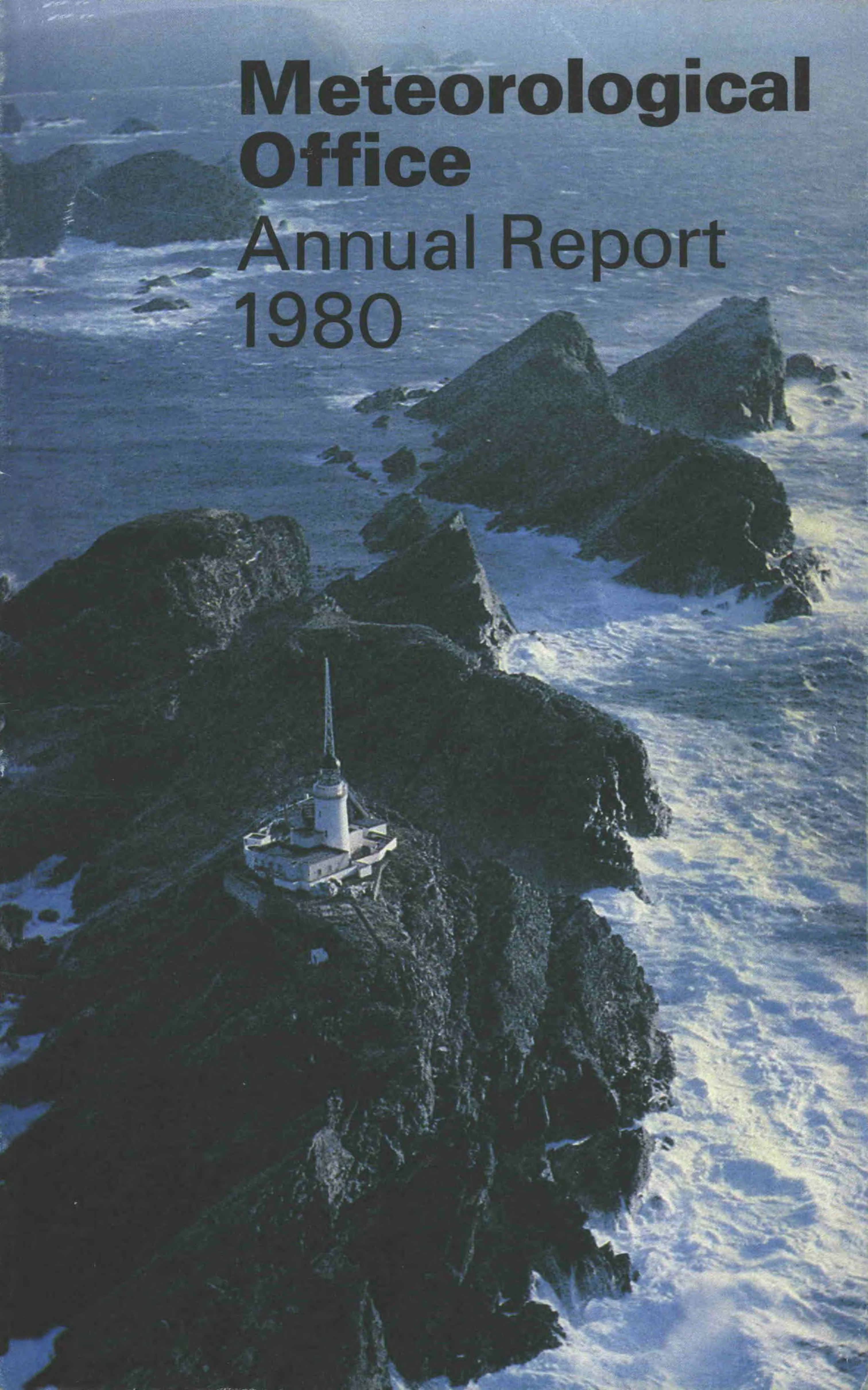
Meteorological Office
Annual Report 1980



Met. O. 945

ANNUAL REPORT

ON THE

METEOROLOGICAL OFFICE

1980

Presented by the Director-General

to the

Secretary of State for Defence

LONDON
HER MAJESTY'S STATIONERY OFFICE

First published 1982

ISBN 0 11 400333 5

Cover photograph: Muckle Flugga, Shetland, one of the Office's auxiliary weather observing stations, is the most northerly inhabited spot in the British Isles. Photograph by courtesy of Mr M. J. Kerley.

FOREWORD BY THE DIRECTOR-GENERAL

During a year in which the Office suffered severe cuts in staff it was hard pressed to meet the continually increasing demand for its services from the Armed Forces, industry, public utilities and the general public. Services for Defence are described in detail in the Special Topic article on page 1.

A total of 2.05 million forecasts was made for military and civil aviation but the number of non-aviation enquiries to forecasting offices fell slightly for the first time in many years, to 2·09 million, because there were fewer staff available to answer them. The number of climatological enquiries again rose sharply, this year to over 40 thousand. The number of calls on the Automatic Telephone Weather Service, 26 million, showed a sharp reversal of the rapid growth of recent years, due partly, no doubt, to a mild winter and the marked increase in the cost of telephone calls. Discussions have taken place with British Telecom aimed at improving the coverage and quality of this service.

There is still much scope for improving the dissemination of weather forecasts and warnings through the media. The introduction of satellite pictures into television presentations has made a strong impact but this offers only a foretaste of what could be done to provide a much more exciting, instructive and informative presentation if more time and modest resources were allocated by the broadcasting authorities. Meanwhile, the introduction of weather forecasters in live presentations on regional BBC television programs was an encouraging development.

The Prestel system now carries some 800 pages of specially prepared weather information but the number of Prestel subscribers is still far less than British Telecom had expected. With the advent of much cheaper reception equipment we both hope that it will now grow rapidly and for this to become a most important revenue earning service.

The demand for accurate tailor-made forecasts has been strengthened by the airlines' urgent need to conserve fuel, by the gas and electricity industries' requirement for more precise predictions of demand, by the offshore industry's activities in the towing, installation and operation of very costly rigs and platforms, and by the increased demand for ship routeing which rose by nearly 60 per cent during the year.

Among the many investigations carried out in support of agriculture, of particular importance is the forecasting of crop and animal diseases. During the year we introduced a new operational program to predict the development of potato blight. An instrument to record the temperature, humidity and surface wetness within a crop every 20 minutes and automatically calculate severity indices for each of a number of crop diseases was tested in the field and may be developed commercially (see page 48).

Enhancement of the message-switching computer system, whose delay has caused us much concern, is at last working satisfactorily and has greatly improved our ability to handle the increasing flow of data and products between Bracknell and other major centres in the USA and Europe.

An automated system of data retrieval and presentation consisting of two minicomputers, automatic chart plotters and visual display units was installed and tested at the Heathrow Office and will become operational very early in 1981. Linked to the Bracknell computer data bank, it will provide a more rapid and flexible service, eliminate labour-intensive chart plotting and achieve considerable staff savings. Similar systems are planned for HQ RAF Strike Command and the London Weather

Centre but this outstation automation cannot be fully implemented until additonal equipment is installed at Bracknell in about two years' time.

Turning now to some highlights of the research program, analysis of the data obtained during the international Joint Air–Sea Interaction (JASIN) project, 1978, was almost completed during the year. Intercomparison of the data obtained by the Meteorological Research Flight (MRF) Hercules aircraft and those collected by research aircraft from the United States and the Federal Republic of Germany, and by four research ships, show excellent agreement and these data should add considerably to our knowledge of the structure of the atmospheric boundary layer over the sea and to the transfer of heat, moisture and momentum between the oceans and the atmosphere.

The MRF, in collaboration with the Central Electricity Research Laboratories, also carried out the first full-scale experiments to study the fate of sulphur dioxide emitted into the atmosphere from power stations. The aircraft was able to identify and follow the plume, by detection of a tracer gas injected into the effluent, over distances of up to 300 miles over which it collected cloud-water, rain-water, particulates and gas samples for chemical analysis. The object is to elucidate the processes which govern the travel and dispersal of the plume, the nature of the chemical reactions within it and the mechanisms by which the pollution is deposited or washed out by rain.

The Hercules and Canberra aircraft were used on simultaneous flights to study the radiative properties of cirrus clouds, which play an important role in energy transfer in the atmosphere. The experimental measurements will be compared with the results of numerical models.

The Hercules intercepted the dust plume from the Mount St Helens volcano when it had reached Gibraltar five days after the eruption. Filter samples of the dust were obtained for physical and chemical analysis. This provided a good test of our ability to predict the travel of particulate clouds over very long distances.

Much effort has been devoted to the development of new operational forecasting models for use on the new giant CYBER 205 computer ordered last year. A 15-level model covering the whole of the northern hemisphere, and the southern hemisphere down to 30°S, which will make it possible for Bracknell to supply flight-planning data to the world's airlines for almost any part of the globe, has now been successfully run on the actual computer that will be installed in Bracknell in May 1981. It appears that this machine, the very first of the next generation, will be considerably faster than specified, perhaps 40 times faster than the present IBM 360/195 for certain specialized dynamical calculations. This will give the Office much greater scientific computing power than any other Meteorological Service, and should ensure that we remain in the forefront of weather forecasting and climate modelling.

In addition to the 'global' forecasting model, a new 15-level fine-mesh model with a horizontal resolution of only 50 km is being developed to provide more detailed forecasts, particularly of rainfall, for periods of up to 36 hours. This will cover not only Europe but extend to the east coast of North America and the Mediterranean. The details of the new models and of the improvements which have been incorporated are described in the Special Topic article on page 75.

Improvements in the accuracy and range of weather forecasts depend, however, not only on better models and larger computers, but also on the coverage and quality of the observations that are fed into them. The great gaps in the observational network over the oceans, the tropics and in the developing world can be filled only by satellites and by automatic observing equipment carried on commercial aircraft, ships and buoys and interrogated by satellite.

The European geostationary satellite Meteosat-1 made an invaluable contribution for two years as part of the global satellite system and the long delay in launching its replacement is particularly worrying.

The improved observations obtained during the recent Global Weather Experiment of 1979 provided an opportunity to test the relative value of various components of the global observing system and to assess the importance of particular gaps. Using the enhanced observations and introducing the seasonally varying radiation and sea surface temperatures, the global circulation model produced a particularly impressive simulation of the timing and suddenness of the onset of the south-west monsoon over Asia and Africa and the northward progression of the African tropical rain belt.

Global models of the atmosphere, similar in many respects to those used for weather forecasting but incorporating additional more slowly acting processes that govern developments over much longer time-scales, are being used to simulate the world's climate and to study how this might be changed by various disturbances, either natural or man-made. The Meteorological Office climate model has now been run to cover three complete annual cycles; with the new computer, which will enable the equations to be integrated at half-hour intervals covering a whole year in about 12 hours, it will be possible to study the evolution of the model climate and its variability over many years and to compare it with the real atmosphere. It will then be possible to establish the magnitude and statistical significance of the model's response to increases in carbon dioxide, changes in the polar ice, soil moisture, vegetation cover, and so on. Many such experiments have already been carried out but only with simplified models that do not properly allow for interactions between the atmosphere, the oceans and the ice masses to which we are now giving serious attention.

We have carried out the most detailed study so far of the climatic consequences of increasing the carbon dioxide content of the atmosphere by 2, 4 and 10 times the present value. The predictions by simpler models of a general warming much accentuated in polar regions are confirmed but the changes in both temperature and rainfall are very unevenly distributed over the globe so that the consequences for some regions may be much more serious than for others. Much further study with improved models on the the new computer will be required before we can assess these climatic effects and their likely economic and social impact with real confidence.

During October I was privileged to lead a Royal Society delegation to China where meteorology is being accorded a high priority in rebuilding the economy and scientific life of the country after the ravages of the Cultural Revolution. This was reflected in the fact that the Central Weather Bureau in Beijing (Peking), housed in a new modern building, was by far the best equipped scientific institute that we saw. We also visited the factory where a meteorological satellite is being built for launch on a Chinese rocket in 1983. China operates 110 upper-air stations, each making four ascents per day, and so makes a major contribution to the global observing system. I hope that our visit, during which we were enthusiastically received and royally treated, will lead to closer contacts between our two Services.

Finally, and on a less happy note, the Meteorological Office could not hope to escape the cuts in spending and staff which the Government has imposed on the Civil Service as a whole. So far we have had to take our full proportionate share of staff cuts, amounting to 10 per cent or 300 staff over the 3-year period April 1979 to April 1982 with no allowance for the fact that half our staff costs are met by the provision, on payment, of services to the public and private sectors. Redundancies have been avoided largely by natural wastage and restricted recruitment. Some posts have been saved by the continued introduction of automation, the contracting out of cleaning and catering at the College and reductions in our commitment to the Ocean Weather Ship scheme. However, we have had to cease a number of long-established activities including the issue of the *Daily Weather Report* and long-range forecasts, close Kew Observatory, and make cuts in research including the rocket-sounding program. Any further significant cuts would seriously impair our ability to meet our Defence and international commitments and the increasing demands for services by world aviation, the offshore oil producers, industry and commerce, reduce our revenue-earning capacity, and also our scientific research program on which our international leadership, innovation and efficiency largely depend.

B. J. MASON

March 1981
Meteorological Office
Bracknell, Berks.

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APPENDICES

FUNCTIONS OF

THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. It forms part of the Air Force Department of the Ministry of Defence. The Director-General is responsible to the Secretary of State for Defence through the Parliamentary Under-Secretary of State for Defence for the Royal Air Force.

The general functions of the Meteorological Office are:

(a) The provision of meteorological services for the Army, Royal Air Force, civil aviation, the merchant navy and fishing fleets; 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 observatories at Kew and 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.

COMMITTEES

In January the Meteorological Research Committee and its subcommittees, and the Advisory Committee on Meteorology for Scotland, were disbanded following the Government's review of non-Departmental Public Bodies. In August the constitution and terms of reference of the Meteorological Committee were revised to enable it to absorb the duties of the defunct Committees.

METEOROLOGICAL COMMITTEE

Terms of reference:

(a) To keep under review the progress and efficiency of the Meteorological Service and the broad lines of its current and future policy.

(b) To keep under review the general scale of effort and expenditure devoted to meteorological services and research.

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

Membership at 31 December 1980:

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

Members: Dr J. Birks, C.B.E.
Professor A. H. Bunting, C.M.G.
Professor H. Charnock, F.R.S.
Mr J. Miller, F.I.O.B.
*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 D. C. A. Lloyd (Assistant Chief of the Air Staff (Operations)); alternate, Group Captain M. J. C. Burton
*Captain F. J. Edwards, R.N. (Director of Naval Oceanography and Meteorology)
*Mr A. P. Flynn (Representative Civil Aviation Authority); alternate for research meetings, Mr O. B. St John
(Two full-member vacancies remain to be filled)

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

* *ex officio*

The Committee met twice in 1980. In future years it plans to meet quarterly, one meeting being devoted to the research program.

PRINCIPAL OFFICERS OF THE METEOROLOGICAL OFFICE

DIRECTOR-GENERAL

Sir John Mason, C.B., D.Sc., F.R.S.

DEPUTY TO THE DIRECTOR-GENERAL

K. H. Stewart, Ph.D.

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DIRECTOR	F. H. Bushby, B.Sc., A.R.C.S.
INTERNATIONAL AND PLANNING Assistant Director	G. J. Day, B.Sc.

FORECASTING SERVICES

DEPUTY DIRECTOR	D. H. Johnson, M.Sc., D.I.C., A.R.C.S.
CENTRAL FORECASTING Assistant Director	D. E. Jones, M.Sc., D.I.C., A.R.C.S.
DEFENCE SERVICES Assistant Director	I. J. W. Pothecary, B.Sc., M.Inst.P.
Chief Meteorological Officer, H.Q. Strike Command	A. G. Forsdyke, B.Sc.
PUBLIC SERVICES Assistant Director	R. J. Ogden, B.Sc.
Chief Meteorological Officer, London/Heathrow Airport	A. Ward

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TELECOMMUNICATIONS Assistant Director	D. N. Axford, Ph.D., C.Eng., M.I.E.E.
DATA PROCESSING Assistant Director	P. Graystone, B.A.
SYSTEMS DEVELOPMENT Assistant Director	R. L. Wiley, Ph.D.

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Assistant Director	D. R. Grant, B.Sc.
Marine Superintendent	G. A. White, Captain, Extra Master
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Assistant Director	C. R. Flood, M.A.
AGRICULTURE AND HYDROMETEOROLOGY	
Assistant Director	C. V. Smith, M.A., B.Sc.
OPERATIONAL INSTRUMENTATION	
Assistant Director	R. E. W. Pettifer, Ph.D.

DIRECTORATE OF RESEARCH

DIRECTOR	K. H. Stewart, Ph.D.

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Assistant Director	C. J. Readings, Ph.D., D.I.C., A.R.C.S.
Special Post	F. B. Smith, Ph.D.
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Chief Meteorological Officer	D. G. James, Ph.D.
METEOROLOGICAL OFFICE RADAR RESEARCH LABORATORY	
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Assistant Director	P. Ryder, Ph.D.
SATELLITE METEOROLOGY	
Assistant Director	D. E. Miller, B.A.

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FORECASTING RESEARCH Assistant Director	P. W. White, Ph.D.
SYNOPTIC CLIMATOLOGY Assistant Director	D. M. Houghton, M.Sc., D.I.C.
PROFESSIONAL TRAINING Assistant Director and Principal, Meteorological Office College	S. G. Cornford, M.Sc.
DYNAMICAL CLIMATOLOGY Assistant Director	A. J. Gadd, Ph.D.
Climate Modelling	P. R. Rowntree, Ph.D.

ADMINISTRATION, FINANCE AND SUPPLY

SECRETARY, METEOROLOGICAL OFFICE	F. R. Howell, M.B.E., F.C.I.S.
PERSONNEL MANAGEMENT Assistant Director	F. Singleton, B.Sc., D.I.C.

METEOROLOGICAL OFFICE ORGANIZATION

(at 31 December 1980)

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

DIRECTORATE OF SERVICES

SPECIAL TOPIC—METEOROLOGICAL SERVICES FOR DEFENCE

Introduction

The first recorded use of meteorological knowledge in the defence of a nation was in 480 BC when the Athenian admiral Themistocles timed his engagement of a large invading force of Persian ships under Xerxes to coincide with the onset of the afternoon sea-breeze between the island of Salamis and the mainland coast at Piraeus. The Persian fleet of 1200 large and unwieldy ships was preoccupied with keeping off the lee shore in rough water with little sea-room and was destroyed by the small but highly manœuvrable Athenian fleet of only 380 ships, forcing Xerxes to abandon his plans for extending the Persian empire westwards over the Mediterranean.

Thereafter history frequently records the unplanned and random effect of weather on the outcome of war, but the occasions when a knowledge of the weather was used in central military planning were rare, although a notable exception was the work of the Meteorological Section of the Royal Engineers in France during the First World War. There were many occasions in the Second World War when military actions were successfully based on meteorological advice, but the one occasion when the outcome of the war could be said to have been decisively determined came in June 1944 with the commitment of the Allied Forces to the invasion of Europe. The invasion was launched on a forecast of the essential short spell of quiet weather in the English Channel. The weather of June 1944 was unusually disturbed but the required spell of quiet weather was accurately forecast at a time when the German High Command had relaxed its vigilance on advice that the weather would be against the launching of the invasion.

Following the end of the Second World War the trained manpower providing meteorological services for the Armed Forces was largely dispersed. The requirements of the Royal Air Force and the Army for meteorological services were once again met from within the civilian resources of the Meteorological Office, although the needs of the Royal Navy continued to be met from within Navy resources, as before the war, by the Naval Weather Service (now the Directorate of Naval Oceanography and Meteorology).

The need to co-ordinate afresh the activities of the Meteorological Office in support of Defence was recognized in 1966 when meteorological services for the Royal Air Force, the Army and the Procurement Executive and the national response to the meteorological needs of NATO were concentrated into one Services Directorate Branch under the title of Defence Services. The concentration within one Branch of almost the entire organizational effort of the Meteorological Office for Defence showed that the response to Defence needs represented the largest single group of activities within the Meteorological Office. Defence has since remained the largest single user of Meteorological Office services, requiring the direct involvement of over a quarter of the total staff at Defence locations in the United Kingdom, Germany and the Mediterranean, and absorbing rather more than 40 per cent of the total costs of the Meteorological Office.

The scale and diversity of meteorological services for Defence are summarized in Table 1. By the end of the financial year 1980/81 a total of 750 staff was employed in direct support of Defence in 62 Defence Services Branch outstation meteorological offices located with the Royal Air Force (53), the Army (4) and the Procurement

Executive (5); 50 of the offices were in the United Kingdom, 8 in Germany and 4 in the Mediterranean. The headquarters of the Defence Services Branch was located in the Meteorological Office Headquarters at Bracknell with 12 staff.

Meteorology in military operations

A decisive factor in modern warfare is the speed and flexibility with which air power can be deployed to its full effect, to the extent that the primary aim of strategy is to achieve supremacy in the air and the primary tactical objective is air superiority. Rather than making weather redundant as a factor in the effective use of air power, increasing sophistication in aircraft design and in the technology of weapons systems is having the effect of lowering the minimum weather conditions in which air power can be effectively used. Success in air operations is more likely to go to the air commander who has the training, experience and meteorological advice which he can apply in assessing the effects of weather on operations under his control, allowing aircraft and weapons systems to be used right down to the minimum weather limits.

The area of interest to the Royal Air Force as a component of the Second Allied Tactical Air Force in NATO's defence of western Europe extends from the North Sea through the Low Countries and the northern half of West Germany eastwards across the north European plain. The climatology of the region falls conveniently into three areas bounded by the longer northward-flowing rivers: between the Rhine and the Weser, the Weser and the Oder, and the Oder and the Vistula. Apart from the ridges of high ground extending northwards on either side of the Weser from the Harz mountains, the area has a low relief mostly below 150 metres. The meteorological data for most airfields in the three areas can therefore be regarded as representative of conditions over wider areas surrounding each airfield.

The analysis in Figure 1, based on published data from airfields representative of each area, shows the average percentage frequency by months of cloud base below 300 feet and/or horizontal visibility less than 1 n. mile, taking all hours of observation together.

The assessment of the level at which weather becomes a significant factor in military operations is a matter for military decision but the analysis in Figure 1 shows that if a cloud base below 300 feet and/or a horizontal visibility less than 1 n. mile restrict air operations, then the chance of failure in the effective use of air power at low level due to poor weather, taking the day as a whole, will lie between 15 and 20 per cent during November–February in the area between the Rhine and the Weser, and in the same range in December between the Weser and the Oder. Between the Oder and the Vistula the incidence of poor weather likely to inhibit low-level operations is less than 10 per cent through the year. West of the Oder the incidence of poor weather falls below 10 per cent only during April–September, although between the Weser and the Oder the incidence falls to less than 10 per cent in March, a month earlier.

The diurnal variation of conditions during winter when the cloud base is less than 300 feet and/or visibility is less than 1 n. mile shows that there is little significant difference between the average incidence of the conditions during the hours of darkness and the hours of daylight. Assuming that close air support is not possible during the hours of darkness, the time during which close air support can be exercised effectively during the four winter months November–February is limited to about 7 hours per day between the Rhine and the Weser, $7\frac{1}{2}$ hours per day between the Weser and the Oder, and 8 hours per day between the Oder and the Vistula.

The percentage frequency of occasions when the cloud base will be above 1000 feet and the horizontal visibility better than 3 n. miles, when the weather is likely to have

TABLE 1—SUMMARY OF DEFENCE SERVICES OFFICES AND STAFF COMPLEMENTS AS ON 1 APRIL 1981

	UK		GERMANY		MEDITERRANEAN		TOTAL	
	Offices	Staff	Offices	Staff	Offices	Staff	Offices	Staff
Met O 6 HQ	1	12					1	12
C Met O HQSTC	1	4					1	4
C Met O HQ RAF Germany			1	2			1	2
Principal Forecasting Office	1	72					1	72
Main Meteorological Offices	6	169	1	27	2	46	9	242
Subsidiary Forecasting Offices:								
RAF Stations	28	260	4	41			32	301
RAF units at MOD(PE) establishments	3	23					3	23
Army Aviation Stations	2	11	1	8			3	19
HQ 1(BR) Corps			1	(1)[1]			1	(1)
MOD(PE)/Army trials establishments	4	43					4	43
NATO Allied Meteorological Office:								
UK staff in AMO Maastricht			(1)[2]	3			(1)	3
Observing Offices:								
RAF Stations	4	19			1	5	5	24
MOD(PE)/Army trials establishments	1	1					1	1
Radiosonde units:								
RAF Stations					1	16	1	16
MOD(PE)/Army trials establishments	(4)[3]	(–)[3]					(4)	(–)
Total serving RAF	43	559	6	73	4	67	53	699
Total serving Defence	51	614	8	81	4	67	63	762

Notes

1. Post held by S Met O Detmold.
2. Office outside Meteorological Office but staff remain on the Meteorological Office complement.
3. Function integrated with subsidiary forecasting offices at MOD(PE) establishments.

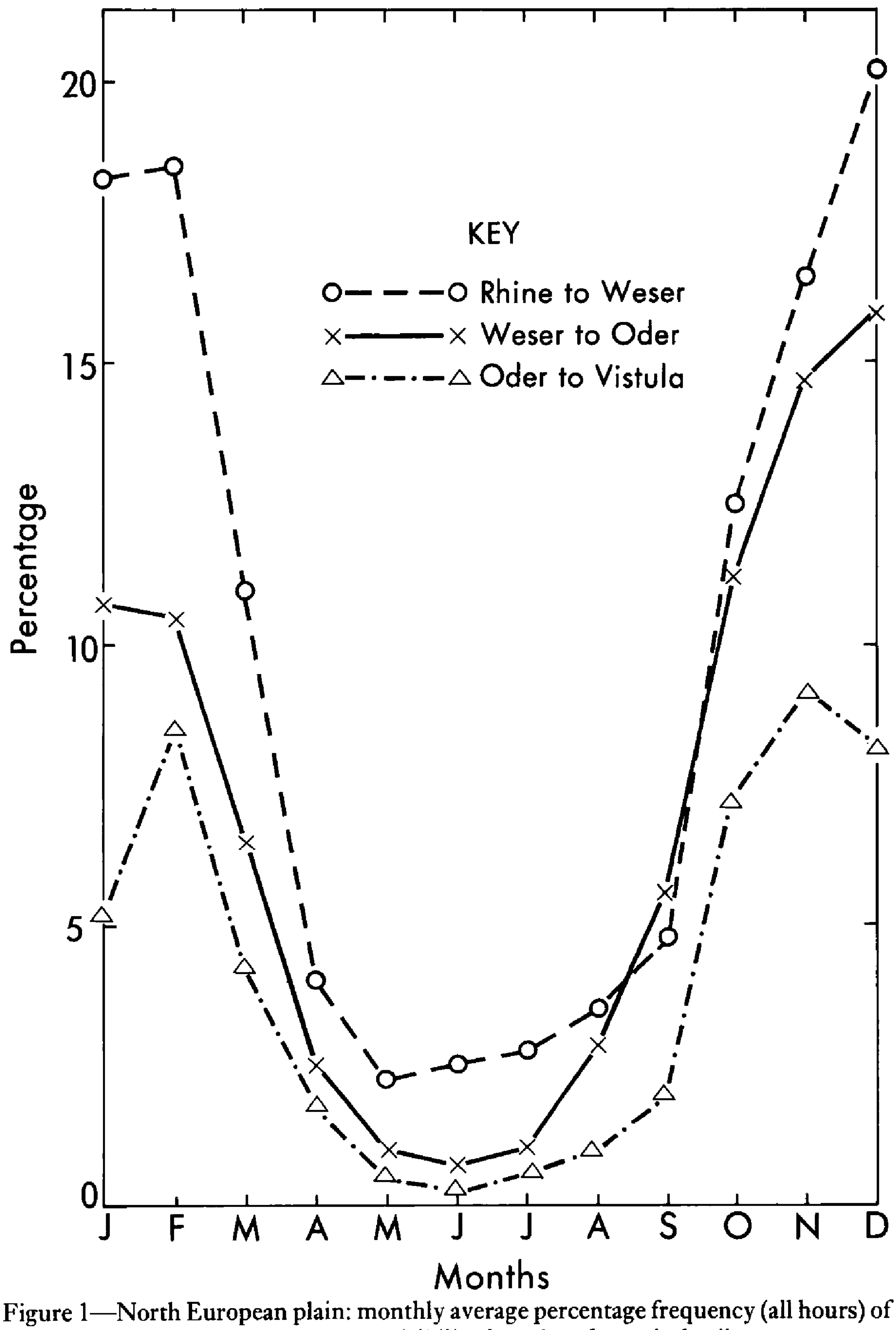

Figure 1—North European plain: monthly average percentage frequency (all hours) of cloud base less than 300 feet and/or visibility less than 1 nautical mile

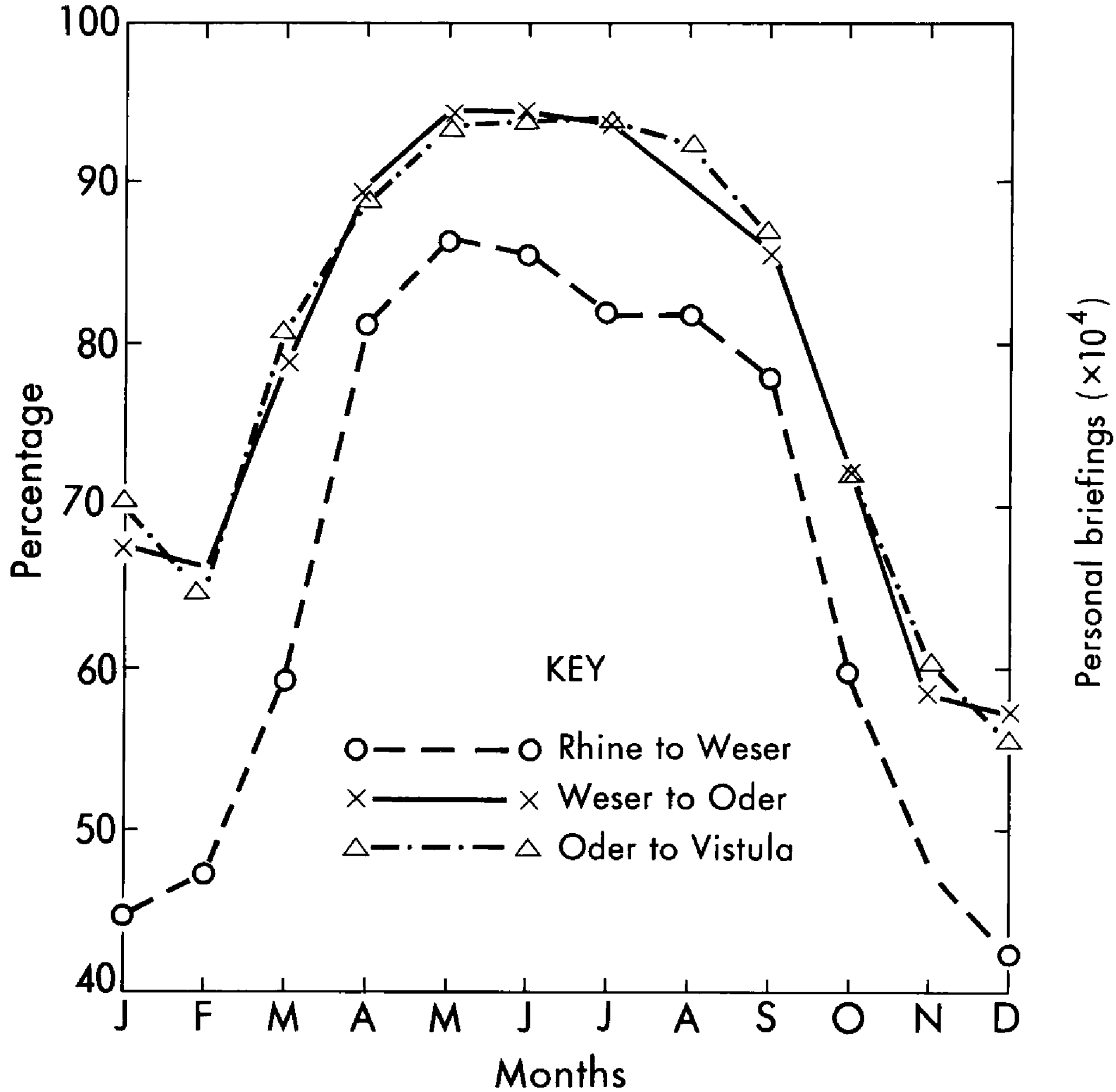

Figure 2—North European plain: monthly average percentage frequency (all hours) of cloud base higher than 1000 feet and visibility more than 3 nautical miles

little or no effect on low-level operations, is shown in Figure 2. Between the Rhine and the Weser such favourable conditions will apply for over 50 per cent of the time during March–October but only between 40 and 50 per cent of the time during November–February. East of the Weser the incidence of such conditions is higher, averaging over 70 per cent in March–October and between 55 and 70 per cent in November–February.

Success or failure in a military operation may depend on exploiting the marginal differences that could tip the balance decisively one way or the other. The commander who assumes that the effects of weather on his operations are the luck of the draw may fail to recognize an opportunity to load the balance in his favour. The commander who is sensitive to the effects of weather on his own and on the opposing forces will be in a position to exploit adverse weather rather than suffer it. The effective use of air power is likely to remain sensitive to weather in western and central Europe because of the high incidence of weather that is sufficiently adverse to affect operations, particularly in winter, even with increasingly sophisticated aircraft. The role of meteorologists in the defence of western Europe is to provide commanders with the advice and services that will allow the opportunities for marginal advantages to be recognized and exploited. For that to be effectively done there is a need for an understanding of the effects of weather on the exercise of air power at all levels of command, and a need for meteorological support to be given with an understanding of the relevance of weather to military operations.

The Meteorological Office response to Defence needs

(a) *Organization of meteorological services for the Royal Air Force*

The close historical relationship between the Meteorological Office and the Royal Air Force goes back to 1918 when the Royal Air Force was formed from the Royal Flying Corps and at the same time the Meteorological Office was brought under the control of the new Air Ministry. The close relationship remains and is reflected in the staff of 699, out of the total of 762 in the Defence Services Branch, who were employed at the beginning of 1981 in 53 meteorological offices in direct support of the Royal Air Force, mostly at operational airfields and at Group and Command Headquarters.

After the Second World War the organization of meteorological services for the Royal Air Force continued to reflect the wartime chain of command down to the operational squadrons in the maintenance of Main Meteorological Offices at the various Group Headquarters. By 1965 the meteorological office at Headquarters Bomber Command at High Wycombe had begun to provide centralized advice directly to a number of airfield meteorological offices and had been designated as a Principal Forecasting Office, although some services to the airfield meteorological offices continued to be provided from the Main Meteorological Offices. By 1968, with the amalgamation of Bomber, Fighter and Coastal Commands into a new Strike Command, the Principal Forecasting Office was working directly to the requirements of most of the meteorological offices at the operational airfields. Meteorological offices at some of the training airfields also received direct technical support from the Principal Forecasting Office. With the incorporation of Air Support Command into Strike Command in 1972 there was a further extension of the direct technical parentage exercised by the Principal Forecasting Office. The growing trend towards centralization in meteorological services for the Royal Air Force was a direct reflection of the command and control of the operational squadrons exercised from Headquarters Strike Command.

Under a long-standing arrangement between the Meteorological Office and the Royal Air Force, meteorological offices serving Royal Air Force needs, with the exception of the Principal Forecasting Office, operate as multi-functional offices. Services for the general public are available from meteorological offices at Royal Air Force stations to the limits set by the staff complements established for the Royal Air Force need alone, and subject always to the priority of the Royal Air Force work. Similar services are also available from the Main Meteorological Offices at Group Headquarters.

In 1977 a requirement for meteorological services was prepared by the Air Staff and endorsed by the Vice-Chief of the Air Staff. The statement of requirement made it possible for the Meteorological Office to develop long-term plans for support for the Royal Air Force on authoritative forward-looking assumptions which took full account of the introduction of a new generation of aircraft into the Royal Air Force. The statement emphasized the importance of meteorological support to the efficient conduct of day-to-day flying training and to the effectiveness of air operations. Particular importance was attached to the forecasting of weather at low level for short periods ahead. The Air Staff also emphasized the importance of the direct relationship between forecasters and aircrew at the airfield level, recognizing that the requirement for details of the physical behaviour of the atmosphere in terms of cloud base, visibility, low-level turbulence and precipitation over a period only up to about six hours ahead is not susceptible to centralized automated methods of analysis and forecasting but is likely to remain, for the foreseeable future, as an area where subjective skills and expertise and local knowledge have a real contribution to make. It was also recognized that there is a need for forecasters in direct contact with operations staffs and aircrew to have a clear understanding of the operational roles for which they are providing meteorological support.

For a number of years the trend towards the centralization of meteorological support had made the outstation forecaster seem less important. The concentration of computer facilities and experienced forecasters in centralized offices was appropriate to the support of aviation conducted at medium and high levels and requiring forecasts well beyond six hours ahead. The Air Staff requirement, however, foresaw the introduction of new aircraft into the Royal Air Force inventory which would change the emphasis towards low-level high-speed operations, generating an increasing demand for forecasts of the physical behaviour of the lowest levels of the atmosphere for only short periods ahead. Support for medium- and high-level operations would still be required but would no longer generate the main demand from the Royal Air Force for meteorological support.

The only effective way in which the Royal Air Force needs can be met, as confirmed by the Royal Air Force, is to maintain the forecaster in direct contact with operations staff and aircrew and to provide him with the support he requires to deploy his professional skills. It would run counter to the stated Royal Air Force requirement if he were to be required to act solely as an agent for a centralized organization rather than as a professional adviser in his own right.

The statement of requirement for meteorological services for the Royal Air Force was timely. The steady trend towards the direct parentage of airfield meteorological offices from the Principal Forecast Office had resulted in the development of a centralized organization but the stage had not been reached when the work of the airfield forecaster could be adequately performed from the centre. Now that the requirement for retaining the forecaster in direct contact with the operators has been clearly established, the centralized organization can be developed as a system which will allow the forecaster to react faster, more effectively and directly to operational demands.

Traditional methods of providing meteorological data to the forecaster by analogue facsimile and slow-speed teleprinter limit the speed and the effectiveness of the response to the operational needs of the Royal Air Force. A computer system is being introduced into the Principal Forecasting Office at Headquarters Strike Command which is designed to support the airfield forecaster in his main task of short-period forecasting for low-level operations. It is planned to install remote computer terminals in airfield meteorological offices, allowing the centralized system supporting the needs of the Royal Air Force to function as a demand system on the initiative of the airfield forecaster rather than as a broadcast system with a content determined at the centre. The system will be tested in pilot projects at RAF Lyneham and RAF Honington during 1982 and, if the pilot projects are successful, it is planned to extend the system to the meteorological offices at all RAF operational airfields over the following two or three years. It should also be possible to process radar and satellite data in the central computer in the Principal Forecasting Office at Headquarters Strike Command into a format which can be called up on the airfield computer terminals at the initiative of the forecaster. The introduction of a computer system in support of services to the Royal Air Force should result in a significant improvement in the standard of service. The ability to provide centrally a constantly updated data bank on which the airfield forecaster can draw as required will provide better technical support than is possible with the present system of fixed-time broadcasts with unavoidable delays in making available the latest data.

Flight-planning for many civil airline operations is a centralized computer-based function which leaves few decisions to be made by the aircraft captain as the result of a personal weather briefing. In military aviation, operations staff and aircrew retain some responsibility for decision making in the detailed conduct of assigned tasks. Weather information imparted at a personal briefing using the latest available data is always relevant to mission planning and sometimes decisive. A comparison of the trends in the number of personal briefings year by year from 1974 to 1980 illustrates this significant difference between civil and military aviation in the use of meteorological support (Figure 3). The total number of personal briefings for civil aviation shows a slight decrease over the seven-year period while personal briefings for military aviation show a marked upward trend over the same period. Further evidence of the increasing use of meteorology in military aviation is shown by the trend in the average annual number of personal briefings for each squadron in service. In 1974 there were 3232 personal briefings per squadron but by 1980 the number of briefings had increased to 4150, an increase of 28 per cent. The upward trend in the annual number of personal briefings confirms the 1977 Royal Air Force requirement for the maintenance of direct contact between forecasters, operations staff and aircrew and reflects an increased commitment to weather-sensitive low-level operations and an increased sensitivity to the importance of weather in mission planning.

A measure of the productivity of Meteorological Office staff in response to the needs of military aviation is provided by relating the number of written forecasts and personal briefings for military aviation to the number of forecasters in the Defence Services Branch. In 1974, with 317 forecasters meeting the needs of military aviation, the average number of written forecasts issued by each forecaster was 2907. In 1980 the number of forecasters had fallen to 262 but the average number of written forecasts issued by each forecaster had increased to 3343, that is by 15 per cent. The average number of personal briefings given by each forecaster in 1974 was 704, but in 1980 the average number had increased to 982 or by 39 per cent.

A significant feature of the role of the civilian Meteorological Office forecasters at operational airfields is that they function as an integral part of the operations staffs and are fully involved in national and NATO exercises, working in protective clothing and respirators in the Combat Operations Centres as and when required and often at short notice. The Meteorological Office is also responsible for the manning of the Mobile Meteorological Units of the Royal Air Force Tactical Communications Wing, operating with other assigned Royal Air Force squadrons as part of the Mobile Force of the NATO Allied Command in Europe. The Units are manned by a small complement of forecasters and observers, all of whom hold Class CC commissions in the Royal Air Force and operate in the field in uniform. The cadre of staff concerned are all volunteers and receive training in basic military skills.

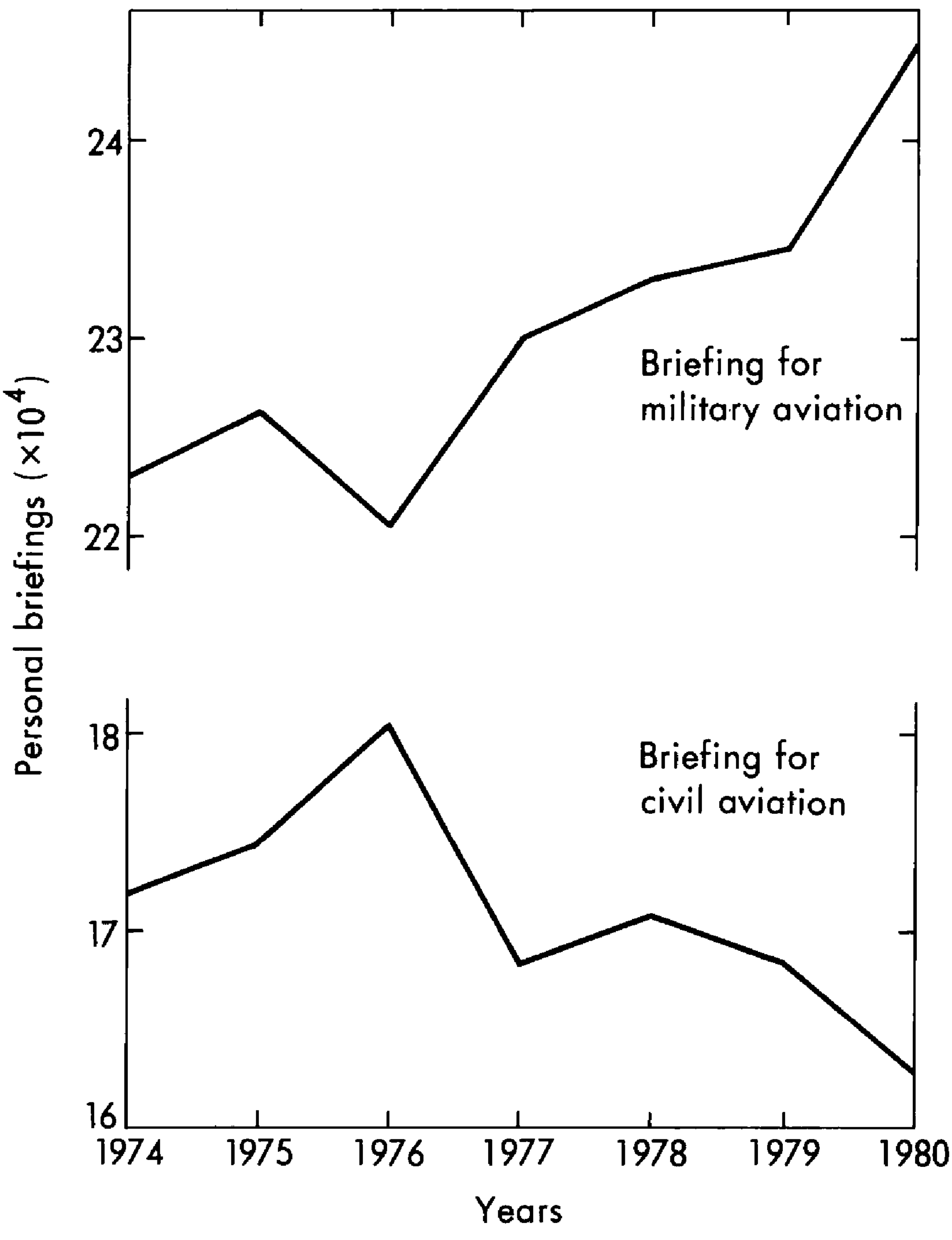

Figure 3—Personal briefings for civil and military aviation

(b) *Organization of meteorological services for the Army*

The Army Air Corps is faced with problems similar to the Royal Air Force in operating helicopters and light aircraft and a close association has developed over the past decade with the Directorate of the Army Air Corps. The scale of effort is very much less than for the Royal Air Force, with only 20 staff employed in three meteorological offices at the Army Air Corps airfields at Netheravon and Middle Wallop and at Detmold in Germany. The services which are provided relate mainly to flight safety in the operation of helicopters and light aircraft, often at very low levels, although there is an increasing awareness on the part of the Army Air Corps of the relevance of meteorological advice to the effective conduct of Army Air Corps support in land-force operations. A routine part of the service to the Army Air Corps is the provision of forecast data related to the natural illumination of ground targets at night resulting from a combination of moonlight and cloud cover. The organization of services for the Army Air Corps is similar to the organization of services for the Royal Air Force. As there are only two meteorological offices serving the Army Air Corps in the United Kingdom and only one in Germany, the offices are integrated into the organization designed to meet Royal Air Force requirements although they react to the needs of the Army.

The wider interest of the Army in environmental support services is not well defined, partly because of a lesser sensitivity of Army operations to weather and partly because the effect of weather on land-force operations is not as natural a part of the training of the field officer as it is in the training of aircrew. Useful experience in the importance of weather in land operations was, however, gained by the Army in the Major BAOR exercise CRUSADER 80 held in the 1(BR) Corps area in September 1980. The Senior Meteorological Officer in the meteorological office at Detmold also holds the post of Senior Meteorological Officer at the Headquarters of 1(BR) Corps. He was fully involved in CRUSADER 80 in the field headquarters of the Corps and was able to demonstrate the capability of the Meteorological Office in providing meteorological inputs to land-force command and control decisions. By making use of the central resources of the Office he was also able to provide advice to the Commander which proved useful in decisions related to minimizing the damage to farmland caused by tracked vehicles.

(c) *Organization of meteorological services for the Procurement Executive*

Meteorological advice for the artillery ranges and the research and development establishments of the Procurement Executive is considered by the users as essential to the effective conduct of trials, in terms both of acquiring data for subsequent trials analyses and for range safety. A total of 43 staff in five meteorological offices is deployed in direct support of the Procurement Executive on the ranges at Aberporth, Eskmeals, Larkhill, Pendine and Shoeburyness. A full radiosonde capability is maintained at each of the ranges, with the exception of Pendine, and is used to provide upper-air data in support of specific trials. The Mk 3 radiosonde system has been specially modified at all four locations to provide detailed upper-air data in near-real time and computer-tape records for use in trials analyses. The meteorological office at Shoeburyness provides services for the Atomic Weapons Research Establishment explosives testing ground at Foulness. The meteorological office at Larkhill, as well as providing services for the Royal School of Artillery, provides services for the Chemical Defence Establishment at Porton and the Royal Aircraft Establishment range on Salisbury Plain.

An important part of the service provided from the meteorological offices on the Procurement Executive ranges is the forecasting of noise propagation which allows explosives and ordnance trials to be conducted with the minimum of inconvenience to the general public. Much of the development work associated with improving the forecasting of noise propagation is carried out in the meteorological office at the Royal School of Artillery in close co-operation with the range authorities. A method for producing noise-propagation forecasts using numerical techniques was developed in the Meteorological Office in 1978 and has since been tested and improved at Larkhill, using the small desk-top computer which forms part of the Mk 3 radiosonde system adapted for use on the ranges. The accuracy of forecasts of noise propagation has been considerably enhanced, giving over-pressure forecasts which verify to within 5 decibels. The application of the technique to acoustic forecasting for artillery trials at Larkhill has minimized periods when firing is restricted because of the likelihood of blast damage. Taped programs have been compiled for use in the other range offices equipped with the Mk 3 radiosonde system.

(d) *Meteorological support for the Home Office*

The Home Office United Kingdom Warning and Monitoring Organization (UKWMO) exists to provide warnings of air attack and to monitor and predict nuclear fallout for both national and NATO civilian and military purposes. Although no Meteorological Office staff are permanently employed in direct support of the Home Office UKWMO, there is a cadre of 15 volunteer staff who man the meteorological cells in the five UKWMO Sector Controls when required. The volunteer staff are normally fully employed elsewhere in the Meteorological Office as forecasters. Their function in the Sector Controls is to provide the meteorological data essential to the calculation of fallout trajectories. The data are obtained through links with the Central Forecasting Office at Bracknell and there are also direct links with the eight radiosonde stations in the United Kingdom.

(e) *Meteorological support for the Royal Navy*

Meteorological services for the Royal Navy are provided by the Directorate of Naval Oceanography and Meteorology (DNOM). The Meteorological Office is responsible for making available to DNOM observational data which are not available from Naval sources and also provides for guidance analyses and forecasts prepared by the Central Forecasting Office at Bracknell. Very close co-operation is maintained between the Defence Services Branch and DNOM, both at the working level between the Principal Forecast Office at High Wycombe and the Fleet Weather and Oceanographic Centre at Northwood and between the Defence Services Branch headquarters and the headquarters of DNOM in Whitehall. A Naval Liaison Officer on the staff of DNOM is located at the Defence Services Branch headquarters in Bracknell. The close co-operation ensures that meteorological support from both the Meteorological Office and the Royal Navy is co-ordinated nationally and within NATO across the whole range of Defence requirements.

(f) *Meteorological Office NATO responsibilities and relations with other national military meteorological services*

National representation for the United Kingdom in the NATO Military Committee Meteorological Group and other NATO agencies concerned with meteorology is provided by staff from the headquarters of the Defence Services and the Telecommunication Branches, supported and advised in Naval matters by staff from the Directorate of Naval Oceanography and Meteorology. National support from the United Kingdom for the small meteorological organization in Europe which is under direct NATO control is provided through the allocation of a forecaster and two assistants from the Meteorological Office to the Allied Meteorological Office at Maastricht in Holland. A Principal Scientific Officer fills the uniformed post, with a Class CC commission in the rank of Group Captain, of Chief Meteorological Officer to the NATO Supreme Allied Commander in Europe at SHAPE Headquarters at Mons in Belgium.

An important aspect of the international work of the Defence Services Branch is the maintenance of a close working relationship, outside the NATO agencies, with the Air Weather Service of the United States Air Force and the German Military Geophysical

Office. The Meteorological Office presence in Germany in support of the Royal Air Force and the Air Weather Service presence in the United Kingdom in support of the United States Air Force results in areas of common concern to all three national meteorological organizations serving military needs. NATO Military Committee policy for meteorological support is based on the various national facilities which can be made available in a time of tension, crisis or war, and increasing use is being made of the meteorological resources of the host nations in support of national and NATO activities. The United Kingdom, through the Meteorological Office representatives in the various NATO bodies, is taking the initiative in improving the NATO-wide co-ordination of national meteorological resources for military purposes. Closer co-operation with the United States Air Weather Service and the German Military Geophysical Office is developing from that initiative.

(g) *Contingency planning*

Most of the meteorological services for Defence are provided through the 62 meteorological offices located with the Royal Air Force, the Army and the Procurement Executive users, but there is a range of activities related to Defence, other than the management of the Defence Services Branch, which is organized by the small headquarters unit of 12 staff located in the Meteorological Office Headquarters at Bracknell. Contingency planning for emergencies both within the Meteorological Office and, in co-operation with all three Services, over the wider requirements for meteorological support in a national emergency is an important feature of the work in the headquarters of the Defence Services Branch, working closely with the Directorate of Naval Oceanography and Meteorology. Particular attention is also paid to emergency plans for providing meteorological advice from the nearest Main Meteorological Office, including computed fallout trajectories, to the various nuclear establishments in the event of the accidental release of nuclear material either from a fixed location or in transit.

Support from the central resources of the Meteorological Office

The extensive central resources of the Meteorological Office at Bracknell provide major support for the meteorological offices meeting Defence needs. The central planning teams responsible for the development of computer-based systems are directly concerned with the extension of automated support to the Defence Services outstation forecasters; the communications needs of the Defence Services organization, in particular the development of automated communication systems, are integrated into Meteorological Office communication planning as a whole and the considerable research capability of the Meteorological Office takes account of Defence needs for meteorological research, previously through the Defence representatives in the Meteorological Research Committee and now through the representation of Service interests in the expanded Meteorological Committee.

With the introduction of a new cost-accounting system in 1978 it became possible to present financial information in detail and to analyse the allocation of expenditure over the whole range of Meteorological Office activities, including the provision of central meteorological support and advice for Defence. The cost-accounting analysis for 1980 showed that more than 40 per cent of the total costs of the Meteorological Office were allocated to activities directly concerned with Defence. The value of providing services for Defence from within one organization meeting almost all the meteorological needs of the nation is demonstrated by the channelling to Defence of over 40 per cent of the total expenditure of the Meteorological Office through only 27 per cent of the total staff. The situation is unique amongst meteorological services meeting military needs and explains why the Meteorological Office is able to maintain the highest standards in its service to Defence, through the capability for drawing on central support such as numerical forecasting, computer-based systems and communication developments and Defence-related research. There is an additional advantage to the manning of Defence Services Branch posts in that the 27 per cent of the total Meteorological Office staff who are required to work in the military environment can be selected from the total complement.

The Meteorological Office, apart from providing the meteorological support required day-by-day for Defence activities, is concerned with developing the organization which meets those needs so that it will remain relevant into the foreseeable future. An important aspect of that task is the maintenance of an understanding of the military needs for environmental support in the Meteorological Office response to the needs for Defence. If meteorological support for Defence activities is to be fully effective it is equally essential that there is a corresponding awareness on the part of military commanders of the effect of weather on military operations.

OTHER WORK OF THE DIRECTORATE OF SERVICES

Forecasting Services

Central Forecasting Office

The Central Forecasting Office (CFO) is continuously developing but its main functions have remained unchanged for a number of years. At the national level as the chief forecasting centre of the Meteorological Office, its principal tasks are twofold. First, it provides guidance to the Meteorological Office outstations by landline, facsimile and teleprinter in the form of plotted observations and charts showing actual and expected synoptic situations with advisory texts covering the following five days. Second, it is responsible for the routine issue of forecasts for sea and land areas, and for warnings of weather hazards including gales, fog, snow, heavy rain, frost, icy roads, thaw and thunderstorms over and around the United Kingdom. These are disseminated to the public on our behalf by radio, television and the Press, but some forecasts are also issued direct to public utilities such as the British Gas Corporation and the Central Electricity Generating Board.

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. The area covered includes a large part of the North Atlantic, Europe and the Arctic. Most of the information is supplied in chart form. However, an increasing proportion is being distributed as sets of numerical values, relating to points of a latitude–longitude grid, in a standardized GRID-code format.

Analyses and forecasts are produced in CFO by a combination of numerical (computer) methods and subjective (manual) methods. The observational data are processed by a computer which provides both analyses and forecasts. These numerical processes are monitored by the forecasters who may modify the products in the light of their experience of the behaviour of weather systems, and their knowledge of the characteristics of the numerical analysis and forecast models, or because of suspected errors in the data used. The forecasters also take into account information not available to the numerical system such as observations that have been received too late or data that have been derived from the interpretation of satellite pictures.

The two forms of the 10-level numerical forecasting model, the coarse-mesh (octagon) version covering most of the northern hemisphere and the fine-mesh (rectangle) version giving more detailed coverage, including rainfall forecasts, for Europe and the North Atlantic, provide the basic guidance. Both versions of the model are run twice a day and are based on atmospheric observations made at 00 GMT and 12 GMT; an additional fine-mesh forecast based on observations made at 06 GMT is also run. The fine-mesh analyses and prognoses of surface pressure, forecast rainfall rates and amounts, and parameters related to mean tropospheric temperature are now being transmitted to the Main Meteorological Office at Rheindahlen, RAF Germany as well as to the Principal Forecasting Offices at London Airport and Headquarters RAF Strike Command.

Forecasts for two and three days ahead are disseminated internationally and issued to meteorological offices throughout the country. They form the basis of forecasts for agriculture and for manufacturing and building industries as well as for the general public, and are particularly useful in forecasting for the offshore oil industry. Forecast charts for four and five days ahead are produced daily by the subjective modification of the numerical forecasts by the Medium-range Forecasters and have been used in CFO for several years for providing extended guidance in the above fields of activity. At the end of the year their routine transmission to Meteorological Office outstations began. They are used to provide the basis for the extended weather outlook issued during the late evening each day on BBC Radio 4. Forecast charts for up to seven days ahead are being received from the European Centre for Medium Range Weather Forecasts and are available on an experimental basis to the Medium-range Forecasters who are assisting scientists in the Forecasting Research Branch to assess their value.

As part of the Area Forecasting System of the International Civil Aviation Organization, the aviation forecasters in CFO provide briefing documentation showing forecast upper winds and temperatures for aircraft flying from western Europe to North America, and for flights from Africa and the Middle East into western Europe. Special documentation is prepared twice a day for Concorde flights across the Atlantic (for British Airways and Air France) and was also prepared three times a week for Concorde flights to Bahrain until the flights were discontinued in late October. Numerical-forecast products for aviation are becoming increasingly important. An experimental index for clear-air turbulence, developed by the Special Investigations Branch, has been prepared for inclusion in the operational suite and is being assessed for its usefulness as a forecasting tool. Another development has been the preparation of digitally coded forecasts in a format describing vertical sections of the atmosphere and tailored to the operating needs of civil aviation; this code has been supplied to British Airways in trials of a new flight-planning system. Coded forecasts have also been prepared for other aviation interests, most notably the Civil Aviation Authority for use in a new air traffic control system.

The performance of the numerical forecasting models is monitored by calculating statistics of model forecast errors; the forecasts are compared both with the actual observations made at the forecast validation time and with analyses based on them. A statistical verification scheme has been implemented for the fine-mesh rainfall forecasts. The statistical verification results are an important tool for assessing the value of modifications to the models and for comparing different models, although subjective assessments also have to be made to determine whether there have been any improvements in the forecast fields from the synoptic point of view. The World Meteorological Organization project for the Intercomparison of Numerical Weather Prediction products from various centres around the world was extended for a second year. The Office increased its participation by supplying forecasts from midday as well as from midnight.

Satellite image data (cloud pictures) have continued to make a valuable contribution to the preparation of surface and upper-air analyses, particularly over the North Atlantic and European regions. Data continued to be received from the United States polar-orbiting satellite NOAA-6 throughout the year and also from TIROS-N until the failure of its picture transmission system in early November. Since picture transmissions from the European Space Agency geostationary satellite Meteosat failed late in 1979, the ground receiving equipment has been used instead to receive pictures from the US geostationary satellite GOES-East (located over Brazil). These pictures have been found particularly useful in providing real-time information for the data-sparse west Atlantic area.

A computerized satellite system with a video display was installed in CFO in September. At present this system stores and displays current pictorial data from the US polar-orbiting satellite (NOAA-6) and the GOES-East geostationary satellite. The system is still under development but it is already capable of displaying satellite pictures with different magnifications and contrasts of shade, and when the next Meteosat is launched in 1981 it will be possible for the forecasters to see a display of 'movie' sequences composed from its frequent pictures covering the same field of view, and this will greatly assist interpretation of the observed cloud patterns. In addition, a composite weather radar display, which interlinks the displays from a number of separate weather radar systems, was installed in CFO during October.

One important routine function of the Central Forecasting Office is the issue of hourly forecast minimum regional pressure values which are used as aircraft altimeter settings (QNH) for a number of regions covering the United Kingdom and the North Sea. These enable national air traffic control centres to maintain safe aircraft separation in the vertical. Forecasting for the North Sea regions remains a particularly difficult undertaking owing to the continuing paucity of observations received from the area but is necessary because of the very large number of helicopters now flying over the North Sea to and from the oilfields. With the offshore search for oil continuing, the need to provide altimeter settings for additional sea areas around the United Kingdom is under discussion with the Civil Aviation Authority.

Forecasts of wind-waves and swell for the North Atlantic for periods up to 48 hours ahead are produced for international broadcasts and are also used by the Meteorological Office Ship Routeing Service. The forecast charts of wave height and direction of travel are prepared by the Medium-range Forecaster, using the products of a wave forecasting model as a primary source. This model uses (as forcing functions) the surface winds forecast by the octagon version of the 10-level atmospheric model. A higher resolution wave forecasting model, using forecast winds from the rectangle version of the 10-level atmospheric model, is run for the Continental-shelf area. Output from this model is sent routinely to London Weather Centre for use in forecasts for the North Sea offshore industry. From September 1980 this output was also made available to Regional Water Authorities for use in their assessments of the possibility of coastal flooding due to wave activity. During the year, products from the fine-mesh wave forecasting model were used to provide real-time and archived data which were supplied under repayment contract to several purchasers. Interest in these models is also being maintained by the Wave Energy Project of the Department of

Energy which is investigating the energy potential of sea waves around our coasts. The Central Forecasting Branch continues to run throughout the winter season a storm-surge prediction model, written at the Institute of Oceanographic Sciences at Bidston, for use by the Storm Tide Warning Service.

A major part of the effort in the computer support section of CFO has been devoted to preparation for the introduction of a new numerical forecasting system which will be run on the new CYBER 205 computer. It will be based on a new numerical model and data-assimilation scheme and it will cover a much larger geographical area and a greater depth of the atmosphere than the present model. A new set of data-extraction programs has been designed and written. These retrieve a variety of forms of data, including both conventional and satellite data, from the synoptic data bank which contains all the data received over the GTS and converts and orders them into a form for presentation to the data-assimilation scheme. Work has started on the provision of facilities to allow CFO to monitor and intervene in the new data-assimilation scheme. A global sea-surface temperature analysis program making use of data from ships, satellites and drifting buoys has been written. Some time has been spent in deriving statistics of observational errors for individual radiosonde stations and for satellite sounding data for use by the data-assimilation scheme. To ensure that full advantage is taken of the fast vector-processing offered by the new computer, a new set of programs has been designed and written to output the numerical analyses and forecasts. Over 700 charts in many different formats are produced every day for use in CFO or for dissemination nationally and internationally and a further 250 frames are put on magnetic tape as stand-by in the event of a prolonged computer failure: formats are also required for producing VDU displays. Thus it is important for the processing to be efficient. The present techniques for interpolating temperature, wind and humidity fields in the vertical are having to be adapted to the new type of vertical coordinate (sigma coordinate) being used in the next model. Co-operation between the two Branches involved in the design of the new Numerical Weather Prediction System is very close and two members of the Central Forecasting Branch have spent part of their time working in the Forecasting Research Branch assisting with the design and programming of the actual model and data-assimilation scheme.

As a consequence of the large effort being put into the new operational model, development work on the current operational forecasting system has been much reduced in comparison with previous years. Satellite sounding data have been included in the analysis of the 100 mb level and a more sophisticated method of weighting the data, dependent on the reported confidence factor, introduced at all levels. Some experiments on the inclusion of satellite sounding data in the stratospheric analysis at levels above 100 mb have yielded promising results. Systematic trends in the forecast have directed attention to the modelling of physical processes at or near ground level and also to the specification of the boundary conditions of the fine-mesh forecast area.

As part of the National Aeronautics and Space Administration (NASA) Commercial Aircraft Fuel Savings Program, run in conjunction with British Airways and the Civil Aviation Authority, some experiments are being made to assess the benefits to aircraft flight planning from using in numerical forecasting all aircraft data from the Aircraft Inertial Data Systems (AIDS). The data being used are those collected during the First GARP Global Experiment (FGGE) for August to November 1979.

A start has been made on an investigation into the possible uses of 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 maximum and minimum air temperature, and forecast parameters given by a numerical atmospheric model.

Until now the effort has largely concentrated on building up the necessary archives of forecast fields for a limited area (the British Isles and western Europe), and also on assessing the various techniques available and the results attained as described in the scientific literature. Early experiments in forecasting maximum air temperature in the winter months show a promising level of success, achieving mean errors out to 72 hours ahead that are less than the comparable errors of subjective forecasts.

The contract with Eurocontrol was satisfactorily concluded early in the year. The detailed tasks of assessing data recorded by Aircraft Inertial Data Systems (AIDS), and subsequently using the quality-controlled data in limited area analyses, yielded valuable information and experience. It is hoped that real-time interrogation of AIDS by a secondary surveillance radar (ADSEL) will enable rapid and timely use of aircraft recorded data in meteorological applications additional to that of short-term forecasts for air traffic control purposes which was the original object of the Eurocontrol contract.

Publication of the *Daily Weather Report*, the *Monthly Summary* and the *Daily Aerological Record* ceased at the end of the year. The *Daily Weather Report* has been prepared continuously for well over a hundred years although its final format differed considerably from that of the brief data sheet first published in September 1860.

Members of the Branch serve on the WMO Working Group on the Global Data Processing System (one of the working groups of the Commission for Basic Systems) and on the Regional Association VI (Europe) Working Group on Co-ordination of Requirements for Data in GRID Code Form.

Services for industry, commerce and the general public

The Meteorological Office provides a wide range of services to the community. During 1980, a policy of maximizing revenue led to a marked increase in both the volume and the variety of repayment work for commerce and industry. With the restrictions on staff numbers imposed on all parts of the Civil Service, this has inevitably meant some reduction in the ability of the public to consult our forecasters free of charge. At some offices this facility had to be withdrawn and at others restricted. However, the traditional public service continued to be given through the media and the amount of general weather information disseminated in this way was greater than ever before.

The pattern of routine presentations on national BBC Television remained largely unaltered during the year. The only significant change was the extension of the time allocation at 2125 on Fridays to allow a brief description of weekend weather over Europe and the Mediterranean to be added to the normal forecast. The BBC request for this reflected the increased public interest in weather on the broad scale, stimulated by the regular showing of satellite pictures which is now a vital and very popular part of our broadcasts. The demise of the European geostationary satellite Meteosat checked the impetus towards the development of techniques to display time sequences of satellite imagery, but this was no more than a temporary setback. Digitized radar displays of rainfall patterns would also be suitable for showing on television and methods by which they might be provided were discussed with the BBC and ITV.

A notable feature in 1980 was the marked increase of interest in the inclusion of live presentations by weather forecasters as part of regional television programs. The once-weekly broadcasts by forecasters from Nottingham Weather Centre on BBC TV (Midlands) which started late in 1979 proved popular with viewers and were stepped up to daily broadcasts, Monday to Friday. During the autumn, BBC TV (South) introduced similar daily presentations by forecasters from Southampton Weather Centre. Other BBC Regions also gave improved weather coverage by taking additional material from the Office; 1980 also saw the first appearances of Meteorological Office staff on commercial television. Forecasters from Aberdeen/Dyce Airport contributed to Grampian TV for a time, and towards the end of the year forecasters from Birmingham Airport started a new daily service for ATV (Midlands).

The forecasters from the London Weather Centre who make up the team of weathermen on national BBC Television are regularly called upon to contribute to other television programs concerned with news, education and other matters. The special New Year program in which they all participate and comment on highlights of the year's weather has become a popular and regular feature. Fittingly, the broadcast at the end of 1980 took as its central theme the closure of Kew Observatory and was the most ambitious production to date. In their own time, the weathermen give talks to a wide range of audiences including universities, schools, Rotary Clubs, Women's Institutes and Societies of all kinds.

In September, for economy reasons, the BBC discontinued the separate regional VHF programs in all English regions except the South-West. Regional forecasts have thus virtually disappeared, and in partial compensation a new live broadcast was introduced on Radio 4 VHF at 0625 as an alternative to the Shipping Forecast transmitted at this time on Radio 4 UK (1500 m); this offers a three- to four-minute weather report and forecast for England. Minor changes on Radio 4 included an additional forecast at 0655 on Sundays and, for a period, two short insertions in the 'Breakaway' program just before and immediately after the 0900 News on Saturdays. By the end of the year, the morning schedule for the radio forecasters broadcasting from the BBC studio at the London Weather Centre (see Plate II) was very exacting; within the space of one hour they broadcast no less than six times—once on Radio Wales, once on Radio London and three times on Radio 4 (including an insert for 'Farming Today'), each broadcast being of a different length, for a different area and in a different style.

The Office contribution to radio extended well beyond the routine forecasts. Many members of staff at Headquarters and at outstations gave interviews and talks whenever current weather became of major news interest and also took part in phone-in programs about the weather. A major documentary about meteorology and the work of the Office was recorded by the London Broadcasting Company in May. Another program on BBC Radio 4 in August concerned weather and climate. Both of these included contributions from several senior staff members. A selection of these broadcasts is included in Appendix II.

The number of calls to the Automatic Telephone Weather Service (ATWS) is to some extent weather-dependent; the clement weather during the first quarter of 1980 produced some 5 million fewer calls than the cold and snowy first quarter of 1979. The total for 1980 was 25 967 894, compared with 24 467 679 in 1978 and 30 805 870 in 1979. Despite the fluctuations, the general trend continued upwards, and in discussions with British Telecom during October it was agreed that the service should be reorganized, extended and more vigorously marketed. As the ATWS is a profit-sharing venture, these changes should increase the substantial revenue to the Office from this source.

The Office contribution as an Information Provider to the Prestel Viewdata System continued to grow throughout the year as the service became available in more parts of the country. Local forecasts for many districts, special forecasts for holiday areas and for major sporting events, and route forecasts for the M4 motorway from London to Bristol all helped to bring increased custom. This last innovation will be the forerunner of similar frames of information aimed at commercial and private travellers. National and shipping forecasts, world-wide climatological information, and regularly updated frames of weather reports from Britain and abroad are regularly supplied and the data base provided by the Office is steadily expanding. There was a considerable increase in the number of Prestel receiving sets in 1980, especially in the business community, providing a growing market for instant weather information. Within a few years Prestel should more than repay the investment made in it by the Office and become a major source of revenue.

The number of enquiries directed to Weather Centres remained at a high level, totals for the past three years being:

	London	Manchester	Glasgow	Newcastle	Southampton	Nottingham
1978	306 993	164 290	123 077	109 988	106 220	71 306
1979	312 908	149 338	112 524	110 840	108 468	69 616
1980	322 102	134 827	99 273	94 987	91 897	83 190

Grand totals: 1978, 881 874; 1979, 863 694; 1980, 826 276.

Enquiry totals reflect only one side of the story. The reduction in free public access to the forecasters has been accompanied by an increase in the number of unlisted telephone numbers used to provide commercial services so that, although the number of enquiries which could be handled was reduced, there was a substantial increase in revenue from them.

In maximizing the income of the Office, three factors are essential for success. Firstly, the information offered must be of high quality. Secondly, it must be what the customer wants. Finally, it must be well publicized. Each of these aspects received appropriate attention in 1980.

Public Service offices receive support and advice from the Central Forecasting Office at Bracknell. Longer-range and more detailed predictions derived from numerical models of the atmosphere and of the ocean surface using the COSMOS computer system, together with weather radar and satellite data, were more widely distributed. The resources available in terms of quantity of data, computing power and sophistication of the models are constantly being upgraded; developments described in other sections of this report will ensure that they will be second to none in the foreseeable future.

For certain industries, cost sharing has many advantages. For example, the offshore services centralized at the London Weather Centre, though tailored for spot locations, are dependent on common scientific and technical resources and on a common data base; by applying the principle of cost sharing to these substantial overheads, the most cost-effective service can be given. On the other hand, flexibility in dealing with individual requirements is essential and this the Office has displayed by, for example, providing whenever needed, and sometimes at less than 24 hours' notice, experienced officers for detachment to offshore sites to advise during highly weather-sensitive stages of platform construction or relocation.

There was a marked expansion of consultancy services during the year. The Dry-spell Service previously available to farmers gave warning of spells of two or three days without rain. During 1980 this was replaced by the Consultancy Service for Farmers and Growers whereby registered subscribers are given an unlisted telephone number on which immediate access to a forecaster may be obtained at any time to discuss whatever is of direct relevance to current farming operations. This type of service was also successfully introduced for the construction industry and indeed for a wide range of customers who were prepared to pay for immediate personal attention. To facilitate the provision of specialized services, document facsimile machines were installed at more offices. Using these, information can be supplied in graphical form.

For example, Water Authorities are provided with charts of forecast weather and sea state by this method.

The services of the Office were publicized in a variety of ways. With professional assistance from the MOD Directorate of Promotions and Facilities and the Central Office of Information, major display stands were mounted at a number of shows and exhibitions, including the Royal and other Agricultural Shows, the Earls Court and Southampton Boat Shows, and three important exhibitions for the offshore industry. The stands were manned by staff from several Branches of the Office and were highly successful from both commercial and public relations viewpoints. Several new brochures were produced during the year to describe and promote Office services. These included 'Services for Civil Aviation', 'Defence Services', and 'Weather Services for Builders'. Existing brochures were updated and reprinted. To a limited extent advertisements were placed in specialist journals and every opportunity was taken to obtain free publicity by writing commissioned articles about meteorological services in newspapers and magazines. A further opportunity to establish good public relations and promote repayment services comes through direct contact with members of the public. Members of the Public Services Branch replied to a very large number of written enquiries from the general public. Organized parties drawn from many walks of life visited the Headquarters of the Meteorological Office at Bracknell, and outstations up and down the country. Many members of the staff gave talks by invitation to outside organizations, usually in their own time.

Services for marine activities

In support of the varied and highly weather-sensitive activities of the offshore oil and gas industry, the Meteorological Office has throughout the year continued to provide a forecasting service specially designed to meet the needs of operators. Considerable efforts have been devoted to improving both the quality of the service and its availability whenever and wherever required. These endeavours are not only justified in their own right but have a special importance in the offshore context because this is an area in which the Meteorological Office is in direct commercial competition with firms in the private sector. Some additional attention has been given to marketing but the quality of a product is its own best recommendation and commercial acceptability gives some indication of success. It is therefore gratifying to note that during the financial year ending in March 1980, revenue from services to the offshore industry rose to over half a million pounds, more than 40 per cent of this coming from foreign-based companies.

The London Weather Centre (LWC), which throughout 1980 has remained the hub of offshore forecasting services, is provided with vital direct support over and above that available to all Main Meteorological Offices from the Central Forecasting Office (CFO) at Bracknell. Numerical models are run on the COSMOS computer to produce detailed forecast charts of wind and waves over the continental shelf and there were regular telephone conferences to discuss the synoptic evolution up to five days ahead. LWC also receives observations directly from offshore installations and exercises the very necessary measures of quality control on these reports. With this wealth of information, and in the light of long experience of weather over the seas surrounding the British Isles, the specialist team of forecasters and supporting staff is able to produce the detailed predictions for up to five days ahead which operators require for their various rig and platform locations over the continental shelf.

Although forecasts are normally supplied from LWC by telex, it is an integral part of the service that a senior forecaster can be contacted by telephone or radio-telephone at any time of day or night. The forward support given by the forecasters at Aberdeen/Dyce Airport has been strengthened during 1980; daily briefings are given face to face with operators based in Aberdeen and the forecaster watch has now been extended to cover the full 24 hours. The subsidiary forecast offices at Lerwick and Kirkwall continued to provide direct support to the tanker terminals at Sullom Voe and Flotta.

Southampton Weather Centre, under the technical supervision of LWC, is well placed to deal with offshore industry activities in the Channel and south-western approaches. For this reason, the Office mounted a stand at the new Channel Offshore '80 Exhibition held in Southampton early in the year. During 1980 fully manned stands were also mounted at both Offshore International '80 held in Brighton and Europec '80 which was held at Earls Court (see Plate II). The staff, display material and supporting telecommunications came from several Branches of the Office so that the full range of forecasting, climatological, instrument and marine services were shown and important commercial contacts were established by discussion with visitors.

Another aspect of Office services for the offshore and marine industries is the provision of specialist forecasters on detachment to offshore locations to give on-the-spot advice during critical operations. Six such detachments took place during 1980, all of them earning valuable foreign currency. One of the most interesting of these operations was the tow of a dry-dock some 300 metres long, 90 metres wide and 30 metres high (see Plate III). Such a structure is highly sensitive both to cross-winds and to waves, and the underwriters understandably wished that a special forecasting service should be available on location throughout the tow from Stavanger in southern Norway to Murmansk in northern Russia. Arrangements were made for certain weather data to be transmitted by Bergen and a great deal of information was sent by radio-facsimile from Bracknell. Using this material, a forecaster aboard the towing vessel prepared detailed written forecasts and was available for discussion as needed. The tow of over 1300 nautical miles was achieved successfully in under nine days. Having immediate and direct access to professional meteorological advice enabled decisions to be taken with confidence when the weather was a vital factor. The marine consultant aboard highly commended the work of the forecaster.

When providing specialist services to the offshore industry the Meteorological Office draws both on the wealth of basic meteorological data collected and distributed in real time under international arrangements and on the numerical predictions produced using the COSMOS computer system at Bracknell. To meet international obligations many of these data are included in meteorological radio transmissions. Not surprisingly, these arrangements cost a considerable amount of money and represent an unavoidable overhead without which no forecast services would be possible. Under the Wireless Telegraphy Act (1949), special transmissions of this kind can only be received legally by the holder of a licence from the Home Office. During 1980 it was decided that this legislation would be enforced so that those wishing to make commercial use of this information will be required to make a contribution towards the cost of providing it.

The Head of LWC is a consultant member of several offshore industry committees such as the International Exploration and Production Forum. During 1980 he attended two meetings concerned with the problem of predicting the movement of oil slicks following spills or blow-outs. It is hoped that meteorological output from the

COSMOS computer at Bracknell will be made available as input to a numerical 'Slikforcast' prediction model developed by the industry for application on a world-wide basis.

Services to shipping via BBC Radio, the Post Office Coastal Radio Stations and our international radio-teleprinter and radio-facsimile broadcasts continued throughout the year. As from 1 January the late-night Inshore Waters forecast and station reports for English, Welsh and Scottish waters broadcast on BBC Radio 4 and BBC Radio Scotland were combined. Owing to the impending automation of Sule Skerry lighthouse, weather reports from this station were discontinued in July and were replaced by reports from Sumburgh (Shetland Isles) in the Coastal Waters station reports. From 1 August a forecast for Northern Ireland Inshore Waters, followed by reports from stations located around the northern Irish Sea, was broadcast by Radio Ulster at 0945 GMT on Mondays to Fridays in addition to the usual late-night broadcasts. During the latter part of the year weather reports from Machrihanish for inclusion in the Inshore Waters forecasts were temporarily replaced by reports from Prestwick. As a temporary service, the Post Office Coastal Radio Station at Cullercoats continued to broadcast weather forecasts and gale warnings for all North Sea shipping areas from Fair Isle to Plymouth in radio-teletype.

The Shipping and Inshore Waters forecasts sent out on BBC Radio 4 are of direct benefit not only to the shipping and fishing industries but to yachtsmen as well. Local radio stations, both BBC and IBA, also have an important part to play. For example, yachting forecasts issued by Southampton Weather Centre are broadcast regularly on BBC Radio Solent, and on 29 August special live broadcasts by a forecaster were directed to the many yachtsmen marooned in Cherbourg as a result of the French fishermen's dispute; all returned safely that day. Late in 1980, following a suggestion by the Rt Hon. Edward Heath, MP, measures were taken to institute a service of strong-wind warnings for broadcast by BBC and IBA Local Radio; it is hoped that this service will become operational from the Easter holiday weekend in 1981 and that more local radio stations will decide to broadcast regular forecasts aimed at sailors of small craft.

Comprehensive services including the supply of weather charts by document facsimile have also been pioneered by Southampton Weather Centre, and many individuals and organizations have now enrolled for marine consultancy services. For a registration fee, direct and immediate access to a forecaster is made available by means of an ex-directory telephone line. Subscribers for this service have included a yachtmaster, a yacht squadron, sailing clubs, the organizers of a power-boat race, and even a local authority concerned with a difficult operation to recover containers of toxic chemicals that were being washed ashore. To give wider publicity to commercial marine meteorological services over and above those for the offshore industry, fully manned display stands were mounted at the Earls Court and Southampton Boat Shows.

The CFO at Bracknell again supplied guidance forecasts and warnings to forecasters who volunteered for service aboard the Trawler Support Ship which was stationed off northern Norway during March and April 1980. The forecasters were able to maintain close liaison with the British fishing fleet then operating in a region where, at that time of year, gales and serious ice accretion can occur all too readily.

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. 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 in Gibraltar also 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.

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 ship/wave 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 wave/performance characteristics from basic ship size and type without recourse to the deck logbook. The ship-routeing officers, who are all Master Mariners with long sea-going experience, are provided with wind and sea predictions up to 72 hours ahead at 12-hourly intervals by the forecasters in CFO and this information is used with the performance curve to determine the most favourable course for the vessel to follow. In this determination consideration is given to the loading state of the vessel, navigational hazards such as shoals, areas of fog and sea ice and also to sea-surface currents. The later stages of the voyage are also borne in mind. Communication with the vessel is usually by Telex prior to sailing and via predetermined coastal radio stations whilst on passage. Routeing advice to tows which do not have restrictive weather parameters is similar to that provided for conventional ships 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.

A voyage assessment service was introduced this year by the ship-routeing officers. In this, an investigation is made into the performance of a ship in relation to the weather encountered during the voyage and the actual weather reported by the ship. The service is of value to shipowners and charterers as it assists them to resolve claims for slow speeds and other delays in the time spent on voyage.

During the year the number of routeings, including tows and salvage operations, increased by 58 per cent. It is significant that this year there has been no slack period in the services provided during the summer months as there has been in previous years. Seasonal contracts have been renewed with two shipping companies and, owing to a high success rate and advertising, the service has continued to become more widely known in shipping circles throughout the world. Routeing advice is being provided to British Nuclear Fuels for the movement of nuclear waste in UK waters. Of special interest, during June and July the service provided a weather watch and routeing for the movement of the first completed Thames Barrier gates from Middlesbrough to the Thames Estuary. Also during September the service, which keeps a careful watch on the development and movement of tropical revolving storms, provided at the request of the vessel's owners current and wind-drift patterns for survival craft to assist the search and rescue services following the tragic loss of the British cargo vessel *Derbyshire* in the North Pacific, south of Japan.

Services for civil aviation

Civil aviation covers a wide spectrum of activity. International and domestic airlines operate scheduled and unscheduled passenger and freight services with aircraft of many types from the Concorde and wide-bodied jets, used on inter-continental routes, to the Islanders and Twin Otters that play such a large part in the economy of the offshore islands. Helicopters are needed to link the offshore oil platforms to their shore bases. There is also the whole range of General Aviation (GA) including air-taxi services, executive, private and club flying, gliding, hang-gliding and ballooning. All this activity comes under the aegis of the Civil Aviation Authority (CAA) and the Meteorological Office provides, on a full repayment agency basis, the whole gamut of weather services that are needed.

The cost of meteorological services, borne initially by the CAA, has to be recovered from users who are themselves under increasing financial pressures due to the escalating price of aviation fuel and the fact that the passenger market has failed to grow as quickly as had been predicted. Clearly there is a need for maximum cost-effectiveness, and this point was made strongly by a small delegation from the International Air Transport Association (IATA) who visited Bracknell during the summer. The Office worked closely with the CAA throughout 1980 to review meteorological services with a view to making all possible economies. By the turn of the year, forecasters had been withdrawn from Stansted and Edinburgh Airports and some reductions in staff complements were made at Gatwick, Cardiff and Glasgow Airports. The small office at the West Drayton Air Traffic Control Centre was closed completely. Although aircraft safety was the paramount consideration, in each case it proved possible to absorb the work at other offices without increases of staff. This was achieved by rescheduling work-loads to eliminate peaks, by introducing new, more efficient and less labour-intensive office and telecommunication equipment and by reducing the amount of personal briefing in line with the revised Statement of Requirements drawn up in 1979 by the Meteorological Services Review Committee. Another successful exercise in reducing costs to civil aviation involved a detailed study of the work-load at the multi-purpose Main Meteorological Office (MMO) at Belfast Airport. After full consultation with the CAA, the RAF, and both Defence Services and Finance Branches of the Office, a new basis of cost allocation between Civil, Military and Public Services was agreed, and this will be applied at all multi-purpose offices in future.

Numerical prediction techniques can readily provide forecast upper-wind and temperature information in digital form which can be fed directly into flight-planning computers. After some years of experience on a regional scale, the major international airlines decided that further economies would come from the use of these methods on a global basis. The advent of the new computer system scheduled for installation at Bracknell during 1981 will enable numerical modelling to be extended to 30° south, and plans were made to supply a greatly extended digital output to British Airways once the new forecast model becomes fully operational. Certain foreign airlines also showed a keen interest in the possibility of obtaining global flight-planning data from Bracknell.

The organization to supply meteorological services to civil aviation in the United Kingdom changed only in detail during 1980. The Principal Forecasting Office (PFO) remained at Heathrow and was supported by MMOs at Manchester, Prestwick and Belfast, by forecasting offices at Gatwick, Cardiff, Birmingham, Glasgow, Aberdeen, Kirkwall and Sumburgh, and by observing/documentation/enquiry offices at Stansted, Bournemouth, Exeter, Blackpool, Edinburgh, Tiree, Benbecula, Stornoway, Inverness and Wick Airports. PFO Heathrow continued as an Area Forecast Centre (AFC) designated by the International Civil Aviation Organization (ICAO) and exchanged forecast products with other AFCs at Washington, Paris, Frankfurt, Rome and Nairobi. Co-ordination is exercised from PFO Heathrow by means of the

Civil Aviation Meteorological Facsimile Broadcast (CAMFAX) which goes to all civil aviation meteorological offices and to the larger non-State airfields as well.

Weather observations at airfields are of great importance, and special Meteorological Aviation Reports (METARs) are made hourly or half-hourly by Meteorological Office staff at all the 21 civil airports noted above. In addition to the requirement for weather observations at the airfields where they are made, there is a need for national and, in some cases, international exchange of these reports. Messages sent on the Aeronautical Fixed Telecommunication Network (AFTN) to the CAA message switch at Heathrow are disseminated nationally on Operational Meteorological (OPMET) teleprinter circuits; similarly, the Meteorological Operational Teleprinter Network in Europe (MOTNE) caters for the international exchanges. Terminal Aerodrome Forecasts (TAFs) also circulate on both OPMET and MOTNE broadcasts to provide information on future landing conditions needed by operators. Much of this material is stored in data banks at Brussels and Vienna and, by using the AFTN, meteorological offices can now access these banks to obtain data not available on routine broadcasts. An innovation during 1980 was the installation in PFO Heathrow of a Visual Display Unit (VDU) linked to the Heathrow switch; this enables METARs and TAFs to be obtained and displayed within 15 seconds, a facility that proved of great value in answering telephone enquiries from GA pilots. Direct access systems of this kind may well largely replace OPMET broadcasts in future. In consultation with the CAA, an operational requirement was therefore formulated for a United Kingdom system to provide ready and almost instant access from any airfield to a central data base, but such a system is unlikely to be available for several years.

The expanding activities of the offshore oil and gas industry, especially in the northern North Sea, have called for an increasing amount of aviation in support. Advisory forecasts for low-level helicopter flights to the rigs and platforms are prepared every six hours by MMO Prestwick, but the forecasting offices at Aberdeen, Kirkwall and Sumburgh Airports have borne the brunt of this activity. The nature of helicopter operations, coupled with the high incidence of low cloud and poor visibility over these northern maritime areas, has maintained a high level of demand for advice and personal briefing.

The altimeters carried by all aircraft indicate height above a pressure level; true altitude can only be determined if the pressure at mean sea level is known. Minimum pressure values are prepared at the Central Forecasting Office (CFO) at Bracknell every hour for each of 20 Altimeter Setting Regions (ASRs) over and around the United Kingdom. These are used primarily to ensure safe terrain clearance at all times, but pressure settings for the ASRs over the sea are used additionally by helicopters, and indeed all low-flying aircraft, to maintain vertical separation standards—a vital aspect of aircraft safety. At the instigation of the CAA, some re-definitions of ASR boundaries over the northern North Sea were introduced during 1980 to fit more closely with the normal pattern of routes to the offshore installations. Late in the year an important meeting with representatives of the CAA and the helicopter operators was held at Bracknell. It was agreed that new ASRs should be defined to extend the coverage to include locations near the edge of the continental shelf where offshore drilling activity has commenced.

After several years of planning, equipment for the first Outstation Automation System (OASYS) was installed at PFO Heathrow during August; after thorough testing, program development and staff training, full operational trials commenced during December. Labour-intensive tasks such as chart plotting will be eliminated and, by means of a locally maintained data base fed from the COSMOS computer system at Bracknell, OASYS will permit rapid data retrieval and display facilities to give improved support to forecasting staff. The responsibility of PFO Heathrow as an Area Forecast Centre providing meteorological information for flights from any part of Europe to North America made it essential to design a system with full back-up to cover the possibility of equipment failure. OASYS therefore comprises two PDP 11/60 minicomputers with two large and three small disc units driving matrix and pen plotters which are also duplicated. The high-speed data links to COSMOS can in the event of failure be replaced by dial-up facilities using the public switched telephone network. The system will be completed early in 1981 by the addition of three graphics VDUs and will enable substantial staff savings to be achieved.

Forecasting support was provided by the Office for both sections of the National Gliding Championships held at Dunstable and Lasham, and also at the inter-Services competition at Greenham Common. Several regional competitions were served by forecasters in their own time. In what was a poor year for gliding, the value of specialized meteorological advice was evident from the success of several competitions. Warm appreciation of the work of all the forecasters involved was expressed by the British Gliding Association.

An important but little publicized aspect of Meteorological Office support for civil aviation is the permanent attachment of two officers to the CAA Directorate of Flight Crew Licensing to provide a meteorological element in the examinations for pilot, flight navigator and air traffic controller licences. Papers are set and subsequently marked, and more than 1700 candidates have been examined during the year. Both officers regularly act as invigilators at examinations held both in London and at provincial centres; during 1980, one officer even travelled twice to the American Airlines Academy at Fort Worth, Texas, to invigilate examinations for British Caledonian Airways staff who are based there. The Principal Meteorological Officer visits all United Kingdom Flying Training Schools to discuss the syllabus with the local instructors and to advise on common errors in examination answers; in a few cases he also interviewed individual students to discuss reasons for failure at an examination.

An international flight departing from any airport in the world can obtain meteorological information for planning and flight documentation from one of seventeen Area Forecast Centres of which PFO Heathrow is one of five designated to serve the European Region. The setting-up of this Area Forecast System by ICAO many years ago was a milestone for international civil aviation, but developments in route patterns, the moves towards computer flight planning on a global basis and, above all, the need for greater cost-effectiveness made it essential to review the organization. ICAO accordingly set up an Area Forecast Panel to study this problem on a world-wide basis and to devise a new system that would more effectively serve the needs of aviation over the years ahead. For the first meeting of the Panel in Montreal during January the CAA delegate was supported by a Meteorological Office adviser who presented five working papers for discussion. Subsequent activity has concentrated on developing a new structure in which it is believed the United Kingdom will play a major part; ideas were crystallized in a working paper prepared for the important Working Group meetings scheduled for January 1981. 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 Offenbach, Federal Republic of Germany, in early September; during this meeting he was elected as chairman of a study group which, over the months ahead, will examine flight documentation practices and will present proposals for improvement.

European aviation matters have also received attention. A member of the Office attended three meetings of the Working Group set up by the Meteorological Advisory Group (METAG) of the European Air Navigation Planning Group of ICAO to consider methods of application of procedures to meet operational requirements in Europe. In September, he also attended the subsequent meeting of METAG itself. Another interesting new task in November was to supply a Meteorological Office staff member to become part of a CAA team under contract to examine civil aviation practices in Argentina with a view to enhancing flight safety.

Services for civil aviation (overseas)

Services for civil and general aviation were provided from the meteorological offices 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 Press, radio 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 general 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 RAF 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, continue to be provided by offices which are organized largely in conformity with the RAF Group organization. Subsidiary forecast offices were reopened during the year at Church Fenton, Chivenor and Cottesmore. The provision of services for the Royal Air Force in Germany continued unchanged. The Main Meteorological Office at the Headquarters of Royal Air Force Germany, Rheindahlen, supports subsidiary forecast offices at the RAF airfields at Wildenrath, Brüggen, Laarbruch and Gütersloh and at the Army Air Corps Unit at Detmold. The staffs of the meteorological offices in Germany were fully involved in NATO evaluation exercises and invariably achieved high markings.

The Principal Forecasting Office 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 RAF Support Command. The resources in the Principal Forecasting Office 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 Principal Forecasting Office and the development of automated support for the forecasters at the subsidiary offices with the aim of achieving greater efficiency and flexibility in responding to the RAF requirement. Plans for introducing a minicomputer system into the Principal Forecasting Office advanced steadily and installation is expected in 1981. 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 eighteen hours up to five days.

Main Meteorological Offices, also manned 24 hours a day, are located mainly at RAF Group or Maritime Air Region Headquarters. The location of the Main Meteorological Offices within separate regions of the United Kingdom allows 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.

At the subsidiary forecast offices at airfields a forecaster is on duty at times determined by the local Royal Air Force requirement and the availability of staff. In the absence of local forecasting staff the forecasting responsibility is assumed by the parent Main Meteorological Office. Many of the subsidiary offices serving the Royal Air Force also provide services for civil and general aviation and for 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 Principal Forecasting Office at Headquarters Strike Command and the Main Meteorological Office at Headquarters No. 38 Group is in the form of a comprehensive six-hourly program of area and route forecasts in chart form which is transmitted by facsimile to the subsidiary offices. The broadcasts are designed to cover most of the routine operational requirements of the Royal Air Force in the United Kingdom. A dedicated teleprinter broadcast from the Principal Forecasting Office allows a continuous flow of actual and forecast data related to the RAF requirements to be transmitted to the subsidiary offices where the personal briefing of aircrew and operational staffs and the provision of shorter-period subjective forecasts is considered by the RAF to be an essential service.

Mobile Meteorological Units, provided by 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 and radio-facsimile recorders and weather-satellite reception equipment. The staff who man the Mobile Meteorological Units hold commissions in Class CC of the Royal Air Force Reserve of Officers.

A forecaster was detached to Barksdale Air Force Base, Louisiana, to provide support to the RAF team participating in the United States Air Force Strategic Air Command, Bombing and Navigation Competition—GIANT VOICE 1980.

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

A routine program of radiosonde and radar-wind observations was maintained for the international upper-air network from the radiosonde unit at RAF North Front, Gibraltar. The Grawsonde was used for upper-air observations related to the local forecasting needs at RAF Akrotiri, Cyprus, and a routine program of pilot-balloon ascents was maintained from the observing office at Paphos.

The VOLMET voice broadcast of plain-language reports from a selection of RAF, USAF and civil airfields continued to be provided from the London Military Air Traffic Control Centre at West Drayton. Meteorological Office staff were withdrawn from West Drayton on 31 October and since then data for the VOLMET broadcast have been processed and supplied directly from the automated communications centre at Bracknell.

The Office continued to meet 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.

Courses on Defence Meteorology for Meteorological Office staff about to take up posts in military establishments were held in January and July with the aim of informing them about Defence matters and the role of meteorological services in support of military aviation. The January course was held at the RAF Staff College, Bracknell, and the July course at RAF Benson, with the assistance of staff officers from the Ministry of Defence, Headquarters Strike Command, Headquarters RAF Support Command and the Directorate of the Army Air Corps. Training in briefing for military needs was an important feature of the courses.

Services for the Army Air Corps

Meteorological services for the Army Air Corps continued to be provided by subsidiary forecast offices at Netheravon and Middle Wallop, under the technical control of the Main Meteorological Office at Headquarters No. 38 Group Royal Air Force, and at Detmold in Germany under the technical control of the Main Meteorological Office at Headquarters Royal Air Force Germany at Rheindahlen. Although the offices serving the Army Air Corps are part of the larger Meteorological Office organization supporting the Royal Air Force, the services they provide are related entirely to the Army requirements.

The Senior Meteorological Officer at Detmold continued to carry additional responsibilities as the Senior Meteorological Officer at the Headquarters of 1(BR) Corps at Bielefeld, and supported Harrier deployments in the field. The Detmold staff were also heavily involved in the 1(BR) Corps exercise CRUSADER 80, held in September, and its forerunner, JAVELIN. It was necessary for the Senior Meteorological Officer to establish a temporary forecasting office at Hildesheim in support of these very large exercises.

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

Meteorological offices continued to be maintained at the Royal School of Artillery, Larkhill, at the Royal Aircraft Establishment (RAE), Aberporth, and at the Proof and Experimental Establishments (PEE) at Shoeburyness, Eskmeals and Pendine. The office at Larkhill also provided meteorological support for the Chemical Defence Establishment at Porton and for RAE and PEE units located on Salisbury Plain. The office at Shoeburyness continued to support the Atomic Weapons Research Establishment at Foulness. The obsolete Mk 2B radiosonde system was maintained in use at Aberporth and Shoeburyness but the Mk 3 radiosonde system, specially modified to meet the requirements of the trials establishments for real-time, high-resolution upper-air data, was brought into service at Larkhill and Eskmeals.

Meteorological Office staff were attached to the Army practice camps at Sennybridge and Otterburn for several periods during the first half of the year to provide meteorological support for artillery firings and 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 two lectures on meteorology were given to the Royal Military Academy at Sandhurst. Headquarters staff, supported by a Mobile Meteorological Unit of the Tactical Communications Wing and staff from Larkhill and Middle Wallop, provided and manned a comprehensive Meteorological Office exhibit at the Royal School of Artillery's open days held at Larkhill during the first week in July.

Liaison with the Royal Navy

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

International Defence Services

The Meteorological Office continued to participate 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, working closely with the Directorate of Naval Oceanography and Meteorology through the Naval Liaison Officer.

The Meteorological Office also provides a Principal Scientific Officer for the post of Chief Meteorological Officer on the staff of the Supreme Allied Commander at SHAPE, holding the rank of Group Captain. The British contribution of three UK staff members was maintained at the NATO Allied Meteorological Office at Maastricht in Holland.

Services to the Home Office

Detailed plans for meeting the meteorological requirements of the United Kingdom Warning and Monitoring Organization (UKWMO) continue to be developed. Forecasting staff were deployed at the meteorological cells in the five Sector Controls during the national exercise in June and the NATO Civil Defence exercise in October. The Meteorological Office provided the charts and data for the assumed weather situation used in the exercise by all participating nations. 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 rehearsed. Similar arrangements cover emergencies which could arise in the transport of radioactive material or which might involve nuclear submarines in port.

Climatological Services

Climatological data

The foundation of the services provided by the Climatological Services Branch is the extensive archive of past observations. The main effort is made on data for the United Kingdom where observations are received each month from about 650 stations (see Table IV). This figure includes about 90 Meteorological Office stations and 60 Auxiliary Synoptic stations which make observations several times a day. The remaining stations, about three-quarters of the total, normally make one observation a day and are run by various public bodies and private individuals; these climatological stations make an important contribution which is gratefully acknowledged by the Office. In particular, this year there has been close co-operation between the Forestry Commission and the Edinburgh office, and between the Department of the Environment (Northern Ireland) Water Services and the Belfast office.

Although some stations inevitably close, the network remains remarkably stable in spite of the commitment required to run a climatological station. Increasing use is being made of thermographs at certain stations, particularly in Scotland, to ensure continuity of temperature information at weekends. The operational problems with the Digital Anemograph Logging Equipment (DALE) have now been cleared and wind data from a few stations are now recorded automatically on a magnetic-tape cassette, thus obviating the need for hand tabulations and manual keying. This is encouraging, though the program for installing DALE at most anemograph stations will take several years to accomplish. Progress on the more ambitious Automatic Climatological Recording Equipment (ACRE) for recording most of the climatological parameters has remained slow, though several potential sites have been assessed as suitable.

The observations are received each month at Bracknell (for England and Wales), Edinburgh (for Scotland) or Belfast (for Northern Ireland) and are keyed at Bracknell into computer compatible form. This process has been improved by the use of a direct link to the main computer rather than the physical transfer of magnetic tape. Given the large amount of data, it is necessary to use computer techniques to assist the quality control of the observations. The areal quality control for England and Wales has been replaced with a technique using a set of empirical orthogonal functions which take into account the past statistical daily behaviour from station to station. Six different elements are tested, and doubtful observations are presented in a map form for easier manual consideration. The manual scrutiny of all the queries raised remains an important step in maintaining the quality and integrity of the data. Also valuable in this respect are the courses for observers run at the Meteorological Office College, Shinfield Park (near Reading) and at the Edinburgh office.

The computer archive has been extended in scope this year. A derived data set of monthly values is being created to cover the 1951–80 period; this involves keying the data for the earlier years and scrutinizing the daily data already available in the archive. Since January 1980, values of the sunshine amount in each hour during the day for about 50 stations have been archived in computer form. Also, marine data from a new source are being keyed—those from oil rigs. Though the data must be used with care (for example, anemometers may be mounted much above the standard height), they will be valuable in providing sequential information for fixed locations.

Land climatology

Interest in the practical applications of climatological data continues to grow and once again there has been an increase in the number of enquiries (see Table XIII). The building industry still heads the table with actual (and forecast) information being important at various stages—for siting and design, for tendering, for site management and for extension of contract claims. Even so, the services could be much more extensively used to the economic advantage of the industry. The Office had a stand at the Scotbuild Exhibition in Glasgow in March and a new brochure 'Weather Services for Builders' was produced and, later in the year, was reprinted in response to demand.

Other areas of frequent enquiries concern agriculture and water resources (see separate sections), legal matters and energy questions. In this connection the North of Scotland Hydro-electric Board discussed the availability of wind data for the Northern and Western Isles for a study of wind generators for electrical power in the small island communities, and Royal Dutch Shell renewed the contract for the supply of degree-day data for Europe after a successful trial last winter. More unusual enquiries sought advice concerning a plan to circumnavigate the world by balloon, a comparison of weather conditions at HM Prisons in Scotland and assistance to a travel agent anxious to guarantee sunny weather for holiday-makers! Enquiries concerning conditions at overseas locations such as Sri Lanka, the Middle East and South America have arisen mainly in connection with building and drainage work.

On the investigations side, a new study of extreme winds over the United Kingdom has been completed using a refined technique and, more important, incorporating eight additional years of data, up to 1979. Fortunately the results are broadly in agreement with earlier estimates. A member of the Branch produced the meteorological section of a major study by the Construction Industry Research and Information Association on the long-term requirements for research and development in civil engineering. The building climatology unit in the Branch, funded by the Building Research Establishment, has co-operated in a variety of projects on such topics as gale damage, domestic fuel consumption, fire risk, cavity-wall insulation, construction delays and frost damage to the substructure of roads. There has been greater contact with the building industry's national organizations to foster interest in the applications of meteorological data. In addition, work has continued on various British Standards Institution Committees.

The Climatological Research Group continues to be actively involved in the study of the spatial variation of climate across the United Kingdom. Characteristic patterns representative of the climate variation have been determined statistically for seven elements (maximum and minimum temperatures, dew-point, soil temperature, sunshine duration, daily rainfall and wind speed). The patterns are of interest in themselves but they have also been used for quality-control purposes and to explore the automatic drawing of climatological maps, the division of the United Kingdom into homogeneous regions, and the trends and discontinuities in meteorological data often associated with site and instrumental changes. Other work has included the statistical modelling of temperature and wind time series by autoregressive techniques so as to increase the use of limited periods of data from some stations, and a comparison of winds from the electrical cup anemograph and the now-obsolete Dines pressure-tube anemograph.

Marine climatology

Marine climatology remains a growth area because of the vital concern of the offshore industries. Advice is often required on the frequency of weather likely to affect oil operations in the North Sea and the extreme conditions to be considered in the design of offshore installations. There is increasing interest in oil exploration to the north and west of the British Isles where operations are affected by the weather to an even greater extent than in the North Sea. However, enquiries are by no means limited to the area around the British Isles or to the demands of the oil industry. A world-wide marine data bank is available and information has been supplied during the year for such distant locations as the Gulf of Mexico, offshore Japan and Tierra del Fuego. For the planning of container-ship services between north-west Europe and the St Lawrence estuary, analyses have been made of the frequency of strong winds, sea fog, sea ice and superstructure icing. Many research projects are concerned with maritime weather and prominent recently have been studies on obtaining energy from wind and waves.

It is important to carry out investigational work to support the enquiry activities, and studies have included techniques for estimating extreme wind speeds in regions subject to tropical storms and the statistical modelling of wind and wave sequences to assist in areas where basic data are irregular and incomplete. Good progress has been made on a joint study program with the National Maritime Institute and much of the computer programming for the analysis has been written and tested.

The marine climatologist attended a study group meeting of the WMO Commission for Marine Meteorology. The group completed proposals for international exchange formats for marine meteorological data on magnetic tape or punched cards for use after the introduction of the new international surface synoptic code on 1 January 1982. Recommendations were also made on the form of presentation of *Marine Climatological Summaries.*

Operational and climatological work on sea ice continued throughout the year. Sea-ice charts are now produced on Mondays, Wednesdays and Fridays only, although daily dissemination on radio-facsimile broadcast continues. The sea-ice and ocean-current sections of Admiralty *Pilots* are kept under review and five volumes were revised in 1980. Wind roses and maps of ocean currents were supplied for a revision of the Admiralty Routeing Charts for the North Atlantic. The work on ocean currents has been facilitated by the enhancement of data resulting from the United Kingdom being designated by WMO as the centre for international collection of such observations.

Publications

The main outlet for climatological data for the United Kingdom is the *Monthly Weather Report*, first published in 1884. It also contains a description of the month's weather and a series of maps. One event of special interest was a record fall of rain of 97.0 mm in 45 minutes at Orra Beg/Orramore in Co. Antrim on 1 August, during which a section of the road from Ballymoney to Cushendall was washed away and deposited some 200 metres down the hillside.

Two further *Climatological Memoranda* were published during the year—No. 110 giving tables of cloud amount for over 50 stations in the United Kingdom, and No. 111 on temperature changes at eight of the stations. The extreme changes noted were rises of 12.4 °C in one hour at Edinburgh on 8 April 1969 and 21.1 °C in six hours at Birmingham on 29 March 1965. A new, more attractive format was used for these booklets and this presentation is being followed for a series of regional *Climatological Memoranda* which deal with the climate of different regions of the United Kingdom. The first two cover Glasgow and the Clyde Valley, and the Thames Valley.

Of more specialized interest are the *Marine Climatological Summaries* which the Meteorological Office is required to produce for the North Atlantic region. With significant progress in completing the marine data bank, the outstanding annual summaries for the period 1961 to 1970 are at last being published. Similarly, analyses for the 10-year *Upper-air Summaries* for Lerwick, Aughton, Hemsby, Crawley and Camborne have been completed and await publication. Finally, in the series *Tables of* *temperature, relative humidity, precipitation and sunshine for the world,* the volume dealing with North America was published in December, while the considerable task of data extraction and compilation for the African volume is well under way.

SERVICES FOR HYDROMETEOROLOGY

The hydrometeorological services provided by the Meteorological Office depend on the ready availability of good quality information from data banks designed to allow presentation or processing in the ways commonly required by customers. In this, the Office relies for its archive (which is available for public consultation) upon the co-operation of water and other authorities throughout the United Kingdom who operate the network of some 6500 rain-gauging stations.

The important primary task of the routine collection of data from the various sources, and their amalgamation into archives, has to be associated with various procedures for data quality control (which are nowadays increasingly computer-based), and some general scrutiny of observing practices, equipment and the site environment. Whilst computer handling of data is carried out at Bracknell, the offices in Edinburgh and Belfast carry out the other advisory functions connected with rainfall reporting stations in Scotland and Northern Ireland respectively.

More water authorities are now developing computerized data-handling systems for rainfall, river-flow and other hydrometeorological variables; this has given rise to increased liaison with the Office to ensure that their systems are not incompatible with those operated at Bracknell. The collaboration has led to some increase in the amount of data exchanged on magnetic tapes rather than in manuscript.

Most stations report rainfall as daily accumulations and the maintenance of the basic network to do so is highly desirable. However, because of the automation of installations such as sewage works and pumping stations, which operate rainfall stations but which no longer require the attendance of staff every day of the year, 1980 saw a continuance of the steady drift away from daily observations to data recorded only irregularly. The resultant problems were eased to some extent by the development of computer programs designed to apportion, into estimated daily totals, those amounts reported as multi-day accumulations. The availability of a reliable background field of actual daily rainfall totals is an essential constituent of these procedures.

Rainfall observations can be automated, and recording rain-gauges have been in use for a very long time. Mechanical systems, such as the tilting-siphon or natural-siphon pattern rain recorders have, in general, required careful supervision and daily chart-changing. In recent years, interest has returned to a tipping-bucket system of rainfall measurement, for this, when connected to magetic-tape or punched-paper-tape devices, enables the data output to be processed by computer directly. The automation of reliable rainfall measurements has proved to be much more complex and costly than many operators expected, and it is essential to maintain an adequate network of 'manual' stations until problems of instrument maintenance and operation have been satisfactorily resolved.

The costs and difficulties of maintaining rain-gauge networks caused the various interested parties to consider ways in which the networks might be rationalized so as to provide the data required in a more cost-effective manner. The joint project between the Office and the Institute of Hydrology, in which methods of network evaluation and design are developed, was continued. Computer programs were written which allow the performance of any network, existing or proposed, to be evaluated (in terms of the likely error of rainfall estimates at ungauged sites), and which allow new networks to be designed to satisfy the stated requirements of users. The methods were extended and tested using the rain-gauge networks in the topographically difficult area of the North West Water Authority, where it was shown that most of the requirements of users could be met by a well maintained network comprising about 60 per cent of the existing number of daily gauges in the area. The possible further reductions of networks in areas covered by precipitation-indicating radars was also studied.

The computerized index of rainfall stations, Rainmaster, was kept up to date. Around 600 amendments were required in 1980 to list changes relating to sites, the frequency of observations and the operation of rain recorders. The index again provided a control of data entry into most operational rainfall programs, in addition to meeting its primary function of control of data entry into the archives. Copies of the relevant section of Rainmaster were provided to the water authorities to confirm that actions initiated by them were incorporated in the national records kept by the Office.

Work ceased on the project under which past rain-recorder charts for a selection of stations were digitized by the Precision Encoding and Pattern Recognition (PEPR) system of the Nuclear Physics Laboratory at Oxford. The procedure, although basically an automated one, still required considerable staff effort.

The Office maintained its network of recording gauges with magnetic-tape event recorders (MTER). There was special collaboration with the North West Water Authority who operate a network of such recorders in the Lake District, and with the Severn–Trent Water Authority and the Thames Water Authority over the rationalization of the rain-recorder network in the lower Severn basin. Because of the low density of rain recorders in Scotland some priority was given to the establishment of MTER stations north of the Border.

This year saw the development of a new data bank of hourly rainfall amounts and, whenever possible, complementary rainfall durations. These data have been available for many years, but not in machinable form. An hourly precipitation archive based on data from many types of rain recorders, each with their respective shortcomings, requires the parallel development of a new type of data quality-control system. In this connection, mutual consistency was sought with the new data bank of radar-derived areal rainfall amounts.

The Office maintains an experimental network of weather radars which covers much of western England and Wales and provides data on the rainfall intensity over small (5×5 km) areas in real time. Whilst the primary use of these data is to assist in meteorological and hydrological forecasting, they may subsequently be employed to supplement the national rainfall archives; first, however, they must be made compatible with the rain-gauge-derived data which may be regarded as providing the 'ground truth'. A research project to develop ways of combining the radar (areal) and gauge (point) rainfall totals and to create an archive of the combined data continued throughout the year. Substantial progress was made on rigorous calibration procedures which remove many of the potential sources of error inherent in any first quantitative view of rainfall fields by radar. Fields of daily areal precipitation which combine both sets of information can now be prepared and presented, automatically, by the computer; some progress was made on the corresponding fields of point rainfall values, but less progress was made on the more demanding task of arriving at combined rainfall fields for periods much less than a day.

The hydrometeorology section of the Office maintained its efforts to identify and analyse the heavier rainfall events, and in this we are indebted to various water and other authorities who provided rain-recorder data on an *ad hoc* basis. The nationwide criteria for categorizing events as noteworthy, remarkable or very rare, formulated by Bilham in 1935, were revised; return period estimates, based upon statistics derived from the Flood Studies suite of computer programs for the particular location, are now used to characterize such rainfall events.

The publication *Monthly and annual totals of rainfall for the United Kingdom* was issued for the years 1971 and 1972. Delays in the publication of data for later years were still imposed by printing arrangements rather than by preparation of the data sets.

Hydrometeorological information was provided to many organizations including the building industry, legal profession, municipal and consulting engineers, water authorities, educational institutions and others. There was some decline in the number of enquiries relating to water resources, owing in part to the demise of the Central Water Planning Unit. A notable increase was apparent in enquiries relating to litigation and to agriculture, drainage and flooding (the summer was notable for heavy rainstorms). The number of enquiries concerning drainage still reflected the interest generated after the publication of the *Flood Studies Report* in 1975 and current Office membership of committees charged with revising standards of drainage-design procedure. The Office has suites of computer programs which enable tabulations to be made of rainfall amounts (or intensity) for specified durations (up to 25 days) and for return periods of a year to a thousand years. Information on the average variation of rainfall intensity with time (storm profiles) can be provided for any point or return period. Programs were modified slightly during the year to take account of amendments in the computed storm profiles and to incorporate a direct reduction of intensity with increasing size of the catchment area. To provide for those interested in a longer-term view of rainfall excess (or deficiency) a suite of programs has been devised to compute the percentage of average rainfall corresponding to a given return period (2 to 1000 years) for any number of consecutive months (1 to 120) starting in a given month. Tabulations can be made for a point or an area and the programs have been developed to supply information at the input of a National Grid Reference or a digitized catchment boundary. An archive of several hundred stations exists for ready reference.

For some time the Visual Display Unit (VDU), linked to the main computer, has been a valuable tool in dealing rapidly with enquiries. Rainfall data for the current and preceding two years can be readily displayed on the screen and 'hard copy' can be obtained at the touch of a button. Although the VDU helped to answer the increasing number of enquiries, additional data-handling facilities are highly desirable. The microfiche archive of rainfall data, which was started in 1978, was used with increasing frequency, particularly for the service which gives daily rainfall for the previous month (mainly to builders and water authorities). This service was itself streamlined during the year to provide a faster despatch of data.

Routine work continued for the Water Data Unit (WDU) of the Department of the Environment and included the assessment of general rainfall month by month for more than 900 catchment areas in the United Kingdom. An account of rainfall, evaporation and soil moisture deficit in 1974–76 (which included the drought years) was supplied, initially for publication in *Surface Water: United Kingdom 1974–76.*

As usual, there were a number of requests for estimates of rainfall, evaporation (potential and actual), soil moisture deficits and hydrologically effective rainfall at points and over areas. Comprehensive programs are available for calculating these quantities and output was provided, as appropriate, in the form of paper print-out, on magnetic tape or as microfiche, either as daily values or as compact monthly summaries. The applications of these data take many, sometimes surprising, forms.

One which has come to the fore in recent years is the assessment of the water balance of waste-disposal sites. Requests for data were received in connection with the enquiry into proposals by British Nuclear Fuels to use Wastwater as a source of cooling water for Windscale, for proposals by the North West Water Authority to use the River Derwent as a source of water supply and for proposals to develop the resources of the Upper Lee at Luton Hoo and parts of East Anglia. Similar work was undertaken for catchments in Northern Ireland and in south-west Scotland (mainly the Dee and Doon basins), and for a hydroelectric scheme in Galloway.

Data arising from the Meteorological Office Rainfall and Evaporation Calculation System (MORECS) were published weekly throughout the year in the form of 14 maps showing, for 40 × 40 km squares, potential and actual evaporation, soil moisture deficit and effective rainfall for various land uses, together with the meteorological variables used for input to the system. After two seasons of operational service, during which users provided helpful comments on the results of the calculations, a reappraisal of the system was carried out and certain improvements introduced. The original soil moisture deficit bulletin, inaugurated in 1962, continued to be published fortnightly because paying customers required the service.

A member of staff contributed to a WMO Working Group concerned with the problems of precipitation and evaporation measurements. A modified form of rain-gauge has been suggested, based partly on theoretical considerations and partly on past experimental results. A useful theoretical explanation was given of the undercatch of existing standard gauges that accords well with the results of numerous experiments.

There was an increased involvement in the major interdisciplinary project to improve methods for designing and testing the performance of urban drainage systems. The work revealed some unsuspected problems. These are now seen to result from the inadequate areal representation of rainfall over catchments during highly variable, short duration, heavy rainfall where only single rain-gauges are deployed. Members of the hydrometeorological section continued to be involved with the British Standards Institution in the updating of their Codes of Practice: those for sewerage and roof systems are currently being revised. A project to investigate and model the physical processes responsible for some types of storms that produce extremely heavy precipitation was initiated during the year. The aim of the project was to point the way towards providing design information on extreme storms that is more physically based than present procedures.

A staff member led the UK delegation to a meeting of the WMO Commission for Hydrology. A major topic here was the program for the transfer of technology to those parts of the world where water resources and water handling are less developed than in the United Kingdom.

Services for Agriculture

The agricultural section of the Meteorological Office provides a variety of weather-related services to the agricultural industry in the United Kingdom, but it is not directly involved in the provision of weather forecasts to farmers and growers. In order to carry out its task in the most effective manner, the section works with and through the advisory services of the Ministry of Agriculture, Fisheries and Food (MAFF) in England and Wales, the Scottish Colleges of Agriculture and the Northern Ireland Department of Agriculture. The larger part of the staff of the section is located in small units at four of the regional offices of the Agricultural Development and Advisory Service (ADAS) of MAFF, the posts there being on a repayment basis, and at the Meteorological Office in Edinburgh. For the last-named a proportion of the cost of running the unit is borne by the Department of Agriculture and Fisheries for Scotland (DAFS).

At the units attached to ADAS and at the Edinburgh office a considerable part of the time is spent on 'routine' advisory work using established techniques, and on the provision of meteorological information in a form useful to the advisory services. However, the knowledge and expertise of the agricultural meteorologist is essential to ensure that the most appropriate choice of techniques or method of analysis is used to deal with a particular problem. In many cases processed meteorological data from appropriate climatological or synoptic stations are needed, and these are provided by the Headquarters section at Bracknell, using the archive data sets available on the COSMOS computer. The agricultural section has written a number of programs to give rapid answers to the most common requests for data, or adapted programs which have been developed in other Branches of the Meteorological Office to suit its particular needs. These programs cover, for example, the straightforward extraction of daily data at a single station, calculations of accumulated temperatures above or below any specified base, and the provision of a variety of statistics concerning the frequency and severity of frost at a particular station. New computer programs, which initially may have been developed to solve particular enquiries, are added to the routine library as appropriate.

In co-operation with the Climatological Services Branch, work went ahead on the compilation of the Agromet Daily Data Set. This had been designed to bring together information which was previously only available on a number of separate data sets but which was likely to be needed simultaneously in many agromet investigations and calculations. By the end of 1980, data for the 115 stations in the initial data set had been archived; for the majority of stations, data spanned the years 1959 to 1979. The data set will be added to annually in future.

The Agromet Daily Data Set will, for example, permit calculations of potential evaporation to be made using a full Penman–Monteith type of equation for a large number of climatological stations in the UK. The availability of a 20-year sample of this important demand that weather places on crops and soils is significant for many investigations in agricultural meteorology, and is an essential prerequisite for an improved irrigation planning service.

The 'real-time' use of synoptic weather data by the section continued to expand. In addition to the daily compilation and transmission of telex messages to the advisory services concerning the occurrence of weather conditions favourable to the development of barley mildew, potato blight, *Rhynchosporium*, *Septoria*, eyespot and apple scab, daily messages of mean temperatures, rainfall and sunshine for selected synoptic stations were sent to the Federal German Republic's agricultural meteorology section so that they might monitor the effects of the current season's weather on agriculture in the EEC. Work started on the automation of the compilation of 'Weekly Weather Notes' which have been issued for the ADAS regions for many years.

A new operational program to predict the development of potato blight in maincrop potatoes from hourly weather observations was run on a trial basis in 1980 for 20 locations at synoptic weather stations in England and Wales. It calculated that weather conditions were more favourable for the development of potato blight than in any year since 1958 and, despite the widespread protective spraying programs used by most farmers, there were many reports from the advisory services of outbreaks of the disease. However, the major test of the value of such an operational computer program lies in whether it can give prior warning of the time of occurrence of the first outbreak before it is visible in the field, so that preventive spraying can be started at the optimum time. The predicted 'first outbreak' and 'epidemic' dates were circulated to plant pathologists in ADAS, so that they might be compared with field observations in the areas concerned.

In many of the major agricultural areas of the UK the present distribution of weather stations that report each hour does not provide sufficient weather data to monitor the likely progress of the important weather-sensitive pests and diseases which may affect crops. The prototype Crop Disease Environment Monitor (CDEM), which was designed to fill gaps in the synoptic observing network, was completed by the Operational Instrumentation Branch (see page 48), and successfully underwent a year's field trial at the Bristol office where the idea originated. This microprocessor-controlled, battery-operated instrument at present records temperature, humidity and surface wetness every 20 minutes and calculates severity indices for each of a number of plant diseases. These indices may be read off once a day from a liquid-crystal display or they may be recorded on a remote teletype. CDEM was demonstrated at the 'Computers for the Farm' exhibition organized by ADAS in May 1980 at Bridget's Experimental Husbandry Farm near Winchester, and aroused considerable interest among both ADAS advisors and the farmers and fruit growers looking for a method of monitoring disease risks in their crops and orchards. Its commercial development now seems likely.

An understanding of transfer processes in the boundary layer of the atmosphere is essential to the solution of a number of problems in agricultural meteorology which have important practical applications.

The duration of leaf wetness in crops has a critical role to play in the development of many plant diseases, and a micrometeorological model of crop canopies was used to demonstrate how, in a dense cereal crop, the lower leaves of an initially wet canopy can remain wet for many hours after screen relative humidities have fallen below 90 per cent (the usual indicator for the continuation of leaf wetness). A development of the model was also used to investigate the effects of weather on the field-drying of hay, and the likely result of field operations such as tedding.

Over the year several investigations were made into past outbreaks of foot-and-mouth disease in sheep, cattle and pigs in order to develop a computerized numerical model which can predict the airborne plume and the concentration of virus-carrying aerosols downwind from an initial source. The model, which has been constructed by the Boundary Layer Research Branch (Met O 14) in conjunction with the agricultural meteorology section and the Animal Virus Research Institute, will be used operationally in future in suspected or confirmed outbreaks of the disease to aid control measures.

Crop-spraying to control weeds or pests and diseases is of major importance in modern intensive agriculture, and a computer program was made available to calculate, from archived data, the periods when the combination of weather conditions necessary for a particular spraying operation to take place would have been satisfied. This information gives farm managers one view of the relative advantage of alternative application systems. However, the pattern of deposition and dispersion of the active chemicals in a spray may be very different from that which is desired, particularly with sprayers which give very small droplets or a large spread of drop sizes. The consequences of spray drift to a neighbouring crop may be disastrous for that crop or for beneficial insects, such as bees, working in that crop. Studies to improve knowledge of the dispersion of spray material took place in conjunction with the Weed Research Organization and with ADAS.

A number of other agricultural meteorology problems were the subject of continuing investigation during 1980. These included the effects of environmental stress at lambing in both lowland and upland flocks, the effect of weather on changes in digestibility of grass during the spring growth period, heat transfer in the soil with resulting soil temperature changes which may be highly significant for seed germination, and workdays for different field operations. Computer models which calculate the growth and yield of cereal crops, the energy balance of glasshouses, and the development of *Septoria* in wheat were constructed and tested against observed data. The results of these investigations were circulated in the form of memoranda, of which 35 were produced in 1980.

A member of the section served as the meteorological expert on the MAFF Land Classification Working Party, and was responsible for the preparation of the part of the report which deals with the influence of climate on land classification.

Although the section is not directly involved with weather forecasting it advised the forecasting services on the special needs of agricultural customers, and arranged for publicity to be given in ADAS newsletters and elsewhere to the Consultancy Service which has replaced the Dry-spell Service. The Cambridge office now provides a weekly 'intelligence report' on farming activities to all units in East Anglia which supply weather forecasts to farmers. A similar report for the country as a whole has been sent from Bracknell to the London Weather Centre and the BBC TV weathermen for the last four years.

Weather forecasts for farmers and the work of the agricultural section were featured in displays at three agricultural shows during the summer. At the Royal Norfolk Show the exhibit 'Science and the Farmer', which was organized by ADAS, included contributions from the Cambridge office of the agricultural section and from the Anglia TV forecasting team, while at the Kent County Show a stand was manned by staff from the MAFF Reading office and from the London Weather Centre. The Meteorological Office stand at the Royal Show had as many visitors as in 1979, most of whom were attracted by the presence of TV personalities from the London Weather Centre. However, the altered design of the stand provided by the Central Office of Information (which gave the agricultural meteorology section an area separate from that devoted to forecasting) made it possible for non-forecasting services to be explained to enquirers and for useful new contacts to be made. The display included a demonstration of the agrometeorological information available on Prestel (the British Telecom Viewdata system) and a large model landscape of a farming area showing situations where weather information could aid farm management.

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) 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 marine 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) and attended a meeting of the Study Group on the Manual and Guide of the GOS to propose changes required to these publications. Senior Branch members serve on international Working Groups concerned with radiation measurements and with the compatibility of data obtained from different upper-air measurement systems as well as on the Advisory Working Group of the WMO Commission for Instruments and Methods of Observation.

Observatories

The Observatories at Kew and Lerwick and the Meteorological Office section at Eskdalemuir (a NERC Geomagnetic and Seismological Observatory) continued to make a wide range of high-quality observations. The work at Kew was gradually run down following a decision to close the Observatory at the end of 1980. The three Observatories also provided valuable facilities for the impartial testing of new or improved instruments and observing techniques.

The program of work at Lerwick is the most extensive of all. In addition to the normal observatory work entailing observations of solar radiation and atmospheric potential gradient, the station was part of the upper-air and thunderstorm-location network. Observations were also made of ozone, and Lerwick continued to be a WMO 'base-line' station for atmospheric pollution studies. To complete its range of work the Observatory accommodated the unit which provided forecasts for the Sullom Voe oil terminal and gave some staff support for this project.

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 1980 the United Kingdom synoptic reporting network consisted of 263 stations, of which 80 made hourly reports and 51 made 3-hourly reports throughout each day of the year. The remaining 132 stations reported less frequently, some closing at night or at weekends. Meteorological Office staff manned 84 synoptic reporting stations, most of which were located at civil and military airfields. At the remaining 179 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 a number of key climatological stations manned by Meteorological Office staff these returns covered the whole 24-hour period. About 530 other stations made climatological returns only, usually of observations made 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. 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 water use, control and planning. Data were received from about 6500 stations most of which measured rainfall only, about 100 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.

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 approximately 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 means of gathering synoptic data from areas, or at times, where it is difficult or unduly expensive to support human observers. Twelve automatic weather stations are now available for operational service. These are gradually being brought into use. Planning work was 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 are required to support the specialized forecasting service given to the offshore industry. An automatic weather station was maintained at Muckle Holm, an island on the approach to the oil terminal at Sullom Voe in Shetland, and two new auxiliary stations were established to help with forecasting weather for the operation of large tankers in the Sullom Voe. Automatic weather stations have also been installed on oil platforms in the North Sea, on buoys in the south-western approaches and Lyme Bay, 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. This officer was awarded the L. G. Groves Second Memorial Award for his work in this difficult area. A second officer was based at Bracknell and dealt with installations south of latitude 55°N. A major effort was directed towards obtaining regular good-quality observations from the fixed production platforms for both synoptic and climatological purposes although advice was also given to observers on the more transitory drilling rigs. Both officers worked closely with the London Weather Centre and represented the Branch at the Europec '80 Exhibition at Earls Court.

Radiation observations

There is a long history of solar and terrestial 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, originally at Kew but at Beaufort Park since 1974, administers the national solar radiation network and also runs a program of research into various aspects of solar radiation measurements. During 1980 the closures of Cardington and Kew were partly offset by the opening of Crawley, and by the end of the year the official United Kingdom network comprised 7 stations of which 4 were using the new data-logging equipment, MODLE 3. There were also 24 other stations belonging to co-operating bodies with an interest in radiation measurements such as universities and agricultural/horticultural institutions. These provided data, mainly in the form of daily totals for which the Office operated quality-control procedures. Regular liaison visits were made to these stations and, to ensure uniformity of measurement over the UK, their instruments were calibrated and minor repairs effected by the Office free of charge.

All stations measured global radiation and 11 of them also measured the diffuse component. The excess of incoming over outgoing short- and long-wave radiation, known as the radiation balance, was measured at 6 stations. By the end of the year, following the installation at Lerwick of such equipment as already existed at Beaufort Park, data were becoming available on the variation with latitude of radiation on inclined and vertical surfaces.

Reliable radiation measurements require regular daily attention to instruments which need to be frequently calibrated against standard or secondary standard pyranometers. These in turn require periodic calibration against the Office's National Standard Ångström pyrheliometer and cavity radiometer both of which, in the interests of international uniformity, were taken to the World Radiation Centre at Davos (Switzerland) in October for a WMO-sponsored International Pyrheliometer Comparison. There they were compared directly with the family of absolute instruments which together comprise the working definition of the World Radiometric Reference—the radiation scale coming into general use in 1981, but which has been used in the Meteorological Office since 1 January 1980. A trial of commercially available radiation balance meters (net pyrradiometers) began in the autumn.

National and international interest in aspects of obtaining energy from solar radiation continued, chiefly through active involvement with the European Economic Solar Radiation Data Acquisition Group and the International Energy Agency Solar Radiation Program Group. The Branch also represents the Office on the WMO Regional Association VI Working Group on Solar Radiation.

Radiation data in tabular and map form with notes on instruments, calibration and quality control were published in the spring as a handbook entitled *Solar radiation data for the United Kingdom 1951–75*. Many enquiries from universities and industry were answered.

Runway visual range

Routine inspections and calibrations of lights used in the human observer method of assessing runway visual range (RVR) have continued to be carried out at six-monthly intervals at most of the major airports in the United Kingdom. The number of civil airports with RVR systems was increased by four during the year and, because of a change in safety regulations, the Civil Aviation Authority requested that new surveys be made, and new sites be found, for the runway observing positions at seven airports.

Upper-air observations

The normal program of upper-air observations comprises 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. This program was maintained by eight stations in the United Kingdom using the Mk 3 radiosonde and at Gibraltar using the Grawsonde. The two Weather Ships—the *Admiral FitzRoy* and the *Admiral Beaufort*—were deployed alternately at North Atlantic Ocean Station 'L' (57°N, 20°W). The upper-air program in the ships was maintained at four complete (temperature, humidity and wind) soundings per day. The performance of high-altitude balloons generally deteriorated but new balloons introduced late in the year showed a marked improvement.

Thunderstorm location and surveillance

A program of observations was maintained throughout the year by a network of direction-finding (CRDF) stations at Lerwick, Camborne, Hemsby, Stornoway and Gibraltar. From early November a program of hourly observations between 06 and 21 GMT replaced the former program of half-hourly observations by day and hourly observations by night. Due to the cut in the program the number of storms located during the year was slightly down on the previous year's total.

User trials and quality evaluation

An experiment in south-east England to identify problems in the observation of surface pressure was completed and the data are being studied with special attention to the identification of poor instrument exposures. The monitoring of data quality from several automatic sensing and reporting weather stations was continued. These include a number of land-based equipments and a system installed on a buoy moored in the south-western approaches. Evaluation was undertaken with favourable results of two aircraft-borne prototype equipments (ASDAR) which use the existing network of geostationary satellites to receive their transmissions and relay them through a central link into the global meteorological communications system. A report was completed upon a proprietary low-starting-speed anemometer and wind-direction system for possible operational use. The algorithm used in a programmable calculator to determine thunderstorm locations using CRDF in an objective way was refined to deal with particular difficulties and extended to provide a running record of bearing corrections for the five direction-finding stations.

A study was completed of data gathered by the Operational Instrumentation Branch in a trial of techniques for an automatic system to replace the present thunderstorm location network. It was concluded that relatively simple analysis techniques gave locations as good as advanced methods with the benefit of a higher data rate. The existing standard instrument for measuring sunshine has a number of defects and is not suitable for automation. Some types of sunshine recorders with electrical outputs were compared with the standard but none of them gave comparable measurements.

A report on the performance during 1979 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. Included in that report is an updated list of radiosonde types in use throughout the network. Further studies were made of the automatic radiosonde (RS3) now in operational use, including a program of direct comparison by means of combined ascents with a radiosonde designed in Western Germany and used by us at Gibraltar. The problem of interpolating low-level winds on those occasions when our wind-finding radars are unable to track the ascending radiosondes was examined and a particular method proposed for routine use.

Marine Division

As the oceans occupy three-quarters of the world's surface, the value of regular weather observations from oceanic areas is obvious, both for forecasting and for climatological purposes. With the exception of H.M. ships, Ocean Weather Ships and research vessels, surface observations from the oceans are provided by the masters and officers of merchant ships and the organization for obtaining them has been the responsibility of the Marine Division since 1855. The vessels from which these observations are obtained form the Voluntary Observing Fleet (VOF) and the ships vary from passenger liners, general cargo ships and supertankers to coastal traders and trawlers. Despite the continued depressed state of the British shipping and fishing industries the strength of the VOF has been maintained during the year. This is largely due to the efforts of the seven Port Meteorological Officers established at London, Liverpool, Southampton, Hull, Newcastle, Cardiff and Glasgow who recruit vessels into the VOF. Most of the older vessels of the British Merchant Navy have now been replaced by larger and faster ships which spend considerably less time in port and thus are at sea for a greater proportion of the year. As a result, the number of observations received continues to increase.

Meteorological work in British merchant ships has always been carried out on a voluntary basis and the Port Meteorological Officers, who are all Master Mariners with considerable experience of meteorological observing at sea, are able to contribute significantly to the maintenance of a high standard of observations received from the VOF. It is gratifying to note that this standard has been maintained throughout the year. The liaison between the Port Meteorological Officers and the various shipping companies continues to be to their mutual benefit and the installation of distant-reading meteorological equipment and automatic weather stations in a number of merchant ships under construction, in order to ease the work-load of observing officers, has continued with the whole-hearted support and co-operation of ship-owners. On a small number of vessels, trials have continued with the automatic radio transmission of ship's weather messages and results indicate that the use of satellite data links is the most reliable and cost-effective method.

Acknowledgement must once again be made of the valuable services rendered by many foreign and Commonwealth Port Meteorological Officers for their services in the replacement of defective instruments and replenishment of stationery in UK Selected Ships on protracted voyages. During the year a number of British observing ships have been sold or ended their sea-going careers in ports abroad, and foreign and Commonwealth Port Meteorological Officers have been of great assistance in the withdrawal of our instruments from these ships.

As in previous years, 'Excellent' awards in the form of books were presented to the shipmasters, principal observing officers and radio officers who submitted the best meteorological logbooks during the year. Similar awards were made to masters and officers on the short sea trades for their work in making sea temperature observations and to a skipper and radio officer of a trawler who made and transmitted valuable non-instrumental weather observations. Four shipmasters were presented with long-service awards in the form of barographs in recognition of their valuable voluntary meteorological work over many years during their careers at sea. The *Marine Observer*, a quarterly journal which contains articles on marine meteorology and oceanography of interest to mariners, was published as hitherto and continues to be well received. A large section of each edition is devoted to observations of meteorological and general scientific phenomena extracted from the meteorological logbooks received from the VOF.

During the year there has been a steady increase in the number of marine enquiries received. These have been principally from shipping interests, solicitors, universities and industrial firms and the subjects have been extremely varied, ranging from the weather conditions prevailing at the time of marine casualties to a request for details of winds over the North Atlantic during a period in September which may have been a contributory cause of the rare sighting of a Sabine's Gull on the River Tweed at Melrose, Borders Region.

The United Kingdom, under the North Atlantic Ocean Station (NAOS) scheme, 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*, continuously manned the station throughout the year with the exception of a four-day period in early November when the *Admiral FitzRoy* vacated the station to land an injured crew member. The weather ships make hourly surface and 6-hourly upper-air observations (for heights reached in upper-air ascents see Table V on page 68), as well as observations of sea temperature and salinity to considerable depths. In addition, rain-water samples are collected for analysis by the International Atomic Energy Agency, observations are made of magnetic variation, sea-water samples are collected on passage to and from station for monitoring radioactive content, and sea and swell records are obtained by using the Tucker ship-borne wave recorder. Also, aurora observations are made for the British Astronomical Association. During the first part of the year, reports of floating pollutants were made for the Intergovernmental Oceanographic Commission and World Meteorological Organization pilot project on marine pollutant monitoring. On about half the voyages to and from station a plankton recorder was towed on behalf of the Institute for Marine Environmental Research.

Operational Instrumentation

This Branch is responsible for taking the necessary steps to develop, specify, oversee the technical aspects of procurement, install and maintain all instrumentation needed to meet the operational requirements of the Office, and for the provision of common services such as engineering drawing, mechanical and electronic workshops, technical writing, test and calibration of instruments, technical training and photography. However, design and development work is only undertaken if user requirement cannot be met by currently available commercial equipment or a straightforward adaptation of such. The Branch also maintains the Meteorological Office Museum (see Plate IV) and is active in several areas of international co-operation including COST Projects 43 and 72 as well as two joint ventures with neighbouring European countries aimed at establishing new operational Ocean Data Acquisition Systems (ODAS).

Design and development of new instruments and systems

A significant proportion of the design and development work undertaken is directed at the derivation or evaluation of novel sensors or the evaluation of commercially available sensors of which we have no operational experience. It is vital that any new sensor adopted operationally should not exhibit an undetected systematic difference from those previously used to make the same measurement. Should this occur, then apparent step-changes in climatological records could be revealed by the analysis of data many years after the instruments have been installed. The accuracy, repeatability, resolution and reliability of equipment are all important features which must be fully established before large investments in operational instrumentation are undertaken.

In the area of the evaluation of commercially available devices several projects have been brought to fruition this year. A very lengthy and detailed analysis of a two-year trial of several commercial visibility sensors has been completed and, as a result, a specification for a short base-length transmissometer has been prepared. Work has continued on the evaluation of two proprietary humidity sensors, the Vaisala HMP-21 and the PCRC-11. A new linearizing circuit has been developed for the PCRC and further refinements are being sought in the techniques developed in previous years for protecting this sensor from attack by halide salts in the atmosphere which, when present in quantity, quickly render it useless.

Work has been completed on the evaluation of a new automatic pressure transducer: the Rosemount 1201F sensor has been found to meet our requirements for an electronic barometer. The MOD Central Packaging Unit has developed a transit case for this sensor to our specification which will enable it to be sent by commercial carrier without loss of calibration. Development work on two entirely novel sensors has been carried out. One of these is required to monitor the wetness of leaf surfaces for agricultural meteorology; the other is a new type of rain-gauge capable of providing continuous, very-high-resolution data on the rate of rainfall and the cumulative total rain over any specified period. The surface-wetness monitor has been developed as part of a new miniature automatic weather station (CDEM) which is described on page 48. The sensor consists of a set of interleaved rhodium electrodes deposited upon a mylar substrate. The electrical resistance between these electrodes is continuously monitored and is a measure of the amount of surface water present on the sensor. The device can be powered by batteries or by mains supply and in either case uses very little power. Problems of corrosion, contamination, fabrication and sensitivity have been encountered and overcome. The first season of testing of the sensor has produced very encouraging results.

The new rain-gauge is at a much earlier stage of development. It is a modification to the standard Meteorological Office tipping-bucket gauge and is externally identical to it. This is a distinct advantage in that it implies that the performance of the gauge in respect of its catch efficiency is known and is consistent with the tipping-bucket gauges already in service. The modification consists of mechanical and electronic components. The mechanical modification is the addition of a strain gauge in which the weight of the tipping bucket and any water it contains generates the tension in a stretched wire. This wire is forced to vibrate between the poles of a fixed magnet at a frequency proportional to the square root of the tension and this is detected in terms of the electromotive force generated by induction in the wire. The electronic modification is one of the first of a new generation of 'intelligent' interfaces now made possible by the micro-electronics revolution. It consists of a low-power single-chip microprocessor supported by a few thousands of 'words' of memory and is sufficiently small to be housed within the rain-gauge and thus become part of the sensor. It measures the frequency of the vibrating wire, computes the rate of change in frequency over any given period and then, by integration, calculates the amount of rain which has been collected since the last time it did a calculation. This period may be set to any value from a minute to many hours or even days. The rate of change of frequency is a measure of the rate at which rain is being collected by the gauge. The principal problems with the gauge have so far been associated with the large dynamic range it must cover. Slight rain amounts to 0.5 mm per hour or less while a thunderstorm may yield rates of 200 mm per hour or even more. However, it is believed that these difficulties are well on the way to being solved and that full field trials of a prototype device will begin early in 1981.

A wide variety of other sensor development activities has continued and includes work on wind-averaging devices, solid-state thermometers, wick lengths for wet-bulb thermometers, evaluation of various commercial wind sensors and the further development and testing of thermometer screens for marine uses.

Action to bring into service the four Continuous Automatic Remote Display (CARD) systems at remote RAF and Army ranges has continued. The systems at Theddlethorpe and Wainfleet have been in service for some time but there have been difficulties associated mainly with the unreliable nature of the power supplies. Considerable work has been done to try to overcome this problem but an entirely satisfactory solution is still not available. The sites at Sennybridge and Otterburn are ready to receive automatic systems but they cannot be equipped until the power supply problems are solved. The prototype Automatic Climatological Recording Equipment (ACRE) has passed its engineering trials and is now due for field test trials in early 1981.

The trials of satellite-based communications systems for retrieving observations from the Voluntary Observing Fleet have continued. The final report of the project set up to develop a technique to solve the problems of retrieving these observations is now available. It shows clearly that methods other than those using satellite data communications links will not successfully provide an automatic or semi-automatic method of retrieving these observations in time for them to be of use to the weather forecasters. On the other hand, methods based on geostationary satellites are highly reliable. The ship-borne equipment is simple and cheap and the retrieval time for observations is less than 20 minutes. The success rate during these trials was in excess of 90 per cent in terms of observations recovered from the container vessel *CP Discoverer* on routine voyages between Britain and North America. One unexpected result of the trials is that the present geostationary satellites appear to operate successfully, so far as their message-relay capability is concerned, well beyond the geographical limits suggested by their designers. Although the experimental trials are now completed, the equipment was retained on the *CP Discoverer* until the end of the year as a routine data-collection system. A similar system was tried out on one of the UK Weather Ships during the last few weeks of the year, and the results are being studied.

A new type of automatic system has been developed and has undergone successful field trials this year. This system, called a Crop Disease Environment Monitor (CDEM), consists of a number of sensors connected to a small dedicated microprocessor system which is programmed to calculate the risk index for a number of weather-dependent fungus diseases of important crops such as potatoes (blight), apples (scab) and barley (brown rust). Although CDEM was designed specifically as a tool for agricultural meteorologists, it has important wider implications. The system is small, of low electrical power consumption and is potentially cheap. Nevertheless it is capable of acquiring analogue or digital signals from a variety of sensors, carrying out quality checks and tests and then manipulating the data so that they are presented to an ouput line in a standard computer-compatible form. This bridges the gap between the microprocessor as a cheap miniature computer and the microprocessor as an integral part of a sensor interface in the manner of other chip-technology devices such as operational amplifiers. The use of the microprocessor as a component of the weighing tipping-bucket rain-gauge ensued from this work and, as such, CDEM marks a shift in the emphasis of the application of microprocessor technology to meteorological data-collection problems. CDEM has proved highly successful, has been reliable in use and has met all the demands for which it was designed. Considerable interest in the device has been shown by many scientists in disciplines other than meteorology, in particular horticulture, traffic and road maintenance, ice formation on runways and roads, and the control of closed environments. It is hoped that a commercial firm will soon apply for a licence to manufacture and market the device.

Activity in the field of automatic systems for use on buoys, platforms and islands has been largely confined to planning for new projects. Early in the year it was learnt that the lighthouse on Sule Skerry, 50 miles north of Cape Wrath, is to become fully automatic early in 1981. This will mean the withdrawal of the lighthouse keepers by the Northern Lighthouse Board and it is therefore planned to install an automatic weather station (AWS) there. The system to be provided is similar to that installed in 1978 on Muckle Holm Island, Shetland, and will report by VHF radio link to Wideford Hill in Orkney. Members of the project team visited both Sule Skerry (with the help of an RAF helicopter from Lossiemouth) and Wideford Hill and completed successful VHF transmission trials. During the year a UK manufacturer of marine systems has taken a commercial licence to manufacture the type of AWS currently in use on Muckle Holm, on the Whitaker Beacon in the Thames Estuary, on the buoy ODAS 1 in Lyme Bay and intended for use on Sule Skerry.

In recent years it has become increasingly obvious that to establish and maintain operational ODAS buoys in the open oceans round north-west Europe is beyond the available resources of any individual European meteorological service. Nevertheless all nations have a need for synoptic meteorological data and for climatological and oceanographic data from such areas. This need is particularly pressing for the northern and western island nations of Europe and for those nations with an offshore oil industry. The Office has therefore played a leading role in negotiations with Norway and Iceland aimed at establishing an operational ODAS in a data-sparse area of the north-east Atlantic around 61°N, 15°W, and in similar negotiations with Ireland aimed at providing another on the Porcupine Bank west of Ireland around 51°N, 12°W. Both of these projects, which form part of the UK contribution to the European co-operative activity COST 43, are at an advanced stage.

Analysis of last year's trial aimed at replacing the present, obsolescent, cathode-ray direction-finding (CRDF) system for thunderstorm location with a fully automatic system based upon the Arrival Time Difference (ATD) principle has now been made in sufficient depth to ascertain that the principle is sound. A cost analysis has shown that an operational system based upon it is economic and the first steps to introduce an operational system have been taken. Work to date has been concentrated upon the definition of a suitable complete system, the acquisition of some development equipment and the design of some of the specialized hardware involved. This is a major program with an installation deadline of about three years.

Now that it has been in service for about two years, the Mk 3 radiosonde has provided sufficient data for some of its inevitable systematic problems to begin to become clear. The most serious of these is that the temperature-element output has been shown to exhibit spurious jumps on occasions during flight. A modification to the sensor is to be incorporated in the next delivery from the manufacturer and this should alleviate the problem. New software has been developed for the ground-station equipment to permit a smooth transition from the use of old to the new temperature sensor. The first phase of a detailed study of the operational results of the Mk 3 system has been completed in an attempt to identify the reasons for the systematic differences which are observed between the Mk 3 and other sondes in common use. So far no faults have been found of sufficient magnitude to account for the discrepancies although some minor faults have been uncovered and corrected. This work continues and will include a continuation of comparison flights between the Mk 3 and the German Grawsonde.

In recent years, as sunspot activity has increased towards its maximum in mid-1980, enhanced propagation has been experienced in the radio-frequency band 27.5–28.0 MHz used by radiosondes in the UK. This has resulted in a substantial increase in interfering signals from citizen band transmitters both in the UK and overseas. A number of methods are being tried to reduce or eliminate this interference. As a short-term palliative, directional antennas have been installed at radiosonde stations and early results suggest that this has had some beneficial effect. Modifications to the ground-station equipment aimed at reducing the bandwidth of the system are being studied and a more sophisticated technique based upon the Fourier analysis of the telemetry signal has been suggested. The most obvious method of dealing with this problem is to redesign the radiosonde to work in the alternative frequency band between 400 and 406 MHz already used by many other nations. However, because of the stringent international specification for bandwidth and frequency stability combined with the relatively high power required for the transmitter, the cost of this solution is at present unacceptable for radiosondes which are disposable instruments and are used at a rate of about 10 000 per year.

Services, maintenance and support

Technical liaison and control of contracts for 20 Synoptic Automatic Weather Stations (SAWS) and 20 Laser Cloud-base Recorders (LCBR) continued throughout the year. Pre-production prototypes are now under construction by the manufacturers. The first production version of SAWS is due for delivery in September 1981; the LCBR will be a little later. Work has started on the technical aspects of the procurement of a further batch of Mk 5 Wind System components. This system is modular in form and allows wind data to be transmitted over long distances on standard telephone lines and then to be displayed in various forms on dials and recorders.

Following the completion of the field trials of various visibility instruments (as mentioned earlier), the procurement exercise for an initial purchase of ten folded-path, short base-length transmissometers is about to start. Work has continued on the procurement of the second purchase of 20 000 Mk 3 radiosondes and is now well advanced. The rapid development of electronics has caused several problems arising from the obsolescence of some of the components used in the original design.

The mechanical workshops continued to provide support to various projects and the work level showed a moderate increase. Among the projects completed were two containers designed to transport Stratospheric Sounding Units (SSUs) in a near-vacuum, and two large mobile support platforms for use in servicing marine buoys.

The work of the engineering design services and drawing office has shown the trend to electronic technology, approximately 60 per cent being involved in the production of printed-circuit designs and associated hardware. The complexity of the printed-circuit boards (PCBs) ranged from the standard Eurocard format to the multilayer, computer-routed, maximum-component-density layout. An increasing involvement in photo-draughting effected a cost saving of 40 per cent on normal methods. The major projects this year have included the automatic weather station for Sule Skerry, the Sferics equipment, and ancillary radiation apparatus. Location photography was provided on 31 occasions by the senior photographer and included the Manchester, Southampton and London Weather Centres, the BBC TV Centre and Kew Observatory. Aerial photography was undertaken for site examination at the Royal Sovereign Light-tower and Beaufort Park.

Activity in the installation section has continued at a high level. Mk 3 radiosonde ground stations have been installed at Larkhill, Eskmeals and Shoeburyness, the resiting of Meteorological Office Weather Observing Systems (MOWOS) has continued and new sites for Synoptic Automatic Weather Stations (SAWS) have been examined for technical suitability. Digital Anemograph Logging Equipments (DALE) have been provided at several stations in England and Scotland. Mk 5B Wind Systems, radiation logging equipment (MODLE 3), crosswind resolvers, and Mk 3A cloud-base recorders have been installed at stations throughout the United Kingdom. The influx of new equipment has brought about the need to increase the number of people engaged on installation work and in the latter part of the year an additional team was formed. The Post Design Services section complete 21 projects which resulted in the issue of 14 modification instructions. A further 15 projects are in hand.

The electronic workshops completed 19 manufacturing tasks, some being highly complex prototype equipment. Most of the repair work during the year was done in response to urgent requirements and included Racal 1772 receivers and PCBs for AWSs and DALE.

The standards within the electronic calibration area were improved by the addition of a high-stability frequency source and a precision voltage source. The provision of a standards laboratory, which has been part of the Office policy for some years, is well advanced and we are now able to offer a calibration service whose standards are traceable to the National Physical Laboratory. A computer-controlled system of measuring the cosine response of radiation instruments has been designed and the hardware completed. Initial trials using software developed in house suggest that the light source used to simulate the sun may be non-homogeneous and further work must be undertaken next year. The number of instruments tested and calibrated is shown in Table XV.

Enquiries were received from a wide range of interests including Government Departments, public authorities, private industry and schoolchildren. The Branch Information Officer was able to supply the information required, sometimes after consultation with an appropriate expert. The revision of the *Handbook of Meteorological Instruments* has progressed to the stage where Volume 1 (Pressure), Volume 2 (Temperature) and Volume 3 (Humidity) will soon be available for issue, Volume 5 is with the printer, Volumes 4 and 6 are being edited and Volumes 7 and 8 are in the initial stages of preparation.

The primary role of the Meteorological Office Maintenance Organization (Met O MO) is to provide a comprehensive field support service for meteorological offices at home and overseas. In the United Kingdom 22 centres have been established and from these technical staff maintain over 1200 instruments installed at 340 widely scattered locations. Some of these equipments are located on exposed coastal sites whilst others are installed on elevated sites, and on remote moorlands in the northern uplands and Scottish Highlands. Many are mounted on towers reaching heights of about 18 metres whilst others are located on top of multi-storey buildings, lighthouses and bridges. Access to offshore platforms is by helicopter whilst a variety of small craft including inflatables are used to visit buoys. A comprehensive maintenance program has been implemented covering the 30 different types of equipment in field use. The magnitude of the task continues to expand. Weather radars at Camborne, Upavon and Hameldon Hill are being maintained, together with their remotely telemetered calibration rain-gauges and the real-time displays located at Manchester Weather Centre, Liverpool Airport, the Central Forecasting Office and Upavon.

The first equipments in the network of DALEs and MODLE 3 are now incorporated in the Met O MO maintenance program as are the Mk 3 radiosonde ground equipments at the Army and MOD(PE) range stations. In addition, the radiosonde central calibration facility is being supported by the maintenance centre at Beaufort Park. Regional Technical Officers have been much involved with the planning arrangements for the introduction of the frequency division multiplexing (Speech plus Duplex) equipment which will permit the simultaneous transmission of facsimile and telegraph traffic on the MOLFAX circuit. Visits have been made to over 80 stations connected to the MOLFAX ring to discuss pre-installation requirements with local staff.

Maintenance of offshore equipment is now becoming routine. Regular visits were made to the automatic weather station on Muckle Holm, the UK Data Buoy (DB1) moored some 137 miles south-west of the Isles of Scilly, to meteorological equipment on gas platforms located in the Hewett and Viking Fields in the southern North Sea and on towers in Christchurch Bay, the Thames Estuary and off Beachy Head (Royal Sovereign). The HQ maintenance centre is becoming increasingly involved with preparations to maintain the enhanced AUTOCOM message switching system and is co-operating closely with the Telecommunication Branch in co-ordinating their training and equipment-familiarization activities. These expanding commitments have imposed a corresponding and progressive increase in the level of support required from Headquarters. Work has commenced to provide an Equipment Information System for Management (EISM). This will use, as source data, information culled from technicians' reports which will be processed by automatic means. Initially the data will be used to promote the cost-effectiveness of Met O MO and later to judge the maintenance effort expended in relationship to the operational availability of equipment. It should also serve as a means of alerting management to the need to initiate equipment replacement programs. The School of Technical Training, staffed by two full-time instructors, has continued to run suitable basic technical training courses on behalf of the Assistant Director (Professional Training). Details of attendance on these courses are incorporated in Table XVII on page 124.

The Branch continues to play a considerable part in the North West Radar Project, originally financed by a consortium of the Office, the North West Water Authority, the Central Water Planning Unit, the Water Research Centre and the Ministry of Agriculture, Fisheries and Food, but operated by the first two authorities only. The unmanned radar system, the first of its kind, situated at Hameldon Hill near Burnley, became operational in May after a number of teething troubles had been overcome. Final solutions to most of the outstanding problems have been provided and none which remains is significant. A long period of assessment in depth of both equipment performance and accuracy of measurement has begun. Precipitation data are fed to the North West Water Authority, Manchester Airport Forecast Office and also to the Meteorological Office Radar Research Laboratory at Malvern.

The Branch is represented on the Operations Working Party which meets every few months. Considerable time was spent on finding a suitable site for a London area radar. The terrain and urban development in the Thames Valley area present much difficulty, but the choice has now fallen on the lower Chilterns north-west of London, though its use is still subject to the approval of various authorities. Preliminary talks have taken place with the Greater London Council and Thames, Southern and Anglian Water Authorities with a view to setting up a consortium similar in nature to that of the North West Radar Project. Technical liaison has commenced with the Directorate of Naval Oceanography and Meteorology which intends to replace radars at Portland and Culdrose with systems similar to that in the North West in order to exchange data with the Meteorological Office network.

The number of enquiries on radar matters from various sources, local, national and international, increases steadily. A member of the Branch is undertaking the rewriting of a World Meteorological Organization *Technical Note* on the use of radar for precipitation measurement. He is also Secretary of the Meteorological Office/National Water Council Joint Working Group on Weather Radar which meets twice annually to discuss matters of joint interest with a view ultimately to planning a national network.

The weather radars at Camborne and Upavon, despite their age and the fact that they were not designed for continuous precipitation measurement, performed satisfactorily both in terms of reliability and the production of useful data. These data are fed to local Main Meteorological Offices, to local Water Authorities and to the Meteorological Office Radar Research Laboratory (Met O RRL) at Malvern, where they form inputs to the radar composite together with data from radars at Clee Hill and at Hameldon Hill. The installation of rain-gauge systems, three sites per radar, necessary to 'calibrate' the radar, proceeded slowly because of delays in the provision of British Telecom equipment, but most were in operation by the end of the year. In addition to forecast offices previously mentioned which have radar displays, the composite picture from Met O RRL is now available in the Central Forecasting Office at Bracknell.

Computing and Data Processing

Though various types of small computer are operated by individual branches for special purposes, by far the most powerful computing resources of the Office are centralized in the facility known as COSMOS. The principal operational computing tasks undertaken are the processing of global meteorological observations received in the Meteorological Telecommunication Centre, and subsequent preparation of analyses and forecast products. Once the operational forecast commitment has been met, research projects take up the greater part of the remaining computing time. Of these, long-period calculations designed to study the general circulation of the atmosphere and, at the other end of the meteorological spectrum, simulations of physical and dynamical processes occurring on the smallest atmospheric scales are the most demanding of computing power. During 1980, however, there was a continuing increase in the number of Services applications, following a trend which has been in evidence for several years. This meant that computing time for research work had to be correspondingly reduced.

In spite of the very wide variety of jobs submitted to COSMOS, the total number of jobs run is found to be a good measure of the total use made of all parts of the computer system. For this reason, Table XIV (page 72) now includes the current year's total of tasks run, together with that of the previous year. For comparison, the corresponding figures for the previous five years were:

1975	1976	1977	1978	1979
		thousands		
272	312	331	397	447

The figures include tasks submitted from remote terminals.

The present COSMOS installation

The two large computers at the heart of COSMOS, the IBM 360/195 and 370/158 machines, have continued to give excellent performance, even though the former has now been in service for over nine years. These computers were serviceable and available for use for 98 and 99 per cent respectively of the scheduled operating time.

They operate in loosely coupled mode with each machine able to take over most of the functions of the other. They can be taken out of commission separately, for scheduled maintenance for instance, and the total time when computing facilities were unavailable due to failures in both processors was only a small fraction of 1 per cent. Interruptions in power supply were a more serious problem in the early part of the year, but ceased to be a problem when the switch gear controlling the supply of power to the Richardson Wing, in which the computers are housed, was replaced.

While no enhancements to the large computers themselves were made during 1980, two important peripheral devices were added. A COM (Computer Output on Microfilm) recorder manufactured by Datagraphix is now used to record a substantial proportion of output from the computers, using microfilm instead of line-printer paper. This device has proved a valuable and economical addition to the computing hardware and significant savings have already been achieved in consumption of paper, while convenience of storage is of great benefit to many users. The other major addition late in the year was a telecommunication control unit (TCU) which, as described below, is essential to support the growing network of remote devices linked to COSMOS. A third Calcomp 960 flat-bed plotting device has been installed, and a fully operational service of automatically plotted charts can now be provided for use in the Central Forecasting Office and for transmission to outstations by facsimile, while the many and varied requirements for line-drawing and plotting services by other non-operational users can also be met.

Enhancement of the COSMOS system

Since the placing late in 1979 of a contract for the delivery of a CDC CYBER 205 computer (see page 57), intensive preparations have been made for its installation. This computer, together with a further CDC processor intended to serve temporarily as a 'front-end' device, and accompanied by ancillary equipment, is to be installed at the eastern end of the computer room. As a consequence several alterations have been made to the location of our present hardware, and space previously allocated to engineers and for storage purposes has been cleared. New accommodation for the latter, as well as room for the electrical plant needed for the new computer, have been constructed in the area of the Richardson Wing below the present computing complex. Provision has also been made there to house the Receipt and Dispatch section, which handles material passing into and out of the computer room, thus freeing space to accommodate the growing magnetic-tape library. The major construction work has been completed, and the mechanical and engineering tasks have now been set in train. The new computer is due to be delivered in the spring of 1981.

Attention has also been directed to the need to replace the IBM 360/195 computer in about two years' time, when it will be nearing the end of its useful life. Though operational forecasting and some major research projects will use the CYBER computer, there remains a large requirement both by Services and Research branches for computing work inappropriate to the new processor. A full assessment of computing needs for the Office as a whole, covering the next 5–10 years, has been carried out and studies conducted, partly through visits by Office staff and partly through invited presentations by manufacturers, of possible replacement processors.

The computing network

The network of remote devices linked to COSMOS has hitherto been mainly confined to the Bracknell area. Teletype and visual display units, linked to the central processor through a TCU, are installed in several Headquarters branches, with a number located centrally for general use. Terminals are also provided at a few outstations, though facilities provided are limited. A major addition to the network in the autumn was the provision of twin minicomputers and associated devices at London/Heathrow Airport (see page 57). The linkage of Heathrow to COSMOS has meant that certain terminal services, which in general have been provided only so far as is consistent with other more urgent tasks, now require to be given operational priority. To this end, an IBM 3705 TCU was installed at the end of the year to control the network, the existing controller which is now obsolescent being retained only for stand-by purposes. The new device is itself a moderately powerful processor, capable of taking some of the load off the 370/158, and steps to utilize such capability are planned for 1981. A further minicomputer system was installed during 1980 at the Meteorological Office College and subsequently linked to COSMOS. Its most intensive use will be during computer courses for Office staff, but it will have wider applications for training purposes. The new TCU is capable of supporting the further operational systems planned for use at HQ Strike Command and London Weather Centre.

Optimization of the system

A small specialist group in the Branch is responsible for adapting and extending the manufacturers' software associated with the main computers, applying modifications appropriate to the particular requirements of the Office and improving its performance in the light of changing requirements. The Multiple Virtual Storage (MVS) operating system introduced on the IBM 370/158 in 1979 was modified this year by Systems Extension 2 (SE2), enabling some 15 per cent additional processing power to be realized. The installation of the TCU at the end of the year required detailed study by the systems group of the associated operating system. Initially this unit will merely carry out the functions of the controller it replaced but it is intended, by means of later software enhancements, to make fuller use of its potential for controlling the network.

The other main task of the group has been to prepare for the introduction of the new CDC computer. This requires detailed study not only of the CYBER operating system but also of the special software being written by CDC to link the new processor to the IBM machines. Two members of the group attended courses at the CDC central facility at Minneapolis in November and December. During their visit they took the opportunity to make appropriate modifications to the standard IBM software with which the CDC operating system is to be linked, so that realistic trials of the complete system can be carried out in the USA before delivery.

Support for computer-based applications

The Branch provides support to computer users throughout the Office, for example in training new recruits and existing staff transferred to computing work. Assistance was provided this year with the basic programming courses at the Meteorological Office College, and instruction in both FORTRAN and IBM Assembler languages, previously provided at the IBM Education Centre, was undertaken this year by Meteorological Office staff. Training in the very specialized form of programming required for the new CYBER computer has been given by Control Data Ltd, and program development work on tasks intended for the new machine has been largely carried out using a terminal at Bracknell linked to a CDC CYBER 203E computer in Minneapolis.

While much effort has been needed to maintain current services, work has increasingly been directed to preparations for the introduction of a new operational forecast suite. Several changes are being made to the procedures for processing and controlling the quality of synoptic data; in particular a new section is being written to handle upper-air reports. This will enable consistency of the vertical profiles of the reported temperatures and winds to be checked and erroneous values corrected. The small group charged with providing standard software for automated line drawing and chart plotting also gave priority to programs required for the new operational suite. Test charts have been produced for equatorial regions and the southern hemisphere, using material extracted from the synoptic data bank. Looking further ahead, new international codes are to be introduced in January 1982 for reports from surface land stations and ships, and preparations are well under way to process these observations and to revise the way in which the data are presented on the automatically plotted charts.

The First GARP Global Experiment

As part of its contribution to FGGE, the Office has processed observations received throughout the FGGE year from Europe, Africa and parts of the Middle East. This processing was mostly completed early in 1980 and results passed to the Surface-based Data Centre in the USSR. Some reports, however, continued to arrive until late in the year and these have been processed as supplementary data. All these reports will eventually be incorporated in the global FGGE data set. Although most FGGE observations were extracted in real time from the synoptic data bank, they were supplemented and in some cases corrected by reports on paper tape received by post. The latter method only added 4 per cent to the total collected from Europe, but 25 per cent in the case of remaining countries. This well illustrates the difficulties still being experienced in reception of observations in real time from some parts of the world.

Storage and preparation of data

The Processor-Controlled Keying (PCK) installation has continued to carry out its routine function of transcribing for subsequent computer processing various forms of tabulated data. Most of these are monthly returns from UK stations, but observations from ships' logbooks, messages from oil rigs and other specialized data are included. Despite a small decrease in the number of staff in the PCK section it has so far been possible to keep pace with the essential routine work. There is, however, a considerable backlog of earlier climatological data, and some of this was keyed earlier in the year in another Government establishment. In the long term it is hoped to process more of the data automatically by extracting the fuller reports from the synoptic data bank which will become available with the introduction of the new common surface codes in 1982.

Systems Development

The Systems Development Branch has continued to be involved with a wide variety of work in 1980, mainly concerning the planning and implementation of new systems based on computers. Two important projects deserve special mention. The computer-based system for the Principal Forecasting Office (PFO) at London/Heathrow Airport was installed in August and started pre-operational trials in December; the main function of the system at present is automatic plotting of basic observations and line drawing of forecast products. A great deal of effort has been devoted to the control of the pre-delivery phase of the contract for the CYBER 205 computer. The CYBER 205 will provide more than twenty times the power of the existing IBM 360/195 for the running of major numerical models.

Automation of outstation functions

The equipment for PFO Heathrow was delivered to Bracknell and accepted by March. A period of intensive development and system integration followed, during which the routines to acquire basic data and forecast products from COSMOS, and to display them in suitable forms on the plotters, were tested and improved.

In August the equipment was moved to the Queen's Building at Heathrow, following the completion of works services. Development work continued until the end of the year, with special emphasis on producing software that would be very easy for staff unfamiliar with computer systems to use, and on stand-by arrangements to cope with failures in computers or lines. The staff at Heathrow were also introduced to the system and given training in its operation during this period. The pre-operational trials started in December with parallel running of the new computer system alongside the existing manual plotting of charts and use of facsimile products from Bracknell.

Work continued on procurement of a similar system for PFO, Headquarters Strike Command and an order was placed in August for the computers. Contract action for the plotting equipment was being taken at the end of the year. A case for a third system to be installed at London Weather Centre has been prepared.

Procurement of CYBER 205 computer

The very powerful computer ordered from Control Data Ltd in November 1979 has been rechristened the CYBER 205; it was previously known as the 203E. A careful watch has been kept on the development and construction of the machine by Control Data Corporation in America, and delivery is now expected in spring 1981. Recent tests suggest that performance of the CYBER 205 will be more than twenty times faster than the IBM 360/195 on numerical modelling computations when care is taken to optimize the algorithms and programs.

Plans for the replacement of the IBM 360/195

The IBM 360/195 has now been in service for over nine years and problems are becoming apparent in maintaining and enhancing the system, mainly the software, to meet changing operational requirements. Accordingly, steps were taken to ascertain the type of machine that could most effectively replace the 360/195 in 1982/83. Probable changes in the work-load, taking into account the transfer of large numerical models to the CYBER 205, new projects and developing services, have been assessed in preparing a specification for the replacement computer.

Study of administrative systems

The final version of the report on the study of the applicability of computers to administrative systems within the Office was issued in February and considered by the Directorate. As a result, three areas were identified that required urgent action. These were stock control, staff-time analysis and word processing.

Detailed consideration of the stock-control problem led to the conclusion that the fastest way to alleviate the existing difficulties, despite the problem of entering our records into the computer, would be to make use of the RAF's supply computer at Hendon. Negotiations with the RAF authorities are still continuing, based on the idea of installing a terminal at Bracknell connected to the computer at Hendon.

Special software was written to meet a requirement for the analysis of staff time and overtime. There is a further requirement for a much more fundamental attack on the whole question of management information and statistics, but the effort required to implement such a system by in-house effort would be excessive. Accordingly, a study of suitable data-base management systems and data dictionaries was commenced.

A small experiment in word processing started in October with a computer terminal in the typing pool. Plans to enhance the experiment by adding more powerful text-handling software were formulated and an operational requirement for a full word-processing system was prepared.

Miscellaneous small projects

At the end of June a small computer was brought into use at the Meteorological Office College, both for program preparation and as a remote job-entry terminal to COSMOS.

Assistance was given to the Boundary Layer Research Branch in preparing for the procurement of a system of two small computers for use at Cardington to perform data-logging and checking work, and also to provide remote job-entry facilities to COSMOS.

Work on the PRESTEL project has proceeded more slowly than expected but, by November, an Operational Requirement had been agreed for an intelligent terminal for PRESTEL use. Assistance was given to the Public Services Branch in preparing the operational requirement and financial case for the terminal.

Experimental work on the PDP 11/40 fell markedly during the year as a new dedicated computer system AUTOSAT (see page 61) took over almost all the work of processing satellite imagery, and development work for automated outstations moved out to Heathrow. Routine data-transcription work is continuing to increase slowly.

Computer-based data archives

Almost half the manpower in the Branch continues to be devoted to incorporating the backlog of data into the archives, and developing schemes for handling new types of data or meeting new requirements. The most serious problem in dealing with the backlog of data has proved to be quality control, i.e. the detection and correction of errors. Most errors can be detected by computer programs at the cost of getting some false indications of errors. Despite strenuous efforts over the years, automatic correction of errors has never been very successful. Interactive methods, involving co-operation between man and machine, are proving to be best for correcting errors, but the full benefits will not be seen until COSMOS can offer a terminal service with a faster and more consistent response. Good progress has been made in filling the gaps in the archives during the year, and long sequences of different types of data are now available covering much of the UK's area of responsibility.

Investigations into new methods of data capture and storage of very large quantities of data have continued. A number of possibilities have come to light but none are yet available in the form of commercial products that meet the Office's requirements at a low enough cost. One interesting possibility is the use of low-cost calculators with a tally-roll printer. If the tally rolls can be read reliably by low-cost optical character recognition equipment there may be a basis of a method for collecting data from voluntary observers without the need for manual key-punching at Bracknell.

A survey of all the machinable data in the Office was begun in the summer and was well advanced by the end of the year. A catalogue is being prepared, as survey results come in, to indicate in detail what is available in the main archives and, in more general terms, what is held by Branches for special purposes.

International co-operation

Staff from the Systems Development and other Branches worked together on a study paper that was prepared as a contribution to the WMO's planning effort directed towards a new design for the World Weather Watch. WMO asked for suggestions for an 'end-to-end data communications system architecture'. The paper prepared by the Office covered this matter but also dealt with general principles concerned with the proposed new design.

Some assistance was given to WMO concerning data management for the Alpine Experiment (ALPEX).

Meteorological Telecommunications

The Telecommunication Branch is responsible for the provision of general communication support to the whole of the Office, for the operation of the Meteorological Telecommunication Centre (Met TC) located at Bracknell, and for the organization of the complex networks of lines and radio channels over which data, satellite imagery and pictorial information are collected and distributed. Meteorological observations of many kinds, including those from land stations, from ships at sea, upper-air soundings and observations derived from meteorological satellites, have to be collected and exchanged. Analyses and forecasts prepared manually, or automatically by data-processing computer systems at Bracknell and other forecast centres, have to be widely disseminated. During 1980 there has been a marked increase in the number of reports derived from satellites and also in the exchange of output products from numerical forecast models.

As a Regional Telecommunication Hub (RTH) on the Main Trunk Circuit (MTC) of the WMO Global Telecommunication System (GTS), Bracknell has responsibility for the link between Europe and North America, for the collection of observational messages from a number of National Meteorological Centres (NMCs) in northern Europe, and for the dissemination to these and other centres of the information from the GTS which they require. The MTC connections are to the Paris RTH and to the World Meteorological Centre (WMC) in Washington. These circuits operate under the control of an automatic message-switching system and transmissions of digital data at 2400 bits/second alternate with transmissions of pictorial information in analogue mode. A Main Regional Circuit (MRC) between Bracknell and Offenbach operates in a similar fashion. Regional circuits to associated NMCs generally operate in digital mode only and pictorial information is sent over separate facsimile networks. Through their NMCs the Bracknell RTH collects observational data from Greenland, Gibraltar, Iceland, the Netherlands, and the Republic of Ireland. A special responsibility is the collection of observations from the weather ships of the North Atlantic Ocean Stations (NAOS) network. These are received by Morse transmissions to the Shore Station at Bracknell Met TC where a microprocessor-controlled data-entry terminal facilitates preparation of the messages for entry to the main message-switching system. Together with messages compiled by the autosystem from data collected from the United Kingdom, all these reports are inserted into the MTC and other GTS circuits for world-wide distribution.

New services provided this year include the supply of information from the GTS to the European Centre for Medium Range Weather Forecasts (ECMWF) at Shinfield Park, near Reading. A dedicated minicomputer system controls data transmission at 2400 bits/second, using special software developed to provide advanced link-control procedures for control of the data exchanges and for the detection and correction of any transmission errors. Information is at present provided in a batch mode but full real-time transmissions are planned for early in 1981. The link is also being used for the reception of analyses and forecasts prepared at ECMWF, and these are made available to the Central Forecasting Office (CFO) at Bracknell.

An extensive network of teleprinter and facsimile circuits enables Bracknell to fulfil its role as the NMC for the United Kingdom. Observational data and processed information are collected and distributed. After many years, during which these services have remained little changed, the first steps have been taken to provide a new general broadcast service of digital information operating at a higher data rate and providing a wider range of information to many offices.

The facsimile network (SATFAX), over which pictorial information from satellites is distributed, has been extended and now serves almost 30 stations. A dedicated minicomputer system (AUTOSAT) for the control and processing of the satellite cloud imagery was brought into operational service. Although loss of imagery from the European geostationary satellite Meteosat has meant that the full potential of this system has not been immediately realized, the processing of products from the orbiting satellites TIROS-N and NOAA-6 has increased their usefulness. The facilities remain for exploitation when the next satellite in the Meteosat program is launched.

Although the imagery facilities of the Meteosat satellite have failed, facilities for collection of information from Data Collection Platforms (DCPs) have continued to operate. Observations of river flows, rainfall, etc., collected by the satellite from DCPs installed by some UK water authorities, are processed in the European Space Operations Centre (ESOC) at Darmstadt, relayed via Offenbach to Bracknell and thence distributed over the British Telecom telex network to recipients in the UK. At the end of the year daily reports from seven platforms were being handled in this way.

A network of landlines connecting Bracknell to centres in Europe provides for the distribution of Washington and Bracknell analyses and forecasts (including Area Forecast Centre products) by analogue facsimile. Countries served include Norway, Denmark, the Federal Republic of Germany, the Netherlands, Ireland, Iceland, France, Italy and Switzerland. For centres not linked to the land-line network, two radio-facsimile broadcasts and a radio-teleprinter broadcast provide for the transmission of pictorial and alphanumeric information. Facilities are available for the reception of similar radio broadcasts from RTHs in Europe and more remote areas so that some limited exchange of essential data can continue even if there are major failures in the land-line networks.

The Met TC is operated in accordance with agreed international and national procedures for the collection and distribution of meteorological information, and 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)

A major development during the year has been the introduction of the Main Enhancement to the Marconi Myriad message-switching computer system (see Plate V). This enhancement, based on twin Ferranti Argus 700S computers, was brought into use in the latter half of the year to take over control of the medium-speed circuits, including the MTC. The enhancement system has much greater capabilities for handling traffic and has capacity for further circuits operating at medium speed. The new system controls the operation of the circuits to Paris, Washington and Offenbach at 2400 bits/second and to Oslo, De Bilt and Dublin at 1200 bits/second. There is a 2400 bits/second link to the Marconi Myriad system. This latter system supports the operation of many low-speed (50 bauds) teleprinter circuits including links to Brussels, Rheindahlen, Hilversum, Reykjavik, Gibraltar, Cyprus, 12 data-collection centres and about 100 other offices in the United Kingdom. It also provides the information transferred automatically between AUTOCOM and the data-processing computer system COSMOS via a special link controlled by an IBM System 7 minicomputer. A significant advantage of the Main Enhancement system is the availability of magnetic-tape units to which message traffic, logs of message receipt and transmission, and statistics of system and channel activity may be directed. Management information in a form suitable for further machine processing is thus made available. A number of programs are under development which will enable close monitoring of system operation to be maintained, and the monitoring of traffic exchanges conducted in accordance with internationally agreed arrangements for World Weather Watch to be performed thoroughly and more easily.

Facsimile services

There were no major developments during the year except for the change to Vestigial Side Band (VSB) mode of transmission on the facsimile networks to improve the general quality of transmission and to facilitate the introduction of shared facsimile and digital transmission over the main Meteorological Office landline facsimile (MOLFAX) network. This has been an important feature of the year's work and is referred to later. There has been a small increase in the number of forecast products prepared on COSMOS and distributed to major outstations—particularly to the London Weather Centre in connection with the supply of information and forecasts to the North Sea offshore industry. Major revisions to the program schedules for a number of services including MOLFAX, the radio-facsimile broadcasts GFE and GFA, and the Area Forecast System (AFS) programs to Heathrow, Dublin and Cyprus were introduced late in the year following significant changes to the program of AFS chart transmissions from the Offenbach Area Forecast Centre.

Satellite data reception and distribution

The RAE satellite ground station at Lasham provided cloud imagery on a routine operational basis throughout the year. An agreed selection of cloud pictures from polar-orbiting satellites was distributed to outstations via the SATFAX network, these comprising Scanning Radiometer (SR) imagery and selected sectors from the Advanced Very High Resolution Radiometer (AVHRR) imagery services provided by TIROS-N and NOAA-6 satellites. Later in the year the service was augmented by the addition of some imagery from the United States GOES-East geostationary satellite.

Development of the special computer system (AUTOSAT) dedicated to the processing of satellite imagery has continued and, since October, it has been used to provide an operational service of facsimile pictures to the outstations connected to the SATFAX network. At the same time an independent service was provided to the Central Forecasting Office in which imagery is made available on a television-type display. Facilities for local operator control and manipulation of the display are provided, allowing control of grey scales and magnification of selected areas of the image to enable examination of small-scale features. These services include the transfer of cloud imagery to map projections suitable for direct comparison with the forecasters' normal working charts, automatic correction of the seasonal variation of grey scale and re-formatting of pictures for compatibility with existing recorders. To make some of these products more generally available, a further 12 stations have been added to the existing SATFAX network. The new system also supplies cloud pictures for showing on BBC television.

A further addition to the facilities at the Lasham reception station has been planned to permit the operational reception of imagery from the WEFAX service of the GOES-East satellite. This will eventually eliminate the transmission of satellite imagery over the Main Trunk Circuit of the GTS. Until this facility becomes available, a temporary service of GOES imagery is being provided by using the Meteosat receiving equipment made available by the failure of that satellite.

Developments in the low-speed telegraph networks

In preparation for the introduction of the new WMO common code for surface synoptic observations on 1 January 1982, effort has been concentrated throughout the year on the introduction of new 100-baud telegraph services which will make shared use of the MOLFAX network. The new telegraph broadcasts will be generated by a single microprocessor which will also produce vital statistical information to assess channel occupancy and overall usage.

The necessary frequency-division multiplexing equipment for the transmitters at Bracknell and the receivers at each of the outstations has been ordered, together with the new teleprinters for operation at 100 baud. Deliveries of equipment have commenced, installation is under way and experimental transmissions of fully multiplexed data have been made.

Other developments in the telecommunication network

The data entry and editing terminal system, AUTOPREP, has been undergoing trials at Innsworth and in the Bracknell Met TC since July. The reliability of the floppy-disc backing store and software has proved to be disappointing and possible modifications are now being investigated by the manufacturer. Nevertheless, the system has shown good potential for facilitating the editing of observations and preparation of bulletins at Collecting Centres for direct transmission to the message-switching computer system at Bracknell.

An automated system for collecting, sorting, checking and translating basic meteorological observations into aviation user information was under development for most of the year and was introduced into service in October. The system which is based on a Gimini microprocessor accepts four streams of basic data and produces two outputs of weather information for use by UK stations receiving the VOLMET broadcasts, and other aviation users.

At a 'Four Centres' meeting held in May in Bracknell, telecommunication representatives from Washington, Offenbach, Paris and Bracknell agreed to take measures leading to the removal of analogue facsimile from the Main Trunk Circuit segments between Washington and Offenbach and also the Main Regional Circuit Bracknell to Offenbach. The scheme requires that each centre will have an independent supply of half-tone satellite pictures, and its implementation will be held in abeyance until this condition is satisfied.

Plans for the permanent high-speed interface between the Main Enhancement and COSMOS have had to be modified and a somewhat less efficient but considerably more economical method of linking the two computer complexes will be developed, using the new Telecommunication Control Unit (TCU) being acquired for COSMOS.

The development of a facility to output hourly and other plotted charts in digital form from COSMOS to MOLFAX has progressed steadily. A suite of programs to control the management functions of an automated facsimile system has been developed. These programs will schedule, decode, code, input and output charts to and from telecommunication lines, conventional facsimile equipment and matrix plotters.

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. Considerable pleasure was taken by the international meteorological community by the appointment of the Secretary-General Emeritus, Dr D. A. Davies, to be a Knight Commander of the British Empire; Dr Davies was a member of the Meteorological Office from 1936 to 1949.

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 32nd Session took place between 20 and 29 May 1980. Two officers attended the EC Preparatory Meeting (between 8 and 17 May) when the main meeting was prepared in great detail. During these sessions four matters were emphasized. These were the detailed planning of the important new program on World Climate approved by Eighth Congress (1979), the planning of studies leading to an improved World Weather Watch, a critical appraisal of the Organization and its scientific and technical programs, and the Precipitation Enhancement Project. The latter is an internationally designed and supervised experiment being conducted by an international team at Valladolid in Spain to determine whether and in what circumstances precipitation can be increased economically. This Project is of great interest to Third World countries.

Other constituent bodies of the WMO are the six Regional Associations, in 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 Hydrology met in Madrid and the one for Basic Systems held an Extraordinary Session in Geneva. The UK was represented at both and also sent experts to important meetings organized by these and other Commissions throughout the year.

The global systems for observation, telecommunication and data processing constitute 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 as 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. A particular problem is experienced in the training of technical officers and the process of

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* Kiribati and Tuvalu were formerly the Gilbert and Ellice Islands respectively, and Vanuatu was formerly the New Hebrides.

'localization' is proceeding more slowly in that field than was hoped. In the case of Vanuatu, the upper-air station at Bauerfield was formerly 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. Informal arrangements have been made to continue the program of observations in the interim but these can only be of limited duration.

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, the award of training fellowships and by other services provided by the developed countries. The annual Informal Planning Meeting of major donors to the VCP was held 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 Executive Committee meeting in May. Concern was voiced by the UK at both meetings at the very small number of donors to the Program and the relatively low level of continuing success of individual projects. Arising out of its concern, the UK is developing closer contacts with Meteorological Services in the countries, mainly Africa, with which it co-operates in this Program. Within this policy, liaison visits to Kenya, Botswana and Zimbabwe were made during April and May. Arising out of the visit to Zimbabwe, the Director of the Meteorological Service of Zimbabwe visited the UK during August for discussions on possible future co-operation.

It has been usual for developed countries to offer training under the VCP in their own institutes. However, during discussions in the last WMO Congress and at meetings of the Executive Committee the UK has argued the need for further development of existing facilities in the Regions to include schools for technicians so that local conditions can be properly recognized during training. To demonstrate how this idea can work in practice, the UK co-operated with WMO in providing a course for eight radar technicians from English-speaking African countries at Nairobi in November and December. A radar was loaned by the UK and two instructors were sent from the Meteorological Office. Accommodation for the course was generously provided by the Kenya Meteorological Service and WMO provided Fellowships for many of those attending. The course attracted very favourable comment and an opening ceremony was well attended and covered by the local Press, radio and television. In a similar manner the UK provided an instructor for a WMO course on instrument maintenance in Cairo in December.

Following an initiative of 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 has reached an advanced stage.

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. As part of the testing of the first numerical prediction model developed by the Centre, forecasts were made available in operational mode to members, from August, over a private telecommunication network established for the purpose. The work of the Centre is supervised by a Council, comprising representatives of the Member States, which is assisted by three advisory committees, namely the Scientific Advisory Committee, the Finance Committee and the Technical Advisory Committee.

The North Atlantic Ocean Stations (NAOS) Agreement, under which the network of weather ships making surface and upper-air observations in the Atlantic is maintained, remains in operation. The Agreement was due to lapse in 1981 but the NAOS Board has made proposals for its continuation until the end of 1985. A consequence of the new proposals is that the UK will charter a ship from January 1982 to occupy Ocean Weather Station 'L' (57°N, 20°W) jointly with the Netherlands, in place of the two ships, operated by the Office, which alternate as sole occupant of this station. Discussions in the WMO committees on an improved World Weather Watch include consideration of possible systems to replace the important but expensive observations from the Ocean Weather Ships but a solution to this difficult problem 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 new 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. Office support for the BAS WWW stations is a continuing commitment which is reviewed from time to time in the light of developing policy. Because of the nature of the Antarctic Treaty which governs activities in that continent, Antarctica does not constitute a WMO Region. However, essential co-ordination of arrangements for meteorological observations and communications is accomplished by a WMO Executive Committee Panel on Antarctic Meteorology.

The Program Review Committee (PRC), which comprises the senior Directorate of the Office, keeps under review the progress of Office programs and the direction and distribution of effort. During the year the Branch continued to assemble management information on a wide range of products and activities in support of the PRC and explored the use of this information by individual project managers.

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 1980

	Within UK	Overseas
Principal Forecasting Offices associated with the RAF	1	—
Main Meteorological Offices associated with the RAF...	6	3
Subsidiary offices associated with the RAF	29	4
Observing offices associated with the RAF	4	1
Principal Forecasting Offices associated with civil aviation	1	—
Main Meteorological Offices associated with civil aviation	3	1
Subsidiary offices associated with civil aviation	9	—
Observing offices associated with civil aviation	7	—
Upper-air observing offices	8	1
Public service offices	6	—
CRDF offices	4	1
Port Meteorological Offices	7	—
Offices associated with the Agricultural Development and Advisory Service (MAFF)	4	—
Other offices	28*	2

* Four of these stations are administered by DR Met O.

Notes

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

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

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

At an observing office no forecaster is available.

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

Public service offices are located in certain large cities.

CRDF offices form the network for thunderstorm location.

Port Meteorological Offices are maintained at the bigger ports.

TABLE II—OCEAN WEATHER SHIPS

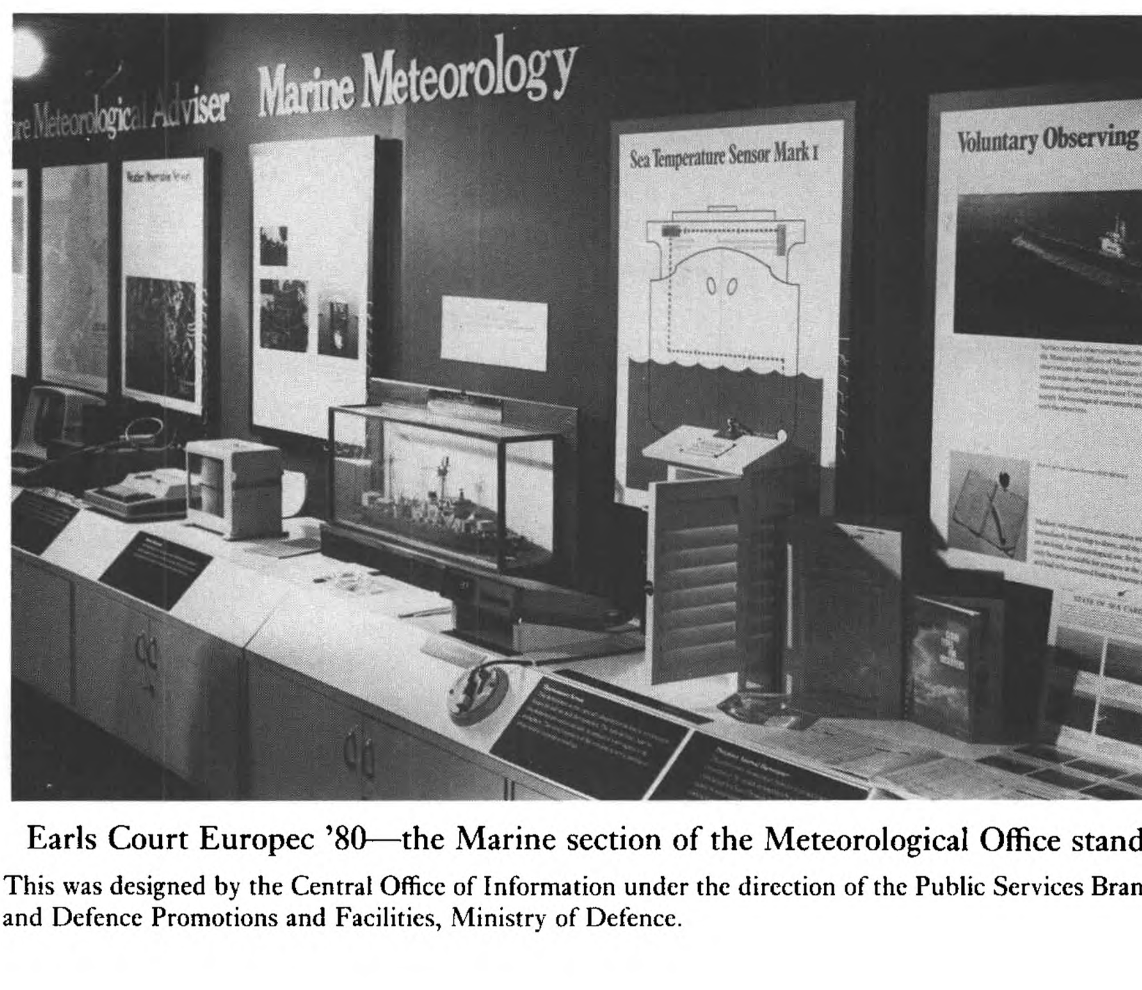
To meet the United Kingdom obligations under the WMO Agreement for the Joint Financing of the North Atlantic Ocean Stations (NAOS), the Office operated two ocean weather ships. These were employed to man ocean station 'L' (57°00'N, 20°00'W) one of the four stations of the network, each ship spending an average of 24 days on station each voyage. The station was manned for a total of 360.8 days in 1980 and the two ships were on passage for 70.4 days. Two ships from France, one from the Netherlands, one from Norway and five ships from the USSR served at the other three stations.

The Director-General in discussion with Vice-Premier Fang Yi in the Hall of the People, Peking, on 14 October 1980

An exerpt from the discussion was included in the national television news bulletin.

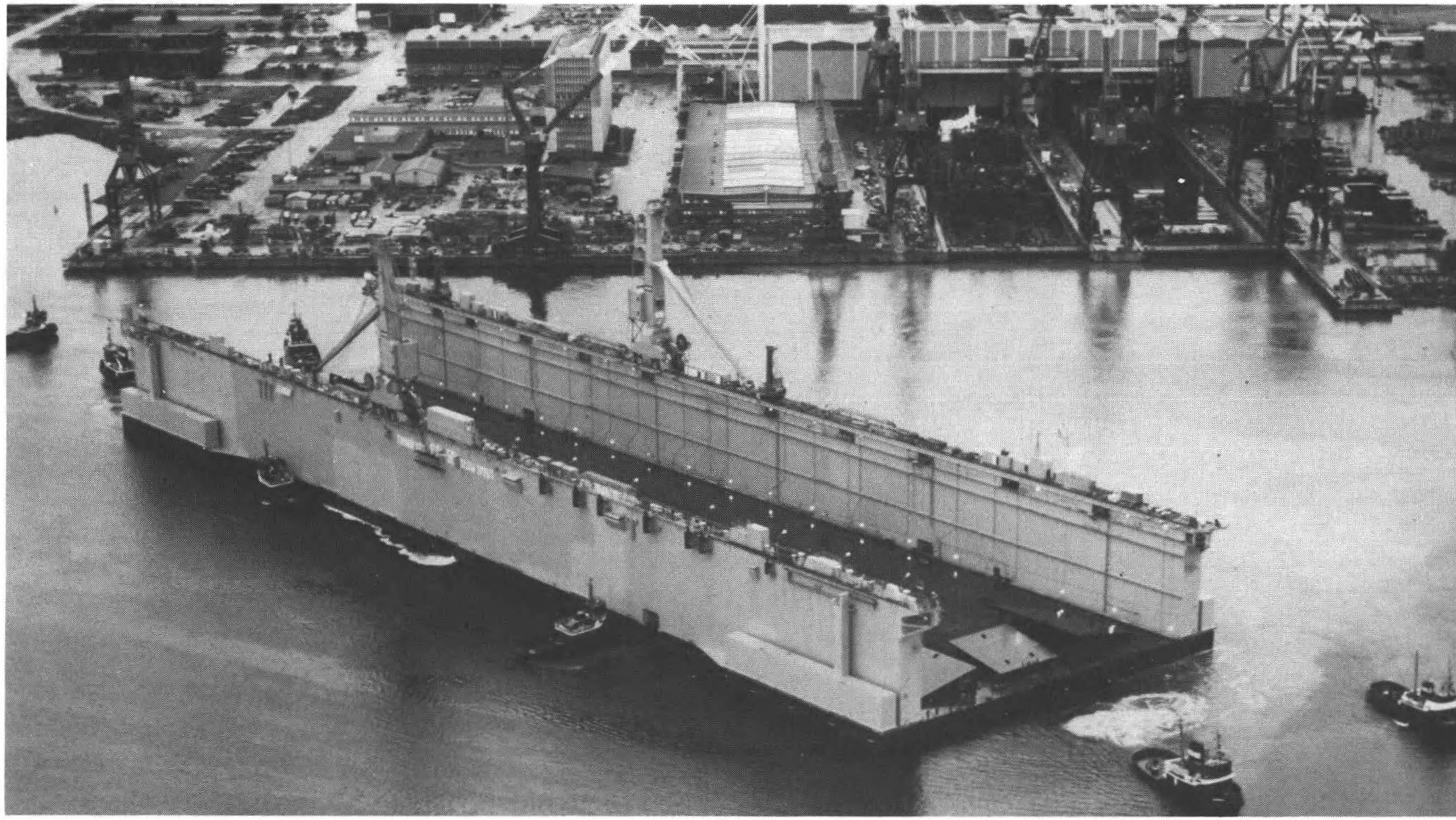
PLATE II

The newly refurbished radio room at the London Weather Centre, with forecaster Richard Porter 'on the air'



Earls Court Europec '80—the Marine section of the Meteorological Office stand

This was designed by the Central Office of Information under the direction of the Public Services Branch and Defence Promotions and Facilities, Ministry of Defence.

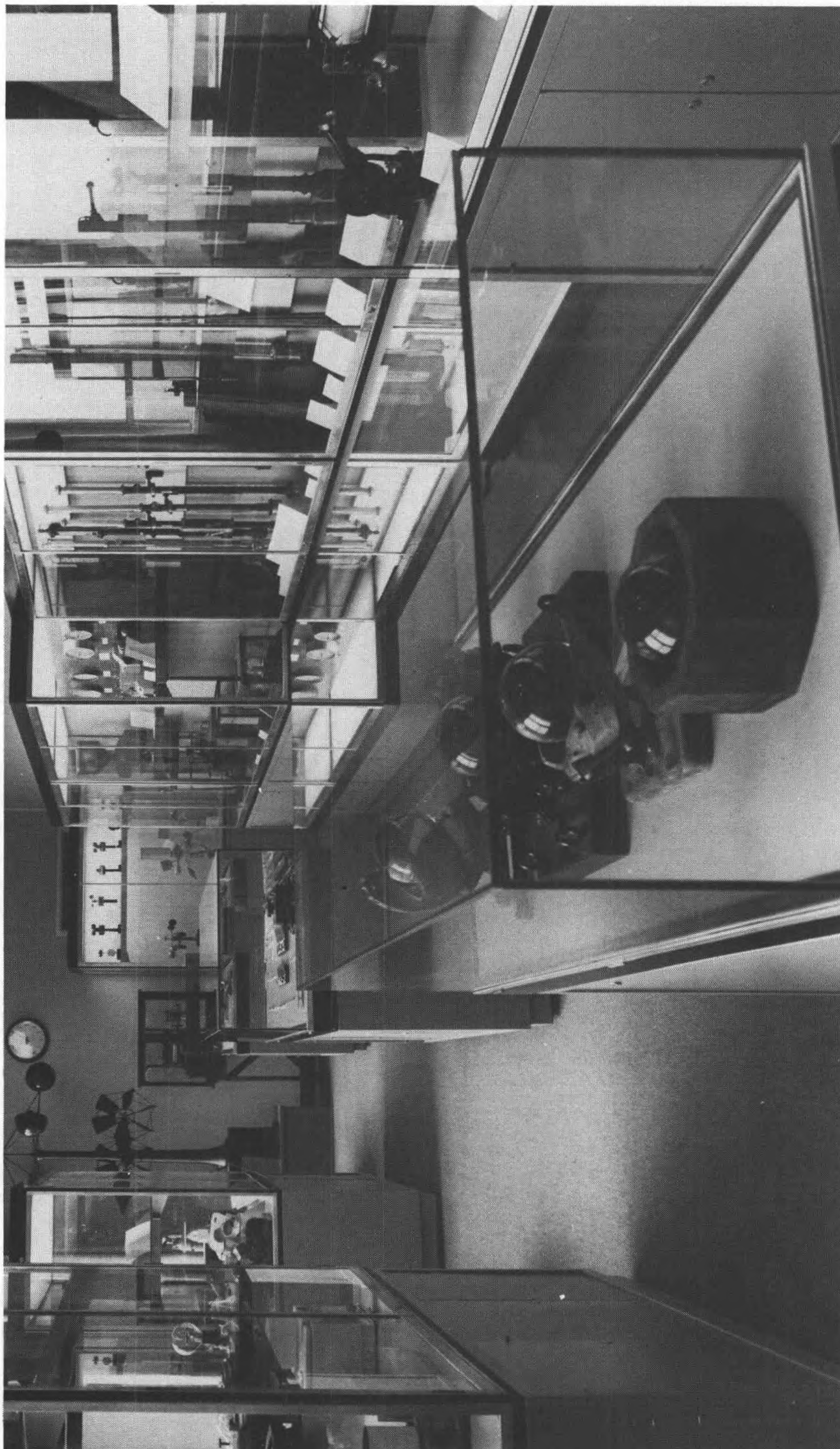


Photograph by courtesy of Gøtaverken Arendal, Norway

Built by Gøtaverken Arendal of Norway, this huge floating dock was towed from Stavanger, southern Norway, to the Russian port of Murmansk

Meteorological support services were contracted through the London Weather Centre and an Aberdeen-based forecaster accompanied the tow throughout the voyage (see page 21).

PLATE IV



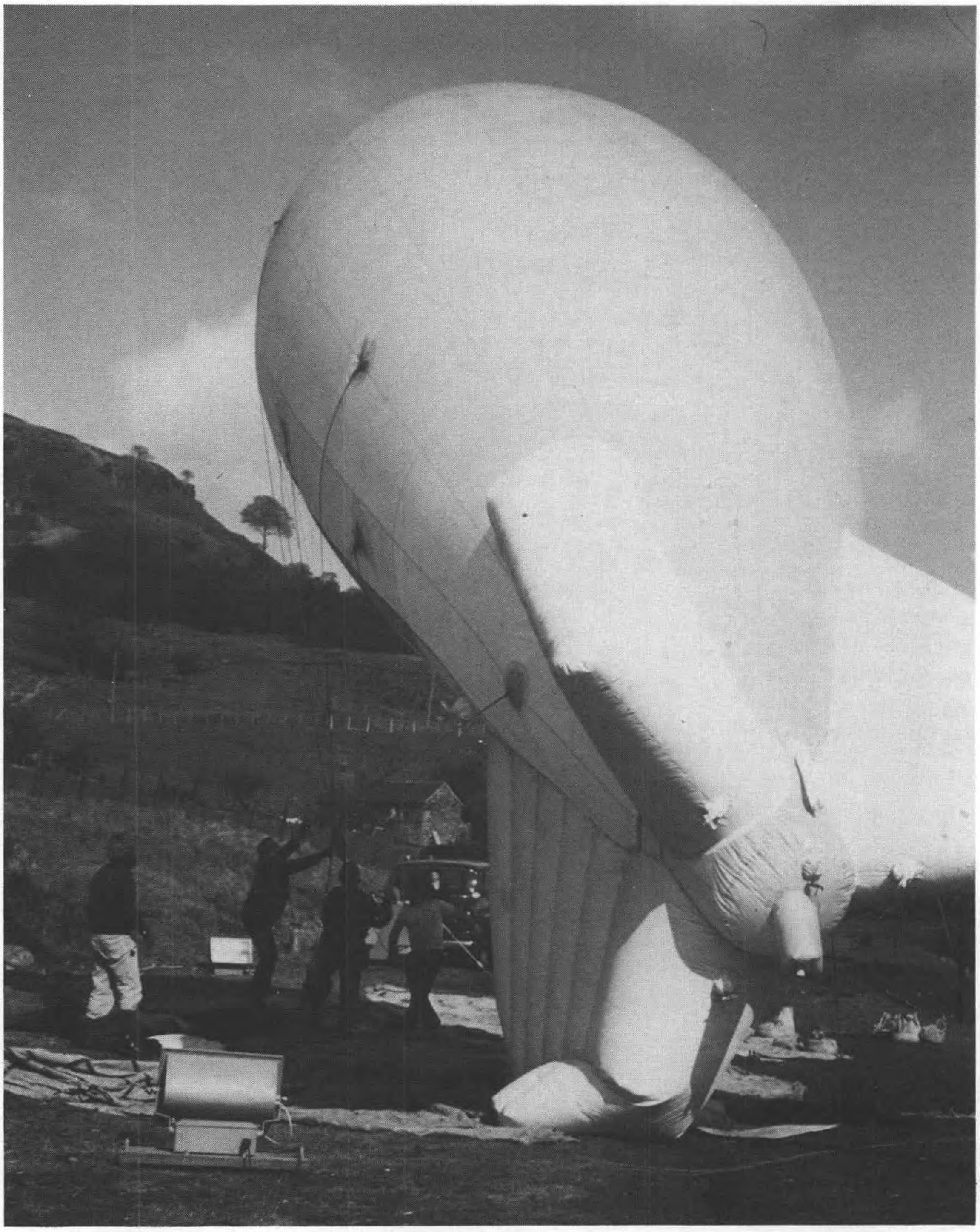
The Meteorological Museum at Headquarters, Bracknell

The Museum displays a variety of equipment, developed over the years, for recording different weather elements.

The Main Enhancement to the Bracknell Automated Telecommunication Complex

Based on twin Ferranti Argus 700S computers, the new system controls the traffic on the medium-speed international circuits of the Global Telecommunication System (see page 60).

PLATE VI



Preparing to launch the tethered kite balloon used during the South Wales experiment
(See page 96.)

TABLE III—MERCHANT SHIPS AND SEA STATIONS

A total of about 7320 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 1980 the numbers of British ships reporting were:

Selected ships	456
Supplementary ships (including 2 trawlers)	22
Coasting vessels	49
Lightships (including 1 light-tower)	13
Trawlers	1
Auxiliary ships	5
Total	546

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

UK to Australasia	20
UK to Far East	27
UK to Persian Gulf	28
UK to South Africa	25
UK to West Indies	12
UK to Atlantic coast of North America	52
UK to Pacific coast of North America	7
UK to South America	10
UK to European ports	97
UK to Falkland Islands and Antarctica	2
UK to distant-water fishing grounds	4
World-wide trading	194

During a typical five-day period in June the average daily numbers of reports received at the Regional Telecommunication Hub (RTH) at Bracknell were as follows:

	Reports 1979	Reports 1980
Direct reception from:		
British ships	157	182
Foreign ships	106	97
Rigs, platforms, buoys	67	57
Total	330	336

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

	1979	1980
Eastern North Atlantic	816	874
Western North Atlantic	284	347
Mediterranean	73	87
North Sea	215	193
Arctic Ocean	88	54
North Pacific	779	845
All other waters	371	410
Total	2626	2810

TABLE IV—CLASSIFICATION OF STATIONS SUPPLYING CLIMATOLOGICAL INFORMATION

A large amount of data is obtained for climatological purposes from stations which are not part of the Meteorological Office. The following table shows how the sources of climatological information in the United Kingdom were distributed on 31 December 1980. 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	32	0	336	24	16	16
Scotland, east	0	6	2	13	45	2	511	35	24	13
Scotland, west	1	6	8	2	49	0	497	25	21	17
England, east and north-east	0	10	3	8	22	5	541	30	16	15
East Anglia	0	11	1	14	21	3	424	24	25	12
Midland Counties	0	8	2	15	41	0	1096	41	37	14
England, south-east and central southern ...	1	16	8	16	34	13	784	55	32	19
England, south-west	0	8	12	5	32	9	609	34	21	11
England, north-west	0	7	2	3	12	2	563	18	21	9
Isle of Man	0	0	2	0	0	1	19	3	1	3
Wales, North	0	1	3	3	16	3	265	12	4	3
Wales, South	0	4	7	6	13	1	337	14	17	4
Channel Islands	0	0	2	0	2	2	17	6	0	2
Northern Ireland	0	2	4	6	51	0	277	25	50	10
Total	3	86	61	92	370	41	6276	346	285	148

* 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 balloon.

	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	5804	92.6	82.8	65.0	13.8	34.6
One station overseas	732	97.8	90.7	75.5	32.7	40.8
One Ocean Weather Station (two ships)	1433	94.9	82.5	69.3	27.2	—
(b) *Wind*:						
Eight stations in the UK	11 660	92.7	73.9	45.7	6.8	34.5
One station overseas	1460	96.2	85.3	53.8	14.1	35.0
One Ocean Weather Station (two ships)	1426	92.8	79.2	66.3	24.6	—

TABLE VI—THUNDERSTORM LOCATION

Number of thunderstorm positions reported by CRDF network in 1980	28 652

TABLE VII—METEOROLOGICAL COMMUNICATION TRAFFIC

Almost all the national and international exchanges of meteorological data which are used in the construction of synoptic charts and the production of forecasts are effected by coded messages. The coded messages mainly comprise groups of five figures and there are about 430 characters in one message. The messages are exchanged by radio and land-line facilities. In addition there is an exchange, both nationally and internationally, of meteorological information in pictorial format. This information is largely analyses and forecasts derived from processing observational data. The transmission method is analogue facsimile by either radio or land-line.

The following figures give an analysis of the traffic (mainly coded messages and information in pictorial format) through the Meteorological Office Telecommunication Centre, Bracknell, for one typical day (24 hours) taken in November 1980 and, for comparison, some corresponding figures are given for one day near the end of 1979.

	In	Out	Total	Total in 1979
		number of messages in one day		
Coded messages:				
Land-line teleprinter and data transmission ...	15 238	66 201	81 439	78 057
Radio transmission	505	3801	4306	4008
Facsimile charts (pictorial format):				
		number of charts in one day		
Land-line transmission...	135	1058	1193	1169
Radio transmissions	60	109	169	215

Notes

The format of the above table has been changed this year. Historically these figures were produced by manual counting of 5-figure groups. However, nearly all traffic statistics are now acquired automatically by computer counts of messages and of characters. Messages have been chosen for presentation in the table.

The increase in the number of messages exchanged by land-line is largely due to a continuing increase in the exchange of processed information. The increase by radio transmission is in part due to increased efficiency of operation of the link to Gibraltar.

Reappraisal of the need for some products has led to the reduction in the number of facsimile charts received by radio.

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
Dry-spell notifications (a summer service primarily for farmers)	1979	139		
*Consultancy Services			1980	159
Weekend temperature forecasts (a winter service primarily for industrialists)	1979/80	96	1980/81	75
Winter road-danger warnings (primarily for local authorities)	1979/80	315	1980/81	272
*Consultancy or Forecast Services			1980/81	18

* See page 19.

TABLE IX—FORECASTS FOR AVIATION

Forecasting for aviation constitutes the primary function of many of the offices. The Central Forecasting Office, acting as a Regional Meteorological Centre of the World Weather Watch, is mainly concerned with the analysis of the weather situation and with the issue of forecast charts for the guidance of other offices, including the two Principal Forecasting Offices which serve civil aviation from London/Heathrow Airport and military aviation from the Headquarters of RAF Strike Command. The Central Forecasting Office also has a commitment to civil aviation in the provision of wind and temperature charts for use with the significant weather charts produced by the Principal Forecasting Office at Heathrow and for the transmission of grid-point data direct to 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 1979 and 1980. These do not include warnings and routine general forecasts.

	1979	1980
Number of meteorological briefings for		
aviation in the UK	370 372	369 643
aviation at overseas stations	32 270	31 684
Number of aviation forecasts issued for		
aviation in the UK	2 136 717	1 894 495
aviation at overseas stations	181 837	154 842

TABLE X—NON-AVIATION ENQUIRIES

Non-aviation enquiries are handled by six Weather Centres, in London, Manchester, Glasgow, Southampton, Newcastle and Nottingham, 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, the 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 1980 figures.

	1979	1980
Total number of non-aviation enquiries	2 186 470	2 088 291
Percentage relating to:		
agriculture	13.0	15·6
building	4.2	4.2
commerce, industry	4.4	4.5
holidays	16.9	16.8
marine matters	13.6	13.4
Press	9.8	10.9
public utilities	8.9	9.3
road transport	10.2	5.3
other known purposes	5.9	8.2
unknown purposes	13.1	11.8

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 1980.

Area	Dense fog	Moderate or heavy snow	Heavy rain	Glazed frost and icy roads	Severe inland gales	Blizzard
Edinburgh and south-east Scotland	—	1	1	—	2	—
Glasgow and south-west Scotland	—	1	1	—	—	—
Belfast and Northern Ireland...	—	—	—	1	2	1
Industrial north-east England	—	—	—	—	5	1
Industrial Lancashire and Merseyside ...	1	—	5	1	3	—
Industrial Midlands	1	1	1	3	1	—
Bristol and Bath	1	1	—	—	—	—
South Wales	—	1	1	—	3	—
London and south-east England	—	1	—	—	—	—
Plymouth and south-west England	—	—	1	—	4	—
Yorkshire	—	2	1	—	1	—
Southampton and Portsmouth	—	—	—	—	1	—
Warnings covering more than one area or blizzards outside industrial areas	—	1	3	1	3	5
Totals	3	9	14	6	25	7

TABLE XII—AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

Information Service Centre	Forecast area	Number of calls 1979	1980
Bedford	40 miles radius of Bedford	341 728	335 717
Belfast	Belfast	393 080	412 488
Birmingham	Birmingham	1 361 230	1 217 758
Bishop's Stortford	40 miles radius of Bedford	165 822	131 619
Blackburn	Lancashire, Cheshire, Greater Manchester and Merseyside	429 050	367 194
Blackpool	Lancashire, Cheshire, Greater Manchester and Merseyside	283 012	240 708
Bournemouth	South Hampshire	470 607	442 389
Bradford	Leeds, Bradford, Huddersfield	258 062	200 397
Brighton and Hove	Sussex coast	928 776	867 314
Bristol	Bristol	1 013 271	772 805
Cambridge	40 miles radius of Bedford	—	30 065
Cardiff	Cardiff	1 215 420	879 809
Canterbury	Kent coast	515 886	349 405
Chelmsford	Essex coast	227 375	199 802
Cheltenham	South-west Midlands	233 701	186 502
Chester	Chester and North Wales coast	237 913	183 171
Colchester	Essex coast	345 968	308 289
Colwyn Bay	Chester and North Wales coast	114 627	115 860
Coventry	Birmingham	444 516	294 044
Derby	Nottinghamshire, Derbyshire, Leicestershire	239 138	209 049
Doncaster	Sheffield, Chesterfield, Doncaster, Barnsley	82 555	71 606
Edinburgh	Edinburgh	510 960	426 632
Exeter	Devon and Cornwall	426 297	456 720
Glasgow	Glasgow	876 963	813 089
Gloucester	South-west Midlands	378 908	292 495
Grimsby	North Lincolnshire and Retford area	128 238	111 168
Guildford	London	255 659	254 806
Hastings	Sussex coast	131 003	148 628
Hereford	South-west Midlands	164 143	137 827
High Wycombe	Thames Valley	240 011	186 705
Huddersfield	Leeds, Bradford, Huddersfield	153 011	120 680
Ipswich	Norfolk and Suffolk	287 656	362 219
Leeds	Leeds, Bradford, Huddersfield	677 974	598 954
Leicester	Nottinghamshire, Derbyshire, Leicestershire	495 256	402 670
Lincoln	North Lincolnshire and Retford area	236 526	242 016
Liverpool	Lancashire, Cheshire, Greater Manchester and Merseyside	433 157	396 537
Liverpool	Chester and North Wales coast	59 532	53 291
London	London	5 146 826	4 027 978
London	Essex coast	227 792	149 895
London	Kent coast	238 438	197 779
London	Sussex coast	426 701	375 216
London	Thames Valley	334 173	263 917
London	40 miles radius of Bedford	215 496	154 064
Lowestoft	Norfolk and Suffolk	—	28 907
Luton	40 miles radius of Bedford	297 321	296 762
Manchester	Lancashire, Cheshire, Greater Manchester and Merseyside	858 756	653 939
Manchester	Chester and North Wales coast	97 939	127 304
Medway	Kent coast	329 352	293 584
Middlesbrough	North-east England	396 316	263 666
Milton Keynes	40 miles radius of Bedford	—	71 955
Newcastle	North-east England	707 229	626 691
Newport, Gwent	Cardiff	185 032	133 367
Northampton	40 miles radius of Bedford	148 804	122 935
Norwich	Norfolk and Suffolk	531 126	482 278

Information Service Centre	Forecast area	Number of calls 1979	1980
Nottingham	Nottinghamshire, Derbyshire, Leicestershire	786 538	619 941
Oxford	Thames Valley	406 120	347 244
Peterborough	40 miles radius of Bedford	184 278	156 556
Plymouth	Devon and Cornwall	643 994	505 477
Portsmouth	South Hampshire	616 258	542 412
Reading	Thames Valley	668 583	532 905
Sheffield	Sheffield, Chesterfield, Doncaster, Barnsley	652 605	561 573
Southampton	South Hampshire	961 035	804 296
Southend	Essex coast	410 777	333 302
Southport	Lancashire, Cheshire, Greater Manchester and Mersey side	84 272	72 082
Swindon	Bristol	89 504	63 059
Torquay	Devon and Cornwall	259 873	201 102
Tunbridge Wells	London	143 701	137 280
Total		30 805 870	25 967 894

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.

	1979	1980
Total number of climatological enquiries	35 641	40 589
Percentages relating to:		
agriculture (farming, forestry, market gardening)		8.9
building and design (including siting)		22.2
commerce (sales, marketing, advertising)		5.5
drainage		2.4
education and literature		5.2
flooding		0.5
heating and ventilation		2.8
industrial and manufacturing activities		4.2
law (damage, accident, insurance)		15.1
medical and health		0.7
Press and information centres		1.6
research		7.1
sports, hobbies, holidays		1.3
transport and communications		2.1
water supplies		5.9
miscellaneous (purpose known)		7.1
miscellaneous (purpose unknown)		7.4

TABLE XIV—DATA PROCESSING

	1979	1980
(a) Computer installations		
(1) Number of tasks run on the 360/195 computer	225 281	256 000
(2) Number of tasks run on the 370/158 computer	174 394	210 000
(3) Number of tasks run using the terminal system	47 969	60 000
(b) Processor-controlled keying system:		
Number of characters keyed	72 370 000	67 224 632
(c) Punched-card installation:		
Number of cards punched	324 000	297 828

TABLE XV—INSTRUMENT TESTING, CALIBRATION AND ACCEPTANCE

	Number of tests or calibrations
General meteorological instruments:	
Wind measuring	1101
Pressure measuring	961
Humidity measuring	32
Precipitation measuring	905
Radiation measuring	237
Sunshine recording	55
Temperature measuring	5571
Miscellaneous	3603
Electrical/electronic instruments and systems	1041
Electrical/electronic components	1899
Balloons	18 866
Radar reflectors	5280
Radiosonde parachutes	25 900
Radiosonde unwinders	1301
Mk 3 radiosonde component parts tested and accepted	165 972
Mk 3 radiosonde humidity transducers skinned and seasoned	3200
Mk 3 radiosonde pressure transducers calibrated	3000
Mk 3 radiosonde pressure reference elements calibrated	3500
Mk 3 radiosonde recoveries received	1742
Total	244 166

DIRECTORATE OF RESEARCH

SPECIAL TOPIC—THE DEVELOPMENT OF THE METEOROLOGICAL OFFICE NEW OPERATIONAL FORECASTING SYSTEM

Introduction

It is perhaps surprising that weather forecasting, an apparently inexact skill, was one of the first practical applications of computers. Indeed, the principles underlying their use for such purposes were established during the First World War, and published shortly after it by L. F. Richardson (1922), a remarkable British mathematician who spent several years working in the Meteorological Office.

Richardson's essential contribution was to set down weather forecasting as a problem in classical physics and to indicate how the resulting equations could be solved by numerical techniques. At that time the conventional method of weather forecasting was based on experience and history. Depressions and anticyclones were followed and their movements extrapolated or predicted on the basis of historical precedents, but this was done without a clear conception of what caused the motion or, indeed, why depressions and anticyclones formed in the first place. Richardson's proposal was to change these inexact, qualitative methods for quantitative techniques based on the established laws of physics. The mathematical problem was formidable. The atmosphere was to be represented by the values of variables (i.e. temperature, pressure, wind, humidity) on a three-dimensional mesh of points with a horizontal separation of 400 km and a vertical separation of about 200 mb. The equations of motion, thermodynamics and conservation of matter could be then written in a form that enabled the changes taking place at a particular mesh point to be calculated from the values at surrounding mesh points. The changes could be added to the initial values to find the expected state of the atmosphere a short time later. The calculations then had to be repeated so that the 'forecast' could be stepped forward towards the time for which it was required. The calculations when carried out by hand were so laborious that Richardson was employed for many months in evaluating a 6-hour forecast for a single point on the earth's surface. The pressure change he calculated (145 mb in 6 hours) was completely unrealistic, and his failure seemed to put paid to attempts to make weather forecasting more quantitative.

Richardson's work on weather forecasting was carried out at least a quarter of a century before electronic computers were developed. When they were, the possibility of using them in weather prediction was recognized by the distinguished American mathematician J. Von Neumann. He collected together a group of talented young scientists to work on the problem and so exploit the potential for more accurate weather forecasts which seemed to be opening up. Some of those involved, for example Professors J. G. Charney and J. Smagorinsky, were to be among the most outstanding and influential dynamical meteorologists of our day. From these beginnings stemmed developments which, over the last three decades, have revolutionized the science and practice of weather forecasting.

Within the United Kingdom similar but independent research on the quantitative description of atmospheric changes was going on, the outstanding names being those of Dr E.T. Eady who worked within the Meteorological Office during the Second World War but, after it, left to become a member of the distinguished group of meteorologists who constituted the Meteorological Department at Imperial College, London, and Dr

R. C. Sutcliffe whose paper in the *Quarterly Journal of the Royal Meteorological Society* in 1947 was the mainspring of developments in dynamical meteorology within the Office for more than a decade. The first models which were used in the Office for research into forecasting by computer methods owed their derivation directly to Sutcliffe's work.

An important element in the researches of that time, which was crucial to the practical application of computers in forecasting, was the elucidation of the main reason why Richardson's initial attempt at forecasting produced such a poor result. Essentially it was that the meteorological observations on which his forecast was based were used in a 'raw' form. In general, measurements made in the atmosphere are influenced by the effects of motion due to meteorological phenomena of many different scales, for example by the motion created by individual clouds or by narrow frontal systems as well as by the depressions and anticyclones, the larger features which the forecasters were hoping to deal with. The motions associated with the features Richardson was hoping to forecast were being seriously contaminated by those caused by much smaller, short-lived features which could not be represented by grid points 400 km apart. This led to the concept of adjusting the initial analyses so that they represented only that part of the wind and temperature field associated with the large systems, and of 'filtering' the equations which formed the atmospheric model to ensure that they did not give rise to unrealistic small-scale motions. When these new ideas were incorporated into the models, the difficulties experienced by Richardson were removed.

The first model used by the Meteorological Office to produce numerical forecasts operationally was a 'filtered' model which had three levels in the vertical where the calculations were carried out and where results were available to the forecasters, and a horizontal mesh with nodes positioned about 300 km apart. The event which enabled this model to be used in providing information directly to the forecaster quickly enough to influence the forecasts issued to the public, was the replacement of the first Office computer, a Ferranti Mercury, by the faster English Electric Leo KDF9. This operational system provided the guidance for Meteorological Office forecasts for seven years, a period during which the products came to be recognized and regarded as the most important information available for forecasting the weather for 24 hours to 36 hours over the British Isles.

However, even before the system became operational, research was indicating rather clearly that the use of filtered equations to suppress extraneous motions sometimes prevented the models from indicating atmospheric developments realistically. The constraints imposed by the filtering could be harmful, and furthermore they were shown to be not strictly necessary. It was discovered that filtering could be replaced by much less restrictive methods and, in effect, one could return to techniques much closer to those introduced by Richardson, provided care was taken to ensure that the initial conditions were still tailored to eliminate certain types of motion not of meteorological interest. If the initial data for a forecast were of the right kind, then, with reasonable care in the numerical techniques, the representations of atmospheric motion remained realistic when the equations were integrated forward in time to obtain a forecast. The new models which then became possible were termed 'primitive equation' as opposed to 'filtered' models and their power was rapidly demonstrated when they were applied to forecasting real conditions. In particular, they could forecast not only the wind field but the rainfall and cloudiness, features which presented enormous difficulties to the earlier models. Furthermore, since they were more general, they had the potential to represent smaller-scale aspects of the meteorological situation, for example frontal systems which are of such significance in the rainfall of this country.

In the Meteorological Office, research aimed at exploiting 'primitive equation' models, particularly to investigate the processes occurring within fronts, was initiated in the early 1960s by J. S. Sawyer. It led to the development by F. H. Bushby of a new model with 10 levels in the vertical and a horizontal mesh length of 100 km (Bushby and Timpson 1967). The first situation on which it was tested was 1 December 1961, when a shallow trough some 500 km west of Ireland developed rapidly to become an active depression and deposited large amounts of rain on southern England as it ran quickly eastwards. The conventional forecast on this occasion was not particularly successful, but the new model predicted the deepening of the depression, its eastward movement and the rainfall very well. The promise of this model was such that when the opportunity arose in 1972, through the replacement of the KDF9 computer by an IBM 360/195, to improve the Meteorological Office numerical weather forecasting system a version of it was chosen as the basis of future operational guidance. Since that time the basic operational system has been essentially unchanged, though of course minor changes have been made from time to time as investigations indicated them to be desirable. At the present time, the 10-level model with a 300 km horizontal mesh length covering most of the northern hemisphere is used twice a day to provide the forecasts for aviation and the basis for forecasts to the general public. In addition, a 'fine-mesh' version of the model covering Europe and the Atlantic is used very soon after the standard observations are received, to provide preliminary guidance and to give more detailed forecasts for the British Isles, including estimates of precipitation. One of the most significant improvements that has been achieved by using this model is that it has been possible to extend the period over which numerical predictions provide guidance from about 48 hours at most with the 3-level filtered model to more than twice this length of time. The model now provides forecasts to 6 days regularly, and the results are useful on most occasions. It is as a result of the improved ranges to which numerical predictions can now be pushed that the European Centre for Medium Range Weather Forecasting was established with the aim of extending the period to 10 days at least. In the future, therefore, the Meteorological Office will be concentrating on the early part of the range, about 1–4 days, leaving the later period to be dealt with by the Centre.

Despite the success of the 10-level model, the desirability of changes on a more fundamental scale than have been undertaken in the last decade has become clear. Almost twenty years since its initial conception and eight years since its introduction into operational use, the model continues to provide forecasts comparable with any produced elsewhere. Indeed, if account is taken of the relatively small amount of computer time it consumes and of the rapidity with which observations are processed and used to provide guidance to weather forecasters, the system as a whole is probably the most effective in the world. Nevertheless, improvements are now desirable, particularly to take account of two new factors. First, forecasts are required for larger areas of the globe and to greater heights in the atmosphere; and second, changes in the meteorological observing network call for different methods of analysis, involving the use of the model itself to derive the best starting point for a numerical forecast. In addition, some aspects of the model need to be redesigned to derive maximum benefit from recent developments in representing atmospheric processes. In the following sections the research on the design of aspects of the new model and the changes in the observing network and analysis techniques are discussed. In the final section the operational system to be introduced in 1981 is described and an example of its performance presented.

Research leading to the design of the next operational model

The atmosphere contains motions on all possible scales. Eddies form downstream of stones, blades of grass, telegraph wires and trees; winds swirl around buildings, sometimes forming intense gusts or vortices; the shimmering seen on hot summer days is caused by hot pockets of air rising from heated surfaces; individual clouds range from the very small to thunderstorms which may be 10 km across and occupy the whole depth of the troposphere. Beyond these systems come the fronts associated with the travelling depressions and anticyclones of middle latitudes which are largely responsible for the variable weather experienced in the British Isles.

The effect of small-scale motions (which are not represented on the model's mesh of points) on the larger-scales (which are) is a very important factor in the improvement of weather forecasts and has been the subject of much research.

In its early stages, numerical forecasting concentrated on the dynamics of the largest scales; the mesh sizes used aimed to deal with features on a scale of 2000 km and upwards adequately, as this included the most commonly observed cyclones and the long waves which tend to control their movement. They were treated almost independently of smaller-scale motions, though it was recognized that on many occasions the latter's influence in modifying the main systems could be significant. This is particularly obvious on some summer days when thunderstorms originating over northern France and moving northwards can transform the large-scale situation, or in winter-time when cold Arctic airstreams reaching Britain from the north are warmed and modified as a result of small-scale heating from the surface by travelling over relatively warm seas. On a slightly longer time-scale, it is necessary to include the effects of small-scale motions in maintaining the vigour of the larger systems because it is generally through them that the energy of the atmosphere is destroyed and replenished. Friction at the earth's surface caused by roughnesses such as waves on the sea surface, trees and buildings destroys about one-twelfth of the kinetic energy of the atmosphere each day. That energy has to be replaced by energy created largely as a result of differential heating, and therefore, for consistency, if the terms representing the slowing down of the large-scale motions by friction are to be included (as they must be to forecast, for example, the decaying stage of a depression's life-cycle), then so must also the differential heating between the tropics and higher latitudes, between land and sea, and between cloudy and cloud-free areas. Most of the heat rises from the earth's surface in small-scale turbulence and is then carried through the depth of the troposphere in cumulus clouds. These effects clearly should be represented in numerical forecasting models.

It is of course out of the question to create a general-purpose model capable of representing all the important atmospheric motions at the same time. Two fairly obvious things can be done. Firstly, the mesh spacing can be reduced so that a larger span of motions can be described adequately in explicit terms. Thus the spacing in the first numerical models was commonly 400–500 km, and this has been reduced progressively to 250 km or less, with even finer mesh models over restricted areas to try to capture the detail required. However, as the mesh is made finer, the computing time for a forecast increases; if the horizontal distance between nodes is halved, the time is increased by a factor of eight, and clearly therefore there is a limit to how far it is profitable to go in this direction. Secondly, one can parametrize (i.e. represent statistically) the effects of the smaller-scale motions in terms of the average values which the model can be assumed to represent; for example, the energy extracted from the wind over a given surface by turbulence can be estimated in terms of the average wind speed over the area. Fortunately, investigations of turbulent motions in the atmosphere have indicated that the more important small-scale phenomena are controlled by the structure of the atmosphere on larger scales together with the character of the underlying surface of the earth, and observations of clouds have shown that they can often be related to the buoyancy characteristics of the airstream in which they occur.

Research aimed at providing adequate parametrizations of the effects of small-scale motions has been a major preoccupation of meteorological research since at least the mid-1960s. It remains an area in which understanding is partial and patchy and from which therefore we can expect research to continue to improve numerical forecasting in the future.

Broadly speaking, the parametrization problem can be split in three:

(1) the interaction between the atmosphere and the earth's surface;

(2) the transfer of heat, water and momentum vertically through the depth of the atmosphere, mainly as a result of buoyancy effects; and

(3) the interaction between the atmosphere and radiation, including the effects of clouds on both short- and long-wave radiation.

The interaction between the atmosphere and the earth depends on the characteristics of the surface—its temperature, roughness and wetness, for example—and also on the lowest atmospheric layers, particularly the wind strength, and whether they are stably or unstably stratified. As the boundary layer, in which the effects on the atmosphere due to the proximity of the earth are appreciable, is usually around 1000 m deep ($\approx$ 100 mb near sea level) and the present operational model has levels 100 mb apart, it is clearly not possible in the model to represent the detailed variation of atmospheric properties close to the ground. The scheme now used to calculate the effects of interaction between the earth and atmosphere has been tailored to these constraints. It was devised by A. J. Gadd and J. F. Keers (1970). Over the oceans, which do not respond significantly to the diurnal variation of solar radiation, a number of simplifications are possible, and therefore the problems to be dealt with are best illustrated by considering the situation over a land surface. The surface temperature responds to the receipt of solar radiation, and there are resultant changes in heating rates, frictional drag, evaporation and cloudiness in the boundary layer. The fractional transmission of solar radiation through the atmosphere depends primarily on the cloud that is present, and in order to find its value an estimate of cloudiness is required. It is deduced from the relative humidity values at grid points. Gadd and Keers then estimate the surface radiation loss using published observations relevant to the cloudiness conditions indicated by the model. The net surface radiation resulting from these calculations is partitioned into heat stored in the ground and sensible and latent heat exchanges with the air, taking account of the wetness of the surface as indicated by climatological data. These exchanges are used in determining the resultant atmospheric changes. It is to be noted that, in this process, surface temperature is not determined explicitly, nor does the stability of the lower atmosphere influence the calculation. For these reasons, among others, the method is limited in its accuracy, and not only the facilities available but the basic understanding have now advanced to the point where it is possible to implement procedures which are capable of calculating the exchanges in a more adequate way.

The new model will have a better resolution in the boundary layer so that stability can be taken into account in the calculation, and surface temperature will be found explicitly, enabling the atmosphere structure near the ground to be inferred more precisely. These changes are desirable on scientific grounds, as they will permit a more realistic simulation of the atmosphere by the model, but they are required in a more direct sense to provide the more detailed information about conditions in the boundary layer that are needed to meet many wide-ranging demands for forecasts. The methods to be implemented in the new model are possible because of a large amount of observational and theoretical research carried out at a number of centres over the globe, but depend particularly on parametrization studies in the Dynamical Climatology Branch. The interaction of the atmosphere with the underlying surface is crucial to an understanding of the physical basis of climate, and investigations concerned primarily with setting up climate models have clarified a number of aspects which have direct relevance also to forecast models.

The surface temperature, and conditions in the atmosphere immediately above, control numerous meteorological processes of direct interest to the forecaster. The accumulation and melting of snow, the rate of cooling at night, the formation and dissipation of fog and frost are obvious examples. As already pointed out, such processes eventually influence the behaviour of the atmosphere on large space-scales and there should therefore be an improvement in the general standard of the forecasts from these measures. The use of the new boundary-layer and surface-exchange parametrization will enable more realistic assumptions to be made about other aspects of the boundary layer. The intensity of the low-level turbulence can be expressed in terms of the low-level wind shear and stability, the infra-red radiative loss will be determined with its appropriate temperature and humidity dependence, and snow predicted by the model will be accumulated or melted according to the calculated values of the surface temperature. Evaporation from the earth's surface will be dependent on the surface wetness, determined from the forecast accumulation of rain reaching the surface, with allowance for percolation into the soil. These parametrizations have already been tested in general circulation models where the validity of the schemes can be assessed from the realism of the climatological simulations. Empirical constants which necessarily appear when particular processes are simplified in a fairly gross way can be chosen to give optimum results on the basis of the calculated climatological distributions of relevant parameters.

Turning to levels above the boundary layer, in which vertical transfer of heat, water vapour and momentum is effected mainly by motions on the scale of individual clouds, a different kind of parametrization is required. Surface heating during the day sets off convection currents which carry the heat up through the atmosphere. The depth of the layer through which it is carried grows as the warm air gradually penetrates and mixes with more stable air at higher levels. In some atmospheric conditions the latent heat released when water vapour condenses to form cumulus clouds capping the convective currents is sufficient to increase their buoyancy to such an extent that the currents accelerate upwards to form rain-shower clouds rising to heights comparable with the depth of the troposphere.

The earliest attempts to represent convective processes in numerical models were based on an examination of the vertical profiles of temperature within the model for buoyant instability and readjusting the atmospheric heat distribution to a neutral or stable configuration. A scheme of this kind was used for some time in the 10-level model. However, the procedure takes little or no account of the actual structure of convective motion as observed. For example, it makes no attempt to represent the direct transfer of heat from the surface to high levels on occasions of vigorous convection. It is not possible to build into it an adequate representation of the vertical transfers of heat, water vapour and momentum nor of the formation of convective clouds and rainfall. Other more elaborate conceptual models have been devised and they permit more realistic representations of such processes.

The current operational model makes use of a parametrization scheme which rests on the supposition that deep convective clouds are initiated and sustained by an input of moisture at low levels concentrated by convergence of the large-scale surface wind field (Hayes 1977). Although such a mechanism is important for some forms of convection (for example within frontal zones), it does not appear to account satisfactorily for other types of deep convection. For example, during the summer months, instability at mid-tropospheric levels is responsible for initiating the growths of cumulonimbus clouds over northern France. They then move northwards across England and Wales, sometimes producing intense hail and thunder and are maintained for several hours by moisture drawn in at low level by ascent within the storms themselves rather than by large-scale convergence. An alternative scheme for representing deep convection in models was developed by P. R. Rowntree and W. H. Lyne (1976), working in the Meteorological Office Tropical Group in connection with the GARP Atlantic Tropical Experiment (GATE). One of the main aims of GATE (see the *Annual Report 1978* for an account of the Meteorological Office's participation in the Experiment, pages 78–85, but especially page 83) was to provide research scientists working in this area with high-quality observations to test the adequacy of proposed parametrizations. In the parametrizations developed in the Office the column of air above each ground-surface grid point is examined for convective instability by determining whether air with a small amount of excess buoyancy relative to its surroundings would remain buoyant if it rose from one level to the next, thus simulating the observed tendency for convection to be initiated by warm bubbles or plumes of air. In this stability assessment, due account is taken of mixing between the rising parcel of air and the surrounding atmosphere and also of the latent heat released as water vapour condenses into liquid water during cloud formation. The liquid water is assumed to fall to the ground as convective rainfall, though allowance is made for some evaporation of the raindrops to take place at intermediate unsaturated levels before they reach the earth's surface. The heating of the large-scale environmental air within which the convective plumes are forming is assumed to arise mainly from subsidence which compensates for the upward mass transfer of the rising buoyant air parcels. Extensive tests of this scheme in tropical forecasts, made and verified using GATE data, showed that it gave appreciably more accurate indications of the amounts and distributions of convective rainfall than simpler methods.

The third area requiring parametrization is the effect of radiation and cloud. Spatially varying radiative exchanges create horizontal and vertical temperature gradients, and air motions are then generated which redistribute the heat. Potential energy lost through the lowering of the centre of gravity of the atmosphere reappears as the kinetic energy of air motion. Such effects are fundamental to the atmospheric circulation both on planetary and local scales. Changes in the average temperature of the atmosphere as a whole have a less immediate impact on the weather.

Two kinds of radiation need to be considered, namely short-wave radiation reaching the earth from the sun and long-wave heat radiation emitted by the surface and the atmosphere.

Apart from the absorption of ultra-violet radiation by ozone in the stratosphere, atmospheric gases are largely transparent to solar radiation, and the main factor determining the amount reaching the earth's surface is cloudiness. Clouds are generally highly reflective to short-wave radiation and therefore they can reduce the heat input to the earth-atmosphere system very substantially. The main difficulty which arises in introducing this effect realistically into numerical models is that clouds are extremely variable in space and time, and in many circumstances there is no clear relation between the amount of cloud and the large-scale variables. Thus, many extensive cloud sheets which reflect a large proportion of the incoming radiative energy are much thinner than the vertical separation of levels in a model, and in a region of mixed cloudy and clear conditions there may be many individual clouds of varying depth and opacity within a single grid area. In these circumstances the 'best' parametrization cannot be derived directly from observations as it will depend on the structure of the model: for example, on the horizontal and vertical grid-spacing, on the parametrizations of other quantities and on the finite difference approximations used in dealing with water vapour. Methods which have been tested and shown to give reasonable results in other Meteorological Office models enable the amount and the depth of cloud to be related not only to the relative humidity, the obvious parameter, but to the vertical velocity and the vertical gradients of temperature and humidity. Such methods are being tested in the new model, but it seems clear that the best parametrization will only be decided after a period of operational testing.

The interaction of infra-red radiation with clouds is also important; thus they trap radiation leaving the earth's surface, and the radiative cooling from cloud tops can lead to the intensification of convective motion within the clouds. The passage of infra-red radiation through the clear atmosphere is also a fairly complex process involving the radiatively active gases, water vapour, carbon dioxide and ozone. While the most significant aspects of infra-red radiative interchanges are, broadly, understood and computer programs are available to calculate them accurately, the particular techniques which work best and are most efficient depend upon the characteristics of the numerical forecasting model and on the specific purposes for which it is used. As with solar radiation and the selection of methods to derive cloudiness, the most appropriate techniques will be selected from the wide range of possibilities available as a result of the experience gained during operational trials.

The meteorological observing network

In the 1950s and 1960s when numerical weather forecasting was being developed into a robust dependable technique, giving predictions of large-scale features of the atmosphere at first comparable with, but later superior to, those of skilled forecasters, the network of observations on which the predictions depended was well-established and fairly static. Surface conditions were recorded at many stations on land, and from numerous merchant ships usually plying the main trade routes across the Atlantic and the Pacific. Observations of upper-air conditions were made at a much smaller number of special upper-air stations which released balloons carrying the necessary instruments twice a day at 00 and 12 GMT, and sometimes at the intermediate hours 06 and 18 GMT.

For many purposes the network of surface observations was probably adequate over most of the northern hemisphere although, not infrequently, small depressions over the oceans escaped detection, and in tropical regions the network was not established on a secure basis. The problem of the oceanic areas could be serious for countries like Britain lying at the ocean boundary; indeed, some of the worst forecast errors were associated with depressions about which detailed information was lacking at a sufficiently early stage of their development. Nevertheless, the supply of observations for the surface was very much better than that for the upper air.

For numerical models the conditions in the upper air are crucial. The models calculate how the atmosphere will change, not by following the history of the motions but by interpreting the atmospheric situation at a particular instant, and therefore they require the three-dimensional structure of the atmosphere to be defined accurately if the forecasts are to be correct. Over most of the land surface in the northern hemisphere the upper-air network was quite good but there were large gaps with no observations, and over the oceans the handful of weather ships could not provide all the detail that was desirable.

In analysing the upper-air conditions with such a relatively scattered set of observed values it was essential to make the maximum possible use of the information available, including theoretical relationships, forecasts from an earlier time, and climatological values as well as the observations themselves. In addition, the methods used sought to make optimum use of the known characteristics of the network. Thus the geographical positions of the observing stations were known and they did not vary from day to day; the observations were made synchronously and therefore it was not necessary to deal with off-time values; although radiosondes differed from one country to another, they were measuring essentially the same variables in a similar way and such variations in accuracy and response characteristics as existed could be allowed for straightforwardly; instrumented balloon soundings almost always measured pressure, temperature and humidity (from which, given the surface pressure, the altitude can be deduced), and most of them tracked the balloons carrying the instruments to measure the upper winds, so that winds could almost always be associated with pressures at the same location. The analysis system that derived initial conditions for numerical models was therefore geared to deal with a fixed network of stations, providing data that were generally reliable and accurate. Additionally, because the forecast area was almost entirely confined to extratropical latitudes, the geostrophic relation could be used rather freely to convert wind information into information concerning the gradient of upper-level pressure and vice versa. [Where the geostrophic relation holds, winds can be inferred with acceptable accuracy from pressure charts; for example, the low-pressure systems or depressions which affect the British Isles have winds blowing around them in an anticlockwise direction. However, in the tropics the relationship is no longer strong and fields of wind and pressure need not be closely connected.] Though the mathematical problem of analysis was difficult because the maximum amount of information had to be extracted, and there was little redundancy in the system to check the results, it could nevertheless be specified in considerable detail and satisfactory methods for solving the problems were developed fairly quickly.

Over the last two decades the observing network has been changing in significant ways. At an early stage in the development of satellites it was realized that they were ideal platforms for meteorological observations as all parts of the earth could be looked at, in large areas simultaneously. It was conceivable that they could provide the extra information from the oceans and from the tropics that was needed to achieve a more adequate monitoring of the atmosphere. There was also the possibility that satellites could replace parts of the conventional network. Essentially, however, the only measurements relevant to the atmosphere that can be made from satellites are of the intensity of the radiation reaching them from a part of the earth's disc. If the measurements are in the visible, then a picture of clouds and the earth's surface can be built up; if in the infra-red then it is possible to deduce information about the temperature of the emitting body, and by taking a variety of wavelengths it is possible to estimate temperatures and (as water vapour is one of the important radiating constituents) humidities through the depth of the atmosphere. When geostationary satellites were put into orbit, work started on trying to deduce winds by tracking suitable cloud elements between pictures taken a short period apart. Research on these aspects of using satellites to obtain winds and temperatures has now been going on actively for over a decade, and some of the latest satellites provide reasonable estimates of temperatures and winds in favourable conditions. What is important from the point of view of analysis, however, is that the estimates are no longer easily compatible with conventional measurements. Thus the temperatures are average values over substantial volumes of the atmosphere rather than discrete values at a point, and their accuracy depends a great deal on how much cloud the volume contains. For measurements of winds from geostationary satellites the main difficulty is in attributing them to specific levels. The level has to be decided from radiation measurements from which it is possible to make estimates of the cloud-top temperatures, and therefore of the approximate height of the cloud in the troposphere. Other technological developments, coupled with the increase in the cost in relative terms of the conventional methods of observing the atmosphere, have led to other changes. Mainly these have been towards automation which enables observations to be made without the need for human skill or human intervention. It is now possible to measure winds accurately in aircraft flying commercial routes without the aircrew having to be involved. They can then be transmitted via a geostationary satellite into the meteorological telecommunications system. Such observations are potentially extremely valuable for analysing atmospheric conditions since they provide accurate measurements at well-defined heights. They do, however, present problems of consistency, because in using them to best advantage it is necessary to try to recreate the pressure and temperature fields at levels below the aircraft winds so that the structure throughout the entire depth is reasonable and leads naturally to the observed winds. Other technological developments have made possible automatic observations of quantities which are already observed and where the gain is mainly in the increased numbers that are, or can be made, available. For example, surface pressure can be measured on unmanned drifting buoys and transferred to the telecommunication network by satellites; more complicated automatic systems have been devised for a wider range of measurements.

The analysis method

From the point of view of analysing the atmosphere these new types of observations have complicated the problem enormously. The observations are no longer synchronous, no longer reasonably uniform in type and accuracy, no longer form a complete set at a particular horizontal location. The new conceptual and mathematical problems are formidable and we cannot be sure at this stage that we know how best to deal with all aspects. This is particularly true because the system and methods of interpreting the observations are still changing. We can, however, create an analysis program which gives better results than we have had before and which is sufficiently flexible to cope with changes in the network which will arise in the future. The question of optimizing the results from the method is a longer-term project when the new operational system is working to reasonable satisfaction.

The analysis problem for numerical weather forecasting is that of representing the three-dimensional structure of the large-scale features in the atmosphere as accurately as possible consistent with the meteorological observations at a particular instant, and of presenting the information to the forecasting model in a form that will allow the best simulation of future developments to be produced. As discussed in the introduction, this implies the creation of a set of internally consistent values which describe only the meteorological features and in which extraneous motions are absent or very small. Ideally, the set should be complete and include realistic vertical motions. However, a particular difficulty concerns the vertical motion at the initial time. It is closely related to the divergent component of the wind, which itself constitutes less than 10 per cent of the wind analysed as being representative of the large-scale features. Atmospheric developments, other than those brought about by simple translation, depend on vertical motion which is the means whereby stored potential energy is converted into kinetic energy and motion. Thus the intensification of depressions requires the ascent of relatively warm air with compensating descent of relatively cold air elsewhere. If the distribution of vertical velocities or of temperature are significantly in error the intensification will be predicted incorrectly. Neither the present observational system nor any likely to exist in the foreseeable future provide the information required to diagnose the vertical motion field associated with large-scale systems directly.

The procedure adopted in the present operational model is to analyse the mass (or, equivalently, pressure) distribution in the atmosphere as accurately as possible. Wind observations are used in this process since in extratropical latitudes they are related to the pressure gradient. The wind velocities over the whole area of the forecast are then deduced theoretically from the mass field by a method which automatically eliminates non-meteorological motions. This procedure, known as initialization, ensures that wildly unrealistic developments do not occur in the subsequent forecast. However, the winds deduced at an observation point may not be precisely the same as those measured and the vertical motions are unlikely to be those required to give the true atmospheric developments in the initial stages of the forecast. Fortunately it is found that the numerical model is generally able to develop more realistic and consistent vertical velocities, so that the developments judged by changes over 12–24 hours are usually correct. The analysis method which has been developed to replace the present operational system is intended to overcome some of these shortcomings. It does so mainly through two significant changes: (1) it deals with observations of different types on the same footing, so that the geopotential will no longer be the prime variable for analysis, and (2) the concept of analysing the observations for a specific instant independently of the numerical model is abandoned in favour of an analysis period within a normal forward run of the model when the observations are allowed to influence and change the model state. Whereas in the present system the vertical velocity is set to zero at the beginning of the analysis and estimated anew from the analysed field of geopotential, in the new system it will be retained and modified like other variables as a result of the gradual assimilation of new information. Such a system is better adapted to circumstances in which many observations apply to times between the main meteorological observing times and are heterogeneous as regards reliability and accuracy. Also it seems to hold out promise for improving the forecast of developments in the first few hours, and could therefore have applications in finer-mesh models designed for short-period forecasting.

Analysis and data-assimilation schemes have been developed over a number of years in the Forecasting Research and the Dynamical Climatology Branches. Techniques developed for analysing tropical data during GATE have been particularly useful. More recently the process of assimilating data into a numerical model has been tested during the Special Observing Periods of the First GARP Global Experiment (FGGE), a world-wide intensive observational program carried out during 1979 to obtain accurate data concerning the entire global atmosphere. In the scheme which has been tested, separate analyses for winds, temperatures and surface pressures are produced. The analysis procedure, known as 'optimum interpolation', uses the observations to calculate corrections to a preliminary estimate of the values of the physical quantities obtained from a forecast from a previous time. The corrections are expressed as weighted averages of the departures of the observed values from this preliminary estimate, the weights themselves being selected so that the statistically expected errors in the analysis are minimized. This assumption enables the weights to be calculated in terms of the expected error distributions of the preliminary estimates, the probable error bounds of each observational technique and, where appropriate, correlations of the error at each observation with those of its neighbours. The procedure takes due account of the differing accuracies of various observing systems (for example, winds inferred from following the movement of clouds viewed from geostationary satellites are likely to be less accurate than those found by tracking balloons with radar).

Two quality-control checks are made to test the validity of the data. Each observation is first checked against the value of the preliminary estimate. It is regarded as possibly erroneous if it departs by more than a pre-set amount, though greater tolerances are allowed for observations made by using techniques assessed as likely to have larger errors. Secondly, a more stringent test is applied by comparing the observed values with values analysed, using all observations except the one being tested.

The corrections calculated by this method are assimilated directly into the forecast model by a method of repeated insertion over a short period of time preceding the observation time. At each time-step the differences between the forecast and the observed values are multiplied by weights calculated in the way just described to provide values of the adjustments required at each grid point. However, to avoid sudden alterations to the forecast values, only a small fraction of the changes are added into the model as the forecast advances time-step by time-step towards the observation time. This is done because sudden local changes are found to generate spurious non-meteorological motions which rapidly disperse the effect of the alterations implied by the observations. In this way the model is steadily adjusted towards the observed state of the atmosphere and a natural balance is set up between the winds and other physical variables which correctly reflects the evolution in time of the weather systems. Realistic vertical velocity patterns are set up and the subsequent forecast continues on a realistic course. When this system was tested during FGGE it was found to give particularly accurate wind analyses, an aspect which in the current operational analysis and initialization procedure is often unsatisfactory. An example showing the detail that can be achieved by the assimilation technique is illustrated in Figure 1 which portrays the analysed winds at 300 mb over the Indian Ocean on a occasion during the summer months of FGGE.

The next operational model

An operational forecasting system must be geared to strict deadlines determined by the needs of forecast offices. Advice has to be available quickly after the making of the observations, and the best possible advice is required for the main forecasts sent out in the early morning and in the late afternoon. To meet this requirement an acceptable schedule has evolved over the 15 years or so during which numerical forecasts have been used operationally in the Central Forecasting Office. It is based on two forecasting models, the first of which covers a limited geographical region and is run as soon as the observations from Europe and the Atlantic have been received; by this time some American observations are usually also available. Preliminary advice based on this model is presented to the forecaster within 3½ hours of the observing time. Before this, the whole sequence of operations to produce a forecast has to be gone through: this involves receiving, sorting and checking the observations; using them in an analysis scheme, with human intervention as necessary, to produce a representation of the three-dimensional state of the atmosphere at the time of the observations; adjusting the initial state to suit the forecasting model and to be free of non-meteorological motions; integrating the forecast model for the required length of time; and, finally, obtaining

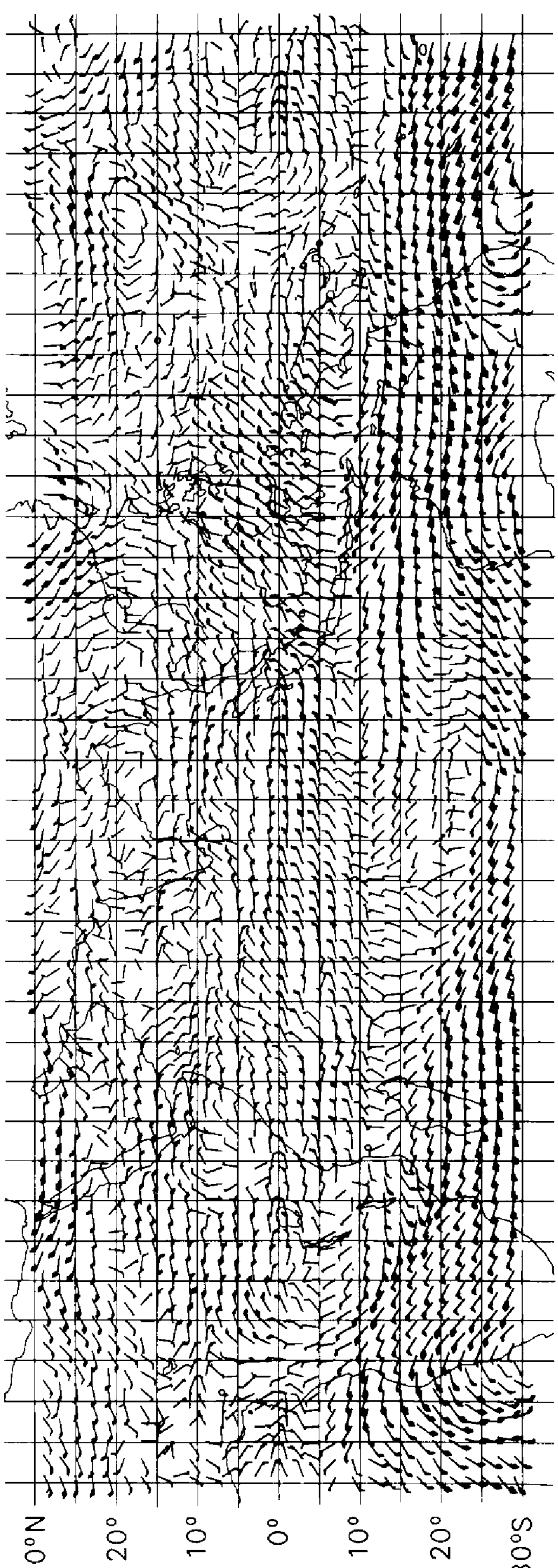


Figure 1—Wind analysis using the FGGE data-assimilation scheme at 300 mb for 12 GMT on 16 June 1979 in an equatorial zone east of the Greenwich meridian to 180° between latitudes 30°S and 30°N

the output quantities in their required formats, which involves drawing charts and the interpretation of model data to determine quantities which are not treated explicitly. It is a tight schedule, which can only be achieved consistently by ensuring that the computer programs and the personnel involved work efficiently with close attention to the deadlines and the alternative routes to be followed should any link in the chain of operations fail. A similar schedule is followed for the large-area model when observations from further afield have been received. In this case results are presented to the forecasters 4½ hours after the observing time.

With the new operational model and analysis schemes, the schedule, again based on two models, will be maintained essentially unaltered. However, the great power of the new CYBER 205 computer (see page 57) will enable many features to be introduced that have been identified by research over the past few years as contributing to improved forecasts; some of these have been described in previous sections.

As now, the large-area model will use a coarser mesh than the limited-area model, and the distinction between the two will remain, namely that the limited-area model aims to provide relatively short-range forecasts over the British Isles while the large-scale model produces forecasts up to several days ahead for a wider area and is used directly for aviation route forecasts. The new area for the large-area model will be the part of the globe north of 30°S, thus placing the southern boundary in a relatively quiet zone from a meteorological point of view. It has been demonstrated in the past that a boundary at or near the equator distorts the active circulation associated with the Intertropical Convergence Zone and the south-east Asian monsoon, and the errors soon spread to higher latitudes. The new area is sufficiently large to cover the major shipping and aircraft routes in the world, and will enable the increasing number of requests for forecasts for longer routes to be met. The limited area will be defined by lines of latitude and longitude (at present it is a rectangle on a polar stereographic map) and this will permit the eastern part of America to be included and its observations used in defining the initial state. It is hoped that this will lead to improved forecasts of the generation of depressions over the western Atlantic; they often move and deepen very quickly and soon affect weather conditions over much of the Atlantic.

The horizontal grid lengths of the two models will be made as small as is compatible with the forecasting schedules and the speed of the computer, since there is ample evidence that a smaller grid length will give more accurate forecasts. It is hoped that the large-area model will have a mesh length of about 150 km; for the limited-area model half or a third of this value is aimed for. The finer resolution will improve a number of features of the forecasts. Areas of rainfall will be more clearly defined, and amounts on average will be nearer those observed (average values now tend to be less than observed, for reasons that are broadly understood); jet streams and frontal systems will be delineated in greater detail; rates of deepening of depressions will, in general, be more accurate. In the vertical, the number of levels will be increased from 10 to 15, with greater concentrations in the boundary layer and near the usual jet-stream levels. As described above, the concentration in the boundary layer will enable the structure of the layer and surface exchanges to be represented more adequately and this should lead to improved forecasts at the earth's surface. Better definition at upper-tropospheric levels should lead to improvements in aircraft wind forecasts, and particularly in the probability of clear-air turbulence, as well as in more general forecasts up to several days ahead.

The models will use a terrain-following vertical co-ordinate rather than pressure as now. This will allow the effects of orography to be calculated more accurately and will dispense with the special mathematical conditions which, in the past, have had to be invoked whenever mountains were intersected by a pressure surface on which values of variables used by the model were specified. Better forecasts of orographic rainfall, and of conditions in mountainous regions generally, will be possible. The numerical technique used for solving the equations will be essentially the same as in the current operational model since it has been shown to be the most efficient (in terms of computer usage) that has yet been devised.

Tests of a version of the new model have already been carried out for several occasions. However, because of limitations in the computing time available before the new computer is delivered, the experimental version had a lower resolution and a smaller forecast area than are to be used in practice. Also, it has not yet been possible to test the combined system fully, including the new data-assimilation technique to provide the initial data analyses. However, despite these limitations, it has become clear that the quality of the forecasts from the new model is distinctly better than from those currently available, particularly for three days or more ahead.

An example of a test forecast is illustrated in Figures 2–5. The initial data were for 12 GMT on 16 June 1980. During the subsequent three days the depression near Iceland moved away and became less active while the pair of small depressions near Newfoundland moved across the Atlantic and combined into a single intense depression which, by 12 GMT on 19 June, was situated north of Scotland (Figures 2 and 3). Westerly surface winds of 40–50 knots were reported to the north of Ireland at this time. The three-day forecasts from the new model (Figure 4) indicated this deep depression only slightly displaced from the observed position. Although the central pressure was slightly too shallow, the model correctly forecast strong westerly winds in about the right areas. The forecast produced by the current operational model (Figure 5) moved the depression too far north to a position west of Iceland with a central pressure some 17 mb too high. As a result, the winds forecast off the coasts of Scotland and Ireland were too weak. In general, it has been noted that the present operational model often forecasts insufficiently strong pressure gradients. The new model appears to offer the prospect of overcoming this defect.

The development of the Meteorological Office operational weather prediction system has been an evolutionary process over many years. In the early stages of numerical weather forecasting research the main problems were those of a mathematical nature. However, it is clear that the design and maintenance of a forecasting system with as wide a range of applications as is proposed for the new system depends heavily on a broadly based research program covering many different facets of meteorology. It is expected that the new operational weather forecasting system will produce more accurate forecasts than is at present possible and will extend the ability of the Meteorological Office to provide the services required by its customers, while the flexibility of its design will allow future improvements and modifications to be made to suit changing needs.

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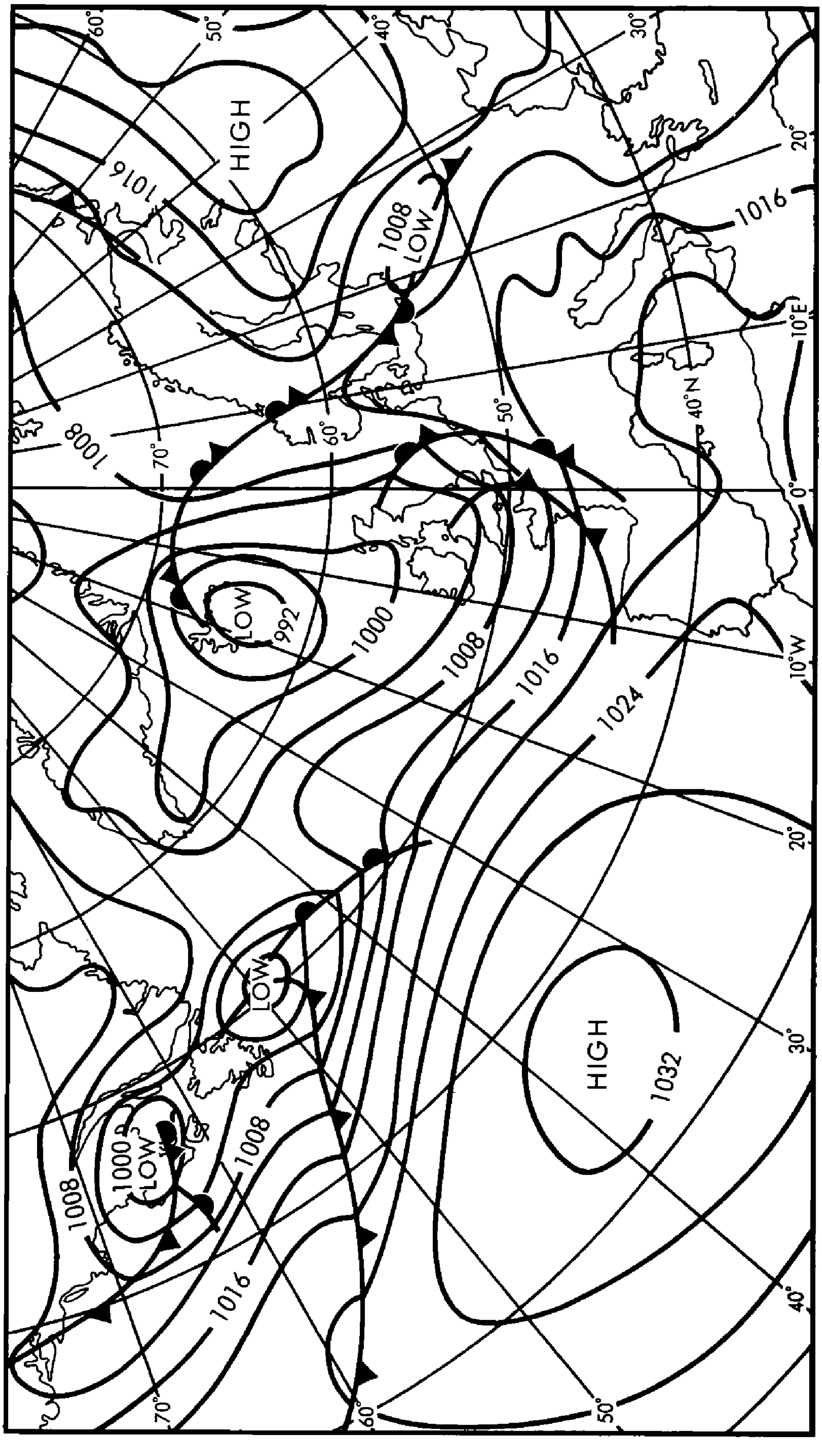

Figure 2—Synoptic chart for 12 GMT on 16 June 1980, as analysed by hand at the Central Forecasting Office, Bracknell

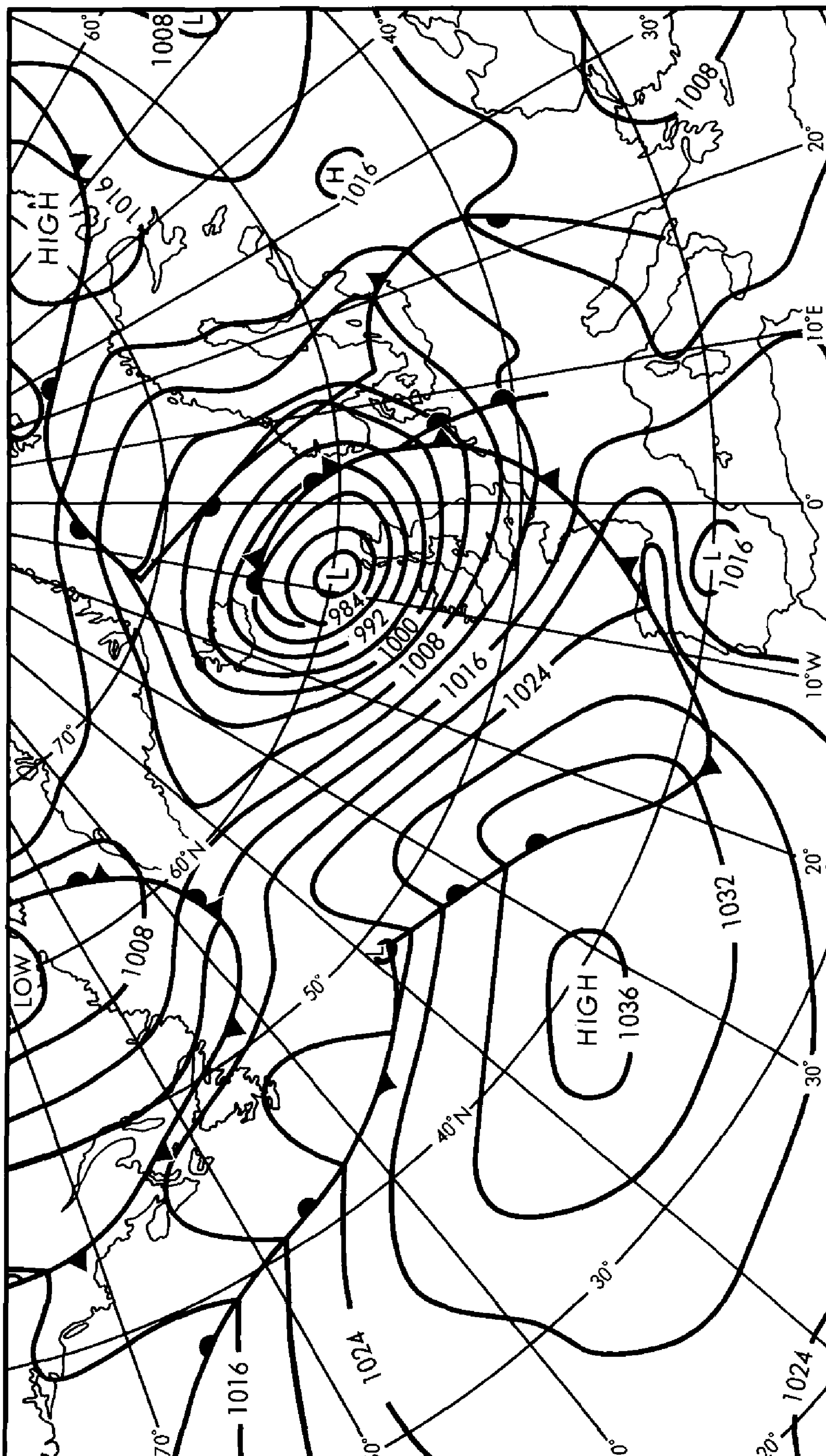

Figure 3—Synoptic chart for 12 GMT on 19 June 1980, as analysed by hand at the Central Forecasting Office, Bracknell

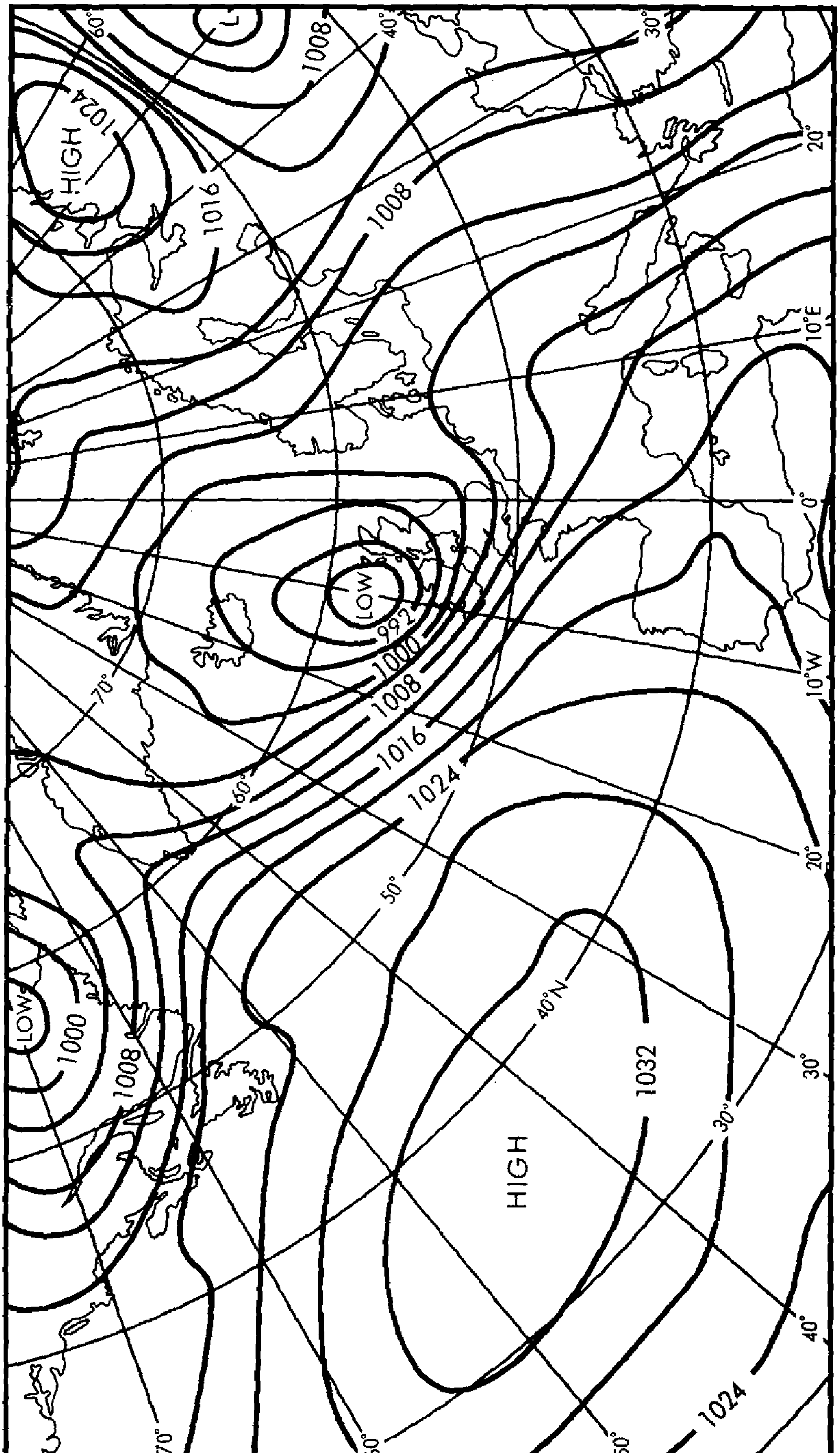

Figure 4—Surface pressure forecast for 72 hours after the data time (12 GMT on 16 June 1980) as produced by the new model

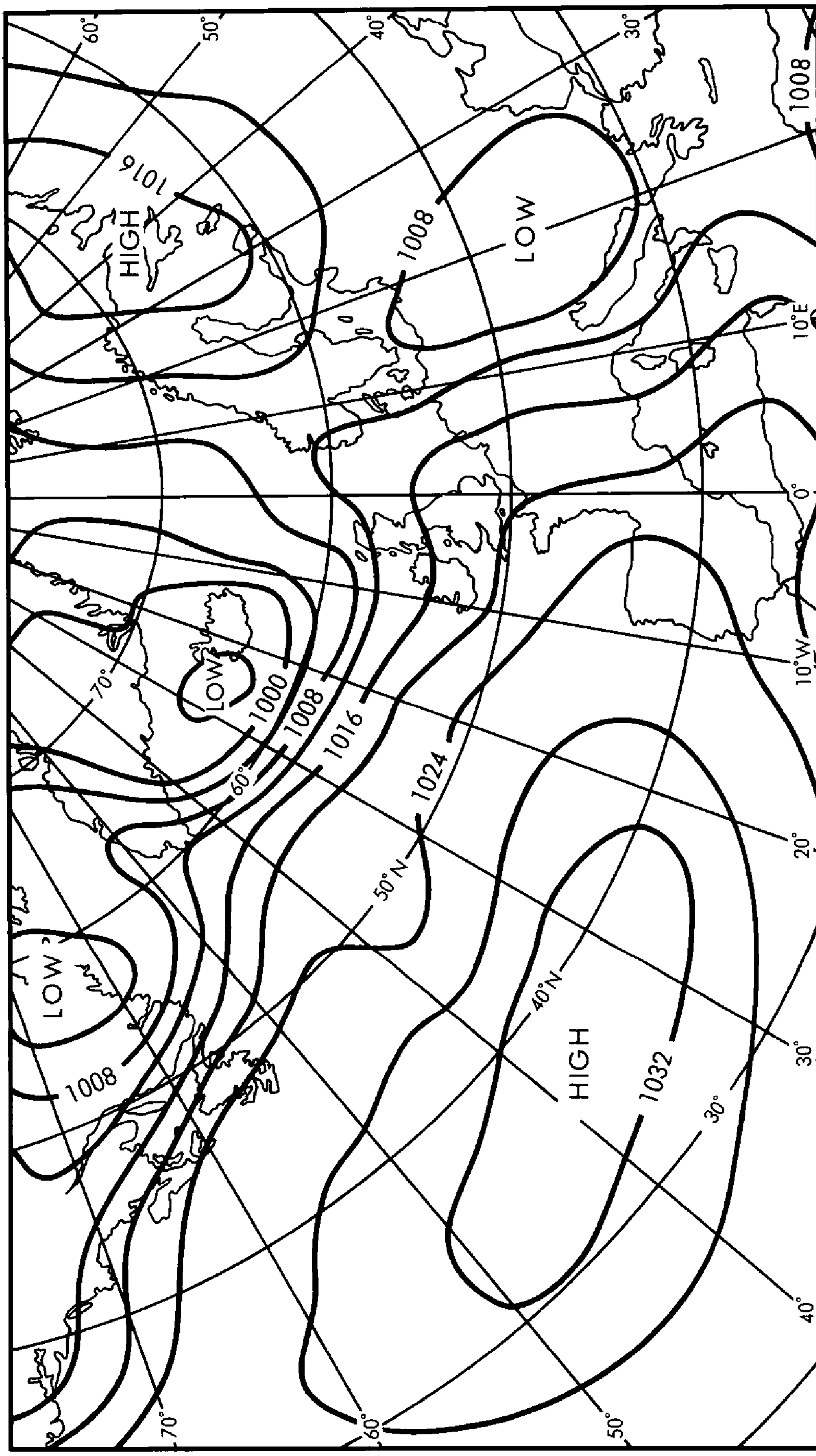

Figure 5—Surface pressure forecast for 72 hours after the data time (12 GMT on 16 June 1980) as produced by the current operational model

OTHER WORK OF THE DIRECTORATE OF RESEARCH

Physical Research

Cloud physics

Water plays a profound role in many of the atmosphere's physical and chemical processes. The formation of precipitation is an important and obvious example of this. The influence of ice and water-drop clouds on the transmission of various forms of electromagnetic radiation is significant also, and the present or absence of clouds plays a major role in the control of the temperature of the earth's surface. In addition to its contribution to the hydrological cycle, precipitation is the major method by which pollutants are scavenged from the atmosphere.

Unlike other atmospheric constituents, water appears in all three phases, solid, liquid and vapour. One of the fundamental problems of cloud physics is that the phase transitions do not necessarily occur at thermodynamic equilibrium. Specifically, those transitions which take place in the direction of increasing molecular order, i.e. from vapour to liquid to solid, must overcome a strong free-energy barrier. The surface tension effect on water droplets is one example of this.

Thus, although clouds and precipitation are important determinants of weather, the prediction of their evolution poses some rather complex physical problems. Nevertheless, as a result of past laboratory studies of water drops, ice crystals and so on, the fundamental physics of many processes thought to be important in cloud formation and development are understood in some detail. Much of present-day cloud physics research is concerned with the application of that understanding to the atmosphere. Such research requires substantial efforts to observe the dynamics and structure of naturally occurring cloud and precipitation forms and to interpret, model and thereby understand them.

For some years a system for studying the large-scale structure and dynamics of cloud systems by means of 'dropsondes' released from aircraft has been under development. The Hercules aircraft of the Meteorological Research Flight (MRF) has been equipped 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 and these data are telemetered back to the aircraft. During 1979 and 1980 this system has been used in studies of warm frontal zones over the North Atlantic. Although the resulting data sets provide an incomplete picture of the frontal structure and dynamics, a number of interesting features have been identified. Specifically, there is a detectable organization of the airflow and of the thermal stability of the atmosphere which is consistent with the embedded cloud and precipitation pattern. Parallel theoretical studies of warm frontal zones suggest that a symbiotic relationship between convection and larger-scale instabilities may be at least partially responsible for this organization, which is often evident as a banded structure in satellite and weather radar data.

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 developments with a three-dimensional numerical model constrained by the thermal, humidity and dynamic structure of 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 extreme rainfall events can be identified and used in the assessment of potential hazards resulting from heavy precipitation. The model is also being used as a diagnostic tool to explore the role of cloud dynamics in thunderstorm electrification. Comparison between aircraft observations and model predictions have highlighted the important role played by ice-phase precipitation in the separation of charge. Further work is planned to try to understand the role played by a number of possible charging mechanisms.

On the smaller scale, studies of fog and stratocumulus cloud have continued using data obtained from the instrumented tethered balloon at Cardington. Various numerical models of processes thought to be important in the formation or dissipation of such cloud have been developed. As a result, a much clearer understanding of the role played by radiative transfer and dynamical processes is emerging. Thus, in radiation fog, radiative cooling affects the thermal stability, the thermal and dynamical stability affect the mixing processes, the mixing processes affect the distribution of water (in all phases), and the distribution of water itself affects the radiative cooling. In studies of nocturnal stratocumulus, attempts to quantify the energy and water budgets have been very instructive but have pointed to the importance of small horizontal variations, which are not easy to establish from routine measurements. Significant progress has been made in understanding the radiative, microphysical and small-scale dynamical processes occurring in the vicinity of cloud tops. Reports on much of this work have been submitted for publication during the year.

Experimental studies of small cumulus cloud have been made using the MRF Hercules aircraft and the Cardington balloon facility. Multi-level turbulence probe measurements from the latter have identified a clear organization of the main updraught and downdraught. Theoretical studies suggest that the resulting asymmetry of the vertical circulation, which resembles that of a letter 'P', is a response to shear in the wind. The aircraft results suggest that such a circulation may generate a preferred mixing region. This can be expected to have some important consequences for the development of the droplet size distribution, and so influence the ability of the clouds to form precipitation.

Of course all such experimental programs require a significant investment in instrumentation. The Hercules aircraft now has the capability of detecting, counting and sizing, with varying degrees of accuracy, particles ranging from the nuclei on which cloud droplets form to the largest raindrops and snowflakes. Of particular interest during the year have been the first attempts to study the characteristics of cirrus cloud using the recently installed holographic camera and a device capable of recording two-dimensional shadow images of individual cloud and precipitation particles. The latter has also been used in a joint study of precipitation with the Rutherford and Appleton Laboratories. A dual-polarization radar developed by them and in use at Chilbolton, Hants, offers the possibility of inferring some characteristics of the rainfall drop-size distribution. Attempts are being made to verify these inferences by direct sampling from the aircraft.

The extensive amounts of data obtained in such experiments, and others designed specifically to obtain the relevant information, are beginning to provide useful statistical data for civil and military aviation. During the year the distribution of liquid water content and droplet-size distributions have been measured in various types of clouds both in relatively clean, maritime air and also in continental air having a higher aerosol burden. The data are being used to provide guidance for those concerned with such problems as helicopter icing.

The atmospheric boundary layer

The boundary layer—roughly speaking the lowest kilometre of the atmosphere—is important, not only because it provides the immediate environment for many human activities, but also because it achieves the transfer of heat, momentum and moisture between the earth's surface and the atmosphere above. Recent effort has been concentrated on a few selected topics, notably effects associated with topography, numerical modelling of convective boundary layers, the structure of stable boundary layers and the long-range transport of pollutants.

During the summer, a study of flow over a simple ridge/valley system was carried out near Tredegar, Gwent. The experiment lasted about five weeks and during it both mean flow and turbulence were measured. For the former, anemometers were mounted on a line of masts 8 metres high lying across the ridge/valley system. Turbulence was measured with the aid of fast-response instruments supported by masts or the tethering cable of a kite balloon (see Plate VI). Preliminary analyses have revealed a number of interesting features, including flow separation on the slope immediately downwind of the summit and high levels of turbulence extending from the valley floor to the ceiling of the balloon system—200 metres above the summit. Further insights into the nature of these phenomena should emerge from numerical simulations of flow over the ridge/valley system and from some flights over the area by the instrumented Hercules aircraft of the Meteorological Research Flight. A numerical model with a contour-following co-ordinate system has been developed to facilitate comparisons with theoretical models.

Concurrently with this work on the nature of flow across two-dimensional obstacles, consideration of the more complex three-dimensional problem has continued with an attempt being made to simulate the broad features of the flow round Ailsa Craig. This is an isolated, nearly hemispherical island lying off the coast of Ayrshire which was studied in the autumn of 1978. Measurements revealed the presence of upward motion immediately downstream of the island and powerful asymmetric vortices with vertical velocities comparable with horizontal flow speeds.

Over more homogeneous terrain, observations often reveal the presence of large two-dimensional rolls with axes aligned almost parallel to the mean wind. These have been simulated by a numerical model in which two-dimensional features such as the rolls can be generated explicitly whilst the smaller scales are parametrized. Results are in broad agreement with experimental findings, clearly demonstrating the production of counter-gradient fluxes by large eddies and reproducing the observed orientation of the rolls. The model is at present being used to study the role of small clouds in the boundary layer by extending the original version to include water vapour and non-precipitating clouds.

Experimental studies of the structure of boundary layers over the sea have continued, with the Hercules aircraft from the Meteorological Research Flight making several more sorties, notably in strong winds. The analysis of the data produced during earlier flights, when interest concentrated on the lower levels of the boundary layer, has been completed. This has revealed marked differences between spectra and cospectra obtained when the aircraft was flying across-wind as opposed to along-wind, there being a shift of energy to low wave numbers in the latter case. Further insights into this and other phenomena should emerge from the analysis of later flights when observations were made at all levels in the boundary layer.

Another major topic is the role of the atmosphere in transporting and dispersing pollution. For instance, a model of short-range dispersion has been used to confirm that airborne transport of virus was an important factor in the spread of foot-and-mouth disease in Hampshire in 1966/67. Hourly meteorological data were used in the calculations and an empirical allowance was made for topography. After further tests it is hoped the model will prove suitable for use in helping to predict the areas at risk in any further outbreak of the disease.

Reflecting a somewhat different emphasis, a stochastic model (akin to classical random-walk models) is being used to further our understanding of the nature of short-range dispersion. Results for the dispersion of a large number of particles released sequentially from a low-level source within a neutral boundary layer show good agreement both with analytic solutions of the diffusion equations and with similarity theory.

As part of a program concerned with the dispersion of heavy gases, the feasibility of using wind measurements made upstream of proposed large-scale (i.e. 10 tonne) experimental gas releases, to select the best moment to release the gas in order to ensure that the plume of dispersing gas passes over a fixed array of concentration monitors, is being investigated. This work is funded by the Health and Safety Executive.

A contract has also been placed by the South of Scotland Electricity Board for a survey of the short-range dispersion climatology of the site at Torness, East Lothian, where an advanced gas-cooled reactor power station is to be built. Preparations are well advanced for the on-site measurements, due to begin in spring 1981.

On a somewhat larger scale, the part played by mesoscale features (in the size range 10 to 100 kilometres) in the dispersal of pollutants continues to receive attention. A method has been devised of obtaining representative boundary-layer trajectories from observed winds and the surface-pressure distribution. These trajectories, together with weather-radar data, are being used to study the interception of boundary-layer air by moving and evolving rain systems, in an attempt to further our understanding of wet deposition processes affecting many pollutants. This topic is also being studied with the aid of a statistical model, differentiating between 'wet' and 'dry' regions. The model also allows for variations in the probability of rain with location and wind directions. Initial results look promising.

In support of all this work, a major program has been initiated aimed at improving the experimental equipment, notably the Cardington balloon-borne sensors. A prototype package, weighing about 2 kg, has already been constructed. This is capable of measuring wind speed and direction, temperature and humidity with frequency response of 0.2 Hz. The package is being evaluated both in its own right and with a view to forming a basis for a turbulence-measuring package with frequency response up to 20 Hz. One novel possibility, at present being studied, is the use of kites to supplement tethered balloons as lifting systems for probes in field experiments. Routine equipment (namely anemometers, thermometers, etc.) is also being improved and during the year a digital cassette system for recording wind was developed and successfully tested.

JASIN

The JASIN (Joint Air–Sea Interaction) project is a field experiment to study the interaction of the atmospheric and oceanic boundary layers. Proposed some eleven years ago by the Royal Society and the Royal Meteorological Society and later involving other agencies, including the Institute of Oceanographic Sciences (IOS), it finally reached its climax with a two-month phase of intensive observations in the vicinity of Rockall, from ships and aircraft of several nations, in the summer of 1978. The Office's contribution to JASIN came from the Boundary Layer Branch and the Meteorological Research Flight.

Since the end of the experimental phase, data reduction has proceeded apace. All the surface data have been quality-controlled and all 160 radiosonde flights made during the trial have been processed. Attempts are now being made in conjunction with co-experimenters at IOS and the Max-Planck Institut, Hamburg, who carried out similar observations from other ships, to use budget techniques to estimate the fluxes of heat, moisture and momentum over the 180-kilometre-sided 'meteorological triangle'. These fluxes were also measured directly using the eddy correlation technique, with fast response data gathered by a balloon-borne turbulence probe. The reduction of these data has proceeded to the stage where spectra and cospectra of wind, temperature and humidity have been produced for almost all the runs.

The analysis of the data collected by the Hercules aircraft from the Meteorological Research Flight has also proceeded according to plan, with the bulk of the processing largely complete. Data have already been transferred between MRF and the University of Washington, Seattle, where the data collected by the Electra aircraft (operated by American scientists) are being analysed. Comparisons between the data from the Hercules, the Electra, the Falcon (operated by scientists from the Federal Republic of Germany) and the four meteorological ships show excellent agreement when average values are considered. Furthermore, preliminary results indicate that this is probably also true of fluxes and spectral quantities.

JASIN has also provided the first opportunity to assess the radiation equipment fitted in the Hercules. Comparisons between the three aircraft proved to be very encouraging so it was decided to combine data from all the aircraft obtained during a study of a well-defined sheet of stratocumulus. Flights were made above, below and within the sheet, with turbulence and cloud physics parameters being measured as well as radiative structure. These data are at present being used to evaluate two different numerical models for predicting the profiles of long- and short-wave radiation.

Meteorological Research Flight

The Meteorological Research Flight (MRF) of the Meteorological Office is located at the Royal Aircraft Establishment, Farnborough. It comprises two RAF aircraft, a Hercules C-130 and a Canberra PR3, suitably and extensively instrumented to carry out research from near the earth's surface (with the Hercules) to the lower stratosphere (with the Canberra). The flight-deck crews are provided by the Royal Air Force. The MRF is used as a research facility by several research branches inside the Meteorological Office, as illustrated in the other sections of this report, 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.

Since February 1978 the Meteorological Office has been collaborating with the Central Electricity Research Laboratories (CERL) in a project designed to investigate the fate of sulphur dioxide (SO_2) carried downwind from an emitting source, such as the smoke stack at a power station. For this purpose the Hercules aircraft has been equipped with CERL instrumentation to capture and analyse samples of air, cloud- and rain-water and other particles; the design, construction and installation of the equipment had taken more than two years. The first test flights were successfully carried out in the spring. In order to establish that the aircraft remains within the specified plume, the emission is 'labelled' with sulphur hexafluoride (SF_6) for 12 hours or so; furthermore, puffs of PP2 (the trade name for a fluorinated hydrocarbon) provide time marks to give an indication of the aircraft's position downstream within the plume. The background air is sampled upstream of the power station by a second aircraft (from Cranfield) with instrumentation for gas detection and analysis similar to that of the Hercules.

Apart from instrument test and calibration flights, only a few full sorties have been carried out this year. These have enabled us to confirm (and modify) the flight plans in that the gas-sampling equipment has been able to identify the plume by detection of the labelling gas for up to 300 miles downstream. Analysis of other gases—in particular sulphur dioxide, ozone and the oxides of nitrogen—have also been possible; these have shown considerable horizontal and vertical structure within the plume itself. Flights are continuing with the general strategy modified by earlier experiences.

The data should provide useful insights into the processes which determine the travel and dispersal of the plume, the nature of the chemical reactions occurring within it and the deposition of pollution. Studies of the mechanisms by which pollutants are incorporated into cloud droplets and rain are also planned.

A program of observations on the radiative properties of cirrus cloud has been started at MRF with the intention of elucidating the effect of irregularly shaped ice particles on energy transfer in the atmosphere. On one occasion both the Hercules and the Canberra were used simultaneously, making measurements above and through a cirrus sheet. The radiometers made measurements of the fluxes of terrestrial and solar radiation in the atmospheric window around 10 μm and in a number of narrow spectral intervals in the 1–3 μm region. Other measurements included temperature and turbulence of the wind, and data on the size, shape and concentration of ice crystals. In another flight, using the Canberra only, it was possible to identify features of the upwelling infra-red radiation on scales of 400 m to 10 km within an extensive cirrus sheet. These could be identified on different passes above the cloud for at least 30 minutes. The data gathered in these aircraft experiments will be compared with numerical models of cirrus clouds.

The Canberra has also made a number of flights to measure water vapour in the stratosphere. The recently developed sub-millimetric interferometer has been used to measure averaged concentrations above the aircraft of various minor constituents.

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, including 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 complicated sequences of chemical reactions, the rates of which depend on the concentration of reactants. These, in turn, depend on the often ill-understood sources and sinks and on a wide range of atmospheric transport mechanisms.

The Laboratory of the Government Chemist has continued to analyse the chemical content of rain-water collected in automatic opening and closing rain-gauges at Lerwick, Eskdalemuir and Bracknell. An assessment of the significance of data obtained over the last decade is in preparation.

The three-channel gas chromatograph has been modified during the year, after a further program of test flights on the MRF Hercules aircraft. As a result, contamination problems previously evident have been overcome, as has the sensitivity of the instrument to fluctuations in cabin pressure. Relative and absolute accuracies are now sufficient to undertake investigations into possible source and sink locations for nitrous oxide, carbon dioxide and chlorocarbon molecules which the apparatus can detect. Absolute calibration is achieved by taking grab-samples in special stainless-steel bottles during a flight for later comparison with standard gas mixtures in the laboratory. The approach initially will be to examine vertical gradients in wind speed and trace-gas concentrations in the boundary layer. Another technique will involve examination of horizontal gradients around urban and coastal areas. These techniques should provide better estimates of the strength of sources and sinks for the various trace gases and so enable us to improve our estimate of their effects on stratospheric ozone.

Numerical computer calculations with a radiative–photochemical column model have been used to examine the effects of chlorofluoromethane releases and carbon dioxide emissions from fossil fuel burning, separately and in concert. This model has also been used to compare diurnal, semi-annual and annual temperature patterns with those observed in the upper stratosphere by the Stratospheric Sounding Unit (SSU) on the TIROS-N and NOAA-6 satellites. Some interesting but as yet unexplained anomalies are emerging.

Diagnostic studies of a 450-day integration of the 13-level troposphere–stratosphere general circulation model have continued, with the emphasis on the fluxes of ozone and water vapour across the tropopause. Considerable effort has also been put into the computation of three-dimensional air trajectories from the model output fields, with the aim of elucidating the motions in the region of interest mainly around jet streams and in the high-latitude stratosphere. This work is also preparing the way for integration of the photochemical calculations as a function of time along three-dimensional air trajectories, a procedure which is intended to test and interpret data which will be received from the Halogen Occultation Experiment (HALOE) instrument, planned by the US National Aeronautics and Space Administration (NASA) for launch on the ERBS satellite in 1983. A further proposal has been accepted by NASA to interpret data from the Upper Atmosphere Research Satellite (UARS) in 1986–89.

Routine observations of total ozone column density by Dobson spectrophotometers have been maintained at Bracknell, Lerwick, Mahé (Seychelles) and St Helena. All results continue to be submitted to the World Ozone Data Centre. The accuracy of the ozone observations and hence their value for assessing possible long-term trends is dependent upon careful calibration and intercomparison of the instruments. During the year one of the Bracknell spectrophotometers was transported to St Helena to effect such an intercomparison and a visit was made to Singapore to assist in the repair and calibration of an instrument in use there. A new electronics package which greatly eases setting up of the spectrophotometer has been developed and is coming into service.

An instrument designed to measure the total column density of nitrogen dioxide by ground-based observations of the absorption of sunlight at wavelengths close to 450 nm has been used in several series of measurements at Beaufort Park and the results have been published. Nitrogen dioxide plays an important role in stratospheric photochemistry.

On 23 May the MRF Hercules was detached to Gibraltar to try to intercept the plume of detritus from the Mount St Helens volcanic eruption which had taken place five days earlier. It was expected that the plume carried eastwards by the strong high-level tropospheric winds would reach the eastern seaboard of the North Atlantic on 23 to 25 May in the vicinity of Gibraltar. During flights on those days in the area 25°–37°N, 10°–15°W several regions of high particulate concentration were detected by instrumentation on the aircraft. Filter samples were obtained and these are being analysed by various techniques. First results suggest that the elemental composition of the intercepted material is very similar to that ejected by the volcano. The main purpose of the experiment was to test the Office's ability to predict particulate trajectories over long distances. This appears to have been confirmed but further detailed analyses of the windfields are under way. Filter samples were also obtained in the stratosphere in the vicinity of the UK by the MRF Canberra aircraft. These are being analysed to try to establish the origin of captured material.

High atmosphere

The Meteorological 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. The instruments already in orbit (on satellites called TIROS-N and NOAA-6, launched in October 1978 and June 1979 respectively) continued to provide data, which are being processed routinely and used in dynamical studies of the stratosphere. Global and zonal mean data are being used for a long-term study of stratospheric temperature and inter-SSU and SSU-rocket comparisons are being used to evaluate changes in instrument performance. Involvement in the test program in the USA included the launch of another satellite, which unfortunately failed to get into the proper orbit. Further laboratory work has elucidated the cause of some anomalous instrument behaviour. Production of the remaining instruments by Marconi Space and Defence Systems Ltd is nearing completion. The US authorities have decided to extend the series, building further satellites which are now expected to provide observations until the end of the 1980s. To exploit this opportunity, an early test model of the SSU is being refurbished to provide a ninth instrument.

Direct measurements of the temperature profile up to a height of 60 km, made by rocketsondes flown as the satellite passes near by, can provide a check on performance of Stratospheric Sounding Units. Twenty-two Skua rocketsondes were launched for this purpose from South Uist during 1980. The Skua program was terminated in December because of staff cuts. In future, checks on the SSU will depend on rocketsondes launched by other agencies, although these are rarely timed so carefully to coincide with overpasses of satellites. The Science Research Council will take over those facilities (e.g. the radar) which are needed to continue support to their research rocket program at South Uist.

Preliminary results have been derived from the Petrel rocket experiment flown in 1979 to investigate the diurnal variation in the concentration of ozone at heights between 50 and 70 km. Theoretical studies, which will involve comparisons between these results and predictions from photochemical models, have been initiated in conjunction with the Department of Atmospheric Physics, Oxford University.

Satellite meteorology

There has been continued liaison with the European Space Agency (ESA) concerning the Meteosat geostationary meteorological satellite program and associated meteorological products. Because of the failure of Meteosat-1 in late 1979 no current data have been available during the year, but certain tasks have been undertaken in anticipation of the launch of Meteosat-2 during 1981 and a number of research studies have been conducted using Meteosat-1 data. These have included the development of techniques for the direct use of satellite measurements to improve humidity analyses in numerical models and for the derivation of vertical velocities in the atmosphere. Additionally, analysis of data obtained by the MRF Hercules during some flights over the tropical Atlantic in the autumn of 1979 yielded valuable radiometric calibration data for the Meteosat-1 sensors that supplemented and extended the ESA calibrations.

Development of a scheme to retrieve tropospheric temperature profiles from raw TIROS-N and NOAA-6 data received at Lasham, Hants has proceeded satisfactorily. Increased effort and attention has been devoted to it and at the end of the year consideration was being given to ways in which it would be possible to implement the scheme operationally to provide a routine input of the temperature profiles to the numerical forecast model.

After lengthy delays, adequate samples of SEASAT data and related documentation were received to allow studies of the techniques for deducing ocean surface winds from measurements of microwave back-scatter to proceed in earnest. In addition to a study of the derivation technique itself, plans were formulated for evaluation of the winds by comparison with numerical analyses and conventional wind observations for selected periods and geographical areas.

The technical feasibility and likely performance of a proposed active microwave satellite-borne instrument to determine surface pressure is being investigated in conjunction with the Physics Department of Heriot-Watt University and the Science Research Council's Appleton Laboratory. The Office has concentrated on theoretical simulation of instrument performance, particularly in the presence of cloud and rain. The aims are to assess the feasibility of an operational version of the instrument and its potential benefits to meteorology.

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 hold considerable promise for improving 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. The Short Period Weather Forecasting Pilot Project, which started in 1978, is a 5–8 year program to develop these techniques and to optimize their impact on the forecasting capability of the Meteorological Office. The project is a balanced program of fundamental and applied research with the new data sources, leading both to an improved understanding of the detailed structure, mechanism and evolution of precipitation 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 the demise of Meteosat-1 late in 1979 the emphasis during 1980 has been on the use of radar data; however, work has been under way to establish a satellite receiving station at Malvern in readiness to receive digital cloud imagery following the launch of Meteosat-2 planned for 1981.

The network of radars which has now been established 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 covered. The accuracy of the radar measurements decreases with distance from each radar and further work remains to be done to improve their accuracy even at close ranges. Most of the radars, although operated as nearly as possible around the clock, are experimental; however, the radar at Hameldon Hill has been established as an operational unmanned weather radar as part of a collaborative project between the Meteorological Office, the Central Water Planning Unit, the Ministry of Agriculture, Fisheries and Food, the North West Water Authority and the Water Research Centre.

Rainfall data from individual radars are sent by telephone in digital form to a small number of meteorological offices and Water Authority users. A fresh rainfall pattern is transmitted every 15 minutes. Data are also sent routinely by telephone to the Meteorological Office Radar Research Laboratory at Malvern where a composite display is generated automatically within 4 minutes of data time. By the end of 1980 the composited data were being sent from Malvern to two operational meteorological offices. The rainfall data, whether from a single radar or from the network of radars, are displayed on colour-television monitors as a matrix of 5 km squares based on the National Grid. Sequences of pictures can be replayed to reveal the movement and development of weather systems. Colours on the display represent rainfall intensity. Equipment for the reception, display and action replay of a limited sequence of pictures, developed by the Royal Signals and Radar Establishment, is being used at most of the locations receiving these data. However, a computer-driven display is available at Malvern which not only enables long sequences of data to be replayed but also is being used to develop and test new methods of quality control, analysis and very-short-range forecasting.

Detailed forecasts of rainfall for the period 0 to 6 hours ahead, using data from the newly established weather radar network, have been assessed during a trial period from November 1979 until June 1980. So far the assessment has been carried out only for frontal rainfall. The forecasts were derived both subjectively in real time, using radar network data displayed on a grid of 128 × 128 5-km squares, and also objectively by means of a computerized rain-cell identification and extrapolation technique using a simplified grid of 32 × 32 20-km squares. The objective method was used to produce forecasts for a very large number of 20 km squares. The subjective method on the other hand, because it is so labour intensive, was used to derive forecasts essentially for an individual 20 km target square. The latter forecasts were used as a basis for comparison with the objective forecasts and as a way of investigating the sources of error in the forecasts. In the case of rainfall rates of 1 mm h^{-1} or more in the target square, the mean percentage error (without regard to sign) in the forecast totals for individual hours was found to be 75 per cent for the objective forecasts compared with 50 per cent for the subjective forecasts. An investigation of all the individual forecasts showed that the biggest improvements in the accuracy of the objective forecasts are likely to be achieved from improved analysis and quality control of the radar data before input into the forecast procedure. About half the errors are due to radar measurement errors. Over the large area of coverage of the radar network as a whole, these errors are due more to the variability with height of the echo intensity from the precipitation than to straightforward radar calibration difficulties. Subtle procedures are required to identify these errors based on an analysis of the meteorological situation in which the radar data are viewed in the context of other kinds of meteorological information. Factors such as the development and decay of rainfall systems, which lead to the breakdown of the assumptions underlying the linear extrapolation method, accounted for about a quarter of the errors in the forecasts.

The physical nature of the errors in the rainfall fields derived from a network of radars, and the resulting requirement to correct these errors on the basis of a knowledge of the overall meteorological situation, together with the opportunity for extending the radar coverage using satellite imagery of rain-producing cloud systems, calls for the development of radically new analysis procedures. These procedures must be carried out quickly if the resulting rainfall analyses and short-period forecasts are to be issued promptly enough to be useful. It is planned to develop and implement these procedures using an interactive display system which will enable radar network pictures, satellite images and conventional meteorological data to be displayed, superimposed, combined and animated on a television monitor. It will permit a high degree of human interaction to enable the analyst easily to modify the data in the light of all the strands of evidence. Repetitive tasks will be automated, enabling the forecaster to make maximum use of his judgement. A functional specification for such a display system was developed during 1980 under contract by Logica Ltd.

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) numerical simulations of corresponding systems using high-speed computers 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 numerical 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 meteorological investigations.

An important adjunct to these investigations is the development and exploitation of advanced laboratory and numerical techniques. Equipment has recently been devised for determining flow velocities throughout the fluid from television images of the motion of neutrally buoyant particles. This significantly extends the range of diagnostic techniques available for laboratory studies and, in particular, makes it possible to investigate energy transformations in time-varying flows with some precision.

The results of several numerical simulations of annulus flows have now been compared with those corresponding laboratory studies. The numerical model has such a fine resolution that the only sub-grid-scale processes present are molecular ones and they can be represented precisely. The range of external conditions over which irregular flows are found is wider for the numerical model than for the laboratory system, but many regular flows have now been simulated numerically and their main features found to be in good general agreement with observation. Detailed features, which would have to be reproduced accurately in a model used for prediction, show significant discrepancies. Moreover, contrary to expectation, improvements resulting from improved 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.

The occurrence under appropriate conditions of highly regular waves 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 turbulence ideas are unduly pessimistic. Some insight into the ordering influence of non-linearity is being obtained from a variety of mathematical studies of 'solitons' and other flows in simple mathematical models.

The flow regimes in annulus flows show a progression from regular wave-like patterns to highly irregular patterns as external conditions are varied. This behaviour is now known to be a general property of many dynamical systems and is the subject of a considerable amount of research in many institutions throughout the world. We have recently started a new series of experiments designed to follow up our earlier work on transitions between different types of flow, having regard to recent mathematical developments in this area.

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 smaller dynamical features are very stable eddies embedded in regions of highly sheared flow. These eddies bear a strong resemblance to stable eddies produced in some special annulus experiments carried out several years ago when effects due to internal heating of the fluid were studied. We have undertaken an extension of this earlier work 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 we have recently completed a series of experiments of the influence of topography on annulus flows. We have also studied 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. Recent experiments with two-layer mechanically driven systems have led to several new findings which in turn have prompted new theoretical studies which are now being followed up.

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. Two of these explore the implications of a new theorem in the electrodynamics of moving media which emerged two years ago from some of our earlier work and they shed light on the structure of magnetic fields produced by the so-called self-exciting dynamo process. The other studies exploit the new meteorological data made available through the FGGE program, which make it possible to calculate for the first time how the atmosphere changes the speed of rotation of the solid earth and moves the poles of the earth's rotation axis relative to the earth's surface. The accurate determination 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 astronomers working on new techniques for monitoring all components of the earth's rotation.

Dynamical and Synoptic Research

Research related to short-period forecasting

Most of the work done in this field during 1980 has been directly connected with the development of the new operational forecasting system, and has been reported in the Special Topic article on that subject (page 75). The following paragraphs report additional work on some specific subjects.

The accurate depiction of the structure of fronts by numerical models is an important factor governing the success of rainfall forecasts. Two cases involving the passage of frontal systems across the United Kingdom have been studied in detail, both by making careful analyses of all available observations to highlight the main features which the models might be expected to forecast, and by performing numerical predictions with the models themselves. Additional case studies will be undertaken in the future.

The sensitivity of numerical predictions of rainfall to the horizontal resolution of fine-mesh models has been investigated by performing some test forecasts over a data-rich area of North America using model grid lengths of 100 km, 75 km and 50 km. The results indicate that the forecast distributions and amounts of rainfall are better for the high-resolution models. Other experiments have been performed which suggest that the accuracy of rainfall predictions in mountainous regions is strongly influenced by the realism of the representation of the mountains in the model. The speed of the new computer will permit the use of a horizontal resolution appreciably higher than that of the current operational fine-mesh model, which has a grid length of 100 km, and a corresponding improvement in the representation of mountains. However, the expected improvement of rainfall forecasts in the British Isles may not be realized unless more detailed observations from satellites and aircraft over the Atlantic are available to the data assimilation system.

Even the limited-area fine-mesh version of the new operational model will not be able to represent phenomena on scales less than about 100 km, nor is it expected to be very effective for forecasts less than about 12 hours ahead. For these purposes a special very-fine-mesh 'mesoscale' model is being developed. Forecasts from this model are unlikely to be satisfactory unless the best possible use is made of the varied observations that are available. For example, the distribution and frequency of the radiosonde observations are inadequate for calculating initial conditions with a high resolution, but it may nevertheless be possible to use them to characterize different air masses, leaving the boundaries between air masses to be recognized through satellite observations and surface reports of current weather, visibility and cloud. Work on problems associated with the objective analysis of these boundaries has just begun.

The initial data must also be 'balanced' in the sense that the values of the meteorological variables should be consistent with the constraints of the dynamical equations. This is a well-known requirement for large-scale motion but it is equally necessary on the mesoscale. It turns out that some variables may need to be known more accurately than others. For example, it has been found that for the prediction of some phenomena the surface pressure in the model can be substantially in error with very little deleterious effect on other aspects of the forecast. However, reliable, accurate and frequent observations of surface pressure are available with a good areal coverage and it is important that such observations should be used effectively. Thus analysis and initialization procedures must include indirect inferences concerning the meteorological fields from all types of observations. To this end, a four-dimensional (i.e. in time and space) analysis scheme based on successive approximations is being developed. Balancing constraints, which include time derivatives, will be imposed as part of the procedure. A simpler initialization scheme has been under development for some time and will soon be complete. It will provide a means of testing some of these ideas.

Various technical aspects of the mesoscale model are being studied, including the possibility of eliminating sound waves by selectively altering some terms in the equations. There are also several possibilities for improving the efficiency of the model and it is expected that, in an operational environment, the delay in making a mesoscale forecast available to the user will be due mainly to the time needed for acquiring the observations and for disseminating the subsequent forecast results, rather than the computer time involved in integrating the numerical model.

A good representation and simulation of boundary-layer turbulence is important for the prediction of the development of some mesoscale phenomena. A boundary-layer scheme based on forecasting the turbulent energy is being developed. This should provide robust and realistic calculations in a wide range of circumstances, and might eventually prove a useful tool for research work on other topics of meteorology.

Errors in numerical forecasts can be assessed in a variety of ways. Throughout the year, forecasts using the operational coarse-mesh model and the medium-range forecasting model developed by the European Centre for Medium Range Weather Forecasts (ECMWF) have been assessed each week by subjectively categorizing them as (a) giving good guidance, (b) having some minor errors, and (c) being misleading in some important respect. By collating the markings from the large sample one can infer that the forecasts are useful (i.e. they fall into categories (a) or (b) on more than 50 per cent of occasions) for up to four or five days ahead. The ECMWF forecasts have a similar accuracy to the operational forecast in the short term but are slightly superior for longer periods. Errors have also been computed objectively at each grid point of the operational model. Their evolution in time has been fitted to a time series using a statistical technique known as the group method of data handling. This makes use of the past errors to predict their future magnitude, thereby providing means of correcting the errors in the numerical forecasts. The technique appears to be successful for reducing persistent errors in the same geographical location but it is less useful when errors arise during the development and movement of meteorological systems.

General circulation of the atmosphere

Several different numerical models are being developed and used to study the general circulation. The most frequently used global models are a 'high-resolution' 11-layer model with a 220 km grid mesh, a 'medium-resolution' 5-layer model with a grid mesh of about 330 km and a 'low-resolution' version of the 5-layer model with a 500 km grid mesh.

Experiments to assess the realism of simulations obtained with these models have, in the past, mostly used prescriptions of the solar radiation, cloud amounts, sea surface temperatures and sea-ice appropriate for a particular time of year, with integrations of the model equations being made for periods of about 50 days, and a mean over the last 30 days taken to represent a sample model month. However, this type of experiment is now being partly replaced by ones in which the radiation, clouds, sea temperatures and ice are prescribed to vary seasonally according to climatology so that the models can simulate the atmosphere's annual cycle. An integration of this type with the 5-layer medium-resolution model has now been taken to $3\frac{1}{2}$ years. In addition to its use as a control for the climate-change experiments discussed later, analysis continues of several aspects of model behaviour. Comparisons have been made of the variability of the real and model atmosphere at low levels over eastern England. In general the amplitudes of the model's temporal variability appear to be realistic, but over periods shorter than a week the model shows less variability than is actually observed. Substantial variations have been found in model behaviour between different years, similar to those observed in the real atmosphere, as for example in the timing and duration of spells of wintry weather. The evaluation of the short- and long-term variability of the model's climate is necessary not only to establish that the model is realistic but also for determining the statistical significance of climate-change experiments.

During the past year a similar experiment has been started using the 11-layer model on the CRAY-1 computer at the European Centre for Medium Range Weather Forecasts. Global analyses for the northern hemisphere summer constructed during the First GARP Global Experiment (FGGE—see page 113 of the *Annual Report 1979*) have been used as initial data and also as verifications of the model's simulations. One particularly interesting feature was a good simulation of the typical timing and suddenness of the onset of the south-west monsoon over Asia and Africa, and the northward progression of the African tropical rain belt. Another is that the depth and positioning of the southern hemisphere low-pressure belt are better simulated than in previous global integrations for this time of year with the 11-layer model. All previous experiments had been run, not from real conditions but from data extracted from an integration in which the low-pressure belt was poorly simulated. There is a strong implication that the noted improvement is due to the use of real initial data for the southern hemisphere.

With the arrival of the new CYBER 205 computer at Bracknell expected early in 1981 (see page 57), a new version of the 11-layer model is being developed using a regular latitude/longitude grid. (The grid for the current version is irregular, but so arranged that each grid point represents approximately the same proportion of the surface of the earth.) The regular grid will have computational advantages and will also provide higher resolution near the poles, which should reduce the truncation errors associated with the large curvature of the latitude circles in this region. In order to make good use of the very powerful vector facilities of the CYBER 205 the model programs have been completely reorganized and rewritten. Whereas the dynamical processes lend themselves naturally to vectorization, since they can be represented by the same simple equations at each point of the grid, the physical process such as condensation, convection and radiation require equations depending on conditions which may vary from one point to another and therefore the vector programs for this part of the model are more complicated. Most of the necessary routines have now been written, and testing is taking place on a CYBER 203 at Minneapolis, making use of a satellite link to a terminal at Bracknell. With the change to a latitude/longitude grid a special study is being made of methods of ensuring computational stability.

The model that has been developed for the new operational forecasting system is being tested to determine whether a version of it could be used for some aspects of research into climate and the general circulation. Computationally it will be very efficient, and there are advantages in reducing the number of numerical models which have to be maintained. However, the operational model lacks certain properties, concerned mainly with the conservation of globally averaged quantities, which have been a feature of the global general circulation models. Tests are being carried out to find how significant such matters are in practice.

There is a continuing effort to improve the parametrizations of the sub-grid-scale physical processes in the general circulation models. Since some of the most important results required from climate modelling experiments will be for variables at or near the earth's surface, attention has been devoted to the modelling of land-surface processes and properties and to the turbulent transfer of heat, moisture and momentum through the atmospheric boundary layer from the underlying surface. The descriptions of the surface and the atmospheric boundary layer in the 11-layer model make it a suitable framework for detailed studies of this nature.

In recent years three different approaches have been programmed for modelling the boundary-layer transfer processes in the 11-layer model and the emphasis has now shifted somewhat from the development of these parametrizations to their use and assessment in the full general circulation model. FGGE analyses are being used to generate and assess a series of 11-layer model, medium-range (up to 10 days) global integrations with sufficiently frequent extraction of information to enable the quality and sensitivity of the simulated boundary-layer structures and evolutions with each method to be determined and compared. Of particular interest are the modelled characteristics at the surface and in the boundary layer over the European and neighbouring sectors.

There is some evidence from existing numerical studies that the land-surface boundary conditions play an important role in determining the ultimate character of the simulated general circulation. To determine the degree of detail that needs to be included in their formulation, a series of integrations is being made with the low-resolution version of the 5-layer model to investigate the sensitivity of its simulations to different simple specifications of the land-surface properties, such as the surface albedo. One ultimate aim is to examine the need to include in a climate model the complicated dependence of surface albedo on the character of the surface as determined by the vegetation, the soil type, the soil moisture and whether the surface is snow- or ice-covered.

Although current general circulation models are complex in structure and make increasingly large demands on the most advanced computers, in many respects their representation of the physical processes and properties at and beneath the land surface is crude and simple. Because of their expected importance in climate modelling, the sub-surface thermal and hydrological processes are receiving particular attention and new methods of modelling them are being examined and tested.

In most of the main atmospheric general circulation models the soil moisture is represented by a single variable, namely the total soil-moisture content, which is altered at each time-step by rainfall, evaporation (condensation), snowmelt and run-off. More realistic soil-moisture schemes with separate predictive equations for surface soil moisture and the total soil-moisture content in a deeper layer are being examined.

Previous experiments with the medium-resolution 5-layer model indicated that its general circulation, and in particular the structure of its stationary long waves, are quite sensitive to the specification of the orographic heights. In experiments with the low-resolution model, the effects of orographic and thermal forcing on the general circulation have been investigated and several different treatments examined and tested. In a particular series 'control' circulations were first established from integrations in which all the surface was 'flat land'. Several integrations were then made with idealized geography and orography to determine the nature and magnitude of the deviations from the control circulations when various combinations of a single elliptical mountain and a single ocean were included in the model. The responses confirmed impressions based on previous experiments with more complicated topography—for example, that a warm ocean in middle latitudes in winter generates a surface low-pressure area and warm upper ridge over the ocean, and a mountain in the latitude of the Himalayas generates an upper ridge near the mountain with a trough downstream.

The results from the above idealized and other studies have led to the examination and testing of new methods for modelling the effects of mountains. For example, it can be argued that the barrier which a mountainous region presents to the airflow is not represented properly when the mean orographic height over a grid box is used. On the other hand, the mean height is more appropriate for certain purposes such as the calculation of snowmelt. In some experiments two heights have been used to characterize mountainous terrain; one, representing the grid-box average peak height, has been used for dynamical and radiative calculations, while another, representing a grid-box average height has been invoked to derive a surface temperature used, for example, to determine the rate of snowmelt. Preliminary results from such experiments show considerable differences in the amount of snow which, because of the high reflectivity of snow, can greatly affect the radiation budget.

Climate modelling

As discussed in the *Annual Report 1979* (on page 112), if general circulation models are to be used to predict changes in climate that may be caused by man's activities, they must be extended so that clouds, sea-ice and oceans are explicitly and interactively modelled in conjunction with the atmospheric models, rather than modelled with characteristics prescribed by present-day climatic observations. It is to develop the ocean and sea-ice modelling capability required to simulate the full land-ocean-ice-atmosphere system that an ocean and sea-ice modelling group has been established. Work has begun to adapt an existing multi-layer ocean model and a thermodynamic sea-ice model for use with the general circulation models, and attention has continued to be given to the representation of the near-surface mixed layer of the ocean. Experiments aimed at interactively coupling the mixed layer and sea-ice models to the 5-layer atmospheric model are currently under way.

Further progress has been made in representing clouds in terms of other model variables, both in the 11- and 5-layer models. An interactive cloud scheme, in which the model cloud amount is related to relative humidity, has been developed for the 5-layer model. The existing 5-layer model was too moist in the upper troposphere. This fault has been alleviated to some extent by a more realistic treatment of subsiding air in the parametrization of convection. When the cloud prediction scheme is used in conjuction with this convection scheme, a quite realistic distribution of cloud cover is produced, including the areas of sparse cloud in the subtropics, and regions of dense cloud associated with the intertropical convergence zone and the Asian summer monsoon.

Research continues into the effects of increased atmospheric carbon dioxide (CO_2). One of the major problems in this work lies in distinguishing between differences in integrations that are due to a change in the model (in this case, the increase in CO_2) and those which arise from the model's natural variability: in other words, distinguishing between the signal and the noise. One method is to use standard statistical tests, and much work has been done in this direction. This may prove ineffective unless relatively long integrations are made. An alternative approach is to run integrations with anomalies of different magnitude (for example with CO_2 increased by factors of two and four) and verify that the resulting changes are in the same sense but increase in magnitude as the perturbation is increased. This strategy has proved extremely useful in the analysis of integrations, described in the *Annual Report 1978* (on page 105), in which CO_2 was doubled.

Studies using observations of the general circulation

Research has continued using the extensive global observational data set collected during the First GARP Global Experiment (FGGE), and the detailed tropical data set collected during the GARP Atlantic Tropical Experiment (GATE). Analyses based on these observations play important roles as initial and verifying data for simulations by general circulation models and in the testing of physical parametrizations.

Methods of data analysis have been further improved. Revised analysis and forecast programs have been rerun with an enhanced observational data set, for the third phase of GATE (30 August to 19 September 1974), to construct a new series of analyses. These agree closely with independent objective and subjective analyses in the lower troposphere. At higher levels (e.g. 250 mb), however, there are some large differences which probably reflect an inadequate data coverage.

The analyses constructed in near real time during 1979 are being used to study aspects of the global general circulation of the atmosphere. At the same time, revised analyses are being prepared, using all the data that were collected both for real-time purposes and in arrears. In some areas substantial amounts of additional data were available after the event, and these should enable the analyses to be improved; for example, satellite wind observations from the Indian Ocean enabled the flows associated with the Indian monsoon to be defined more accurately. A comparison of the two analyses will show how new types of observations, such as satellite winds, are likely to help analyses in data-sparse areas.

The global circulation during the two Special Observing Periods of the FGGE has been studied on a zonally averaged basis using real-time analyses. Some of the results, such as the fair agreement between the major terms in the angular momentum budget have provided evidence of the internal consistency of the analysed fields. In general, the northern hemisphere circulation statistics agree with previous estimates to within the expected inter-annual variation. However, in the southern hemisphere the intensity of the winter depressions was greater than most previous estimates. Detailed comparisons of these statistics with those for simulations by general circulation models are in progress.

The large-scale characteristics of the summer monsoon over the Indian Ocean have been studied in the FGGE analyses and compared with results from general circulation models, both in climate simulations and forecasts from real situations. For both the 5-layer model and the 11-layer model it has been found that integrations with seasonally varying radiation and sea surface temperature gives good simulations of the rapidity of the onset of the monsoon.

Some experiments have been performed using the FGGE observations and analysis scheme to quantify the impact of individual components of the global observing system. They are part of a co-ordinated international effort using different analysis schemes, since a lack of impact in any one experiment might be due to a failure of the particular scheme effectively to utilize the information inherent in the observations. Eventually the information gained from these observing system experiments will assist the planning of cost-effective improvements in the operational global observing system. An experiment in which all satellite data were excluded showed noticeable degradation of analyses and ensuing forecasts in the southern hemisphere. Excluding drifting-buoy data also changed the southern hemisphere analyses but, in the case studied, had surprisingly little impact on the forecast.

Upper atmosphere research

Theoretical studies of the upper atmosphere and the routine analyses of stratospheric observations from satellites are now being carried out in a more closely linked manner following a reorganization of the upper-atmosphere research effort. Temperatures from the Stratospheric Sounding Units (SSUs) on board the TIROS-N series of operational satellites are calculated in near-real time using a data link from the United States, and synoptic grid-point temperature analyses at stratospheric levels are performed daily using space- and time-weighted interpolation of the retrieved values along satellite orbits.

Studies of the observational data have been concentrated on the stratospheric warmings of the 1978/79 and 1979/80 winters, for which the SSU data provide excellent coverage. Diagnostic calculations which give an approximation to the Lagrangian circulation have been found more useful than the conventional Eulerian mean calculations. The relationship between the occurrence and intensity of the stratospheric warmings and the prevailing zonal mean wind structure is being studied. There is theoretical and observational evidence to suggest that when the polar-night jet is displaced northward of its climatological position, the upward propagating influence of tropospheric motions is directed into high latitudes. The displaced jet core is sometimes associated with the decay of an earlier minor warming. Among other features of the observational data which are being investigated are periodicities on a global scale in the zonally meaned radiances; these seem to be similar to oscillations reported by other workers but as yet their nature is not understood.

A study is under way to compare the objective analyses based on satellite radiance data with manual analyses of radiosonde and rocket data at the lower stratospheric levels. It will serve to quantify the uncertainties in the analyses both in the basic fields and in various derived quantities of dynamical interest.

Two models for dynamical studies of the upper atmosphere have been developed and applied: a linearized diagnostic model of planetary wave structures and a three-dimensional primitive-equation model. In the linearized model, zonal mean wind and temperature data, together with a specification of the wave pattern at the lower boundary, are used to calculate the longitude–height structure of planetary waves in the stratosphere and mesosphere according to quasi-geostrophic theory. Data derived from the SSU analyses for December 1979 and January 1980 have been used to test the validity of some widely used modelling assumptions. In particular, it has been shown that a steady state assumption does not lead to accurate results when the model is applied to monthy mean data. It has been demonstrated for shorter periods that considerably closer agreement with observations is obtained when time-dependent features of the plantary-wave behaviour are included in the calculations, and that travelling wave components (even with periods as long as 30 days) have a significant influence on the monthly mean results.

The primitive-equation model is designed to simulate flow in the stratosphere and mesosphere on a global three-dimensional grid with the lower boundary usually at 100 mb. Geopotentials are specified at the lower boundary to simulate either simple idealized situations or observed events. The numerical techniques used are still undergoing development, but a number of satisfactory results have already been obtained. The model's simulations of idealized sudden-warming events are similar to those obtained by other workers using linearized models, except during the immediate pre-warming stage when a brief acceleration precedes the main acceleration of the westerly flow. This feature has also been found in observations and is a topic of further study. A numerical simulation of the sudden warming of February 1979 has been a principal target of the numerical modelling effort. SSU data have been used to define initial conditions, and the FGGE analyses to provide 100 mb boundary conditions. The work has brought to light a number of deficiencies in the three-dimensional model which have not yet been completely eliminated. However, recent experiments have achieved pleasing simulations of the main qualitative features of the warming over a period of several days. The primitive-equation model is being extended to permit studies of processes involved in the transports of important minor constituents of the upper atmosphere.

Research related to long-range forecasting

For the sixteenth successive year, forecasts for 30 days ahead have been published at the beginning and mid-point of each month, each forecast comprising information on the general character of the expected weather over Britain and the associated temperature and rainfall. An indication was also given of the likelihood of frost, fog, snow, gales and thunderstorms, depending on the time of year. In addition to the forecast, the *Monthly Weather Survey and Prospects* contained climatological information relevant to the time of year and a description of the weather of the previous month. In connection with Government economy measures it was announced that this publication and the public issue of the long-range forecast would cease at the end of the year.

Special long-range forecasting services have been provided for a number of industrial and commercial customers, in particular predictions of the probability of occurrence of specific levels of temperature and rainfall in Britain and other parts of Europe and of the expectation of wave heights in the North Sea below certain operational threshold values. The wave forecasts have proved the most successful. From discussion with customers it has become clear that research in synoptic climatology generates information which is useful to those sectors of industry and commerce which are sensitive to changes in the weather on time scales of two to four weeks or more. Arrangements have therefore been made to continue a consultancy service so that companies may be able, on repayment, to benefit from past and future research.

An exhaustive review was completed of the success of long-range forecasts over the years and the individual performance of the variety of statistical methods which have been employed. Forecasts of temperature and rainfall, though showing only a modest degree of skill, have comfortably exceeded the success which would have been achieved by always predicting the climatological average. The descriptive element in the long-range forecast known as 'additional information' has been subjected to careful and independent scrutiny and its merit judged on a simple A to E marking. It has been judged useful on the whole and of higher quality than either the temperature or rainfall forecasts alone.

Most of the statistical methods which have been employed over the years are incapable of further useful development, but they have been refined and automated to the point at which a forecast in statistical terms can be produced routinely and with minimum effort. This will provide a standard against which other methods of long-range forecasting may be judged, and also a basis for a consultative service for commerce and industry in the future.

Recent research into improved statistical techniques has sought to capitalize on the greatly improved historical base of machinable data which has been built up and an enhanced computing capability, particularly new and more efficient programs. A forecasting model has been developed employing several advanced statistical techniques applied to a large number of different predictor variables. These include surface pressure at high and low latitudes, sea surface temperature and the fields of temperature in the lower troposphere. All these fields are represented mathematically by a limited number of 'principal components' or eigenvectors. The most significant departure from previous analyses of this sort is the development of prediction schemes for synoptic patterns over the United Kingdom. The variety of weather types and associated ranges of temperature and rainfall in all seasons is such that this approach, determining the most likely of a set of possible atmospheric developments, has most chance of giving useful results. Another method is concerned more with the evolution of fields of pressure round the hemisphere, again using eigenvectors to represent the fields. The coefficients of the first eight eigenvector patterns of 5-day mean surface pressure over a period of five years are subjected to spectral analysis, and the amplitude and phase information for all that part of the spectrum which rises above the random-variance level is used to make autoprojections of the coefficients for up to about three months ahead. The eigenvector patterns are then reassembled and 5-day mean surface pressure maps derived covering this forecast period. The application of this method to the forecasting of wave heights over the North Sea is showing some useful results.

Adequate data on past weather are essential to any progess in understanding the origins of changes in the circulation of the atmosphere, whether large or small. A continuing effort has been directed to maintaining the 20 or so major data sets which are used for research both within the Office and by other scientific institutions. New data are added after undergoing careful quality control, and temporal and spatial gaps are filled as a result of a continuing search for reliable records, often in collaboration with other meteorological services. Quality-control procedures on sea surface temperature data have had to be substantially modified in the light of experience, and the complete historical set of over 40 million observations from 1854 to date is now ready for operational and research use. Preparations have been completed to receive and use data from the next European satellite.

Good progress has been made in a joint project with Reading University and the European Centre for Medium Range Weather Forecasts (ECMWF) to study the fluctuations of meteorological variables on time-scales from days to months. The global numerical model of ECMWF uses world-wide meteorological observations to determine fields of the primary meteorological variables—wind, temperature and humidity. From these fields, quantities describing various important features of the circulation of the atmosphere, such as heat and momentum fluxes or vorticity advection, can be calculated. These quantities and their time variations will be used to study, in a historical context, the influence of, for example, sea surface temperature variation on European weather, and to investigate the predictability of blocking, an immediate cause of many extremes.

Studies of the large-scale circulation of the atmosphere

A catalogue has been completed of the occurrence of blocking in the northern hemisphere over the past ten years. Details are included of the location, duration and movement of all blocks observed. Blocking is found to be most frequent over the east Atlantic, Scandinavia, the western USSR, the east Pacific and the Canadian Rockies, but within each region there are important variations in frequency and persistence between seasons. For instance, blocks occur frequently over the east Atlantic in November/December, whereas in January/February they occur more often over Scandinavia and western Russia where they usually lead to spells of very cold weather over a good deal, if not all, of western Europe.

Alongside these climatological studies of blocking, a large number of integrations of the 5-level general circulation model have been analysed to compare the statistical distribution of blocking in the typical model atmosphere. The results show that the model, while not very good at predicting individual blocks, produces a distribution of blocking patterns both by month and by longitude which is very similar to the distribution in the real atmosphere. More than 70 50-day integrations of the model were used in this study. The main limitations of the model were that it produced fewer than half the number of blocks found in the real atmosphere and had difficulty in maintaining blocks in the strong flow in winter. Individual cases are being studied in more detail.

Work continued on the project to map mean monthly flow patterns from 1660 onwards for the North Atlantic–Europe area and to relate these patterns to variations of temperature and rainfall in western Europe, particularly to variations in extremes. The pressure fields associated with particular combinations of temperature and rainfall are being used as background to make the best possible inferences from the scanty pressure data available before 1800. This work forms part of a research contract for the Department of the Environment. Also included in this contract is a study of past data on temperature and rainfall over Britain and the surrounding area in a search for possible trends which may be extrapolated into the future, and in the derivation of better statistics on the incidence of extreme conditions. The daily catalogue of Central England Temperature has so far been taken back to 1755 and it should be possible, though with a few gaps, to carry it back to 1660. This will be combined with data on rainfall and wind flow to develop a better appreciation of the occurrence of extreme conditions in these early years, especially severe winters, droughts and damaging gales.

Climatic change

Studies have continued into the behaviour of global and local climate over the past 100 years or so. The period most amenable to study is after 1948, when a world-wide network of upper-air sounding stations began to come into operation. Because all existing global and hemispheric upper-air data sets contain errors and uncertainties sufficient to obscure any real movement of climate over the period, it has been necessary to build a new definitive data set from scratch. For a selection of some 150 stations over the hemisphere, mean monthly upper-air data have been requested from the countries of origin, together with information on the instruments used and launching sites. Good progress has been made over the year in building up this data set and programs have been developed to examine the data for evidence of a change in climate or its variability taking into account, as necessary, changes due to instrument or launching site. From the data so far received, about one-fifth of the total, there is no evidence of any movement of climate. A preliminary study of the Canadian data shows a good deal of fluctuation on quasi-biennial and 5–10 year time-scales.

As for more local changes over Britain, the long-period daily record of Central England Temperature, available from 1814, has been examined for climatic variations in relation to various weather types, using both the Lamb daily catalogue which goes back to 1861 and an objectively defined daily catalogue based on local grid-point surface pressures available from 1880. The objective catalogue has a much higher resolution of air trajectory than the Lamb catalogue and it appears that the warming of westerly and anticyclonic Lamb types in October has been due to a small change in the trajectory of the air rather than to a warming of the ocean.

A large number of enquiries were received from the Press, radio and television on matters related to climate and climatic change, mostly in connection with extremes of weather experienced during the year and the eruption of the Mount St Helens volcano. In all cases it was possible to demonstrate from an examination of all the evidence available that the variety of weather experienced during the year, both at home and abroad, was not unusual. Similarly, the amount of volcanic dust released into the atmosphere from Mount St Helens appeared to be only a small fraction of the total dust produced by other volcanoes in recent years.

Application of dynamical methods to long-range forecasting

Valuable experience has been gained in running the 5-level model operationally in support of long-range forecasting. With few exceptions, integrations have been effected for periods of 50 days starting near the 10th and 25th of each month. A procedure has been developed for evaluating these model forecasts: a series of charts is examined which shows the average 500 mb geopotential over consecutive periods of 5 days and particular attention is paid to the positions of the main long-wave features. This use of 5-day mean charts effectively suppresses many of the transient features in the flow which cannot be accurately modelled over long times. A Hovmöller diagram is produced for latitude 50°N which presents at a glance the evolution in time of the long-wave features around the hemisphere. Known deficiencies in the model are allowed for subjectively and the final step in the forecast is to infer the likely sequence of weather events over the British Isles due to the expected movement of the long-wave pattern through the month.

One aspect of the model which has to be allowed for in using it as a forecasting tool is that its 'climate' (i.e. its average behaviour) is not the same as that of the real atmosphere. In order to interpret model integrations properly it is necessary to consider the difference between the model climate and the real climate for the time of year. Model climates are being derived by averaging for each month ten 50-day integrations from different real data. So far, they have been completed for the months of January, April and July. The results show that the model westerlies are much too weak in summer; in winter, although they are about the correct strength, the main flow is too far north. A study is also being made of the manner in which the model adjusts from real data towards its own climate.

As yet there is insufficient evidence on which to base a general assessment of the accuracy of model forecasts, but there is no doubt that occasionally the model has shown a surprising degree of skill in predicting the general evolution of the long-wave pattern. At other times the forecast has been rather poor. The model integration can provide a great deal of information and it is important to decide which variables have most predictive skill. Some recent results indicate that the model appears to be able to predict changes in the 1000–500 mb thickness particularly well. This could be very useful since there is a close link between observed changes in thickness and changes in surface temperature.

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 in their application to practical problems. Most of its investigations have been connected with aviation, but the proportion of non-aviation enquiries has increased in recent years. A principal theme of much of this work is the development of techniques and aids for local forecasting from central and outstation sources.

Aviation authorities have long been concerned about the effect of low-level wind variations on the handling of large jet aircraft. 'Wind-shear' warning trials mounted by the Meteorological Office at the request of British Airways in 1977 have shown enough success for British Airways to request a permanent wind-shear warning service. This has been on trial since February and may be adopted on an operational basis in 1981.

Concern has been expressed that the wind supplied by air traffic control just before landing and take-off is often based on a centrally sited anemometer 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 anemometers (3.2 km apart) at London/Heathrow Airport to investigate spatial wind differences, and has recorded 12 months of uninterrupted data. A parallel study of the structure of surface wind squalls at Heathrow has been completed and is being considered by the Royal Aircraft Establishment at Bedford as a potential aid to the improvement of the realism of input to aircraft simulators. 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.

The increasing use of helicopters in bad winter weather, particularly for rescues 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.

Airlines are still concerned with clear-air turbulence (CAT) which causes occasional passenger discomfort and (rarely) injuries. About 5000 CAT flight histories were collected on ten reporting days in spring 1976 and have now been analysed. Multiple regression techniques have identified the relevant parameters to be used in an objective method of forecasting now undergoing operational trials.

The Office has a representative on the Civil Aviation Authority Data Recording Panel which examines the outputs from flight data recorders fitted to about 40 aircraft in civil transport service to search for abnormal flight behaviour. Study of these may result in the identification of potential causes of accidents and lead to changes in procedure.

There is an increasing demand, mainly from the aviation sector, for very large quantities of climatological data—an apparently straightforward task which, in practice, often requires considerable computer programming expertise 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 250 overseas airports and also of updated equivalent head-wind data used for flight planning.

A small team helps and encourages outstation staff in carrying out investigations related in the main to the forecasting of local weather. Computer services for the provision of data and guidance on methods of analysis and interpretation of results are given. These services are also provided for student projects at the Meteorological Office College. This team is also developing mesoscale analysis techniques which may improve the local forecasting of fog, showers, stratocumulus and surface temperatures, and is co-ordinating a field project at RAE Bedford where an acoustic sounder for measuring fog-top heights, and a low-starting-speed anemometer for use in fog forecasting have been installed. This work is an additional source of data for outstation investigations.

Development has continued of objective methods of forecasting surface temperature and the probability of precipitation up to three days ahead. These methods (like those used for forecasting CAT, as mentioned above) are based on correlations between observed values and derived quantities predicted by the numerical forecasting models. The archiving of a small fraction of the model daily output for the past two years provides the data base for this 'model output statistics' approach to the forecasting problem.

A method of deriving convective parameters over the United States by direct computer processing of upper-air data has been successfully developed for flight-planning purposes at Heathrow, and has contributed to staff saving there.

In the non-aviation sector, the volume of enquiries concerned with pollution has maintained a high level. These are mainly concerned with advice to firms in the chemical industry in forecasting the spread of chimney plumes and helping 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. Forecasts were made of the trajectories of volcanic dust from the eruption of Mount St Helens, Washington, USA, to direct the MRF Hercules on particulate sampling flights off the north-west coast of Africa. Several related enquiries were also answered.

Radio-meteorological enquiries continue at a significant level and are principally concerned with the effects of precipitation and evaporation ducts on microwave communication links.

Library, Editing, Publications, Archives and Cartographic Section

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 Meteorological Office Library Accessions and Retrieval System (MOLARS) has continued to arouse interest among librarians; details were supplied to the Australian Meteorological Service and the Swiss have asked if the data base could be made available on Euronet. Some preliminary work has been done on the second or retrieval stage which is to be implemented in 1982.

Following discussions with the Royal Meteorological Society, work was started on a union catalogue of rare meteorological books, i.e. those published before 1850, held by the Society and the Office. The work is funded by a grant from the British Library.

Enquiries continued at a high level and covered the usual wide range, including one for the year of the 'great' frost (1814) required to date the murder of 'Silver' Jones (a Welshman who liked to be paid in silver) whose body was found under the ice, and another for the weather between London and Manchester on 4 May 1908—the day Charles Rolls first met Harry Royce.

Accessions to the Library during the year were similar to those in 1979 apart from slides and photographic material received by the Visual Aids unit which increased markedly for the second year running; loans were much the same. Some statistics are given in Table XVI (page 124).

Co-operation with other Government and local librarians continues, giving savings in time and money.

Accommodation for staff and equipment remains very cramped, and present financial restraints hold little hope of amelioration in the near future.

The Editing Section remains responsible for preparing for printing most of the official publications of the Office, and co-operates closely with Her Majesty's Stationery Office (HMSO) in the maintenance of publishing standards; the Section also liaises with HMSO on questions relating to Crown Copyright. Works published during the year are listed in Appendix III; they include the *Meteorological Magazine*, a monthly journal containing scientific articles, reviews and items of interest to meteorologists everywhere.

The distribution of publications, both official and commercial (scientific journals, textbooks, works of reference, etc.), to the Office's many outstations is under the control of the Publications Section which is also responsible for the half-yearly issue of some 350 000 observation forms of all kinds to over 6000 reporting stations. The Section also distributed periodical publications such as the *Daily Weather Report* and the *Monthly Weather Survey and Prospects.*

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; see Table XVI for details.

The Cartographic Section prepares diagrams 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 and slides for lectures, and the large number of diagrams and charts for various areas of the world that are used for plotting meteorological observations. Statistics of the work carried out are given in Table XVI.

Following the decision to close the local HMSO Press at Bracknell, the Section has been closely involved with HMSO Print Procurement Division in the provision of detailed estimates of the printing work that would have been carried out on the Press in 1981 and future years. This work includes the printing of virtually all the maps, charts, diagrams and forms used for the routine operational work of the Office at Headquarters and outstations; a close and effective working relationship had been built up between the Press, the Cartographic Section and the various user Branches.

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 Navy 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 field-work, for the analysis and use of meteorological charts 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. 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 and by facsimile.

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 transported to and from the College by private coach. Teaching is always at the College but students on such courses may use the 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 659. On the Scientific Officers' Course, for those with good honours degrees, usually in mathematics or physics, there were 23 students on the course which finished early in the year; 18 came from within the Meteorological Office, 3 from Malaysia, 1 from Hong Kong and 1 from Brunei. Because of staff reductions the course did not operate this autumn. The Applied Meteorology Course is for new entrants with a degree or Higher National Certificate and for existing staff who are similarly qualified. The course which ended early in the year had 32 students, including one each from Switzerland, Jersey and International Aeradio Limited. The course which began this autumn had 20 students, including 3 from Hong Kong, 1 from Jamaica, 1 from Lesotho and 1 from Malaysia. 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. It consisted of 39 students in 1980. Nine other services were represented; students from Mozambique, Netherlands Antilles, Sudan, Tanzania and Thailand 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. The latter is a sandwich course which requires, as preliminary qualifications, GCE 'A' level passes in mathematics and physics. So that students may obtain both a good degree and real experience in meteorology, the course lasts $3\frac{1}{2}$ years and consists of alternating periods of academic work in the University and work experience in the Office. The latter 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 no members of the Office joined the Sandwich Course but three graduated with First Class Honours.

After several years' experience forecasters normally return for a 7-week Advanced Forecasting Course. Most members of this course are Scientific Officers of the Meteorological Office in the field for promotion to Higher Scientific Officer; they are given an audition by the BBC. This year three courses were held for a total of 25 students from the Office and 8 from other services, including 5 from western Europe.

To implement the policy of providing refresher courses for Higher Scientific Officers at intervals of 5–10 years, three Extension Courses were run this year. On these 4-week courses students revise their knowledge of synoptic meteorology and bring it up to date. They are guided in the choice of a project which they undertake in order to help them later to conduct minor investigations into the weather in the areas for which they are responsible. Other courses for Higher Scientific Officers are the Advanced Forecasting (Refresher) Course and the Further Extension Course. Both last three weeks. The former is essentially for revision and updating of the students' practice and knowledge of synoptic meteorology, whereas the latter is intended to deepen the insight of those who have completed an Extension Course more than 5 years previously. There were no students for the Refresher Course this year but one Further Extension Course was held.

One-week courses in Defence Meteorology for forecasters entering that field were run in co-operation with senior officers of all three fighting services. After the Applied Meteorology Course one was held at the Royal Air Force Staff College, Bracknell, and after the Initial Forecasting Course one was held at Royal Air Force, Benson. On these courses special emphasis was put on finding out about and meeting the needs of the various arms and on appropriate techniques of briefing.

Plans were made for a 3-day residential seminar on the Management of Scientific and Technical Activities, similar to that held in December 1979, for staff at about the Principal Scientific Officer level. The seminar is expected to take place in April 1981.

Assistant Scientific Officers who have newly joined the staff and are to work initially in support roles in 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 of observations. After it, as after all initial courses whether for assistants or forecasters, training continues at the station and is an essential part of the scheme. 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, communications, pilot-balloon work and elementary instrument maintenance. This year one initial, one basic and five advanced courses were held at the College. For ASOs with long experience, three Extension Courses for Assistants were held.

The 4-week Scientific Officers (Supervisors) Course continues to serve as a refresher course and as a course for those newly promoted to fill supervisory posts. Three were held. Their purpose was akin to that of the 3-week Senior Meteorologists' Course which, at a higher level, 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, Hong Kong, the Netherlands and Switzerland as well as from all parts of the UK. While restrictions on recruitment led to fewer people attending initial courses, separate courses continued to be run at the College for observers who man the Auxiliary Reporting and Climatological Stations in the UK, for Air Traffic Control staff who make weather observations at some aerodromes and for Senior Observers of the Saudi Arabian Department of Meteorology. College instructors gave four one-week courses in weather observing at HM Coastguard School at Brixham. Two initial courses for Office staff who use the COSMOS computer system were also well attended. Both were followed by six to nine months' training on the job and then a two-week second course. A number of specialized lectures on these courses were given by members of the Data Processing Branch and one member of that Branch regularly acts as a full-time lecturer during such courses. This training of computer users became much more effective with the installation during the summer of a PDP 11/34 minicomputer (linked to the COSMOS computer system at Bracknell) and six Volken–Craig visual display terminals.

Other courses were held in Low-latitude Meteorology, Meteorological Statistics and Instrument Maintenance. These last were for meteorological technicians from overseas. Thirteen attended one course on non-electronic instruments, from nine different countries. 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 training on the maintenance of electronic instruments, on manufacturers' courses, for eight technicians from four countries, as well as some courses in the School of Technical Training.

There has been little scope this year for outside organizations and other Branches of the Office to use the College for meeting and conferences.

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 113. A further 53 members of staff are taking Open University or other Further Education courses with assistance under the Civil Service Further Education scheme. In addition, 26 staff began, or continued with, block-release courses at the Reading College of Technology for the Higher National Certificate. A new Business Education Council/Technician Education Council course at this level, in mathematics, statistics and physics, was devised and began in the autumn. Block-release courses consist of four six-week periods of full-time study, spread over two years. During these periods of full-time study staff live at Shinfield Park or at Boundary Hall. Seven members of the staff took their final examination this year and all were successful. During the year 13 members of the staff were on Special Leave with Pay for full-time University studies or to attend sandwich courses. Three who were in their final year at Reading were all awarded First Class Honours. In addition, five scientists are taking advantage of a scheme under which they work in the Office and, at the same time, study towards a PhD degree. Supervision is shared between the Office and the University. This year co-operation was with Oxford, Reading and Southampton. Support was also given to two members of the Office to attend one-week Field Study Courses run by the Royal Meteorological Society.

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 or under the British Technical Assistance Program. In addition, 19 underwent practical training on the job in various Branches of the Office; they came from 10 different countries and territories and gained experience in various areas of work but mostly forecasting.

The training of technical staff continues to reflect the variety and complexity of electronic equipment in or entering service. This year the training of Radio (Meteorological) Technicians was carried out at the School of Electronic Engineering, Arborfield, by REME staff, and at Shinfield Park. Further training of the technicians who develop, install and maintain radars, computers, microprocessors, communications, facsimile sets and so on continues at Shinfield Park and at Beaufort Park. Those who operate the equipment, especially that for routine sounding of the atmosphere, are usually trained at Beaufort Park. This year Mk 3 radiosonde equipment was installed at three more stations and staff there were trained to use it. In addition, one member of the staff destined for the Ocean Weather Ship service was trained in the use of the VIZ sonde and one technician was introducted to ASTOR sonde techniques before secondment to Port Vila, Vanuatu.

Technical staff in the telecommunication field are given training in the operation of new equipment and new procedures by a full-time training officer in the Telecommunication Branch. He also provides telecommunication staff with suitable trade and refresher training in their basic duties.

The Office continues to support a number of fellowships under the Voluntary Co-operation Program (VCP) of the World Meteorological Organization. As part of the program, students from Costa Rica, Ethiopia (2), Jamaica, Mauritius and Uganda (3) attended the Instrument Maintenance Course, and one from Lesotho the Applied Meteorology Course at Shinfield Park. In addition, VCP students from Ghana (2), Nepal, the Netherlands Antilles, Nigeria and Tanzania are reading for first degrees in meteorology and one from Tanzania and one from Jamaica for higher degrees in agricultural meteorology at the University of Reading. At the same University during the year two VCP students graduated as BSc and one as PhD.

General Activities of the Research Directorate

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

The Meteorological Research Committee, which has monitored and guided the scientific research of the Office since 1941, ceased to exist at the end of 1979; the saving was about £3000 per annum. The Meteorological Committee is to take on increased responsibility for reviewing the research of the Office.

The Gassiot Committee of the Royal Society also ceased to exist and a small committee, the Gassiot Grants Committee, was set up to advise the Director-General on the support provided by the Office to university research projects. In the past some support was provided through the old Gassiot Committee and some through a sub-committee of the Meteorological Research Committee. The Gassiot Grants Committee met once, in June, and recommended the award of eight grants totalling £49 000.

During the year several members of university staffs worked in the Office as consultants for short periods, and one scientist from Kenya, sponsored by WMO, spent a longer period working with data collected during the FGGE.

K. H. Stewart
Director of Research

STATISTICS OF THE RESEARCH DIRECTORATE

TABLE XVI—LIBRARY, ARCHIVES AND CARTOGRAPHIC SECTION

Library	
Publications received:	
Daily weather reports ...	10 012
Books, journals, etc. ...	7 651
Films, slides and photographs ...	1 791
Individual books, pamphlets, articles, etc. classified and catalogued ...	10 177
Publications lent (excluding internal 48-hour loans):	
Daily weather reports ...	21 291
Books, journals, etc. ...	16 821
Films, slides and photographs ...	11 185
Requests met by photocopies or copy microfiche ...	753
Number of exchange agreements ...	1 120
Number of pages translated by Library translator ...	557
Number of pages translated by outside translators ...	97
Archives	
Number of loans ...	380
Cartographic Section	
Number of diagrams, maps and charts completed during year ...	3 736
Number of reprographic jobs during year ...	342

TABLE XVII—TRAINING

The following figures give details of courses completed during 1980 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 ('79) ...	1	23	18	5	23
Applied Meteorology Part II ('79) ...	1	10	17	4	21
Applied Meteorology (Prep) ('80) ...	1	3	11	5	16
Applied Meteorology Part I ('80) ...	1	10	14	6	20
Applied Meteorology Part II ('80) ... (Support Scientists)	1	3	8	0	8
Pre-Initial Forecasting ...	1	2	14	11	25
Initial Forecasting ...	1	16	24	14	38
Advanced Forecasting ...	3	7	25	8	33
Extension ...	1	4	8	1	9
Further Extension ...	1	3	12	1	13
Senior Meteorologists ...	1	3	11	5	16
Meteorological Statistics ...	1	4	8	0	8
Tropical Meteorology ...	1	3	0	5	5
Initial Programmers ...	3	4	35	0	35
Second Programmers ...	3	2	40	0	40
Assistants' Basic ...	1	4	12	0	12
Initial Synoptic Assistants ...	1	4	6	0	6
Advanced Synoptic Assistants ...	5	6	42	4	46
Extension, Synoptic Assistants ...	3	4	29	0	29
Senior Officers (Supervisors) ...	3	4	33	0	33
Auxiliary and Co-operating Observers ...	8	1	0	100	100
Air Traffic Control Staff ...	5	1	0	60	60

TABLE XVII (*continued*)

	Number of courses	Length in weeks	Met. O. staff	Others	Total
Defence Meteorology	2	1	28	0	28
Saudi Arabian Observers	2	8	0	22	22
Instrument Maintenance	1	6	0	13	13
ASO/RMT Conversion ('79)	1	14	4	1	5
*ASO/RMT Electronics ('80)	1	33	9	0	9
Met. Office Wind Finding Radar No. 4 ...	1	5	2	0	2
MOWOS	1	2	7	0	7
FAX Equipment	1	3	6	4	10
SATFAX Equipment	1	2	7	4	11
Wind-finder Data Print-out	1	2/5	4	0	4
Digital Anemograph Logging Equipment ...	1	2	8	0	8
Mk 3 Radiosonde Equipment	2	5	10	0	10
Totals			452	273	725

* Course carried out for Meteorological Office by the School of Electronic Engineering, REME Arborfield, Berks.

Students from the following territories attended courses which terminated during 1980.

	Number of students
Brunei...	1
Bahrain	5
Bangladesh	1
Belgium	4
Costa Rica	1
Cyprus	1
Ethiopia	2
Guernsey	1
Hong Kong	7
Territories served by International Aeradio Ltd	6
Jamaica	2
Jersey ...	4
Kenya ...	1
Lesotho	1
Malaysia	3
Mauritius	1
Mozambique ...	1
Nepal ...	2
Netherlands	3
Netherlands Antilles ...	2
Nigeria	1
Saudi Arabia ...	22
Sudan ...	1
Switzerland	2
Syria ...	3
Tanzania	4
Thailand	1
Trinidad	1
Uganda	3
Zimbabwe	1
Total	88

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 are located at the Headquarters at Bracknell while the numbers at other stations range from about 130 at London/Heathrow Airport to only two at some Port Meteorological Offices. This wide diversity of station size poses a number of management problems not usually found 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. In this way the career prospects of staff can be viewed as a whole and the opportunities open to them do not depend on the location or size of their particular unit. Central control also yields the benefits of maximum flexibility in meeting varied staff requirements. Some aspects of the Personnel Management work are outlined in the following paragraphs.

Manning

Movements of most members of the staff are the responsibility of the manning sections at Bracknell, but short-period detachments may be arranged by Principal Meteorological Officers at outstations. The majority of posts at outstations and a substantial number at Headquarters have to be manned for 24 hours a day, 7 days a week, and this requires considerable planning coupled with a high degree of mobility. During 1980 the number of postings averaged about 21 a week. A decrease in the number of posts following the general reduction in the size of the Civil Service and a ban on recruitment has exacerbated the manning problem and, at times, there has been an imbalance between numbers of staff and posts at the various grade levels. Consultation between line managers and the career development section helps to ensure, as far as possible, that long-term needs and preferences of individuals are taken into account, as well as the meeting of short-term requirements. A close liaison is maintained with trade union local branches. The manning sections also interview members of staff to help clarify individual wishes and also to ascertain suitability for certain types of work and, in particular, for postings overseas to RAF bases in Germany, Cyprus and Gibraltar.

Career development

Career development panels continued to monitor and guide the careers of staff members—the Senior Career Development Panel and the Main Career Development Panel and Postings Board for senior and high-potential specialist staff, and other panels within the Personnel Management Branch for the remainder. Career interviews were given on the basis of requests from individuals, requests by line managers, recommendations by promotion boards and information contained in Staff Reports. The total number of interviews (about 130) was 50 less than last year and more business was conducted by telephone and letter. During the year, increasing restrictions imposed by low levels of recruitment and promotions have made the task of the career development section more difficult as individual needs have increasingly conflicted with the needs of the Office.

The careers section has, this year, been able to give greater attention to selection for professional courses at the Meteorological Office College. This has led to higher course numbers and hence a more efficient use of training resources and a steady erosion of the number of staff overdue for training. The improvement of training nomination procedures has been due, in part, to the establishment of a more systematic recording of training needs and courses attended. Management training facilities provided by the Civil Service Department and the Ministry of Defence have continued to be used and, in addition, in-house training in skills of staff reporting and appraisal interviewing was given to 254 staff in the year ending 31 August 1980.

Cash restrictions this year affected the number of study concessions granted. Priority was given to those courses leading to qualifications which are of assistance in helping staff to develop their careers—primarily the Higher National Certificate (or HTEC). In the event, the majority (83 per cent) of all applications were approved.

Records

Personal records for the majority of staff members are held centrally in the records section which is responsible for maintaining up-to-date information on the CIPMIS system. Staff have been involved in discussions leading to the greater use and improvement of CIPMIS. Secretarial work for the various promotion boards in the Meteorological Office is carried out by the records staff, working in co-operation with the career development and manning sections. Some functions, such as approval of special leave, are delegated to Principal Meteorological Officers and other line managers although policy matters and many questions on conditions of service and general administration, together with discipline etc., are handled through the records section.

Manpower planning

Continuous monitoring of staff numbers has been essential during a year in which the total complement was being reduced, and the Branch has become increasingly involved in the provision of management information. Short-term projections relating to the effects of complement reductions on promotion and recruitment prospects have been made. The effects of natural wastage on grade sizes have also been studied and are monitored in order to ascertain the ability of the Office to reduce to required manning levels. Manpower-planning computer programs developed by the Civil Service Department have been used mainly for the assessment of training needs at Assistant Scientific Officer and Scientific Officer level. Statistics of staff numbers, promotion, recruitment and wastage patterns are produced by the Defence Economic and General Statistics Division of MOD in co-operation with the Personnel Management Branch. These statistics are being used as a basis for the computer-based manpower-planning projections.

Recruitment

The Personnel Management Branch is responsible for recruitment to most grades in accordance with regulations laid down by the Civil Service Commission, although the recruitment of graduates is part of the Commission's centralized recruiting program.

The announcement by the Government that there would be cuts in the size of the Civil Service meant that target figures for the recruitment of graduates and Assistant Scientific Officers had to be reduced during the recruiting exercise. The number of graduates eventually recruited was only six and, despite interviewing 201 candidates for appointment as Assistant Scientific Officers, it was not possible, in the event, to offer a post to any.

Recruitment to other grades was also affected and apart from 13 Clerical Assistants, who were recruited early in the year, double figures were not reached in any other grade.

The total number of new full-time staff entering the Meteorological Office in 1980 was 57, the lowest since 1976. However, it is of interest to report that, for the first time in more than ten years, three Radio (Meteorological) Technicians were recruited, two of them having had no previous Civil Service connections.

In addition to the staff mentioned above, temporary staff included 4 college-based sandwich-course students undergoing industrial training and 4 vacation students who were employed for about two months in the summer.

In July the Office co-operated in a one-week Work Experience scheme with a school in Wokingham and in September, for the first time, Career Advisers from Universities and Polytechnics were invited for a half-day Career Seminar.

Staff numbers

At the end of 1980 the total number of posts of all grades was 3052, a decrease of 156 over the year. The actual strength at the end of the year was made up as follows:

Deputy Secretary	1
Under Secretary	2
Science Group	
Chief Scientific Officer	1
Deputy Chief Scientific Officer	6
Senior Principal Scientific Officer	25
Principal Scientific Officer	110
Senior Scientific Officer	275
Higher Scientific Officer	494
Scientific Officer	462
Assistant Scientific Officer	801
Administrative Group	
Assistant Secretary	1
Principal	1
Executive grades	33
Clerical grades	133
Marine Staff	
Marine Superintendent	1
Nautical Officer grades	13
Ocean Weather Ships	
Officers and non-industrial grades	43
Crew and industrial grades	42
Professional and Engineering Staff	
Principal Professional and Technology Officer	1
Professional and Technology Officer Grade I	4
Professional and Technology Officer Grade II	8
Professional and Technology Officer Grade III	5
Professional and Technology Officer Grade IV	5
Technical and Signals grades	272
Typing and miscellaneous non-industrial grades	138

Industrial employees	80
Locally entered staff and employees overseas	51

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 Office cover between them cost and management accounting, financial control and expenditure monitoring, and cash expenditure, receipt and accounting. In recent years the work emphasis has moved from traditional Vote and cash accounting activities to cost and management accounting. From these are derived the Memorandum Trading Account and the following statements showing the operating expenses for the management areas of the Office and its sources of income.

Although, as part of the cost accounting process, the reporting of staff time in relation to activities is done on a selective basis only, there remain considerable difficulties with the input and processing of the data, both of which are carried out almost entirely manually. Some relief has now been given by computer processing of initial inputs which attribute staff time to activities. Additional computer assistance is being planned to reduce further the amount of manual processing in the later stages of the system, and so make it less vulnerable to staff turnover and improve the time-scale for producing regular reports. The systems in use at other Ministry of Defence establishments are being examined to see whether they can be adapted for the Meteorological Office, and an assessment is being made of the suitability of various kinds of data-base systems available from commercial sources.

The tables which follow give the operating expenses of the component parts of the Meteorological Office: the cost of carrying out major functions—forecasting, collecting observations, etc., and the estimated income receivable from repayment services, all for the financial year 1979/80.

STATEMENT OF OPERATING EXPENSES BY METEOROLOGICAL OFFICE FUNCTIONS FOR THE YEAR ENDED 31 MARCH 1980

	1979/80		1978/79	
	£000	£000	£000	£000
Main functions				
1. Making and handling observations	8430		7694	
2. Forecasting	8331		7237	
3. Meteorological (including climatological) advice	3702		3508	
4. Research and development	5794		5828	
		26 257		24 267
Supporting functions				
5. Administration	1899		1983	
6. Technical support	3463		3148	
7. International activities	1282		1186	
8. Computer services	2323		2053	
9. Telecommunications	4759		3980	
		13 726		12 350
		39 983		36 617

METEOROLOGICAL OFFICE RECEIPTS 1979/80 (CASH RECEIVABLE)

(1)	(2) 1979/80 £000	(3) 1979/80 £000	(4) 1979/80 £000	(5) 1978/79 £000
SERVICES TO:				
Ministry of Agriculture, Fisheries and Food			120	105
Other Exchequer Departments (Department of the Environment etc.)			72	47
Civil Aviation Authority			10 951	9665
Natural Environment Research Council			24	31
Other non-Exchequer Departments			58	27
			11 225	9875
Meteorological Office College—Training of meteorologists ...			140	95
Secondments to outside bodies			61	87
Comprehensive forecasting service for the offshore oil industry...		508		416
Forecasting service developed to meet individual user's special needs:				
Ship-routeing Service	57			29
Gas Boards	106			90
Central Electricity Generating Board	71			59
British Rail	8			8
Independent Broadcasting Authority	20			16
British Broadcasting Corporation	33			24
Press	21			15
Other customers' special services	72			34
		388		
Automatic Telephone Weather Service (British Telecom) ...		178		189
Issues of forecasts by prior arrangement	8			6
Issue of local detailed forecasts by prior arrangement	4			4
Issue of forecasts up to 24 hours in advance	65			56
Issue of expected occurrences of specified weather (Frost, Fog etc.)	50			48
Pigeon-racing forecasts	7			7
Issue of three-day dry-spell forecasts	1			6
Issue of road-danger warnings	39			28
Issue of weekend temperature forecasts	7			4
Consultations on present or future weather	1			—
Investigations and other professional work as required	97			82
Preparation of Weekly, Monthly and Annual Weather Summaries	15			12
Preparation of Certified Statements	24			16
Outside attendances by professional staff (Court appearances) ...	1			2
Supply of copies of data/records	56			56
Daily Weather Reports/Publications/Met. Forms	11			7
Other services	11			16
		397		
			1471	
			£12 897	£11 287

FINAL STATEMENT OF OPERATING EXPENSES OF THE METEOROLOGICAL

(1) Expenditure	(2) Offices at RAF stations £000	(3) Offices at CAA/ATCC stations £000
1. Personnel (pay, allowances, ERNIC and Superannuation) ...	6075	3945
2. Materials (stores, minor equipment, maintenance, ships' expenses, etc.)	302	100
3. Staff travel and subsistence	140	80
4. Accommodation	705	101
5. Office support (stationery, office machines etc.)	65	49
6. Telecommunications		
7. Equipment support (aircraft and motor transport)	106	
	7393	4275
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 contribution (FGGE)...		
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		
	7393	4275
11. Depreciation (Historical):		
Equipment	41	25
Computers		
Ships		
Aircraft		
	7434	4300

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

OFFICE FOR THE YEAR ENDED 31 MARCH 1980

(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Other met.	Met. Office HQ Directorates				
Weather centres	services outstations*	Met. Services	Research*	Admin.	1979/80 Total	1978/79 Total
£000	£000	£000	£000	£000	£000	£000
1505	3343	6712	3009	1450	26 039	22 921
49	1585	792	605	69	3502	3653
30	82	136	72	29	569	456
181	298	888	794	345	3312	2662
18	46	82	45	23	328	274
		1122			1122	1123
	32	30	1005	42	1215	1086
1783	5386	9762	5530	1958	36 087	32 175
	(1972)				(1972)	(1854)
			32		32	33
		142			142	123
		467			467	393
		143			143	182
		533			533	576
		45			45	41
		1066			1066	1269
		16			16	17
		1			1	1
		46			46	41
		1445			1445	1779
		80			80	71
		8			8	—
1783	3414	13 754	5562	1958	38 139	34 847
9	171	111	93	1	451	442
		640	9		649	584
	492				492	492
			252		252	252
1792	4077	14 505	5916	1959	39 983	36 617

EQUIPMENT

Meteorological equipments are increasing in range and complexity. There are already about 11 000 special meteorological items and these are supported by the Met O 4 stores organization which is now handling around 23 000 requests for stores a year.

The stores organization combines the roles of supply manager, stores depot and accounting unit, being responsible for provisioning, procurement (by local purchase or purchase by others), stockholding and accounting, and expenditure forecasting and control. The systems employed are old and labour-intensive, and investigations into improvements are proceeding. Present efforts are concentrated on participation in the RAF supply system centred on the computer complex at Hendon. The idea has been accepted in principle and no insuperable obstacles have come to light so far. If none of any consequence emerge in the early part of 1981 there is a strong probability that transfer will be effected by the spring of 1982. Future benefits are expected to include more accurate accounting and provisioning with more effective use of the funds available, an ability to control and utilize efficiently the combined holdings at outstations and storehouse, and some reduction in administrative manpower.

F. R. HOWELL
Secretary
Meteorological Office

INTERNATIONAL CO-OPERATION

The major meetings of international organizations with which the United Kingdom co-operates have been discussed in the report of the International and Planning Branch on pages 63–65. A complete list of WMO meetings or joint WMO meetings with other international bodies, in which Meteorological Office staff took part, is as follows.

Subject	*Place and date*	*Attended by*
WMO Workshop on Two-dimensional Ozone Layer Modelling	Toronto January	Dr S. A. Clough (Met O 20)
CBS Working Group on Codes, Restricted Session	Geneva January	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)
Working Group on FGGE Data Management, 4th Session	Shinfield Park February	Mr M. V. Jones (Met O 22)
CBS Working Group on the GDPS, 5th Session	Geneva March	Miss M. J. Atkins (Met O 2)
Commission for Hydrology, 6th Session	Madrid April–May	Mr C. V. Smith, AD Met O(AH)
WMO Scientific and Technical Advisory Committee	Geneva May	Sir John Mason, Director-General
Preparatory Committee for 32nd EC Session	Geneva May	Mr G. J. Day, AD Met O(IP) Mr M. W. Stubbs (Met O 2)
EC Panel on VCP	Geneva May	Mr G. J. Day, AD Met O(IP)
Executive Committee of WMO, 32nd Session	Geneva May	Sir John Mason, Director-General Mr G. J. Day, AD Met O(IP) Mr M. W. Stubbs (Met O 2)
Meeting to assist in assessment of the 1980 field program of WMO Precipitation Enhancement Project	Valladolid, Spain May	Mr P. Goldsmith, DD Met O(P)*
Symposium on Systems Performance and Early Results of the Global Observing System for FGGE—23rd COSPAR Meeting	Budapest June	Dr D. R. Pick (Met O 19)
NAOS Board, 5th Session	Geneva July	Dr N. E. Rider, DD Met O(O) Captain G. A. White, Marine Superintendent
Informal Planning Meeting, ALPEX Data Management	Shinfield Park July	Mr M. V. Jones (Met O 22)
WMO/ICSU/Norwegian National GARP Committee, International Conference on Preliminary FGGE Data Analysis and Results	Bergen July	Dr W. H. Lyne (Met O 11)
Third WMO Scientific Conference on Weather Modification, 8th Cloud Physics Conference	Clermont-Ferrand, France July	Sir John Mason, Director-General Mr P. Goldsmith, DD Met O(P) Dr P. Ryder, AD Met O(CP), and members of Met O 15
Study Group on the Manual and Guide to the GOS	Geneva August	Mr D. R. Grant, AD Met O(OP)

* The full titles of the Deputy Directors (DDs) and the Assistant Directors (ADs) are given on pages x–xii. Other abbreviations are explained in Appendix IV, pages 163–165.

Subject	*Place and date*	*Attended by*
IOC/IAMAP/WMO Ozone Symposium 1980	Boulder, Col. August	Dr A. F. Tuck (Met O 15) Mr G. Vaughan (Met O 19)
WMO Study Group on Digital Facsimile	Geneva September	Mr D. McNaughton, AD Met O(TC)
CAeM Working Group on PROMET	Offenbach September	Mr P. D. Borrett (Met O 7)
Technical Conference on Evolution and Standardization of Observing Techniques in the light of Automation	Norrköping, Sweden September	Dr D. N. Axford, AD Met O(OI) Dr R. E. W. Pettifer (Met O 16) Mr A. H. Hooper (Met O 1)
CBS Working Group on the GTS, 9th Session	Geneva September	Mr D. McNaughton, AD Met O(TC)
CMM Study Group on Marine Climatology	Asheville, Ala. September	Mr D. J. Painting (Met O 3)
CAS Working Group on Long-range Forecasting	Geneva September	Mr D. E. Parker (Met O 13)
WMO Symposium on Probabilistic and Statistical Methods in Weather Forecasting	Nice September	Mr R. Dixon (Met O 11) Miss J. E. Woods (Met O 2) Mr R. H. Maryon (Met O 13)
Informal Planning Meeting, Integrated Systems Study II	Geneva September	Dr. R. L. Wiley, AD Met O(SD)
International Pyrheliometer Comparisons	Davos September–October	Mr J. H. Seymour (Met O 1)
Repair and calibration of Dobson ozone spectrophotometer on loan to Singapore Meteorological Service	Singapore October	Dr E. L. Simmons (Met O 15)
WMO Precipitation Enhancement Project Panel Meeting	Geneva October	Mr P. Goldsmith, DD Met O(P)
RA I Course on Care and Maintenance of the WF3 Radar	Nairobi October–December	Mr P. J. Collins (Met O 16) Mr G. D. Frost (Met O 16)
CIMO Meeting of Experts on Precipitation and Evaporation	Geneva November	Mr C. K. Folland (Met O 8)
WMO Regional Training Workshop/ Seminar on Basic Instrument Maintenance	Cairo November	Mr G. P. Sargent (Met O 16)
Inspection and calibration of Dobson ozone spectrophotometer	St Helena November–December	Mr J. M. Regan (Met O 15)
CBS Extraordinary Session	Geneva December	Mr F. H. Bushby, Director of Services Mr D. R. Grant, AD Met O(OP) Miss M. J. Atkins (Met O 2)

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

Subject	*Place and date*	*Attended by*
ICAO Area Forecast Panel, 1st Meeting	Montreal January	Mr R. J. Ogden, AD Met O(PS)
Helicopter Icing Trials Meeting	Ottawa January	Dr J. B. Andrews (Met O 9) Mr M. E. Crewe (Met O 9)
EEC Climatology Advisory Committee on Program Management	Brussels January, June, July, November	Mr A. Gilchrist, DD Met O(D)

Subject	*Place and date*	*Attended by*
NATO MCMG Sub-group II	Brussels January, October	Mr C. E. Goodison (Met O 5)
NATO MCMG Sub-group VII	Ramstein, Germany (F.R.) January	Mr J. G. Moore (Met O 2)
Discussions on Balloon-borne Instrument Techniques	Hamburg January	Dr P. J. Mason (Met O 14) Mr D. T. Tribble (Met O 14)
ESA Scientific and Technical Advisory Group to Meteorological Satellite Program Board	Paris January	Mr D. E. Miller, AD Met O(HA)
ESA Meteorological Satellite Program Board	Paris February, May, June, September	Dr K. H. Stewart, Director of Research
ESA Meteosat Operations Advisory Group	Darmstadt February, May, July	Mr A. I. Johnson (Met O 19)
ECMWF Observing System Impact Studies Group	Shinfield Park February	Mr D. B. Shaw (Met O 20)
Central Region Meteorological Training Program	Maastricht February	Mr K. Pollard (Met O 6)
NATO MCMG Rapporteurs Documents Review	Bracknell February	Dr J. I. Gibbs (Met O 6)
ECMWF Finance Committee, 21st Session	Shinfield Park February	Mr G. J. Day, AD Met O(IP) Mr J. W. Grant, Head of Met O 4
Subcommittee F of Offshore Industry Exploration and Production Forum	The Hague February	Mr R. M. Morris (Met O 7)
ICAO European Region, Working Group on Methods of Application Meteorology (MAPMET), 2nd, 3rd and 4th Meetings	Paris February, March, May	Mr P. D. Borrett (Met O 7)
IMCO Subcommittee on Safety of Navigation, 24th Session	London February	Captain G. A. White, Marine Superintendent
NATO—TWN ACEWEX Meeting	Traben-Trarbach, Germany (F.R.) February	Mr K. Pollard (Met O 6)
International Energy Authority Planning Meeting	Prestwick February	Dr P. J. Mason (Met O 14)
Visits to CDC Cybernet Computer Center for development of general circulation models for the CYBER 205 computer	Minneapolis, Minn. February, September	Dr P. W. White, AD Met O(FR) Dr A. J. Gadd, AD Met O(DC) and members of Met O 2, Met O 11, Met O 20
COST Project 72 Technical Committee on Measurement of Precipitation by Radar	Brussels March, May, November	Mr G. A. Clift (Met O 16)
NASA, First project meeting of the satellite-based Halogen Occultation Experiment (HALOE)	Langley, Va. March	Dr A. F. Tuck (Met O 15)
Comparison of wave forecast models of the North Sea	De Bilt, Netherlands March	Mr B. Golding (Met O 2)
NATO MCMG, 51st Working Group	Lisbon March	Dr J. I. Gibbs (Met O 6)
ESA Satellite Users Group	London March	Dr K. A. Browning (Met O RRL) Dr A. J. Eccleston (Met O RRL)
Meetings on European Meteorological Satellite System (EUMETSAT)	Paris March, May, June, September	Dr K. H. Stewart, Director of Research Mr J. W. Grant, Head of Met O 4
North Sea Meteorological Panel, 3rd Meeting	Paris April	Mr R. M. Morris (Met O 7)

Subject	*Place and date*	*Attended by*
Visit to Netherlands Meteorological Service and lecture to Dutch Physical Society, University of Utrecht	The Hague/Utrecht April	Sir John Mason, Director-General
Meeting of Directors of European Meteorological Services	Athens April	Sir John Mason, Director-General
ECMWF Council, 11th Session	Shinfield Park April	Sir John Mason, Director-General Mr G. J. Day, AD Met O(IP)
International Symposium on Hydrological Forecasting	Oxford April	Sir John Mason, Director-General Mr C. G. Collier (Met O RRL)
AFCENT Meteorological Committee, 28th Meeting	Heidelberg April	Mr J. Keers (Met O 6)
International Energy Agency Working Party on Task 5 of Solar Energy R & D	Brussels April	Mr B. R. May (Met O 1)
	Toronto October	Mr W. G. Durbin (Met O 1)
Liaison visits to Meteorological Services in Africa	Africa April—May	Mr D. J. Clark (Met O 17)
Pre-launch testing of Stratospheric Sounding Unit on NOAA-B	Western Test Range, USA	Dr J. Nash (Met O 19)
JASIN—Workshop on Balloon, Radiosonde and Surface Program	Hamburg April	Dr G. J. Jenkins (Met O 14) Dr K. L. Webber (Met O 14)
CEC Seminar on Radioactive Releases and their Dispersion in the Atmosphere following a Hypothetical Reactor Accident	Risø, Denmark April	Dr F. B. Smith (Met O 14)
Lecture at Louvain University, Belgium	Louvain April	Sir John Mason, Director-General
Conference on Petroleum and the Marine Environment (PETROMAR '80)	Monaco May	Mr R. M. Morris (Met O 7)
COST 43 Regional Sub-group for Azores/Biscay	Lisbon May	Dr R. E. W. Pettifer (Met O 16)
Seminar and Discussion on Cloud Physics Research	Cambridge, Mass. May	Dr P. Ryder, AD Met O(CP)
EEC Solar Energy R & D Program Project F	Julich, Germany (F.R.) May	Mr B. R. May (Met O 1)
	Brussels November	Mr W. G. Durbin (Met O 1)
Four Centres Telecommunications Meeting	Bracknell May	Mr D. McNaughton, AD Met O(TC) Dr D. N. Axford, AD Met O(OI)
Contract liaison for SAWS	Helsinki May, November	Mr J. E. Wright (Met O 16) Mr K. J. T. Sands (Met O 16) Mr P. C. Dibben (Met O 16)
C Met O SHAPE's Subcommittee	Belgium May	Mr D. Forsdyke (Met O 6)
ECMWF Scientific Advisory Committee	Shinfield Park May	Mr F. H. Bushby, Director of Services
NATO CDC Group of Experts on Fallout Warning Exercises	London May Bonn December	Mr P. G. Rackliff (Met O 6)
Visits to Amdahl and IBM computing establishments	N.Y./Calif. May–June	Mr P. Graystone, AD Met O(DP) Dr W. A. McIlveen (Met O 22)
ECMWF Technical Advisory Committee	Shinfield Park June	Mr D. H. Johnson, DD Met O(F) Dr R. L. Wiley, AD Met O(SD)
NATO MCMG, 37th Meeting	Washington, D.C. June	Mr I. J. W. Pothecary, AD Met O(DS)
Visit to Irish Meteorological Service	Dublin June	Mr F. H. Bushby, Director of Services

Subject	*Place and date*	*Attended by*
Liaison with USAF	Illinois June	Mr I. J. W. Pothecary, AD Met O(DS)
International Computer System Conference	Amsterdam June	Mr M. Phillips (Met O 12)
ECMWF Meeting of Forecasters to Assess Synoptic Quality of Products	Shinfield Park June	Mr J. Findlater (Met O 9)
AGARD Meeting on Interaction of Aircraft with Atmospheric Electricity	London June	Dr J. B. Andrews (Met O 9)
Conference on Preliminary FGGE Results	Bergen June	Mr A. C. Lorenc (Met O 20) Mr R. Swinbank (Met O 20)
Meetings of ESA Scatterometer Experts	Friedrichshafen June, September, November Hamburg September Paris December	Mr D. Offiler (Met O 19)
Invigilations of CAA Aircraft Technical Examinations	Fort Worth, Texas June–July	Mr J. Chester (Met O 7)
Joint Buoy Project Planning Meeting	Reykjavik July	Dr R. E. W. Pettifer (Met O 16)
International Conference on Dendroclimatology	Norwich July	Mr D. E. Parker (Met O 13)
JASIN—Workshop on Aircraft Program	Karlsruhe, Germany (F.R.) July	Dr C. J. Readings, AD Met O(BL) Mr S. Nicholls (MRF)
ECMWF Finance Committee, 22nd Session	Shinfield Park July	Mr G. J. Day, AD Met O(IP) Mr J. W. Grant, Head of Met O 4
International Symposium on Middle Atmosphere Dynamics and Transport	Urbana, Ill. July–August	Dr A. F. Tuck (Met O 15) Dr T. N. Palmer (Met O 20)
Sixth International Conference on Atmospheric Electricity	Manchester July–August	Sir John Mason, Director-General Dr P. Ryder, AD Met O(CP) Mr F. Rawlins (Met O 15)
Meeting of the European Geophysical Society	Budapest August	Dr R. Hide, Head of Met O 21
AFCENT Meteorological Sub-group Support to Land Forces	Traben-Trarbach, Germany (F.R.) August	Mr K. Pollard (Met O 6)
ESA Scientific and Technical Advisory Group	Paris September	Dr K. H. Stewart, Director of Research
Liaison on weather radar by invitation of Portuguese Government	Lisbon September	Mr G. A. Clift (Met O 16)
Thermal vacuum testing of NOAA-C spacecraft and Stratospheric Sounding Unit	Princeton, N.J. September	Mr B. Tonkinson (Met O 19)
Scientific Results of the GARP Atlantic Tropical Experiment	Kiev September	Dr P. R. Rowntree (Met O 20)
NATO Army Armaments Group AC/225, Panel XII, 17th Meeting	Brussels September	Mr P. G. Rackliff (Met O 6)
NATO SHAPE Meteorological Committee, 22nd Meeting	Hilversum September	Dr J. I. Gibbs (Met O 6) Mr D. Forsdyke (Met O 6)
JASIN—Workshop on the overall Meteorological Program	Southampton September	Dr C. J. Readings, AD Met O(BL) Dr G. J. Jenkins (Met O 14) Mr A. Grant (Met O 14) Mr S. Nicholls (MRF)
Nordiska Forskarkurser Lecture Course	Helsinki September	Dr F. B. Smith (Met O 14)
ECMWF Finance Committee, 23rd Session	Shinfield Park September	Mr G. J. Day, AD Met O(IP)

Subject	*Place and date*	*Attended by*
ECMWF Seminar on Data Assimilation	Shinfield Park September	Miss M. J. Atkins (Met O 2) Mr R. S. Bell (Met O 2) Mr G. J. Barnes (Met O 11) Mr J. Purser (Met O 11)
COST 43 Seminar, Management and Regional Sub-group Meetings	Bergen September	Dr D. N. Axford, AD Met O(OI) Dr R. E. W. Pettifer (Met O 16)
Technical inspection	Cyprus September	Mr P. J. Collins (Met O 16)
EEC Working Group on Comparison of Radiation Instruments	Brussels September	Mr J. H. Seymour (Met O 1)
ICAO Meteorological Advisory Group of European Air Navigation Planning Group	Paris September–October	Mr P. D. Borrett (Met O 7)
Sabbatical leave, Courant Institute	New York, N.Y. September–December	Dr M. J. P. Cullen (Met O 11)
Visit to International Condensation Nuclei Workshop, Desert Research Institute	Reno, Nev. October	Mr M. Kitchen (Met O 15)
Visit to meteorological institutions of the Chinese Academy of Sciences and the Chinese Meteorological Service under the auspices of the Royal Society and the Chinese Academy of Sciences	Peking/Shanghai/ Nanking/Hong Kong October	Sir John Mason, Director-General Mr D. E. Jones, AD Met O(CF)
European Working Group on Limited Area Modelling, 2nd Meeting	Dublin October	Mr A. Gilchrist, DD Met O(D)
NATO MCMG, 52nd Working Group	Brussels October	Dr J. I. Gibbs (Met O 6)
Organization Review	GMCO Traben-Trarbach/ HQ RAF Germany, Rheindahlen/HQ 1(BR) Corps, Bielefeld October	Mr I. J. W. Pothecary, AD Met O(DS)
Working Group on Numerical Experimentation, 19th Session	Corvallis, Oreg. October	Mr F. H. Bushby, Director of Services
International intercomparison of aircraft probes used to measure cloud liquid water content	Ottawa October	Mr M. Kitchen (Met O 15)
International Conference on Climate and Offshore Energy Resources	London October	Mr D. M. Houghton, AD Met O(SC)
NOAA discussions on processing satellite sounding data	Washington, D.C./ Madison, Wis. October	Mr D. Jerrett (Met O 19)
International Conference on Climate and Offshore Energy Resources	London October	Dr C. J. Readings, AD Met O(BL)
ECMWF Council, 12th Session	Shinfield Park November	Sir John Mason, Director-General Mr F. R. Howell, Sec Met O Mr G. J. Day, AD Met O(IP)
NATO/CCMS 11th International Technical Meeting on Air Pollution Modelling and its Application	Amsterdam November	Dr F. B. Smith (Met O 14)
International Experimental Study of Convective Boundary Layers—KONTUR Planning Meeting	Hamburg November	Dr P. Ryder, AD Met O(CP) Dr C. J. Readings, AD Met O(BL)
CAA Advisory Team concerning Air Safety Matters	Argentina November	Mr B. D. Hunt (Met O 7)

Subject	*Place and date*	*Attended by*
International Symposium on Wind Propulsion of Commercial Ships	London November	Mr D. J. Painting (Met O 3) Mr J. E. Atkins (Met O 3)
Course on Satellite Meteorology, International School of Meteorology of the Mediterranean	Erice, Sicily November	Dr J. R. Eyre (Met O 19)
Science Team Meeting for the UARS Project	Greenbelt, Md. November	Dr A. J. Gadd, AD Met O(DC)
Training in CDC computer software	Minneapolis, Minn. November–December	Dr S. R. Mattingley (Met O 12) Mr R. Stephens (Met O 12)
COST 43 Management Committee	Brussels December	Dr R. E. W. Pettifer, AD Met O(OI)

The following staff were released by the Office during 1980 for service with international and other organizations:

Mr R. P. Rumney	HSO	Grassland Research Institute
Mr B. J. Mott	TTO III	Government of Vanuatu
Mr P. F. Emery	SSO	Government of Vanuatu
Mr D. B. Shaw	PSO	ECMWF
Mr K. F. Silvester	SO	WMO, Geneva
Mr A. L. Douglas	SO	International Aeradio Ltd
Mr P. L. Lavington	HSO	International Aeradio Ltd
Mr K. Sadler	HSO	International Aeradio Ltd

Staff returning from international and other seconded appointments were:

Mr G. D. Whitelock	ASO	The Royal Society Aldabra Research Station
Mr R. W. Lunnon	SSO	European Space Agency
Mr C. Temperton	SSO	ECMWF
Mr A. C. Lorenc	SSO	ECMWF
Mr C. S. Clarke	HSO	ECMWF
Mr M. Leeson	ASO	British Antarctic Survey
Mr J. A. Nelson	TTO III	New Hebrides Condominium
Mr E. R. Thomas	SSO	New Hebrides Condominium
Mr A. Stemmler	HSO	Brunei Government
Mr P. L. Stewart	HSO	International Aeradio Ltd

STAFF HONOURS AND DISTINCTIONS

The City University, London, conferred on the Director-General the degree of Doctor of Science, *honoris causa*, on 1 December 1980.

The following honours were announced in the Queen's Birthday Honours List 1980:

Mr S. R. Smith was appointed as a Member of the Order of the British Empire.

Mr C. L. Hawson was appointed to the Imperial Service Order.

Mr W. G. Estcourt and Mr E. G. Helyer were both awarded the Imperial Service Medal.

The L. G. Groves Memorial Prize for Meteorology was awarded to Dr P. J. Mason and Mr T. Denholm received the L. G. Groves Second Memorial Award.

APPENDIX I

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

ADAMS, R. J., Ph.D.; Available spray days 1979/80 season. London, British Crop Protection Council, BCPC 17th Annual Review of Herbicide Usage, 1980, 1980.

ADAMS, R. J., Ph.D.; Towards an objective method of categorising a given season in terms of suitability for spraying. London, British Crop Protection Council, BCPC 16th Annual Review of Herbicide Usage, 1979, 1980.

ADAMS, R. J., Ph.D. and MUNRO, I.; Methods of short term irrigation planning. ADAS Booklet B2118, 1980.

ATKINS, N. J.; Interesting cloud formation seen on satellite imagery. *Meteorol Mag*, **109**, 1980, 85–88.

ATKINS, J. E. and PAINTING, D. J., B.Sc.; Wind propulsion of ships—climatological factors. London, Royal Institution of Naval Architects, Symposium on Wind Propulsion of Commercial Ships, London, Nov. 4–6 1980, 1980.

AXFORD, D. N., Ph.D., C.Eng., M.I.E.E.; Data acquisition, processing and local archiving techniques for meteorological measurements. Geneva, WMO, Instruments and observing methods, Report No. 1, 1980, 221–226.

AXFORD, D. N., Ph.D., C.Eng., M.I.E.E. and PETTIFER, R. E. W., Ph.D.; The meteorological contribution to COST-43 by the UK—a further progress report. *Proc COST-43 Seminar, Bergen*, 1980.

BATTYE, D. G. H., M.Sc.; A note on singularities. *Meteorol Mag*, **109**, 1980, 358–362.

BENNETTS, D. A., Ph.D. and GLOSTER, J.; Bimodal droplet size distributions within cumulus clouds. UGGI/IAMAP, Communications à la VIII^ème^ conférence internationale sur la physique des nuages, Vol. I, 1980, 129–132.

BENNETTS, D. A., Ph.D. and RAWLINS, F., B.A.; A joint numerical and observational study of cumulonimbus clouds. UGGI/IAMAP, Communications à la VIII^ème^ conférence internationale sur la physique des nuages, Vol. II, 1980, 461–464.

BENNETTS, D. A., Ph.D. and RYDER, P., Ph.D.; An investigation of a frontal zone. UGGI/IAMAP, Communications à la VIII^ème^ conférence internationale sur la physique des nuages, Vol. II, 1980, 589–592.

BENNETTS, D. A., Ph.D., RYDER, P., Ph.D., LATHAM, J. and STROMBERG, I. M.; The electric field structure of convective cloud. University of Manchester Institute of Science and Technology, Abstracts [from the] VI International Conference on Atmospheric Electricity, 28 July–1 Aug. 1980, Session XI-6, 1980.

BIRD, L. G.; Irrigating the potato crop. *ADAS Bull, Harrogate*, January 1980.

BLAIR, R. H.; An index of Scottish summers. *Weather*, 35, 1980, 39–42.

BOLTON, J. A., M.Sc.; The sensitivity of the 5-level general circulation model to changes in the parametrization of convection. ICSU/WMO, GARP Working Group on Numerical Experimentation, Report No. 21, Geneva, 1980, 72–74.

BOOTH, B. J.; Unusual wave flow over the Midlands. *Meteorol Mag*, **109**, 1980, 313–324.

BRADBURY, T. A. M.; Meteorological conditions favourable for long closed circuit soaring flights over England. *Aerorevue, Zurich*, 4/1980, 226–230.

BRADBURY, T. A. M.; A met report on the lee waves of April 18. *Sailpl Gliding*, 31, 1980, 160–161.

BROWN, R., B.Sc.; A microphysical model of radiation fog. UGGI/IAMAP, Communications à la VIII^ème^ conférence internationale sur la physique des nuages, Vol. II, 1980, 313–316.

BROWN, R., B.Sc.; A numerical study of radiation fog with an explicit formulation of the microphysics. *Q J R Meteorol Soc*, **106**, 1980, 781–802.

BROWN, R., B.Sc.; Some field observations of radiation fog and their interpretation. UGGI/IAMAP, Communications à la VIII^{ème} conférence internationale sur la physique des nuages, Vol. II, 1980, 309–312.

BROWNING, K. A., Ph.D., D.I.C., F.R.S.; Radar as part of an integrated system for measuring and forecasting rain in the UK: progress and plans. *Weather*, 35, 1980, 94–104.

BROWNING, K. A., Ph.D., D.I.C., F.R.S.; The South Wales floods of late December 1979. *Weather*, 35, 1980, 202–203.

BROWNING, K. A., Ph.D., D.I.C., F.R.S.; Structure, mechanism and prediction of orthographically enhanced rain in Britain. ICSU/WMO, GARP Publication No. 23, 1980, 85–114.

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TYLDESLEY, J. B., B.A. and THOMPSON, N., Ph.D.; Forecasting *Septoria nodorum* on winter wheat in England and Wales. *Plant Path*, **29**, 1980, 9–20.

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APPENDIX II

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

ADAMS, R. J., M.Sc., Ph.D

Available spraying days and the application of herbicides. *Chemical Industry Day, Weed Research Organization, Yarnton, Oxford.* 28 February.

ALLARDICE, J. G.

Out and about in Glasgow. *BBC Radio Clyde.* 30 January.

The work of Glasgow Weather Centre. *BBC Radio Scotland.* 18 September.

ALLEN, J. J.

Meteorology for yachtsmen. *Two courses of five lectures at the Adult Further Education Centres, Guildford and Fleet, Hants.* January to March.

ATKINS, J. E. and PAINTING, D. J., B.Sc.

Wind propulsion of ships—climatological factors. *Symposium on Wind Propulsion of Commercial Ships, Royal Institution of Naval Architects, London.* 4 November.

BACON, J. G., B.Sc.

1980 summer weather.

Interview on 'Nationwide', BBC 1 (TV). 2 July.

BBC 1 (TV) program 'What's on Wogan'. 12 July.

Patterns in science. *BBC TV Schools Program.* 26 November and 5 December.

BENNETTS, D. A., Ph.D.

The interaction of convective and symmetric instabilities. *Seminar at Atmospheric Physics Department, Imperial College, London.* 1 May.

Conditional symmetric instability and the development of convection by differential advection. *Royal Meteorological Society Specialist Group on Dynamical Problems. Meteorological Office College, Shinfield Park.* 15 May.

Two lectures: (1) Bimodal droplet size distributions within cumulus clouds, (2) A joint numerical and observational study of cumulonimbus cloud. *VIII International Cloud Physics Conference, Clermont Ferrand, France.* 15–19 July.

BEST, K. E.

Weather patterns related to road dangers. *BBC Radio Solent.* 2 January.

Discussion on the introduction of SATFAX at Southampton Weather Centre. *BBC TV (South).* 14 March.

BLACKALL, R. M., B.Sc.

Lectures and instruction at the Royal Meteorological Society Field Study Course on 'Mountain Weather'. Betws-y-Coed, Gwynedd. 25 July to 8 August.

BOND, J. E., B.Sc.

Meteorological aspects of the Fastnet storm. *Welsh Centre of the Royal Meteorological Society and the Penarth Yacht Club.* 21 February.

Satellite and radar observations during the Fastnet storm. *School of Navigation, City of London Polytechnic.* 25 February.

BRAND, J. N.

Weather and hill walking. *Guide Association National Outdoor Activities Training Conference, University of Warwick, Coventry.* 12 April.

BROWN, A. A.

Meteorology. *Series of 10 lectures, Winter term, Extra-Mural Department, University of Birmingham.* 29 September to 8 December.

BROWN, D. W.

General meteorology.

Course of 10 lectures to the Workers' Educational Association, Pewsey, Wilts. January to March.

Course of 10 lectures to the Workers' Educational Association, Swindon Adult Education Centre. September to November.

Course of 10 lectures to the Workers' Educational Association, Trowbridge Teachers' Centre. September to November.

Meteorology for yachtsmen.

Course of 10 lectures, Chippenham Technical College. January to March.

Course of 10 lectures, Jefferies School, Swindon. October to March.

Weather for hang-gliding. *Talk to the Thames Valley Hang-gliding Club, Pinge Wood, Berks.* 27 August.

Meteorology with regard to nuclear fallout. *Five lectures for the Home Office Warning and Monitoring, Shewsbury, Carmarthen, Bristol, Exeter and Yeovil.* September.

BROWN, R., B.Sc.

Some field observations of radiation fog and their interpretation. *VIII International Cloud Physics Conference, Clermont Ferrand, France.* 15–19 July.

Observation and modelling of the microphysical properties of radiation fog. *Royal Meteorological Society Discussion Meeting, London.* 10 December.

BROWNING, K. A., Ph.D., D.I.C., F.R.S.

Weather forecasting using radar and satellites. *Institute of Electronic and Radio Engineers, South Midlands Section, Malvern.* 16 January.

Local weather forecasting.

Applied Physics Seminary Series, Royal Signals and Radar Establishment, Malvern. 28 February.

Review lecture, Royal Society, London. 6 March.

Local weather forecasting: prospects for the next decade. *Hydrological Group of the Institution of Civil Engineers, South Wales Association, Malvern.* 17 May.

The Meteorological Office weather radar program. *Welsh Water Authority, Brecon.* 8 September.

The use of radar for the study of bird and insect flight and related weather phenomena: comments of a radar meteorologist. *Joint Discussion Meeting, Royal Meteorological Society/British Trust for Ornithology/Royal Entomological Society, London.* 19 November.

BRUCE, W. J.

Weather forecasting today. *Oxford University Air Squadron.* 19 May.

CARPENTER, K. M., Ph.D.

Cloud-induced low-level convergence. *Royal Meteorological Society Specialist Group on Dynamical Problems, Meteorological Office College, Shinfield Park.* 15 May.

Progress in the simulation of surface winds over Oahu. *IEA Wind Power Project Progress Meeting, ERA Technology Ltd, Leatherhead, Surrey.* 2 June.

CAUGHEY, S. J., Ph.D.

The convective boundary layer. *Department of Applied Mathematics and Theoretical Physics Seminar, Cambridge.* 30 May.

Two lectures: (1) Multi-level turbulence probe studies of the structure of small cumulus cloud, (2) Simultaneous measurements of the turbulent and microphysical structure of nocturnal stratocumulus cloud. *VIII International Cloud Physics Conference, Clermont Ferrand, France.* 15–19 July.

CLOUGH, S. A., Ph.D.

Two-dimensional chemical modelling in the Meteorological Office. *WMO Workshop on Two-dimensional Ozone-layer Modelling, Toronto.* 29 January.

COLLIER, C. G., B.Sc., A.R.C.S.
The North West Weather Radar Project: the establishment of a weather radar system for hydrological forecasting. *Oxford Symposium on Hydrological Forecasting*. 15 April.
A radar and satellite rain-monitoring system. *Institution of Civil Engineers, Hydrological Group Summer Meeting, Malvern*. 24 September.
Design and operation of the Meteorological Office weather radar network. *Joint Meeting of the Royal Meteorological Society Specialist Group on Surface-based Remote Sensing and the Remote Sensing Society, Malvern*. 26 November.
CRABTREE, J., B.A.
Meteorology: nuclear, biological and chemical warfare. *Two lectures to the Scientific Advisers' Advanced Course at the Defence, Nuclear, Biological and Chemical Centre, Winterbourne Gunner, Wilts*. 12 to 16 May.

DAVIES, T., Ph.D.
Weather forecasting—past, present and future. *British Association for Young Scientists, Basingstoke*. 3 March.
DENT, L., B.Sc.
Meteorology. *Series of three lectures to the Air Transport Operations and Planning Course, College of Aeronautics, Cranfield*. 27 November.
DICKINSON, A., Ph.D.
Experience of the British Meteorological Office using the ECMWF computing facilities. *Computing Representatives' Meeting, ECMWF, Shinfield Park*. 21 October.
DIXON, R., B.Sc.
Modification of numerical forecast height errors by the GMDH [Group Method of Data Handling]. *WMO Symposium on 'Probabilistic and Statistical Methods in Weather Forecasting', Nice, France*. 9 September.
DURRANT, M. J.
Weather. *Talk to the Chiltern Wives' Club, Woodcote, Oxon*. 8 September.

EMERY, P. F.
The occluded front. *Royal Meteorological Society, North-East Centre, Durham*. 14 March.
EYRE, J. R., D.Phil.
Calibration and some exploratory uses of Meteosat water-vapour channel imagery. *Second Meteosat Scientific Users' Meeting, London*. 12 March.
Quantitative use of water-vapour imagery. *International School of Meteorology of the Mediterranean, Erice, Sicily*. 14 November.

FILE, R. F.
The development of severe weather in remote and mountainous areas. *Royal Military Academy, Sandhurst*. 5 and 8 February.
FISH, M. J.
Life and work of television weathermen. *Liverpool Astronomical Society*. 15 February.
Depressions. *BBC Radio Schools program*. 24 April.
FLOOD, C. R., M.A.
Economic implications of climate and climatic change. *Open Meeting, Meteorological Office, Edinburgh*. 22 April.
FOLLAND, C. K., B.Sc., M.Inst.P.
The application of meteorological information to flood design. *Institution of Civil Engineers Conference on 'Flood Studies Report—Five Years on', Manchester University*. 22 July.
FOOT, J. S., Ph.D.
Aircraft observations of the radiative properties of cirrus cloud. *Royal Meteorological Society Discussion Meeting, London*. 10 December.

GEORGE, D. J.

Weather for mountaineers. *Royal Meteorological Society/Sports Council Field Course, National Centre for Mountain Activities, Capel Curig, Gwynedd.* 19–25 October.

GILCHRIST, A., M.A.

Prediction using general circulation models. *International Conference on Climate and Offshore Energy Sources, London.* 22 October.

GILES, W.G.

Weather forecasting. *Royal Aeronautical Society, Boscombe Down, Wilts.* 19 February.

Weather forecasting with special reference to satellite analysis.

Geographic Society, University of Bristol. 17 October.

University of Wales, Cardiff. 30 October.

GOLDING, B., B.Sc.

An introduction to the Meteorological Office wave-forecast model. *Oceanographic Technical Advisory Group of the UK Offshore Operators Association, London.* 28 February.

GOLDSMITH, P., M.A.

Man's influence on climate. *Atomic Energy Research Establishment, Harwell, Oxon.* 19 June.

GREGSON, J. A.

Use of satellite pictures in weather forecasting. *Lecture to Senior School students, Royal Meteorological Society, Scottish Centre, Edinburgh.* 26 September.

HARDY, R. N., B.Sc.

Synoptic aspects of the severe winter of 1978/9. *Royal Meteorological Society Discussion Meeting, London.* 16 January.

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

Magnetic flux linkage of a moving medium: a theorem and applications to planetary interior and magnetic fields.

Bullard Symposium, University of California, San Diego. 11 January.

Mathematics Department, University College, London. 29 February.

Department of Applied Mathematics and Theoretical Physics, University of Cambridge. 7 March.

Culham Laboratory, Near Abingdon, Oxon. 12 March.

British Theoretical Mechanics Colloquium, Cambridge. 27 March.

Fourth UK Geophysical Assembly, Birmingham. 16 April.

European Geophysical Society, Budapest. 25 August.

Planetary interiors and magnetic fields.

Department of Mathematics, University of St Andrews. 30 January.

Geophysics Department, University of Edinburgh. 31 January.

Rotating fluids in planetary physics.

Department of Mathematics, Heriot-Watt University, Edinburgh. 1 February.

Fourth UK Geophysical Assembly, Birmingham. 15 April.

School of Mathematics and Physics, University of Sussex, Brighton. 27 November.

University of Liverpool. 1 December.

Fluctuations in the angular momentum of the atmosphere during FGGE and variations in the length of the day. *Fourth UK Geophysical Assembly, Birmingham.* 14 April.

Jupiter and Saturn: giant magnetic rotating-fluid planets. *Halley Lecture, University of Oxford.* 5 May.

On Giuseppe Campani, the rotation of Jupiter and the heliocentric system. *Symposium on 'Aristarchus of Samos', Samos, Greece.* 17 June.

Cowling's theorem. *Mathematics Department, University College, London.* 31 October.

HOOPER, A. H.

Automation of upper-air measurements. *Technical Conference on 'Evolution and Standardization of Observing Techniques in the Light of Automation', Norrköping, Sweden.* 1–5 September.

HOPKINS, J. S., B.Sc., A.R.C.S.

Summer weather in Scotland. *BBC Radio Scotland.* 28 July.

Meteorological data for solar and wind energy applications. *Scottish Solar Group, Edinburgh.* 12 November.

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

Long-range forecasting. *Radio interview, Swedish Broadcasting Service.* 2 January.

Long-range forecasting for Scotland. *Interview on BBC Radio Highland.* 15 January.

Severe winters—is early warning possible? *Royal Meteorological Society Discussion Meeting, London.* 16 January.

Methods of long-range forecasting. *Interview on BBC Radio Wales 'Keynote' program.* 25 January.

Climate and climatic change. *Interview on BBC World Service.* 28 January.

Possibilities for the long-term prediction of weather windows. *Oceanology International Conference, Brighton.* 4 March.

Analysis, interpretation and application of global sea surface temperature data. *Meeting on 'Oceanographic Programs in Relation to Climate', Royal Society, London.* 28 March.

Coastal meteorology. *Queen's University, Belfast.* 29 March.

Towards a new Ice Age? *Discussion on BBC World Service.* 10 May.

Are we expecting a wet summer? *'Good Morning Scotland', BBC Radio Scotland.* 14 July.

The farming summer. *Radio 210 (Thames Valley Broadcasting Ltd).* 31 July.

Towards better long-range forecasts. *Seminar, Atmospheric Physics Group, Imperial College, London.* 27 November.

Long-range forecasting—science or sorcery? *Henley Lectures Society.* 10 December.

HUNT, G. S. F.

Weather and water activities. *Guide Association National Outdoor Activities Training Conference, University of Warwick, Coventry.* 12 April.

HUNT, R. D., B.Sc.

Here is the weather forecast. *A lecture to staff members at the Post Office Telecommunication Headquarters, London.* 22 January.

JENKINS, G. J., Ph.D.

Lectures and instruction at the Royal Meteorological Society Field Study Course on 'Weather Science and Forecasting', Nettlecombe, Somerset. 20–27 August.

Kites and balloons in boundary-layer research. *Royal Meteorological Society, Scottish Centre, Glasgow.* 12 December.

South Wales experiment. *Recorded interview for 'Wales Today' program, BBC TV.* 14 May.

Some aspects of research in the Boundary Layer Branch of the Meteorological Office. *Institute of Meteorology and Arid Land Studies, Jeddah, Saudi Arabia.* 29 November.

JENKINS, I., B.A.

Snowfall of 1978. *Royal Meteorological Society, Welsh Centre, Cardiff.* 21 February.

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

Aspects of current research in climatology.

Conference, Institute of British Geographers, University of Lancaster. 5 January.

Conference, Mathematical Society, University of Kent, Canterbury. 17 January.

JOHNSON, A. I., B.Sc.

The use of satellites in weather forecasting. *Royal Meteorological Society Sixth Form Lecture, London.* 13 and 14 November.

JONAS, P. R., Ph.D., D.I.C.

Laboratory and numerical studies of baroclinic waves in an annulus.

Mathematics Department, University of Exeter. 29 May.

Mathematics Department, University of Bristol. 27 November.

JONES, D. E., M.Sc., D.I.C., A.R.C.S.
The Meteorological Office operational numerical weather prediction system.
Two lectures at the Institute of Atmospheric Physics, Chinese Academy of Science, Peking. 17 October.
Department of Meteorology, University of Nanking. 19 October.
Royal Observatory, Hong Kong. 24 October.
Modern methods of weather prediction. *Institution of Electrical Engineers, North Eastern Centre, Newcastle.* 8 December.

KEEPING, W. N. C., B.A.
Performance of general circulation models in the stratosphere and the influence of the upper boundary conditions. *Royal Meteorological Society Specialist Group on Dynamical Problems, ECMWF, Shinfield Park.* 23 October.

LARKE, P. R.
Compositing data from a network of radars. *Joint Meeting of the Royal Meteorological Society Specialist Group on Surface-based Remote Sensings and the Remote Sensing Society, Malvern.* 26 November.
LORENC, A. C., B.A.
The ECMWF data-assimilation scheme. *International Conference on 'Preliminary FGGE Data Analysis and Results', Bergen, Norway.* 25 June.
LYNE, W. H., Ph.D.
The Meteorological Office data assimilation scheme for FGGE. *International Conference on 'Preliminary FGGE Data Analysis and Results', Bergen, Norway.* 27 June.

MASON, SIR JOHN, C.B., D.Sc., F.R.S.
Recent advances in numerical weather prediction. *Royal Signals and Radar Establishment, Malvern.* 4 February.
Recent developments in the forecasting of weather and climate with giant computers. *Foundation Lecture, The City University, London.* 20 February.
The atmospheres of the planets.
University of Cambridge, Physics Society. 28 February.
University of Durham. 23 April.
Numerical modelling of the global climate and of some possible natural and man-made changes. *National Institute of Agricultural Engineering, Silsoe, Beds.* 10 March.
Computer modelling of the global climate and its changes.
Dutch Physical Society, University of Utrecht. 8 April.
University of Louvain, Belgium. 30 April.
Numerical modelling of the global climate with the aid of giant computers. *Public Lecture at University of Leeds.* 27 October.
Man's influence on the climate. *The Colin Roscoe Lecture, University of Manchester.* 28 October.
Recent developments in weather forecasting with the aid of giant computers. *Daresbury Laboratory, Warrington, Cheshire.* 29 October.
MASON, P. J., Ph.D.
Flow over hills. *International Energy Agency Planning Meeting, Prestwick, Ayrshire.* 18 February.
Two-dimensional large eddy model of a convective planetary boundary layer. *University of Reading.* 14 March.
MENMUIR, P., B.Sc.
The use of radar in weather forecasting. *Interview on BBC Radio Wales.* 23 January.
Interview on ATV 'Midlands Today' program, discussing a topical sequence of radar rainfall pictures. 21 May.
MILLER, D. E., B.A.
Weather satellites. *Royal Society of Arts, London.* 21 April.

MORRIS, R. M., B.Sc.

Contribution to Fastnet Race Seminar. *School of Navigation, City of London Polytechnic.* 25 February.

Weather forecasting—improved accuracy for offshore surveyors and operators. *Oceanology International Conference, Brighton.* 4 March.

Understanding the weather forecast. *Scottish Offshore Training Association, Aberdeen.* 13 March.

Weather during the Fastnet Race 1979. *School of Navigation, City of London Polytechnic.* 24 March.

The value of weather services to the public. *The Royal Overseas League, London.* 9 June.

Weather forecasting for offshore operations. *Europec '80 Conference, Earls Court, London.* 21 October.

NICHOLASS, C. A., B.Sc.

The radar/rain-gauge archive and its applications. *Institution of Civil Engineers, Hydrological Group Summer Meeting, Malvern.* 24 September.

NICHOLLS, S.

Energy and momentum budget measurements from aircraft data. *Marine Physics Seminar, Institute of Oceanographic Sciences, Wormley, Surrey.* 10 July.

OGDEN, R. J., B.Sc.

Meteorological services for the public. *Interview on London Broadcasting Company radio program 'Decision Makers'.* 12 May.

OWENS, R. G., B.Sc

Short-range forecasting for hydrology using weather radar. *Institution of Civil Engineers, Hydrological Group Summer Meeting, Malvern.* 24 September.

Display of weather radar data for use by forecasters. *Joint Meeting of the Royal Meteorological Society Specialist Group on Surface-based Remote Sensing and the Remote Sensing Society, Malvern.* 26 November.

PALMER, T. N., D.Phil.

Observations of Eliassen-Palm cross-sections in the stratosphere. *Royal Meteorological Society Specialist Group on Dynamical Problems, Reading.* 12 March.

Observation and simulation of a stratospheric sudden warming. *Fourth UK Geophysical Assembly, Birmingham.* 16 April.

PARKER, D. E., B.Sc.

Exploring the world's climate. *Royal Meteorological Society Sixth Form Lecture, University of Nottingham.* 26 November.

PARKER, G. H., B.Sc.

Meteorology.

School of Navigation, City of London Polytechnic. 4, 11 and 18 February.

Merton Yachtmaster's Course. 19 February.

Weather and sailing. *City of London Polytechnic School of Navigation Course, Newport, Isle of Wight.* 24–31 May.

PARTINGTON, S. J. G.

Weather of the summer of 1980. *BBC TV (Northern Ireland).* 5 September.

PEPPERDINE, E. C.

The weather. *A series of phone-in programs on BBC Radio Nottingham.* 16 and 23 May and 8 July.

Producing a weather forecast. *Midlands Group, Royal Observer Corps, Nottingham University.* 19 May.

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

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.* 6 and 7 February.

Lasers and their uses in atmospheric sciences. *Recorded interview on Anglia TV.* 7 February.

PICK, D. R., D.Phil.

Early results based on the stratospheric channels of TOVS [TIROS Operational Vertical Sounder] on the TIROS-N series of operational satellites. *Symposium on 'Systems Performance and Early Results of the Global Observing System for FGGE', 23rd COSPAR Meeting, Budapest.* 6 June.

PORTER, M. R.

The work of the Meteorological Office. *Federation of Business and Professional Women, Grangemouth, Fife.* 14 October.

RACKLIFF, P. G.

Meteorological manning and co-ordination for nuclear fallout exercises. *Southern Sector Warning Officers' Conference, Malvern.* 29 March.

RAWLINS, F., B.Sc.

A numerical study of thunderstorm electrification using a three-dimensional model incorporating the ice phase. *Sixth International Conference on Atmospheric Electricity, Manchester.* 28 July to 1 August.

READINGS, C. J., Ph.D.

Numerical study of the atmospheric boundary layer. *KONTUR Meeting, Max-Planck Institut für Meteorologie, Hamburg.* 25 November.

South Wales experiment. *Recorded interview for BBC Radio Wales.* 13 May.

RIDDAWAY, R. W., Ph.D.

Numerical weather prediction. *University of Sussex, Brighton.* 6 November.

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

Field studies of nocturnal stratocumulus. *Royal Meteorological Society Discussion Meeting, London.* 10 December.

ROWE, J.

Meteorological aspects of drainage design. *Drainage Course, Planning and Transport Research and Computation (International) Co. Ltd, London.* 21 April.

ROWNTREE, P. R., Ph.D.

Plans for ocean and sea-ice modelling. *Meeting on 'Oceanographic Programs in Relation to Climate', Royal Society, London.* 28 March.

Energy utilization and its climatic effects. *Operational Research Society, London.* 21 April.

Modelled atmospheric responses to North Atlantic Ocean temperature anomalies. *North Atlantic Pilot Ocean Monitoring Study Meeting, Institute for Oceanographic Sciences, Wormley, Surrey.* 16 June.

Large-scale modelling. *International Conference on Scientific Results of GATE, Kiev, Ukraine.* 18 September.

RYDER, P., Ph.D.

The electric structure of pre-thunderstorm convective cloud. *Institute of Physics Lecture, Culham Laboratory, Culham, Near Abingdon, Oxon.* 27 February.

Cloud physics research in the Meteorological Office. *Air Force Geophysical Laboratory Seminar, Cambridge, Mass., USA.* 12 May.

An investigation of a frontal zone. *VIII International Cloud Physics Conference, Clermont Ferrand, France.* 15–19 July.

The electric field structure of convective cloud. *Sixth International Conference on Atmospheric Electricity, Manchester.* 28 July to 1 August.

SCOTT, J.

Weather and the building industry. *Federation of Building Trades Employers, Northampton.* 21 March.

Contribution to discussion program on weather. *Yorkshire TV.* 15 July.

Weather and industry. *Association of American Military Engineers, London.* 16 October.

SHAW, D. B., B.Sc.
Data network studies at the Meteorological Office. *International Conference on 'Preliminary FGGE Data Analysis and Results', Bergen, Norway.* 25 June.

SIMMONS, E. L., D.Phil.
Measurements of NO_2 vertical column. *Department of Atmospheric Physics, University of Oxford.* 29 May.

SLINGO, A., Ph.D.
High-resolution radiation and microphysical observations of nocturnal stratocumulus. *VIII International Cloud Physics Conference, Clermont Ferrand, France.* 15–19 July.
The influence of bulk and microphysical structure on the radiative properties of clouds. *ECMWF, Shinfield Park.* 16 October.
Computation and observations of radiative flux in layer clouds. *Royal Meteorological Society Discussion Meeting, London.* 10 December.

SLINGO, JULIA M., B.Sc.
Interactive cloud and radiation in the Meteorological Office general circulation models. *ECMWF Workshop on Radiation/Clouds in Numerical Models. ECMWF, Shinfield Park.* 15 October.

SMITH, C. V., M.A., B.Sc.
Hydrometeorological aspects of the 1978/79 winter. *Royal Meteorological Society Discussion Meeting, London.* 16 January.

SMITH, F. B., Ph.D.
Diffusion of pollution in the atmosphere. *Three lectures to an M.Sc. Course, University of Surrey, Guildford.* 1, 8 and 15 February.
The influence of meteorological factors on radioactive dosages and deposition following an accidental release. *Seminar on Radioactive Releases and their Dispersion in the Atmosphere following a Hypothetical Reactor Accident, Risø, Denmark.* 22–25 April.
Probabilistic determination of long-range dispersion. *School of Agriculture, University of Nottingham.* 17–18 July.
Dispersion of pollution in the atmosphere. *Four lectures at the Nordiska Forskarkurser Lecture Course, Finnish Meteorological Institute, Helsinki.* 2–11 September.
The statistics of precipitation scavenging during long-range transport. *Eleventh NATO/CCMS International Technical Meeting on 'Air Pollution Modelling and its Application', Amsterdam.* 24–27 November.

SPALDING, T. R., L.I.M.A.
Mountain weather. *Course of lectures at the Royal Meteorological Society Field Study Course, Betws-y-Coed, Gwynedd.* 2–8 August.

SPARKS, W. R., B.Sc.
Weather and plant disease. *Joint Meeting of Royal Meteorological Society and the Botanical Society of the British Isles, University College, London.* 26 April.

STARR, J. R., Ph.D.
Physics of rain, snow and hail. *Blackheath Scientific Society.* 19 February.
Climate and the need for animal housing. *Easter School, University of Nottingham, Sutton Bonington, Notts.* 14 April.
Weather and animal well-being. *British Veterinary Association Congress, University of York.* 14 September.
Animal health. *Interview for BBC Radio Scotland.* 14 September.
Weather for farmers and growers. *Discussion on Southern TV 'Farming' program.* 21 September.

SWINBANK, R., B.A.
The atmospheric circulation during two Special Observing Periods in 1979. *Fourth UK Geophysical Assembly, Birmingham.* 16 April.
The global circulation during the Special Observing Periods of FGGE. *International Conference on 'Preliminary FGGE Data Analysis and Results', Bergen, Norway.* 26 June.

THOMPSON, N., Ph.D.
Physical aspects of crop spraying. *Weed Research Organization, Yarnton, Oxford.* 1 February.

TUCK, A. F., Ph.D.

The transport of water vapour between the stratosphere and tropopause in a general circulation model. *Middle Atmosphere Program Symposium, Urbana, Ill., USA.* 28 July to 1 August.

An investigation of the ability of a radiative photochemical model to reproduce the temporal variations of ozone and temperature in the stratosphere. *Quadrennial Ozone Symposium, Boulder, Col., USA.* 4–9 August.

TURNER, J., B.Sc.

Techniques of numerical weather prediction. *British Computer Society, Guildford Branch.* 17 January.

WHITE, A. A., Ph.D.

Lateral boundary conditions for quasi-geostrophic models. *Royal Meteorological Society Specialist Group on Dynamical Problems, ECMWF, Shinfield Park.* 23 October.

Numerical simulation of baroclinic flow in a rotating annulus. *Atmospheric Physics Group, Department of Physics, Imperial College, London.* 13 November.

WICKHAM, P. G., M.A.

Forecasting methods. *A course of six lectures to M.Sc. Students, Department of Geophysics, University of Reading.* January to February.

APPENDIX III

PUBLICATIONS

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

The following publications have been issued; those published by Her Majesty's Stationery Office are marked with an asterisk.

PERIODICAL

Annual

*Annual Report on the Meteorological Office 1979**
Annual Weather Summary (London)
Annual Weather Summary (Southampton)
Annual Weather Summary (UK)

Quarterly

*Marine Observer**
Stratospheric charts for the Northern Hemisphere, 2nd, 3rd and 4th quarters, 1979
Stratospheric charts for the Southern Hemisphere, 2nd, 3rd and 4th quarters, 1979

Monthly

Anomaly maps (London Weather Centre)
Comprehensive data for Abbotsinch
Daily Weather Diary (Southampton)
Daily Weather Summary (Newcastle and NE England)
Degree days (Heathrow)
Full tabulation of anemograms (London Weather Centre)
*Meteorological Magazine**
Monthly analysis of rainfall during the working day (Manchester Weather Centre)
Monthly (coloured) *Ice Maps* (to October 1980)
*Monthly Summary of the Daily Weather Report** (discontinued after December 1980)
Monthly Supplement to the *Daily Weather Summary* (Newcastle and NE England)
*Monthly Weather Report** (to November 1979)
Monthly Weather Summary (Central southern England)
Monthly Weather Summary (London)
Monthly Weather Summary (Nottingham Weather Centre)
Monthly Weather Summary (SE England)
Monthly Weather Summary (Southampton)
Monthly Weather Summary (Southern Sussex)
Monthly Weather Summary (UK)
*Monthly Weather Survey and Prospects** (discontinued after December 1980)
Rainfall analysis (London Weather Centre)
Relative humidity and vapour pressure at Abbotsinch
Statistics of inclement weather in the NE Midlands (Nottingham Weather Centre)
Sunshine tabulation (London Weather Centre)
Temperature at Abbotsinch

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 Aerological Record** (discontinued after 31 December 1980)
Daily Remarks (London Weather Centre)
*Daily Weather Report** (discontinued after 31 December 1980)
Daily Weather Summary (London Weather Centre)
Shipping Chart and Forecast (Southampton Weather Centre) (Monday–Friday)
Shipping Chart and Forecast (Glasgow Weather Centre)

SERIAL

Climatological Memorandum No. 110: *Tables of total cloud amount for the United Kingdom 1957–76.*

Climatological Memorandum No. 111: *Rate of change of air temperature in the United Kingdom in time-scales of between 1 and 6 hours.*

Hydrological Memorandum No. 43: *Revised monthly and annual totals of rainfall representative of Kew, Surrey for 1697–1870 and an updated analysis for 1697–1976.*

Tables of temperature, relative humidity, precipitation and sunshine for the world. Part 1: *North America and Greenland (including Hawaii and Bermuda).**

OCCASIONAL

Dew-point tables for screen readings.
Map of duration of rainfall in hours, 1941–70, United Kingdom (scale 1:2 million).
Monthly and annual totals of rainfall for the United Kingdom, 1971.
Solar radiation data for the United Kingdom, 1951–75.
Weather plotting chart for Yachtsmen.

APPENDIX IV

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
AGARD	Advisory Group on Aerospace Research and Development
AIDS	Aircraft Inertial Data Systems
ALPEX	Alpine Experiment
ASR	Altimeter Setting Region
ATWS	Automatic Telephone Weather Service
AUTOCOM	Automated Telecommunication Complex
AUTOPREP	Automatic Message Preparation Equipment
AWRE	Atomic Weapons Research Establishment
CAA	Civil Aviation Authority
CAeM	Commission for Aeronautical Meteorology (WMO)
CAMFAX	Civil Aviation Meteorological Facsimile Network
CAS	Commission for Atmospheric Sciences (WMO)
CBS	Commission for Basic Systems (WMO)
CCMS	Committee on the Challenges to Modern Society
CDC	Control Data Corporation
CDEM	Crop Disease Environment Monitor
CEC	Commission of the European Communities
CFO	Central Forecasting Office
CIMO	Commission for Instruments and Methods of Observation (WMO)
CMM	Commission for Maritime Meteorology (WMO)
COSMOS	Meteorological Office computing system
COSPAR	Committee for Space Research (ICSU)
COST	European Co-operation in Science and Technology
CRDF	Cathode Ray Direction Finding
DALE	Digital Anemograph Logging Equipment
DAFS	Department of Agriculture and Fisheries for Scotland
EC	Executive Committee (WMO)
ECMWF	European Centre for Medium Range Weather Forecasts
EEC	European Economic Community
ESA	European Space Agency
EUMETSAT	European Meteorological Satellite System
FGGE	First GARP Global Experiment (WMO/ICSU)
GARP	Global Atmospheric Research Program (WMO/ICSU)
GATE	GARP Atlantic Tropical Experiment (WMO/ICSU)
GDPS	Global Data Processing System (WMO)
GOS	Global Observing System (WMO)
GTS	Global Telecommunication System (WMO)

IAMAP	International Association of Meteorology and Atmospheric Physics (IUGG)
IBA	Independent Broadcasting Authority
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)
LCBR	Laser Cloud-base Recorder
LWC	London Weather Centre
MAFF	Ministry of Agriculture, Fisheries and Food
MCMG	Military Committee Meteorological Group (NATO)
METAG	Meteorological Advisory Group (ICAO)
Met O RRL	Meteorological Office Radar Research Laboratory, Malvern
MMO	Main Meteorological Office
MOD(PE)	Ministry of Defence (Procurement Executive)
MOLFAX	Meteorological Office Land-line Facsimile Network
MORECS	Meteorological Office Rainfall and Evaporation Calculation System
MOTNE	Meteorological Operational Teleprinter Network in Europe
MOWOS	Meteorological Office Weather Observing System
MRF	Meteorological Research Flight
MTER	Magnetic Tape Event Recorder
NAOS	North Atlantic Ocean Stations
NASA	National Aeronautics and Space Administration, USA
NATO	North Atlantic Treaty Organization
NERC	Natural Environment Research Council
NMC	National Meteorological Centre
NOAA	National Oceanic and Atmospheric Administration, USA
OASYS	Outstation Automatic System
ODAS	Ocean Data Acquisition System
OWS	Ocean Weather Ship, ocean weather station
PFO	Principal Forecasting Office
PROMET	Provision of Meteorological Information required before and during flight
RAE	Royal Aircraft Establishment
RA I	Regional Association I—Africa (WMO)
RMC	Regional Meteorological Centre
RTH	Regional Telecommunication Hub
RVR	Runway Visual Range
SATFAX	Satellite Facsimile Network
SAWS	Synoptic Automatic Weather Stations
SHAPE	Supreme Headquarters Allied Powers in Europe
SSU	Stratospheric Sounding Unit
TCU	Telecommunication Control Unit
TTO	Telecommunication Technical Officer
TWN	Teleprinter Weather Network

UARS	Upper Atmosphere Research Satellite
UKWMO	United Kingdom Warning and Monitoring Organization
USAF	United States Air Force
VCP	Voluntary Co-operation Program (WMO)
VDU	Visual Display Unit
VOF	Voluntary Observing Fleet
WMO	World Meteorological Organization
WWW	World Weather Watch (WMO)

Printed in England for Her Majestys' Stationery Office at the Alden Press, Oxford.
Dd 716691 C11 11/82.

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ISBN 0 11 400333 5