd |
| ICAO | International Civil Aviation Organization |
| ICSU | Interntaional Council of Scientific Unions |
| IEA | International Energy Agency |
| IMA | Institute of Mathematics and its Applications |
| IMO | International Maritime Organization (formerly Intergovernmental Maritime Consultive Organization (IMCO)) |
| INMARSAT | International Maritime Satellite Organization |
| JASIN | Joint Air-Sea Interaction Experiment (Royal Society) |
| JSC | Joint Scientific Committee (WMO/ICSU) |
| KONTUR | Konvektion und Turbulenz |
| MAFF | Ministry of Agriculture, Fisheries and Food |
| MGMG | Military Committee Meteorological Group (NATO) |
| METAG | Meteorological Advisory Group (ICAO) |
| MIT | Massachusetts Institute of Technology |
| MIZEX | Marginal Ice Zone Experiment |
| MMO | Main Meteorological Office |
| MMS | Marine Meteorological Services |
| MOD(PE) | Ministry of Defence (Procurement Executive) |
| MOLARS | Meteorological Office Library Accessions and Retrieval System |
| MOLFAX | Meteorological Office Land-line Facsimile Network |
| MORECS | Meteorological Office Rainfall and Evaporation Calculation System |
| MOSS | Meteorological Observers' System for Ships |
| MRF | Meteorological Research Flight |
| MTS | Marine Technology Society |
| NAOS | North Atlantic Ocean Stations |
| NASA | National Aeronautics and Space Administration, USA |
| NATO | North Atlantic Treaty Organization |
| NATS | National Air Traffic Services |
| NERC | Natural Environment Research Council |
| NESDIS | National Environmental Satellite Data Information Service |
| NOAA | National Oceanic and Atmospheric Administration, USA |
| OASYS | Outstation Automation System |
| OECD | Organization for Economic Co-operation and Development |
| OJCS | Office of the Joint Chiefs of Staff |
| OSTIV | Organisation Scientifique et Technique International du Vol a Voiles |

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|---|---|
| PFO | Principal Forecasting Office |
| PROMET | Provision of meteorological information required before and during flight |
| RA VI | Regional Association VI—Europe (WMO) |
| SAWS | Synoptic Automatic Weather Station |
| SCOR | Scientific Committee on Oceanic Research (WMO) |
| SHAPE | Supreme Headquarters Allied Powers in Europe |
| SSU | Stratospheric Sounding Unit |
| TECIMO-II | Second Technical Conference on Instruments and Methods of Observation |
| TIROS | Television Infra-red Observation Satellite |
| TOVS | TIROS Operational Vertical Sounder |
| TWN | Teleprinter Weather Network |
| UARS | Upper Atmosphere Research Satellite (NASA) |
| UKWMO | United Kingdom Warning and Monitoring Organization |
| UMIST | University of Manchester Institute of Science and Technology |
| UNEP | United Nations Environment Programme |
| VCP | Voluntary Co-operation Programme (WMO) |
| VOF | Voluntary Observing Fleet |
| WMO | World Meteorological Organization |
| WWW | World Weather Watch (WMO) |

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