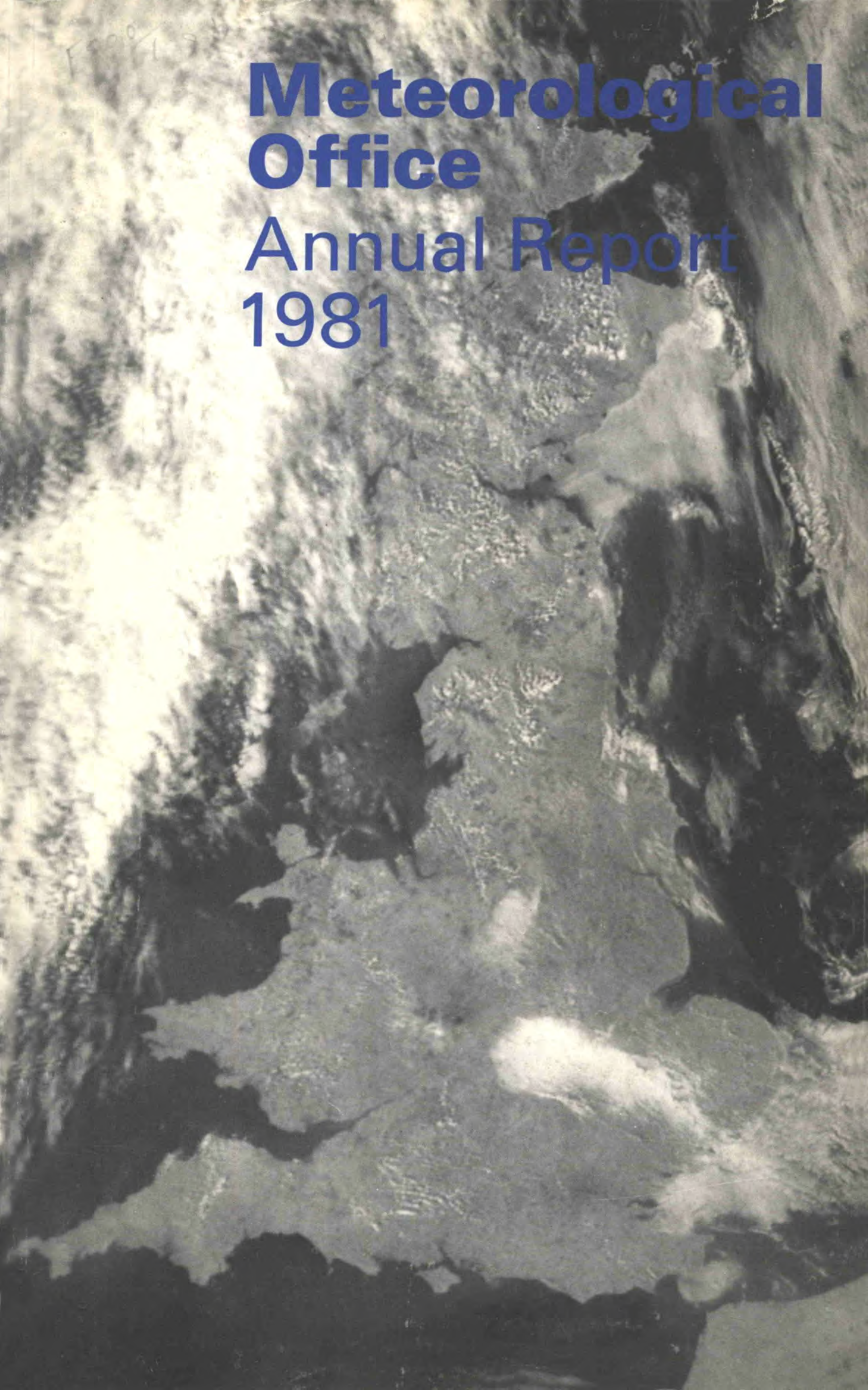
Meteorological Office

Annual Report 1981



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ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE
1981

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

LONDON
HER MAJESTY'S STATIONERY OFFICE

U.D.C.
551.5(058)

First published 1982

ISBN 0 11 400339 4

Cover photograph: Picture taken by the polar-orbiting satellite NOAA–7 on 28 August 1981 at 1316 GMT in the visible spectrum. There is a weak front over the North Sea, some areas of fog over the Midlands, the Thames estuary, and off the coasts of East Anglia and eastern Scotland, and a cloud mass to the west of the British Isles associated with a depression and fronts which moved across Wales and much of England the next day. The picture is reproduced by permission of the University of Dundee (Electronics Laboratory).

FOREWORD BY THE DIRECTOR-GENERAL

In another busy year the Office was hard pressed to meet all the demands for its services and enquiries from the general public were limited by the shortage of telephone lines and staff. Nevertheless a total of 1.93 million forecasts was made for civil and military aviation whilst the number of non-aviation enquiries reached 2.03 million. The number of calls made on the Automatic Telephone Weather Service increased by nearly 17 per cent to 30.3 million.

Despite the recession our repayment receipts for 1980/81 increased by 22 per cent to £15.8 million, the income from sources other than civil aviation having increased by no less than 49 per cent. In the same period staff numbers fell by 6 per cent and by the end of the year by nearly 9 per cent.

The main telecommunication system, AUTOCOM, was enhanced by the commissioning of a pair of Ferranti Argus 700S computers, which now handle all the traffic on the medium-speed international channels, and by a new electronic link between AUTOCOM and the data-processing computer system. After many problems in the development stage this new system is working with great reliability and for more than 99.7 per cent of the time. Another new system, AUTOPREP, is being installed at outstations that act as collecting centres for weather observations where the bulletins can now be prepared and edited with the help of a dedicated microcomputer, thus eliminating a laborious task and saving staff. One of our greatest problems arises from the continued rapid increases in British Telecom charges which far exceed the provision for inflation made in our planned expenditure under strict cash limits. Despite all our efforts to rationalize and streamline our communication system, which lies at the heart of our operations, we may well not be able to meet all our national and international commitments next year.

The new giant CYBER 205 computer, capable of 400 million floating-point operations per second, was delivered in June and commissioned in August. The very first machine of a new generation, it has worked very well on its own, achieving speeds about four times greater than specified, but its link to the IBM 360/195 and 370/158 computers is not yet fully operational. The IBM COSMOS computer system, now 10 years old, is beginning to deteriorate but nevertheless executed more than half a million jobs during the year. Tenders have been received for new computers to replace this system in 1982/83. The special article on page 1 traces the progress of automation throughout the Office since we obtained our first computer in 1959.

A special warning service for small craft was introduced during the year. During the holiday season, between Good Friday and the end of October, warnings are issued promptly over local radio whenever the wind is expected to reach Force 6 within five miles of the coast. Despite a reduction in shipping activity the ship-routeing service has made steady progress, a contract being placed by a Middle Eastern line to route their entire fleet across the Atlantic, involving some 160 routeings per year.

A revised system for calculating the differences between rainfall and evaporation for a variety of crop and soil combinations was introduced, providing accurate and comprehensive guidance to the agricultural industry on the requirements for irrigation. A new method of calculating the downwind spread of foot-and-mouth disease was devised and was tested when the disease was discovered in Brittany, Jersey and the Isle of Wight in March and gave valuable guidance within hours of confirmation of an outbreak in the United Kingdom.

After considerable delay caused by problems with the Ariane rocket, the second European geostationary satellite, Meteosat-2, was successfully launched in July (see Plates I and II). Visible and infra-red images are being transmitted but winds derived from cloud displacements will not be available until early next year.

On the research front, a great deal of effort was devoted to developing the next operational weather forecasting model and its data-assimilation scheme for use on the new CYBER 205 computer. Good progress has been made and experimental forecasts covering the whole globe have been made once a day for up to 6 days ahead. The new model is expected to become fully operational by mid-1982.

In recognition of the fact that fluctuations in the world's climate is likely to be determined by changes in the oceans and the ice sheets as well as by changes in the atmospheric circulation, models representing the upper mixed layers of the oceans and a thermodynamic model of the sea-ice are being developed to interact with the atmospheric model which is being used to assess the effects of natural and man-made perturbations, in particular those likely to be produced by increasing carbon dioxide and by ozone-reducing chemicals.

The Hercules flying laboratory took part in a co-operative experiment with research groups from the Federal Republic of Germany to study convective and turbulent motions on a variety of scales over the German Bight. An important aim was to relate the structure and development of convective clouds to the turbulent motions and fluxes in the sub-cloud layer. Our recent researches in the atmospheric boundary layer are described in the special article on page 00.

Measurements by our stratospheric sounding radiometer on board the US polar-orbiting satellites NOAA–6 and NOAA–7 have provided the most precise observations to date of the lunar tide in the stratosphere. Geomagnetic data from the satellite MAGSAT have been used by US scientists to confirm Dr Hide's method of determining the radius of the electrically-conducting core of a planet from observations of secular changes in its external magnetic field. They report that the radius of the Earth's core determined by this method agrees within 2 per cent of that obtained from seismological data.

Despite a further reduction of staff posts this year I have judged it essential to maintain a steady flow of new young scientists into the Office, so this year we have recruited 14 high-quality graduates.

At the Meteorological Office College a total of 620 students completed courses during the year, including 70 overseas students from 22 countries.

We were very pleased to receive a delegation of six senior Chinese meteorologists led by Professor Ye Duzheng, Vice-President of the Chinese Academy of Sciences (see Plate V). They saw a wide cross-section of our operational and research activities and gave several lectures on their own researches. This visit, made under an exchange scheme between the Chinese Academy of Sciences and the Royal Society, followed the visit to China which I led last year.

B. J. MASON

February 1982
Meteorological Office
Bracknell, Berks.

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APPENDICES

FUNCTIONS OF
THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the 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 Parliamentary Under-Secretary of State for Defence for the Armed Forces.

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.

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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
*Sir John Mason, C.B., F.R.S. (Director-General, Meteorological Office)
*Mr D. C. Humphreys, C.M.G. (Deputy Under-Secretary of State (Air))
*Air Vice-Marshal K. W. Hayr (Assistant Chief of the Air Staff (Operations)); alternate, Group Captain M. J. C. Burton
*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 O. B. St John

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

**ex officio*

The Committee met four times in 1981. One meeting was devoted to the research program.

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DEPUTY TO THE DIRECTOR-GENERAL

K. H. Stewart, Ph.D.

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Chief Meteorological Officer, London/Heathrow Airport	K. Bryant

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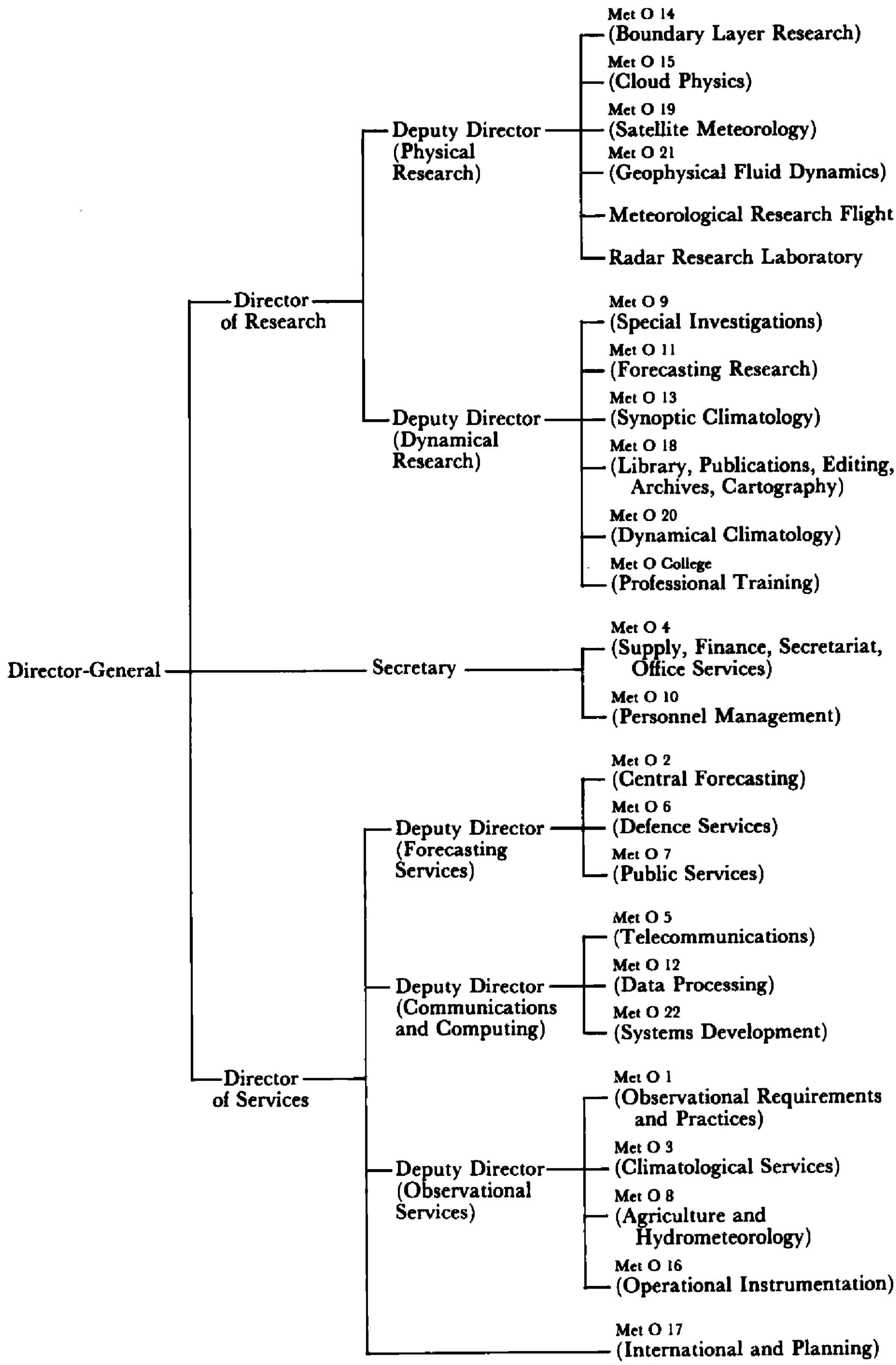
Personnel Management	
Assistant Director	D. M. Houghton, M.Sc., D.I.C.

METEOROLOGICAL OFFICE ORGANIZATION

(at 31 December 1981)



DIRECTORATE OF SERVICES
SPECIAL TOPIC—AUTOMATION IN THE METEOROLOGICAL OFFICE

Introduction

Weather forecasting is perhaps the best known field in which there was an early and successful application of electronic computers. Ideas for numerical weather prediction had been proposed in the early 1920s by L. F. Richardson who suggested that teams of mathematicians, whose efforts would be synchronized by a 'conductor', could perform the necessary calculations. The idea has echoes in today's Distributed Array Processor, in which a large number of cheap microprocessors all attack parts of the same overall problem. Practical implementation of those ideas had to await the arrival of the modern electronic computer and the development of more refined numerical models. By 1951 staff from the Office were experimenting with computers and two years later the first numerical weather forecasts were produced. Since then the Office has remained in the forefront of the development and use of numerical models for weather prediction and, more recently, for climatic research.

In retrospect it is perhaps a little surprising that as long as a decade elapsed between the first experiments with numerical models and the development of any other computer applications in the Office. The explanation probably lies with the difficulties of programming and operating the early computers and the fact that the Office's first computer was not available until 1959. Only in those cases where it was difficult or impossible to achieve an objective without a computer was the use of one favoured. Through the 1960s, however, an increasing variety of applications was implemented on the Office's computer. The opportunity came with the introduction of an English Electric Leo KDF9 computer in 1965. This made possible numerical weather forecasting on a routine operational basis and also provided opportunities to carry out a much wider range of other computational work for research, operations and supporting services.

By 1970 the cost of small computers with restricted supporting system software (programs to schedule the machine's resources and provide standard programs to assist in the development of a user's applications) was falling dramatically. This provided new opportunities for introducing automation in situations where geographical separation or real-time problems (in which the computer must respond to external events within a specified time) made it difficult to use the Office's central computer facility. The list of projects now using dedicated minicomputers includes:

AUTOCOM	— automation of central telecommunications at Bracknell.
AUTOSAT	— automation of satellite image processing.
AUTOPREP	— automation of data preparation and collection at regional centres.
SAWS	— Synoptic Automatic Weather Stations.
MOLARS	— Met. Office Library Accessions and Retrieval System.
MATE	— Met. Office College Automated Training Equipment.
OASYS	— Outstation Automation SYStem.

Ground stations for Mk3 radiosonde system.
Control computers for weather-radar network.
Computer at Meteorological Research Flight, Farnborough.
Processor-controlled keying (of manuscript data) to magnetic disc.

Another feature of the 1970s was the increasing use of the main computer system to the point where every branch in the Office has an interest in the facilities that are available. Many numerical models have been developed to investigate different scales of motion, ranging from studies of individual cumulonimbus to climatic variations on the global scale. The ability to store and process significant volumes of archival data has led to increasing use of the computer for enquiry purposes and an interesting recent application has been the introduction of a computer program to predict the most probable pattern of spread of outbreaks of foot-and-mouth disease.

One clear trend for the 1980s is to very simple electronic computers (microprocessors) which are opening up new areas of application because large-scale production is leading to very low hardware costs. As a result of the large market base, the cost of standard computer programs, which are expensive to develop but cheap to copy, can also be very low. The overall effect is that a usable system for a limited range of small applications can be operational at a cost of only a few per cent of what was previously possible. In the Office, therefore, the microprocessor is most likely to be used on applications in the telecommunication, instrumentation and administrative fields. A growing problem is the increasing cost of developing and maintaining computer programs for meteorological purposes. During the 1980s there will be considerable growth in aids to writing programs quickly and accurately. Although such aids will require significant amounts of computer time, the falling costs of the hardware will ensure that the outcome is fully cost-effective. The exception to this general pattern is likely to be in numerical models where the necessary performance can only be achieved by giving considerable attention to programming efficiency.

History of the main computer installation

From 1950 to 1958 staff from the Office were using computers actively but the Office did not have its own machine until early in 1959 when a Ferranti Mercury computer was acquired by the Office. There are many parameters that may be used to indicate the performance of a computer over a range of work, and for scientific work a reasonable measure is the number of floating-point multiplications that can be performed in a second. For Mercury, that figure was 3000 and the performance was comparable with one of today's better programmable pocket calculators. Only one program could be run at a time and it was left to users to run their own work during assigned time-slots.

An English Electric KDF9 was obtained in 1965. The KDF9 gave a major increase in performance as it was able to produce up to 50 000 results per second. It was also possible to have up to four programs in the machine at a time and so total throughput could be increased when running programs which did not individually use the whole of any one resource of the system (this is called multiprogramming). The introduction of multiprogramming made it impracticable for users to run the machine themselves and so full-time operating staff were introduced. Whereas the technology used in the Mercury computer is now completely outdated, KDF9 was recognizably a modern computer using semiconductors for logic and ferrite cores for main storage. A true high-level language, Algol, was available and the impact of this, along with increasing use of numerical models for operational forecasts and research, meant that the computer was soon completely utilized. The numerical forecast was running on an operational basis before the end of 1965 and the need for an even more powerful machine to permit the running of more elaborate models soon became clear.

Late in 1971 an IBM 360/195 was brought into use. In special situations close to 5 000 000 results could be calculated in a second. As well as offering improved scope for running more advanced numerical models, the 360/195 was able to handle an increasing range of general scientific work. A notable advance was the use of plotting equipment that was fast and accurate. High-speed film plotters and slower pen-and-ink plotters were introduced and this eventually led to the automation of many of the manually intensive plotting functions at Headquarters. About three years after the installation of the 360/195, a 370/158 was added as a 'front-end' computer. This allowed removal of small inappropriate jobs from the 360/195, and it provided an on-site back-up for running operational work, albeit much more slowly. The 370/158 can only run about a twelfth of the work of the 360/195 on double-precision floating-point operations; in contrast it can run a third of the work of the 360/195 on integer and character manipulations. More recently, the main memory and backing storage (discs and tapes) have been enhanced for both machines. In all, the system throughput has been roughly trebled for only 50 per cent additional cost.

In the late 1970s increasing emphasis was placed, at both national and international level, on the need for better understanding of climatological processes. At the same time, interest in short-term mesoscale forecasting models increased. Both these tasks needed substantially greater computing power than was available on existing resources and there were also indications that routine numerical forecasts might be required to cover an extended area of the globe using a higher-resolution grid. Research into monthly and seasonal forecasting was also beginning to involve the use of global circulation models. In August 1981 a CYBER 205 computer, manufactured by the Control Data Corporation, USA, was brought into use, enabling the development of the relevant models to go ahead. The maximum performance of the CYBER is 400 000 000 results per second. In practice, the performance is something over 30 times better than the 360/195 for numerical models. The CYBER 205 is a specialized machine and much care and effort is needed by programmers to ensure that it gives its best performance.

Automation of telecommunications

Until the early 1970s the handling of observational data at meteorological telecommunication centres was based on 'torn tape' methods, although analyses and forecasts in pictorial form were handled by facsimile techniques. These centres used teleprinters, paper-tape readers and paper-tape punches, operating at speeds of about ten characters per second, to prepare, transmit and receive the data. Observational data and forecast products are the life-blood of meteorological services, both nationally and internationally, and rapid accurate transmission is essential. Because more basic data were becoming available and more forecast products were required, the World Meteorological Organization had developed plans by the mid-60s for a Global Telecommunication System

(GTS) with an automated Main Trunk Circuit (MTC) of medium-speed lines (initially running at about 300 characters per second) encircling the world via a chain of 'store-and-forward' message-switching computer systems. Each centre had responsibilities for the support of the MTC and also for providing services to the country in which it was sited and, in some cases, to other countries in its region. Bracknell was designated as a Regional Telecommunication Hub (RTH) and has responsibility for maintaining the flow of data to and from Washington on the one hand and Paris and Offenbach on the other. In addition, Bracknell is responsible for ensuring that data from a number of nearby European countries and from the UK itself are injected into the MTC, and equally that those countries obtain data and products from the MTC.

The design of the MTC was somewhat complicated by the fact that meteorological communications involved procedures and facilities over and above those that could be handled by the commercially available message-switching systems of the 1960s. In particular, a completely new protocol* for the efficient two-way transmission of blocks of data had to be designed, and there remained the requirement to handle analogue facsimile as well as digital data. Almost every country which tried to implement automated meteorological communications encountered difficulties. Without exception all took longer to implement operational working systems than had been planned. It is a tribute to the original designers that, after a slow start, the Bracknell system has given a decade of useful service. Although significant staff savings took some years to achieve, automation soon halted what would otherwise have been a steady increase in staff numbers.

The first stage of automating telecommunications involved the use of a dual-processor system based on Marconi Myriad II processors. This system only served the MTC and paper tape remained very much in evidence even for the link to the main data-processing computer installation. The system worked in full dual mode with each processor receiving, checking and storing all data, but only the currently active processor performed output functions. This system went operational in 1972 but within two years improved software and additional hardware allowed the connection of medium-speed lines to several European countries dependent on Bracknell and of low-speed lines for the UK national network and connections to some other countries. A new pair of processors was acquired to allow development work to proceed in parallel with operational work and to permit an easy switch-over to the new system.

Increasing demands for medium-speed lines quickly reached the capacity limits of the system, and overloading arose from the general increase in traffic and the resultant complexity of the routeing lists required to switch the messages. Plans were laid to increase the message-handling capability of the system by adding further processors, and also to implement an electronic link to the data-processing computer system. The electronic link was progressively implemented during 1975 and 1976, using an IBM System 7 computer which was easy to connect to the IBM mainframes. Software was written which caused the System 7 to appear to be a peripheral of the Myriad computers. The additional capacity was provided by a pair of Ferranti Argus 700S computers which went operational early in 1981. Towards the end of 1981 a new sub-system replaced System 7; this makes more use of standard techniques and

*A protocol is a set of rules setting out the structure, meaning and ordering of messages so that they can be exchanged between two information-processing systems.

offers flexibility for future developments. Telecommunication methods are now used throughout the whole system but conversion between protocols is necessary: the Myriad and Argus computers use the WMO protocol while the IBM machines provide support for Binary Synchronous protocol. In addition, a connection to ECMWF (European Centre for Medium Range Weather Forecasts) is supported by a higher-level protocol based on the international high-level data-link control (HDLC) protocol. A Ferranti Argus computer, compatible with but less powerful than those used for the main message switch, is being used to convert between protocols. This machine, known as the TPU (Telecommunication Processing Unit), has capacity to cope with further tasks involving straightforward manipulations of data or protocols.

There have been a number of developments in the automation of telecommunications apart from the main system. Synoptic data are passed to Bracknell via collecting centres which are responsible for collating messages, correcting data and inserting headings. The main system requires headings which exactly match those in its routeing lists if operator intervention is to be avoided. At peak times there can be a significant delay if too much work falls on the operator. Accordingly a system called AUTOPREP was developed which assists the staff at collecting centres in the laborious task of editing messages and adding the headings to groups of bulletins. Each installation consists of a powerful microcomputer, operator's visual display unit and printer. This system has contributed to speed and accuracy by avoiding the need to prepare paper tapes and to key in message headings at collecting centres; information received from observing stations is edited and standard headings are added by the use of simple commands. AUTOPREP has only recently been introduced into satisfactory operational service; the software delivered with the system proved to be unsatisfactory in real use, but new software written in the Office has proved to be much more resilient. AUTOPREP now promises to ease the workload on operators both at collecting centres and at Headquarters but this does not add up to a major saving; the real benefit is in the improved accuracy and punctuality.

A very important recent development has been the use of microprocessors to adapt telecommunication services to changing demands. The rudimentary system software, extremely limited memory and interdependent applications software suites do not provide the possibilities for change which users of mainframe processors are apt to take for granted. Microprocessors have been used to strip off message headings and the like which do not contain meteorologically useful information, and they have been used to combine three 50-baud outputs to generate one 100-baud broadcast. The introduction of 100-baud working was necessary to provide the capacity needed to handle information in new WMO codes to be introduced on 1 January 1982. The new codes provide more detailed information but at the cost of being longer. Two new broadcasts are being transmitted on the same circuits as the main analogue facsimile broadcasts by a technique known as frequency division multiplexing. Very useful cost savings have been achieved from the resulting reduction in the number of low-speed lines required.

Some interesting developments have occurred in the broadcasting of VOLMETs, meteorological information in speech form for aircraft in flight. Until recently, the preparation and broadcasting of VOLMETs was done manually. Appropriate data are now automatically selected and converted into a message suitable for speech transmission. At present this message is still read by an operator but plans are in hand to automate the process further by using a microprocessor controlled-speech synthesizer. Some data, however, are difficult to convert into forms that will lead to comprehensible VOLMET transmissions, but the Civil Aviation Authority (CAA) has already automated the speech-production function by restricting automation to data sources that can be relied on to meet standard formats.

Some meteorological reports from aircraft in flight (AIREPs) are currently made available for incorporation into numerical weather prediction schemes and data bases, but checking and code conversion are labour-intensive tasks. The burden on operating staff is likely to increase when the new forecast system on the CYBER 205 begins to accept observations made at asynoptic times and when CAA provides additional AIREPs from lower levels than are currently reported. Automation offers some hope of checking and formatting the bulk of AIREPs, leaving only rejected reports for operator action.

The extensive use made of analogue facsimile charts by users has been a significant obstacle in the way of improving the effectiveness of digital transmission. The two systems are essentially incompatible and either separate lines have to be used or links within a network have to be switched from one mode to the other as the occasion demands. With the notable exception of high-quality satellite imagery, most charts can be digitized and the information compressed or encoded for later reconstruction, so that digital facsimile takes no longer than the analogue equivalent. Given digital transmission, the same line can then be used for character data and for pictorial data. The two streams can even be transmitted simultaneously by using V-29 modems which provide two or more logical channels on one physical circuit. Agreement in principle has been reached on using this type of technique on the MTC between Washington, Bracknell, Paris and Offenbach. Measures are also in hand to eliminate the hand carriage of automatically plotted charts to the manually operated facsimile transmitters. Instead, digital information representing the chart content will be passed direct to equipment that will convert the information for transmission on either digital or analogue facsimile circuits as necessary. This equipment will also serve the MTC requirement.

Other automated systems

During the early 1960s a small degree of automation was introduced into the Library at Bracknell (which is also the National Meteorological Library) in the form of typewriters with facilities for punching and reading paper tapes (Flexowriters). These were used primarily to assist in the preparation of entries for the various catalogues maintained by the Library. The Flexowriters avoided the need to type complete entries for each catalogue (a typical item might appear in five of the ten special catalogues) but still demanded partial retyping and a considerable amount of manipulation of paper tapes. Accordingly, as the Flexowriters approached the end of their useful life, the possibility was examined of using automated methods to allow all the catalogue entries to be produced from one typing. It was concluded that a small computer system would allow a reduction of about 30 per cent in the typing effort needed to prepare the catalogues, and would release the Library's staff from much of the mundane checking work. In addition, such a system would provide a basis for developing an on-line catalogue, with search facilities through terminals, and some assistance in the control of loans. A computer system went into operation in 1978 to handle catalogue preparation and it is planned that extensions to other tasks will be implemented in the future. The benefits of this small automation project exceeded expectations: the reduction in typing effort approached 50 per cent rather than the 30 per cent planned, and the time taken to prepare the list of monthly accessions was reduced from six weeks to three.

One of the most significant automation projects, in terms of making staff savings, has been the introduction of computer systems at major outstations. These offices have to do much local plotting of observations on charts against strict deadlines, and this work is very labour-intensive. The first possibility considered was the use of remote plotters, driven by programs running in the central computer at Bracknell. This scheme was quite feasible for one site but was likely to become impracticable as the number of sites increased. The use of small computers then became the preferred choice since other functions could be performed in addition to remote plotting, and the use of telecommunication facilities could be rationalized. The first of these systems went operational at the Principal Forecasting Office (PFO), London/Heathrow Airport in January 1981 and comprises two small computers, two high-quality pen-plotters that can draw in four colours, and two faster printer/plotters which draw in black and white, together with associated consoles, communication interfaces and so on. The system is organized so that essential work can continue even when major components of the system are unserviceable. The Heathrow installation saved 16 junior posts.

The equipment for a similar system at the PFO at Headquarters RAF Strike Command (HQSTC) was moved to its operational site in November 1981 and will begin full working early in 1982. Similar systems are envisaged at other sites. Five colour graphics visual display units (GVDUs) were also delivered in December, three for use at Heathrow and two at HQSTC. These will provide the forecasters with direct access to data in the local data base which will be presented in a form that is easy to assimilate and in a convenient order. Experiments are also in hand involving the interactive use of the GVDUs. Terminals at two RAF airfield offices connected to the computers at HQSTC are to be used to test methods of accessing appropriate meteorological information quickly and effectively and to assist in the rationalization of telecommunication facilities.

Training in computer programming at the Meteorological Office College at Shinfield Park, near Reading, used to be significantly hampered by the distance from Bracknell and the consequent difficulty in providing adequate direct experience for trainees. A small computer was introduced in June 1980 which provides facilities to test small Fortran programs at the College and to submit complete jobs via a line to Bracknell. Students enter their work through visual display units, rather than punching cards for transport to Bracknell, and results are stored in the local computer for examination or printing. The saving on rental of card-punches and the elimination of transport requirements for cards and listings means that the project will pay for itself within three years. The major benefit is in improved training which is difficult to quantify but undoubtedly is much greater than the direct savings. The success of the project has led to plans to extend the use of the computer by running special packages to support other courses, and by the development of a training aid relevant to automated outstations.

The acquisition of meteorological data has traditionally been heavily dependent on manual labour. Observations have to be made, recorded on paper, entered on teleprinters, transcribed to manuscript forms for climatological purposes, keyed for computer analysis, quality control and storage, and these activities have traditionally been carried out by staff and voluntary observers. Recently, however, synoptic automatic weather stations and climatological data-logging equipments have been introduced into operational service. There are certain types of observation, e.g. cloud types, that are extremely difficult to make automatically but, nevertheless, they are extremely useful for providing some information to cover gaps in the observing network, whether these occur because of absence of observing stations or because of the economics of placing staff in the relevant areas. There is little doubt that the most cost-effective observing system for the UK will result from a judicious mixture of automated and manual systems.

Manuscript records have always posed special problems of conversion to machinable form. When computers started to be used for analyses of climatological data the necessary records were converted using card-punches. Card-punches are noisy, relatively difficult to use and particularly awkward for correcting punching errors which require a new card to be created. In 1972 the position was improved with the introduction of processor-controlled keying (PCK), sometimes known as key-to-disc. PCK provides better data entry and correction facilities than card-punches, reducing the number of key strokes needed and so economizing on the staff effort needed to convert a given number of documents. However, it is important to try and reduce the keying effort even further. The new meteorological codes, to be introduced in 1982, are expected to contribute to a further reduction of about a third in keying effort; this is because a relatively small increase in the amount of information sent via telecommunication channels for synoptic purposes will enable the data to be used for climatological purposes as well. For the future, optical character recognition and electronic entry of data by observers appear to offer possibilities of reducing the staff effort in PCK still further.

Conclusion

Automation has made a major contribution to improving the services provided by the Office and to reducing the cost of providing those services. With falling costs of computer hardware, increased understanding of the strengths and weaknesses of automated systems and improved programming methods, substantial further benefits can be expected.

OTHER WORK OF THE DIRECTORATE OF SERVICES

FORECASTING SERVICES

Central forecasting

The Central Forecasting Branch comprises the Central Forecasting Office, which provides the main guidance on the weather developments up to five days ahead, and a development section which is responsible for maintaining and improving the operational numerical forecast system.

The Central Forecasting Office (CFO) maintains a round-the-clock forecasting service. Internationally, CFO is a Regional Meteorological Centre in the World Weather Watch system of the World Meteorological Organization and, as such, is responsible for providing forecasts and advice to a number of European National Meteorological Centres. This is mostly in chart form but there is an increasing use of 'grid-code' bulletins (sets of numerical values at an array of points forming a regular grid) and, in March, the output of such bulletins rose to 92 a day. The area of responsibility covers a large part of the North Atlantic, Europe and the Arctic. At the national level, CFO is the chief forecasting centre of the Meteorological Office and it provides guidance to Meteorological Office outstations in the form of charts showing the actual and expected synoptic situations up to 5 days ahead, together with advisory texts describing the likely weather developments. Additionally, it has responsibilities for warnings of weather hazards including gales, fog, snow, heavy rain, frost, icy roads, thaw and thunderstorms over and around the United Kingdom and for the issue of various forecasts to users.

For public services, a number of forecasts are produced for radio, the Press and public utilities such as the British Gas Corporation and the Central Electricity Generating Board. There are also frequent conferences between the Senior Forecaster and staff at the London Weather Centre responsible for the live radio and television forecasts. For shipping, services include the issue of gale warnings, the shipping forecast four times a day and storm warnings for the North Atlantic. Captains and crew members of ships at sea are able to consult the forecasters in CFO by radiotelephone. Further details are given in the section on 'Services for marine activities' (page 15).

As described in the section on 'Services for civil aviation' (page 19), the aviation forecasters in CFO provide flight documentation showing forecast upper winds and temperatures for aircraft flying from western Europe to North America. For Concorde, special forecasts are prepared twice a day for British Airways and Air France for flights across the Atlantic. A new form of coding, in which the data are presented for vertical columns of the atmosphere, was introduced in February when British Airways began receiving the information via a direct computer-to-computer link. Another innovation this year was a chart showing a numerically forecast index of clear-air turbulence, developed in the Special Investigations Branch, for use by the aviation forecasters.

Satellite cloud pictures have continued to make a very important contribution to the preparation of surface and upper-air analyses, not only for the North Atlantic and European area but also for the many data-sparse parts of the world, including the southern hemisphere. CFO is now receiving immediate transmission of data from the two United States polar-orbiting satellites: NOAA-6 which operated throughout the year and its fellow NOAA-7 which was launched in June; together these provide coverage of the North Atlantic and European area about every 6 hours. The second European Space Agency satellite, Meteosat-2, was also launched in June (see Plates I and II). It provided valuable pictures with a fixed field of view at frequent intervals for our sector of the northern and southern hemispheres. A computerized visual display system in CFO allows pictures to be viewed with different selected magnifications and contrasts of shade. Forecasters can also display a 'movie' sequence composed of the pictures from Meteosat-2. Another useful television-type display in CFO shows a composite weather-radar picture, merging the results from four separate weather radars. This experimental system is being developed by the Meteorological Office Radar Research Laboratory at Malvern and indicates the position, intensity and movement of the main rain areas over a large part of England and Wales. Routine messages describing the main features are now issued by CFO to Meteorological Office outstations.

All the outstation guidance and forecasts are produced in CFO by a combination of numerical (computer) methods and subjective (manual) methods. Experience shows that neither method alone produces as good results as the 'man–machine mix'. The numerical data are closely monitored by two forecasters, who try to ensure that the starting analysis for the forecast model is as accurate as possible. This is done by inserting new information from the subjective hand-drawn analysis and correcting or rejecting doubtful observations, using visual display terminals connected to the computer. The two forms of the operational 10-level numerical forecasting model are run twice a day. The coarse-mesh (octagon) version covers most of the northern hemisphere and the fine-mesh (rectangle) version gives more detailed coverage, including rainfall forecasts for Europe and the eastern North Atlantic. In addition to this basic guidance, the forecasters use their experience of the behaviour of weather systems and their knowledge of the characteristics of the numerical analysis and forecast models. They are also able to take into account information not available to the numerical system such as satellite pictures, weather-radar displays and conventional observations received too late for inclusion in the numerical computations.

Outstation advice for the shorter periods up to 24 or 30 hours ahead is normally provided four times a day though this is done more frequently if the occasion warrants it. From late October the time of running the fine-mesh forecast was brought forward by 20 minutes to begin 2 hours after observation time, while the time of issue of some of the written guidance to outstations was retarded slightly. This combination gives the Senior Forecaster just enough time to study the latest numerical forecasts before issuing his guidance. Other changes around the same date were the introduction of a facility to repeat a main 00 or 12 GMT fine-mesh run if it is judged that the forecast has been seriously impaired by a poor analysis, and the discontinuation of the fine-mesh forecast based on observations for 06 GMT. Forecasts up to 5 days ahead are produced regularly for issue to meteorological offices throughout the country. The medium-range forecaster makes extensive use of numerical model output from the octagon and that provided from the USA, the Federal German Republic and the European Centre for Medium Range Weather Forecasts, but is free to use his own judgement in coming to his conclusions. These forecasts have improved markedly in quality in recent years, particularly those for 2 and 3 days ahead which are disseminated internationally.

As indicated earlier there is also a numerical weather prediction group within the Central Forecasting Branch. Its prime task is to maintain and improve the operational numerical forecast system. A number of changes have been made to the existing system, for example in response to requests for different output, but the main work during the year has been to develop and test the next system. A completely new series of computer programs has been written for running on the CYBER 205 computer. These programs carry out the input stages of extracting and sorting the observations and including the modifications made by forecasters and the output stages of producing the charts and coded bulletins, archiving the results and checking the accuracy of the forecasts. There has been close co-operation with members of the Forecasting Research Branch who have been responsible for the objective analysis of the observations and the numerical forecast model. An important operational change is that the new system is global, whereas the coverage of the current model is restricted to the northern hemisphere north of 15°N. There are numerous other differences (for example, there is a smaller horizontal and vertical separation of the grid-points in the model) and it is expected that these will lead to an improvement in the accuracy of the forecasts.

Development work was carried out initially via a link to a computer in the USA and by visits to Minneapolis, but much faster progress was made once the CYBER 205 was installed at Bracknell. A trial of the new system began in September and, after some initial difficulties, the new suite of programs ran regularly with a series of 6-hourly analyses and one main forecast a day based on the 12 GMT analysis. Forecasters from CFO, aided by support staff, worked on a daily roster to assess the results and to monitor and modify the global surface and upper-air analyses. This modification is likely to continue to be necessary with the new model, especially in the southern hemisphere. The computer programs and the numerical weather prediction system itself were under continual development in this period, errors being corrected and the formulation improved. Results were promising though the work was by no means complete at the end of the year.

Waves and swell at sea are forecast with a different type of numerical model. Results from a coarse-mesh version are used to assist ship routeing across the Atlantic. A fine-mesh version, which includes depth-dependent processes, provides forecasts for the continental-shelf area round the British Isles. Output was sent routinely to the London Weather Centre and during the year the area of coverage was extended to the Mediterranean. The model was also used to give advanced warning to water authorities of possible coastal flooding due to wave activity. An occasion of extremely high waves at Chesil Beach was successfully forecast during March. Other commercial applications of the model included investigations into response characteristics of different areas of the North Sea under certain idealized wind conditions and the use of the wave-analysis archive by the Wave Energy Project of the Department of the Environment.

A number of other investigations have been carried out. Work was undertaken to assist the assessment of fuel-saving benefits in flight-planning arising from the use of winds obtained by AIDS (Aircraft Integrated Data System). Development work has continued on a statistical forecasting technique known as Model Output Statistics (MOS). The basis of MOS rests on establishing a statistically significant relationship between observed weather variables, such as air temperature or visibility, and forecast parameters given by a numerical weather prediction model. Experimental temperature forecasts for four stations during the winter half of the year were at least as good as the subjective forecasts currently being issued.

New work resulted from the introduction of an Outstation Automation System (OASYS) at Heathrow meteorological office in January. A programming support unit was set up in the Central Forecasting Branch to maintain the operational effectiveness of the OASYS and, in consultation with users, to design and develop applications programs. A more complete description of the system is given in the section on 'Systems Development' (page 51), the Branch which carried out the initial development and installation.

The Daily Weather Report Section formally closed on 9 January, shortly after the final issues of the *Daily Weather Report* and the *Daily Aerological Record* for 31 December 1980 were prepared.

Services for industry, commerce and the general public

Forecast services for the general public, commerce and industry are provided from a network of public service forecast offices distributed throughout the UK. Some of these offices are located on military and civilian aerodromes where the primary commitment is to Defence and civil aviation respectively. Here the public service commitment is on a limited scale. Dedicated public service offices called Weather Centres are mostly situated near city centres with easy access to commercial customers and the media. Two new Weather Centres were opened in 1981, at Bristol in August (see Plate III) and at Cardiff in December, bringing the total number of Weather Centres to eight. The extension of the network was due to the rationalization of Defence, civil aviation and public service commitments in the west country and Wales with a consequential improvement in the effectiveness of the services accomplished with fewer staff. The reorganization included, *inter alia*, the closure of the forecast offices at RAF Innsworth and Cardiff/Wales Airport and this enabled some reduction of staff to take place in the area. Each Weather Centre serves a large area including the city in which it is located; for example, Bristol Weather Centre handles services throughout Gloucestershire, Somerset, Avon and Wiltshire while Cardiff Weather Centre deals with the whole of Wales.

Public services carried out by the outstations fall into distinct categories. General forecasts are prepared for dissemination on television, radio and in newspapers, at no direct cost to the public. Rather more detailed and specific forecasts are available on the Automatic Telephone Weather Service and on Teletext systems at relatively small cost to the public. All Weather Centres and certain other public service offices are listed in telephone directories so that a facility exists for staff to deal directly with the general enquiries from the public. Dedicated forecast services are provided on a commercial and contractual basis for a wide range of weather-sensitive activities including transport, power, construction and farming. There is also an increasing demand for forecast services in connection with leisure activities. These commercial forecasts are usually tailored to meet the specific requirements of the individual customers.

The amount of weather information provided through the media expanded further during the year. The presentations given by the 'Weatherman' team on BBC Television remained largely unaltered although a new live broadcast was inserted during the year into the peak viewing time on Saturday evenings. The BBC carried out an independent public survey on the usefulness and effectiveness of the 'Weatherman' presentation. The results of the survey were very encouraging indeed and, in effect, the BBC was offered a clear mandate to expand and develop presentation of weather on television. Live presentation of forecasts in the BBC regions also expanded during 1981 with BBC West and BBC Wales taking services from Bristol and Cardiff respectively, to add to the services already provided for BBC Midlands and BBC South West. There were parallel increases in the services provided to independent television companies. The Meteorological Office forecasters at Birmingham Airport provided a daily live presentation on ATV. The scope of this service is likely to increase in 1982 following the award of the East Midlands franchise to ATV in 1981. Negotiations with Harlech Television took place towards the end of the year on the possibility of a live presentation using forecasters from Bristol Weather Centre.

National radio services were, in general, unchanged during 1981 although there was a significant modification to the BBC Radio 2 schedules. A live broadcast was introduced at 2200 hours replacing the one previously put out at 1830. This rearrangement usefully filled a gap in the Office's output on national radio; up until then there had been no live broadcasts between 1830 and 0010. There was also an important alteration made to the service provided for the BBC Motoring Unit: it is now given warnings, for broadcasting to motorists, of hazardous weather conditions for the whole country, rather than just for motorways as had mainly been the case previously. As in 1980, the number of forecasts on local radio showed the greatest expansion. By the end of 1981 there were over 20 BBC or IBA radio stations issuing forecasts broadcast by staff from public service offices. Many other local stations receive scripts which are read out by radio announcers, and as the local network plans to expand over the next few years there should be an increasing demand for weather forecast services. The Meteorological Office recognizes the importance of local radio for disseminating its information and every effort will be made to satisfy the needs of new stations as they become operational.

Apart from the routine broadcasts on radio and television, Office staff were involved in many other programs during 1981. There was a six-part BBC 2 series 'Under the Weather', which attempted to explain various aspects of weather and climate; the series was presented by Jack Scott, the senior BBC TV weatherman, and featured contributions by a number of meteorologists including some from the Office. The arrival in the summer of the new computer (see page 49) prompted a large number of requests for interviews in news programs, as did some of the more newsworthy current weather events: in particular, the severe conditions which occurred widely throughout the UK towards the end of April.

The amount of weather information provided to Prestel and Teletext grew during 1981. The number of television sets capable of displaying the Prestel data base is still disappointingly small but it is rising, mainly among the business community. The current emphasis on the business rather than the residential market has led to changes in the Office's contribution during 1981. For instance, weather information for general aviation purposes is now routinely put on to the data base; feedback from the customers has shown this to be a valuable addition. Interest from the travel trade has led to an increase in the quantity of world-wide material. Prestel set owners can now have a comprehensive weather service displayed in their offices or homes. This, together with further improvements in the data base, especially those suggested by users, should lead to a marked increase in revenue for the Office from Prestel over the next few years. Meanwhile, as Teletext technology increases, more information will be disseminated by this means. The Office is watching developments carefully and will be ready to meet the demand for more information when it arises.

A major reorganization of the Automatic Telephone Weather Service (ATWS) was implemented with British Telecom in 1981. As a result many of the areas for which forecasts are prepared were redefined and most other parts of the United Kingdom not previously covered by forecasts are now included in the service (see Table XII, page 67). Eventually the whole of England and Northern Ireland will be covered, together with much larger parts of Wales and Scotland than at present. With an increase of coverage and increased publicity to ATWS given by both British Telecom and the Office it is likely that the number of calls to the revenue-sharing service will continue to rise. The trend has been upwards for several years; in 1981 the number of calls to ATWS was 30 310 956 compared to 25 967 894 in 1980.

The number of enquiries to Weather Centres has remained at a high level as the following table shows; note that the figure for Bristol is for five months only and that for Cardiff is only for December.

	1979	1980	1981
Bristol	—	—	20 051
Cardiff	—	—	6 438
Glasgow	112 524	99 273	96 684
London	312 908	322 102	331 315
Manchester	149 338	134 827	119 903
Newcastle	110 840	94 987	97 731
Nottingham	69 616	83 190	81 511
Southampton	108 468	91 897	100 622
Totals	863 694	826 276	854 255

One of the consequences of the staff cuts imposed on the Office has been the reduction of free telephone access to forecasters by the general public. As many of these enquiries are seeking information similar to that which is provided on ATWS or radio, callers are encouraged to make more use of these facilities.

To meet a commercial demand for specific forecast advice by telephone, a consultancy service is provided for a modest fee whereby the client has access to the forecaster on an ex-directory line. This consultancy service has proved extremely popular and cost-effective with many commercial organizations.

The consultancy service is just one type of commercial service operated from public service offices. One of the most important revenue-producing services is that provided to the offshore industry, described more fully in the section on 'Services for marine activities' (page 15). The gas and electricity industries are also major users of specialist meteorological advice. The demand for power from industrial and domestic consumers is closely related to changes in temperature. Forecasts of temperatures up to 36 to 48 hours ahead in fine detail are prepared and issued by the Weather Centres to local gas and electricity regions several times daily. On a smaller scale, heating engineers can make considerable economic use of forecasts to control heating and ventilation in factories and offices. It is estimated that enormous savings can be made in fuel costs by more widespread and effective use of meteorological advice in this way.

Many local authorities take Meteorological Office advice. In winter, warnings of frost or snow allow a more effective use of grit and salt on roads. In summer, road-dressing operations are sensitive to high temperatures and prompt warnings can be very helpful. The activities of farmers and growers are very weather-sensitive throughout the year; in particular, when sowing, crop-spraying and harvesting, farmers need to know how confident forecasters are of the likelihood of specific weather conditions. Water authorities require advance notification of heavy rain or the onset of a thaw after a heavy snowfall.

During a period of severe industrial recession it is very encouraging to see that revenue received by the Meteorological Office for forecast services to industry and commerce rose by 50 per cent in the financial year 1980/81 compared with 1979/80. This achievement is no doubt partly due to the increasing awareness within the community as a whole of the value of effective use of the best professional meteorological advice.

Promotion of meteorological services is undertaken in many ways. A film, entitled 'A Question of Weather', describing some of the forecast services, was produced by the MOD Film Unit and issued in 1981. This film has been shown to many different types of audiences ranging from the general public to groups with a highly specialist interest in the weather. A major new Meteorological Office brochure entitled 'Looking at the Weather' was issued during the year. Reactions to both of these products from most who have seen them have been very favourable. Many other smaller brochures describing individual services are produced by the Office; among them 'Services for Agriculture' and 'Weather Advice to the Community' were updated in 1981.

The Office was represented at many exhibitions during the year with most of the stands designed and produced with the assistance of MOD Directorate of Promotions and Facilities (MOD(DPF)) and the Central Office of Information. Her Majesty the Queen visited the Office stand at the Royal Show in July (see Plate IV) where the many ways the Office assists the farming community were described to her. This and other agricultural shows provide an excellent opportunity to promote consultancy services to farmers as well as to carry out major public relations exercises. This latter aspect is extremely important if the Office is to increase the confidence of both public and industry in its services. For the first time ever, and at the request of MOD(DPF), the Office was featured at the Ideal Home Exhibition at Earls Court (see Plate IV). 'A Question of Weather' was shown continuously in a small cinema constructed as part of the stand. Aiming at a more specialist market, a stand was again mounted at the Offshore Europe '81 Exhibition in Aberdeen, and also at the Business and Light Aviation Show in Cranfield where there was a display of general aviation forecast services available on Prestel.

Direct contact with the public is maintained daily by members of the Public Services Branch who reply to hundreds of letters received during the year and who escort organized parties from a wide variety of backgrounds around the operational part of Meteorological Office Headquarters. Many members of staff at Bracknell and elsewhere gave a number of talks and lectures, usually in their own time, again with a public relations aspect in mind but also using every opportunity to publicize the specialized services which are available on a repayment basis.

Services for marine activities

The Meteorological Office forecasting services for the offshore oil and gas industries have been maintained at a high level of commitment. Most of the forecast preparation is carried out at the London Weather Centre where computer forecasts of surface wind and waves are received on dedicated telecommunication lines from Bracknell. The forecasters at the Weather Centre continually update charts of wind, weather and sea state over a broad area embracing the continental shelf around the British Isles and adjacent waters. By making judicious use of computer guidance, they prepare and issue forecasts to over 50 commercial customers at least twice daily. The forecasts, which are usually for periods up to 72 hours ahead, are mostly despatched by telex to the shore-based company offices for onward transmission to the offshore platforms, rigs and support vessels. Local forecasting advice is provided on a smaller scale at the meteorological office at Dyce, near Aberdeen, where the forecasters maintain regular direct contact with the offshore companies through daily briefing of the marine personnel. Local forecasting services are also provided at Kirkwall in the Orkneys and at Lerwick in the Shetland Islands for the oil-tanker-loading operations at Flotta and Sullom Voe respectively. All these local forecast offices receive general guidance from the London Weather Centre by facsimile, telex and telephone.

The expansion of the production phase in offshore operations led to an increase in the number of tankers loading at Flotta and Sullom Voe. The exploration phase also continued with a high level of activity; the number of daily forecasts issued increased but, more significantly, the number of forecasters deployed offshore at the sites of operations also grew. Offshore companies recognize that on-the-spot advice can be the most efficient and effective means of utilizing a forecast service during critical weather-sensitive operations. The offshore-based forecaster is supplied with a comprehensive amount of data by telex from the London Weather Centre. As many as three forecasters have been deployed offshore simultaneously during 1981 and at least one company is intent upon maintaining a forecaster on an offshore platform throughout the winter of 1981–82. Forecast advice is being provided for exploration in the Norwegian Sea and the Mediterranean Sea.

The Meteorological Office also gave technical advice to the offshore industry through its representation on a number of committees. The Principal Meteorological Officer at the London Weather Centre is the meteorological adviser to the Oceanographic Committee of the United Kingdom Offshore Operators Association (UKOOA) and to the Oceanographic and Meteorological Sub-committee of the International Exploration and Production Forum. During the year advice has been given on the siting of instrumented ocean data-collection buoys from which observations will be collected for use in establishing operational and design criteria. The importance of frequent timely and accurate weather and sea-state observations for operational forecasting cannot be over-stressed and, although many offshore operators recognize this fact, the network of offshore observations still needs to be improved considerably.

Services to shipping via BBC Radio, Coast Radio Stations (British Telecom International) and our international radio-teleprinter and radio-facsimile broadcasts continued with some additions throughout the year.

As a result of the automation of the Noord Hinder Light-vessel, weather reports from this station were discontinued in the BBC Radio 4 Shipping Forecasts for coastal sea areas and replaced by reports from the Goeree Light-tower. For the same reason, weather reports from Lizard were discontinued in the Inshore Waters forecasts and replaced by reports from Land's End. The temporary replacement of weather reports from Machrihanish by Prestwick in the Inshore Waters forecasts has become permanent.

In October the Coast Radio Station at Oban, together with its 'slaves' on Lewis and Skye, ceased to operate between the hours of 2200 to 0800 GMT daily and arrangements were made for gale warnings to be issued for sea areas

Rockall and Bailey between these hours to be broadcast by Portpatrick Radio. The Coast Radio Station at Cullercoats continued to broadcast weather forecasts and gale warnings for all North Sea and adjacent forecast areas from Fair Isle to Plymouth in radio-teletype as a temporary service.

The Small Craft Warning Service came into operation for the first time. This service is provided in the holiday season between Good Friday and 31 October and warnings are issued whenever the wind is expected to reach Beaufort force 6 or more within five miles of the coast. The warnings are issued by Weather Centres to local radio stations which broadcast the information as soon as possible. Because of the distribution of local radio stations not all coastal areas are covered by the warning service and, indeed, in Scotland the service is almost non-existent.

The Meteorological Office gave specialist advice for three major sailing events. For the Observer/Europe 1 Transatlantic Race, organized by the Royal Western Yacht Club of England, a pre-race briefing was given by forecasters at Plymouth meteorological office on 5 June; gale and storm warnings were issued from the Central Forecasting Office (CFO) to the BBC World Service throughout the race which finished on 18 July. A limited amount of weather information was sent to CFO by the yachts although much of it tended to be too late for immediate operational use.

A comprehensive forecast service was provided to the Royal Ocean Racing Club for the Admiral's Cup series. Actual and forecast charts were provided through the Southampton Weather Centre and, for the Fastnet Race only, outlooks were prepared by CFO for up to six days ahead. Several teams, including some from overseas, were provided with individual briefing and consultancy services on a repayment basis. Extra broadcasts were made on BBC Radio Solent on the morning of the start of each race with a live presentation by the duty forecaster.

The third yachting event was the Whitbread Round the World Yacht Race which commenced on 29 August. Pre-race briefing was provided by the Southampton Weather Centre and the Meteorological Office arranged with British Telecom International for the transmission by radio-telephony of relative sections of the Atlantic Weather Bulletin for Shipping—normally broadcast by wireless-telegraphy—for the periods when the yachts were in the areas covered by the Bulletin.

CFO again supplied guidance forecasts and warnings to the forecaster on board the trawler support ship stationed off the coast of northern Norway during March and April. The forecaster maintained close liaison with the British fishing fleet in the area, issuing forecasts and warnings of gales and ice accretion.

Oil slicks and pollution at sea are emergencies in which CFO plays its part in issuing forecasts and meteorological advice. CFO also works closely with the officers of the Storm Tide Warning Service who are responsible for issuing alerts on occasions when unusually high tides caused by strong winds give rise to the risk of flooding on the east coast of England.

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 meteorological office at Pitreavie continued to provide a winter forecast service for the benefit of North

Sea fishing vessels. The forecasts issued covered a 72-hour period and were broadcast daily from October to April. 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 provided forecasts for Royal Corps of Transport vessels operating from Akrotiri mole.

A ship-routeing service is provided to advise on North Atlantic and North Pacific passages and to offer advice in regard to the movement of tows and salvage operations. Advice is also given to vessels on passage in other parts of the world on request. For conventional vessels the object of the service is to select the best route for the ship to follow in order to reach her destination in the shortest possible time with the most economical fuel consumption commensurate with least damage to ship and cargo. To achieve this, data are extracted from the ship's deck logbook to determine the vessel's response to various sea-wave fields and a performance curve is constructed. However, the service has now amassed a large amount of performance data for almost all types of vessels and it is frequently possible to assess performance characteristics from basic ship size and type without recourse to the deck logbook. The forecasters in CFO provide the ship-routeing officers, who are all Master Mariners with long sea-going experience, with wind and sea predictions up to 72 hours ahead at 12-hourly intervals and this information is used in conjunction with the performance curve to determine the most favourable course for the vessel to follow. At the same time, consideration is given to the loading state of the vessel, navigational hazards such as shoals, sea-ice and areas of fog, and also to sea-surface currents. The latter stages of the voyage are also taken into consideration. Communication with the vessel to be routed is usually by telex prior to sailing and via predetermined coast radio stations whilst on passage. Routeing advice to tows which do not have restrictive weather parameters is similar to that provided for conventional vessels but allowance is made for the slower speed of the tow and for restricted manœuvrability. For tows with limiting weather factors—which may be wave height or period, amount of heel or wind force—the routeing service advises when and where to seek shelter or when to resume passage.

Despite the current recession in the shipping industry, the number of routeings has been maintained at a high level during the year and now averages more than 30 per month. A major contract was secured with a Middle Eastern shipping company to route their entire fleet of container ships and bulk carriers across the North Atlantic; this contract entails approximately 160 routeings per year. During the latter part of the year the routeing service provided a weather watch for some of the eight remaining large Thames Barrier gates on passage from Middlesbrough to the Thames estuary.

The voyage assessment service, which was introduced last year, in which an investigation is made into the performance of a ship in relation to the weather encountered during the voyage and the weather reported by the ship, has proved to be of value to shipowners and charterers.

The Meteorological Office, in collaboration with the Ministry of Defence and the Central Office of Information, provided a stand at the Offshore Europe '81 Exhibition in Aberdeen during mid-September. Amongst the exhibits was an automatic weather station which had been deployed offshore and considerable interest was shown in this type of data-collection system.

Services for civil aviation

The provision of meteorological services for civil aviation in the United Kingdom follows closely the guidance provided by the Standards and Recommended Practices of the International Civil Aviation Organization (ICAO). In the terms of these regulations the Civil Aviation Authority (CAA) is the meteorological authority for civil aviation matters. The role of the Meteorological Office is to provide professional advice to the CAA and to provide meteorological services on a repayment basis. The CAA recovers the cost of the meteorological services as a part of the *en route* charges which are levied on all aircraft using navigational services within United Kingdom airspace.

The organization of meteorological services for civil aviation is centred upon the Principal Forecasting Office (PFO) at London/Heathrow Airport, which is also designated by ICAO as the Area Forecast Centre (AFC) responsible for the provision of forecasts for all flights from Europe across the Atlantic to Canada and the USA. COSMOS output, modified to include detail of the structure and position of jet streams by a team of specialist upper-air forecasters in the Central Forecasting Office at Bracknell, is passed to PFO Heathrow. With the addition of significant-weather charts prepared by aviation forecasters at Heathrow, the upper-air charts from Bracknell are distributed widely throughout Europe by land-line and radio-facsimile. Within the United Kingdom these forecast charts are distributed by the land-line Civil Aviation Meteorological Facsimile broadcast (CAMFAX), together with a selection from other area forecast centres of charts which are required for long routes. The charts are photocopied as necessary at airfields to provide flight documentation.

This centralized output is adequate to satisfy the needs of the majority of commercial aviation flights which operate at high level, but is necessarily broad in its treatment of the weather. Main Meteorological Offices (MMO) at Manchester Airport, Prestwick and Aldergrove support the PFO at Heathrow and provide the more detailed output for northern England and North Wales, Scotland and Northern Ireland respectively. These MMOs provide general guidance for dependent forecasting offices located at other major civil airports and services at non-state aerodromes. All forecasting offices provide Aerodrome Forecasts (TAFs) on a routine basis which provide detailed guidance for take-off and landing. Individual route forecasts are prepared for aircraft flying at lower levels, usually below 5000 feet, but below 14 000 feet over the mountainous terrain of Scotland. Face-to-face briefing of aircrew from commercial operators is no longer considered to be essential, although the service is still available at a number of aerodromes and General Aviation pilots frequently consult a forecaster, normally by telephone, before commencing a flight. The ensuing discussions are time-consuming and can result in the overloading of forecasters at busy periods. In an effort to reduce the burden of general aviation forecasting an automatic telephone answering service, the General Aviation Visual Flight Forecast Service, has been established by the CAA and an experimental, very limited service of forecasts is being included on Prestel.

The supply of forecast grid-point data to British Airways for computer flight planning has continued throughout the year. The method of transmission was greatly improved by the installation of a 9600 bits/second direct link to the British Airways computer. Considerable interest has been shown in the ability of the Office to supply such data and parties from several large international airlines visited the Meteorological Office at Bracknell during the year. Scandinavian Airlines System (SAS) has already indicated its intention to take grid-point data from Bracknell.

Various measures which had been taken to produce economies in the provision of meteorological services were noted in *Annual Report 1980* and pressures for further economy have continued unabated during 1981. The withdrawal of forecasters from Edinburgh Airport was finally completed during January. Responsibility for the provision of Edinburgh forecast services was transferred to Glasgow Airport, except that a cutback in staff there resulted in the service for both Edinburgh and Glasgow being provided from MMO Prestwick during the period 1800 to 2300 hours daily. Coincident with the move of the Heathrow PFO to the Control Tower building (see page 21) has been the withdrawal of forecasters from the aircrew-briefing area. Personal briefing is still available on request but under this new scheme there has been a saving of five staff. Later in the year the responsibility for forecast services for Cardiff–Wales Airport was transferred to the newly-opened MMO in the city centre, leaving an observing and aircrew documentation service at the airfield itself.

A forecast service was provided for the two sections of the National Gliding Championships, at Greenham Common in May and at Dunstable in August. The first meeting was marred by some of the worst weather in the history of the Championships and gliding is one of the very weather-dependent types of general aviation which is becoming increasingly difficult to serve effectively.

Weather observations at airfields are of great importance, and special Meteorological Aviation Reports (METARs) are made, usually half-hourly, at most civil airports. Where no Meteorological Office staff are available, the observations are made and reported by Air Traffic Control staff who are specially trained for this purpose. In most cases the observations are transmitted by teleprinter on the Aeronautical Fixed Telecommunication Network (AFTN) to the CAA message switch at Heathrow from where they are disseminated nationally on Operational Meteorological (OPMET) teleprinter circuits and internationally over the Meteorological Operational Teleprinter Network, Europe (MOTNE). TAFs are also exchanged on the OPMET and MOTNE broadcasts to provide the information on future landing conditions needed by operators. Copies of bulletins of METARs and TAFs which are made locally at aerodromes complete the forecast documentation provided by area forecast charts or lower-level route forecasts.

To assist with terrain clearance over land and with vertical separation over the sea, forecast minimum values are prepared each hour by CFO for each of 20 Altimeter Setting Regions over and around the United Kingdom. The forecast values are distributed both by Meteorological Office teleprinter channels and by AFTN. These values are used primarily by aircraft *en route* and outside controlled airspace.

A very important service to civil aviation is the issue of warnings of weather which could affect the safety of aircraft operations both in the air and on the ground. The in-flight requirement is met by the issue of SIGMET information which is passed to individual aircraft, or broadcast by appropriate Air Traffic Services (ATS) units. Meteorological Watch Offices (MWO) designated by ICAO are responsible for the issue and supply of this SIGMET information to the ATS units in a particular area (often corresponding to a Flight Information Region (FIR)). Heathrow and Prestwick are the MWOs in the United Kingdom and as well as being responsible for the London and Scottish FIRs respectively, their area of responsibility extends well into the North Atlantic. SIGMET information is issued to cover several types of weather phenomena at subsonic cruising levels which may necessitate adjustments to aircraft track or flight level. A specialized SIGMET service is provided for the operations of supersonic civil aircraft within our area of responsibility. All current SIGMET information is available to aircrews at pre-flight briefing. Aerodrome warnings are issued for the occurrence of weather phenomena likely to affect ground operations, including take-off and landing. Unexpected snow and ice can cause severe disruption of services at airports and consequent financial penalties to the operators. Accurate warnings of commencement, duration and intensity of snowfall plus relevant surface wind and temperature predictions are vital if the very costly equipment and materials used in aerodrome snow and ice clearance are to be used effectively and economically. In conjunction with the Special Investigations Branch, British Airways and the CAA, the trial of an aerodrome wind-shear forecasting service has continued at London/Heathrow Airport. Comparisons have been made between the subjective forecasts of wind shear and reports from aircraft of wind shear encountered on the approach or climb-out. These have resulted in some 'fine tuning' of the forecasting criteria and the results have been sufficiently encouraging for the trial to continue.

The Outstation Automation System (OASYS), described in *Annual Report 1980* (pages 25–26), became fully operational in the Queen's Building at Heathrow on 19 January 1981. To ensure no interruption in the service during the move to new accommodation in the Control Tower Building, a duplicate OASYS was installed there before the move. The change-over was successfully accomplished during the night of 14 July 1981. The move and the automation at Heathrow marked the successful completion of a long-planned project. Some other changes which have taken place during the year serve to highlight one of the problems regarding developing airports. New construction plans are constantly leading to a reassessment of meteorological instrument sites and observing positions. At Birmingham Airport the plans for a new Airport Terminal necessitated the demolition of the remote observing office on the eastern side of the airfield. All the instruments have been moved to a new site which, as far as can be foreseen, is not scheduled for further development. At Gatwick, alterations to the northern taxiway system mean that the anemometer tower must be relocated.

The Office continued to provide a meteorological content in the examinations for flying crew and air traffic controllers' licences through the attachment of two members of staff to the CAA Directorate of Flight Crew Licensing. During the year, changes were made to the content to bring it more into line with current procedures, and a start was made to the revision of the meteorological sections of Air Traffic Control manuals. The number of candidates examined fell from about 1650 annually to just over 1300, reflecting the recession in the airline business.

The Area Forecast System (AFS), of which Heathrow is an important Centre, was established in the mid-60s. Since then the performance and range of modern aircraft has increased tremendously, so that a revision of the AFS has become necessary. The new plan, developed by the Area Forecast Panel of the

International Civil Aviation Organization (ICAO), envisages two levels of Area Forecast Centres (AFC), with World and Regional responsibilities respectively. The two World Centres will provide forecast grid-point data in digital form for a series of levels with near-global coverage. These data will be communicated to the associated Regional Centres for onward transmission to airlines for computer flight-planning purposes and also for conversion to chart format for distribution to state services and aerodromes within the Region for flight documentation. The recent meeting of the Area Forecast Panel (21 September to 9 October 1981) recommended Bracknell and Washington as the sites for the two World Area Forecast Centres (WAFC) and that a choice of the Regional Centre for Europe should be made from Frankfurt, Paris and Bracknell. There will be a total of 8 Regional Area Forecast Centres (RAFC) world-wide. The final decisions will be made by the ICAO Communications/Meteorology Divisional Meeting to be held in Montreal in April/May 1982. The reorganization of the system is likely to be implemented by November 1984. The Meteorological Office played a full part in the work of the Panel by providing an adviser to the CAA Member and submitting a large number of working papers. The Office also provided a representative for the meeting of the WMO Working Group on the Provision of Meteorological Information Required Before and During Flight (PROMET), which was held in Washington, D.C. in November. As the Chairman of the study group examining flight-documentation practices the work of this representative will become even more important as the implementation of the new World Area Forecast System begins. Two meetings of the Meteorological Advisory Group (METAG) of the European Air Navigation Planning Group of ICAO have been held in Paris this year. A member of the Office attended these meetings and it is likely that a UK Member will be required to serve on a new Working Group to be set up to study meteorological services for helicopters on offshore operations (primarily over the North Sea).

Increasing aviation fuel costs are placing importance upon accurate wind and temperature forecasts for flight-planning. This is especially important in the organization of aircraft tracks across the Atlantic where the vertical and horizontal separation of aircraft is carefully controlled. Discussions have taken place between the Air Traffic Controllers, the International Air Transport Association and CAA to examine ways in which they could make better use of the available meteorological data. The Meteorological Office has been closely involved in these discussions.

Services for civil aviation (overseas)

Services for civil and general aviation were provided from the meteorological office at RAF North Front, Gibraltar, and in Germany at RAF Wildenrath and RAF Gütersloh.

Services for the general public (overseas)

The meteorological office at RAF North Front, Gibraltar, provided meteorological services for the Gibraltarian general public through the medium of the Press, radio (including live broadcasts) and television and for various civil departments and engineering and commercial concerns, including oil exploration companies working off the Moroccan coast. The services were provided in accordance with charging policies for similar services in the United Kingdom. In Cyprus, services to the public from the meteorological office at RAF Akrotiri were limited to forecasts broadcast by the British Forces Broadcasting Service.

Services for the Royal Air Force

Senior officers of the Meteorological Office continued to fill the posts of Chief Meteorological Officer on the Air Staffs at Headquarters Strike Command and at Headquarters Royal Air Force Germany. The Chief Meteorological Officers act as advisers on meteorological matters to the Air Officer Commanding-in-Chief Strike Command and to the Commander-in-Chief Royal Air Force Germany and are responsible for the organization of meteorological services to meet the needs of the Royal Air Force.

Meteorological services for the Royal Air Force in the United Kingdom, including the units at the MOD(PE) airfields at the Royal Aircraft Establishments at Farnborough and Bedford and the Aeroplane and Armament Experimental Establishment at Boscombe Down, were provided by offices which are grouped partly in conformity with the Royal Air Force command and control organization.

The Principal Forecasting Office (PFO) at Headquarters Strike Command, continuously manned by senior forecasting staff, is responsible for the technical control of the output from the subsidiary forecast offices at all the airfields in Strike Command and at several airfields in Support Command. The resources in the PFO allow the subsidiary offices to meet the requirements of military aircraft operating in widely differing roles. Work continued on the extension of automated methods of working to the PFO and the development of plans for automated support for the forecasts at the subsidiary offices, with the aim of achieving greater efficiency and flexibility in responding to the Royal Air Force requirement. Plans for introducing a minicomputer system into the PFO in early 1982 advanced steadily. The powerful computer system at Bracknell continued to provide major support to the offices serving the Royal Air Force in the United Kingdom and overseas through the automated selection and transmission of large amounts of data and the provision of forecasts for periods beyond about 18 hours up to 5 days.

Main Meteorological Offices (MMOs), manned 24 hours a day, are located at RAF Group or Maritime Air Region Headquarters. The location of the MMOs within separate regions of the United Kingdom allow expertise in regional meteorology to be applied not only to services for Defence but also for civil and general aviation and for the general public. Many of the subsidiary offices serving the Royal Air Force also provide services for civil and general aviation and the general public from within the resources necessary to meet the Defence need.

The major part of the routine support provided for the subsidiary offices by the PFO at Headquarters Strike Command and the MMO at Headquarters No. 38 Group is in the form of a comprehensive routine program of analyses and area and route forecasts in chart form, transmitted by facsimile to the subsidiary offices and designed to cover most of the routine operational requirements of the Royal Air Force in the United Kingdom. A dedicated teleprinter broadcast from the PFO also allows a continuous flow of actual and forecast alphanumeric data related to the Royal Air Force requirements to be transmitted to the subsidiary offices. The personal briefing of aircrew and operational staffs and the provision of shorter-period subjective forecasts is well supported by dedicated facsimile and teleprinter transmissions.

Mobile meteorological units, forming part of the Tactical Communications Wing and manned by Meteorological Office staff in uniform, continued to support the Royal Air Force in the field and participated in exercises. Each unit has its own air-transportable sets of instruments and communication equipment for use in remote locations, including radio-teleprinters, radio-facsimile recorders and weather-satellite reception equipment. The staff who man the mobile meteorological units hold commissions in the Royal Air Force Reserve.

The Main Meteorological Office at the Headquarters of Royal Air Force Germany supported subsidiary forecast offices at the RAF airfields at Wildenrath, Brüggen, Laarbruch and Gütersloh and the Army Air Corps airfield at Detmold. However, as a result of a review of the organization required to provide meteorological support to the British Armed Forces in Germany, plans were made, in close consultation with the Royal Air Force, to close the Main Meteorological Office at HQ Royal Air Force Germany. The re-engineering of the communication network was completed by the end of the year and this facilitated the increased use of host-nation resources from the German Military Geophysical Office at Traben-Trarbach. The staffs of the meteorological offices at the RAF airfields in Germany were fully involved in NATO evaluation exercises during the year and invariably achieved high markings. Staff from the Gütersloh office went into the field on a number of occasions in support of Harrier deployments.

United Kingdom Defence requirements for meteorological support in the Mediterranean were met from the Main Meteorological Office at RAF Akrotiri and the observing office at Paphos in Cyprus, and from the Main Meteorological Office at RAF North Front, Gibraltar.

The Grawsonde upper-air soundings at RAF Akrotiri ceased in the spring with the development of a Cyprus Meteorological Service upper-air station at Athalassa, near Nicosia. Staff at the Main Meteorological Office at Akrotiri provided considerable assistance to the Meteorological Office Headquarters Branches involved and also to the Cyprus Meteorological Service in establishing this facility. A routine program of pilot-balloon ascents was maintained from the Meteorological Office observing office at Paphos.

Plain-language reports from a selection of RAF, USAF and civil airfields were provided for the VOLMET voice broadcast made from the London Military Air Traffic Control Centre at West Drayton. Data for the VOLMET broadcast are processed and supplied directly from the automated Telecommunication Centre at Bracknell.

The Office met the requirements of the Royal Air Force for training in meteorology by the provision of lectures and tutorial assistance, mainly at the Support Command training airfields where young aircrew receive their first experience of support for their tasks from Meteorological Office staff.

Services for the Army Air Corps

Meteorological services for the Army Air Corps were provided by subsidiary forecast offices at Netheravon and Middle Wallop, under the technical control of the Main Meteorological Office at HQ No. 38 Group Royal Air Force, and at

Detmold in Germany under the technical control of the Main Meteorological Office at HQ Royal Air Force Germany.

Other services for the Army and Establishments of the Ministry of Defence Procurement Executive

The Senior Meteorological Officer at Detmold carries additional responsibilities as the Senior Meteorological Officer at the Headquarters of 1(BR) Corps at Bielefeld. He and his staff supported Army deployments in the field throughout the year.

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 provided meteorological support for the Chemical Defence Establishment at Porton and for RAE and P & EE units located on Salisbury Plain. The office at Shoeburyness provided support for the Atomic Weapons Research Establishment at Foulness and the Royal Armament Research and Development Establishment at Potton Island. Shoeburyness also provided significant support for a large-scale trial conducted by Shell Research Ltd during the summer months to investigate the vapour and fire hazards arising from a major accidental spillage of liquid petroleum gas. The Mk 3 radiosonde replaced the obsolete Mk 2b system at Aberporth and Shoeburyness, thus completing the change-over at the trials establishments. Further development of the Mk 3 software ensured the provision of real-time, high-resolution, upper-air data in support of range activities.

Meteorological Office support was also provided for the Army practice camps at Sennybridge, Otterburn and Okehampton for several periods throughout the year. Staff were attached to the rocket range at South Uist in the Hebrides for a program of missile firings during the summer. Several Defence establishments were provided with meteorological data and advice connected with the development of weapons and military equipment, and joint trials for the assessment of explosive sound propagation were mounted in March and October at CDE Porton and the Lavington range at Larkhill respectively. The Senior Meteorological Officer at Larkhill was the co-ordinator for the trial in March with logistic support provided by CDE. Salford University and staff from Larkhill and the Defence Services Branch participated in both trials.

Liaison with the Royal Navy

Close co-operation in Defence matters was maintained with the Directorate of Naval Oceanography and Meteorology, mainly through the Naval Liaison Officer attached to Meteorological Office Headquarters 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 needs and also contributed to studies associated with that support. The co-ordination of Meteorological Office activity in NATO exercises was centred in the Defence Services Branch.

The Meteorological Office provided, for the United Kingdom, a Principal Scientific Officer in the post of Chief Meteorological Officer on the staff of the Supreme Allied Commander at SHAPE in the rank of Group Captain. The British contribution of three UK staff was maintained at the NATO Allied Meteorological Office at Maastricht in the Netherlands.

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. Forecasting staff were provided for the meteorological cells in the five Sector Controls during the national exercises held in March and November. The Meteorological Office also provided the charts and data for the assumed weather situation to be used by all nations planning to participate in the NATO Civil Defence exercise scheduled for March 1982. Lectures on the Meteorological Office organization related to fallout monitoring were given to UKWMO Sector Control staff, warning officers and the Royal Observer Corps.

Services for nuclear establishments

Arrangements for Main Meteorological Offices 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 constant review and frequently exercised.

CLIMATOLOGICAL SERVICES

The scope and diversity of climatology and its applications are such that it is convenient for hydrometeorology and agricultural meteorology to be the province of a Branch separate from that dealing with 'general' climatological services. These rather specialized functions will be dealt with in two other sections of this report (pages 31 and 33). Similarly, the acquisition of data, the ensuring of standard observational practices among observers, whether they be official Meteorological Office staff or co-operating observers, the prospecting for new sites for manned observing or automatic weather stations are matters for the Branch concerned with observational practices whose work will also be discussed elsewhere in this report (page 36).

The Climatological Services Branch has three main functions. First, there is the continuous and never-ending compilation of the climatological archive which forms the weather memory of the nation. Secondly, there is the production of publications summarizing these data, both for general use and some specialized applications. Thirdly, there is provision of enquiry services which deal with a wide range of meteorological problems. Many of these enquiries are on a repayment basis and it is gratifying to be able to record that the income for 1981 was more than four times that for 1976 although staff costs, which form a major part of the charge, have barely doubled in the same period. Despite the recession the ratio of income to staff costs has shown an increase every year since 1978.

Climatological data

The provision of climatological services and production of publications is dependent upon the existence and continual updating of the climatological data bank. United Kingdom data originate from some 630 stations comprising about 145 Meteorological Office and auxiliary synoptic stations, together with nearly 490 co-operating observers who make up over 75 per cent of the climatological network (see Table IV). These co-operating observers include the staff of various authorities and organizations which have an interest or a need for weather data, as well as private individuals, some of whom are simply interested in the weather for its own sake and some whose interest is engendered by their business activities, for example farmers and estate owners. The Meteorological Office is extremely grateful to these co-operating observers who provide much valuable information which could not be made available in such an economic fashion in any other way.

Over the last year it has become increasingly noticeable that the recession has made it difficult for some co-operating bodies to finance the provision or replacement of instruments and observer coverage, especially at weekends and Bank Holidays when overtime payments may be involved. As a result, and also because some private observers withdrew for personal reasons, there has been a net decrease of 15 in the number of voluntary manned stations over the year. The number of losses has exceeded the number of new recruits, a trend which, if it continues, could have serious effects on the climatological data bank. The Office is tackling this problem in a number of ways. First, and when there is a good case on network grounds, use can be made of a limited fund to give modest financial support to co-operating observers or, occasionally, instruments can be supplied on loan. Secondly, the number of thermographs used to obtain temperature measurements during weekends is increasing. Thirdly, slow but steady progress is being made with Automatic Climatological Recording Equipment (ACRE). Proposals have been made for the placing of ACRE equipment at Synoptic Automatic Weather Stations (SAWS) and a start has been made on identifying the optimum disposition of the 90 ACRE equipments which may eventually become available for the whole of the United Kingdom. Digital Anemograph Logging Equipment (DALE) installation has proceeded more or less steadily over the year and some 35 equipments have now been commissioned. There have been some problems during the commissioning process but DALE is already resulting in a decrease in the laborious manual tabulation and keying of wind data because the information is recorded automatically on to magnetic cassette for direct read-out by computer and reduction into archival form.

Observations from all United Kingdom climatological stations are received initially at Bracknell (for England and Wales), Edinburgh (for Scotland) and Belfast (for Northern Ireland) and are then keyed into the computer by staff at Bracknell. After the running of quality-control programs, queries are checked by staff at the appropriate office and amendments made, sometimes after reference to the originating station.

The formation of a data set containing monthly means and extremes has been completed and work has now started on developing procedures to compute the 30-year means for 1951–80. Some difficulties were encountered because of earlier quality-control programs not being as efficient as those in use today.

Land climatology

For the first time since 1972 there has been a slight reduction (see Table XIII) in the number of enquiries concerning the application of climatological data although income from climatological enquiries has continued to rise, more than keeping pace with costs. In a time of financial restraint it is significant that increased charges have not resulted in a decrease in revenue of the enquiry sections and there is clearly potential for increasing the income of the Branch. Steps are being taken to give increased publicity to the services on offer and of their value.

Enquiries for the construction and building industries, together with those for legal and insurance purposes, form over 35 per cent of the total. Many of these enquiries result in charges which are probably very modest compared to the cost of the work or project to which they pertain. For example, a contractor wishing to estimate possible 'downtime' for tendering purposes on a major construction project (possibly involving expenditure of several millions of pounds) can obtain the necessary information for £50 or less.

The climatology unit for the building industry, funded by the Building Research Establishment, has been involved with various projects concerning building design including energy conservation, the loading of buildings by snow and the exposure of walls to wind-driven rain. Sòme of these studies are linked to possible improvements to the British Standards Institution codes of practice. The unit has also been concerned with ways in which weather can interfere with outdoor construction work with a view to increasing the relevance of both climatological and weather forecasting services to the construction industry. Efforts to publicize such services continue to be made, partly through contact with various trade organizations and partly by distribution of the brochure 'Weather Services for Builders'. Some interest has been expressed in the presentation of climatological data for 'time lost' purposes and the Royal Incorporation of Architects in Scotland published a short article entitled 'Exceptionally inclement or adverse weather'. There have been subsequent requests from architects and quantity surveyors for copies of a leaflet on the subject prepared by the Edinburgh meteorological office.

Examples of the higher-revenue-earning enquiries dealt with during the year include a relatively complex analysis of wind data in computer-compatible format for 50 United Kingdom stations (for the Building Research Establishment) and advice to the Central Electricity Generating Board on meteorological conditions relating to transport of nuclear fuel. Other enquiries have led to the provision of environmental extreme data, one of these related to aircraft operating at about 10 000 feet and another to roadside electronic control and signalling equipment.

Not all enquiry work results in revenue being earned. No charge is made for advice to the Crown in legal cases or for weather statements to the Police, and many customers are referred to books, publications and other sources of data. Other non-chargeable work is for the British Standards Institution upon whose committees members of the Branch sit as experts. During the year much consideration has been given to charging policy and practices in dealing with enquiries as well as for the supply of bulk data from the quality-controlled computer archive. In the latter case no charge is made for the data as such since this is available in manuscript form as a Public Record, but a charge is levied to contribute towards the costs of the keying, quality-control and archiving work.

Changes in Government accounting practice have led to policies being implemented by which other Government Departments are charged for services and by which payment is made, in turn, to other Government Departments for services rendered.

The offices in Edinburgh and Belfast, in addition to being responsible for controlling the quality and archiving of data mentioned earlier, also answer enquiries on Scotland and Northern Ireland respectively. Support for these offices, especially in the writing and running of computer programs for climatological analysis purposes, is available at Bracknell. In addition to these functions the Edinburgh and Belfast offices are also responsible for the inspection of most climatological and rainfall stations in Scotland and Northern Ireland. Particularly important is the role played by these offices in liaising with Scottish and Northern Ireland Government Departments.

Marine climatology

There is continuing interest in those aspects of weather that affect the design, construction and operation of offshore installations around the British Isles which give rise to a steady flow of enquiries, many of which are undertaken on a repayment basis. Liaison has continued with agencies such as the Department of Energy and the British Standards Institution which are concerned with safety offshore. Increasing numbers of enquiries are being received for data and analyses for other seas and oceans and efforts are being made to compile a global archive of surface marine meteorological data as complete as possible. To this end, agreement has been reached with the USA, the Federal Republic of Germany and the Netherlands to exchange all available data from their respective areas of responsibility. Similar agreements are being sought with Japan and India.

Major projects currently in progress include a summary of all North Sea oil-rig data for the United Kingdom Offshore Operators Association (UKOOA), and an assessment of the wind as an offshore energy resource for the Department of Energy. These are expected to yield revenue of up to £54 000. A joint project with the National Maritime Institute to assess the accuracy of visual estimates of wind speed and to develop an objective method of estimating wave heights from visual estimates of wind and wave height is coming to a successful conclusion.

Members of staff from the Marine Climatology section manned a stand at the Offshore Europe '81 Exhibition in Aberdeen in an effort to publicize commercial services being offered to the offshore industry. Standard computer products were demonstrated using a terminal system linked to COSMOS in Bracknell.

Research and development work continued upon the accuracy and failings of methods of extreme-value analysis and also on statistical models on wind and wave height. The latter is a co-operative project with staff from British Petroleum.

The marine climatologist attended the Eighth Session of the Commission for Marine Meteorology of the World Meteorological Organization. The Commission re-established the Working Group on Marine Climatology with revised terms of reference and the marine climatologist will continue to participate in the work of the Group.

Operational and climatological work on sea-ice continued throughout the year. Updated daily charts of sea-ice and sea temperature were disseminated by radio-facsimile broadcasts on Mondays, Wednesdays and Fridays, the latest charts being repeated on the intervening days. The sea-ice and ocean-current sections of the Admiralty *Pilots* are continually kept under review and four volumes were revised in 1981.

Investigations and development work

Work on the statistical modelling of time-series of hourly mean wind speeds over the United Kingdom has continued. A model has been formulated which can generate a series of wind speeds which have similar statistical properties to the actual data. The work has been undertaken for one station (Elmdon) and will now be extended to other stations and locations. The model will provide a method of calculating extreme values and probabilities of spells of wind speeds above or below given values.

An index of windiness for the United Kingdom has been derived as a method of comparing the windiness of months, seasons and years for different regions over the last 100 years. Observed monthly mean wind speeds were used from 1965 onwards for 17 anemograph stations and multiple-regression techniques were employed to extend the period back to 1880 using the data set of surface pressure gradients.

The comparison of wind speeds from pressure-tube anemographs and from standard electrical cup-generator anemographs was completed. This work was immediately useful in providing advice to British Gas on how wind data from London/Heathrow Airport could be used to help predict gas consumption, using a statistieal technique developed earlier and based on data from Kew Observatory which has now closed.

A study on the influence of topography on local climate continues and an investigation into the variation of minimum temperatures with topography has begun.

Work on the compilation of the 1951–80 averages led to an investigation into methods of estimating missing data. Defects were found in the standard statistical methods of doing this when these were applied to meteorological data. A method which combines several simple regressions has been developed with the effect that the errors of estimated values have been reduced by over 30 per cent.

Publications

Publication continued of the *Monthly Weather Report*, the first issue of which was brought out in 1884. Many of the tables in the *Report* are produced by computer output on microfilm but consideration is being given to replacing this technique by mechanical chart-plotting. It is hoped that this will result in a higher standard of printing, because reduction to page size will be used rather than enlargement, thus giving a sharper, more legible, end product.

The first two of a new series of regional *Climatological Memoranda* were published during the year. These covered Glasgow and the Clyde Valley (CM 124) and the Thames Valley (CM 134). The Introduction to these Memoranda is in an advanced state of publication. Also published during the year were the 10-year *Upper-air Summaries* for Lerwick, Aughton, Hemsby, Camborne and Crawley. Work on the African volume of *Tables of temperature, relative humidity,* *precipitation and sunshine for the world* is well in hand although there have been some considerable delays because of the discovery of large quantities of data which had not previously been incorporated.

The discontinuation of the *Daily Weather Report* (DWR) at the end of 1980 resulted in a demand from DWR customers to print out in DWR format (the synoptic code form) both daily and hourly data from the computer archive. Programs have been written, first to increase the flexibility and efficiency of dealing with requests for this print-out and, secondly, in order to cope with the new synoptic weather reporting codes due to be introduced in January 1982. From 1 January 1982 customers will receive the information in decoded form. This will overcome difficulties which would have been encountered in printing the variable length of the new code and, at the same time, will avoid the need for customers to learn the new international synoptic codes.

SERVICES FOR HYDROMETEOROLOGY

The hydrometeorological services provided by the Meteorological Office depend on the ready availability of good-quality data held in computer data banks in a form suitable for processing to meet the varied requirements of both customers and the Office. The Office relies upon the co-operation of water and other authorities throughout the United Kingdom who operate most of the network of some 6500 rain-gauging stations for the supply of the basic data.

The important primary task of the routine collection of the data from the various sources was supported by various procedures for data quality control before completion of the computer data bank. Although the quality-control system has been generally further developed over recent years, it was possible this year for the first time to make use of data held in the Synoptic Data Bank to examine the weather on each day in the vicinity of each rainfall station as a new computer-based aid to data quality control. This procedure came into use in January 1981 for England and Wales, but the less-dense synoptic reporting network in Scotland and Northern Ireland prevented application of the method in those areas. The general scrutiny of observing practices, equipment and site environment continued in an effort to ensure that uniformly high standards were maintained by co-operating bodies. All computer handling of data was carried out at Bracknell, but the offices in Edinburgh and Belfast undertook the initial collection of data from Scotland and Northern Ireland respectively.

Work on the development of techniques for the statistical evaluation and redesign of rain-gauge networks continued with contributions from the Institute of Hydrology. In a case study, the networks in the North West Water Authority area were theoretically redesigned and a reduction of about 40 per cent in rain-gauge numbers was shown to be possible.

The decision was taken in 1980 to cease work on the project under which rainfall-recorder charts for a selection of stations were digitized at short time intervals by the Precision Encoding and Pattern Recognition (PEPR) system of the Image Analysis Group of the Nuclear Physics Laboratory, Oxford University. However, following representations from the Greater London Council, the authority for many of the stations included in the project, an agreement was reached under which a member of their staff would be released to work at Bracknell on the characteristics of short-duration rainfall.

The hourly-precipitation data bank, introduced in 1980, into which data were entered primarily from manually analysed tilting-siphon rain-recorder charts, was extended by the inclusion of data from other types of rain recorder.

The Meteorological Office computerized index of rainfall stations, Rainmaster, was maintained and used as the control data set for entering most of the data into the computerized rainfall archives. Copies of the index were provided to the water authorities annually for them to confirm that reported changes had been incorporated in the national records kept by the Office. Copies of the index were sold to customers who wished to make their own selection of stations for the provision of data. The Pluvius Department of the Eagle Star Insurance Company and the Environmental and Medical Sciences Division of the Atomic Energy Research Establishment at Harwell were two such customers.

The publication *Monthly and annual totals of rainfall for the United Kingdom* was issued for the years 1972, 1973 and 1974 . Delays in the publication of data for later years were still imposed by printing difficulties rather than by data-set preparation.

The number of enquiries showed a decline in 1981, following a peak in the late summer and autumn of 1980. Enquiries were received from, amongst others, the building industry, the legal profession, municipal and consulting engineers, water authorities and educational institutions, and covered a wide spectrum of interests. As usual, the largest number of enquiries was from the building industry. The suites of computer programs for drainage network design work were maintained. These enable tabulations to be made of rainfall amount and intensity for specified durations (for frequencies of from twice a year to once in 1000 years) and of storm profiles. For dealing with telephoned enquiries, a ready-reference archive of data was held giving rainfall totals and intensities at 300 stations for specified durations (from 1 minute to 25 days) which may be equalled or exceeded over a wide range of return periods. To complement data provided by the use of computer terminal, a microfiche archive of monthly, daily and hourly rainfall data was also used to deal with enquiries. This particular archive was expanded considerably to cover the years 1961 to 1981.

Routine work continued for the Water Data Unit of the Department of the Environment. Assessments of total area rainfall month by month for 960 catchment areas in Great Britain were made, estimates being completed up to the end of 1979; estimates of average monthly rainfall for the period 1941–70 were also completed for the 960 catchments. The work was carried out using digitized catchment boundaries and digitization of the annual and monthly average rainfall maps at intervals of 3⅓ km and 5 km respectively. The Unit was provided with an account of rainfall, evaporation and soil moisture deficit over the United Kingdom in 1979, for publication in the Unit's Year Books.

Other work during the year included the 'water balance' for 1980 of 27 catchment areas, covering most of Northern Ireland. Daily areal rainfall and monthly potential evaporation were estimated for the northern chalk area of the Lincolnshire River Division of the Anglia Water Authority for the years 1920–49 and 1976–79. These data were required for the assessment of the water resources of the aquifer.

The Meteorological Office maintains an experimental network of weather radars (which covers a large area of England and Wales) and which provides rainfall estimates over small (5 x 5 km) areas in real time. Investigations continued into methods for combining the radar (areal) and rain-gauge (point) rainfall totals. The techniques for combining daily data were refined, more particularly by the introduction of a method for identifying and removing erroneous data resulting from anomalous propagation of the radar beam. Good progress was made on the solution of the more difficult problem of combining the data for periods of less than a day, for which very few rainfall values determined from rain-gauges are available. Work began on using the combined data for a number of purposes, including the quality control of rain-gauge data.

Other research was carried out into the application of rainfall statistics in hydrology. A study of extreme hourly rainfall values revealed useful insights into the nature of the statistics relevant to the design of drainage networks for coping with heavy falls in short periods. Special consideration was given to aspects of rainfall in the preparation of the Meteorological Office contribution to the Institute of Hydrology report, published in October, *The Wallingford Procedure: Design and analysis of urban storm drainage.* In particular, investigations considered the extent to which the catch of a single rain-gauge can represent areal rainfalls over short time intervals and the effect of the interaction between storm profile shapes and catchment characteristics on peak stream flows.

A project, with the aim of gaining a greater physical understanding of the atmospheric processes resulting in extremely heavy precipitation, continued throughout the year. The expectation is that guide-lines for calculating 'probable maximum precipitation', a quantity used for designing hydrological structures, may eventually be revised. A numerical model of a cumulonimbus cloud was used and the indications are that extreme rainfall is associated with a unique combination of atmospheric variables (including water-vapour content, temperature and vertical wind shear) and with the interaction between one cloud and another. The modelled results were compared with the characteristics of storms over the United Kingdom deduced from radar data.

Services for Agriculture

During the year the Office continued to provide a direct service to agriculture through small teams of agricultural meteorologists at outstations. These were supported by a somewhat larger unit at the Bracknell Headquarters. The outstation staff worked in close co-operation with the Agricultural Development and Advisory Service (ADAS) in England and Wales or with the Scottish Colleges of Agriculture. As in the past, four of the outstations were located at ADAS Regional Offices in Harrogate, Cambridge, Bristol and Reading while a fifth unit was based in Edinburgh.

Following the increase in charges for meteorological services in April 1981, protracted negotiations with the Department of Agriculture and Fisheries in Scotland failed to produce agreement on financial support for the Edinburgh unit in future years. As a result this unit closed at the end of 1981 after some 26 years of existence.

The Headquarters unit at Bracknell has ready access to computer-based data banks. A considerable amount of current weather data was extracted from these and collated for transmission, on a daily or weekly basis, to outstations or directly to ADAS. Particularly important among these transmissions were daily estimates of the progress of a number of important plant diseases that would follow from the weather of the preceding 24 hours. Further use of the computer was made in extracting and processing the weather information needed by outstations to answer local queries. Programming support was also provided for a number of longer-term investigations started by outstations.

The production of a special agro-meteorological data set for use by Agricultural Research Council institutes and the agricultural section at Bracknell was well advanced by the end of the year. Daily data from some 160 climatological stations for the preceding 20 years or so (elements of which were previously archived on several separate data sets) were brought together and will prove particularly convenient for agricultural investigations. The very strict quality control employed allowed the identification and correction of a number of errors in the original information.

The outstations were again much preoccupied with providing rapid solutions to a variety of agricultural problems which were seen as having a meteorological content. On occasion, the available routine weather observations were inadequate for the task in hand and local meteorological measurements were required. These were made both manually and automatically. Particularly interesting among the automatic devices used during the year was a prototype microprocessor-based device developed in conjunction with the Operational Instrumentation Branch (see page 44) to monitor crop environment and to calculate indices showing the likely development of a number of plant diseases.

Throughout the year rainfall can be both a help and a hindrance to the agricultural community, and it is therefore appropriate to report a number of studies involving the consequences of rainfall. An investigation was undertaken with the object of characterizing those situations where soil-engaging operations (ploughing, harrowing, etc.) cause significant damage to soil structure because of high moisture levels in the surface layer; reference to past-weather data allowed the opportunities for work on different soils in various parts of the country to be compared. The resulting information was sought by farm management for labour and machinery investment planning purposes. Also useful for planning and design purposes was the computer program developed to estimate, again from the weather of past seasons, the need for irrigation. Water amount and the frequency of application were the variables examined.

The disparity between evaporation and rainfall during the growing season determines irrigation need and affects crop yields. The Meteorological Office Rainfall and Evaporation Calculation System (MORECS) was used to calculate this difference for a variety of crop and soil combinations. MORECS was extensively revised early in the year and the results checked against a number of measurements of soil moisture by neutron probe. The new version was brought into operational use and provided an accurate and very comprehensive service for agriculture.

One of Britain's most important crops is grass, and it was appropriate that work continued within the Branch on a number of aspects of grass production. A joint study was begun with the Grassland Research Institute, partly funded by the EEC, to investigate the variation of grass production in relation to weather in Britain and a number of other European countries. Another study (again funded in part by the EEC) drew on micrometeorological models of hay-drying developed at Bracknell to assess the prospects for field hay-drying in north-west Europe under a number of climate change scenarios.

Britain's other main crops are the cereals: current production runs at about 18 million tonnes. Typical fluctuations from year to year of around 1 million tonnes which are caused directly by weather have a major influence on Britain's overseas trading in grain. Hence it was appropriate that work should continue on the development of an operational scheme relating weather and yield, intended to give warnings, well before the harvest, of substantial deficits in cereal yields compared with average values.

The agriculture industry shares the national concern for energy saving, especially that part concerned with protected cropping. Work continued within the Branch on the relationships between weather and glasshouse-heating requirements.

Significant losses in crop production are caused by a wide variety of pests and diseases; these losses can be minimized by careful programs of spraying. Weather plays an important part in the build-up of pest and disease levels and in the effective and safe application of protective sprays. A comparison between a weather-related computer model of populations of the potato-blight organism and the previous empirical method of predicting the progress of the disease showed the former to give better results. This new model became operational during the year. Other weather-related advice on spraying concerned fire-blight on apple and pear trees, and control of pea moths and cut-worms. Work continued on the development and extension of an analysis of days on which spraying can be done safely and efficiently. In co-operation with ADAS, the preparation of a general guide to the hazard posed by spray drift in different weather conditions was completed. The importance the Branch attached to work on spraying was reflected by the inclusion of members of staff in the British Crop Protection Council's Working Group on Weather and Spray Applications. Levels of pest infestations depend to some extent on how successfully a species is able to survive over the winter period and the Branch collaborated in a number of experimental studies to examine the survival of the peach-potato aphid, an important carrier of damaging viral diseases.

Significant losses to livestock occur through disease and bad weather; work on these topics continued. Foot-and-mouth disease is potentially a very serious threat to cattle and pigs. The virus responsible can be spread by wind. A meteorologist was held available to travel at short notice to the site of an outbreak and to give meteorological advice to the epidemiological team responsible for control measures in the field. A new method of calculating the downwind spread of the disease was devised; it included quantitative estimates of the dispersion of virus-bearing particles through the atmosphere and resulted in a more precise indication of the area in which control measures should be applied. The response of the Office to a foot-and-mouth outbreak was tested when the disease was discovered in Brittany, Jersey and the Isle of Wight in March 1981 and valuable help given to the epidemiologists within a matter of hours of confirmation of the disease in the United Kingdom. Investigations into previous cases of the spread of the disease over land and sea continued. A study of the airborne spread of Newcastle disease (fowl pest) was started.

On a limited-trial basis, forecasts of wind-chill and cold stress in lambs were issued during the first part of the year. Subsequent action to shelter the stock resulted in minimal lamb losses being recorded. Other animal/weather studies concerned sheep and cattle housing, spoon-gassing of rabbits and the likely extent of *Ostertagia* larvae on pasture.

During the year many talks and lectures were given to a variety of organizations. Contributions were made to a number of agricultural shows including the Royal Show and the Bath and West Show. Collaboration continued with international agencies and with the Commission for Agricultural Meteorology of the World Meteorological Organization.

Observational Requirements and Practices

The Branch, of which the Marine Division under the Marine Superintendent is a part, has responsibility for arranging that regular meteorological observations of suitable quality are made on land, at sea and in the upper atmosphere in sufficient numbers and with an appropriate distribution in time and space to meet national and international requirements. It specifies how meteorological sensors and observing systems shall be exposed, details the observing techniques to be employed and arranges for World Meteorological Organization (WMO) reporting codes to be implemented at UK stations. It arranges for observing stations to be inspected regularly to ensure that approved standards of site, instrumentation and observational procedures are maintained. The Branch establishes, on behalf of the forecasting, climatological and hydrometeorological Branches, requirements for new or improved sensors, observational systems or practices and organizes field trials to determine their suitability for operational work, optimum procedures for their routine use and the effect of their introduction on the accuracy and comparability of the basic observational data. It works closely with the Operational Instrumentation Branch on the specification of new sensors or observational systems and on the design of trials to establish the performance of prototypes.

The Branch provides the Chairman and Secretary of an internal working group concerned with reviewing the UK Observational Networks; the working group has revised important policy statements on networks of synoptic, climatological and automatic weather stations and is currently preparing similar statements on radiation and rain-gauge networks. In the international field the Assistant Director (Observational Practices) serves on the WMO Working Group on the Global Observing System (GOS) which met in Geneva in November. He is also a member of the Study Group on the Manual and Guide of the GOS which keeps these publications under continuous review. Senior Branch members served on the Advisory Working Group of the WMO Commission for Instruments and Methods of Observation and on international Working Groups concerned with radiation measurements and with the compatibility of data obtained from different upper-air measurement systems.

The Branch has been involved in planning the introduction of the new common synoptic reporting code which will replace many of the existing codes on 1 January 1982.

Observatories

Lerwick Observatory and the Meteorological Office section at Eskdalemuir Observatory continued to make a wide range of observations. The work at Kew Observatory ceased on 31 December 1980 and the Meteorological Office finally vacated the premises on 5 April 1981.

Although Eskdalemuir is a NERC Observatory the Meteorological Office staff are involved in most aspects of the work there, which includes measurements of solar radiation, earth tremors, earth's magnetism, evaporation, atmospheric electricity and atmospheric pollution. The program at Lerwick includes measurements of the solar radiation falling on horizontal, vertical and inclined surfaces, direct and diffuse radiation, radiation balance, ozone, atmospheric potential gradient, air-to-earth current and atmospheric pollution. The Observatory also forms part of the upper-air and thunderstorm-location network and provides some staff support for the forecasting unit which is housed there to provide a service to the Sullom Voe oil terminal.

Surface observations

Several different kinds of surface observations are made to meet particular requirements. For weather analysis and forecasting purposes a network is maintained consisting of observing stations making weather reports at fixed times agreed internationally. It is essential that such reports, known as 'synoptic' reports, should be received without delay. At the end of 1981 the United Kingdom synoptic reporting network consisted of 263 stations, of which 79 made hourly reports and 48 made 3-hourly reports throughout each day of the year. The remaining 136 stations reported less frequently, some closing at night or at weekends. Meteorological Office staff manned 83 synoptic reporting stations, most of which were located at civil and military airfields. At the remaining 180 stations, known as auxiliary reporting stations, reports were made by people such as coastguards, lighthouse keepers and private individuals. Special courses for training auxiliary observers in the making and reporting of weather observations were held at the Meteorological Office College. When it was not possible for an auxiliary observer to attend one of these courses a member of the staff of a nearby meteorological office visited the auxiliary reporting station and gave instruction on the spot.

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

Many stations making synoptic reports submit climatological returns as well, usually for several observing hours each day. At 66 climatological stations manned by Meteorological Office staff these returns covered the whole 24-hour period. About 500 other stations made climatological returns only, usually of data read at 09 GMT though some made returns for additional hours. Most of these stations were operated by local authorities or similar organizations but a number were still operated by private individuals on a voluntary basis. The increasing cost of maintaining a climatological station, which often involves the local authority in special payments for observations at weekends and during holidays, has resulted in the loss of some stations. Courses for climatological observers were held at the Meteorological Office College and the Edinburgh office. Inspections of both synoptic and climatological stations were carried out regularly, those for climatological stations now being made biennially.

For rainfall a more extensive network is required to provide the data needed to determine the distribution. This information is of great value for the use, control and planning of water resources. Data were received from about 6110 stations most of which measured rainfall only, about 85 having magnetic-tape event recorders. The majority of rainfall stations were maintained by co-operating authorities, usually Regional Water Authorities, the remainder being operated by a variety of other authorities and by private individuals. The Meteorological Office collected data from rain-gauges that met suitable standards of exposure and equipment and carried out an inspection program to ensure that these particular standards were maintained. The time interval between inspections at most stations was maintained at about three years. During the year it was decided to terminate several sub-standard rainfall stations in particularly well-represented parts of Scotland. This action is the main cause of the lower number of rainfall stations than in previous years in east and west Scotland in Table IV. However, there remain many areas where the rain-gauge network is very deficient. For example, the heavy rainfall of September and October 1981, which resulted in serious flooding in the lower reaches of the Findhorn river, was not recorded in the upper part of the Findhorn catchment which lies in the uninhabited Monadhliath range of mountains to the south of Inverness.

In order to assist the forecasting of weather conditions along major roads a network of 67 stations provided plain-language reports of current weather. These are located at road maintenance depots alongside motorways and at Automobile Association and Royal Automobile Club offices. Reports were made at roughly 3-hourly intervals during daylight hours throughout the year and also at some stations during the night in winter months. These stations were inspected regularly.

Automatic weather stations are now sufficiently reliable and accurate to be used to supplement the surface observing system. They cannot yet give the wide range of observations provided by the human observer but they provide the only practical means of gathering synoptic data where, or when, it is difficult or unduly expensive to support human observers. Eighteen automatic weather stations (some at offshore sites) were in operational service at the end of the year. Planning work continued for the installation of a further 20 stations over the next two to three years in response to the proposals of the Working Group on UK Observational Networks.

Observations were also made to support the specialized forecasting service given to the offshore industry. A major effort was directed towards obtaining regular good-quality observations from fixed production platforms for both synoptic and climatological purposes and advice was also given to observers on the more transitory drilling rigs. Automatic weather stations have been installed on platforms in the North Sea, on buoys in the south-western approaches and Lyme Bay, Sule Skerry (about 60 km west of Orkney) and on the Whitaker Beacon in the Thames Estuary. Advice was given to the offshore gas and oil industries on meteorological instrumentation and observational procedures. One officer was based at Aberdeen and dealt with installations within the United Kingdom offshore area north of latitude 55°N. A second officer was based at Bracknell and dealt with installations further south. Both worked closely with the London Weather Centre and the Aberdeen officer represented the Branch at the Offshore Europe '81 Exhibition at Aberdeen.

Radiation

Observational network. There is a long history of solar and terrestrial radiation measurements in the Office but it was not until the 1950s that observations began to be made systematically from a number of stations. The National Radiation Centre at Beaufort Park administers the national solar radiation network and also runs a program of research into various aspects of solar radiation measurements.

During 1981, with the commencement of measurements at Hemsby, Camborne and Aughton, the network increased to 10 stations. Each station has now been equipped with an up-to-date logging system which records the data on magnetic tape.

There were also 24 other stations belonging to organizations with an interest in radiation measurements such as universities and agricultural or horticultural institutions. Five of these provide hourly radiation totals, the remaining 19 provide daily totals. The Meteorological Office controls the quality of the data recorded. Regular visits were made to these stations and, to ensure uniformity of measurement over the United Kingdom, their instruments were calibrated and minor repairs effected by the Office free of charge.

All stations measured the intensity of short-wave radiation falling on a horizontal surface, including radiation direct from the sun and 'diffuse' radiation received from the sky and clouds; the diffuse component was measured at 11 stations and 3 of these measured the direct component as well. The difference between incoming and outgoing short- and long-wave radiation was measured at 3 stations; 2 stations, Beaufort Park and Lerwick, recorded radiation on inclined and vertical surfaces.

Reliable radiation measurements require regular daily attention to instruments which need to be calibrated frequently against primary standard or working standard pyranometers. These in turn require to be calibrated internationally and the Office's two standard pyranometers were calibrated against international standards during the year. The Office started to replace the pyranometers in routine use with a type which has a better performance.

Theoretical. Although the network of radiation stations is gradually being improved, it is still not dense enough for the preparation of accurate maps of monthly means. In order to improve the coverage, use can be made of measurements from sunshine recorders together with an empirically derived relationship between the monthly sunshine duration and the total irradiance. This technique has been extended to obtain similar relationships for monthly totals over specific hours during the day. These data will be used in the preparation of maps of monthly mean irradiation (i.e. radiant energy per unit area) for selected hours. Since most sunshine records are quoted only in the form of daily totals, the dependence of hourly on daily totals (for monthly averages) is also being investigated.

Co-operation. National and international interest in aspects of obtaining energy from solar radiation continued, chiefly through active involvement with the European Economic Community Solar Radiation Data Acquisition Group and the International Energy Agency Solar Radiation Program Group. Many enquiries from universities and private individuals were answered and payment received. A suite of programs has been developed to enable diverse radiation data to be readily accessed and displayed in the form of tables.

Runway visual range

Routine inspections and calibrations of lights used in the observer method of assessing runway visual range (RVR) have continued to be carried out at six-monthly intervals at 35 civil airports and 33 RAF stations, the latter including stations in Germany. It is planned to decentralize this work for the RAF and, during visits to RAF stations towards the end of the year, instruction in the procedures were given to local Meteorological Office staff. The Civil Aviation Authority (CAA) has been asked if it can take over these duties at civil airports. In addition to the routine visits, the CAA requested that an RVR system should be brought into use at Biggin Hill. A survey and an initial calibration was carried out in November.

Upper-air observations

The normal program of upper-air observations, using the Mk 3 radiosonde, continued at eight stations in the UK and at Gibraltar. This consists of pressure, temperature and humidity soundings by radiosonde at 00 and 12 GMT and upper-wind measurements by radar at 00, 06, 12 and 18 GMT.

The two Ocean Weather Ships, the *Admiral FitzRoy* and the *Admiral Beaufort*, were deployed alternately at North Atlantic Station 'L' (57°00′N, 20°00′W). An upper-air program in the ships was maintained at four complete soundings per day (temperature, humidity and wind), using a sonde with a navigational-aid system for determining the winds.

The quality of high-altitude balloons was not good and some types were downgraded because test batches did not live up to expectations. Table V shows the heights reached in upper-air ascents during the year.

A five-week course of instruction for staff of the Cyprus Meteorological Service was carried out by a member of the Branch at the new radiosonde station at Athalassa, near Nicosia.

Thunderstorm location

A program of hourly observations from 06 to 21 GMT was maintained throughout the year by a network of direction-finding stations at Lerwick, Camborne, Hemsby, Stornoway and Gibraltar. The data were processed at Beaufort Park using a programmable desk calculator to determine the thunderstorm locations. The calculator program was improved during the year and also extended to provide calibration statistics for the individual stations. The number of thunderstorm positions reported during the year (see Table VI) is less than in 1980 owing to a reduction in staff numbers which resulted in a curtailment in the observational program.

User trials and quality evaluation

A trial of a number of commercially available hygrographs was carried out before selecting a replacement for the instrument currently used by the Meteorological Office.

An initial evaluation of the prototype Synoptic Automatic Weather Station (SAWS) was made. An anomaly was observed in some of the pressure readings and was investigated by the manufacturer. A longer-term evaluation trial was started late in the year. An evaluation of the Automatic Climatological Recording Equipment (ACRE) was also started.

The monitoring of data quality from several automatic weather stations was continued with some additions. These stations include a number of land-based equipments together with instruments installed on tethered buoys, inshore navigation and research towers, and platforms used in the production of North Sea oil and gas. A method has been developed which will automate much of this work which to date has been done manually.

The analysis of twin-flight data collected during a program of direct comparisons between the UK radiosonde Mk 3 (RS3) and a radiosonde designed in the Federal Republic of Germany was completed. As a result of changes made to the RS3 thermometer early in the year a second program of twin flights was conducted, using these modified radiosondes and the same German design; the initial data analysis from this was completed.

An algorithm was developed which greatly improves the process of automatic selection of significant turning points for radiosonde temperature and humidity data and was tested on archive data.

A report on the performance during 1980 of the many upper-air stations in the northern hemisphere was completed for the World Meteorological Organization using data provided by the operational numerical analysis section of the Central Forecasting Branch. As a result of changes being made to the operational forecast model these data will no longer be available. Consequently a program was developed within the section which will enable these studies to continue and possibly be improved.

Marine Division

The voluntary observing fleet. The value of regular weather observations from ships at sea becomes apparent when it is realized that the oceans cover 71 per cent of the earth's surface. With the exception of HM ships, research vessels, ocean weather ships and data buoys, these observations are provided by the masters and officers of merchant ships, and the Marine Division has been responsible for obtaining them since 1855. These co-operating merchant ships are collectively known as the Voluntary Observing Fleet (VOF) and vary from very large crude-oil carriers and passenger liners to trawlers and small coastal trading vessels.

The current recession in world trade has had a considerable impact on the British shipping and fishing industries. As a result, much older tonnage of the British Merchant Navy has been scrapped or sold off, leaving a reduced fleet of larger and faster ships which spend less time in port and hence a greater proportion of the year at sea. The seven Port Meteorological Officers established in the major ports of London, Liverpool, Southampton, Hull, Newcastle, Cardiff and Glasgow have been hard put to maintain the strength of the VOF and it is largely as a result of their unflagging efforts that the reduction in voluntary observing ships has been kept to a minimum. Despite the reduction in strength, the number of observations has marginally increased as a result of the time spent at sea by modern merchant ships.

The making, recording and transmission of meteorological observations in British merchant ships have always been carried out on a voluntary basis and, as the Port Meteorological Officers are all Master Mariners with considerable experience of meteorological observing at sea, they are able significantly to affect the standard of the observations received from the VOF. Once again it is gratifying to note that a high standard continues to be maintained.

The installation of distant-reading meteorological equipment in a number of ships under construction in order to reduce the work-load of observing officers, and also in view of the downward trend in complements of merchant ships, has continued with the whole-hearted support and co-operation of shipowners. Trials have also continued with the automatic transmission of ships' weather messages.

Once again, acknowledgement must be made of the valuable assistance given by many foreign and Commonwealth Port Meteorological Officers in the replacement of defective instruments and replenishment of publications and stationery in ships of the British VOF which seldom return to the UK. These foreign and Commonwealth Port Meteorological Officers have also rendered valuable services in connection with the withdrawal of equipment from British observing ships which have been sold or ended their sea-going careers in ports abroad.

The shipmasters, principal observing officers and radio officers who submitted the best meteorological logbooks during the year were presented with 'Excellent' awards in the form of books, as in previous years. Similar awards were made to masters and officers serving on short sea traders for their work in making sea temperature observations and to a trawler skipper and radio officer who made and transmitted valuable non-instrumental weather observations. In recognition of their valuable voluntary meteorological observational work over many years during their careers at sea, four shipmasters were presented with long-service awards in the form of barographs.

A quarterly journal, *The Marine Observer*, containing articles on marine meteorology and oceanography of interest to mariners, was published as in previous years and continues to be well received. The purpose of the journal is to encourage mariners to make meteorological and other observations of general scientific interest and a large section of each edition is devoted to such observations which are extracted from the meteorological logbooks received from the VOF.

Marine enquiries, principally from shipping interests, solicitors, universities and industrial firms, have continued at a high level. These have covered a wide variety of subjects ranging from the general meteorological conditions prevailing off the south-east coast of Scotland during the sea trials of HMS *Speedy*, the Royal Navy's new waterjet-propelled hydrofoil, to a request for actual weather conditions experienced by HMS *Ark Royal* in the Bay of Biscay during a period in the early 1950s.

The ocean weather ship service. Under the North Atlantic Ocean Station (NAOS) scheme the United Kingdom continued to operate two Ocean Weather Ships on Station 'L' situated at 57°00'N, 20°00'W. The ships, the *Admiral FitzRoy* and the *Admiral Beaufort*, alternately manned the station throughout the year with the exception of a four-day period in January when the *Admiral Beaufort* vacated the station to land an injured crew member, a one-day period in August when the *Admiral FitzRoy* vacated the station to evacuate an injured crew member by helicopter and a further one-day period later in August when the *Admiral FitzRoy* had to vacate the station prematurely owing to shortage of fuel. These ships are now approaching the end of their useful life and arrangements were made during the year for them to be taken out of service early in 1982.

The weather ships make hourly surface and 6-hourly upper-air observations (for heights reached in upper-air ascents see Table V on page 64). Sea and swell records using the Tucker ship-borne wave recorder were continued throughout the year. Sea-water temperature and salinity readings to within 100 metres of the sea bed, observations of magnetic variation, 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. On behalf of the Institute for Marine Environmental Research, a plankton recorder was towed on about half the voyages to and from station during the year. Also, aurora observations are made for the British Astronomical Association.

Operational Instrumentation

This Branch is responsible for the installation and maintenance of all instrumentation needed to meet the operational requirements of the Office. New equipment is developed (if necessary) and technical advice is given with regard to procurement. Common services such as engineering drawing, mechanical and electronic workshops, technical writing, test and calibration of instruments, technical training and photography are provided and the Office Museum is maintained. The Branch is also active in several areas of international co-operation including COST Projects 43 and 72 (see page 48) as well as two joint ventures with neighbouring European countries aimed at establishing new operational ocean data acquisition systems (ODAS). In order to provide the structure needed to support these functions the Branch is divided into two parts: about 20 per cent of the total manpower resources form two design and development (D & D) groups, the other 80 per cent form a service, maintenance and support group.

The requirements of the user Branches are co-ordinated and defined by the Observational Requirements and Practices Branch in close co-operation with the Operational Instrumentation Branch. Only if these requirements cannot be met from currently available commercial equipment, or a straightforward adaptation from it, is the task first directed to one of the D & D groups. Once the necessary D & D work has been completed and a field prototype of a new system has been successfully tested, or immediately if no D & D is needed, a procurement specification is written and the task is passed for procurement action to a section of the services and support group which works closely with the equipment supply Branch.

Design and development of sensors

The work of the sensor development section has this year been concentrated mainly in three areas. First, some commercial sensors which have shown promise as possible future operational devices have been subjected to a careful program of evaluation. Typical of this work has been the field test carried out on the Vaisala HMP-21 humidity sensor which continued the work reported last year. The results obtained with this sensor so far show general agreement to within 2 per cent relative humidity of control values from an aspirated psychrometer. Further work has also been carried out on the difficult problem of providing a suitable permeable-membrane protective for the useful but vulnerable PCRC-11 humidity sensor and a contract has now been let to procure initial samples of an appropriate commercial product.

Secondly, development work on new sensors has continued 'in house'. Notable among these programs have been the highly successful tests of the new leaf-surface-wetness sensor developed for use with CDEM (see below) and extensive testing of the weighing tipping-bucket rain-gauge design. Several difficulties with this latter device have been overcome and it now shows great promise as an operational device for measuring both total rainfall and rate of rainfall over any chosen interval greater than a second or so.

The work on this device has led directly to a third area of effort which is the development of 'intelligent' interfaces for meteorological sensors. These interfaces will use dedicated microprocessors with limited memory to perform basic data sampling, quality control and filtering so as to standardize outputs for further display, processing and communication systems. Such interfaces are being developed for the standard wind sensors and for the rotating-beam ceilometers and laser cloud-base recorders.

Land and marine systems

Good progress has been made in the development and commissioning of automatic systems for land and marine use. The land-systems group has succeeded in overcoming difficulties which have seriously delayed the implementation of the Continuous Automatic Remote Display (CARD) systems at four RAF and Army ranges. This has been achieved by utilizing the OBOE type (see page 45) remote data-acquisition system, used successfully on Muckle Holm, Shetland, since 1978, together with a commercial microcomputer at the receiving station to decode and display the meteorological data. A system installed during March 1981 at RAF Donna Nook, Lincolnshire, has functioned without fault for the rest of the year and orders have now been placed for sufficient hardware to equip all four stations early in 1982.

The Automatic Climatological Recording Equipment (ACRE) has undergone a long series of field trials under the supervision of the representative of the user Branches. These have proved to be very successful although they have revealed some difficult meteorological problems associated with intrinsic differences between data obtained automatically and data obtained by manual observation. These problems will present climatologists with some hard choices between the need for more data and the need for long data series without discontinuities when new measurement devices are introduced. The next stage in the ACRE program is to write procurement and test specifications and to pass them to the procurement group for action.

A specification has been prepared for the procurement of ten Meteorological Observing Systems for Ships (MOSS). This system is based on the prototypes which proved highly successful in trials over recent years and uses a geostationary satellite communication link (either Meteosat or GOES-East) to retrieve ships' observations from the North Atlantic in good time to be of use to the weather forecasters.

A second prototype Crop Disease Environment Monitor (CDEM) was constructed and was deployed during the 1981 crop-growing season. The results have been most encouraging with the new leaf-wetness sensor performing particularly well. Valuable local indications favourable for the development and spread of potato blight were recorded and, as a result of this success, the Agricultural Development and Advisory Service (ADAS) is considering an order for a further ten systems for evaluation.

The year has been one of very considerable progress in the establishment of systems on buoys, platforms and remote islands. It has been possible to install an automatic weather station on Sule Skerry (about 60 km west of Orkney) to restore the observations lost when the lighthouse keepers were withdrawn. This automatic station is based on the Offshore Buoy Observing Equipment (OBOE) and includes a commercial microcomputer at the base-station, Kirkwall in Orkney. The microcomputer decodes the raw sensor data and converts the messages into international synoptic code to facilitate onward transmission. The establishment of the Sule Skerry station involved the use of a twin-engined helicopter to lift and place the complete structure (some 1½ tons) on a prepared base. The successful transmission of meteorological data on the same day that the equipment was installed was an indication of the high degree of planning, co-operation and enthusiasm of the project team, the contractors, the finance and the procurement staff.

The local-data read-out systems already established on the three North Sea platforms, Amoco 49-27-A (Leman Bank), Piper A and Beryl A have been upgraded to automatic stations. All these systems are based on the successful OBOE marine automatic weather station, supplemented with commercial microcomputers for the local display and input of visually observed data.

Continuing the international co-operative ventures under the auspices of the European Community committee COST 43, a joint project between the UK, Norway and Iceland to establish a buoy near 61°N 15°W led to the deployment of the buoy ODAS 451 in November.

Upper-air systems

Work has continued on improving the performance of the new Mk 3 radiosonde by overcoming some functional difficulties discovered in the early production units. For example, mechanical faults in the temperature sensor have been cured, and a program of batch calibration has been initiated to reduce minor problems of non-uniformity in the temperature element. The result has been a considerable improvement in the consistency of the sonde system output. Progress in this area is likely to continue as refinements are introduced into the manufacturing process guided by data obtained in the calibration process.

The legalization of citizens' band (CB) radio on a frequency band from 27.5 MHz to 28.0 MHz has caused severe interference to our operational radiosonde network which has, for some 40 years, operated in this frequency range. CB interference is now so intense that radiosonde operation must be transferred to another part of the radio spectrum.

The only feasible long-term alternative to 27.5–28.0 MHz is the band allocated to radiosonde use around 403 MHz. However, the frequency stability demanded by the UK authorities is so great that the cost of the disposable radiosonde unit will be substantially increased by changing to this frequency band. A redesign of the sonde is being studied and a special team has been set up to deal with this task. A detailed specification has been drawn up and it is planned to request a commercial concern to undertake a study contract and report upon the feasibility and production costs of the proposed redesign.

At the most optimistic estimate, the redesigned sonde, together with the necessary modifications of all the automatic ground-station equipment, cannot be ready for operational service within three years. Therefore, as a short-term palliative, frequencies around 30 MHz have been 'loaned' to the radiosonde network by another department of the Ministry of Defence and a program of conversion to these temporary frequencies has been undertaken. The conversions are expected to be ready for operational use by 1 January 1982.

Installation of the four modified Mk 3 radiosonde ground stations for use on Army and MOD(PE) ranges was completed this year and all four are in operational use.

One of the major tasks currently being undertaken within the Operational Instrumentation Branch is the development and procurement of a replacement for the obsolete cathode-ray direction-finding (CRDF) system for thunderstorm location. The replacement will be a highly automated system based on the Arrival Time Difference principle. Development of hardware and software for the outstation installations is being undertaken 'in house' and the control station will be supplied by an external contractor.

Services and maintenance support procurement

The technical procurement section has had a very busy year as several projects have passed from the development laboratories to the procurement stage. The production prototype of the Synoptic Automatic Weather Stations being manufactured by Vaisala Oy, Helsinki, was delivered on 1 June 1981. Intensive trials of this model showed that modifications were necessary and these have been incorporated in the production models, delivery of which began on time in October. Twenty field units and ten 'polling' units for use at collecting centres are to be delivered in the initial contract.

The contract for 20 laser cloud-base recorders (LCBR) has progressed steadily through the year and the delivery of the first production prototype is due in January 1982.

Invitations to tender have been issued for the manufacture of a further 26 digital anemograph recorders and 10 short-base-line transmissometers. Work is also in progress in preparation for the procurement of 10 Meteorological Observing Systems for Ships (MOSS), the procurement of a further 26 Mk 5 wind systems and the refurbishment of all the Mk 4 wind-finding radars.

Technical management and services

The mechanical workshops have produced their usual high standard of work over the past year. Some 370 tasks have been completed. The most notable of these have been work on the automatic weather station tower for Sule Skerry, parts for an internally heated annulus experiment for the Geophysical Fluid Dynamics Laboratory and a radiometer to monitor cloud temperatures for the Cloud Physics Branch. The engineering design and drawing office continued to provide support for the Office in general where required. High-grade photographic services were also provided. The Information Officer dealt with approximately 500 'outside' queries on instrumentation.

A member of the installation section provided expert advice and assistance in the installation of a wind-finding radar and radiosonde ground station at Athalassa in connection with the Voluntary Co-operation Program of the WMO on behalf of the Government of Cyprus. The first installation of the Synoptic Automatic Weather Station for trials took place at Beaufort Park. The installation and conversion of the Mk 5 Wind Systems continued. The year also saw completion of the telemetered rain-gauge installations associated with the weather-radar network and the first phase of the Digital Anemograph Logging

Equipment (DALE) program, together with further installations of radiation logging systems (MODLE 3).

Post Design Services (PDS) and the electronic workshops provide a modification, manufacturing and repair service to support the wide range of Meteorological Office instrumentation requirements, including the production of specific pieces of equipment and printed circuit boards. An increasing amount of PDS time is concerned with modification arising from obsolete components in the older types of operational equipment.

There has been no reduction in the demand for the services of the test and calibration section. The section was placed under considerable strain owing to staffing difficulties and the severe disruption caused by serious flooding of the Simpson Building at Western Road, Bracknell in June. An ultrasonic cleaning bath, purchased to deal with flood-damaged equipment, has proved invaluable by saving thousands of pounds' worth of equipment which would otherwise have been scrapped owing to corrosion and silt or water damage.

Structural improvements in the Mk 3 radiosonde calibration unit accommodation at Eastern Road, Bracknell, have now been completed. These have resulted in a much better working environment for the operators.

An outside calibration facility for radiometers was completed during the summer. The system for recording the cosine response of radiation instruments is still held up by the lack of a suitable light source. The purchase of a dual floppy-disc drive for the desk-top computer which controls the radiometer calibration chamber has made possible further improvements in the calibration programs. Alternative sources for the supply of high-altitude sounding balloons are being sought and evaluated. The number of instruments tested and calibrated is given in Table XV (page 69).

The revision of the *Handbook of meteorological instruments* has been largely completed and all the new chapters except one are now either ready for issue or in the hands of the printer and editors.

The Meteorological Office Maintenance Organization continued its prime task of inspecting and maintaining standard meteorological equipments and systems which have a significant electrical or electronic content and which are used operationally. Equipments are located at sites throughout the UK and at certain overseas stations.

The range and number of such equipments have increased. The Organization installed and commissioned over 80 frequency division multiplexing systems at stations in the UK during the first eight months of the year and assumed maintenance responsibility for them. Twenty-four data-loggers (20 DALEs and 4 MODLEs Mk 3) and 6 Mk 5 Wind Systems installed during the year have been added to the field maintenance program. Introduction of the enhancement to the message-switching system in the Meteorological Telecommunication Centre at Bracknell has increased the complexity of the maintenance task in this area. The Organization has also taken over responsibility for maintenance of the Thames Tower, Christchurch Bay and Sule Skerry offshore automatic weather systems. Maintenance of the radars, displays and rain-gauges which currently comprise the National Weather Radar Network continues.

Technicians at the Ocean Weather Ship Base have been involved in acceptance-testing and proving software for the Navaid/Locate systems used on the Ocean Weather Ships. They have also taken part in the detailed planning for the removal of the equipment from the present ships and its reinstallation aboard the m.v. *Starella* which is due to take place early in 1982.

The School of Technical Training has run courses on behalf of the Meteorological Office College. Details are given in Table XVII (page 121).

Weather radar

The Branch has continued to be involved in the North West Radar Project. Most of the technical problems associated with running the unmanned radar system, the first of its kind, at Hameldon Hill near Burnley have been overcome. A new interface between the radar and the on-site computer, designed and built at the Meteorological Office Radar Research Laboratory at Malvern, was installed in the autumn and is expected to reduce significantly the occurrence of spurious signals between the radar and the computer. An investigation into the effects of attenuation of the radar signal due to radome wetness is under consideration.

Negotiations between the Meteorological Office, the Greater London Council, the Thames and the Southern Water Authorities are continuing with a view to setting up a consortium, similar in nature to that of the North West Radar Project, to finance and implement a London Weather Radar. If this goes ahead, a weather radar of the same type as that at Hameldon Hill would be operated at a site on the lower Chilterns to the north-west of London.

The weather radars at Camborne and Upavon which, together with those at Clee Hill and Hameldon Hill, comprise the current UK network, continued to function satisfactorily but are not capable of providing data of the same quality as that from Hameldon Hill. The installation of adjustment rain-gauge systems for these radars was completed during the year and radar adjustment techniques, having been tested at Clee Hill, were implemented at Hameldon Hill towards the end of 1981.

International co-operation

The Branch has been actively engaged in the European program of Co-operation in Science and Technology (COST) with a senior member of the staff serving throughout the year as the Chairman of COST Project 43 which is aimed at the establishment of a network of offshore data-acquisition systems on the European continental shelf. Other members of the staff have been closely involved with the joint buoy projects with Norway, Iceland and Ireland. A member of the staff has also served on the interim management committee of COST Project 72 (Measurement of Precipitation by Radar).

The Assistant Director in charge of the Branch attended the 8th Session of the WMO Commission for Instruments and Methods of Observation in Mexico City in October and was elected as Vice-President of the Commission for a four-year term.

A senior member of the staff visited the National Weather Service of the United States to study the progress that had been made in the automation of airfield observing systems so that we may be better placed to respond to any requests for work in this area which may arise in the near future.

Computing and Data Processing

Since 1975 the Meteorological Office computing system known as COSMOS has relied for its processing power on two IBM computers, the 360/195 and the 370/158, which function in a loosely coupled mode and are controlled from a single console.

Both machines continued to give good service, though with a few more outages than in previous years. The range of tasks did not change substantially, comprising a mixture of operational, research and service applications. The latter requirement increased slowly at the expense of computing time available for research. The two central processors are supported by a variety of peripheral units, comprising graphics, storage and output devices, and apart from the addition of two magnetic-tape units these remained unchanged during the year. However, a significant increase in computing power was effected in the second half of 1981 with the commissioning of the new CYBER 205 machine.

Enhancement of the COSMOS system

The CYBER 205 is manufactured by the Control Data Corporation (CDC) and the machine installed at Bracknell was the first to be delivered. Its speed of operation is at its greatest when similar computations are being performed on large groups of numbers. Hence it is difficult to express its speed with any single figure—this will depend on the nature of the program being run and on the skill of the user in formulating problems to make best use of the computer's vector capability. The machine has already demonstrated that it can perform certain mathematical computations at up to 400 million floating-point operations per second. The new computer was delivered in June and formally handed over in August.

The installation of the CYBER 205 required extensive structural modification and engineering work in the Richardson Wing at Bracknell Headquarters, involving close collaboration with the Property Services Agency and contractors. Taken as a whole the operation was very successful. There were some difficulties initially with the supply of chilled water and control of the environmental conditions within specified limits but remedial steps were taken and longer-term measures to improve the system are in hand. New accommodation has been provided for the engineers' quarters, a receipt and dispatch section and a card-punch room, and the original receipt and dispatch area has been adapted to extend the magnetic-tape store.

The increasing demands on the IBM 370/158 have become a matter of great concern. A high proportion of its central processor power is taken up with system tasks such as job-scheduling, data-handling and control of the network of terminal devices. An additional load is now about to arise from linkage to the new CYBER computer. The IBM 360/195 uses an obsolete operating system which cannot be adapted to handle all the tasks falling on its sister machine—a weakness which, together with its age, makes its replacement a matter of increasing urgency. Measures already in train to effect this replacement are described in the report of the Systems Development Branch (page 52). The replacement of the IBM 360/195 by a modern computer should also relieve the present congestion on the channels which enable the two computers to communicate with each other and with their peripheral units. The allocation of these channels was reorganized during the year to allow linkage to the CYBER machine, and there is now no spare capacity on them.

A number of changes have been implemented during 1981 in the network of terminal devices linked to COSMOS. A computer-to-computer connection was established for the transmission of flight-planning data to British Airways, and also to the minicomputer installed at the Meteorological Research Unit at Cardington to support their research. Remote terminals are also occasionally set up temporarily, an example being a visual display unit installed at the Offshore Europe '81 Exhibition in Aberdeen so that visitors to the Meteorological Office stand were able to retrieve information held on storage devices at Bracknell. Early in the year a link between COSMOS and the new minicomputer system at Heathrow was used to transmit observations stored in the Synoptic Data Bank. It later became possible, by further software development, to meet this requirement through a direct link between Heathrow and the automated telecommunication complex (AUTOCOM) and the new procedure became operational in June. A further terminal link was established between Bracknell and the CDC computer centre in Minneapolis to allow program development to proceed in advance of delivery of the CYBER. This service was withdrawn in August when the 205 was formally handed over.

Optimization of the system

A small group within the Data Processing Branch is established to liaise with computer manufacturers in maintaining system software and adapting it to local requirements. One of their prime tasks in 1981 was to acquire familiarity with the CYBER 205 operating system. To this end, staff collaborated with Control Data specialists both before and after the machine was delivered, and helped to identify deficiencies in the operating system or its documentation. Housekeeping and accounting methods were developed to assist in controlling the allocation of computing time on the CYBER machine.

The new communications controller installed at the end of 1980 to support the growing network of remote terminal devices was brought into service, and its software adapted to control nearly all the different varieties of device. The main burden of operating the network continued to fall on the IBM 370/158 however, and steps were taken to transfer some of this load to the communications controller by installing a new and more versatile access method known as VTAM. This major undertaking was ready for implementation at the end of the year. Software was also written to allow the same controller to link COSMOS with AUTOCOM, thus enabling the Office to dispense with the IBM System 7 computer that has provided the link since 1975.

Support for computer-based applications

Computing skills are widely spread throughout the Office, the tasks of problem formulation and programming usually being undertaken by scientists and support staff working on their own specialist problems. Certain services of general application are, however, provided by small groups in the Data Processing Branch.

One such service is maintenance of the Synoptic Data Bank suite of programs. These include procedures to recognize and store all incoming synoptic data, applying in the process a limited degree of quality control, and also to provide access routines appropriate to various applications—the most important being operational analyses and forecasts. Substantial changes were made during the year to allow processing of surface observations in the new WMO codes that are to be introduced on 1 January 1982. With the co-operation of outstations, several trials of the reliability of the new routines in handling real data were conducted. Radiosonde messages are usually received in several separate parts, and a new procedure has been introduced to combine these into a single message before checking for consistency in the vertical dimension. Upper-air data are thereby provided in a form more fitted to the new operational forecast procedures.

Another service to users is the provision of software to produce plotted charts and contour maps using the various COSMOS graphics devices. An extensive study of map projections was made during the year and general-application software written. Of immediate practical use are programs to plot observations or draw contours over areas not previously covered—the equatorial regions and the southern hemisphere.

Advice is provided by the Branch on programming techniques, and assistance is given in resolving intractable programming difficulties. Occasionally this contact with users reveals errors or deficiencies in system software, information about which can then be passed to manufacturers. This role of the programming techniques group has assumed increased importance following the installation of the CYBER 205. Training of programmers in IBM Assembler and Fortran languages has continued to be undertaken by members of the group assisted by staff of the Meteorological Office College. Instruction in CYBER programming has been given so far by Control Data personnel but preparations are in hand for this commitment to be taken over by the Office later in 1982. Routines have now been written in CYBER Fortran to provide users with general-purpose facilities not included in the manufacturer's software.

Preparation and storage of data

The data preparation and entry group continues to prepare climatological data in a form suitable for computer processing and subsequent entry into archival records. It has been possible to reduce the size of this section gradually while maintaining the keying schedule needed to keep pace with incoming monthly climatological returns and making slow inroads into a large backlog of similar data. This has been achieved with the help of a similar data-entry establishment at the Ministry of Defence, Bureau West, Devizes, which is able to use any intermittent spare capacity in this way. The manual-keying work-load will eventually be reduced by the extension of automatic methods when the new WMO codes allow climatological data to be extracted and processed directly on COSMOS.

Systems Development

The introduction and further development of automated methods has continued to dominate the activities of the Systems Development Branch. Wider aspects of automation are considered in this year's Special Topic (page 1). During 1981 two new projects of significance have emerged. First, preparatory work on the procurement of a computer to replace the IBM 360/195 culminated in the issue of an Operational Requirement in October and the receipt of proposals late in November. The second new development was the preliminary design of the first stages of an administrative support system for the

Office to run on the main scientific computer system COSMOS. The balance of the remaining areas of work has changed a little as proven systems have been handed over to users but the major lines of work continued much as before. Those lines include, notably, further progress in establishing machinable archives, introduction of small computer systems at major outstations, the planning of major changes to COSMOS and the support of selected projects involving the application of small computers.

Procurement of CYBER 205 computer

A CYBER 205 computer was delivered to Bracknell Headquarters by Control Data Ltd on 6 June and was handed over on 11 August. The numerical processing capability of the 205 has exceeded expectations. A performance better than 20 times faster than the IBM 360/195 was contracted for a specified mixture of bench-mark programs. The actual performance on this mixture is in excess of 30 times faster than the 360/195. This is due partly to the 205's ability to handle sparse vectors efficiently, i.e. those in which only a random selection of elements are required for processing, so permitting vector operations on what hitherto were regarded as scalar processes, and partly to the very high speed of vector processing. The performance on complete programs of practical importance, for example new models for weather forecasting and climatic research, is also very encouraging. In specialized sub-routines of very limited applicability nearly 100 times the performance of the 360/195 can be achieved. As was to be expected, there have been some problems with the 205 which is an early model of a new design. Nevertheless, despite some difficulties with environmental control, the availability of the hardware has been better than was projected before delivery, although the link to the IBM computers in COSMOS had not been fully implemented by the end of the year. The link is essential to allow operators to control both the CYBER and IBM computers from a single console position, as well as to transfer programs and data between the front- and rear-end processors.

Replacement of IBM 360/195

The 360/195 is now close to the end of its economic life. The first steps towards obtaining a replacement were taken during the year and financial approval was granted in June. The new computer is not planned as a direct replacement for the 360/195 as major number-crunching work will now be carried out on the CYBER 205. On the other hand, the replacement must provide better throughput on general-purpose data processing which is highly inappropriate to the 205. A high degree of compatibility with IBM hardware and software is essential to allow a smooth transition and continuity of important work at an acceptable cost. An Operational Requirement (OR) issued in October indicated the work-load to be undertaken and the need for IBM compatibility. A substantial effort went into ensuring that the OR conformed to the new EEC/GATT regulations introduced in January 1981. Proposals were received late in November.

Automation of outstation functions

Full operational working of the computer Outstation Automation System (OASYS) at the Principal Forecasting Office (PFO) at London/Heathrow Airport started on 19 January, allowing 16 junior posts to be given up. The equipment has automated the production of many plotted and line-drawn charts. During the first half of the year a team in the Central Forecasting Branch took over routine support of OASYS so allowing full effort to be maintained on further developments.

By July a second OASYS, eventually destined for the PFO at HQ Strike Command (HQSTC), had been assembled and this was installed in the Control Tower at Heathrow, ahead of the move of the PFO from the Queen's Building. The first OASYS was then returned to Bracknell for further development work prior to installation at HQSTC.

Orders were placed for graphic visual display units for both systems in June and these were delivered in December. Forecasters will be able to call up information in either text or pictorial forms when hard copy is not essential.

The case for a third OASYS at London Weather Centre is under consideration. Direct savings would not be as great as at the other two major outstations but a useful increase in revenue is expected. Some assistance was given to staff from the Directorate of Naval Oceanography and Meteorology in preparing a draft OR for an OASYS at the Fleet Weather and Oceanographic Centre.

Machinable archives

The incorporation of data of adequate quality into uniform machinable archives continues to be a major task. A useful stage was reached this year with the completion of a survey of available data and the production of a machinable catalogue that can be kept up to date much more easily than the old typescript version. The new catalogue provides ready access to current information and may be used as the basis for the automated retrieval of selected data.

The search for means of capturing a greater proportion of data in forms that do not require manual conversion to machinable form is a continuing concern. The new WMO codes for surface meteorological data, to be introduced on 1 January 1982, provide an opportunity to extract more climatological data from the message received through communication channels. The potential gain could be a 35 per cent reduction in the keying of data from manuscripts. Investigations have continued into the possible use of optical character recognition and individual keyboard-to-cassette systems to reduce manual keying still further.

Administrative computer-based systems

During the early months of the year various sub-systems needed to set up a complete system of budgetary monitoring and control were investigated in detail. By adopting a modular approach using 'basic building bricks' it has been possible to devise, on the basis of need and practicability, an implementation plan that will give some early benefits while moving steadily towards the goal of more effective budgetary control. Accordingly, detailed work started in the autumn on sub-systems for activity monitoring, staff-time analysis, a catalogue of local stores, long-term costings and COSMOS usage. At the same time work was put in hand on some of the fundamental points concerning data acquisition, storage, retrieval and presentation which are being based on a commercial data-base management system (DBMS).

Three further sub-systems, those for text processing, stock control and some aspects of staff records will be handled separately.

Miscellaneous projects

Detailed plans were prepared for an enhancement to the Library's computer that would provide for an enlarged on-line catalogue, the inclusion of some abstracts and assistance to staff concerned with the handling of loans (see page 6).

Further consideration was given to the need for a more efficient terminal to assist in the supply of meteorological information to Prestel, and steps were taken late in the year to acquire such a terminal which would reduce telephone charges to the Office.

Assistance was given to the Climatological Services Branch in preparing a case and specification for a microcomputer system, intended primarily to provide live displays at exhibitions. The present disproportionate effort in arranging temporary lines to the main sources of information at Bracknell will thereby be avoided and demonstrations of the Office's data services will be more effective and will generate more revenue-producing contracts.

Last year assistance was given to the Boundary Layer Research Branch in procurement action for two small computers. With the delivery of the computers late in the summer, staff from the Systems Development Branch guided the generation of system software to support the data-logging activities on one computer and remote job-entry facilities to COSMOS on the other.

The PDP 11/40 continued to provide a media conversion service and there was little innovative work.

Early in the year a new contouring package was handed to users for field tests. The package was developed with the aim of being efficient on a wide range of machines from minicomputers to vector processors and compatible with a variety of plotting devices. The package has now been modified to take account of user reactions and is superior, in most applications, to anything available commercially. Special features include shading, masking, dashed lines and clear labelling.

METEOROLOGICAL TELECOMMUNICATIONS

The Telecommunication Branch is responsible for the provision of telecommunication support to the whole of the Office, and for the operation of the Meteorological Telecommunication Centre (Met TC) located at Bracknell. An important aspect of the Branch activities is the planning and organization of the complex networks of communication lines, and radio channels, over which data, pictorial information in chart or tabular form, and satellite imagery, are received and distributed.

As a Regional Telecommunication Hub (RTH) on the Main Trunk Circuit (MTC) of the WMO Global Telecommunication System (GTS), the Bracknell Met TC is responsible for the link between Europe and North America, for the collection and injection in to the GTS of observational data from a number of National Meteorological Centres (NMCs) in north-west Europe, and for the dissemination to these and other centres of the information which they require from the GTS. These operations are controlled in the Met TC using computer-based automatic message-switching systems. The MTC connections are to the Paris RTH and to the World Meteorological Centre (WMC) in Washington. On these circuits, and on a Main Regional Circuit (MRC) between Bracknell and the Offenbach RTH, digital data transmissions at 2400 bits/second alternate with the transmission of pictorial information in analogue mode.

These methods have been successfully employed over the past decade, but towards the end of this year trials began of new methods of operation intended to increase traffic capacity and to improve efficiency. These are discussed later in the report. Regional circuits to NMCs generally operate in digital mode only, pictorial information being sent over separate facsimile networks. Observational data from Greenland, Gibraltar, Iceland, the Netherlands, and the Republic of Ireland, collected through the respective NMCs, together with data from the United Kingdom, collected through the Met TC, form the input to the GTS of the Bracknell RTH. A special responsibility is the collection of observations from the Ocean Weather Ships of the North Atlantic Ocean Station (NAOS) network. Morse transmissions of the observational reports from the Norwegian, Dutch, British, French and Russian vessels which form the network are received at the Bracknell Shore Station, and microcomputer-controlled data-entry facilities enable the reports to be inserted rapidly on to the GTS for world-wide distribution.

Data from the GTS are supplied to the European Centre for Medium Range Weather Forecasts at Shinfield Park, near Reading, over a dedicated circuit using special link-control procedures. From July 1981, coded analyses and forecasts from the Centre have been received and inserted for distribution on to the GTS. Transmission speed on the link, formerly 2400 bits/second, was increased to 4800 bits/second late in the year to ensure the prompt exchange of information.

An extensive network of teleprinter and facsimile circuits enables Bracknell to fulfil its role as the NMC for the United Kingdom. Observational data of many kinds, including those from land stations, from ships at sea, and from aircraft over the east Atlantic, are collected and distributed. Analyses and forecasts prepared manually, or automatically by computer systems, are widely disseminated. Offices formerly served by the MCC1, MCC2 and MCC3 50-baud teleprinter broadcasts have, from 1 September 1981, received the new 100-baud MCC A and MCC B broadcasts. By using frequency division multiplexing techniques these new services are, for the most part, provided over the same circuits as those used for the MOLFAX analogue facsimile transmissions, thereby achieving a considerable saving in total circuit costs, whilst at the same time providing faster transmissions and greater traffic capacity. The MOLFAX schedule provides forecasting offices throughout the United Kingdom with regular transmissions of plotted charts, and analyses and forecasts in chart form.

The successful launch of the second European geostationary satellite, Meteosat-2, in June 1981 has made more images available for distribution through the automatic satellite imagery handling system (AUTOSAT). Some 30 stations receive a program of images from Meteosat-2 and the NOAA-6 and NOAA-7 polar orbiting satellites over the SATFAX facsimile network. The system also supports a television-type display in the Central Forecasting Office at Bracknell which provides a user-selectable program of visual and infra-red images including 'cine loop' displays of Meteosat images. Special programs to the London Weather Centre and the Principal Forecasting Offices (PFOs) at Heathrow and HQ Strike Command also contain a limited number of images from the US geostationary satellite GOES-East.

A network of land-lines connecting Bracknell to centres in Europe provides for the distribution of analyses and forecasts by analogue facsimile. Several different programs, comprising mainly Area Forecast System products originated by Bracknell and the PFO Heathrow in support of civil aviation operations, distribute this information in chart form to many countries including Norway, Denmark, the Federal Republic of Germany, the Netherlands, the Republic of Ireland, Iceland, France, Italy, Austria and Switzerland. For centres not linked to the land-line network, a radio-facsimile broadcast, GFE, provides a similar program of charts, and also a range of products suited to recipients with maritime interests, including ships at sea. A second radio-facsimile broadcast, GFA, provides a range of products of more general meteorological interest. Alphanumeric information is broadcast over the GFL 50-baud radio-teleprinter broadcast. Corresponding radio broadcasts from other RTHs in Europe, and from more remote areas, are received in turn and passed to the Met TC, thereby providing information which is not available by other means.

The Met TC is operated in accordance with agreed international and national procedures for the collection and distribution of meteorological information. Members of the Branch play an active role in the international working groups which study the requirements and formulate these procedures.

Bracknell Automated Telecommunication Complex (AUTOCOM)

The twin Ferranti Argus 700S computer system, first brought into service late in 1980, now controls all the medium-speed circuits connected to the Met TC. The new system has shown great reliability, with an availability of over 99.7 per cent throughout the year, and its magnetic-tape records of message handling and other system activities have greatly aided the tasks of system and traffic monitoring. The system controls the operation of the MTC and MRC circuits to Paris, Washington and Offenbach at 2400 bits/second, and to Oslo, De Bilt, and Dublin at 1200 bits/second. In June a 4800 bits/second link was implemented between the minicomputer system at the PFO Heathrow and AUTOCOM. A link at 2400 bits/second to Brussels was added in July. In November a connection to a pair of Argus 700G computers, known as the Teleprocessing Units (TPUs), was brought into service to provide a permanent link at 4800 bits/second between AUTOCOM and the data-processing computer complex COSMOS. The connection, which provides a faster and more reliable means of communication, replaces the IBM System 7 minicomputer which has controlled the exchange of data between AUTOCOM and COSMOS over the past 7 years.

The Marconi Myriad Phase II message-switching computer system, first brought into service in 1974, continues in use for the control of the many low-speed teleprinter circuits which are operated through the Met TC. The system provides the data for the new MCC A and MCC B 100-baud national teleprinter broadcasts, via a dedicated microcomputer system. Other circuits include the 50-baud links to Iceland, Rheindahlen, Hilversum, Gibraltar, Cyprus and the 12 data-collection centres in the United Kingdom. The bulletins of UK data distributed on the GTS are compiled automatically by the system, and transferred over a 2400 bits/second link to the Argus 700S system for international distribution. Difficulties have been experienced with the maintenance of the Phase II system in recent years, particularly with the moving-head disc units. Much effort has therefore gone into defining the requirement for a new system to replace Phase II (see below).

Satellite data reception and distribution

A planned addition to the RAE satellite ground station at Lasham has been completed during the year, in that imagery from GOES-East has been made available in addition to that from Meteosat-2. The availability of the GOES-East data will facilitate the plan (described below) to introduce the CCITT recommendation V-29 mode of operation on the MTC. During the year the polar-orbiting satellite TIROS-N was replaced by a similar satellite, NOAA-7, and data from this satellite, together with that from the existing NOAA-6 satellite, have been supplied operationally as an input to the AUTOSAT computing system at Bracknell. The data supplied include Scanning Radiometer (SR) imagery, TIROS Operational Vertical Sounding (TOVS) data, selected sectors from the Advanced Very High Resolution Radiometer (AVHRR) imagery, selected images from the WEFAX broadcast from GOES-East, and Secondary Data User Station (SDUS) pictures from Meteosat-2. In addition to the above data, an independent supply of Stratospheric Sounding Unit (SSU) data from the NOAA satellites has been provided over a special circuit from Washington for processing by the Dynamical Climatology Branch.

Development towards new telecommunication services

Plans formulated by the national centres at Bracknell, Washington, Paris and Offenbach to change the mode of operation on the medium-speed MTC links have made good progress during the year. The proposed new mode of operation utilizes V-29 modems working at 9600 bits/second with Time Division Multiplexing (TDM) facilities which provide two channels at 2400 bits/second and one at 4800 bits/second. The two lower-speed channels will be used for the transmission of data, while the higher-speed channel will be used for the transmission of uncoded digital facsimile charts. During the year the standards of operation were agreed and the necessary equipment was procured. Tests were in progress at the end of the year, both on the MTC and on a further V-29 circuit between Bracknell and Iceland.

At the beginning of the year an important decision was taken to procure a new message-switching system (AUTOCOM Phase IV) to replace the obsolete Phase II system. A User Requirement was prepared and a number of equipment suppliers were invited to make presentations. It is planned to place a contract next year to provide the replacement system within a two-year period.

Programming for the two Ferranti Argus 700G computers, which function as Teleprocessing Units, has been carried out entirely within the Branch. The system is designed to fulfil several roles. Firstly, it supports a link from AUTOCOM to ECMWF using standard WMO protocols between AUTOCOM and the TPU, and a complex 4-layer (CCITT recommendation) X-25 protocol between the TPU and ECMWF. Secondly, it provides a link between the TPU and the IBM 3705 telecommunication control unit in COSMOS, using bisynchronous protocol. Later it is planned to use the TPU to support the medium-speed links to outstation OASYS systems.

Eight AUTOPREP data-entry and editing systems were installed at Collecting Centres during the year, and further software and hardware development is being carried out to improve the system reliability and to extend the system capabilities. Action has been taken to reduce the system load on the floppy discs which form part of the original system data store, by enhancing the systems with solid-state bulk-memory stores.

Management of telecommunication resources

The imposition of strict cash limits on the procurement of new equipment and routeing of new lines, and on the maintenance of existing lines and circuits, has created serious difficulties during the year. A considerable amount of rationalization and re-planning of the communications facilities and networks has been carried out, and the recent introduction of a microcomputer-based record-keeping system has already begun to prove its worth. A senior officer of the Branch visited the neighbouring NMCs at Paris and Offenbach to study their organizational structure and management of resources.

INTERNATIONAL AND PLANNING

The Meteorological Office has continued to play a leading role in the international co-operative programs which are essential for the operation and development of meteorological services. The focal point of much of this co-operation is the World Meteorological Organization (WMO), a specialized agency of the United Nations, to which the United Kingdom is the third largest contributor amongst the membership of about 150.

The governing body of the WMO is the Congress, composed of the Permanent Representatives of Members, which meets every four years. Between Congresses the work of the Organization is supervised by the Executive Committee (EC) of which the Director-General is one of 19 members elected to represent the international meteorological community rather than their countries. The EC meets annually and the 33rd Session took place between 8 and 17 June 1981. At the suggestion of the new President of WMO, Dr R. L. Kintañar of the Philippines, the Session was shorter than usual but a reorganization of working methods provided about the same time for discussions. The Director-General was assisted at this meeting by the Assistant Director (International and Planning) and Mr M. W. Stubbs who both attended the EC Preparatory Meeting between 1 and 5 June when selected items for the main meeting were prepared in great detail. During these sessions the whole range of WMO activities were discussed but two matters were emphasized. These were the possibility of a fundamental redesign of the structure of WMO and its constituent bodies and the development of a detailed program for WMO for the next two financial periods, that is for the years 1984 to 1991. The latter subject was discussed by a small working group chaired by the Director-General who continued the work with the WMO Director of Technical Programs during the year. Questions of WMO structure are in the hands of an advisory committee appointed by the EC which is to report to the 9th Congress in 1983; the Assistant Director (International and Planning) attended an open meeting of that committee in Geneva in February.

Other constituent bodies of the WMO are the six Regional Associations, by which matters of interest in particular geographical areas are co-ordinated, and the eight Technical Commissions in which particular aspects of meteorology and hydrology are studied and co-ordinated. Neither of the Regional Associations of which the UK is a member (those for Africa and for Europe) met during the year. Of the Technical Commissions, that for Marine Meteorology met in Hamburg, Federal Republic of Germany, between 14 and 25 September and the Commission for Instruments and Methods of Observation met in Mexico City between 19 and 30 October; both were preceded by Technical Conferences. The UK was represented at both the Commission meetings and the Technical Conferences and sent experts to important meetings organized by these and other Commissions throughout the year. It hosted a meeting of a study group of the Commission for Basic Systems on the Best Mix of Observing Systems during September.

The global systems for observation, telecommunications and data processing constitutes the World Weather Watch (WWW) program of the WMO. The UK makes important contributions to the program through the operation of its facilities at Bracknell as a Regional Telecommunication Hub and a Regional Meteorological Centre, and through its observational network. In addition, the UK continues to contribute to the observational network in data-sparse areas by operating a number of stations which it has established during recent years for surface and upper-air observations. All but one of these stations are in the newly independent countries of Kiribati, the Seychelles, Tuvalu and Vanuatu. The remaining station is on the remote South Atlantic island of St Helena. Most of these stations have had UK-based officers in charge and technical officers, supported by locally employed staff, but a training program is gradually allowing the replacement of the UK-based staff. In Vanuatu (formerly the New Hebrides) the upper-air station at Bauerfield had been supported jointly by France and the United Kingdom under an inter-Governmental Agreement concluded in Paris on 19 April 1971. This became void with the granting of Independence on 31 July 1980 and, despite strenuous attempts started in 1978 in anticipation of the event, it has not yet proved possible to come to an understanding with all the parties concerned on the future of the station. It is now clear that a joint Agreement between the UK and France on the one hand and Vanuatu on the other will not be possible. However, negotiation of separate Agreements or understandings have begun and the matter should be brought to a satisfactory conclusion.

The WMO Voluntary Co-operation Program (VCP) was established as a way in which developing countries could be helped to fulfil their obligations to the WWW program by donations of equipment and training fellowships and by other services provided by the developed countries. Mr G. J. Day, Assistant Director (International and Planning), attended the annual Informal Planning Meeting of Major Donors to the VCP in Geneva in February to discuss the development of this Program; the conclusions of this meeting were discussed by the EC Panel on the VCP during the WMO EC meeting in June. An important decision was made to send a small team of experts to investigate and to assist in diagnosis and the institution of remedial measures to some of the Regional Telecommunication Hubs shown by WMO's regular monitoring studies to have problems of operation. If the experiment proves successful similar missions will be sent to other Regional Telecommunication Hubs.

Following an initiative by the Director-General at the Commonwealth Meteorologists' Conference in 1979, the possibility has been explored of providing a quick-response technical-support service, in co-operation with manufacturers, for equipment donated by the UK. Detailed planning for a service had reached an advanced stage in 1980 when budgetary constraints prevented further progress. However, it is hoped to continue the development of this important initiative when circumstances permit.

A noteworthy example of international co-operation is the European Centre for Medium Range Weather Forecasts which developed from a project of the

European Co-operation in Science and Technology (COST). The Centre, which has its permanent headquarters at Shinfield Park near Reading, is supported by 17 European countries under an inter-Governmental Convention. The staff, numbering about 145, are drawn from the member countries as far as possible in proportion to the contributions made to the budget but UK staff predominate in most grades. The task of the Centre is to devise numerical prediction methods to forecast to 10 or 12 days ahead, a problem of great difficulty and requiring access to very powerful computing facilities. At present, statistical tests on the products circulated over the Centre's private telecommunication network show some skill at 5 or 6 days. The work of the Centre is supervised by a Council (which meets twice a year) comprising representatives of the member States which is assisted by three Advisory Committees. Mr F. H. Bushby, Director of Services, is an elected member of the Scientific Advisory Committee as an individual expert, Mr G. J. Day, Assistant Director (International and Planning) represents the UK on the Finance Committee (and is its Chairman-elect) and Mr D. H. Johnson, Deputy Director of Forecasting Services, represents the UK on the Technical Advisory Committee.

The North Atlantic Ocean Station (NAOS) Agreement, under which the network of Ocean Weather Ships making surface and upper-air observations in the Atlantic is maintained, remains in operation. The Agreement, which was due to lapse in 1981, has been extended until 1985. Under the extended Agreement the UK will charter a ship to occupy Ocean Weather Station 'L' jointly with Norway in place of the two ships the Meteorological Office now operates as sole occupant of this station. Discussions on an improved WWW in the WMO committees include consideration of possible systems to replace the important but expensive observations from the Ocean Weather Ships but a solution is not yet evident.

The meteorological aspects of other international activities are dealt with through such organizations as the International Civil Aviation Organization (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 Program of which the World Climate Program is now an important part.

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 its Bases. The Meteorological Office supports the operations of BAS WWW stations by providing consumables and some capital equipment; the level of this support is reviewed from time to time in the light of changing circumstances. Unfortunately, a serious fire at Halley Bay in August destroyed stores and severely damaged some equipment used in the meteorological program, but arrangements have been made for a skeleton program to be continued whilst the future of the work is considered. 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 communication is accomplished by a WMO EC Panel on Antarctic Meteorology of which Mr G. J. Day, Assistant Director (International and Planning), is Chairman.

The Program Review Commitee (PRC), which comprises the senior Directorate of the Office, keeps under review progress of Meteorological Office programs and the direction and distribution of effort. The International and Planning Branch provides the Secretariat for the PRC which met during January and October. During the year, the Branch continued to assemble management information on a wide range of projects and activities in support of the PRC and explored the use of this information by individual project managers.

Appendix III (page 149) lists the meetings of WMO and other international 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 1981

	Within UK	Overseas
Principal Forecasting Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF	5	3
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	9	—
Observing offices associated with civil aviation	7	—
Upper-air observing offices	8	1
Weather Centres	8	—
CRDF offices	4	1
Port Meteorological Offices	7	—
Offices associated with the Agricultural Development and Advisory Service (MAFF)	4	—
Other offices	14*	—

*Three of these stations are administered by DR Met O

Notes

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

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

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

At an observing office no forecaster is available.

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

Weather Centres 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 two ocean weather ships. These were employed to man Ocean Station 'L' (57°00'N, 20°00'W), one of the four stations of the network, each ship spending an average 24 days on station each voyage. The station was manned for a total of 358.8 days in 1981 and the two ships were on passage for 64.9 days. Two ships from France, one from the Netherlands, 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 7498 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', offshore platforms, rigs and buoys also make and transmit meteorological observations.

On 31 December 1981 the numbers of British ships reporting were:

Selected ships	446
Supplementary ships (including 4 trawlers)	16
Coasting vessels	45
Lightships (including 1 light-tower)	13
Trawlers	—
Auxiliary ships	5
Total	525

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

UK to Australia	23
UK to Far East	28
UK to Persian Gulf	23
UK to South Africa	20
UK to West Indies	13
UK to Atlantic coast of North America	47
UK to Pacific coast of North America	4
UK to South America	10
UK to European ports	98
UK to Falkland Islands and Antarctica	2
UK to distant-water fishing grounds	4
World-wide trading	190

During a typical five-day period in June the average daily number of reports from ships and sea stations received at the Regional Telecommunication Hub (RTH) at Bracknell were as follows:

	Reports	
	1980	1981
Direct reception from:		
British ships	182	190
Foreign ships	97	112
Rigs, platforms, buoys	57	83
Total	336	385

Total number of reports received by geographical location (direct to RTH Bracknell and via the Global Telecommunication System):

	1980	1981
Eastern North Atlantic	874	880
Western North Atlantic	347	330
Mediterranean	87	80
North Sea	193	247
Arctic Ocean	54	65
North Pacific	845	777
All other waters	410	495
Total	2810	2874

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. The following table shows the distribution on 31 December 1981 of stations which supply climatological information. The areas and titles of the districts are those used in the Monthly Weather Report.

	Stations supplying Returns							Stations supplying Autographic Records		
	Observatories	*Met. O. Synoptic*	*Auxiliary Synoptic*	*Agrometeorological*	*Climatological*	*Holiday Resorts*	*Rainfall**	*Sunshine*	*Rainfall*	*Wind*
Scotland, north	1	7	5	1	30	0	333	24	15	16
Scotland, east	0	6	3	11	46	2	477	32	21	13
Scotland, west	1	6	7	2	47	0	510	24	23	18
England, east and north-east	0	9	3	7	22	4	532	27	15	16
East Anglia	0	10	1	13	20	3	414	24	24	11
Midland Counties	0	7	2	14	39	0	1043	39	38	15
England, south-east and central southern	0	15	6	14	34	13	769	45	29	20
England, south-west	0	8	10	4	34	7	592	32	21	14
England, north-west	0	6	3	2	13	2	539	16	25	12
Isle of Man	0	1	2	0	0	1	18	3	1	3
Wales, North	0	1	3	3	15	3	263	13	4	3
Wales, South	0	4	6	5	12	1	304	12	17	5
Channel Islands	0	2	0	0	1	2	17	5	0	2
Northern Ireland	0	2	6	8	51	0	279	28	48	12
Total	2	84	57	84	364	38	6090	324	281	160

*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 100 mb (≈16 km)	50 mb (≈20 km)	30 mb (≈24 km)	10 mb (≈30 km)	Percentage of largest balloons reaching 10 mb (≈30 km)
(a) *Temperature, pressure and humidity:*						
Eight stations in the UK ...	5785	92.3	83.4	65.4	16.2	48.0
One station overseas ...	730	98.1	88.5	72.3	27.0	33.3
One Ocean Weather Station (two ships)	1455	96.7	82.3	62.6	9.6	—
(b) *Wind*						
Eight stations in the UK ...	11 604	94.6	78.6	51.0	9.8	49.9
One station overseas ...	1458	97.3	87.4	59.7	13.5	33.3
One Ocean Weather Station (two ships)	1452	93.3	77.7	58.5	6.4	—

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network in 1981 ... ... 16 511

TABLE VII—METEOROLOGICAL COMMUNICATION TRAFFIC

Almost all the national and international exchanges of meteorological observations which are used in the construction of synoptic charts and the production of forecasts are effected by coded messages. These coded messages usually comprise groups of five figures and there are about 466 characters per message. The messages are exchanged by radio and land-line facilities. In addition there are exchanges, both national and international, of meteorological information in pictorial format. This information mainly comprises analyses and forecast charts derived from processing observational data. The transmission method is analogue facsimile by either radio or land-line.

The following figures are taken from an analysis of the traffic (mainly coded messages and information in pictorial format) handled by the Meteorological Telecommunication Centre, Bracknell, for one typical day (24 hours) in November 1981. For comparison, some corresponding figures are given for 1980.

	In	Out	Total	Total in 1980
	number of messages/products in one day			
Codes messages:				
Land-line teleprinter and data transmission ...	17 279	85 379	102 658	81 439
Radio transmission	509	3243	3748	4306
Facsimile products (pictorial format):				
Land-line transmission	256	1046	1302	1193
Radio transmission	46	112	158	169

Notes

The increase in the total for land-line teleprinter and data transmission messages is mainly due to the introduction of medium-speed links with the European Centre for Medium Range Weather Forecasts and with the London/Heathrow OASYS minicomputer system.

The reduction in the total for radio transmission of coded messages reflects the removal of duplicated messages following a reorganization of the circuits to Gibraltar.

The increase in the total for land-line transmission of facsimile products is due to the launch during the year of two new satellites, NOAA-7 and Meteosat-2, and the reception and dissemination of their products.

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 service for farmers and growers	1980	159	1981	184
Weekend temperature forecasts (a winter service primarily for industrialists) ...	1980/81	75	1981/82	74
Winter road-danger warnings (primarily for local authorities	1980/81	272	1981/82	274
*Consultancy or forecast services ...	1980/81	18	1981/82	46

*See page 14.

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office at Bracknell, 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 the British Airways BOADICEA and APOLLO computers at Heathrow and Prestwick respectively and to the Dutch and Belgian Meteorological Services.

The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings that took place during 1980 and 1981. These do not include warnings and routine general forecasts.

	1980	1981
Number of meteorological briefings for		
aviation in the UK	369 643	382 325
aviation at overseas stations	31 684	33 852
Number of aviation forecasts issued for		
aviation in the UK	1 894 495	1 773 885
aviation at overseas stations	154 842	151 549

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 requests 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. Recorded answering systems, other than ATWS (see Table XII), are gradually being withdrawn. Enquiries to these systems are therefore not included in the 1981 figures.

	1980	1981
Total number of non-aviation enquiries	2 088 291	2 029 685
Percentage relating to:		
agriculture	15.6	14.4
building	4.2	4.0
commerce, industry	4.5	4.4
holidays	16.8	16.2
marine matters	13.4	10.3
Press	10.9	12.3
public utilities	9.3	9.7
road transport	5.3	7.8
other known purposes	8.2	7.9
unknown purposes	11.8	13.0

TABLE XI—FLASH WEATHER MESSAGES

FLASH weather messages are passed to the BBC and to most independent broadcasting companies for inclusion in their programs at a convenient break. They are, effectively, warnings of the actual occurrence of weather conditions which might cause considerable inconvenience to a large number of people. The following table shows the kind of weather and areas of the country for which FLASH messages are broadcast and the number issued in 1981.

Area	Dense fog	Moderate or heavy snow	Heavy rain	Glazed frost and icy roads	Severe inland gales	Blizzard
Edinburgh and south-east Scotland ...	—	—	3	—	1	—
Glasgow and south-west Scotland ...	—	2	4	—	2	—
Belfast and Northern Ireland ...	—	1	3	—	3	3
Industrial north-east England ...	—	1	3	2	2	1
Industrial Lancashire and Merseyside ...	—	—	—	2	1	—
Industrial Midlands ...	—	4	—	1	3	—
Bristol and Bath ...	—	—	—	—	—	—
South Wales ...	—	1	4	—	5	1
London and south-east England	—	1	3	—	1	—
Plymouth and south-west England	—	2	4	1	7	3
Yorkshire ...	—	3	1	—	5	—
Southampton and Portsmouth ...	1	—	1	—	—	—
Warnings covering more than one area or blizzards outside industrial areas ...	—	12	8	2	8	8
Totals ...	1	27	34	8	38	16

TABLE XII—AUTOMATIC WEATHER SERVICE FORECASTS

Information Service Centre	Forecast area	Number of calls 1980	Number of calls 1981
Bangor	Northern Ireland*	0	9 846
Bedford	40 miles radius of Bedford	335 717	417 216
Belfast	Northern Ireland*	412 488	475 529
Birmingham	Birmingham and Warwickshire*	1 217 758	1 334 461
Bishop's Stortford	40 miles radius of Bedford	131 619	134 689
Blackburn	North-west England*	367 194	466 963
Blackpool	North-west England*	240 708	263 378
Bournemouth	Dorset & Hampshire coast & Isle of Wight*	442 389	497 569
Bradford	West Yorkshire*	200 397	245 529
Brighton	Sussex coast	867 314	936 322
Bristol	Somerset and Avon*	722 805	926 397
Cambridge	40 miles radius of Bedford	30 065	120 040
Cardiff	Glamorgan and Gwent*	879 809	899 350
Canterbury	Kent and Essex coasts*	349 405	573 197
Chelmsford	Kent and Essex coasts*	199 802	248 821
Cheltenham	South-west Midlands	186 502	198 236
Chester	Anglesey and North Wales coast*	183 171	183 646
Colchester	Kent and Essex coasts*	308 289	355 552
Colwyn Bay	Anglesey and North Wales coast*	115 860	129 757
Coventry	Birmingham and Warwickshire*	294 044	371 901
Derby	East Midlands*	209 049	333 221

Information Service Centre	Forecast area	Number of calls 1980	1981
Doncaster	South Yorkshire and Peak District*	71 606	96 163
Edinburgh	Edinburgh and Lothian	426 632	418 624
Exeter	Devon and Cornwall	456 720	498 925
Glasgow	Glasgow and District	813 089	856 608
Gloucester	South-west Midlands	292 495	345 760
Grimsby	Lincolnshire and Humberside*	111 168	129 590
Guildford	London	254 806	250 453
Hastings	Sussex coast	148 628	181 189
Hereford	South-west Midlands	137 827	167 635
High Wycombe	Oxfordshire, Buckinghamshire & Berkshire*	186 705	235 749
Huddersfield	West Yorkshire*	120 680	153 371
Ipswich	Norfolk and Suffolk	362 219	429 785
Leeds	West Yorkshire*	598 954	599 736
Leicester	East Midlands*	402 670	451 205
Lincoln	Lincolnshire and Humberside*	242 016	276 686
Liverpool	North-west England*	396 537	430 187
Liverpool	Anglesey and North Wales coast*	53 291	53 713
London	London	4 027 978	4 910 633
London	Kent & Essex coasts* (formerly Essex coast)	149 895	165 939
London	Kent & Essex coasts* (formerly Kent coast)	197 779	212 850
London	Sussex coast	375 216	439 841
London	Oxfordshire, Buckinghamshire & Berkshire*	263 917	329 063
London	40 miles radius of Bedford	154 064	201 709
Lowestoft	Norfolk and Suffolk	28 907	52 890
Luton	40 miles radius of Bedford	296 762	393 567
Manchester	North-west England*	653 939	912 370
Manchester	Anglesey and North Wales coast*	127 304	95 602
Medway	Kent and Essex coasts*	293 584	282 678
Middlesbrough	North-east England	263 666	289 094
Milton Keynes	40 miles radius of Bedford	71 955	90 598
Newcastle	North-east England	626 691	674 197
Newport, Gwent	Glamorgan and Gwent*	133 367	171 145
Northampton	40 miles radius of Bedford	122 935	130 273
Norwich	Norfolk and Suffolk	482 278	562 686
Nottingham	East Midlands*	619 941	658 406
Oxford	Oxfordshire, Buckinghamshire & Berkshire*	347 244	419 524
Peterborough	40 miles radius of Bedford	156 556	199 538
Plymouth	Devon and Cornwall	505 477	634 381
Portsmouth	Dorset & Hampshire coast & Isle of Wight*	542 412	616 522
Reading	Oxfordshire, Buckinghamshire & Berkshire*	532 905	538 483
Sheffield	South Yorkshire and Peak District*	561 573	587 041
Southampton	Dorset & Hampshire coast & Isle of Wight*	804 296	1 103 946
Southend	Kent and Essex coasts*	333 302	385 106
Southport	North-west England*	72 082	81 225
Swindon	Avon and Somerset*	63 059	88 973
Torquay	Devon and Cornwall	201 102	203 955
Tunbridge Wells	London	137 280	181 722
Total		25 967 894	30 310 956

*New definition of area covered, with effect from 1 July 1981

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.

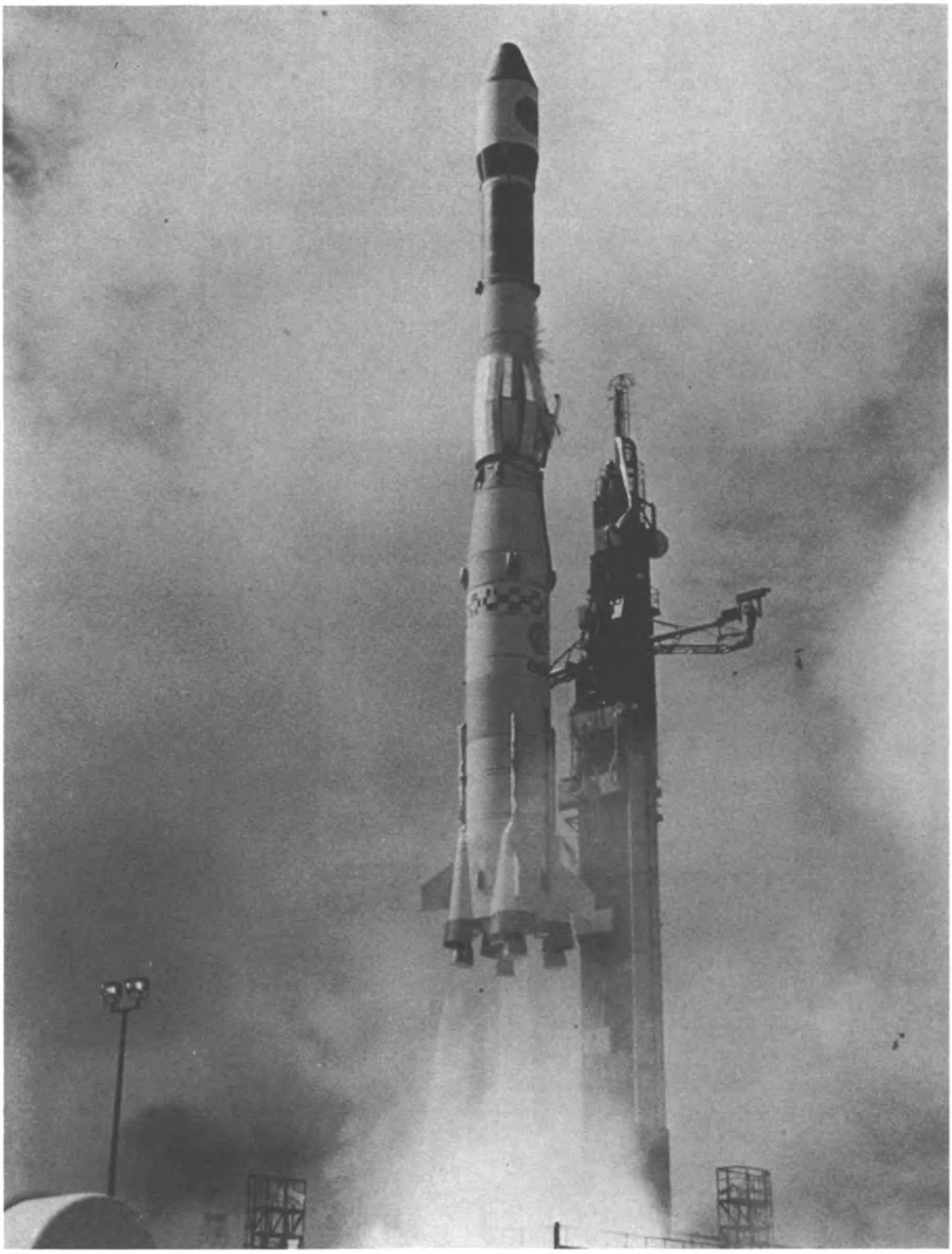
	1980	1981
Total number of climatological enquiries	40 589	37 936
Percentages relating to:		
agriculture (farming, forestry, market gardening)		9.0
building and design (including siting)		20.1
commerce (sales, marketing, advertising)		6.9
drainage		1.8
education and literature		4.9
flooding		0.4
heating and ventilation		4.6
industrial and manufacturing activities		2.9
law (damage, accident, insurance)		15.6
medical and health		0.4
Press and information centres		1.2
research		7.4
sports, hobbies, holidays		1.2
transport and communications		1.8
water supplies		5.6
miscellaneous (purpose known)		8.2
miscellaneous (purpose unknown)		8.0

TABLE XIV—DATA PROCESSING

	1980	1981
Computer installations:		
Number of tasks run on the 360/195 computer	256 000	269 000
Number of tasks run on the 370/158 computer	210 000	221 000
Number of tasks run on the CYBER 205 computer	—	18 000
Number of tasks run using the terminal system	60 000	58 000
Processor-controlled keying system:		
Number of characters keyed at Bracknell	67 224 632	76 600 000
Number of characters keyed at Devizes	—	309 000
Punched-card installation:		
Number of cards punched	297 828	350 000

TABLE XV—INSTRUMENT TESTING, CALIBRATION AND ACCEPTANCE

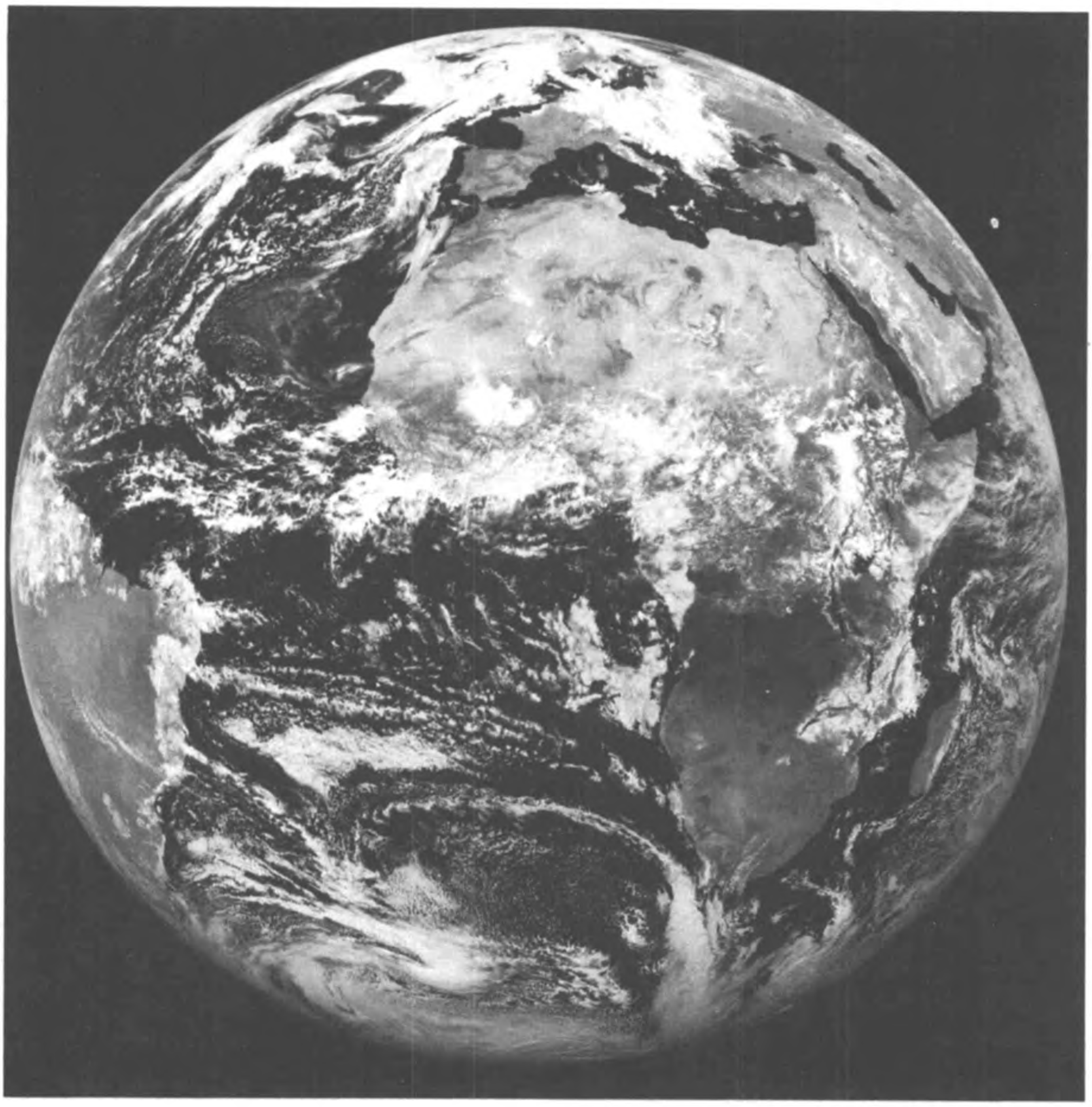
	Number of tests or calibrations
General meteorological instruments:	
Wind measuring	1093
Pressure measuring	1299
Humidity measuring	66
Precipitation measuring	1707
Radiation measuring	200
Sunshine recording	69
Temperature measuring	3249
Miscellaneous	1556
Electrical/electronic instruments and systems	747
Electrical/electronic components	1084
Balloons	55 920
Radar reflectors	11 800
Radiosonde parachutes	36 350
Radiosonde unwinders	10 829
Radiosonde component parts accepted	326 000
Radiosonde humidity transducers skinned and seasoned	7800
Radiosonde pressure transducers calibrated	4800
Radiosonde pressure reference elements calibrated	5000
Mk 3 radiosonde recoveries received	1990
Total	471 559



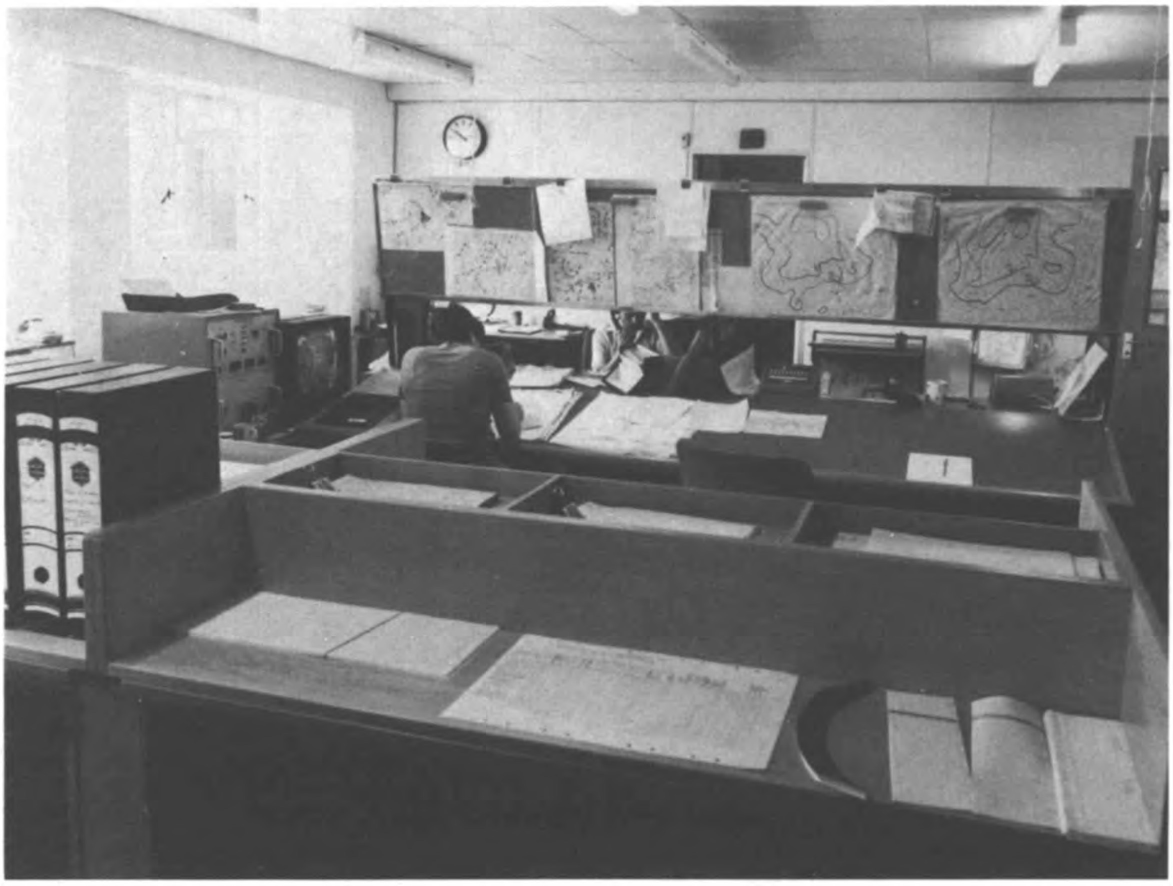
Photograph by courtesy of the European Space Agency

The third test version of the European Ariane rocket (LO3) was launched successfully from the French Guiana Space Centre at 1233 GMT on 19 June 1981. Its payload included the European Space Agency geostationary meteorological satellite Meteosat-2.

PLATE II



The first image in the visual spectrum produced on 28 July 1981 by the new European Space Agency geostationary meteorological satellite Meteosat-2, launched on 19 June 1981.



The reception desk (above) and forecast room (below) at the new Bristol Weather Centre which was opened on 7 August 1981.

PLATE IV

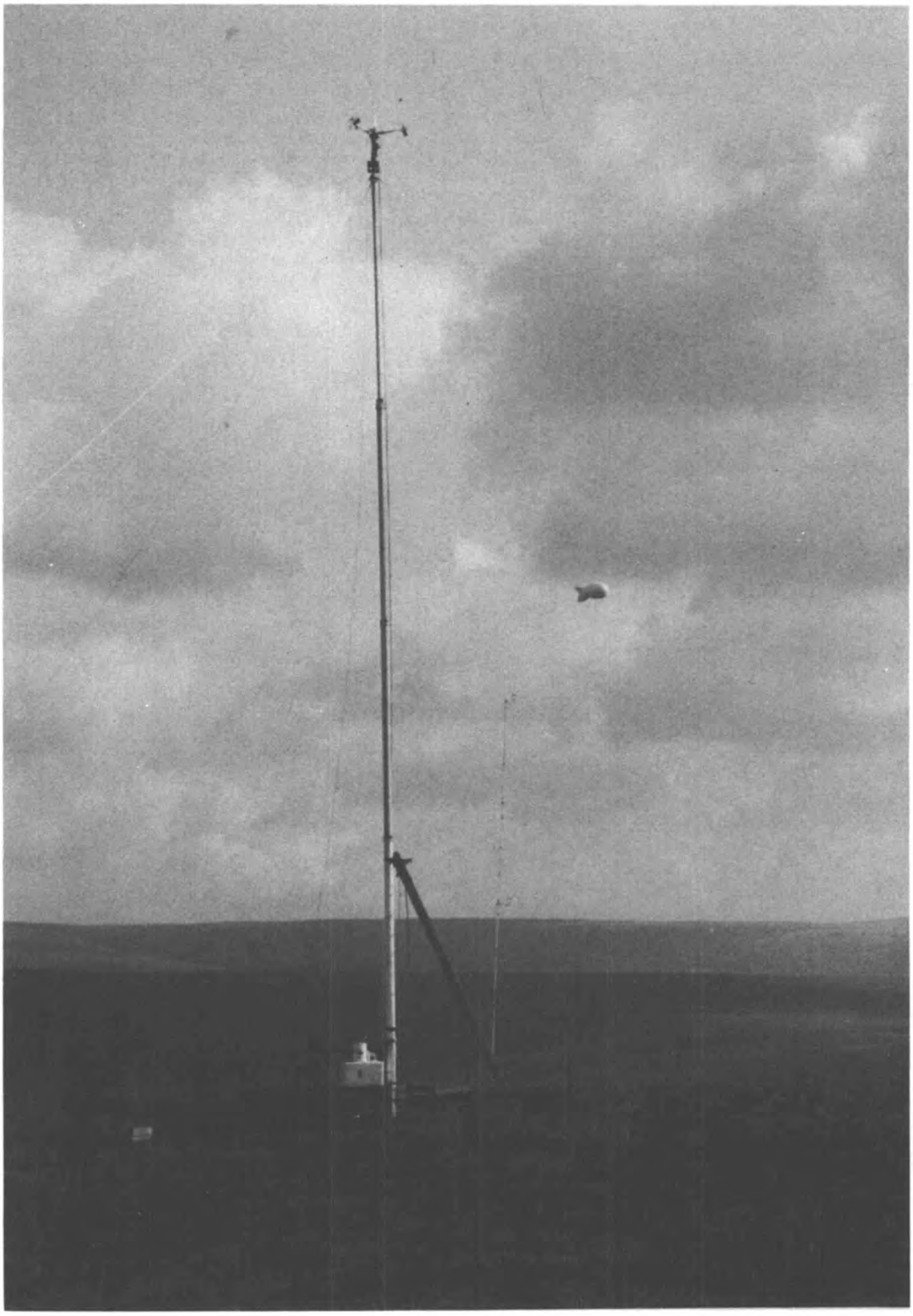
Photograph by courtesy of the Royal Agricultural Society of England

H.M. the Queen at the Meteorological Office stand at the Royal Show, Stoneleigh, on 8 July 1981.

Meteorological Office stand at the Ideal Home Exhibition, March–April 1981.

The Director-General with members of the delegation from the Chinese Academy of Sciences who visited the Office during November and December 1981. Left to right: Assistant Professor Zhou Xiaoping, Professor Ye Duzheng, Sir John Mason, Professor Xie Yibing, Dr Zhao Yanzeng, Mr Chen Chunshu, Second Secretary (Science and Technology), Chinese Embassy, London, and Mr Wang Yude.

PLATE VI

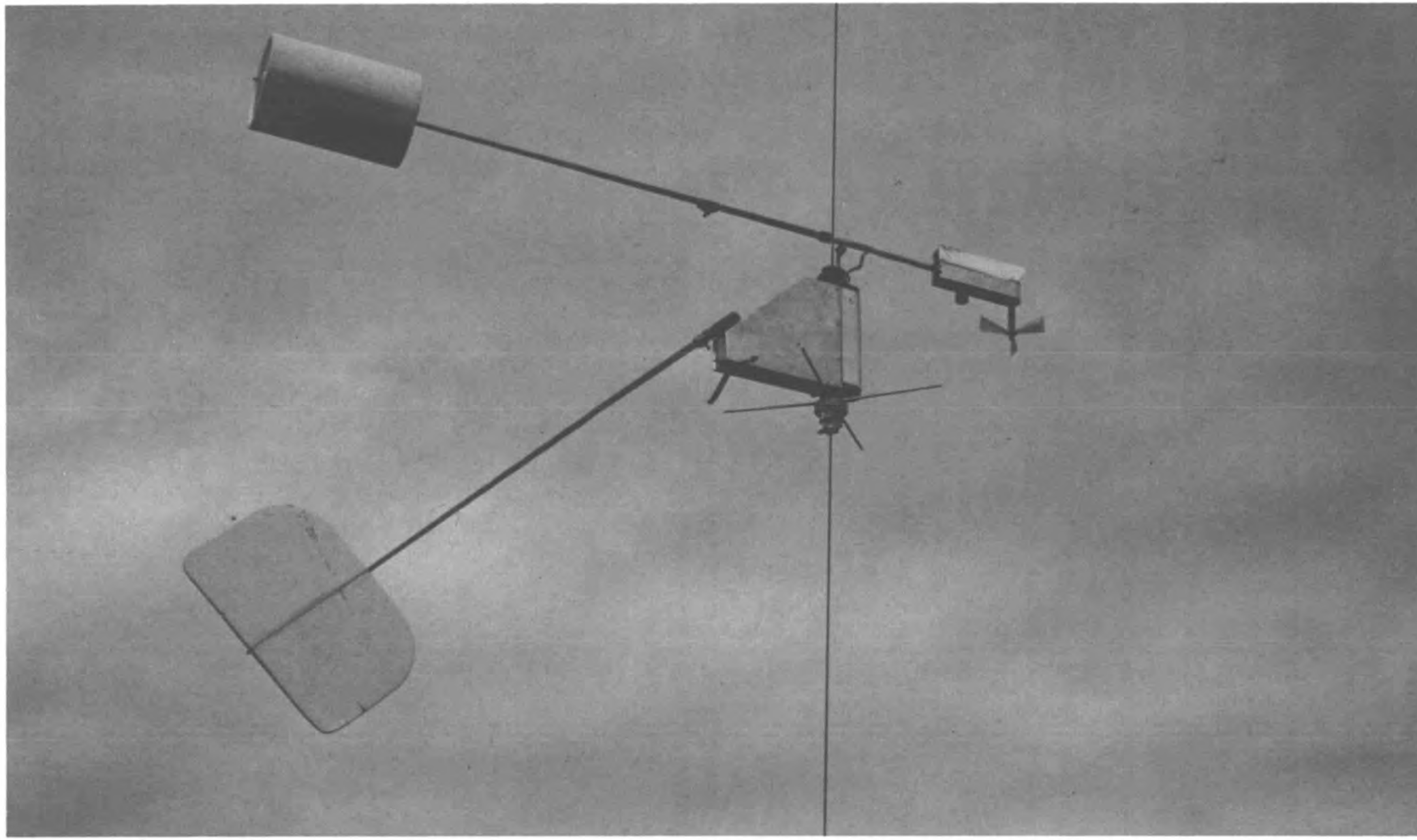


The Sirhowy Valley experiment

Measurements of turbulence levels, requiring fast-response sensors and high-speed data logging, were made on hill tops and in the valley through the use of a mobile laboratory. Seen here is turbulence instrumentation atop a 16-metre mast on one of the hills; a further 16-metre wind profile mast is visible behind, as well as the tethered balloon flown above the valley (see page 78).

The Sirhowy Valley experiment

The winds which blew in the optimum direction for gathering data on cross-valley flow also brought with them torrential rain which caused flooding of the balloon site and made working conditions difficult around the instrument caravans (see page 78).



Development of boundary-layer instrumentation

Measurements of wind speed and direction, temperature, humidity and pressure are digitally telemetered every 3 seconds from this prototype mean-value probe supported on a tethered balloon cable. The probe, as well as being used to provide profile data on field experiments, acts as a test bed for some sensors which are to be incorporated into a second-generation Cardington turbulence probe now under design (see page 78).

DIRECTORATE OF RESEARCH

SPECIAL TOPIC—THE WORK OF THE BOUNDARY LAYER BRANCH

Introduction

The boundary layer—roughly speaking the lowest kilometre of the atmosphere—is important for many reasons. It provides the immediate environment for many human activities and is of direct consequence to pollution dispersal, structural loading and so on. However, in addition, by bringing about the transfer of heat, momentum and moisture between the earth's surface and the atmosphere above, it plays a large part in determining the properties of weather and atmospheric motion systems on all scales and hence is of more general meteorological importance. The importance of the boundary layer and the gaps in our knowledge of it have long been appreciated by the meteorological community as a whole and over the last decade there have been several large international experiments aimed at furthering our understanding of this part of the atmosphere; notable among these are the Minnesota Experiment, the GARP Atlantic Tropical Experiment (GATE) and the Joint Air–Sea Interaction (JASIN) experiment—(see below). The Office has made (and continues to make) major contributions to this work, both over land using the tethered-balloon facility based at Cardington, Bedfordshire, and over the sea using the instrumented aircraft of the Meteorological Research Flight.

The aim of boundary-layer work is to be able to calculate—and hence predict—the properties and effects of the layer both on the large scale, affecting transfers between earth and atmosphere, and on the local scale, where they determine such things as the wind-speed at the crest of a particular hill or the pollution in a particular configuration of valleys. The difficulties of this work are exacerbated by the wide range of scales of motion involved, from the large-scale changes of airflow caused by changing weather systems, or by hills or coasts, to the small-scale eddies caused by blades of grass. The boundary layer is, almost by definition, the region where motions on all these scales interact and no one scale can be treated in isolation from the others. It is, in practical terms, impossible to calculate motions on a wide range of scales simultaneously at the same level of detail. Progress is made by setting up mathematical representations ('models') which reproduce the scale of major interest faithfully and which represent the other scales by means of various simplifications or approximations. The theoretical modelling work, of course, has to go hand in hand with corresponding experimental work to check the adequacy of the models in different situations and suggest ways of improving them where they are inadequate. The required measurements—again involving motions on many different scales—are by no means easy, and improved measuring techniques are still needed in some areas.

Despite many years of work our knowledge of the boundary layer is reasonably satisfactory only for the simplest of situations, namely over flat uniform land with a dry atmosphere that is neutral or slightly unstable. In the presence of clouds, over the sea, over hilly terrain or in stable inversion conditions there is a great lack of good observational data and of models which can represent and predict the phenomena at all adequately. Our current program of work is directed towards collecting data and setting up models to cover a wide range of practical situations reasonably well, rather than to refining and perfecting models for the idealized case of flat uniform land and a simple atmosphere. However, in moving towards more realistic conditions, it is important to take one step at a time. Thus, in considering flow over hills and valleys, effort has initially been concentrated on isolated hills of smooth and simple shape rather than the complex geographic features normally met in practice.

Airflow and turbulence within the boundary layer are of course of direct relevance to the dispersion of airborne pollutants. Originally work in dispersion was motivated by an interest in chemical warfare arising out of the First World War. Experiments were carried out over short distances of travel in nearly steady, mostly neutral conditions. The classical diffusion equation provided a theoretical backing but only in the simplest cases. This and subsequent work led to the adoption of the Gaussian plume model which, even today, seems reasonably adequate for many purposes, though attempts to refine it and apply it to complex situations have continued. On the somewhat larger scale, interest in the long-range transport of pollutants received a stimulus from the suggestion that pollutants released by distant sources, notably power-stations, might make important contributions to the increased acidity of rain in certain parts of the world.

This article attempts to review the current interests of the Boundary Layer Branch, seeking to demonstrate the wide range of topics that have to be covered if the needs of customers of the Meteorological Office are to be met. The work is considered under three main headings: firstly the extension of earlier work on boundary layers over flat land to include the effects of cloud, the effects of stable atmospheric stratification and effects occurring over the sea; secondly, work on flow over hills and valleys; and thirdly, work on the dispersion of pollutants in the atmosphere.

THE BOUNDARY LAYER OVER FLAT SURFACES

Introduction

A clear understanding of the structure of quite simple atmospheric boundary layers is basic to progress in more complex areas or actual applications. A distinction must be drawn between observations made over land and those made over the sea. The former are subject to large diurnal variations in the flux of heat energy (which is responsible for the generation of turbulence through buoyancy), normally associated with convective activity in daytime and stable conditions at night. Conditions over the sea are more constant and heat fluxes generally smaller, with fluxes of water vapour being of more consequence. The surface of the sea is also 'smoother' than the land. These differences are of fundamental importance to theoretical treatments.

A further point worth stressing is the paucity of data above the near-surface layer. Experimental techniques for adequate studies of the atmospheric boundary layer well above the surface have only recently become available, so the bulk of the data available to theoreticians relates to the first ten metres of the atmosphere.

Over land

In the early seventies the Branch was prominent in pioneering detailed studies of the whole (as opposed to just the near-surface) atmospheric boundary layer, using the tethered-balloon facility at Cardington as a platform on which to mount instruments capable of measuring the turbulence structure of the atmosphere. Some of this work was undertaken in collaboration with the Boundary Layer Group at the Air Force Cambridge Research Laboratories, Bedford, Massachusetts, who provided high-quality surface data needed to complement that recorded up to heights of about 2000 metres by the turbulence probes flown from the tethering cable of a kite balloon. This culminated in the Minnesota Experiment, in which the two groups combined their resources to study the structure of the atmospheric boundary layer over an extensive flat plane. Papers based on these data have significantly advanced our knowledge of the atmospheric boundary layer by providing, for the first time, detailed information covering its full depth. Thus, for example, it showed how energy is transferred between the surface and the 'free' atmosphere, how mixing varies with height, how some of our basic theoretical ideas need to be modified if they are to be applied above the surface layer, and so on (Kaimal *et al.*, 1976).

At home, the Branch carried out detailed studies of the way the dissipation of velocity and temperature fluctuations varied with height (Rayment, 1973; Caughey and Rayment, 1974), as well as collaborating with the radar group at Malvern in studying the evolution and erosion of overhead inversions (Palmer *et al.*, 1979; Rayment and Readings, 1974) and with several University groups in studying the development of the convective boundary layer (Moores *et al.*, 1979). More recently the Branch, in collaboration with University College, London, has used an acoustic radar to study the structure of the atmospheric boundary layer (Caughey *et al.*, 1980; Cole *et al.*, 1980). Some of the findings from this work are directly applicable to the forecasting of fog and stratocumulus and a simple acoustic sounder is at present being tested operationally.

Current interest centres on the role of clouds in the atmospheric boundary layer and on stable conditions. Most previous work over land has been concerned with clear boundary layers, despite the prevalence of cloud which can radically alter the characteristics of the atmospheric boundary layer, mainly by providing new sources or sinks of energy. The Branch has started to tackle this topic by considering the measurement of one of the most important parameters, namely the buoyancy, in the presence of cloud. Problems arise because of the difficulty of measuring temperature in the presence of cloud when the temperature sensors become wet. One solution is to measure the total water content together with the wet-bulb temperature. This enables measures of temperature, water vapour and liquid water content to be derived. To this end an instrument based on a commercial Lyman-Alpha hygrometer is being developed, in which liquid water is vaporized before being measured. Preliminary work suggests that an accuracy in temperature of about ± 0.1 °C is attainable, which is quite adequate for the present purposes.

The Branch is also concerned with the structure of stably stratified boundary layers and earlier this year a limited experimental study of nocturnal boundary layers was mounted in the Fens. During this study, arrays of anemometers and thermometers, together with a sonic anemometer and a new 'mean-value' probe, were set up at a site near March, Cambridgeshire. This is a fairly flat site, unlike Cardington (the site of previous studies—Caughey and Readings, 1975) which is strongly influenced by local ridges. The data should help provide some clear insights into the basic nature of these types of boundary layer, notably their spatial characteristics. This is very important when considering such things as the diurnal evolution of the convective boundary layer, the transitions at sunrise and sunset, fog formation and the spread of pollutants.

In support of this work the Branch is developing an improved instrument to study turbulence structure (and hence mixing and energy transfers) for use in conjunction with the tethered-balloon facility which will be more flexible, lighter and more accurate than the existing devices. The instrument will take the form of a freely moving vane attached to the tethering cable of the balloon. Velocities relative to the vane will be measured with a fast-response cup anemometer and hot-film sensors, while a magnetometer and some inclinometers will be used to determine the orientation of the vane. Other sensors will monitor temperature, wet-bulb temperature and pressure. The data will be relayed to the ground by radio telemetry where they will be recorded by a computer-based data-acquisition system. This instrument is derived from the 'mean value' instrument which was developed in recent years and has been operated successfully in the field for over a year. An essential difference in the new instrument is the use of fast-response sensors.

It is intended to fly up to ten of the new instruments simultaneously on one cable, so as to make detailed studies of vertical structure, notably in the vicinity of clouds or an inversion. They will complement the facilities provided by the instrumented Hercules aircraft of the Meteorological Research Flight (MRF). The Branch is also considering the use of kites to supplement the tethered-balloon facility.

Over sea

As indicated above, there are substantial differences between atmospheric boundary layers over land and sea, reflecting differences in the basic parameters. Over the years considerable effort has been devoted to the study of the lower atmosphere over the sea using the tools available, notably the instrumented Hercules aircraft of the MRF and tethered balloons. Both facilities were used in GATE (Nicholls and LeMone, 1980; Barnes *et al.*, 1980; Thompson *et al.*, 1980). Current interest centres on JASIN, flights near Britain and KONTUR (see page 75).

JASIN was a field experiment to study the interaction of the atmospheric and oceanic boundary layers. Proposed some 10 years ago by the Royal Meteorological Society and the Royal Society, it finally reached its climax with two months of intensive operations in the vicinity of Rockall during the summer of 1978, with ships and aircraft of several nations participating. The Office's contribution consisted of the instrumented Hercules aircraft from the MRF and surface instrumentation on three ships, one of which (HMS *Hecla*) served as the base for staff from the Branch who made radiosonde ascents and flew tethered-balloon turbulence probes, as well as supporting an instrumented toroidal buoy. The enormous task of data analysis is not yet complete, but initial results confirm that JASIN should provide valuable insights into the transformations of energy and the mixing processes, as well as providing some information on the role of clouds (especially the coupling between cloudy layers and well-mixed clear regions beneath them). Particularly encouraging has been the wealth of data provided by the Hercules aircraft, which are of sufficient quality to be able to infer wind divergence, geostrophic wind, etc. as well as the more usual meteorological variables, wind, temperature and humidity; this makes it possible to relate detailed structure to large-scale developments.

Separately from JASIN, the Hercules aircraft has been used to study the structure of the atmospheric boundary layer in sea areas around the British Isles in a wide range of stability conditions. Initial work concentrating on the lower levels of the atmosphere has already been published (Nicholls and Readings, 1981, 1979; Nicholls, 1978). Even though these data do not include surface measurements, several interesting points have already emerged, notably significant differences between 'across wind' and 'along wind' structure and the contrasts between this type of boundary layer and that encountered over land. This work is at present being extended to cover the whole boundary layer, using data gathered during the last few years.

However, work of this nature, involving a single aircraft with no supporting data, will never provide all the information needed and it is desirable to mount more comprehensive experiments specifically designed to concentrate on particular aspects: the latest of these is KONTUR (KONvektion und TURbulenz). This is a study of convective boundary layers which took place in autumn 1981 in the German Bight. Several German research institutes combined to provide extensive surface instrumentation, radiosonde stations, an aircraft and the central organization. The Office's participation was limited to one aircraft, the MRF Hercules. Although data analysis has only just started it is clear that the experiment will complement JASIN by providing data on convective, as opposed to neutral and stable, boundary layers. Several cases where mesoscale organization (e.g. cloud streets) was observed should prove particularly interesting. Both the Cloud Physics Branch and the Meteorological Research Flight are collaborating with the Boundary Layer Branch in this work (see page 89).

Theoretical work on uniform boundary layers

In order to understand and extend experimental findings and help identify definitive experiments it is necessary to develop relevant theoretical models. Thus, concurrently with the Minnesota experiments and the studies of convective boundary layers (see above), the Branch developed simple analytic models capable of representing broad features of this type of boundary layer (Carson, 1973). In recent years more advanced models capable of representing many more of the features observed in boundary layers have been developed.

Current models depend on separating the spectrum of eddy motions in the atmosphere into two parts, 'large' eddies which are represented explicitly and in detail and 'small' eddies whose effects are represented in a simplified, averaged way. Initial work concentrated on dry neutral boundary layers in which the only types of 'large' eddy represented were long rolls (vortices) with horizontal axes. Such rolls are not uncommon in the atmosphere, particularly over the sea. Results (Mason and Sykes, 1980) depend markedly on the orientation of the rolls with respect to the wind. Another interesting feature is the presence of slow variations on a time-scale of many hours (the Coriolis scale).

The model has been extended to include buoyancy and has already been used to simulate dry convective boundary layers with overhead inversions. The results (which have not yet been published) are very encouraging, reproducing many of the features associated with these types of boundary layer and providing useful insights into the physical processes that occur (see Figure 1). One notable finding is the dependence of the generation of internal gravity waves, in the stable region above the boundary layer, on the orientation of the rolls.

At present, the model is also being used in a study of stable boundary layers and already it has produced instabilities reminiscent of the 'resonant over-reflection mode' proposed by Davis and Peltier (1980). In this, energy from 'Kelvin–Helmholtz' breakdown is fed into long waves which grow in amplitude, the energy being trapped between the surface and a region of low Richardson number above. Further insights into this and other phenomena affecting the structure of stable boundary layers will no doubt also appear when the model is used to help interpret data from the Fens experiment.

Recently, this two-dimensional model has been further extended to include water (liquid and vapour phases) and it is currently being used to study the structure of cloudy boundary layers. Furthermore, the basic model is being extended to three dimensions, for runs to be conducted on the Meteorological Office's new CYBER 205 computer.

Flow over hills

Introduction

Many practical problems, including wind stresses on buildings, the selection of sites for the use of wind power, the dispersion of pollutants and the safety of aircraft, require a knowledge of how wind velocities and turbulence are affected by hills. There is surprisingly little quantitative information on these things; measurements of the wind velocity distribution for specific sites on hills are not uncommon, but until quite recently there have been few attempts to relate them to general characteristics such as height, slope, etc. Almost nothing is known about the turbulence characteristics of such flows. A few years ago the Branch began a series of experiments and theoretical studies, beginning with simple shapes of hills, intended to improve our ability to give practical advice.

Experimental program

The first set of field experiments carried out was on Brent Knoll, a roughly circular hill about 140 metres high, situated in Somerset. This is fairly smooth and quite isolated, with slopes of about 1:5—rather large for comparisons with simple theory but having the advantage of giving easily measured changes. Wind speeds above the ground were measured at various sites and the data compared with the predictions from a generalized form of the Jackson and Hunt theory (Mason and Sykes, 1979b). The theory was found to give reasonable predictions of the observed velocities; in particular the speed-up at the crest was observed to be about 2.3 compared to a theoretical value of 2.0.

Following this preliminary work, a more ambitious study was undertaken of flow over a nearly circular and isolated hill steep enough to produce flow separation. The site chosen for this work was the island of Ailsa Craig off the coast of Ayrshire, south-west Scotland. This island has a height of 330 metres and, apart from cliffs along the western and southern sides, the terrain has slopes of about 30 to 45°. The object of this experiment was to obtain as full a picture as possible of the three-dimensional flow field under conditions of near-neutral stability. Three types of measurement system were used: anemographs

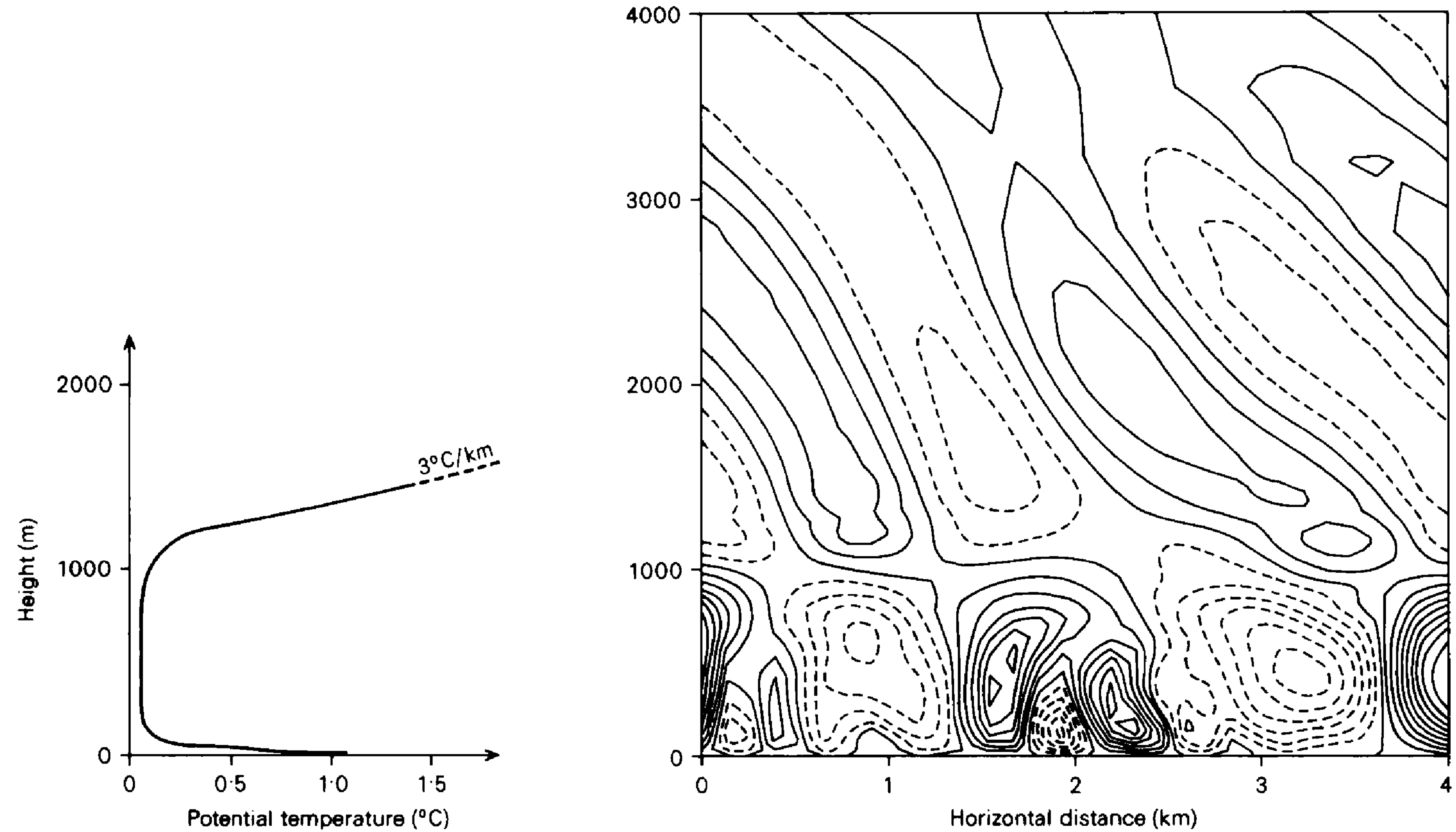


Figure 1—Eddies in and above a dry boundary layer

The main diagram shows results from a two-dimensional model of airflow in a dry boundary layer, with the temperature profile shown in the left-hand diagram. The lines in the diagram are contours of vertical velocity, with a spacing of 10 cm s^{-1}; solid lines represent upward motion, dashed lines downward motion.

to measure mean wind at 4 metres, turbulence probes supported by a tethered-balloon system giving vertical profile information and the instrumented Hercules aircraft from the MRF giving velocities both upwind and downwind of the island.

The anemographs produced a coherent picture of flow round the island showing reversed flow and separation on the downstream side. Data from the balloon-borne probes indicated that the turbulence structure was highly distorted, with large increases in the cross-wind component of turbulence energy. Aircraft observations revealed a very powerful trailing vortex downstream of the obstacle with its axis orientated along the upstream wind direction, and circulation velocities of the same order of magnitude as the undisturbed horizontal speed (Jenkins *et al.*, 1981).

Subsequent theoretical studies have confirmed that this vortex arises from the elliptical shape of the island. The mechanism is essentially the same as vortex generation by a 'lifting body' such as an aircraft wing. However, it is surprising that with the 'stalled/separated' flow and an ellipticity of 1:1.5, a powerful vortex results.

In 1980 an experiment was mounted in the Sirhowy Valley, South Wales. This is one of a series of valleys with axes lying approximately north–south and together they form a reasonable approximation to a two-dimensional system which is much more amenable to theoretical analysis. As with Ailsa Craig an array of anemographs was used to record flow across the valley while Cardington turbulence probes (Readings and Butler, 1972) monitored turbulence levels from the tops of two masts and from the tethering cable of a kite balloon (see Figure 2 and Plates VI, VII and VIII). This pilot experiment revealed several interesting features, notably much higher levels of turbulence than expected. These and other points were studied further this year when a group from the Branch returned to the site with new equipment better suited for use in high turbulence levels. Of particular interest are a sonic anemometer, some hot-film instruments and the new 'mean-value' probe mentioned above (page 73). The weather proved quite favourable with strong westerly flows for much of the time. Thus it should prove possible to identify the main characteristics of the flow from the data set, including the high turbulence levels and the 'separation bubble' which occurs in the lee of the windward ridge. The latter was in fact shown up at times during the experiment by the use of small zero-lift balloons. Tracer experiments were carried out at the same time and will be used to check the analysis of airflow.

Further experiments are planned on a hill in North Uist in the Outer Hebrides which meets all the criteria needed to carry out a definitive experiment, namely it is isolated, easily accessible, of uniform shape and of uniform roughness, being free of hedges, trees and the like. Data obtained from this site, using equipment now becoming available, should be of sufficiently high quality to test the various theories properly, particularly those involving turbulence parameters because, for the first time, changes in turbulence structure should be mainly determined by the general shape of the hill and not reflect local changes in roughness.

Theoretical work

At present there is a sound theoretical basis for the study of laminar flow over obstacles, though numerical investigations of separated flows have only recently

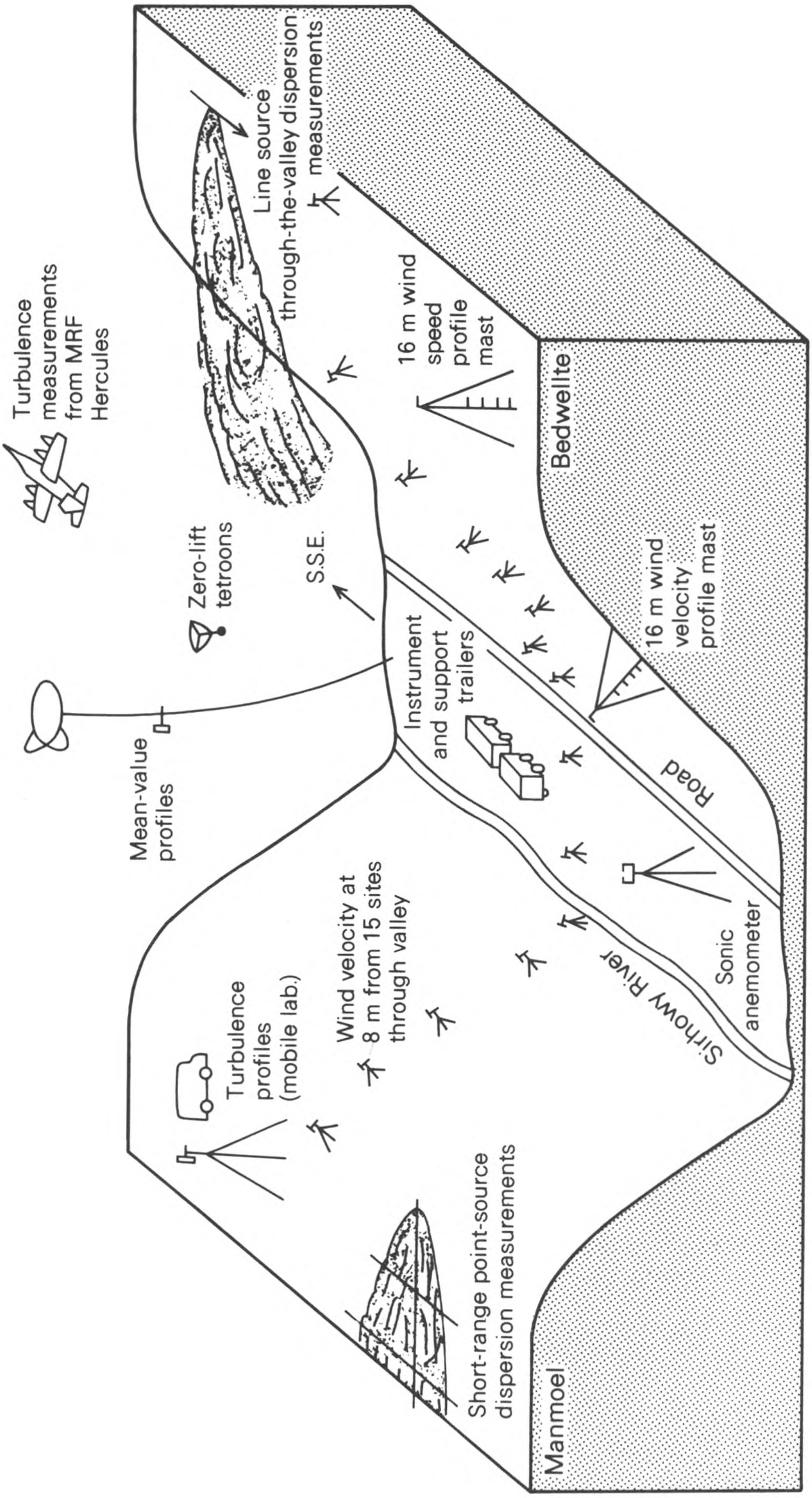


Figure 2—The Sirhowy Valley experiment, 1981

been undertaken (Mason and Sykes, 1979a; Sykes, 1978). However, if accurate predictions of wind speed near the surface are to be made, then the fact that the atmosphere is turbulent must be taken into account and a convincing model has yet to be formulated.

To compare with the Brent Knoll experiment (see page 76), Mason and Sykes (1979b) extended Jackson and Hunt's linear analytic theory of flow over gentle topography to three dimensions and it was surprising how well this model predicted many of the features observed experimentally, given the relative steepness of the hill's slopes. However, subsequently Sykes (1980) developed a higher order asymptotic theory for flow over a shallow ridge and showed that even a simple representation of the flow (i.e. an inviscid potential flow) is adequate as far as perturbations in mean velocity are concerned, so they are not a sensitive test of theoretical models. Thus, for the case of gentle topography, measurements of more sensitive quantities such as the Reynolds stresses are needed to test the validity of theoretical models adequately; hence the planned experiment in North Uist. Interest in these Reynolds stresses is not academic; they are vital for determining pollution dispersal and wind loading and their details are critical in determining the net momentum transfer between the boundary layer and the free atmosphere above.

In steeper topography, when flow separations may occur, even the mean flows are very poorly understood. The main features revealed by the Ailsa Craig experiment have been qualitatively explained by the application of a three-dimensional laminar-flow model but quantitative work awaits the development of a fully turbulent model. However, the two-dimensional numerical model described earlier has been applied to the site of the field experiment in South Wales. Initial results have confirmed the extent of the surface separation region and it is hoped that the extended data acquired in 1981 will provide further insights into use of the model.

In turbulent flow over hills, the divergence in the Reynolds stress only dominates the pressure gradient and advective effects in the thin equilibrium region near the surface, so to model such flow successfully a high resolution normal (and close to) the surface is needed. Accordingly a 'terrain-following' (as opposed to the original 'Cartesian mesh') co-ordinate numerical model has now been set up. In this the surface (as opposed to an absolute height) acts as the reference level, thus helping to ensure that resolution is highest where it is most needed. The model, with this extension, has already been used to study flow over the South Wales valley.

Although the three-dimensional form of the analytic model of Jackson and Hunt and the Branch's own two-dimensional numerical model have provided some insight into flow over surface features, the next big step must be the application of a numerical three-dimensional large-eddy model capable of modelling turbulent flow properly. As already mentioned, the development of such a model is in hand.

ATMOSPHERIC DISPERSION

Introduction

The Office's advice is often sought on how material released into the atmosphere will be dispersed and transported. Typical examples are releases of sulphur compounds, radio-nuclides, toxic materials, inflammable vapours and heavy gases. Some releases will be accidental and of short duration, others will be continuous over long periods, and each poses a different problem. Routine enquiries are generally handled by the Special Investigations Branch, leaving the Boundary Layer Branch free to concentrate on research aimed at furthering our understanding of dispersion and the mechanisms which control it, or to deal with major problems which raise new or non-routine issues.

Dispersion and subsequent deposition processes are important in determining concentrations both in the atmosphere and on the ground. However, a wide range of scales is involved, ranging from a few tens of metres to global distances. Thus it is convenient to divide the ranges of interest into four main categories:

Short range—from the source out to a few kilometres.

Medium range or mesoscale—tens to a few hundreds of kilometres.

Long range—several hundreds of kilometres and more.

Global—this covers interhemispheric and tropospheric–stratospheric exchanges and is not dealt with in this article (but see page 91).

Short range dispersion

In this range, details of the actual release (i.e. source height, duration, etc.) and the structure of the atmospheric boundary layer all have to be considered. Turbulence plays a dominant role and ultimately its variability limits the accuracy with which concentrations and dosages can be predicted—the problem becoming more acute the shorter the period being considered. This makes the use of sophisticated models difficult to justify in many instances. The Branch has recently carried out a preliminary study of this problem, seeking to determine the sensitivity of a simple Gaussian model to uncertainties in the basic meteorological parameters. Surprisingly, this showed that surface concentrations were not markedly affected by variations in vertical mixing, being much more dependent on variations in the horizontal wind components, though any mean inclination of the flow to the ground was also important. This makes the use of the concept of an eddy diffusivity to represent turbulence processes seem quite reasonable in many instances because, although the consequent errors may be substantial, they are generally acceptable compared with the specifications of other parameters affecting plume dispersal.

The resulting diffusion equation has been solved analytically only for rather idealized conditions, so for more realistic states numerical techniques have to be used. An alternative approach which the Branch has used for many years (Smith, 1968; Hall, 1975), is the 'random walk' model in which the trajectories of particular elements of fluid (called particles) are calculated through the step-wise application of equations which simulate the effect of real eddies. In the most recent version developed in the Branch (Ley, 1982), these equations, whilst correlating the motion of the particle with its earlier motion, introduce a new randomly-selected impulse at each time-step characteristic of its position which ensures that, in a statistical sense, mass, momentum, energy and shearing stress are conserved. This model has already been used by the Branch to simulate dispersion in neutral conditions; the results show good agreement with experimental data, analytic solutions and established theory. A variant of this model has been developed for use by the Agricultural Meteorology Branch to study crop-spraying under a variety of conditions. At present it is being extended to cover stable conditions and ultimately it is hoped to apply it to unstable conditions and to other cases of practical interest. The technique is also to be used to study the relative diffusion of two or more particles in order to examine the development of short-release clouds and the likely variations of concentrations within a continuous plume. This work has relevance to the detection of odours, chemical defence problems, inflammable vapours and air chemistry.

Two basic processes control the vertical spread of material in the atmosphere, namely mechanical mixing and buoyant mixing. The former is directly related to the wind speed and the latter to temperature differences which lead to the vertical transfer of heat energy either from the surface to the air (a positive heat flux: unstable conditions) or from the air to the surface (a negative heat flux: stable conditions). A positive heat flux encourages vertical mixing while a negative one inhibits it. Normally, however, the heat flux cannot be measured directly on a routine basis so it has to be determined indirectly. A comprehensive set of data on the surface energy balance recorded at Cardington, Bedfordshire, covering a period of one year, is being analysed to see how the heat flux can best be estimated from routine meteorological observations. The first stage of this work, namely developing a method for estimating the reduction of solar radiation by varying amounts of different types of cloud, has already been completed. The results of this work will be used to improve a scheme for assessing the stability of the atmosphere from simple parameters such as wind speed, cloud cover, etc. This scheme, which is widely used, was originally developed by Dr F. Pasquill and has since been extended and put on a firmer theoretical basis (Smith, 1979).

In parallel with this work, precision instrumentation whose output is logged has been established at Porton, Wiltshire, in order to assess various alternative schemes that have been proposed for estimating Pasquill stability. This involves the measurement of variables such as temperature gradient, radiation, and fluctuations in wind direction. Data are also being recorded at a site in Scotland, at Torness, where the Branch has established similar instrumentation at the instigation of the South of Scotland Electricity Board. A nuclear power-station is being constructed at Torness and the meteorological data will be used to determine the dispersion climatology of the area required by the Board for risk assessment analyses.

Another topic attracting great interest at present is the consequences of releasing a large cloud of heavy vapour into the atmosphere. The Health and Safety Inspectorate are sponsoring some field trials involving several controlled releases and the Branch was asked to conduct an experimental study aimed at determining the feasibility of using upwind direction measurements to optimize the moment of release for the gas cloud so that it travels well within the downwind network of sampling monitors. This work, which is now complete, has clearly demonstrated the potential of the technique in slightly unstable conditions when the wind speed is above 3 metres per second.

Medium-range dispersion

Dispersion at short ranges depends mainly on turbulent diffusion but, as the distance of travel increases, the pattern of concentration at a given location becomes increasingly dependent on variations in the general wind flow associated with synoptic developments, on mesoscale circulations (e.g. lee depressions and sea-breezes) and on the presence of topographic features, as well as on the time-evolution of the boundary layer. Deposition, chemical reactions and the nature of the source must also be considered. It is a complex area to study as few approximations are viable. The results find application in chemical warfare, the spread of viruses and major release of radio-nuclides.

Here the Branch's work on flow round hills has found application in two areas. The first is in predicting the spread of foot-and-mouth virus by developing a technique which allows for the presence of hills, ridges, etc. This appears to improve significantly the Office's ability to forecast realistically areas at risk (Blackall and Gloster, 1981). It was successfully used by the Agricultural Meteorology Branch to predict the possible spread of the virus during the outbreak in Brittany, Jersey and the Isle of Wight in the spring of 1981. Several countries have expressed an interest in the technique.

The second area of application is to the problem of plume dispersal in laminar flow round an isolated hill. Two findings of particular interest are the large changes in surface concentration which can arise through plume impact and the increase in plume dispersion caused by flow distortion (Mason and Sykes, 1981). In support of this work some tracer studies were carried out during the 1981 Sirhowy Valley experiment. It is hoped that these data will prove suitable for checking the findings of the theoretical models.

Long-range dispersion

At these ranges the distribution of pollutants is basically independent of the characteristics of the source (apart from the duration of release). Trajectories are frequently curved, and elements of the plume may experience several diurnal cycles of the boundary layer. Concentration profiles tend to be rather uniform throughout the depth of the boundary layer and the losses of pollutant by various processes, such as wet and dry deposition, are significant. The lateral width of the 'plume' depends on synoptic developments as well as the period of release (or sampling).

There is considerable interest in this topic, both in Europe and North America, arising mainly from concern over possible damage to the natural environment caused by 'acid rain'. Large areas in Scandinavia and Canada are particularly sensitive owing to the nature of their soils and rocks. The acidity of rain is often quite high (pH = 3 to 4) and a contributory factor to this acidity is the uptake of pollution emitted into the air from fossil-fuelled industrial installations sometimes many hundreds or thousands of kilometres upstream. Unless effectively buffered in the soil there is some evidence that this acid can have lasting consequences for fish populations and other biosystems.

The Branch has played an active role in two major international projects concerned with this problem. The first was under the auspices of the Organization for European Co-operation and Development (OECD) and started in 1971. The second, under the United Nations Environmental Program, was started in 1978. Recently a very simple model has been developed within the Branch to simulate the emission–transport–conversion–deposition cycle of industrial pollutants in Europe. This model produces reasonably realistic estimates of dry and wet deposition in good accord with measured values. It requires very little computer time so it can be used to explore the effects of changing basic parameters such as the rate at which sulphur dioxide is converted to sulphate. Furthermore it can serve as a yardstick by which to judge more complex models, to see whether extra sophistication really produces worthwhile improvements in deposition estimates. The concept of wet and dry synoptic regions is being added to the model in order to judge whether to develop a complex stochastic model capable of simulating the variability of rainfall in space and time. This development is coupled with the use of trajectory analyses, together with radar data from the Meteorological Office Radar Research Laboratory at Malvern, to study the probability of rain occurring at specified points along a trajectory. This relates directly to a theoretical study which introduced a stochastic element, intended to represent the patchy nature of rain, into a numerical model for predicting the long-range transport of material (Smith, 1981). Current models employ spatially and temporarily smoothed rainfall fields and tend to underestimate the long-range transport of pollutants by removing them too quickly.

In support of this work the Branch is also active on the experimental side, notably in a joint experimental study of the long-range transport of pollutants being carried out in collaboration with the Central Electricity Research Laboratories, Leatherhead, as well as the Cloud Physics Branch. This uses chemical samplers installed in the instrumented Hercules aircraft from the Meteorological Research Flight to track the advection of pollutants from a particular source for long distances across the North Sea. The plume from a power-station in South Yorkshire is 'labelled' with two tracer gases so that it can be uniquely identified in both space and time and hence the same portion of plume tracked for long distances. Eleven flights have already taken place including one 'two-day' study when the same plume was tracked across the North Sea for two successive days (see Figure 3). Plumes have been detected at distances as far as 700 km from the sources.

The Central Electricity Research Laboratories will use data from these flights to study chemical transformations in the atmosphere, while the Branch is particularly interested in the travel and structure of plumes and the loss of pollutants from the boundary layer. Analysis has already advanced sufficiently for several interesting points to emerge, notably the generally fragmented nature of the plumes, possibly reflecting the presence of mesoscale features not detected by standard meteorological observations. One such system was found over the North Sea just downwind of the Yorkshire Moors.

In a similar vein, the Branch participated in a joint study, together with other parts of the Meteorological Office, of the plume from the main explosion of the Mount St Helens volcano, Washington. A trajectory model (basically a modified form of the operational one used by the Central Forecasting Office) was used to study the movement of the plume; it showed that while most of the plume reaching the eastern Atlantic was at low latitudes, fragments moved in a more northerly track towards the United Kingdom and Scandinavia, a prediction confirmed by aircraft observations over The Wash and over southern Scandinavia. Amongst other things, work of this nature has great relevance to the long-range dispersion of radio-nuclides from nuclear installations, whether one is considering small continuous releases (as covered by Article 37 of the Euratom Treaty) or large releases in accidents.

CONCLUSION

As this article has tried to show, the work of the Boundary Layer Branch covers a wide range of subjects and finds application in many and diverse fields. Many of the enquiries received in recent years cannot be answered in terms of simple

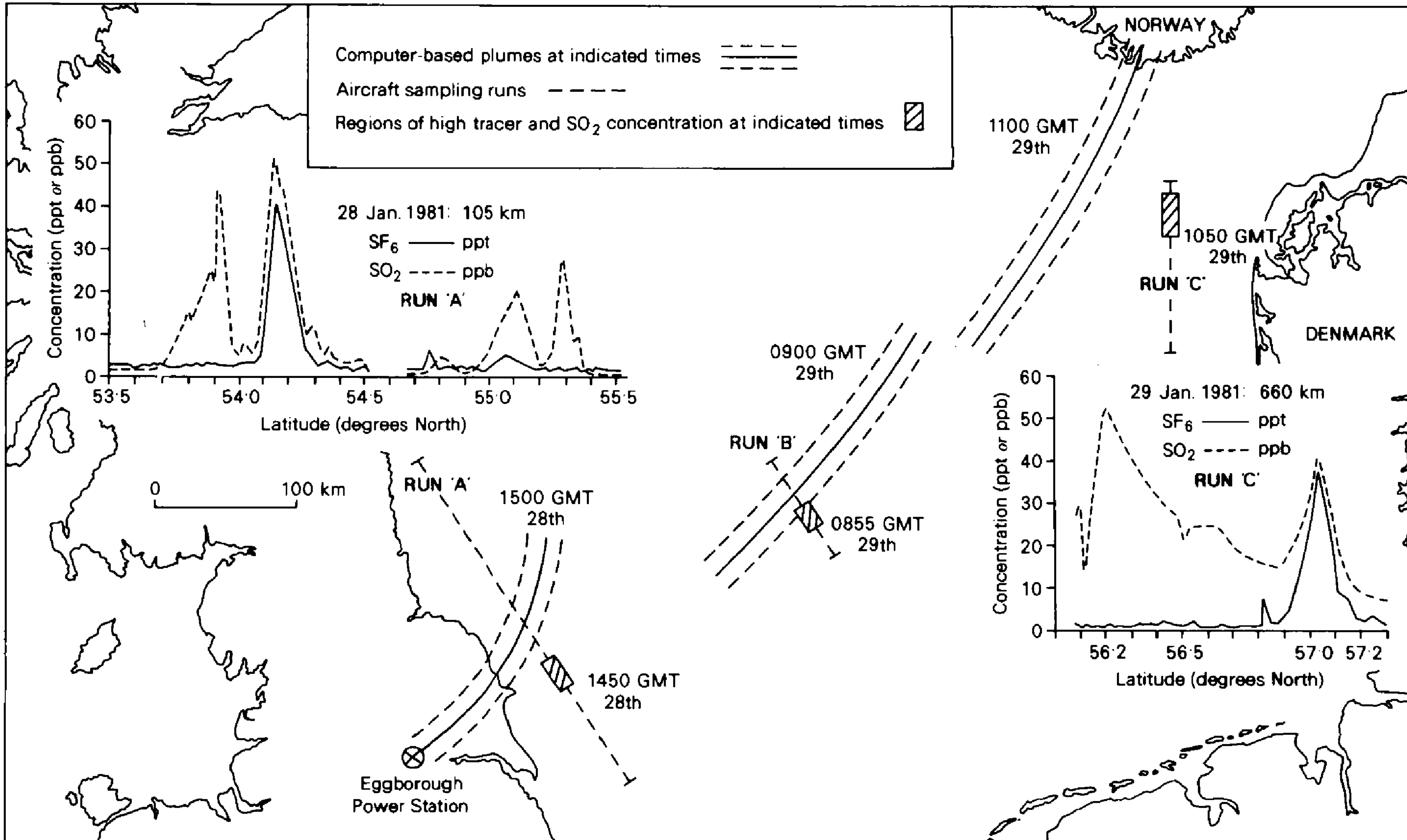


Figure 3—Plume study: two-day experiment, 28–29 January 1981
Inset diagrams (a) and (b): Variation of concentration of sulphur dioxide and tracer with latitude along aircraft sampling runs at 105 and 660 km from Eggborough.

idealized pictures of boundary-layer behaviour but require a deep knowledge of the basic turbulent characteristics, physics and meteorology. The Branch cannot study each subject in detail but, by concentrating on a few selected topics chosen because of their immediate relevance, it aims to make substantial progress with these topics, while maintaining a broad level of competence that can be applied to boundary-layer problems of any type, whenever they may arise.

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OTHER WORK OF THE DIRECTORATE OF RESEARCH

Physical Research

Cloud physics

Many of the physical and some of the chemical properties of the atmosphere are profoundly affected by the various forms of water substance it contains. As a result, studies of cloud and precipitation find application in many of the Office's activities. Such research has obvious relevance to the forecasting of rain, snow and hail and to the assessment of the probability of occurrence of extremes of precipitation and of aircraft icing which provide valuable engineering design data. There are more subtle influences too. Water vapour, ice particles and water drops (referred to generally as 'hydrometeors') can have a significant effect on the transmission of various forms of electromagnetic radiation through the atmosphere. Perhaps this is most obvious in the poor visibility in fog, but the presence or absence of many forms of cloud is important for forecasting temperature through the modification of both long- and short-wave radiative cooling and heating rates. Understanding this influence is an important element in studies of climate because changes in the amount or nature of cloud may either amplify or reduce the effects of changes in external factors on climate. These same scattering and absorbing properties of hydrometeors can be used to advantage in various techniques for remote sounding of the atmosphere. The use of radars to monitor the intensity and movement of rainfall over large areas of the UK is described elsewhere in this report (page 94). For remote soundings from satellites, clouds may be useful (as when they serve as tracers revealing wind motions) or a hindrance (as when they prevent the reception of radiation from lower levels); in both cases it is necessary to know their properties accurately if the soundings are to be interpreted properly.

As a result of past laboratory studies of the formation of and interaction between water droplets and ice crystals, the physics of many of the relevant fundamental processes is understood in some detail. Much of present-day cloud physics research is concerned with the application of that understanding to the real atmosphere and the practical problems outlined above. Such research requires substantial efforts to observe the dynamics and structure of naturally occurring cloud and precipitation forms and to interpret, model and understand them.

The Meteorological Research Flight (MRF) Hercules aircraft plays a crucial role in such studies. During the last few years much effort has been expended in equipping the aircraft with a number of instruments capable of detecting, counting and sizing particles ranging from the nuclei on which cloud droplets form to the largest raindrops and snowflakes. In addition, a facility for studying the large-scale structure and dynamics of cloud systems, by means of 'dropsondes' released from the Hercules, has been developed. The aircraft is able to release such sondes and track them as they fall by parachute and drift with the wind. Sensors on the sondes detect the ambient temperature, humidity and pressure. The resulting data are transmitted to the aircraft to provide a comprehensive description of the atmosphere below the flight level. The aircraft is also equipped to measure temperature, humidity, air motions and radiative fluxes along its flight path with high resolution and accuracy.

These facilities have been used in the study of rain-bearing systems over the North Atlantic, away from the complicating influence of a land mass. A recent experiment has provided a clear insight into the role of differential air motions, organized on the scale of tens to a few hundreds of kilometres, in creating preferred areas for the formation of cloud and precipitation. These manifest themselves in satellite pictures of cloud as rather persistent bands moving with the large-scale flow. The phenomena appear to owe their origin to one or more forms of instability in that flow. Possible mechanisms are being studied with the help of numerical models which seek to reproduce salient features of the observations.

The concentrations of ice crystals detected at various altitudes during these studies provide a sensitive indicator of the microphysical processes which are involved in the creation of precipitation. Interestingly, many more ice crystals were found than expected from the straightforward application of the results of laboratory drop-freezing experiments. The atmospheric observations suggest either that individual cloud elements were mixing with the frozen residues of earlier clouds or that some form of ice splintering process was in operation.

The growth of vigorous convective cloud and precipitation has been monitored from the Hercules aircraft on a number of occasions. Successful attempts have been made to simulate these phenomena with a three-dimensional numerical model constrained by the patterns of temperature, humidity and motion in the atmosphere observed during the individual case studies. More recently, model predictions of surface rainfall have been compared with rainfall rates and total precipitation accumulations observed by weather radar and rain-gauge networks; again results are encouraging. This work offers some hope that the features which contribute to the efficient production of rainfall can be identified and used in the assessment of potential hazards resulting from heavy and sustained precipitation. Recent developments suggest that self-sustaining multicellular and merging single-cell cloud systems can each maximize rainfall in mid-latitude maritime air masses. The model has also been used as a diagnostic tool to explore the role of cloud dynamics in thunderstorm electrification.

During the year a major research effort has been made to study somewhat less vigorous convective cloud through a substantial Office participation in the KONTUR (KONvektion und TURbulenz) experiment. This was sponsored by various research groups in the Federal Republic of Germany and took place in the German Bight during September and October. Surface and radiosonde observations were made from various ships, light-vessels and a research platform in the area. Co-ordinated flights of the MRF Hercules and a Falcon 20 aircraft of the Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (DFVLR) provided detailed data on temperature, humidity, wind, turbulence, cloud microphysics, aerosols, and radiation flux above, within and below a number of convective cloud types. Although the data analyses have only just begun it is clear that much useful information has been obtained in conditions exhibiting open cellular structure, mesoscale bands and cloud streets. The results will be used to gain a better description and understanding of the properties of mid-latitude convection on a wide range of scales. It is hoped that the observations will also help to elucidate the roles of entrainment and mixing in clouds, a subject receiving much attention at present. Measurements made in the sub-cloud layer in strong winds will provide an opportunity to study the evolution of spray droplets, a matter of some relevance to the icing of ships and marine platforms.

Earlier field studies of fog and layer cloud have now borne fruit. Papers have been submitted for publication which discuss the various budgets relevant to the formation and dissipation of nocturnal stratocumulus cloud, the characterization of turbulence, radiative and microphysical structure and the elucidation of the entrainment process in such clouds. A thorough investigation of short-wavelength radiative exchange in layer cloud has been written up to augment a similar study of the long-wavelength process. These results have been used to help describe the structure and radiative properties of daytime marine stratocumulus. Following a careful assessment of the processes which are important in the evolution of fog, an attempt is being made to represent them in a model of the lower atmosphere and surface which might find use as a predictive tool.

During the winter months a series of experiments has been carried out to measure the distribution of water in layer clouds. The aim is to assess the probability of occurrence of liquid water contents likely to create icing hazards for helicopters. When combined with a climatology of such cloud the assessment of the problem and possible solutions can be tackled in a systematic manner.

Atmospheric chemistry

The growing awareness that the atmosphere is not an infinite or passive sink for the waste products of human activity has provided a substantial impetus to the study of atmospheric chemistry in recent years. Much interest has centred on the trace species which, it is believed, might destroy stratospheric ozone; these include water, the oxides of nitrogen and the chlorofluoromethanes. The growing use of fossil fuels as a source of energy is known to be increasing the atmospheric concentration of carbon dioxide, an important determinant of the atmosphere's radiative balance. Sulphur is a ubiquitous constituent of most fossil fuels. Its release during burning provides the raw material for a complex sequence of chemical reactions contributing to so-called 'acid precipitation'. All these processes involve large numbers of interdependent chemical reactions, the rates of which depend on the concentrations of the reactants. These, in turn, depend on often ill-understood sources and sinks and on a wide range of atmospheric transport mechanisms.

Because of this undoubted complexity there is a clear need for long-term monitoring of key species: sometimes a source molecule, but often the end or a major intermediate product of the chemical process. The Office participates in the Background Air Pollution Monitoring Network (BAPMoN), organized by the World Meteorological Organization (WMO) by collecting rainwater samples at Eskdalemuir for subsequent chemical analysis. This is carried out by the Laboratory of the Government Chemist on monthly samples obtained in rain-gauges which are open only during periods of rainfall, operating alongside others which are always open. The arrangement allows some separation of the deposition in rain from 'dry deposition'. Similar collecting gauges are operated at Lerwick and Bracknell. It is hoped that the program will allow early detection of changes in pH, and the concentration of sulphate, nitrate and various metallic ions in rainfall, and hence in the atmosphere. International comparisons of analysis techniques take place at regular intervals to help achieve the necessary long-term stability. At the request of the Department of the Environment the Office has contributed to a small working party, the

Review Group on Acid Rain, whose task is to assess data obtained in the United Kingdom during the last decade.

The Office also participates in the WMO-sponsored ozone-monitoring network by accepting responsibility for measurements of total ozone column density at a number of sites. Dobson ozone spectrophotometers are maintained at Bracknell, Lerwick, St Helena and Mahé for this purpose. Operation of the latter instrument was taken over by the Republic of Seychelles during the year. Again the accuracy of the ozone observations, and hence their value for assessing long-term trends, is dependent upon careful calibration and the maintenance of stability in instrument performance. Comparison of the UK travelling standard with the St Helena instrument was completed early in the year, and of the former with the world standard instrument at Boulder, Colorado, during the summer.

Total reliance on long-term monitoring leaves something to be desired as a technique for detecting possibly harmful trends, and there is a continuous investigation of methods of predicting changes through better understanding of the complex physico-chemical processes which control ozone. Recently a column model incorporating a comprehensive radiation scheme and set of chemical reactions and rate coefficients, but somewhat simplified representation of dynamical processes, has been used to investigate the diurnal variation of ozone in the upper stratosphere. It has been found that the predicted variation during daylight hours between altitudes of 40 and 50 km is a sensitive function of the variation of the chemical kinetics with altitude. This raises the possibility of testing the model photochemistry by measurements of ozone having good relative accuracy over a period of hours during daylight but perhaps low absolute accuracy. Methods of obtaining such data from balloon or satellite-based experiments are under consideration.

A similar Oxford University model has been used to interpret mesospheric diurnal ozone measurements made during 1979 rocket experiments, with some success.

Almost all the sources and sinks of trace chemical species are located in the troposphere. Their contribution and effectiveness, even in principle, is far from certain. Therefore the MRF Hercules has been fitted with a 3-channel electron-capture gas chromatograph and sampling facility. Development of this has continued during the year and mixing ratios of $CFCl_3$, CF_2Cl_2, CH_3CCl_3, CCl_4, CO_2 and N_2O can now be measured with useful accuracy. A first attempt to make such measurements upwind and downwind of the UK has been completed successfully. The instruments, together with some developed by the Central Electricity Research Laboratories and now installed on the Hercules, offer the potential of studying a number of facets of the chemical evolution of atmospheric participants in the sulphur, nitrogen and chlorine cycles. A start has been made as described on page 93, but several other potentially important studies are planned.

A central theme of the work of the Office in this area is the emphasis which is placed on a proper representation of transport processes in any attempt to describe atmospheric chemical evolution. To this end, the predictions of a 13-level general circulation model have been used to diagnose fluxes of water vapour, ozone and potential vorticity between the troposphere and stratosphere. It appears, for example, that regions of low stratospheric humidity owe much to the influence of the tropospheric 'Walker circulation', a zonal equatorial circulation with ascent over the warm west Pacific (and adjacent regions) and descent over the cool east Pacific. As a corollary to this work, it is clear that global scale measurements of the concentration of some long-lived stratospheric trace species may be necessary to describe their distribution adequately. Such data are most readily obtained from satellites. The Office is represented on the scientific team of the Halogen Occultation Experiment (HALOE) due to be flown on the Upper Atmosphere Research Satellite (UARS) in the mid to late 1980s. This experiment is expected to produce data from which the concentrations of a wide range of trace species can be deduced while other experiments on the satellite allow inference of the corresponding physical state of the upper atmosphere. The aim is to test the evolution of model chemistry along stratospheric isentropic trajectories, constrained by measurements at points along it. In this way, limitations introduced by averaging in one- or two-dimensional models will be bypassed.

Meteorological Research Flight

The Meteorological Research Flight (MRF) of the Meteorological Office is located at the Royal Aircraft Establishment, Farnborough. Until 1981 it operated two RAF aircraft with appropriate RAF aircrews, a Hercules C-130 and a Canberra PR3, suitably and extensively instrumented to carry out research from near the sea surface (with the Hercules) to the lower stratosphere (with the Canberra). As an economy measure, however, the Canberra was disestablished at the end of the financial year 1980/81. The MRF is used as a research facility by several research branches inside the Meteorological Office and by universities and other research groups outside the Office, but studies of some atmospheric phenomena are also carried out by scientists based at Farnborough as part of the establishment of the flight.

Before the Canberra was removed from service a number of flights above and below cloud sheets were made with a multi-channel radiometer. From these measurements the transmission and reflection of sunlight by clouds is being obtained in narrow spectral intervals. On some occasions coincident microphysical measurements were made within the cloud using the Hercules' instrumentation. It is intended to use these observations to further our understanding of radiative transfer in cloudy atmospheres. A first look at the data shows that the reflectivity of ice clouds in this spectral region can be distinguished from water clouds, which contain generally smaller particles. One of the next steps will be to see whether variations in crystal shape significantly affect the transfer of radiation or whether the crystals can be represented by, say, spheres with an equivalent radius.

When a stably stratified airstream encounters a mountain ridge the resulting disturbance in the flow can cause waves to occur. In some conditions, e.g. flow over an extensive ridge such as the Rocky Mountains, the disturbance may be sufficiently intense to be a hazard to aircraft owing to severe clear-air turbulence and strong downslope winds; the waves may also act to cause a significant drag on atmospheric motions.

There have been numerous investigations of disturbances caused by large orographic features, notably the Rocky Mountains, but far fewer concerning relatively small mountain complexes such as those found in Britain. In recent years, the MRF aircraft, separately or together, have made a number of flights over the mountainous regions of Britain to investigate the wave characteristics of the disturbed flows caused by wide areas of relatively small mountains. Analysis of these flights is now well under way.

Theoretical studies show that the wave drag acts on high levels in the atmosphere and is communicated to the surface by a downward flux of momentum, which may be measured using the wind-finding systems on the Hercules and Canberra. On the most recent flight, a downward flux of about 0.4 N m^{-2} was measured at several levels in the lower and mid-troposphere. This is comparable with surface friction, and the constancy of the value with height is in good agreement with theory. Observations of the wavelength and variation of wave amplitude with height from several flights have been compared with results from a simple model in which these quantities depend only on the wind and temperature profiles in the airstream approaching the mountains. Good agreement was obtained on most occasions.

Further studies with this model using typical wind and temperature profiles indicate that the waves will in general be most sensitive to the wind speed at low levels. High wind speeds are associated with long wavelengths and also with larger downward fluxes of momentum. Observations give some support to this conclusion, and future flights will enable this relationship to be studied more closely.

Collaborative work with the Central Electricity Research Laboratories (CERL) has continued. The initial phase of this project was described on page 98 of *Annual Report 1980* which outlined the fitting of the Hercules aircraft with specially designed and constructed instruments and the early test flights. The experience gained on these flights suggested minor modifications to the instrumentation and also to the flight plans. Before early March 1981, when the aircraft was grounded for a 'major' service and installations, 11 operational sorties were achieved. These were carried out usually over the North Sea downwind of a specific power-station stack, the emission from which had been 'labelled' with chemicals which could be sampled from the aircraft. Within the emitted plume, measurements were made of the constituents of the air and any cloud and rain, and chemical analysis was carried out both aboard the aircraft in flight and later on the ground at CERL. Data from these flights and also from background investigations carried out simultaneously from a second aircraft, are being processed.

The Short Period Weather Forecasting Pilot Project

The ability to observe and analyse cloud and precipitation patterns has been greatly improved by advances in radar and satellite imagery and by new methods of processing, transmitting and displaying the data. These improvements are expected to lead to improvements in the 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. As a result of these and other advances in mesoscale observational capabilities, many new opportunities for site-specific weather forecasts are being opened up, and this has led in many countries to a surge of effort in what has (regrettably) come to be known as 'nowcasting'. The first international symposium on nowcasting was held in 1981 and Office scientists were able to take a leading role.

The Short Period Weather Forecasting Pilot Project, which started at the Meteorological Office Radar Research Laboratory in Malvern in 1978, is aimed at developing precipitation nowcasting techniques for use in the Office. The project is a balanced program of fundamental and applied research, with the new data sources leading both to a better understanding of the mesoscale weather systems and to the development of improved forecasting techniques.

The principal source of satellite data for this project is the European geostationary satellite, Meteosat. Following a hiatus after the demise of Meteosat-1 in 1979, Meteosat-2 was launched in June 1981. With the help of the Department of Electrical Engineering and Electronics at the University of Dundee, a Primary Data User Station (PDUS) has been established at Malvern to receive the digital imagery in the visible, infra-red and water-vapour channels. The resulting pictures are automatically remapped to a National Grid projection (identical to that of the radar data) and displayed within 8 minutes of nominal data time on a colour television monitor with an action-replay capability for revealing motions, development and decay.

The network of weather radars in the UK, which has been established since 1979, includes radars at Camborne (Cornwall), Upavon (Wiltshire), Clee Hill (Shropshire) and Hameldon Hill (Lancashire). Qualitative coverage extends over a large part of England and Wales but London and eastern parts of England are not yet properly covered. The accuracy of the radar measurements decreases with distance from each radar and further work still remains to be done to improve their accuracy even at close range. Nevertheless, experience indicates that the qualitative patterns of precipitation, when properly combined with other data, are of great value for forecasting purposes. Most of the present radars, although operated as nearly as possible round the clock, are old systems; however, the radar at Hameldon Hill has been established as a new operational unmanned weather radar as part of a collaborative project between the Meteorological Office, the Ministry of Agriculture, Fisheries and Food, the North West Water-Authority and the Water Research Council.

Rainfall data from individual radars are sent digitally at 15-minute intervals using British Telecom lines to a small number of meteorological offices and Water Authority users. The data are in the form of rainfall patterns, and also totals over predefined areas. In addition, data are sent routinely to the Meteorological Office Radar Research Laboratory at Malvern where a composite display is generated automatically within 4 minutes of data time. These data are used extensively for research and development at Malvern. So far the composited data are being sent to only two operational meteorological offices, although it is planned to extend this service.

The rainfall data, whether from a single radar or from the network of radars, are displayed on a colour television monitor as a matrix of 5 km squares based on the National Grid. Just as with the Meteosat cloud imagery, sequences of pictures can be replayed to reveal movement and development. Equipment for the reception, display and action replay of a limited sequence of pictures, originally developed by the Royal Signals and Radar Establishment but now available commercially, is being used at most of the locations receiving these data. However, a computer-driven display is available at Malvern. This enables long sequences of data from the radar network and satellite to be replayed and combined, and is being used to develop and test new methods of quality control, analysis and very-short-range forecasting.

One of the characteristics of the rainfall fields derived from a network of radars is that most of the errors are physical in nature and a knowledge of the general meteorological situation is required in order to correct them. This calls for the development of analysis procedures whereby the radar 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. The procedures which are being developed at Malvern to analyse and check the quality of the radar data involve the use of interactive video-display techniques whereby a human analyst can modify the computer processing applied to the data in the light of the results he sees. The interactive procedures are also being developed to enable the satellite and radar data to be combined so as to provide coverage of precipitation systems over an area greater than that covered by the radars alone. Forecast rainfall patterns for the period 0 to 6 hours ahead can be derived totally objectively using the Malvern system by means of a computerized rain-cell identification and extrapolation technique. However, this too requires intervention by the forecaster before the resulting products can be issued with confidence. An analysis of the kind of system required to enable a forecaster to carry out these tasks rapidly has led to the design of a special interactive display system whereby the forecaster is enabled to implement his meteorological judgement effectively within the context of an otherwise highly automated system. The necessary equipment and software are being developed under contract and will be delivered next year.

Satellite meteorology

The Office is providing infra-red radiometers, known as Stratospheric Sounding Units (SSUs), as part of the instrumentation of the current United States series of polar-orbiting meteorological satellites. Failure of the first of these satellites in February terminated the operating life of our first instrument. It had operated in orbit for 868 days, making about 16 million sets of measurements of infra-red emission from the stratosphere. These observations have been used to provide daily information on the global distribution of temperature in the stratosphere. Observations were maintained by a SSU on the NOAA-6 satellite, which has been operating successfully since mid-1979. Another SSU came into service in July, as a result of the launch of the NOAA-7 satellite. Marconi Space and Defence Systems Ltd delivered the eighth and last flight-standard instrument and completed refurbishment of the test model. It is planned that these, and other instruments already delivered, will be flown between 1982 and 1988.

Performance of the SSUs has been monitored closely. Laboratory and theoretical investigations have provided techniques to detect small changes in spectroscopic performance of SSUs on the ground and in orbit. Radiation measurements by SSUs in the vicinity of rocketsonde sites around the time of rocket launchings have been compared with values calculated from the rocketsonde temperature profile. As a result of these (and other) checks and the low noise level of the SSU outputs, daily mean temperatures for stratospheric layers over various latitude bands can be derived with high precision and consistency between instruments. SSU observations of the daily cycle of stratospheric temperature and its latitude dependence have been compared with predictions of a radiative model of the stratosphere, developed in collaboration with the Atmospheric Physics Department, Oxford University. Comparison of series of daily zonal mean temperatures from two SSUs, in different orbits, during 1979–80 have provided the most precise observations so far of the lunar tide in stratospheric temperature. These observations are being studied in collaboration with Exeter University.

Meteosat-2, the second European geostationary meteorological satellite, was successfully launched on 19 June by the European Space Agency (ESA), (see Plates I and II). Distribution of Meteosat images to user reception stations and thence to forecast offices etc. was restored in August, having been suspended since failure of the systems on Meteosat-1 in November 1979. Liaison has been maintained with ESA on all aspects of the Meteosat program. The main computers at the ESA central Meteosat ground facility are being replaced to reduce operating costs (to which the Meteorological Office subscribes the UK share). As a result, quantitative products (e.g. winds, sea surface temperatures) extracted from Meteosat imagery will not be available before the first quarter of 1982.

Good progress has been made in the development of a scheme to retrieve tropospheric temperature and humidity distributions from observations made by instruments on the US polar-orbiting satellites. The facilities and software necessary to process, as a matter of routine, those observations made within range of the reception station at Lasham have been determined, and the general scheme has been approved. Initially, methods of processing will be based on software generously provided by the Development Laboratory of the US National Earth Satellite Service. This software has been tried out and is being adapted to our requirements. Research continues into improved methods of interpreting the satellite observations in terms of meteorological parameters.

Several activities have been developed aimed at improving exploitation of satellite images. An efficient method was evolved for calculating latitude/longitude grids and coastlines for use with polar-orbiter imagery. Images from Meteosat-2 and polar-orbiting satellites are being used in a case study of sea fog with the aim of improving forecasting techniques.

An assessment was completed of the quality of ocean surface winds derived from observations made by the microwave scatterometer on the SEASAT satellite. A scatterometer is one of the instruments to be flown on the recently approved ESA Remote Sensing satellite, ERS-1. A member of staff has participated in an ESA group which is advising on the characteristics of this instrument. The Office has participated in discussions with other Departments concerning the facilities which would be needed to make best use within the UK of ERS-1 observations.

Studies of the technical feasibility and likely performance of a proposed active microwave satellite-borne instrument to determine surface pressure have continued in conjunction with the Physics Department, Heriot-Watt University, the Rutherford Appleton Laboratory (Science and Engineering Research Council) and the Jet Propulsion Laboratory, Pasadena, California. Methods were developed to simulate instrument performance in the presence of cloud and rain. These methods were tested, using a two-channel passive microwave radiometer and high-resolution satellite imagery. An outline design of a potential satellite instrument was prepared, with our collaborators, and submitted to ESA in response to an announcement of an opportunity to fly an additional experimental package on the ERS-1 satellite.

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 atmosphere is but one example. Other natural fluid systems in which rotation plays a dominant role are the atmospheres of other planets, the oceans and the liquid core of the earth where the earth's magnetism originates.

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 corresponding systems 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 studies 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. We cannot, for example, change the rate of rotation of the earth to see if a theory continues to apply, but we 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 annulus, the inner and outer walls of which are maintained at different temperatures. The transfer of heat by the fluid between these walls simulates the transport of heat from the equatorial regions towards the poles by the wind systems. The laboratory studies show that several different regimes are possible. The flow may be axisymmetric, it may contain a 'jet stream' with regular wave-like perturbations or it may be highly irregular. 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 is found 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 institutes throughout 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 precise investigations of energy transformations in time-varying flows.

The results of many numerical simulations of annulus flows have now been compared with the corresponding laboratory studies. The numerical model has such a fine resolution that the only sub-grid-scale processes present are molecular viscosity and thermal conductivity and they can be represented precisely. The main features of the regular flows are found to be in good general agreement with observations, but certain details, which would have to be reproduced accurately in a model used for prediction, show significant discrepancies. Moreover, contrary to expectation, improvements resulting from increased grid-resolution in the numerical model have been slight. These comparative studies have implications for attempts to model the more complex flows found in the atmosphere and to develop a soundly based theory of atmospheric predictability, which is a major goal of our work.

There are two general types of regular flows found in laboratory systems, namely steady flows and periodically varying flows ('vacillation'). After some considerable initial difficulties it has recently proved possible to reproduce certain examples of vacillation numerically.

The occurrence of the regular-waves regime in the annulus system is of major theoretical significance and has not yet been fully explained. The 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 are unduly pessimistic. Some insight into the ordering influence of non-linearity is now being provided by a variety of studies of 'solitons' and other flow phenomena found in simple mathematical models.

The high-resolution pictures of the atmosphere of the planet Jupiter obtained by the Voyager 1 and 2 space probes confirm that the Great Red Spot and several dynamically similar though smaller features are very stable eddies embedded in regions of highly sheared flow. These eddies bear a strong resemblance to the baroclinic eddies produced in some special annulus experiments carried out several years ago when effects due to internal heating of the fluid were investigated. This earlier work is now being extended with a view to resolving several theoretical questions concerning the stability and mutual interactions of such eddies.

The surface of the earth is irregular and the study of 'topographic' effects is of major importance in atmospheric dynamics. Such effects can also be studied in the laboratory and experiments on the influence of topography on annulus flows have proved instructive. We are also studying the effects of changing the distribution of heating and cooling at the boundaries.

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 flows. In our most recent work in this area the emphasis has been on numerical simulations of intransitive flows.

In the field of geophysics we have carried out several studies bearing on the origin of the earth's magnetic field and the structure and dynamics of the earth's interior. One of these concerns the behaviour of axisymmetric magnetic fields and leads to certain predictions, now being tested by various archaeomagnetic and palaeomagnetic groups, as to changes in the spatial structure of the geomagnetic fields during a polarity transition. Geomagnetic data from the orbiting satellite MAGSAT have been used by an American group of geophysicists to make a further test of the practical usefulness of Hide's method for determining the radius of the electrically conducting core of a planet from observations of secular changes in the magnetic field of the planet in the accessible region at and above the surface of the planet. They report a 'magnetic' radius for the earth's core that agrees within 2 per cent with the 'seismological' radius, thus demonstrating not only that the principle of the method is sound but that the procedure for carrying out the calculations is stable. Other studies exploit the new meteorological data made available through the First GARP Global Experiment (FGGE) program, which made it possible to assess the accuracy of astronomical determinations of changes in the speed of rotation of the solid earth and to evaluate the meteorological contribution to the observed movements of the earth's pole of rotation. The accurate monitoring of these effects is of interest not only to meteorologists concerned with the general circulation of the atmosphere but to geophysicists concerned with the dynamics of the mantle and crust, where earthquakes originate, and to astronomers working on new techniques for monitoring all components of the earth's rotation. A notable recent discovery stemming from this work is of a significant fluctuation in the general circulation of the atmosphere on the time-scale of about 50 days.

Dynamical and Synoptic Research

Research related to numerical short-range forecasting

The availability in recent years of larger amounts of observational data for the atmosphere obtained from remote-sensing instruments has opened up new possibilities for improving the accuracy of numerical weather forecasts. In the conventional systems, observations are made from ground level to the high stratosphere at internationally agreed fixed times (synoptic hours) using instrumentation that is, as nearly as possible, standardized and gives direct measurements of the meteorological variables—temperature, pressure, humidity and wind. The development of microprocessors and satellites over the past few years, however, has led to the use of a wide variety of new instrumental techniques and to the successful application of new methods of inferring values of the basic meteorological variables indirectly from other, more easily observed, features of the atmosphere. Polar-orbiting satellites, for example, are able to sense the radiation emitted by the atmosphere at infra-red wavelengths and this information is processed by computer to produce estimates of the mean temperatures within layers at different heights above the earth's surface. Temperature estimates by this technique do not have the precision of those made using the more conventional radiosonde balloon ascents, but they provide information at much higher spatial density, enabling deductions to be made about horizontal temperature gradients that are extremely valuable over areas of the globe where observations from the conventional observational network are few and far between; one example is the oceans, where radiosonde balloons are released from only a few isolated islands and a small number of ocean weather ships. The examination of photographs taken from geostationary satellites at short intervals enables winds to be deduced by following individual groups of clouds. Again, the value of these data lies in their widespread availability in data-sparse regions, since the absolute accuracy of an individual wind estimate is not as good as a measurement made by the more conventional technique of tracking balloon-borne radar targets.

Research work over the past few years has led to the design of a data-assimilation scheme that uses all the observational data obtained from both the new types of automatic and remote instrumentation and the conventional network of stations to obtain more accurate analyses of the state of the atmosphere. Forecasts, using these improved analyses as initial data, are then made by employing finite-difference techniques to solve a set of equations describing the physical processes in the atmosphere. Details of the research work for the new analysis scheme and forecasting system have been described in an article on pages 75–93 of *Annual Report 1980*. The acquisition in 1981 of a Control Data Corporation CYBER 205 computer has permitted the calculations involved in these techniques to be performed fast enough for them to be included in a new operational numerical weather forecasting system.

During this year a great deal of work has been devoted towards developing the data-assimilation scheme for the next operational forecasting system. Observational data are assimilated dynamically as the forecast equations are integrated through a six-hour assimilation period. At each time-step corrections to the forecast variables are calculated, using a statistical technique to interpolate observational data to the grid points of the finite-difference mesh. This technique minimizes the expected mean-square error of the interpolated values, and a proportion of the resulting corrections are added to the predicted fields of temperature, wind, humidity and surface pressure. In this way the forecast is continuously reminded of the observed state of the atmosphere, and is nudged towards this state during the assimilation period. Since the applied corrections are small, the forecast model retains its own internal dynamic balance by allowing, for example, the wind field to become consistent with the changes in the mass field implied by temperature observations. The temperature field adjusts in the same way to changes implied by wind observations. Consequently a state is achieved that not only fits the observed data but is also in approximate dynamic balance and ready for the subsequent forecast. Any roughnesses generated by the assimilation procedure are controlled by a diffusion process which damps the vertically integrated divergence field. This effectively damps only the 'external gravity wave', but leaves other details of the divergence field unmodified.

Considerable effort has been applied to writing the program in a suitable form to take advantage of the vector-processing capability of the CYBER 205 computer. This is a particular problem for data assimilation owing to the variable number of observations and their irregular distribution in space. Efficient vector processing demands long vectors of contiguous data. However, progress has been made in this direction and it is now expected that the data assimilation should run in an acceptably short period of time.

Another major item of work undertaken during the year was the development of the new operational numerical weather prediction model to run efficiently on the CYBER 205. For the first half of the year, before the installation of the CYBER 205 at Bracknell, this work was performed on a similar but slower computer, the CYBER 203 in Minneapolis, mainly via a transatlantic satellite telecommunication link. Some development work was also carried out on the CRAY-1 computer at the European Centre for Medium Range Weather Forecasts.

The new forecast model will have 15 levels in the vertical, compared with 10 in the current operational model; the distribution of these levels has been chosen to give extra resolution in the boundary layer and near the tropopause. In the horizontal the model will use a regular latitude–longitude grid, with a resolution of $1\frac{1}{2}°$ in latitude and $1\frac{7}{8}°$ in longitude. The time-integration scheme will be similar to that used in the current operational model. Methods of representing sub-grid-scale physical processes, such as cumulus convection, boundary-layer turbulence and radiation, have been adapted from those developed in the Dynamical Climatology Branch for use in general circulation models of the atmosphere. The data-assimilation scheme (described above) will use a version of this model covering the whole globe whereas the forecasts themselves will be run using a version with a boundary at 30°S, though an extension to include the whole globe will probably be introduced at a later date.

In addition there will be a limited-area fine-mesh version, covering the North Atlantic and western Europe, to replace the current operational 'rectangle' model. This version will also have 15 levels, but its horizontal resolution will be two or three times finer than that of the coarse-mesh model in order to provide more accuracy and greater detail for short-range forecasts. Its main use will be in predicting details of the weather in the British Isles for 36 hours ahead.

Investigation has continued into the possibility of improving numerical forecasts by coupling them with statistical predictions of the development of model errors in space and time and making subsequent corrections to the model output. Although these experiments have been conducted with the present operational 10-level 'octagon' numerical forecasting model, they will be adapted to use the results from the new model as soon as they become available on a regular basis.

Regular weekly assessments of the guidance value of the numerical forecasts up to 7 days ahead produced by the ECMWF and Meteorological Office octagon operational models have continued; forecast sequences up to 5 days ahead produced by the new model (coarse mesh version) have also been included in these assessments. The process of assessment has continued to be entirely subjective, the forecast for each day being categorized as (a) good guidance, (b) containing some minor errors, or (c) misleading in some important respects. Towards the end of the year, individual assessments of days 5, 6 and 7 were abandoned in favour of grouping the three days together and categorizing the guidance value of the 3-day sequence (days 5/6/7) according to slightly less restrictive criteria; a similar assessment is also carried out for days 4/5 as a 2-day sequence.

Investigation has continued of the performance of limited-area fine-mesh numerical models in situations yielding large amounts of precipitation over the United Kingdom and attention has been focused, in particular, on the representation of the structure and evolution of fronts as predicted by the models. During the course of the past year several interesting cases have been selected for detailed study involving, wherever possible, the comparison of the structure of observed features (from the evidence of routine synoptic observations, radar-network data and satellite photographs) with that predicted by the models. Forecasts produced by the operational fine-mesh model (rectangle) have been used in these case studies. As an extra diagnostic aid, a computer program has been developed to extract two-dimensional vertical cross-sections of a range of model atmospheric variables, using the operational fine-mesh data; it has so far been used to look at typical model treatment of the quasi-two-dimensional characteristics of active fronts. In addition, programs are being developed to produce horizontal fields of derived model variables such as various measures of frontogenesis.

The new fine-mesh limited-area model has also been run (on the CRAY-1 computer at ECMWF) for several of these case studies, starting from ECMWF coarse-mesh initial data, and its performance is being assessed with a view to improving, *inter alia*, the model's representation of precipitation processes. In these integrations of the new model three different horizontal grid-lengths (150 km, 75 km, and 50 km) have been experimented with, and our earlier experiences of the effect on predicted rainfall of reducing the grid-length have generally been confirmed. From recent evidence it appears that, while the predicted rainfall is normally substantially increased when grid-length is reduced from 150 km to 75 km, there tends to be little extra enhancement on further reduction to 50 km. The use of a grid-length less than 75 km is only justified, therefore, if the initial data contain information on finer scales than were available for these experiments.

Some work is being started on trying to understand certain defects of forecast models which appear to be insensitive to changes in the numerical approximation techniques or the representation of physical processes. It is known from research in other branches of physics that large-scale errors can result from incorrect treatment of regions where rapid changes occur. In the atmosphere, regions such as fronts and jet streams fall into this category. Observations of mesoscale systems also indicate localized regions of rapid change. Under these circumstances it is necessary to be careful about how the mathematical problem is solved, or else spurious solutions can be generated. Several separate projects are being started to study the mathematics of these cases.

Work has continued during the year on a number of problems associated with the development of an objective system to predict weather up to 12 hours ahead on scales of a few tens of kilometres using a mesoscale forecast model. Up to the present time, integrations of this model for real cases have used initial data interpolated from the larger-scale operational numerical forecast model. During the year, progress has been made towards establishing an independent initialization scheme taking advantage of the close spacing of surface observing stations in the UK. A two-dimensional analysis scheme has been used successfully to analyse data of variable density by a numerical filtering technique. A static initialization based on variational techniques is then applied to the analysed data to ensure consistency and prevent high-frequency oscillations from disturbing the forecast. Development of this technique is near completion and it has been succesfully tested on idealized data. More fundamental work on the use of observations has concentrated on finding an objective method for diagnosing boundaries between different air masses using surface observations. This would permit much more effective use of the few available upper-air soundings. The logical processes needed to do this were established and tested, but results using sets of real observations indicated that there are many difficulties to be overcome.

The basic mesoscale model itself has not changed much during the year, but a major task has been reprogramming it to run on the new computer. A new boundary-layer scheme based on forecasting the turbulent energy has been successfully tested and is being extended to include the effects of moisture. Work has also started on the inclusion of moisture transport and precipitation. During the first part of the year a series of integrations was carried out to determine the sensitivity of the model to changes in the surface-exchange parametrization. The case studies run this year have concentrated on airflow over hills as part of an international comparison of mesoscale numerical models related to research into the location of wind-power devices. These have tested the model severely and much has been learned about its performance near steep ground. In particular, these experiments have confirmed the need for a reformulation of the conditions applied at the model's upper boundary.

General circulation of the atmosphere

The development of models of the atmospheric general circulation has continued as part of the research directed towards the construction of a climate model to include representations of the ocean and areas covered by snow and ice as well as the atmosphere and land surface. This year the effort has been divided between the analysis and further improvement of the 5- and 11-layer models, described in previous reports, and design and development work directed towards the new version of these models for use on the CYBER 205 computer.

The first experiment with the 11-layer model to include a prescribed seasonal variation of radiation, sea surface temperatures, ice, etc. completed its first simulated year, yielding a large quantity of information on the model's response to seasonal forcing. The results have been compared with the observed climate and with the results of the similar experiment with the 5-layer model discussed in the *Annual Report 1980*. An interesting difference between the two models is that the 11-layer model has generally more rain over the ocean than the 5-layer model and less over the tropical and subtropical continents, with observations generally lying between the two simulations. The polar high which affects 5-layer model integrations throughout the year is absent from the 11-layer model in winter and less prominent in summer. Analysis of these contrasts should contribute to an understanding of the deficiencies and their subsequent elimination.

In preparation for future experiments with climate models, in which land-surface characteristics may need to vary both spatially and temporally, a series of experiments has been run with a low-resolution version of the 5-layer model to assess the model's sensitivity in this area. The first experiments explored the impact of large-scale variations in surface reflectivity. It was found that, for summer conditions, changing the reflectivity of all snow-free land surfaces, from a low value typical of forests to a high one appropriate for deserts, considerably reduced both the surface-pressure gradient between the oceanic anticyclones and the continental monsoon lows, and also the rainfall over large areas of the tropical and subtropical continents. This sensitivity indicates the need for care in specifying surface reflectivities and suggests the possible sensitivity of climate to more realistic, smaller changes. Other experiments involving similar large-scale differences in the initial soil moisture have confirmed earlier indications that over large areas of the middle latitude and subtropical continents the surface moisture availability plays a major part in determining the model's summer rainfall. Drying of the surface usually increases the reflectivity; the consequent positive feedbacks evident from the above discussion are being explored in further experiments in which the reflectivity depends on the soil moisture. The adequacy of present treatments of the soil hydrological processes is being reviewed in the light of the sensitivity of climate models to soil moisture. Inexpensive single-column versions of the three-dimensional models have been developed to help the assessment of more elaborate treatments of the transfer of heat and moisture in the soil.

One of the most difficult problems in current research remains the treatment of clouds. Both 5- and 11-layer models have similar cloud prediction schemes, and global integrations have been made from FGGE data in which the clouds are fully interactive with the rest of the model. Comparisons of the predicted cloud distributions with satellite photographs taken during FGGE allow a subjective test of the schemes on short time-scales, but it is also important that they should be similar to observed data when averaged over longer periods. Such comparisons show results to be generally realistic but also reveal the need for some modifications of the schemes.

Comparison of the three boundary-layer schemes developed for the 11-layer model has continued, using global integrations from both January and June FGGE initial data. One aspect of the model's performance which appears sensitive to the choice of scheme is the strength and position of the tropical rainfall belt. Over the winter continents all three schemes allow a marked cooling relative to real data. A detailed study of the model's heat budget has therefore begun, with emphasis on a limited region over the Eurasian land mass. The contributions to the budget from all physical processes treated by the model are being diagnosed, enabling a comparison of the model climatology in this region with observations.

Further work has been carried out on the representation of mountains in general circulation models. In particular, the treatment of the barrier effect of a mountainous region has been investigated. The applicability of different computational techniques has been studied using a model with an isolated mountain on an otherwise flat land surface. The results are being used to help the analysis of global integrations of the 11-layer model from FGGE data, in which barrier effects are incorporated for the major mountain features such as the Himalayas.

Climate modelling

The study of climate, climate variability and climate change using general circulation models has continued. The normal procedure is to run a control integration with a suitable model and then repeat the integration, changing one aspect of the model such as soil moisture or carbon dioxide concentration. One interesting result which emerges is that the response to such an anomaly depends on the prevailing circulation. For example, both precipitation and evaporation over Europe are reduced by reducing the local soil moisture when the prevailing model circulation is weak or from the east; however, when moister westerly winds predominate, the reduction in evaporation brought about by the drier surface may not reduce the moisture available for precipitation sufficiently to prevent the gradual erosion of the soil-moisture anomaly.

The experiments to investigate the effect on climate of increasing atmospheric carbon dioxide concentrations have been extended, analysed and written up. When sea surface temperatures are held at their present values, doubling atmospheric CO_2 leads to a decrease in precipitation over the oceans, and an increase along the eastern coasts of continents in summer. Land surface temperatures rise on average by only 0.4 °C. If, however, CO_2 amounts are doubled and sea surface temperatures are held 2 °C higher than at present, as is generally expected with doubled CO_2, precipitation increases generally over both oceans and continents, although there are some areas of decrease, particularly in the subtropics. Over land, the surface temperature increases by

2.8 °C. The global mean changes in precipitation and temperature in each of these experiments are consistent with those found by research workers in the United States. It should be noted that these changes vary from place to place and from season to season.

The contrasting responses found in the two experiments above illustrate the importance of including the ocean's response when assessing changes in climate. Before running an atmospheric model interactively with an ocean model it is important that the atmospheric model should be in radiative equilibrium at present-day temperatures, otherwise the temperatures will adjust until a new equilibrium is reached. This is not so critical with existing atmospheric models because the atmospheric temperatures are to some extent constrained by the prescribed ocean temperatures. The 5-layer atmospheric model has been brought closer to radiative equilibrium at present-day temperatures by including the frictional heating generated when kinetic energy is dissipated, by formulating the diffusive processes more carefully and by a number of other measures. This version is being used in interactive experiments using the ocean mixed layer and sea-ice models discussed later.

During 1981 the new CYBER 205 computer was installed at Bracknell. Testing of programs for this machine, which had taken place on a CYBER 203 at Minneapolis via a satellite link from Bracknell, has now been transferred to the CYBER 205. Development has continued of the new version of the 11-layer model using a latitude/longitude grid. In order to make good use of the very powerful vector facilities of the CYBER 205 the model programs are very different from those of earlier general circulation models. Considerable attention has been given during the year to the testing of methods of ensuring computational stability and controlling noise. Versions of the model have successfully run for 50 days and the results will be compared with those from other models, including the new numerical forecast model. After this comparison a decision will be taken on the most suitable model for future use for climate-modelling purposes.

Comparisons between different versions of the model are already yielding useful information. One experiment used a multipoint filter designed to control the noise which commonly develops in numerical integrations, by eliminating the shortest waves whilst having negligible direct effects on meteorological waves. This technique was difficult and expensive to apply in the previous model because of its irregular grid. A number of beneficial effects are evident compared with the standard model in which a less scale-selective diffusive treatment was employed. Development of depressions is more intense, allowing an increased poleward transfer of energy which maintains warmer conditions in high latitudes; the conservation of heat and moisture are also improved but the loss of mass by truncation error is increased.

An important feature of the new model is its flexibility, intended to allow its use with a wide range of mesh sizes. Only minor programming changes were needed to change from a coarse mesh (6° latitude by 6° longitude) version used for initial testing to a finer mesh (2° by 3°) appropriate for fairly detailed simulations. This version requires only 4 minutes computing for one model day even though program optimization is not yet complete. The IBM 360/195 model, with resolution similar to this, required over 50 minutes computing per day.

Because of the greater speed of this model it will be practicable to run long simulations designed to assess the response of climate to the steady increase in carbon dioxide expected over the next few decades. The feasibility of making longer runs will allow a thorough investigation of the variability from year to year inherent in the model and a comparison with the observed variability. With such long integrations it will not be practicable to keep as full a record as previously of the model's behaviour. Considerable thought has therefore gone towards planning the future diagnostics so that they will be of manageable size but still provide sufficient data for all likely analysis purposes.

The use of a standard, but flexible, method for diagnostics allows a more rapid investigation of results from new sources and ensures that charts and diagrams are produced in standard formats. Other diagnostic facilities which have been developed are cine films for the study of sequences of analyses in particular regions and trajectories for the study of air motion and transports in the general circulation.

Extension of the general circulation models to include explicit representation of oceans and sea ice is necessary for any realistic study of climate change and attention has continued to be given to the development of this capability. Parts of the work are being carried out in conjunction with Cambridge University —aspects of the ocean modelling with the Department of Applied Mathematics and Theoretical Physics and of the sea-ice modelling with the Scott Polar Research Institute. A priority is to provide, at an early stage, an ocean and sea-ice model suitable for interactive experiments with the new atmospheric model on the CYBER 205. For this purpose, simple oceanic mixed-layer models and thermodynamic models of sea-ice will be needed initially. A substantial part of the effort has been directed to developing a model of the oceanic mixed layer. This is the layer, typically some tens of metres deep and separated from the colder water below by a region of steep temperature gradient known as the thermocline, in which the solar heating near the surface is spread downwards by turbulent eddies generated by the action of the wind on the ocean surface. The depth of the layer is controlled by a balance between the mixing effects of the wind and the stabilizing effects of heating at the surface. Simulation of this layer is particularly important in summer when, with weak wind mixing, the layer can become very warm. Extensive tests have been carried out on the behaviour of mixed-layer models when driven by simulated atmospheric data derived from a general circulation model. Results of experiments so far indicate that the main features of the seasonal variations of the mixed-layer depth can be reproduced only if special measures are taken to prevent the wind mixing becoming too weak, particularly during the heating season in middle latitudes. These studies have now progressed to the experiments mentioned earlier in which the ocean mixed-layer and sea-ice models are interactively coupled to the 5-layer atmospheric model. The long-term emphasis, however, is on the development of a model of the deep ocean, including representation of mixed-layer processes and sea-ice, suitable for interactive runs over several decades. To this end, an existing limited-area ocean model is being expanded and adapted for use on a global grid. First tests of the model in this mode are now in progress on the IBM 360/195 whilst vectorization of its routines for the CYBER 205 is being actively pursued.

Studies based on observations of the general circulation

The observational data set collected during the First GARP Global Experiment (FGGE) and the sequence of analyses produced from these observations have continued to provide the basis for a range of research activities. The analysis system has now been modified to deal with the full set of FGGE observations, including those which were not available during the course of the experiment but have been collected subsequently. Analyses produced from the full set of observations have been compared with those which were produced during the course of the experiment and with those (also based on the full set of observations) which have been produced at ECMWF using a different analysis system. The comparisons include both monthly mean general circulation statistics and case studies of synoptic features. The case studies completed so far have included one for data-sparse regions of the southern hemisphere and one for the Mediterranean region.

The availability of the two sets of observational data and of results from two distinct analysis systems provides some information on the reliability of derived general circulation statistics. Studies have suggested that monthly mean fields of height, wind and temperature for January and July 1979 may be reliably calculated for almost all regions of the global atmosphere from the observations which were available during the course of FGGE. With covariances and flux quantities, however, there is greater uncertainty, and either the additional observational data or the method of analysis have been shown to have an important influence on derived statistics in particular regions. For example, although the zonal wind is adequately defined by the observations available during the experiment, the mid-latitude upper-tropospheric convergence of the horizontal flux of zonal momentum in the southern hemisphere winter is considerably greater when based on the full set of observations.

Comparisons completed so far indicate that the ECMWF analysis system gave a better fit to the observations and achieved a better balance between height and wind fields. Two advantages of the Meteorological Office analyses, however, are the better representation of the tropical Hadley circulation (which is distorted by certain aspects of the ECMWF system) and the more realistic flow near mountains (resulting from the use of a more accurate orography).

Using the Office's FGGE analysis system with the full set of observations, a study is in progress to determine the impact of aircraft data on the analyses and on forecasts computed from them. Selected sequences of the data assimilation have been repeated with aircraft data excluded, producing analyses, and thence forecasts, for comparison with control runs which used all observations. Similar experiments will follow for other types of FGGE data and also, where appropriate, for more recently proposed types of data retrieval from satellite measurements. The results of this work will assist planning for the use of new types of observation, and will also provide a contribution to a co-ordinated international series of observing system experiments designed to assist in selecting cost-effective improvements to the operational global observing system.

Following diagnostic work on the global angular momentum budget during the Special Observing Periods of FGGE, and in general circulation model simulations, a regional study was carried out to investigate the strong torques applied to the atmosphere by the Andes mountains during a period in May 1979. Unfortunately, uncertainties in the mountain torque values have made the regional angular momentum budget difficult to interpret.

Further study has been made of the summer monsoon circulation over the Indian Ocean during FGGE. In collaboration with a visiting scientist from

Kenya, the relationship of the monsoon circulation to surface pressure changes in the Mascarene high-pressure region has been investigated. Time-series of the low-level (850 mb) wind speed, averaged over the Arabian Sea region, have provided a useful objective index for the onset of the monsoon. At the time of the 1979 onset this statistic increased from a pre-monsoon value of about 5 m s^{-1} to a monsoon value of about 14 m s^{-1} in a period of about 13 days. On the basis of such time series, the 1979 onset has been compared with those of 1980 and 1981, for which ECMWF operational analyses are available, and with simulations by the 5- and 11-layer general circulation models. The observational data illustrate pronounced inter-annual variability of the onset's characteristics, whilst the simulations reveal a sensitivity to model resolution and formulation (especially to the properties of the model's convective parametrization).

Following the production of improved objective analyses for the third phase (in September 1974) of the GARP Atlantic Tropical Experiment (GATE), some diagnostic work has been completed. Phase means, standard deviation and covariances of analysed fields and of observations have been compared and documented.

Upper atmosphere research

A co-ordinated research program for theoretical studies, numerical modelling experiments and routine daily analyses of satellite observations of the stratosphere has led to a strong interaction between these three aspects of the work. Daily analyses of thicknesses retrieved from radiances measured by the Stratospheric Sounding Units (SSUs) on board the Tiros-N series of operational satellites are carried out in near-real time and, used in conjunction with analyses of 100 mb height fields, provide a global data base of temperature, geopotential, and geostrophic wind from 100 to 1 mb. These data are used internally for research, and selected fields are disseminated internationally for use by other workers.

Long-term archives are being built up from the stratospheric analyses and will provide valuable new climatological information, particularly for the southern hemisphere stratosphere which was previously poorly observed. It is already becoming evident that the southern polar night jet is much stronger and shows less variability than its northern counterpart, which is itself rather stronger in midwinter than was previously recognized.

Detailed study of the behaviour of the winter stratosphere is now carried out day by day, as the analyses are produced, by means of additional computer programs which calculate zonal mean and harmonic wave characteristics of the flow. This permits case-study investigations to be initiated at an early stage. For example, examination of diagnostics for December 1980 led to a study using the three-dimensional, primitive-equation, stratosphere–mesosphere, numerical model in idealized conditions. It was possible to demonstrate that large amplitudes of the longest planetary wave in the stratosphere can result from non-linear interactions between different stratospheric waves as well as from upward propagation from the troposphere, thus providing a plausible explanation of the observed behaviour in December 1980. This result demonstrates that results from quasi-linear models (which allow interactions only between waves and the mean flow) may sometimes be misleading.

The stratospheric analyses have continued to be used to provide initial and verifying fields for simulations with the stratosphere–mesosphere model. Certain features of the simulation of the February 1979 sudden stratospheric warming have been significantly improved by using higher vertical and zonal resolutions in the model. Study of the results of simulations has led to work designed to achieve greater accuracy near the poles through modification of the model's finite difference scheme. Alternative methods of specifying lower boundary conditions for the model are also being investigated.

A central topic of recent research has been the study of interactions between wave pertubations and the zonal mean flow, with special application to sudden warmings. A refractive index relationship describing the influence of the zonal mean wind distribution on wave propagation has been derived theoretically and tested in model studies. The relationship has proved instructive when examining observational data, but was particularly valuable in the interpretation of stratosphere–mesosphere model results pertinent to the major warming in February 1979. This warming was unusual in that it was induced by a 'wavenumber-2' perturbation and began in high latitudes, whereas model simulations by other workers had suggested that wavenumber-2 warmings would begin in low latitudes. A series of experiments was carried out with the stratosphere–mesosphere model, with zonal mean winds specified either from climatology or observations and with lower boundary heights specified either from observations or according to simple analytic functions, to identify the essential requirements for the warming. Two such requirements were found to be the structure of the zonal mean wind distribution before the warming and the progression of the forcing wavenumber-2 pattern at the lower boundary. Although the influence of the mean flow had been predicted on theoretical grounds, the importance of the propagating forcing pattern was unexpected. A paper on the results of this study, the first to use a numerical model in this way to link theory with observed behaviour in the stratosphere, has been submitted for publication. Further study is in progress to clarify the critical features in the initial zonal mean flow and to understand better the evolution of the flow subsequent to the warming.

Some of these dynamical ideas have also been tested in a linear planetary-wave model, once again in association with results diagnosed from the stratospheric analyses. In particular the importance of travelling wave components has been demonstrated, thus highlighting the distinction, often overlooked in the literature, between monthly mean states and stationary planetary-wave solutions.

The stratosphere–mesosphere model has been extended for chemical tracer studies by the incorporation of an improved representation of radiation and of a predictive equation for ozone (with parametrized sources and sinks). Further work on the radiation scheme is in progress. The extended model has been used to compare ozone transports resulting from transient wave forcing and dissipative processes with the predictions of linear theory.

Planning work has continued in connection with the Office's proposal to carry out data assimilations of satellite-derived stratospheric and mesospheric data as part of NASA's Upper Atmosphere Research Satellite (UARS) program. The planned date for the launch of the first of two UARS is now late 1988.

Synoptic climatology

The Synoptic Climatology Branch is concerned with the study of the behaviour of the atmosphere on time-scales beyond about ten days, using observations of the real atmosphere as the basis of the studies. This section describes the basic work done on assembling, analysing and interpreting the observations, and the following section deals with the development of improved methods of long-range forecasting, which is the main aim of all the work.

Extensive archives are maintained of data from climatological stations throughout the world and new data are added continually, after careful control of their quality. Many gaps exist in past records and a constant search for reliable information to fill them is made, often in consultation with other Meteorological Services and institutions. One potentially valuable record of surface observations to which special attention has been given is that from Sitka, Alaska, which extends back to 1832.

A world-wide network of upper-air soundings began to operate in 1948 but all the available compilations of results contain many errors and uncertainties, sufficient to confuse or obscure any small changes in climate that may have taken place. Much effort has been put into building up a reliable data set for the northern hemisphere, by requesting mean monthly upper-air data from the countries of origin for 150 selected stations, together with information on the instruments used and on the launching sites. Monthly or daily data from over 100 of these stations have been received and subjected to quality control. A study of the Arctic upper-air data for the last 15 years shows evidence of a warming trend, particularly in spring; the data set is not yet complete enough to extend this study to lower latitudes.

A new and potentially very important source of data is provided by meteorological satellites, and special attention is being given to archiving relevant data. Greatest progress has been made with an archive of global cloudiness from three polar-orbiting satellites and the geostationary Meteosats. Surface temperature is also stored and other parameters such as humidity and surface albedo are to be included.

A comprehensive global set of sea surface temperature observations made during the last century or so had been assembled and checked by 1980 and this set is being used as the basis for studies (done as part of a contract with the Department of the Environment) of the association between anomalies of sea surface temperature and atmospheric circulation patterns. An archive of global sea surface temperature data, blending satellite, ship and buoy observations, is also being compiled.

In addition to directly observed data, archives of analysed data are also maintained, in the form of the objectively analysed grid-point data produced by the Central Forecasting Office and data on derived quantities such as mean westerly flow and horizontal and vertical fluxes of heat and momentum. These latter quantities are being produced in a joint project with Reading University based on the daily global analyses of wind, temperature and humidity at the European Centre for Medium Range Weather Forecasts. Attention has so far been concentrated on 15-day mean values but the project is now being extended to give daily values too. These diagnostic quantities will be used to study the nature of variations in global circulation on time-scales of two weeks and over, and to investigate blocking and other phenomena.

Research related to long-range forecasting

The public issue of long-range forecasts ceased in December 1980 because of reductions in staff, as did the quarterly preparation of seasonal forecasts. However, experimental monthly forecasts are still prepared, to a less-demanding schedule and using simplified, less-labour-intensive methods. The forecasts are prepared by a 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 new method of multivariate analysis which has been under development for several years has now been fully incorporated into the forecasting procedure. It uses a variety of statistical approaches to construct forecasts of surface circulation patterns from several types of data including surface pressure, surface air temperature and sea temperature from much of the northern hemisphere; several of the old statistical methods are effectively incorporated in this more general technique. Further automation of the methods by which the experimental long-range forecasts are produced is being pursued as rapidly as possible. Information from medium-range numerical forecasts (available to about 6 days ahead) is also incorporated in the first few days of the forecast. Results from longer-period numerical forecasts are often taken into consideration too, though it is recognized that they do not provide reliable guidance at present.

A prime function of the long-range forecasting experiment is to focus attention on the many practical problems that have to be solved if regular monthly forecasts are to be produced in a form which maximizes the (inevitably limited) information available for the benefit of customers. For example, there is the problem of amalgamating the variety of indications given by several different forecasting techniques into one coherent forecast; also it is not easy to transform a forecast of a mean circulation pattern into, for instance, a surface temperature forecast, nor is it obvious that a monthly mean surface temperature is the best parameter to forecast when viewed in the light of the characteristic lengths of spells of temperature above or below average. The experimental forecasts are nevertheless still sent by telex to a small selection of commercial customers in order to maintain contact with users' views and requirements.

As usual, the forecasts have been carefully assessed for their accuracy. The method of presenting some of the information in the forecasts has been revised so as to make it easier to check objectively. The forecasts are assessed against the observations from a standard set of stations observing the weather in the United Kingdom, and the methods of selecting and assembling these observations have been further developed and automated to improve the assessment process.

Dynamical methods of forecasting, using large computers, have been very successful for forecasts a few days ahead but give very little useful guidance on the monthly time-scale. The numerical forecasts may contain useful information on long-term behaviour of the atmosphere but this is usually swamped by short-term fluctuations and by errors associated with the model or with imperfect specification of the initial conditions. Careful study of the behaviour of the models and of their response to various types of perturbation is needed if they are to be used effectively in monthly forecasting. The use of a hemispheric version of the 5-layer general circulation model in long-range forecasting and the study of particular characteristics of its behaviour on the monthly time-scale has continued. The 50-day forecasting integrations made each month with initial conditions derived from current operational analyses continue to further our experience in producing and interpreting dynamically-based numerical long-range forecasts. As the number of forecasts available for each month of the year has increased, deficiencies in the model's simulations have become more clearly defined. In particular, the model's average behaviour (its 'climatology') is much more like that of the real atmosphere in winter than in summer. It is usually assumed that the future state of the real atmosphere will depart from the climatological mean in the same way as a model forecast departs from its model climatology and this sort of seasonal variation of the realism of the model will clearly complicate the process of interpretation of forecasts.

The model's economy in running and the quality of its general circulation simulations have made it a suitable vehicle for gaining initial experience in how dynamical methods can be introduced into long-range forecasting but it is clearly not good enough for use operationally. This experience is now guiding the selection and introduction of a more appropriate dynamical model, which is likely to be based on the next operational forecasting model but will incorporate changes to suit the very different role of long-range forecasting. The new CYBER 205 computer will be used not only for improved numerical models which, in principle at least, are better equipped for the task, but also to develop and experiment with methods of producing and assessing numerical long-range (monthly) forecasts which have hitherto not been a practical feasibility. A monthly forecast goes beyond the currently accepted range of deterministic predictability but remains within the limit of influence of the initial conditions. It is intended to examine the possibility and worth of creating an ensemble of forecasts, each starting from a different state from within a range of initial states centred on the best available estimate of the actual initial state. Techniques will be developed to interpret, present and assess such an ensemble of forecasts relative to a soundly derived model climatology.

The study of particular characteristics of the numerical simulations including their sensitivity to changes in the initial and boundary conditions has continued. In particular, following the analysis of the spatial and temporal distributions of blocking features in the 50-day forecasts, more detailed analyses have been carried out to compare the dynamical and physical structures associated with blocking patterns which are simulated with those of the real atmosphere. They are also being examined to test various published hypotheses put forward to explain the onset and persistence of atmospheric blocking.

The sensitivity of monthly and seasonal forecasts from the 5-level model to anomalies of sea surface temperature is another major study (partially funded by the Climate Research Programme of the European Economic Community). Guidance on the sort of sea temperature anomaly to be studied is provided by the analyses of sea surface temperature and atmospheric circulation mentioned earlier, but the numerical experiments need to be very carefully designed if the effects of anomalies are to be distinguished from random fluctuations in the model.

Special investigations

Many requests for meteorological advice need work going beyond the routine extraction of data and the straightforward application of meteorological theory. Unless they are so specialized as to require the attention of one of the main research Branches, such requests are handled in the Special Investigations Branch which has built up considerable expertise in the assembling of fact and theory from diverse sources and their application to practical problems. These problems have arisen mainly in relation to aviation weather hazards, but there are also many non-aviation problems.

A principal theme of much of this work is the development of forecasting techniques, on the one hand to aid the local forecaster at outstations and on the other to produce forecasts of various parameters (mainly for automatic use) from the operational numerical model. The transfer or development of techniques for use on the new 15-level model due to replace the present 10-level model has now begun.

The local forecasting of fog, showers, stratocumulus and surface temperatures depends on careful mesoscale analysis, and improved techniques for this are being studied and developed. A study of the value of an acoustic sounder (measuring fog-top height) and a low-starting-speed anemometer in forecasting fog is being carried out at RAE Bedford. Forecasts of the surface temperature of roads and runways are of considerable practical importance, and as a first step special observations of temperature 5 mm below the surface of a concrete runway at Lyneham have been used to derive an empirical relationship for forecasting this quantity from observations of cloud, wind and surface wetness. The Branch also provides help with many investigations carried out locally by outstation staff. Most of them are concerned with forecasting weather at airfields and the Branch advises on data sources and methods of analysis. Similar services are provided for students on certain courses at the Meteorological Office College.

The increasing use of helicopters in adverse winter conditions, particularly in a rescue role and by the North Sea oil industry, 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 assembling appropriate climatological data. A unique set of data from cloud observations made on a regular basis by meteorological reconnaissance aircraft from several stations during and after the Second World War is being put into machinable form for climatological studies for helicopter icing.

Aviation authorities have long been concerned about the effect of low-level wind variations on the handling of large jet aircraft. 'Wind-shear' warnings provided by the Meteorological Office on a trial basis at the request of British Airways in 1977 have shown enough skill for a routine wind-shear warning service to be instituted. This has been on trial since February 1980 and may be adopted on a permanent basis in 1982.

Concern has been expressed that the wind supplied by air traffic control just before landing and take-off is often based on an anemometer centrally sited which may be unrepresentative of the wind experienced by the aircraft up to 3 km away. Automatic digital-logging equipment has been attached to the two Heathrow anemometers (3.2 km apart) to investigate spatial wind differences, and has recorded 12 months of uninterrupted data. The Civil Aviation Authority has set up a working group on surface-wind reporting to influence the implementation, in air traffic control procedures, of results reached by these and other studies.

There is an increasing demand, mainly on behalf of civil aviation, but also from military interests, for very large quantities of climatological data—an apparently straightforward task which, in practice, often requires considerable computer-programming expertise and time to extract and present the data in the form required. Recent examples have been the compilation for British Airways of climatological summaries of airfield meteorological data for 266 overseas airports and also of updated equivalent head-wind data used for flight-planning.

In the non-aviation sector, the volume of enquiries concerned with pollution has maintained a fairly high level. These are mainly concerned with advice to firms in forecasting the spread of chimney plumes and to help them plan emergency action in the event of a serious leakage of dangerous contaminants. A re-examination of the validity of atmospheric thermal stability indices used in this work has continued. A climatology of the frequency, distribution and intensity of thermal inversions is also being prepared.

Radio-meteorological enquiries are handled and are principally concerned with the effects of precipitation and evaporation ducts on microwave communication links. Consideration is being given to the possibility of producing numerical forecasts of the presence of evaporation and elevated ducts.

For the first time, an analysis of the climatological distribution of sferic sources ('atmospherics' or the radio interference generated by the electromagnetic radiation emitted by lightning flashes, and used to locate the storms for forecasting purposes) has been attempted and the patterns obtained correlate well with the distribution of surface reports of thunderstorms. This analysis yields valuable information on thunderstorm distribution over sea areas and will be used to evaluate stability indices for thunderstorm forecasting.

Methods of deriving forecasts of particular parameters directly and automatically from the output of numerical forecasting models are becoming increasingly important and progress is being made with several such methods. A particular forecast product used by airlines is the significant weather chart (SWC). These are at present prepared manually by the bench forecasters and indicate areas and flight levels where clear-air turbulence, icing and thunderstorms are likely to occur. It is planned to generate these SWCs from the operational model. Numerical forecasts of the probability of encountering at least moderate clear-air turbulence per 100 km of flight have been in operational production for a few months. The development of numerical forecasts of icing and thunderstorm areas has begun.

Upper-wind forecasting for aviation has long been a major service provided by the Meterological Office. A parameter of particular interest is the 'equivalent head-wind'. In flight-planning, airlines use wind forecasts to prescribe routes which usually represent a trade-off between minimum distance and minimum equivalent head-wind. Thus routine monitoring of the errors in the forecast product is necessary, and is at present being developed for the new operational model.

An objective technique has been developed, from a statistical analysis of two years of model forecasts, for forecasting the probability of precipitation up to three days ahead. Trials of this technique are being carried out at two outstations, the results being compared with similar forecasts made by subjective methods.

Library, Editing, Publications, Archives and Cartography

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 comprehensive holdings in its field, particularly of overseas climatological data, and is often able to supply information not readily available anywhere else in the world. The Monthly Accessions List, generally available by the 20th of the following month, contains on average some 750 entries and is the most up-to-date listing in the field.

The production of this Accessions List and other work connected with accessions is greatly helped by the computer-based Meteorological Office Library Accessions and Retrieval System (MOLARS), and all accessions since 1972 (100 000 items) are now recorded in the data base. The development of the second stage of MOLARS (search and retrieval) is going very slowly because of staff shortages.

A union catalogue of the rare books (published before 1850) held by the Royal Meteorological Society and the Library has been prepared using MOLARS and should be published early in 1982. This work was funded by a grant from the British Library.

The number of publications received by the Library during the year fell owing to the cessation of the UK and Danish *Daily Weather Reports* and other similar items. Because of the severe financial constraints of the past five years the purchase of journals and books for the Library and for supply or circulation to outstations has been under constant review; there is now little room for further manœuvre. Accessions to the Visual Aids unit were again high, particularly of satellite material. Liaison with other Government and local libraries has been maintained, leading to savings in time and money.

Loans continued at about last year's level but those to outside users were down to 12 per cent, some 3 per cent lower than in 1980. Visual Aid loans were lower than last year's peak numbers but again a large proportion of loans were to outside users.

Enquiries continued to cover the weather of the world, and indeed some come from as far afield as Baghdad, Mauritius and the Cayman Islands. Planning preparations for a round-the-world balloon trip, a Paris to Peking motor race, transatlantic yacht racing and airship operations have led to some of this year's enquiries.

Because of staff cuts the translator post was given up and Ministry of Defence Headquarters facilities are now used.

The Editing Section prepares for printing most of the official publications of the Office. The work has shown a slight increase in the number of publications handled compared with previous years. Most of the major items have been passed to Her Majesty's Stationery Office (HMSO), with whom the Section co-operates closely, but a growing number have been produced through Ministry of Defence facilities as a result of changes in HMSO policy, particularly items having limited sales potential outside official requirements. Works which were published during the year are listed in Appendix IV.

The distribution of publications is the main concern of the Publications Section which deals with scientific journals, textbooks, works of reference, observation forms, and a wide selection of internal administrative material. Since the beginning of the year copies of most 'in house' Meteorological Office publications not specifically intended for internal use only have been sent to Chadwyck-Healey Ltd of Cambridge, for inclusion in their *Catalogue of British Official Publications (not published by HMSO)*.

Close liaison has been maintained with the Copyright Section of HMSO on questions concerning the use of Crown Copyright material by commercial publishers.

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 a large number of people from both inside and outside the Office.

The Cartographic Section prepares artwork for Meteorological Office publications, for internal memoranda and for papers contributed to scientific journals by members of the staff. It also prepares data-entry forms, exhibition displays, viewfoils, slides and lecture aids, and the large number of diagrams and charts for various areas of the world that are used for manual and automatic plotting of meteorological observations or for transmission by facsimile machines.

Following the closure of the local HMSO press at the end of 1980, the Section has liaised directly with contract printers assigned by HMSO; almost all maps, charts and data-entry forms are handled in this way. In addition, a large volume of miscellaneous printing is dealt with by use of Ministry of Defence reprographic facilities.

Statistics on the work of the Library, Archives and Cartographic Section are given in Table XVI (page 121).

PROFESSIONAL TRAINING

Policy on the professional and managerial training of Meteorological Office staff is determined by the Meteorological Office Training Board, under the chairmanship of the Director-General. Most of the formal professional training is carried out at the Meteorological Office's own residential College or its School of Technical Training. Some staff, however, attend specialist courses outside the Office. The College maintains contacts with neighbouring Colleges of Technology, the University of Reading, the European Centre for Medium Range Weather Forecasts (which is next door), the British Council, the Royal Naval School of Meteorology and Oceanography, the Royal Electrical and Mechanical Engineers' School of Electronic Engineering at Arborfield and other relevant bodies.

The Meteorological Office College is situated at Shinfield Park, south of Reading. It accommodates just over 100 students and carries out training in basic meteorology as well as in forecasting, observing and related topics. The College is well equipped for class-room teaching, for making instrumental observations, for field-work, for the analysis and use of meteorological data and for briefing training, including the use of closed-circuit television and video recording. It has a cinema which seats 94, two lecture theatres and 13 class-rooms, including one designed for tuition on instruments. It has a computer with seven visual display units for students' use: the computer can be linked to the COSMOS main-frame computer at Bracknell. An important part of many courses is the simulation of the work in operational forecasting offices. For this purpose, current meteorological observations from many parts of the world, including those obtained by satellites, are received by teleprinter, by facsimile and through the computer link.

The grounds of the College provide room for field-work, the siting of instruments and for relaxation. Cricket, football, putting and croquet are played in the Park. Other recreational facilities include three tennis courts, a squash court, a bar and rooms for table tennis and television (fitted to receive Teletext broadcasts).

When the College is full, some courses are accommodated at Boundary Hall, Tadley, some 10 miles away, and are transported to and from the College by private coach. Teaching is always at the College but students on such courses may use recreational facilities at both Shinfield Park and Boundary Hall.

Whilst most courses are designed for staff of the Meteorological Office, when places are available they are open to students nominated by other meteorological services. Occasionally courses are devised and run entirely for members of other services. Fees are paid in advance. Enquiries should be addressed to: The Principal, Meteorological Office College, Shinfield Park, Near Reading, RG2 9AU.

The general pattern of courses has been similar to that of previous years and is summarized in Table XVII. The total number of students completing courses this year was 620. On the Scientific Officers' Course which began in the autumn, for those with good honours degrees (usually in mathematics or physics), there were 24 students: 18 came from the Meteorological Office, 3 from Malaysia and 3 from Hong Kong; 4 hold doctorates, 2 have completed their doctoral studies and 8 have other higher degrees or postgraduate qualifications. The Applied Meteorology Course is for new entrants with a first degree or Higher National Certificate and for existing staff who are similarly qualified. The course which ended early in the year had 20 students, including 3 from Hong Kong, 1 from Jamaica, 1 from Lesotho and 1 from Malaysia. The course which began this autumn was rather smaller with 9 Meteorological Office students and one each from Iraq, Zimbabwe and Switzerland. Students from this course go on to become support scientists or, after further training on the job, forecasters.

The other course concerned with basic training in forecasting is the Initial Forecasting Course. In 1981 it too was smaller than in recent years: there were two students each from the Office, from Belgium and from Saudi Arabia and one each from Bahrain, Brunei, Hong Kong and Malta. Some took the course as an integral part of their studies in the University of Reading for the MSc or the Honours BSc degree in meteorology. Arrangements for the latter changed this year: it is no longer formally a Sandwich Course. So that students may obtain both a good degree and real experience in meteorology, however, they may continue to gain work experience in the Office in addition to their academic work at the University. Work experience is usually in a forecasting unit, though members of the staff of the Office also gain experience in one or more Headquarters Branches. This year two members of the Office completed the BSc course at Reading and graduated with Honours.

After several years' experience forecasters normally return for a 7-week Advanced Forecasting Course. Members of the Office who join this course are usually Scientific Officers in the field for promotion to Higher Scientific Officer. This year four courses were held for a total of 15 students from the Office and 16 from other services, including three from western Europe and 10 from International Aeradio Limited.

To implement the policy of providing refresher courses for Higher Scientific Officers (HSOs) at intervals of 5–10 years, three Extension Courses were run again this year. On these 4-week courses 28 HSOs and 5 members of overseas services revised their knowledge of synoptic meteorology and brought it up to date. They were also guided in the choice and prosecution of a project which they undertook in order to help them later to conduct minor investigations into the weather in the areas for which they are responsible. Five or more years after their Extension Course HSOs may follow a Further Extension Course. This lasts three weeks and is intended to deepen the students' insight, especially into the use of numerical weather prediction products. One Further Extension Course was held this year for 10 members of the Office and a Major of the Royal Netherlands Air Force. Teams from both the Royal Air Force and the Royal Navy gave presentations at the College during the year.

In April a 3-day residential seminar on the Management of Scientific and Technical Activities was held for staff at about the Principal Scientific Officer level.

Assistant Scientific Officers (ASOs) who have newly joined the staff and are to work initially in support roles at Headquarters and in research teams at outstations attend a 4-week course in Basic Meteorology. New ASOs who will work in forecasting and observing units, on the other hand, normally begin their training on an Initial Assistants' Course. On this 4-week course they are taught plotting, coding and the making and transmission of observations. Afterwards, as after all initial courses whether for assistants or forecasters, training continues at the station. This training on the job is regarded as an essential part of the Office's training program. After about three years, ASOs from forecasting and observing offices attend the Advanced Assistants' Course which provides a review of basic skills, training in basic meteorology and elementary instrument maintenance. This course was shortened from six weeks to four weeks during the year. Four Initial, one Basic and four Advanced Courses were held. In addition two Extension Courses were held for ASOs with long experience.

The 4-week Scientific Officers' (Supervisors) Course continues to serve as a refresher course. In addition a new 3-week Initial Supervisors' Course was devised for SOs newly promoted to fill supervisory posts. Two of the former and three of the latter courses were held. At a higher level the 3-week Senior Meteorologists' Course aims to give Senior Scientific Officer forecasters and support scientists a broad view of recent developments. One such course was run this year and was attended by meteorologists from Belgium and Hong Kong as well as from many parts of the United Kingdom. While restrictions on recruitment and tighter manning levels throughout the Office led to fewer courses and fewer people attending them, separate courses continued to be run at the College for observers who man the Auxiliary Reporting and Climatological Stations in the UK and for Royal Air Force and civilian Air Traffic Control staff who make weather observations at some aerodromes. College instructors gave four short courses at HM Coastguard School at Brixham. Three initial courses for staff who use computers were also well attended. Such courses are followed by six to nine months' training on the job. Those using the COSMOS computer system then take a 2-week second course. Some of the lectures on these courses are given by data-processing specialists, one of whom regularly acts as a full-time instructor during the courses. This training of computer users is the main role of the College's PDP 11/34 minicomputer and its visual display terminals. The computer is also used to support other courses such as the Scientific Officers' Course, the Extension Course and the course in Meteorological Statistics. Using the computer's link to the COSMOS system, observations from around the world are available within an hour or two of their being made. This adds reality to courses such as that in Tropical Meteorology and makes it possible to instil a global view of the atmosphere.

Especially for students from overseas, courses were also held in the maintenance of instruments. Eight attended one on non-electronic instruments, two from Tanzania, three from Libya and one each from Bangladesh, Malawi and Lesotho. Ten weeks were spent learning general engineering skills at Farnborough College of Technology and then six weeks in applying these skills in the repair and maintenance of specifically meteorological equipment. In addition, the College Registrar co-ordinated arrangements for an international course in Basic Electronics at the Reading College of Technology. The course will last for five terms and be followed by instruction in meteorological instruments within the Office.

Members of the College staff produced training packages to assist outstations and Auxiliary Observers in implementing the new Common Surface Reporting Code. All courses starting in the autumn used the new code *ab initio*. This was greatly assisted by the provision over the computer link with Bracknell of current weather data which COSMOS had recoded into the new format.

With rather fewer students this year there has been more opportunity to use the College for meetings and conferences. The Meteorological Committee met at the College in January, July and October. There were several well-attended conferences arranged under the auspices of the World Meteorological Organization, NATO, and European and national bodies with meteorological interests, as well as other Branches of the Office.

Staff joining the Meteorological Office as Assistant Scientific Officers are expected to improve their scientific qualifications by further study, usually at technical colleges and colleges of further education. The number of staff released for part-time study this year was 101. A further 34 members of staff are taking Open University or other Further Education Courses with assistance under the Civil Service Further Education scheme. In addition, 29 staff began, or continued with, block release courses at the Reading College of Technology for the Higher National Certificate. In particular a Business Education Council/Technician Education Council Course at this level, in mathematics, statistics and physics, was well supported. These block release courses consist of four six-week periods of full-time study spread over two years. During these periods staff live at Shinfield Park or at Boundary Hall. Ten members of the staff took their final examination this year, eight were successful and one had to sit one subject a second time. During the year another 10 members of the staff were on Special Leave with pay for full-time University studies or to attend sandwich courses. In addition, 14 were on Special Leave without pay for first-degree studies and four graduates continued to take advantage of a scheme under which they work in the Office and, at the same time, study towards a PhD degree. Under this scheme supervision is shared between the Office and the University. This year co-operation was with Oxford, Reading and Southampton. Support was also given to three members of the Office to attend one-week Field Study Courses run by the Royal Meteorological Society.

The training of technical staff continues to reflect the variety and complexity of electronic equipment in or entering service. As last year, the training of Radio (Meteorological) Technicians was carried out at the School of Electronic Engineering, Arborfield, by Army staff, and at Shinfield Park. Further training of the technicians who develop, install and maintain radars, computers, microprocessors, and communications and facsimile sets and so on continues at Shinfield Park and Beaufort Park. (Five members of the Royal Navy attended such courses in the Office in 1981.) Staff who operate the equipment for routine sounding of the atmosphere are trained at Beaufort Park and at the radiosonde outstations.

Technical staff in the telecommunication field are given training in the operation of new equipment and new procedures by a full-time telecommunication training officer. This officer also provides telecommunication staff with suitable trade and refresher training in their basic duties and new entrant ASOs with an introduction to telecommunications. Scientific colleagues of his gave practical training to staff at six Main Meteorological Offices in operating microcomputer-based systems (AUTOPREP) which were installed during the year to facilitate the collection of observations.

Table XVII shows the number of students from overseas who have attended courses at the Meteorological Office College and the School of Technical Training during the year. Most were sponsored by their governments, by the World Meteorological Organization (WMO) or under United Nations Development or British Technical Assistance Programs. In addition 19 students from 11 countries completed 143 weeks of practical training on the job, both at forecasting outstations and at Headquarters.

The Office continues to support the Voluntary Co-operation Program (VCP) of WMO. VCP Fellows from Ghana, Nepal, Tanzania and the Netherlands Antilles are reading for first degrees in meteorology at the University of Reading and two Fellows from Tanzania are reading for higher degrees in agricultural meteorology. One VCP Fellow from Nigeria graduated as BSc from the University of Reading this year and one from Jamaica as MSc. A VCP Fellow from Botswana began a two-year post-graduate course at the University of Essex leading to a Diploma in telecommunication systems management. In addition VCP Fellows from Jamaica, Seychelles, Kenya (2) and Zimbabwe began the 5-term Basic Electronics Course at the Reading College of Technology; one from Zimbabwe attended the Applied Meteorology Course at Shinfield Park and one from Kenya attended the Extension Course there.

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 June, and recommended the award of 7 grants totalling £55 000. Eleven 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.

K. H. Stewart
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY, ARCHIVES AND CARTOGRAPHIC SECTION

Library	
Publications received:	
Books, journals, etc.	6724
Daily weather reports	8715
Films, slides and photographs	5394
Individual books, pamphlets, articles, etc. classified and catalogued	9803
Publications lent:	
Books, journals, etc.	16 458
Daily weather reports	7505
Films, slides and photographs (387 occasions)	8310
Requests met by photocopies or copy microfiche	882
Number of exchange agreements	1105
Number of pages translated by MOD translators	457
Number of pages translated by outside translators	26
Archives	
Documents received from Headquarters Branches:	
Charts for permanent retention	23 600
Charts for limited retention	26 400
Ships' logbooks	1500
Rainfall cards for 1978 (number of stations)	5060
Documents received from outstations:	
Daily Registers	1956
Autographic charts (station-months)	1600
Radiosonde data from OWS Base, Greenock (station-years)	10
Enquiries dealt with:	
Charts extracted for perusal by visitors	59 500
Loans to Headquarters Branches	292
Cartographic Section	
Number of diagrams, maps and charts completed during 1981	3168
Number of reprographic jobs during 1981	501

TABLE XVII—TRAINING

The following figures give details of courses completed during 1981 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 I	1	14	18	6	24
Applied Meteorology Part II (1980)	1	9	0	6	6
Applied Meteorology (Prep) (1981)	1	3	6	1	7
Applied Meteorology Part I (1981)	1	9·6	9	3	12
Initial Forecasting (Prep)	1	2	0	7	7
Inital Forecasting	1	16	2	8	10
Advanced Forecasting	3	7	15	13	28
Advanced Forecasting	1	6	0	3	3
Extension	3	4	28	5	33
Further Extensions	1	3	10	1	11

TABLE XVII *(continued)*

	Number of courses	Length in weeks	Met. O. staff	Others	Total
Senior Meteorologists	1	3	11	1	12
Tropical/Mediterranean Meteorology	1	3	0	8	8
Initial Programmers	2	4	19	0	19
Second Programmers	2	2	23	0	23
Initial Assistants	4	4	36	1	37
Advanced Assistants (1980/81) ...	1	6	12	1	13
Advanced Assistants (1980/81) ...	2	4	14	2	16
Extension Assistants	2	4	23	0	23
Scientific Officers (Supervisors) (Initial)	3	3	30	0	30
Scientific Officers (Supervisors) ...	2	4	21	0	21
Auxiliary and Co-operating Observers	10	1	0	129	129
Air Traffic Control Observers ...	5	1	0	59	59
Saudi Arabian Observers ...	1	8	0	11	11
Instrument Maintenance ...	1	6	0	8	8
Management, Scientific and Technical	1	0.6	21	0	21
ASO/R(M)T Conversion ...	1	20	11	0	11
Data Processing Unit	1	2	8	0	8
Facsimile	1	2	1	5	6
Speech + Duplex	1	2	7	0	7
Mk 3 Radiosonde	1	2·4	9	0	9
SAWS (Hardware)	1	2	4	0	4
SAWS (Software)	1	2	4	0	4
Totals	... ...	... ...	342	278	620

Students from the following territories attended courses which terminated during 1981.

	Number of students
Brunei	1
Bahrain	5
Bangladesh	1
Belgium	6
Guernsey	1
Hong Kong	8
Iraq	1
Territories served by International Aeradio Ltd	10
Ivory Coast	1
Jamaica	1
Jersey	2
Kenya	1
Lesotho	2
Libya	5
Malawi	1
Malaysia	4
Malta	1
Netherlands	2
Saudi Arabia	13
Switzerland	1
Tanzania	2
Zimbabwe	1
Total	70

ADMINISTRATION

Personnel Management

Introduction

Meteorological Office staff serve at over 100 locations in the United Kingdom and overseas. About 40 per cent of the staff work at the Headquarters at Bracknell, and the numbers at other stations range from about 130 at London/Heathrow Airport to only 2 at some Port Meteorological Offices. This wide diversity of station complement poses a number of management problems not usually encountered in other areas of the Civil Service. Personnel Management for the majority of staff, including all those in the scientific and technical grades, is undertaken centrally by the Secretary of the Meteorological Office and, under him, the Assistant Director and staff of the Personnel Management Branch at Bracknell. Thus the career prospects of staff are viewed as a whole and the opportunities open to them do not depend on the location or size of a particular unit. Central control also yields the benefits of maximum flexibility in meeting varied staff requirements. On 1 December 1981 the Director-General was given authority, within certain limits, to allocate manpower resources throughout the Office. Hitherto this has been the responsibility of the Air Force Department's Inspectorate of Establishments. The delegated powers are now vested in the Secretary of the Meteorological Office and his staff.

Manning and manpower planning

Foremost among problems encountered during the year was the requirement to make a proportional contribution, about 200, to the reduction in the size of the Civil Service. Only 11 staff were made redundant following transfer to a private firm of catering at the College at Shinfield Park. All other staff reductions were effected through normal retirement, resignation and so on, and in a few cases through early retirement. Fortunately there was still room for some limited recruitment of graduates and basic grades. Manpower-planning computer programs developed by the Civil Service Department were used to monitor promotion and recruitment needs within the revised staff limits, while statistics of staff numbers, promotion, recruitment and wastage patterns produced by the Defence Economic and General Statistics Division of MOD in co-operation with the Personnel Management Branch were used as the basis for computer-based manpower planning projections. Short-term projections showing the effects of complement reductions on promotion and recruitment were made alongside longer-term projections showing the effects of natural wastage on grade sizes and the needs for recruitment of basic grades.

Movements of most members of the staff are administered by a small unit at Bracknell known as the 'Manning section', though Principal Meteorological Officers at outstations may arrange short-period attachments. The requirement to man the majority of posts at outstations and a substantial number at Headquarters 24 hours a day, 7 days a week, demands careful planning coupled with a high degree of mobility. During 1981 the number of postings averaged 16 a week. Consultation with line managers and the Career Development section helps to ensure, as far as possible, that due account is taken both of the long-term needs of the Office and the preferences of the individual. A close liaison is maintained with the trade union local branches.

Recruitment

The Personnel Management Branch has delegated authority to recruit most grades employed in the Office in accordance with regulations laid down by the Civil Service Commission, but the recruitment of graduates is in concert with the Commission's annual centralized exercise. The number of graduates recruited fell just short of the target of 17, with 14 being appointed. A nation-wide recruiting exercise was held for Assistant Scientific Officers and 42 were appointed. Vacancies in clerical, data processing and industrial grades at Bracknell were advertised locally. The response was massive and all targets were met without difficulty. To meet temporary requirements at the Meteorological Office College several industrial employees were recruited on a casual basis pending the change to contract services. A number of university and polytechnic students joined the Office for limited periods, 5 College-based Sandwich Course students commenced their industrial training during the year and 7 vacation students were employed during the summer. The Office co-operated with several local schools in Work Experience Schemes and with the Manpower Services Commission in the Youth Opportunities Program for industrial staff.

Records

Personal records, staff reports and career histories for the majority of staff are held in the Records section. Basic information and details of postings, promotions, etc. are held on the Ministry of Defence Civilian Personnel Management Information System (CIPMIS). Greater use is now being made of CIPMIS for a variety of management purposes and it is envisaged that the system will develop to allow a wider range of data to be held, and to give a faster retrieval of information and greater flexibility in presentation in support of Promotion Board procedures. Secretarial work for the Meteorological Office Promotion Boards and Main Career Development Panel is carried out by the Records staff in conjunction with the Careers section. The Records section also provide general administrative support in respect of matters such as Special and Sick Leave.

Career development

The aim of the Careers section is to encourage the development of individual potential, the achievement of individual job satisfaction, and thus the most effective use of the Office's manpower resources. Annual appraisals of the performance of each individual by his line manager are documented in detail and the reports scrutinized by a Careers Officer who initiates action on any recommendations made. Over the last few years considerable effort has been devoted to training line managers to develop the skills required to prepare Staff Reports and to carry out Job Appraisal Reviews. Career Interviews are conducted at intervals of a few years on the initiative either of the individual or the Personnel Branch. Many Career Interviews during 1981 were with staff affected by complement reductions, but despite a cut in the staff of the Careers section the number of interviews conducted was very close to the 1980 figure.

Another important factor in the development of an individual's potential is training, either to improve his performance in his current job or to equip him for a wider range of duties. The Training Liaison Officer co-ordinates arrangements for attendance at professional and management training courses and maintains a training record for each member of staff. Extensive use is made of facilities for management training at the Civil Service College and the Ministry of Defence Management Studies Centre. Concessions for external studies are also co-ordinated by the Training Liaison Officer; 75 per cent of new applications for Higher National Certificate, Technician Education Council and 'A' level courses were granted.

International co-operation

The following staff were released by the Office during 1981 for service with international and other organizations:

Dr T. N. Palmer	SSO	University of Washington, Seattle, USA
Mr B. J. Davey	HSO	International Aeradio Ltd
Mr J. Rowe	HSO	International Aeradio Ltd
Mr R. J. Young	HSO	International Aeradio Ltd
Mr W. J. Oxley	HSO	International Aeradio Ltd
Mrs H. J. Booth	SO	National Economic Development Council

Staff returning from international and other secondment appointments were:

Mr C. A. Brimacombe	HSO	European Space Agency
Mr G. C. Bridge	HSO	European Space Agency
Mr D. E. Bashford	ASO	European Space Agency
Mr P. J. R. Smith	TTO III	Seychelles Government
Mr J. R. Maxfield	HSO	Seychelles Government
Dr A. O'Neill	PSO	University of Washington, Seattle, USA
Mr M. A. Blandford	ASO	British Antarctic Survey
Mr D. S. Handley	STO	International Aeradio Ltd

Staff numbers

At the end of 1981 the total number of posts of all grades was 2885, a decrease of 167 over the year. The actual strength at the end of the year was made up as follows:

Deputy Secretary	1
Under Secretary	2
Science Group	
Chief Scientific Officer	1
Deputy Chief Scientific Officer	6
Senior Principal Scientific Officer	26
Principal Scientific Officer	110
Senior Scientific Officer	275
Higher Scientific Officer	478
Scientific Officer	456
Assistant Scientific Officer	780

Administration Group	
Assistant Secretary	1
Principal	1
Executive grades	32
Clerical grades	126
Marine Staff	
Marine Superintendent	1
Nautical Officer grades	14
Ocean Weather Ships	
Officers and non-industrial grades	42
Crew and industrial grades	45
Professional and Engineering Staff	
Principal Professional and Technology Officer	1
Professional and Technology Officer Grade I	4
Professional and Technology Officer Grade II	7
Professional and Technology Officer Grade III	5
Professional and Technology Officer Grade IV	5
Technical and Signal grades	270
Typing and miscellaneous non-industrial grades	137
Industrial employees	66
Locally entered staff and employees overseas	51

EQUIPMENT

The general constraints upon public expenditure and, in particular, upon equipment Votes had an impact on the rate of implementation of many equipment programs, and occasionally impaired the level and quality of support that could be provided to existing systems. The resources of the Meteorological Office's supply organization were stretched to maintain a viable service, especially as the recruiting ban meant that it was 30 per cent below strength for most of the year.

In June 1981 the stores organization and the Test Room facilities in the Simpson Building in Bracknell were seriously affected by flood-water. Though many pieces of equipment and stores were immersed, losses were minimized by the staff's prompt action.

FINANCE

Except for the services provided by the Property Services Agency on an allied service basis, the cost of the Meteorological Office is borne by Defence Votes to which all receipts from repayment services are also credited.

The finance sections of the Secretary's department of the Office cover cost and management accounting, financial control and expenditure monitoring, and cash expenditure, receipts and accounting. The emphasis has continued to move from the traditional Vote and cash to cost and management accounting. From the latter is derived the Memorandum Operating and Trading Account (MTA).

The reporting of staff time in relation to activities is done on a selective basis although a more frequent system of reporting was introduced during the year. Difficulties experienced in the past were eased somewhat by the computer processing of initial inputs on COSMOS using Fortran. This scientific language is not ideal for administrative and financial purposes, and planning has continued towards using a commercial data-base management system. This will also use tape input from the Accounts Directorate at Bath to provide payroll and travel and subsistence data without the need for the present manual transfer. The aim is the more rapid production of management information for project and budgetary control.

The following tables, drawn from the MTA, show the operating expenses of the component parts of the Office for the year 1980/81: the cost of carrying out the major functions of forecasting, collecting and processing observations, etc. and the income receivable from repayment services. It should be noted that total costs for charging purposes are somewhat greater than the figures shown in the tables and in Defence Estimates because they include certain notional sums which a commercial organization would have to bear. An example is insurance premiums which are not included in Voted expenditure because the Government bears its own risks. Receipts from other Government Departments are at 'Exchequer' rates. These preferential rates ceased from 1 April 1981 so that next year the accounts will reflect increased receipts from these services.

The tables include figures for the previous year, 1979/80. Costs for charging purposes increased by just over 18 per cent, marginally more than inflation because of the staging of Civil Service pay awards. On the other hand, receipts rose by 22 per cent, giving an increase in real terms of 4 per cent. If the major customer, the Civil Aviation Authority, to whom the increase in charges was 17½ per cent, is excluded the remaining repayment receipts increased by a quite dramatic 49 per cent.

STATEMENT OF OPERATING EXPENSES BY METEOROLOGICAL OFFICE FUNCTIONS FOR THE YEAR ENDED 31 MARCH 1981

	1980/81		1979/80	
	£000	£000	£000	£000
Main functions				
1. Making and handling observations	9683		8430	
2. Forecasting	10 082		8331	
3. Meteorological (including climatological) advice ...	4646		3702	
4. Research and development	6300		5794	
		30 711		26 257
Supporting functions				
5. Administration	2211		1899	
6. Technical support	4838		3463	
7. International activities	1493		1282	
8. Computer services	2734		2323	
9. Telecommunications	5745		4759	
		17 021		13 726
		47 732		39 983

STATEMENT OF OPERATING EXPENSES OF THE METEOROLOGICAL

(1) Expenditure	(2) Offices at RAF stations £000	(3) Office at CAA/ATCC stations £000
1. Personnel (pay, allowances, ERNIC and Superannuation) ...	7639	4881
2. Materials (stores, minor equipment, maintenance, ships' expenses, etc.) ...	343	162
3. Staff travel and subsistence ...	141	79
4. Accommodation ...	842	121
5. Office support (stationery, office machines, etc.) ...	75	55
6. Telecommunications ...		
7. Equipment support (aircraft and motor transport) ...	109	
	9149	5298
8. North Atlantic Ocean Station (NAOS) operating cost receipts ...		
9. Grants and subscriptions:		
Research Grants ...		
Grants to World Met. Organization ...		
Subs to World Met. Organization ...		
World Weather Watch upper-air stations Overseas ...		
Subs to ECMWF ...		
Training expenses of Voluntary Co-operation Program of World Met. Organization ...		
European Space Agency Meteosat Program ...		
First GARP Global Experiment (FGGE) contribution ...		
European Network of Ocean Stations (ENOS) ...		
Co-operative Automatic Weather Radar ...		
North Atlantic Ocean Station (NAOS) contribution ...		
10. Other expenditure:		
Payment to auxiliary observers ...		
Manufacturers' courses ...		
	9149	5298
11. Depreciation (Historical):		
Equipment ...	39	26
Computers ...		
Ships ...		
Aircraft ...		
	9188	5324

*Operating expenses of research outstations have been included in column 7.

OFFICE FOR THE YEAR ENDED 31 MARCH 1981.

(4) Weather centres £000	(5) Other met. services outstations* £000	(6) Met. Office HQ Directorates Met. services £000	(7) Research £000	(8) Admin. £000	(9) 1980/81 Total £000	(10) 1979/80 Total £000
1926	4123	8368	3649	1635	32 221	26 039
81	1955	994	621	104	4260	3502
30	83	147	83	25	588	569
211	343	1098	969	441	4025	3312
21	49	94	49	26	369	328
		1271			1271	1122
	33	56	1248	30	1476	1215
2269	6586	12 028	6619	2261	44 210	36 087
	(2316)				(2316)	(1972)
			36		36	32
		230			230	142
		464			464	467
		156			156	143
		647			647	533
		60			60	45
		696			696	1066
		—			—	16
		5			5	1
		—			—	46
		1474			1474	1445
		98			98	80
		2			2	8
2269	4270	15 860	6655	2261	45 762	38 139
9	163	120	92	1	450	451
	125	641	10		776	649
	492				492	492
			252		252	252
2278	5050	16 621	7009	2262	47 732	39 983

METEOROLOGICAL OFFICE RECEIPTS 1980/81 (CASH RECEIVABLE)

	1980/81			1979/80
(1)	(2) £000	(3) £000	(4) £000	(5) £000
SERVICES TO:				
Ministry of Agriculture, Fisheries and Food			172	120
Other Exchequer Departments (Department of the Environment etc.)			47	72
Civil Aviation Authority			12 886	10 951
Natural Environment Research Council			27	24
Other non-Exchequer Departments			107	58
			13 239	11 225
Meteorological Office College—Training of meteorologists ...			190	140
Secondment to outside bodies			69	61
Comprehensive forecasting service for the offshore oil industry ...		772		508
Forecasting services developed to meet individual user's special needs:				
Ship Routeing Service	87			57
Gas Boards	143			106
Central Electricity Generating Board	90			71
British Rail	12			8
Independent Broadcasting Authority	32			20
British Broadcasting Corporation	44			33
Press	11			21
Other customers' special services	50			72
		469		
Automatic Telephone Weather Service (British Telecom) ...		225		178
Issue of forecasts by prior arrangement	32			8
Issue of local detailed forecasts by prior arrangement	4			4
Issue of forecasts up to 24 hours in advance	115			65
Issue of expected occurrences of specified weather (Frost, Fog, etc.)	78			50
Comprehensive forecasting service for the construction industry	1			—
Pigeon-racing forecasts	8			7
Consultancy service for farmers and growers	4			1
Issue of road-danger warnings	50			39
Issue of weekend temperature forecasts	8			7
Consultations on present or future weather	9			1
Investigations and other professional work as required	190			97
Preparation of Weekly, Monthly and Annual Weather Summaries	15			15
Preparation of Certified Statements	23			24
Outside attendances by professional staff (Court appearances) ...	5			1
Supply of copies of data/records	56			56
Daily Weather Reports/Publications/Met. Forms	36			11
Other services	164			11
		798		
			2 264	
			15 762	12 897

F. R. HOWELL
Secretary
Meteorological Office

STAFF HONOURS AND DISTINCTIONS

The Institute of Physics awarded the Charles Chree Medal and Prize to Dr K. A. Browning for his application of radar techniques to meteorological problems.

Mr A. Hemmings, Mr C. E. Millington and Mr E. J. Perrow were each awarded the Imperial Service Medal.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

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WOODROFFE, A.; The Fastnet storm—a forecaster's viewpoint. *Meteorol Mag*, **110**, 1981, 271–287.

APPENDIX II

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

BACON, J. D.
Discussion of American weather presentation. *BBC TV 'Swop Shop'.* 14 March.
Broadcast about the heavy snow. *BBC TV 'Nationwide' and TV News.* 27 April.

BADER, M. J. and BENNETTS, D. A.
Precipitation from convective storms. *Royal Meteorological Society Discussion Meeting, London.* 15 April.

BENNETTS, D. A.
Three papers presented: (1) Precipitation in convective storms: an observational and numerical study, (2) Microphysical and dynamical measurements in a cumulus anvil, (3) A study of mesoscale convective bands. *IAMAP Third Scientific Assembly, Hamburg.* 17–28 August.

BEST, K. E.
Weather and energy conservation. *Southern Gas, Gas Energy Management Awards, Southampton.* 21 October.
Weather forecasts and their presentation on television. *Royal Television Society, Southern Centre, Southampton.* 28 October.

BROWN, A. A.
Introduction to weather. *Series of lectures to West Bromwich and Birmingham Schools.* 9–25 June.
Meteorology. *Series of lectures at the Department of Extra-Mural Studies, University of Birmingham.* 30 September to 2 December.

BROWN, D. W.
Weather and weather forecasting. *Series of 10 weekly lectures, Workers' Educational Association, Chippenham.* January to March.
Weather and the oceans. *Series of 10 weekly lectures, Workers' Educational Association, Pewsey.* January to March.
Meteorology for fall-out prediction. *Annual Conference of Royal Observer Corps Southern Sector, Malvern.* 21 March.
Weather and weather forecasting. *Women's Institute, Ogbourne St Andrew Branch, Wilts.* 23 April.
Half-day school on 'Weather and weather forecasting', Workers' Educational Association, Seend, Wilts. 26 September.

BROWNING, K. A.
Weather in the satellite age. *Institute of Electrical Engineers, Worcestershire Sub-centre, Evesham.* 9 February.
Maximizing the usefulness of rainfall data from radars. *COST 72 Workshop/Seminar, ECMWF, Shinfield Park.* 9 March.
Structure and mechanism of orographic rain. *Royal Meteorological Society Discussion Meeting, London.* 15 April.
Short-period weather forecasting using radars and satellites. *McGill University, Montreal.* 4 May.
Airflow within frontal systems and the associated rainfall. *Royal Meteorological Society, Manchester Centre.* 14 May.
Two lectures: (1) A total system approach to a weather-radar network, (2) The use of climatological and synoptic data for forecasting orographic enhancement of rainfall. *IAMAP Third Scientific Assembly, Hamburg.* 26 August.

Two lectures: (1) Maximizing the usefulness of rainfall data from radars, (2) Interesting weather events as seen by the UK weather-radar network and Meteosat. *Technical University of Denmark, Copenhagen.* 31 August.

Two lectures: (1) A total system approach to a weather-radar network, (2) Interesting weather events as seen by the UK weather-radar network and Meteosat. *Royal Netherlands Meteorological Institute, De Bilt.* 24 November.

Rain in the Welsh hills. *Royal Meteorological Society, Welsh Centre, Swansea.* 26 November.

BRUCE, W. J.

Meteorology and energy problems. *Watt Committee on Energy, University of Reading.* 11 September.

BRYANT, G. W.

Use of graphics hardware in the Meteorological Office. *Seminar on Graphical Applications in Meteorology, ECMWF, Shinfield Park.* 21 October.

CARSON, D. J.

Current parametrization of land-surface processes in atmospheric general circulation models.

Study Conference, NASA Goddard Space Flight Center, Greenbelt, Md. 5–10 January.

Royal Meteorological Society Discussion Meeting, London. 16 December.

Two lectures: (1) Development of seasonal prediction techniques using atmospheric models, (2) The sensitivity of atmospheric general circulation models to the land-surface properties and processes. *First meeting of the contact group 'Contact Modelling' of the EEC Climatology Research Program, Brussels.* 26–27 May.

The influence of land-surface albedo and soil-moisture content on the hydrological cycle as simulated in an atmospheric general circulation model. *IAMAP/IASH Symposium on Variations in the Global Water Budget, Oxford.* 10–14 August.

The parametrization of boundary-layer processes in the Meteorological Office 11-layer general circulation model. *Workshop on Boundary-layer Parametrization, ECMWF, Shinfield Park.* 25–27 November.

CARPENTER, K. M.

Use of radar network data for forecasting rain. *COST 72 Meeting, Shinfield Park.* 10 March.

A mesoscale forecast for 14 August 1975—the Hampstead storm. *IAMAP Third Scientific Assembly, Hamburg.* 27 August.

An interactive display system for radar data. *Seminar on Graphical Applications in Meteorology, ECMWF, Shinfield Park.* 21 October.

CAUGHEY, S. J.

The convective boundary layer. *Royal Meteorological Society, Manchester Centre.* 10 February.

Current weather and contents of forecasts. *BBC Radio Ulster 'Breakfast Special'.* 14 July.

Poor late spring and summer weather in Northern Ireland. *Ulster TV.* 21 July.

CLOUGH, S. A.

Numerical model studies of an observed sudden warming. *IAMAP Third Scientific Assembly, Hamburg.* 20 August.

COCHRANE, J.

Weather and cereal farming. *Cereals Consultancy Group, ADAS, Lincoln.* 20 January.

Weather and drainage. *Drainage Contractors Group, Market Harborough.* 2 February.

An interdisciplinary approach to pest control (jointly with B. Emmett). *Entomology Group, Association of Agricultural Biologists, London.* 25 February.

Meteorological advice in pest-control strategies. *ADAS Entomologists Conference, Malvern.* 27 October.

COCKRELL, P. R.

A new approach to the production of contour charts. *Seminar on Graphical Applications in Meteorology, ECMWF, Shinfield Park.* 21 October.

COLLIER, C. G.

Local weather forecasting. *'Conference Computers in Visual Communication'—International Conference and Exhibition, London.* 13 January.

Three lectures: (1) The United Kingdom weather-radar network, (2) On the accuracy of radar rainfall data, (3) Merging data from several weather radars. *COST 72 Workshop/Seminar, ECMWF, Shinfield Park.* 9–10 March.

Microwave radar for the remote measurement of precipitation. *Royal Meteorological Society Discussion Meeting, London.* 11 April.

Measurements of rainfall by radar. *Conference of River Engineers, MAFF Land and Water Service, Cranfield.* 7 July.

Two papers presented: (1) Objective rainfall forecasting using data from the United Kingdom weather-radar network, (2) A system for the combined use of data from multiple radars and satellites in the United Kingdom. *IAMAP Third Scientific Assembly, Hamburg.* 27 and 28 August.

Two lectures: (1) The United Kingdom weather-radar network, (2) On the accuracy of radar rainfall data. *Technical University of Denmark, Copenhagen.* 31 August.

The United Kingdom weather-radar network. *Royal Netherlands Meteorological Institute, De Bilt.* 24 November.

The measurement and forecasting of rainfall using a radar network. *Royal Meteorological Society Sixth Form Lecture, London.* 3 and 4 December.

Radar for measuring and forecasting rain. *Hereford and Worcester Technical Colleges.* 8 December.

CRABTREE, J.

Two lectures: (1) Practical schemes for estimating dispersion, (2) Urban models. *Scientific Advisers' Course at the Defence, Nuclear, Biological and Chemical Centre, Winterbourne Gunner, Wilts.* 28 and 29 March.

CREWE, M. E.

Icing climatology data from routine observations (NATO area) and icing flight trials. *MOD(PE) Symposium on Helicopter Icing—Meteorological Aspects, London.* 18 March.

CULLEN, M. J. P.

Finite elements in weather prediction. *Naval Postgraduate School, Monterey, Calif.* 23 February.

Intercomparison of numerical weather forecasting. *Fleet Numerical Oceanography Center, Monterey, Calif.* 25 February.

Intercomparison of large atmospheric models. *National Center for Atmospheric Research, Boulder, Col.* 22 April.

Finite elements for hyperbolic problems. *Lawrence Livermore Laboratory, Livermore, Calif.* 30 June.

Numerical weather forecasting. *Lawrence Livermore Laboratory, Livermore, Calif.* 6 August.

Finite elements for Navier–Stokes equations. *Naval Postgraduate School, Monterey, Calif.* 17 August.

Some aspects of solutions to non-linear differential equations in physics. *University of Reading.* 16 October.

DENT, L.

Series of lectures on Meteorology. *Air Transport Planning and Operational Course, Cranfield Institute of Technology.* 1 June and 26 November.

DICKINSON, A.

Optimization of numerical weather prediction models for the CRAY 1 and CYBER 205 computers. *Conference on Vector and Parallel Processors in Computer Science, Chester.* 28 August.

DOUGLAS, H. A.

Meteorological factors affecting soil temperatures. *Soils Discussion Group, Edinburgh.* 12 March.

The Meteorological Office's support in the identification of the effects of outdoor climate on animals and man. *Royal Meteorological Society Specialist Group on Agricultural Meteorology, Edinburgh.* 3 April.
The role of the Meteorological Office's Agricultural Branch. *Department of Agriculture, Belfast.* 6 May.
Meteorological factors influencing cereal yields. *East of Scotland College of Agriculture, Edinburgh.* 2 December.

DORWARD, A. S.
Participation in film on the work of a Weather Centre. Border TV. 11 June.
Participation in program 'Talk about Ten'. BBC Radio Newcastle. 23 July.

DUTTON, M. J.
Limited area modelling in the UK Meteorological Office. *Meeting of the European Working Group on Limited Area Modelling, Copenhagen.* 24 August.

EYRE, J. R.
Meteosat water-vapour imagery. *Seminar at Department of Atmospheric Physics, University of Oxford.* 5 February.
Improvements of humidity analyses by direct use of Meteosat water-vapour channel radiances. *IAMAP Third Scientific Assembly, Hamburg.* 25 August.

FISH, M. J.
Discussion on the heavy rain. 'Points West', BBC TV Bristol. 13 March.
Participation in 'phone-in'. BBC Radio London. 4 June.
Behind the scenes of a television forecast. *Royal Meteorological Society, Manchester Centre.* 29 October.

FLECK, D. J.
Weather forecasts for the public. *Manchester Branch of the UK Federation of Business Women.* 13 October.

FORRESTER, D. A.
Cloud and icing climatology. *MOD(PE) Symposium on Helicopter Icing—Meteorological Aspects, London.* 18 March.

GEORGE, D. J.
Meteorology and fallout. *UKWMO Belfast Group, Lisburn.* 15 April.

GILCHRIST, A.
Effects of increased CO_2 on the climate system. *OECD, Paris.* 11 February.
Climate modelling by numerical simulation. *University of Liège, Belgium.* 25 May.
On the use of general circulation models for climate response studies. *The Royal Danish Academy of Sciences, Copenhagen.* 7 September.
Long-range forecasting in the Meteorological Office (Parts 1 and 2). *ECMWF, Shinfield Park.* 14 and 15 September.

GILES, W. G.
Weather forecasting. *Schools Program 'Read on', BBC TV.* 22 January.

GLASSEY, S. D.
Public weather services. *Wolverhampton Law Society.* 6 February.
Meteorology and science. *Association of University Women, Lichfield.* 3 June.
Setting a household barometer. *ATV.* 16 June.
Weather and the community. *Lecture course at Department of Extra-Mural Studies, University of Birmingham.* 5 October to 7 December.

GLOSTER, J.

Airborne foot-and-mouth disease. *The Welsh Veterinary Officers' Conference, Llandudno.* 29 March.

The effects of the weather on agriculture. *Royal Horticultural Society, Wisley.* 6 May.

The airborne spread of foot-and-mouth disease in the 1981 outbreak. *Animal Virus Research Institute, Woking.* 19 and 21 May.

The airborne spread of foot-and-mouth disease.

Scottish Veterinary Officers' Conference, St Andrews. 11 November.

Central Veterinary Research Club, MAFF, Weybridge. 25 November.

Veterinary Research Club, London. 11 December.

GOLDSMITH, P.

The atmospheric aerosol. *Royal Meteorological Society, London.* 17 June.

A check on a long-range trajectory model using the plume from the Mount St Helens eruption. *IAMAP Third Scientific Assembly, Hamburg.* 21 August.

Status of weather modifications. *Royal Meteorological Society, Scottish Centre, Edinburgh.* 16 October.

GOODISON, C. E.

Digital facsimile. *Seminar on Graphical Applications in Meteorology, ECMWF, Shinfield Park.* 21 October.

HIDE, R.

Two lectures: (1) Stable baroclinic eddies in the laboratory and in Jupiter's atmosphere, (2) On the influence of rotation, thermo-electric effects and compressibility on the generation of cosmical magnetic fields. *European Geophysical Society, Uppsala.* 25 August.

Rotating fluids in geophysics, planetary physics and astronomy.

Harold Jefferys Lecture, Royal Astronomical Society, London. 9 October.

Mathematical Institute, University of Oxford. 12 October.

Institute of Mathematics and its Applications, Royal Military College of Science, Shrivenham. 14 October.

HILLS, T. S.

A model to study the response of climate in Europe to increases in atmospheric CO_2. *Meeting of the EEC Contact Group 'Anthropogenic Climate Perturbations' of the Climatology Research Program, Brussels.* 26 October.

HOPKINS, J. S.

Weather and tourism in Scotland. *Discussion on BBC Radio 4 (Scotland).* 8 May.

HOUGH, M. N.

Cereal growth and the weather. *Guisborough Arable Discussion Group.* 13 November.

HUNT, G. S. F.

Meteorology for Private Pilot's Licence. *Coventry Technical College.* 13 and 27 January and 24 February.

Meteorology for yachtmasters. *Stourbridge Technical College.* 28 January.

HUNT, R. D.

The use of weather forecasts in the energy industry. *Institution of Plant Engineers, London.* 3 February.

INGHAM, B.

Climate and fruit growing. *Somerset Fruit Growers' Club, Ilminster.* 17 February.

JAMES, P. K.

Radar-site signal processing and control in the United Kingdom Meteorological Office short-period weather forecasting pilot project. *COST 72 Workshop/Seminar, ECMWF, Shinfield Park.* 11 March.

JENKINS, G. J.

Two lectures: (1) Basic synoptic meteorology, (2) Introduction to atmospheric dispersion. *Scientific Advisers' Course at the Defence, Nuclear, Biological and Chemical Centre, Winterbourne Gunner, Wilts.* 27 March.

Lectures at the Royal Meteorological Society Field Study Course on 'Weather Science and Forecasting', Williton, Somerset. 26 August to 2 September.

JENKINS, I.

Mountain-wave forecasting. *Ogwr Mountaineering Club, Mid Glam.* 4 March.

Weather map workshop. *University College of Swansea.* 11 March.

South Wales floods of December 1979. *Joint Meeting of the Royal Meteorological Society (Welsh Centre) and Institute of Civil Engineers (Hydrological Group), Brecon.* 12 March.

JONES, M. V.

Applications of graphics devices at the meteorological office, London Airport. *Seminar on Graphical Applications in Meteorology, ECMWF, Shinfield Park.* 21 October.

KEEPING, W. N. C.

The orographic and thermal forcing of the general circulation. *IAMAP Symposium on the Dynamics of the General Circulation, Part 1, Reading.* 4 August.

KERLEY, M. J.

Technical aspects of instrumentation deployment and operation of 2.5 metre wave-following data buoys. *Seminar on Data Buoys, The Society of Underwater Technology, London.* 19 March.

Developments in automatic data acquisition systems (ODAS) for marine locations. *Royal Meteorological Society Discussion Meeting, London.* 11 April.

KIDD, J. G. R.

Weather and sailing. *Course for yachtsmen, Adult Education Centre, Manchester.* 7 April.

KITCHEN, M.

Some case studies of the dynamics and associated microphysics of cumuliform cloud. *Royal Meteorological Society Discussion Meeting, London.* 15 April.

The response of surface aerosol concentrations to changes in some boundary-layer parameters. *IAMAP Third Scientific Assembly, Hamburg.* 28 August.

LEE, A. C. L.

The Meteorological Office automated Sferics system. *Royal Meteorological Society Discussion Meeting, London.* 11 April.

The Sferics system of the Meteorological Office. *Clarendon Laboratory, Oxford.* 22 October.

LORENC, A. C.

Meteorological data analysis. *Lectures at a course on 'Weather Predictions by Fine-mesh Models', International School of Meteorology of the Mediterranean, Erice, Sicily.* 17–30 October.

LOVE, J. P.

Agricultural meteorology in Scotland. *Doune and Dunblane Branch of the National Farmers' Union, Doune.* 19 March.

MACKIE, G. V.

The operation of the Ship Routeing Service and activities of the Marine Division of the Meteorological Office. *Department of Nautical Science, South Shields Marine and Technical College.* 29 January.

The Meteorological Office Ship Routeing Service. *Beaufort Society, Hydrographic Department, Ministry of Defence, Taunton.* 7 October.

MANSFIELD, D. A.

Blocking in the Meteorological Office 5-level model. *Meeting of Royal Meteorological Society Dynamical Problems Sub-group, Shinfield Park.* 18 June.

MASON, SIR JOHN

Modelling the world's climate. *Royal Geographical Society, London.* 22 January.

Britain's part in international meteorology. *Cross-bench Peers, House of Lords, London.* 19 February.

Modelling of the world's climate with the aid of giant computers.

Centenary of Physics Department, University of Nottingham. 12 March.

Joint Meeting of the Physical and Chemical Societies, University of Surrey, Guildford. 10 November.

Modelling and forecasting for climate and weather. *Southern Operational Research Group and Institute of Physics, Bracknell.* 18 March.

Climate modelling. *Environmental Society, Plymouth Polytechnic.* 30 March.

The atmospheres of Venus and Jupiter. *The Cockcroft Memorial Lecture, UMIST, Manchester.* 3 April.

The numerical prediction of weather and climate. *Symposium on the Lower Atmosphere, Australian Academy of Science, Canberra.* 1 May.

Man's influence on climate. *Public lecture, Australian Branch of the Royal Meteorological Society, Sydney.* 4 May.

Observation of the atmosphere from space. *Public lecture, Australian Branch of the Royal Meteorological Society, University of Melbourne.* 7 May.

Modern techniques of weather forecasting. *J. D. Bernal Lecture, Birkbeck College, London.* 27 May.

Thirty years of cloud seeding in retrospect and prospect. *Royal Meteorological Society Summer Meeting, UMIST, Manchester.* 26 August.

Weather forecasting. *The Maxwell Society, King's College, London.* 26 October.

Weather forecasting in the satellite and computer age. *The Courtauld Lecture, Manchester Literary and Philosophical Society, UMIST, Manchester.* 16 November.

MASON, P. J.

Recent measurements of wind around hills. *Symposium organized by the Institute of Mathematics and its Applications, Cambridge.* 16 March.

Two lectures: (1) Modelling of the neutral atmospheric boundary layer, (2) Modelling of the buoyantly unstable boundary layer. *Geophysical Fluid Dynamics Seminar, Department of Applied Mathematics and Theoretical Physics, Cambridge.* 29 April and 6 May.

Orographic vortices. *Joint Seminar, Royal Meteorological Society (Australian Branch)/Monash University, Clayton, Victoria.* 28 May.

Flow over hills. *Division of Environmental Mechanics, CSIRO, Canberra.* 15 June.

Theoretical and experimental studies of flow over hills. *Joint Seminar, Monash University/Australian Meteorology Research Centre, Clayton, Victoria.* 18 June.

Horizontal roll vortices in the atmospheric boundary layer. *Monash University, Clayton, Victoria.* 24 June.

Flow over complex terrain. *IAMAP Third Scientific Assembly, Hamburg.* 27 August.

MITCHELL, J. F. B.

Evaluation of the impact of an increase in CO_2 on European climate. *Meeting of the EEC Contact Group 'Climate Models' of the Climatology Research Program, Brussels.* 26 May.

The hydrological cycle as simulated by an atmospheric general circulation model. *IAMAP/IASH Symposium on Variations in the Global Water Budget, Oxford.* 15 August.

MONK, G. A.

Examples of interesting weather events as seen by the radar network and Meteosat. *ECMWF, Shinfield Park.* 10 March.

MORRIS, R. M.

Use of satellite data in weather forecasting. *Symposium organized by OYEZ International Business Communications Ltd, London.* 23 February.

MURRAY, R.

Forecasting. *Royal Meteorological Society, North-east Centre, Durham.* 13 March.

NEWMAN, M. R.
Numerical simulation of the onset of the south-west summer monsoon with particular reference to 1979. *IAMAP Third Scientific Assembly, Hamburg.* 18 August.
Use of data acquired during FGGE and regional experiments. *WMO Seminar on the Use of Meteorological Data with Implications for Forecasting and Research in Tropical Countries, Reading.* 10 September.

OGDEN, R. J.
Meteorology—physics in action. *Institute of Physics, Birmingham.* 3 March.
OULDRIDGE, M.
Theoretical modelling and the icing environment. *Ministry of Defence Symposium on Icing Research, London.* 18 March.
OWENS, R. G.
The use of radar in local weather forecasting. *Royal Meteorological Society, East Midlands Centre, Sutton Bonington.* 6 October.

PALMER, T. N.
A diagnostic study of planetary-scale motion in the troposphere and stratosphere. *IAMAP Symposium on the Dynamics of the General Circulation, Part 1, Reading.* 3 August.
PARKER, D. E.
Estimates of recent climatic change using upper-air data. *IAMAP Third Scientific Assembly, Hamburg.* 21 August.
PARKER, G. H.
Weather forecasting. *Croydon Scientific and Natural History Society.* 15 January.
Weather and sailing. *Course run jointly with the Royal Meteorological Society and Medina Valley Centre, Newport, Isle of Wight.* 23–30 May.
PARTINGTON, S. J. G. and SMYTH, E. A.
Weather and agriculture. *Northern Ireland Institute of Agricultural Science, Lisburn.* 11 November.
PEPPERDINE, E. C.
Work of the Nottingham Weather Centre. *Institute of Medical Laboratory Sciences, Derby/Nottingham Branch.* 30 April.
PETTIFER, R. E. W.
Three lectures: (1) Laser radar as an atmospheric probe—basic theory, (2) and (3) Laser applications in meteorology (Parts 1 and 2). *MSc. Course in Opto-electronics, University of Essex, Colchester.* 19 and 20 February.
Laser radar in meteorology. *Royal Meteorological Society Discussion Meeting, London.* 11 April.
Three lectures: (1) Automatic meteorological observations, new methods and new problems, (2) A crop disease environment monitor, (3) ACRE—an Automatic Climatological Recording Equipment. *TECIMO II, Mexico City.* 13 and 16 October.
Energy and electronics—contributions in meteorological instrumentation. *Watt Committee on Energy, Education and Conservation, London.* 3 December.
PONTING, J. F.
Autosat raster display. *Seminar on Graphical Applications in Meteorology, ECMWF, Shinfield Park.* 21 October.
PURSER, R. J.
Variational initialization for a mesoscale model. *Fifth American Meteorological Society Conference on Numerical Weather Prediction, Monterey, Calif.* 4 November.
Mesoscale initialization. *National Meteorological Center, Washington, D.C.* 12 November.

READINGS, C. J.

Research on local wind environments—introductory talk. *Symposium organized by the Institute of Mathematics and its Applications, Cambridge.* 16 March.

Airborne flux measurements. *NATO Workshop, Bedford Institute of Oceanography, Dartmouth, Nova Scotia.* 29 April.

ROACH, W. T.

Meteorological requirements for helicopter icing—the Meteorological Office program. *MOD(PE) Symposium on Helicopter Icing—Meteorological Aspects, London.* 18 March.

Field studies of nocturnal stratocumulus. *Seminar at the Department of Atmospheric Physics, University of Oxford.* 28 May.

Mesoscale studies of some weather hazards to aviation. *IAMAP Third Scientific Assembly, Hamburg.* 25 August.

Airships—the meteorologists' role. *Evening Symposium of The Airship Association, Royal Aeronautical Society, London.* 4 November.

ROWNTREE, P. R. and BOLTON, J. A.

Effects of soil moisture anomalies over Europe in summer. *IAMAP/IASH Symposium on Variations in the Global Water Budget, Oxford.* 11 August.

The sensitivity of atmospheric general circulation models to land-surface processes. *Royal Meteorological Society Meeting, London.* 16 December.

RYDER, P.

Cloud physics research from aircraft. *The Gaskell Memorial Lecture, Royal Meteorological Society, Manchester Centre.* 22 January.

Aircraft studies of the distribution of water in cloud. *Ministry of Defence Symposium on Icing Research, London.* 18 March.

The physics of clouds and precipitation. *Physics Department, Brunel University, Uxbridge.* 19 March.

SCOTT, J.

Six-part program 'Under the Weather'. *BBC2 (TV).* 20 July to 24 August.

Weather outlook favourable. *Senior Schools Lecture, Royal Meteorological Society, Edinburgh.* 16 October.

The weather business. *British Institute of Management, London.* 12 November.

SINGLETON, F.

Weather and sailing. *Decca Sailing Club, Cruising Section, Tolworth.* 19 February.

SMITH, C. V.

Structure and uncertainty in rainfall events. *Royal Meteorological Society Discussion Meeting, Bracknell.* 10 October.

The meteorologists' contribution to disease control. *FAO International Workshop on Exotic Disease Management for Senior Veterinary Staff, MAFF, Tolworth.* 13 October.

Meteorological services for agriculture. *Regional Agricultural Officers' Conference, MAFF, London.* 16 October.

SMITH, F. B.

Diffusion of pollutants in the atmosphere. *Lectures to MSc. Course, University of Surrey, Guildford.* 12, 15 and 19 February.

A review of the European EMEP program on the long-range transport of pollution, and some ideas on how to treat wet deposition. *WMO Review Meeting of European Monitoring and Evaluation Program (EMEP), ECMWF, Shinfield Park.* 30 March.

Keynote address. *Canadian Meteorological and Oceanographic Society, Special Interest Group on Air Pollution Meteorology, Saskatoon.* 21 May.

Long-range transport of sulphur in the atmosphere and acid rain. *WMO Executive Committee Meeting, Geneva.* 15 June.

Statistical prediction of the removal of pollutants by precipitation. *University of Reading.* 19 June.

Dispersion—an overview. *Wind Engineering Research Group, Building Research Establishment, Watford.* 8 July.

Inherent variability in turbulence and its consequence for pollution concentration estimates. *Los Alamos National Laboratory, New Mexico.* 20 October.
The fate of man-made material in the atmosphere. *OYEZ International Business Communications Ltd, London.* 25 November.

SPACKMAN, E. A.
Meteorological aspects of irrigation. *Irrigation Discussion Meeting, Woodbridge.* 14 February.
Aspects of spray drift. *Chemical Applications Committee, British Crop Protection Council, London.* 5 March.
Further work on the objective determination of climatic regions of the UK. *Association of British Climatologists, Durham.* 23 September.

SPALDING, T. R.
Mountain weather. *Crowthorne Youth Group.* 25 February.

SPARKS, W. R.
The crop disease environment monitor. *ADAS Plant Pathologists' Technical Conference, Great Malvern.* 5 March.

STARR, W. R.
Weather and the fruit grower. *East Kent Fruit Society, Canterbury.* 7 January.
Weather on the farm. *Institute of Agricultural Secretaries, Henley.* 12 February.
Making use of weather records. *Newport Horticultural Society, Isle of Wight.* 17 March.
Meteorological aspects of irrigation planning. *Hampshire College of Agriculture, Sparsholt.* 19 and 23 March.
Weather and lamb mortality. *Royal Meteorological Society Specialist Group on Agricultural Meteorology, Edinburgh.* 3 April.
Meteorological aspects of earliness in the south-east. *Horticultural Education Association, Sparsholt.* 22 April.
Tornadoes, hurricanes, floods. *International Emergency Action Group, Dorking.* 23 July.
Climatic aspects of earliness in the south-east. *Sparsholt College Management Meeting.* 16 September.
Flukes, frost, calves and crops. *Imperial College Physical Society, London.* 14 November.
Weather studies. *Kent County Council Teachers' Course, East Malling.* 28 November.

SWINBANK, R.
A study of the global angular momentum balance. *IAMAP Symposium on the Dynamics of the General Circulation, Part I, Reading.* 3 August.

TEMPERTON, C.
Normal mode initialization at ECMWF.
National Center for Atmospheric Research, Boulder, Col. 8 July.
Goddard Laboratory for Atmospheric Science, Washington, D.C. 14 July.
Fast methods on parallel and vector computers. *Conference on Vector and Parallel Processors in Computer Science, Chester.* 27 August.

THOMPSON, N.
Meteorological Office Rainfall and Evaporation Calculation System. *Institute of Hydrology, Wallingford.* 10 April.
The climatology of field drying of hay. *Hay Research Discussion Group, Cardington.* 2 December.

TUCK, A. F.
Stratospheric water vapour. *WMO/NASA Meeting, Hampton, Va.* 18–22 May.
Global changes in atmospheric composition. *Conference on Living with Uncertainty—Risks in the Energy Scene, London.* 25–26 November.

WARRILOW, D. A.
Meteorological aspects of drainage design. *Drainage Course, Planning and Transport Research and Computation (International) Co. Ltd, London.* 8 April.
Rainfall design information in the Wallingford Urban Storm Drainage Design Procedure. *National Launch Seminar of the Wallingford Procedure, London.* 29 October.

WASS, S. N.

Environmental influences on glasshouse heating requirements. *Horticultural Advisers' Conference, ADAS, Bristol.* 5 March.

WEBBER, K. L.

Some recent developments in meteorological data-acquisition systems. *Watt Committee Summer School on Energy and Electronics.* 11 September.

WHITE, A. A.

Numerical modelling of baroclinic flow in thermally and mechanically driven rotating systems. *University of Warwick.* 6–9 January.

Numerical, theoretical and experimental studies of intransivity in a laboratory system (written jointly with JONAS, P. R., *IAMAP Symposium on the Dynamics of the General Circulation, Part 1, Reading.* 3–7 August.

WHITE, P. W.

Prediction of weather and climate using supercomputers. *Institution of Electrical Engineers, Liverpool.* 19 January.

Numerical weather prediction in the Meteorological Office for defence services. *Air Force Geophysics Laboratory, Hanscom Air Force Base, Boston, Mass.* 16 April.

Numerical weather prediction in the Meteorological Office. *National Meteorological Center, Washington, D.C.* 20 April.

The current and future operational fine-mesh numerical weather prediction models and the mesoscale model. *Three lectures at a course on 'Weather Predictions by Fine-mesh Models', International School of Meteorology of the Mediterranean, Erice, Sicily.* 22 October.

WICKHAM, P. G.

Forecasting methods. *Six lectures at a course for MSc. students, Department of Meteorology, University of Reading.* February–March.

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 58–61. Attendances at WMO meetings, or joint WMO meetings with other international bodies, are as follows.

Subject	*Place and date*	*Attended by*
CIMO Advisory Working Group	Geneva January	Mr A. H. Hooper (Met O 1)
CIMO Working Group on Upper-air Data Compatibility	Geneva January	Mr D. W. Jones (Met O 1)
JSC Study Conference on Land Surface Processes in Atmospheric General Circulation Models	Greenbelt, Md. January	Dr P. R. Rowntree (Met O 20) Dr D. J. Carson (Met O 20)
Informal Meeting—NAOS Telecommunications	Bracknell February	Dr D. N. Axford, AD Met O(TC)* Captain G. A. White, Marine Superintendent Mr R. J. Sowden (Met O 5) Mr R. Hope (Met O 5)
Working Group on Design of WMO Central Computerized Catalogue of Climate Data	Geneva February	Mr D. E. Parker (Met O 13)
EC Panel of Experts—Review of the Scientific and Technical Structure of WMO	Geneva February	Mr G. J. Day, AD Met O(IP)
VCP Informal Planning Meeting—Major Donor Members	Geneva February	Mr G. J. Day, AD Met O(IP)
RA VI Working Group on Co-ordination of Requirements for Data in GRID Code Form	Offenbach March	Dr R. A. Bromley (Met O 2)
WMO Meeting of Experts on Education and Training	Geneva March, June	Mr S. G. Cornford, AD Met O(PT)
Assessment of the meteorological aspects of the first phase of the EMEP Program	Shinfield Park March/April	Dr F. B. Smith (Met O 14)
WMO EC Advisory Panel on Cloud Physics and Weather Modification	Geneva May	Mr P. Goldsmith, DD Met O(P)*
WMO/NASA Meeting—The Stratosphere 1981: Theory and Measurements	Hampton, Va. May	Dr A. F. Tuck (Met O 15)
Preparatory Committee for 33rd Executive Committee Session	Geneva June	Mr G. J. Day, AD Met O(IP) Mr M. W. Stubbs (Met O 17)
Executive Committee, 33rd Session	Geneva June	Sir John Mason, Director-General Mr G. J. Day, AD Met O(IP) Mr M. W. Stubbs (Met O 17) Dr F. B. Smith (Met O 14)

*The full titles of the Deputy Directors (DDs) and the Assistant Directors (ADs) are given on pages ix–xi. Other abbreviations are explained in Appendix V (pages 159–160).

Subject	*Place and date*	*Attended by*
WMO Scientific and Technical Advisory Committee	Geneva June	Sir John Mason, Director-General
EC Panel on the VCP	Geneva June	Mr G. J. Day, AD Met O(IP)
NAOS Board, 6th Session	Geneva June/July	Dr N. E. Rider, DD Met O(O) Captain G. A. White, Marine Superintendent Mr J. R. Hughes (Met O 4)
Installation and commissioning of equipment at new rawinsonde station; training of staff	Athalassa, Cyprus July/August September/October	Mr R. Greener (Met O 16) Mr F. J. Harding (Met O 1)
Commission for Atmospheric Sciences, 8th Session	Hamburg August	Dr K. H. Stewart, Director of Research Mr P. Goldsmith, DD Met O(P)
JSC Working Group on Numerical Experimentation, 2nd Session	Stockholm August	Mr F. H. Bushby, Director of Services
IAMAP Nowcasting Symposium—Mesoscale Observation and Short-range Prediction	Hamburg August	Mr P. Goldsmith, DD Met O(P) Dr W. T. Roach, AD Met O(SI) Mr D. E. Parker (Met O 13) Dr P. J. Mason (Met O 14) Dr D. A. Bennetts (Met O 15) Mr M. Kitchen (Met O 15) Dr K. A. Browning (Met O RRL) Dr K. M. Carpenter (Met O RRL) Mr C. G. Collier (Met O RRL) Dr J. R. Eyre (Met O 19) Dr H. Cattle (Met O 20) Dr S. A. Clough (Met O 20) Mr M. R. Newman (Met O 20) Mr C. Gordon (Met O 20)
IAMAP/IASH Symposium on Variations in the Global Water Budget	Oxford August	Dr D. J. Carson (Met O 13) Mr C. J. Folland (Met O 13) Dr P. R. Rowntree (Met O 20) Dr J. F. B. Mitchell (Met O 20)
Comparison of UK standard ozone spectrophotometer with world standard instrument	Boulder, Col. August/September	Dr E. L. Simmons (Met O 15)
CBS Study Group on Best Mix Observing Systems	Shinfield Park September	Miss M. J. Atkins (Met O 2)
Commission for Marine Meteorology, 8th Session	Hamburg September	Captain G. A. White, Marine Superintendent Mr R. J. Shearman (Met O 3)
Technical Conference on Automation of Marine Observations and Data Collection	Hamburg September	Captain G. A. White, Marine Superintendent Mr D. J. Painting (Met O 16)
WMO Seminar on the Use of Meteorological Data with Implications for Forecasting and Research in Tropical Countries	Shinfield Park September	Mr M. R. Newman (Met O 20)
Informal Planning Meeting—Data Referral Facility of World Climate Program	Geneva September/October	Mr R. A. Pearson (Met O 22)
TECIMO II	Mexico City October	Mr R. E. W. Pettifer, AD Met O(OI) Mr A. H. Hooper (Met O 1)

Subject	*Place and date*	*Attended by*
Commission for Instruments and Methods of Observation, 8th Session	Mexico City October	Dr N. E. Rider, DD Met O(O) Dr R. E. W. Pettifer, AD Met O(OI) Mr A. H. Hooper (Met O 1)
Scientific results of the Monsoon Experiment (MONEX)	Bali October	Dr A. J. Gadd, AD Met O(DC)
GOS Working Group	Geneva November	Mr D. R. Grant, AD Met O(OP)
CAeM Working Group on PROMET, 2nd Session	Washington, D.C. November	Mr P. D. Borrett (Met O 7)
Data collection for World Climate Program	Geneva November	Dr R. E. W. Pettifer, AD Met O(OI)
Long-range transport of pollution	Downsview, Ont. November/ December	Mr J. Crabtree (Met O 14)
EC Advisory Panel on Cloud Physics and Weather Modification	Boulder, Col. December	Mr P. Goldsmith, DD Met O(P)
Interim Committee of ASDAR participants	Geneva December	Mr G. J. Day, AD Met O(IP)

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

Subject	*Place and date*	*Attended by*
Intergovernmental Conference on Operational Meteosat System	Paris January	Sir John Mason, Director-General Dr K. H. Stewart, Director of Research
ESA Meteorological Satellite Program Board	Paris January, February, March, November	Dr K. H. Stewart, Director of Research
Meeting of Meteorological Group, ICAO Area Forecast Panel	Montreal January	Mr D. H. Johnson, DD Met O(F)
Visiting scientist at University of California and participating guest	Berkeley, Calif. January– September	Dr M. J. P. Cullen (Met O 11)
Computational fluid dynamics	Palo Alto, Calif. January	Dr M. J. P. Cullen (Met O 11)
Fluorocarbons and the ozone layer	Brussels January	Dr A. F. Tuck (Met O 15)
ESA Scientific and Technical Advisory Group to Meteorological Satellite Program Board	Paris January	Mr D. E. Miller, AD Met O(SM)
ESA Scatterometer Experts Group	Toulouse/Paris January, March, October	Mr D. Offiler (Met O 19)
SCOR Working Group 55 (El Niño Prediction)	San Diego, Calif. January	Dr P. R. Rowntree (Met O 20)
CDC Computing Center	Minneapolis, Minn. January/February March/April, May	Mr R. S. Bell (Met O 2) Mr J. Turner (Met O 2) Mr P. R. Benwell (Met O 2) Dr S. R. Mattingly (Met O 12)

Subject	Place and date	Attended by
Meteosat Operational Program—Working Group	Paris February, March, May, June, November	Dr K. H. Stewart, Director of Research
IEA Workshop on CO_2 Research and Assessment	Paris February	Mr A. Gilchrist, DD Met O(D)
EEC Climatology Advisory Committee on Program Management	Brussels February	Mr A. Gilchrist, DD Met O(D)
EEC Project F Meeting—Action 4.1	De Bilt February	Mr W. G. Durbin (Met O 1)
Visits to IBM establishments	Paris/Montpellier February	Mr P. Graystone, AD Met O(DP)
ECMWF Finance Committee, 24th Session	Shinfield Park February	Mr G. J. Day, AD Met O(IP)
Thermal vacuum testing of NOAA-D spacecraft and SSU	Princeton, N.J. February	Dr J. Nash (Met O 19) Mr E. R. Hibbett (Met O 19)
Development of general circulation models for CYBER 205	Minneapolis, Minn. February	Mr T. S. Hills (Met O 20)
NASA/UARS Science Team Meeting	Greenbelt, Md. February	Dr A. J. Gadd, AD Met O (DC)
COST 72 Symposium	Shinfield Park/ Malvern March	Sir John Mason, Director-General Dr N. E. Rider, DD Met O(O) Dr K. A. Browning (Met O RRL) Dr K. M. Carpenter (Met O RRL) Mr C. G. Collier (Met O RRL) Dr P. K. James (Met O RRL) Mr P. R. Larke (Met O RRL) Mr G. A. Monk (Met O RRL) Mr R. G. Owens (Met O RRL) Mr G. A. Clift (Met O 16)
Meteosat Operational Program Technical Sub-group	Paris March, June	Dr K. H. Stewart, Director of Research
EUMETSAT Sub-group on Institutional Matters	Paris March, May, September	Mr G. J. Day, AD Met O(IP) Mr M. W. Stubbs (Met O 17)
NATO MCMG 5th Sub-group II	Athens March	Mr C. E. Goodison (Met O 5)
ECMWF Workshop—Tropical Meteorology and its Effect on Medium-range Weather Prediction in Mid-latitudes	Shinfield Park March	Dr W. H. Lyne (Met O 11)
Society of Underwater Technology—International Conference on Data Buoy Technology	London March	Dr R. E. W. Pettifer, AD Met O(OI) Mr M. J. Kerley (Met O 16)
IMCO Marine Safety Committee	London March/April	Captain G. A. White, Marine Superintendent
11th Informal Conference of Directors of European Meteorological Services	Munich April	Sir John Mason, Director-General
EEC Project F, Contractor's Co-ordination Meeting on Solar Radiation Data	Brussels April	Mr W. G. Durbin (Met O 1)
International Symposium on Food, Nutrition and Climate	Ferndown, Dorset April	Mr C. R. Flood, AD Met O(CF)
NATO MCMG, 53rd Working Group	Athens April	Mr J. I. Gibbs (Met O 6) Mr C. E. Goodison (Met O 5)
US Army Meso-Met Advisory Panel	Las Cruces, N.M. April	Dr P. W. White, AD Met O(FR)

Subject	*Place and date*	*Attended by*
ECMWF Council, 13th Session	Shinfield Park April	Mr G. J. Day, AD Met O(IP)
Attending factory trials on CYBER 205 at CDC	Minneapolis, Minn. April/May	Dr R. L. Wiley, AD Met O(SD)
Visits and lectures	Melbourne/ Sydney/ Canberra April/May	Sir John Mason, Director-General
NATO Workshop on Humidity Flux	Downsview, Ont. April/May	Dr C. J. Readings, AD Met O(BL)
ECMWF Scientific Advisory Committee	Shinfield Park May	Mr F. H. Bushby, Director of Services
EEC Climatology Advisory Committee on Program Management	Brussels May	Mr A. Gilchrist, DD Met O(D)
Planning implementation of Bracknell–Brussels medium-speed link	Bracknell May	Dr D. N. Axford, AD Met O(TC) and Met O 5 staff
NATO, AFCENT Meteorological Committee, 29th Meeting	Munster May	Mr J. Keers (Met O 6) Mr K. Pollard (Met O 6) Mr M. G. Waller (Met O 6)
TWN and ACEWEX	Wezembeek, Belgium May	Mr K. Pollard (Met O 6)
METAG, 5th Meeting	Paris May	Mr P. D. Borrett (Met O 7)
Symposium on Wave Dynamics and Radio Probing of the Ocean	Miami, Fla. May	Dr B. Golding (Met O 11)
EEC Climatology Research Program—1st Meeting of Contact Group on Climate Modelling	Brussels May	Dr D. J. Carson (Met O 13) Dr J. F. B. Mitchell (Met O 20)
Visit to Stormy Weather Group, McGill University	Montreal May	Dr K. A. Browning (Met O RRL)
Special Interest Group on Air Pollution Meteorology—Annual Congress	Saskatoon, Sask. May	Dr F. B. Smith (Met O 14)
COST 43, Management Committee Meeting	Brussels May, December	Dr R. E. W. Pettifer, AD Met O(OI)
ESA Meteosat Operations Advisory Group	Darmstadt May, September, November	Mr A. I. Johnson (Met O 19)
Development of general circulation models for CYBER 205	Minneapolis, Minn. May	Miss M. K. Hinds (Met O 20) Mr A. E. Todkill (Met O 20)
Scientific discussion and collaboration	Clayton, Vic., Australia May/June	Dr P. J. Mason (Met O 14)
Technical inspections	St Helena/ Seychelles May/June, November	Mr P. J. Collins (Met O 16)
Visits to Meteorological Office stations and Cyprus Meteorological Service	Akrotiri/Nicosia June	Mr D. H. Johnson, DD Met O(F)
ECMWF Technical Advisory Committee, 3rd Session	Shinfield Park June	Mr D. H. Johnson, DD Met O(F) Dr R. L. Wiley, AD Met O(SD)
17th OSTIV Congress	Paderborn, Germany (F.R.) June	Mr T. A. M. Bradbury (Met O 2)
C Met O SHAPE's Sub-committee	Mons, Belgium June	Mr D. Forsdyke (Met O 6)

Subject	*Place and date*	*Attended by*
NATO Civil Defence Committee, Working Group of Experts on Fallout Warning Exercises	London June	Mr P. Rackliff (Met O 6)
Reorganization of meteorological services in Germany (RAFG)	Rheindahlen/ Traben-Trarbach June, September	Mr I. J. W. Pothecary, AD Met O(DS) Mr D. G. Strachan (Met O 6) Mr K. Pollard (Met O 6)
NATO MCMG, 38th Meeting	Brussels June	Mr I. J. W. Pothecary, AD Met O(DS)
KONTUR Project	Nordholz, Germany (F.R.) June	Dr C. J. Readings, AD Met O(BL) Dr P. Ryder, AD Met O(CP) Members of MRF staff
Pre-launch testing of SSU on NOAA-C spacecraft	Western Test Range, USA June	Mr B. Tonkinson (Met O 19)
ESA briefing meeting for potential ERS-1 experiments	Paris June	Dr D. R. Pick (Met O 19)
JASIN Workshop	Wormley June/July	Dr C. J. Readings, AD Met O(BL) Dr G. J. Jenkins (Met O 14) Mr A. L. Grant (Met O 14) Mr S. Nicholls (MRF)
Visit to the State Agricultural University	Wageningen, The Netherlands July	Dr N. Thompson (Met O 8)
Visits to agricultural research and advisory centres	Braunschweig/ Ahrensburg, Germany (F.R.) July	Dr N. Thompson (Met O 8)
Visits to scenes of outbreaks of foot-and-mouth disease	Brittany/Normandy July	Mr J. Gloster (Met O 8)
NATO MCMG, 6th Sub-group II	Bracknell July	Mr C. E. Goodison (Met O 5)
NATO AFCENT—NBC Sub-group	Brunssum, The Netherlands July	Mr K. Pollard (Met O 6)
ECMWF Finance Committee, 25th Session	Shinfield Park July	Mr G. J. Day, AD Met O(IP)
Visiting scientist at Goddard Laboratory and the National Center for Atmospheric Research	Washington, D.C./ Boulder, Col. July	Mr C. Temperton (Met O 11)
Visit to the Irish Meteorological Service	Dublin July/August	Sir John Mason, Director-General
IAMAP Symposium on the Dynamics of the Atmospheric General Circulation	Reading August	Sir John Mason, Director-General Dr A. Gadd, AD Met O(DC) Mr S. J. Foreman (Met O 11) Dr D. A. Mansfield (Met O 13) Dr S. C. B. Raper (Met O 13) Members of Met O 20 staff
NATO SHAPE Meteorological Committee, 23rd Meeting	Oslo August	Mr J. I. Gibbs (Met O 6) Mr D. Forsdyke (Met O 6)
European Working Group on Limited Area Modelling	Copenhagen August	Mr M. Dutton (Met O 11)
Pollution research meeting	Darmstadt August	Dr F. B. Smith (Met O 14)

Subject	*Place and date*	*Attended by*
European Geophysical Society	Uppsala, Sweden August	Dr R. Hide, Head of Met O 21
Visit to the Technical University of Denmark, Electromagnetics Institute	Lyngby August	Dr K. A. Browning (Met O RRL) Mr C. G. Collier (Met O RRL)
3rd Meeting of Halogen Occultation Experiment (HALOE) Team	Munich August/ September	Dr A. F. Tuck (Met O 15)
Workshop on a Danish National Climate Program	Copenhagen September	Mr A. Gilchrist, DD Met O(D)
ECMWF Seminar on Problems and Prospects in Long- and Medium-range Weather Forecasting	Reading September	Mr A. Gilchrist, DD Met O(D)
NATO Army Armaments Group AC/225, Panel XII, 18th Meeting	Brussels September	Mr P. G. Rackliff (Met O 6)
Sub-group Meeting on the Future of COST 43	Hamburg September	Dr R. E. W. Pettifer, AD Met O(OI)
Future of the rawinsonde station in Vanuatu	Paris September	Mr M. W. Stubbs (Met O 17)
ECMWF Finance Committee, 26th Session	Shinfield Park September	Mr G. J. Day, AD Met O(IP) Mr M. W. Stubbs (Met O 17)
Offshore Industry Exploration and Production Forum—Subcommittee C	Paris September/ October	Mr R. M. Morris, AD Met O(PS)
ICAO Area Forecast Panel, 2nd Meeting	Montreal September/ October	Mr D. H. Johnson, DD Met O(F)
International Conference on Wave and Wind Directionality with applications to the design of structures	Paris September/ October	Mr J. J. Ephraums (Met O 2) Mr R. J. Shearman (Met O 3)
Inauguration of upper-air station at Athalassa	Cyprus October	Sir John Mason, Director-General
European Working Group on Observing System Experiments	Frankfurt October	Mr A. Gilchrist, DD Met O(D)
Visits to Meteorological Telecommunication Centres	Offenbach/ Paris October	Mr R. J. Sowden (Met O 5)
ECMWF Seminar in Geographical Applicators in Meteorology	Shinfield Park October	Dr D. N. Axford, AD Met O(TC) Mr R. J. Sowden (Met O 5) Mr C. E. Goodison (Met O 5) Mr J. Ponting (Met O 5)
International exchange of meteorological warnings and monitoring information with the Republic of Ireland	London October	Mr P. G. Rackliff (Met O 6)
NATO MCMG—*Ad hoc* Group	London October	Mr I. J. W. Pothecary, AD Met O(DS)
FAO International Workshop on Exotic Disease Management	Tolworth October	Mr C. V. Smith, AD Met O(AH) Mr J. Gloster (Met O 8)
Course on Weather Predictions by Fine-mesh Models	Erice, Sicily October	Dr P. W. White, AD Met O(FR) Mr A. C. Lorenc (Met O 20)
Workshop on Parametrization of Mixed-layer Diffusion	Las Cruces, N.M. October	Dr F. B. Smith (Met O 14)
Meeting to discuss current status of deposition modelling in long-range transport field	Stockholm October	Dr F. B. Smith (Met O 14)
Thermal vacuum testing of NOAA-E spacecraft and SSU	Princeton, N.J. October	Mr. B. Tonkinson (Met O 19)
NATO MCMG, 54th Working Group Meeting	Brussels October	Mr J. I. Gibbs (Met O 6) Mr C. E. Goodison (Met O 5)

Subject	*Place and date*	*Attended by*
EEC Contact Group on Anthropogenic Climate Perturbations	Brussels October	Mr T. S. Hills (Met O 20)
Inspection of radiosonde station	Gibraltar October	Mr J. T. Tunstall (Met O 1)
ECMWF Seminar on Graphical Systems and Applications	Shinfield Park October	Mr M. J. Blackwell, DD Met O(C) Dr R. L. Wiley, AD Met O(SD) Dr W. A. McIlveen (Met O 22) Mr M. V. Jones (Met O 22) Mr K. W. Whyte (Met O 22) Mr P. R. Cockrell (Met O 22) Dr G. W. Bryant (Met O 12) Mrs L. Cushley (Met O 12)
ECMWF Council, 14th Session	Shinfield Park November	Sir John Mason, Director-General Mr F. R. Howell, Sec Met O Mr G. J. Day, AD Met O(IP) Mr M. W. Stubbs (Met O 17)
EEC Climatology Advisory Committee on Program Management	Brussels November	Mr A. Gilchrist, DD Met O(D)
Liaison visits to NOAA and NASA establishments	Washington, D.C. November	Dr N. E. Rider, DD Met O(O)
EEC Project F Meeting—Action 4.1	Athens November	Mr W. G. Durbin (Met O 1)
EEC Project F, Contractor's Co-ordination Meeting	Brussels November	Mr W. G. Durbin (Met O 1)
International Conference on Industrial Islands	London November	Mr R. J. Shearman (Met O 3)
METAG, 6th Meeting	Paris November	Mr P. D. Borrett (Met O 7)
5th American Meteorological Society Conference on Numerical Weather Prediction	Monterey, Calif. November	Mr R. J. Purser (Met O 11)
Discussion with British Antarctic Survey, Foreign and Commonwealth Office and Scott Polar Research Institute	Cambridge November	Mr G. J. Day, AD Met O(IP)
Marine Safety Committee of IMCO	London November	Captain G. A. White, Marine Superintendent
Visit to Royal Netherlands Meteorological Institute	De Bilt November	Dr K. A. Browning (Met O RRL) Mr C. G. Collier (Met O RRL)
COST 72, Committee on European Weather Radar Project	Brussels November	Mr C. G. Collier (Met O RRL)
COST 43, Regional Sub-group for North Sea/Faeroes/Shetland	Brussels December	Dr R. E. W. Pettifer, AD Met O(OI) Mr D. J. Painting (Met O 16)
Hay Research Discussion Group	Cardington December	Dr N. Thompson (Met O 8)

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 purchased directly from the Meteorological Office. Catalogues of both of these classes are available free on request.

The titles which follow are those that were completed during 1981; an asterisk indicates that the publication concerned was handled by HMSO.

PERIODICAL

Annual
- *Annual Report on the Meteorological Office* 1980*
- *Annual Weather Summary* (Southampton)
- *Annual Weather Summary* (UK)
- Introduction to the *Monthly Weather Report**
- *Monthly and annual totals of rainfall for the United Kingdom,* 1972, 1973, 1974
- *Snow survey of Great Britain,* 1979/80

Quarterly
- *Marine Observer**
- *Stratospheric charts for the Northern Hemisphere,* all quarters 1980, 1st quarter 1981
- *Stratospheric charts for the Southern Hemisphere,* 1st, 2nd and 3rd quarters 1980

Monthly
- *Anomaly maps* (London Weather Centre)
- *Builders' Inclement Weather Summary* (Nottingham Weather Centre)
- *Daily Weather Summary* (Newcastle and NE England)
- *Degree days* (Heathrow)
- *Full tabulation of anemograms* (London Weather Centre)
- *Lincoln Weather Diary* (Nottingham Weather Centre)
- *Lincoln Weather Summary* (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** (to December 1980)
- *Monthly Weather Summary* (Bristol Weather Centre)
- *Monthly Weather Summary* (Central southern England)
- *Monthly Weather Summary* (London)
- *Monthly Weather Summary* (SE England)
- *Monthly Weather Summary* (Southampton)
- *Monthly Weather Summary* (Southern Sussex)
- *Monthly Weather Summary* (UK)
- *Monthly Wind Summary* (Bristol Weather Centre)
- *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
- *Estimated Soil Moisture Deficit and Potential Evapotranspiration over Great Britain*
- *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)
- *Weekly Weather Summary* (London)

Daily

Daily Remarks (London Weather Centre)
Daily Weather Summary (London Weather Centre)
Shipping Chart and Forecast (Glasgow Weather Centre)

SERIAL

Climatological Memorandum No. 108: *Climate of the agricultural areas of Scotland*
Climatological Memorandum No. 124: *Climate of Great Britain—Glasgow and the Clyde Valley*
Climatological Memorandum No. 134: *Climate of Great Britain—The Thames Valley*
Hydrological Memorandum No. 44: *Maps of average monthly rainfall over the British Isles for 1941–70* (1981 reprint)
London Weather Centre Memoranda Nos. 30–46: *Twenty years of Central London weather (1961–80 averages).* [Data by individual months, and whole year (Nos. 30–42), *Temperature and relative humidity* (No. 43), *Rainfall* (No. 44), *Wind* (No. 45), *Sunshine, fog, pressure* (No. 46).]

OCCASIONAL

Leaflet No. 1: *Weather advice to the community* (1981 edition)
Leaflet No. 3: *Weather bulletins, gale warnings and services for the shipping and fishing industries* (1981 edition)
Leaflet No. 6: *Rules for rainfall observers* (1981 edition)
Leaflet No. 12: *Publications* (1981 edition)
Upper-air summaries 1961–70: Part 2, *Crawley;* Part 3, *Lerwick;* Part 4, *Aughton;* Part 5, *Hemsby;* Part 6, *Camborne.*
Handbook of meteorological instruments (2nd edition)*: Volume 1, *Measurement of atmospheric pressure;* Volume 2, *Measurement of temperature;* Volume 3, *Measurement of humidity;* Volume 5, *Measurement of precipitation and evaporation.*
Handbook of meteorological telecommunications
Abbreviated weather reports (new edition for use from January 1982)*

APPENDIX V

ACRONYMS AND ABBREVIATIONS

ACEWEX	Allied Command Europe Weather Exchange
ACRE	Automatic Climatological Recording Equipment
ADAS	Agricultural Development and Advisory Service
AFCENT	Allied Forces Central Europe
AIDS	Aircraft Integrated Data System
ASDAR	Aircraft to Satellite Data Relay
ATWS	Automatic Telephone Weather Service
AUTOCOM	Automated Telecommunication Complex
AUTOPREP	Automatic Message Preparation Equipment
AUTOSAT	Automatic Satellite imagery handling system
CAA	Civil Aviation Authority
CAeM	Commission for Aeronautical Meteorology (WMO)
CBS	Commission for Basic Systems (WMO)
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 Marine Meteorology (WMO)
COSMOS	Meteorological Office computing system
COST	European Co-operation in Science and Technology
DALE	Digital Anemograph Logging Equipment
EC	Executive Committee (WMO)
ECMWF	European Centre for Medium Range Weather Forecasts
EEC	European Economic Community
EMEP	European Monitoring and Evaluation Program
ESA	European Space Agency
EUMETSAT	European Meteorological Satellite System
FAO	Food and Agriculture Organization (United Nations)
GOS	Global Observing System (WMO)
GTS	Global Telecommunication System (WMO)
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	International Council of Scientific Unions
IEA	International Energy Agency
IMCO	Inter-Governmental Maritime Consultative Organization
IUGG	International Union of Geodesy and Geophysics (ICSU)
JASIN	Joint Air–Sea Interaction Experiment (Royal Society)
JSC	Joint Scientific Committee (WMO/ICSU)

MAFF	Ministry of Agriculture, Fisheries and Food
MCMG	Military Committee Meteorological Group (NATO)
METAG	Meteorological Advisory Group (ICAO)
MMO	Main Meteorological Office
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
MRF	Meteorological Research Flight
NAOS	North Atlantic Ocean Stations
NASA	National Aeronautics and Space Administration, USA
NATO	North Atlantic Treaty Organization
NERC	Natural Environment Research Council
NOAA	National Oceanic and Atmospheric Administration, USA
OASYS	Outstation Automation System
OECD	Organization for Economic Co-operation and Development
ODAS	Ocean Data Acquisition System
OSTIV	Organisation Scientifique et Technique International du Vol à Voile
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
TWN	Teleprinter Weather Network
UARS	Upper Atmosphere Research Satellite (NASA)
UKWMO	United Kingdom Warning and Monitoring Organization
UMIST	The University of Manchester Institute of Science and Technology
VCP	Voluntary Co-operation Program (WMO)
VOF	Voluntary Observing Fleet
WMO	World Meteorological Organization
WWW	World Weather Watch (WMO)

Printed in England for Her Majesty's Stationery Office by Albert Gait Ltd., Castle Press, Grimsby, S. Humberside.
Dd 717713 C.10 3/82

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