The Met. Office

# Annual Review

1991/92

# The Meteorological Office

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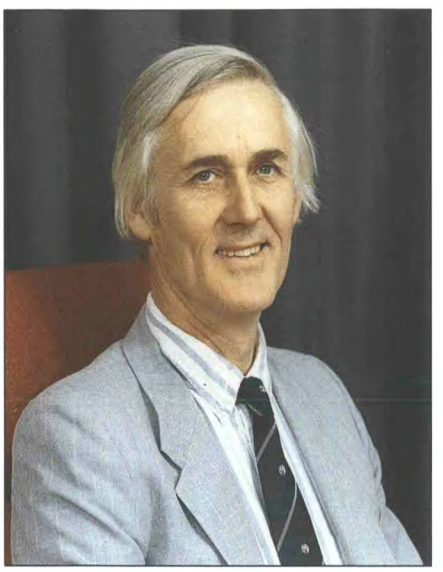
# *Review* 1991/92

# Foreword



In my foreword to this first Annual Review since succeeding Sir John Houghton as Chief Executive on 1 January 1992 I must begin by saying how impressed I have been by the Meteorological Office, and how welcoming and helpful everyone has been. Sir John added his distinctive contributions to those of his illustrious predecessors from Admiral FitzRoy onwards in leading the Meteorological Office towards its present high standing, and in encouraging the friendliness and dedication of its staff. I shall work hard to continue this tradition.
It is quite a challenge learning about the Meteorological Office's many functions and to visit even a small fraction of its sites. As well as making a start on the visits, I have also had meetings with some of the Government departments, businesses and research organizations whom we serve, and with whom we collaborate.

The Meteorological Office is first and foremost an outstandingly successful operational organization. Our experience is mainly in meteorology, but our customers have wider environmental interests for which we can provide expertise, such as air quality, sea ice, waves, surges of coastal waters and soon, currents and temperature structure of the deep ocean. The Meteorological Office is distinguished by being:

- a research organization of the highest international standard,
- a worldwide observing and communications organization, working within the World Meteorological Organization (WMO) and EUMETSAT (the organization responsible for managing Europe's meteorological satellite activities), and contributing its own high-quality data (based in part on the work of many voluntary observers),
- unique for its thorough validation of data and its comprehensive archives,
- a world-class operational centre for numerical modelling and computation of atmospheric and oceanic processes.
- an integrated operational organization serving the meteorological and other environmentally related needs of the defence services, aviation, commerce and the general public,
- an organization which practices good management, strong financial control, and high standards of training,
- staffed by highly professional and well motivated personnel, about three-quarters of whom are trained meteorologists. (Of these a high proportion also have expertise in business, technology and other sciences.)

In the past year the Meteorological Office has continued to make further progress in meeting the demanding targets that are set each year in consultation with government, and in reaching the objectives set when the Office moved to Executive Agency status in 1990. These will be reconsidered, when the Framework Document is reviewed in 1992/93.

The accuracy of UK forecasts has continued to improve beyond the already high figure of 84%, achieved for the early-evening BBC Radio 4 forecast for the next day's weather. The accuracy of this forecast is continually reviewed at top management level, and fresh initiatives have been introduced this year to improve verification of a range of other forecast products and services.
The National Severe Weather Warning Service, introduced after 1987, is functioning well.
We have recently introduced a 30-day forecasting service for commercial customers known as The Monthly Prospect. This successful service provides a significant improvement on simply using climate records, and has a substantial commercial value. At the same time we are also concentrating on very-short-term local forecasts, particularly where hazardous weather is involved, and their dissemination to a range of customers.
I have learnt about the ever increasing number of our commercial products and have been pleased to hear about our many satisfied customers, for example the world's airlines, a majority of which

use Bracknell's forecasts for their international flights. At the other end of the scale I have been impressed by the hard work of sales staff in regional Weather Centres winning many small contracts for providing local weather information. All these customers make a vital financial contribution to offsetting the Office's core costs.

Invoiced revenue from Commercial Services showed a substantial increase this year, despite adverse effects of the continuing recession. This is an excellent result.

An important development in 1991 was the announcement by HM Government of a reduction in the size of the Armed Forces. This will lead to a reduction in numbers of Meteorological Office personnel as airfields are closed under the Options for Change programme. However, the United Kingdom's defence will continue to rely on the most advanced technology. There will be a continuing need for the very best local and global forecasting, including, for the Royal Navy, ocean forecasting using new models and new sea-surface data from satellites.

My visits to RAF stations confirmed that defence applications of meteorology present a great technical challenge which provide a constant spur to improve our forecasting. Improvements in dissemination of weather information to aircrew and other operational staff are essential if the full value of currently available information is to be realized. Such improvements will be achieved wherever possible, by incorporating information, in the Automated Low Flying Enquiry and Notification System (ALFENS), which is being developed under National Air Traffic Services auspices. At a number of non-ALFENS sites derivations of the Meteorological Information System (MIST) will be employed. There is spin-off into commercial applications.

The Research Directorate, comprising three Divisions, has continued to maintain its standards of excellence and to show its commitment to applying its expertise to improve the Office's operations and providing advice to government on environmental change, both on a global and local scale. We congratulate Dr. Keith Browning of the Research Directorate on his election as a Foreign Associate Member to the US National Academy of Engineering for his pioneering research on weather radar and its application for nowcasting – which was further developed in 1991 with the expansion of the weather radar network covering Scotland.

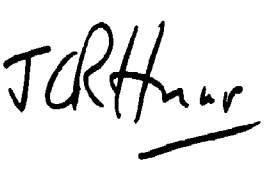
In June last year the Research Divisions, in close collaboration with the Central Forecasting Office, implemented a new higher-resolution numerical weather prediction model on the CrayY-MP8 computer, leading to further improvements in forecast accuracy. The new model is the culmination of 100 man-years of research and extensive operational testing. It will continue to be improved.

A version with 16 km resolution is also being developed to provide more-detailed weather patterns over the United Kingdom or over other regional areas anywhere in the world.

Increasingly, much of the research activity in the Office is planned to be part of wider projects involving other European and international research groups.

It is our intention that establishment of the European Climate Support Network, planned for 1992, will reinforce these activities in the field of research, prediction, and monitoring of climate. Other European and international initiatives are described in this review. Particularly noteworthy is our participation in the formation of an Economic Interest Grouping with other European Meteorological Services in order to promote development of commercial services on a European scale, that becomes possible with the advent of the Single Market.

Some new initiatives of an organizational nature are just beginning to make an impact; some of the more important examples are the Financial And Management Information System (FAMIS), improvements in project management, introduction of Total Quality principles for the systematic incremental improvement of performance and organization of many aspects of the Meteorological Office, and the introduction of advanced 'workstations' in the Central Forecasting Office and at outstations to replace paper charts wherever possible. Other important innovations relate to changes in personnel policy and improved internal communications aimed at enhancing staff morale. During the 1990s, the Meteorological Office is concerned with two major projects: expanding the computational power of the Office (and, probably, changing the nature of the computers used) and the introduction of a new generation of satellites for operational meteorology and climatology.



J.C.R. Hunt
Chief Executive, 30th June 1992

*Chief Executive and Directors, from left to right Michael Bowack, Bernard Herdan, Julian Hunt CE, Peter Ryder and Paul Mason.*

Public Met. Services

CAA

Defence

Commercial Services

DOE Climate Research

## CENTRAL SUPPORT OPERATIONS

Observations
Communications and Computing
Central Forecasting
International Operations
Research and Development
Finance and Administration

# Who we are

The Meteorological Office provides weather and environment-related services to five major customer groups: the general public, defence, civil aviation, industry and commerce, and the Department of the Environment for the climate research programme. The Office has the capability to forecast weather anywhere in the world, for example, severe weather in the United Kingdom, movement of tropical storms, detailed flying conditions for aviation worldwide, weather for offshore operations, and drought in Africa.

## ORGANIZATION

The Meteorological Office is headed by the Chief Executive, Professor Julian Hunt, who together with four Directors form the Management Board which runs the organization. Each has responsibilities as follows:

**Julian Hunt:** *Chief Executive.* Responsible to the Secretary of State for Defence for the efficient and effective management of the Agency.

**Peter Ryder:** *Director of Operations.* Responsible for provision of observations, instrumentation, communications, system developments, technical support, data processing, computer systems and operations of central and Defence forecasting offices, supply of meteorological services to the Civil Aviation Authority and the public, co-ordination of international and European activities of the Office, and maintenance of the National Meteorological Library and National Meteorological Archive.

**Paul Mason:** *Director of Research.* Responsible for planning and implementing the Office's research programme and for the DOE-funded climate prediction research. (**Keith Browning** was Director of Research until the end of September when he left for a year's sabbatical at the Joint Centre for Mesoscale Meteorology, University of Reading.)

**Bernard Herdan:** *Director of Commercial Services.* Responsible for the marketing, sales and provision of services to industry and commerce.

**Michael Bowack:** *Director of Finance and Administration.* Responsible for finance, planning, personnel, training, legal and administration services.

The four Directorates are divided into nine Divisions to meet the special needs of customers and core activities efficiently and effectively.

A variety of specialized services are provided in the United Kingdom from Weather Centres to a wide range of customers. Services for military customers are provided from airfields, and from offices in Cyprus, Germany, Gibraltar, and the South Atlantic.

## PERSONNEL

Recruits mainly come direct from school, higher education institutes, and universities. Many attend our Training College early in their careers, or go to other institutions for further training depending on the required specialism. Some staff remain working in a chosen area of interest and become promoted to senior positions. Others develop their careers by applying their experience and skills in a variety of disciplines in the Office. Of the 2500 staff, about half are located at, or close to, the headquarters in Bracknell; the remainder are located at around 100 other sites. Staff training, primarily at the Meteorological Office College at Shinfield Park, accounts for some 3% of the Office's expenditure. However, some of this cost is offset by the revenue obtained by the College from training and services supplied to other international meteorological services.

*The Met. Office College at Shinfield Park near Reading.*

*The dramatic changes in East–West relationships and the collapse of the Soviet Union has led NATO to develop a new strategy to counter envisaged threats. Adapting to this change will require more mobile forces capable of reacting quickly to any threat to NATO. Meteorological support to NATO's new force structure is a vital element of the requirement and the Met. Office has been playing a prominent role in developing new arrangements.*

*Courtsey British Airways*

*The Met. Office continues to support CAA, ICAO and CAeM to improve efficiency and safety in civil aviation.*

*Main Photograph: Sgt Rick Brewell*

# Customer services

All our services require comprehensive observations from around the world, efficient telecommunications systems and powerful computers to process numerical models. Human interpretation of the results is also essential to maintaining the quality of services. Modern technologies, such as personal computers and fax are also bringing higher levels of customer service to all types of user.

## SERVICES FOR DEFENCE

The Defence Services Division continued to work to challenging standards, and other service provision targets. Meteorological services for the Royal Air Force, military ranges and the Army Air Corps (AAC) at over 50 locations in the United Kingdom and overseas remained a key activity, with over 550 staff directly committed to meeting defence requirements. In response to 'Options for Change', two offices were closed but a new forecasting office for the AAC was opened at Dishforth in Yorkshire. These changes provided the stimulus for a more efficient and better managed network of offices in the United Kingdom by aligning operational, technical and financial responsibilities.

Overseas a uniformed officer of the Mobile Meteorological Unit (MMU) has been based at Incirlik Air Base, Turkey, since July 1991. The forecaster is committed to the support of Operation WARDEN and works closely with staff of the US Weather Service.

A review of the meteorological training material for aircrew (both RAF and AAC) came to fruition with the publication of a consolidated training manual for RAF Support Command (RAFSC). The 25 chapters cover every aspect of concern to military aircrew and were prepared by Defence Services staff working with the subject coordinator at RAF Cranwell.

Forecasts for military ranges are essential for the safe and efficient conduct of trials which often involve new weapon systems. Defence Services carries out research and development leading to new services to meet these requirements. For example, the wind structure near the surface is very important in predicting the propagation of noise produced by explosions and the testing of ballistic weapons at military ranges, a particular problem for P&EE (Proof and Experimental Establishment) Shoeburyness, where noise complaints have been received from locations as far as 50 km away. To assist the range authorities in minimizing noise nuisance, an assessment model has been run routinely by the range met. office. A new model, developed with the University of Salford, was installed at Shoeburyness met. office for a validation trial and remote monitoring units have been set up on the range to give noise measurements along a 10 km line. It is expected that the new model will overcome current deficiencies.

An assessment of the performance of the Office's very-high-resolution mesoscale model for predicting elevated radio ducts was completed. The results showed, for example, it is capable of predicting some ducting situations. The main limiting factor was found to be insufficient representation of the initial vertical temperature and humidity profile of the atmosphere. With the expected improvements in initialization techniques, performance will be significantly enhanced.

## SERVICES FOR CIVIL AVIATION

Throughout the year the Met. Office continued actively supporting the Civil Aviation Authority (CAA), the International Civil Aviation Organization (ICAO) and the Commission of Aeronautical Meteorology (CAeM). Work was carried out under these authorities with the common aim of improving the efficiency and safety of all forms of civil aviation.


*Mr Bernard Herdan (Met. Office) and Mr Tom Murphy (CAA) signing an agreement at the Royal Aeronautical Society.*

The two World Area Forecast Centres (WAFC), Bracknell and Washington, carried out a study of the improvement in the accuracy of aviation wind information – a result of changing the grid spacing of aviation data with the introduction of new models in both the United Kingdom and USA. As a result of this study the airlines will decide on a 135 km grid-point spacing, compared to the existing 5° X 2.5° (long./lat.) grid. This higher resolution of the data will provide more-accurate wind and temperature data to the airlines to the economic benefit of flight planning.

Development of automatic production of significant weather charts for route planning continued. This will eventually enable WAFC Bracknell to provide them for the globe, and enable the ICAO planning towards the final stage of the World Area Forecast Service to be pursued. In this context the Met. Office was part of an ICAO Regional working group looking at the proposed dissemination of aviation meteorological data via satellite. The concept, approved within the European Region, was extended to enable users in Africa to benefit from the service as well. If finally approved, such a service could start in '93/94.

## COMMERCIAL SERVICES

As well as supporting Defence and the CAA, the Met. Office serves a wide range of customers, which includes radio and TV, local authorities, the food retailing industry, and offshore oil exploration, as well as the general public.

### TV and Radio Services.

Both of the business units through whom the Met. Office supplies services to TV and radio have recently been involved in major studio developments. International Weather Productions (IWP) moved into their new premises at the end of the last financial year and from there, now produce the ITV national weather forecast, and weather services to Granada


*The BBC unit moved into new purpose-designed studios at BBC TV Centre, from where all national television, radio and World Service broadcasts are made.*
*The BBC World Service TV programmes are a new market for the Met. Office. Initially, the BBC team covered Europe with international highlights of the weather, then included Asia in October, and plan to extend the coverage to Africa during 1992. BBC weather presenters now produce 70 domestic TV broadcasts, and 111 World Service broadcasts a week.*

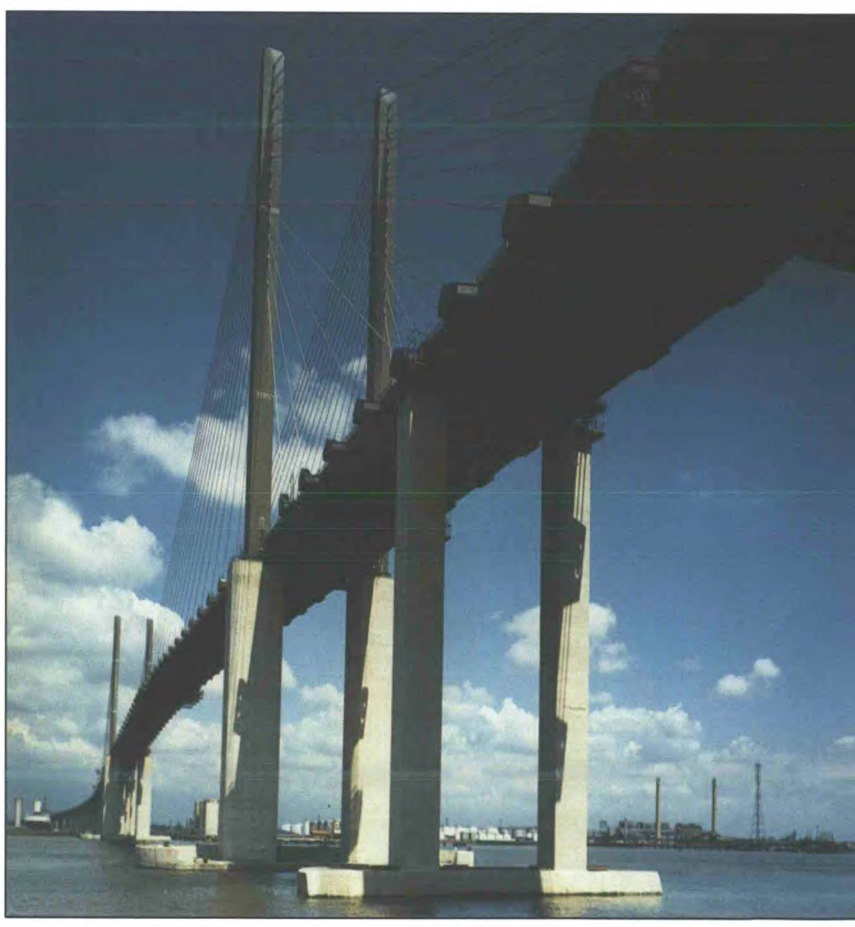
Television through IMAGINET, a co-development with the Chelsea Multi-Media Group. IWP now also supplies the B-Sky-B weather service and plans to launch a number of new services in the United Kingdom, Europe and overseas during the next year.

Over the year some 35 000 broadcasts with 25 000 scripts were prepared by our fourteen Weather Centres for more than forty regional or local radio stations.

The Office has recently begun to include an estimate of the probability of precipitation in its forecasts. The Central Forecasting Office issues such forecasts for tomorrow about 12 hours in advance and for today about 1 hour in advance of the period from 0600 to 1800. Checks for 12 stations shows that the use of the probabilities in these forecasts was well matched to the actual occurrence of rain over the year. Here, as elsewhere, the verification results provide information from which the forecaster can learn how to make further improvements in performance.

### Growth in Press Services.

A new commercial deal signed with Computer News Services (CNS) enables the Met. Office to concentrate on daily provision of tabular and graphical information in a single package to serve all the Press customers. CNS prepare camera-ready listings of sport, financial and TV information for most major newspapers, and under this agreement get weather data from the Met. Office, while taking the responsibility for designing and marketing the specialized weather graphics.



*This year a five-year contract was awarded to the Met. Office by the Dartford River Crossing Company to supply OpenBridge services for winter maintenance planning. An innovation is a service incorporating a wind-risk element to aid the drivers of high-sided vehicles.*

## Transport Services.

Trials are being undertaken to reduce the manual effort involved in the OpenRoad services. Using forecast data directly from the Mesoscale model is producing encouraging results. Taken together with the widespread use of road sensors, the new, demanding, target of 87% accuracy of forecasting road icing was exceeded. This is of major importance to local authorities, 95% of whom now use the OpenRoad service to keep highways clear and cut costs during winter.
This year, a new service which forecasts the type of snow has been taken up by British Rail.
The mild winter, though, has meant that it has not yet been tested in anger.

## Offshore and marine services.

The Met. Office has continued to support the offshore industry mainly in the North Sea, with services provided from our Aberdeen Weather Centre and staff detached to offshore rigs.
The Office secured a new contract with Total Oil and strengthened business with other leading companies during the year, while developing its capabilities in other parts of the world.
The Marine Products Group quality control observations from vessels and installations at sea and store them. Services for design and operational planning are produced from these data, along with post-operational performance.

The North European Storm Study (NESS), a hindcasting design study sponsored by major North Sea operators, is archived here. There has been a steady growth in the number of ships that take the ship routeing service as the effects of the Gulf war recede. The Met. Office was appointed to route the *QE2* around the world during its 90-day tour.

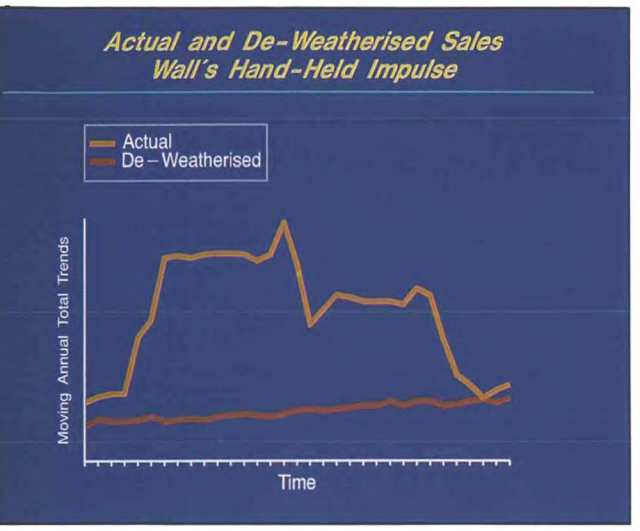
## The intelligent use of weather consultancy.

Using forecast information to predict sales is now demonstrably more fruitful than relying on historical comparisons. The Weather Initiative (TWI) has been active in promoting the need for all branches of British industry to take the weather sensitivity of their products seriously.
An important component in the success of TWI's approach is The Monthly Prospect, developed by the Hadley Centre, which provides clear and concise weather information for periods of six to fifteen days and sixteen to thirty days ahead.

A report produced jointly with Nielsen, the international market research organization, highlighted the subtle relationships between sales and weather parameters, such as those found in the hot- and cold-beverage markets.
Accurate, quantified data enables purchasing and distribution decisions to be made with higher levels of confidence.

*Heeremac's giant crane DB102 lifting the Shell Gannet jacket from a barge* *Courtesy Heerema Offshore Construction Group BV*

Wall's Ice Cream uses carefully constructed mathematical models to remove the effects of weather and reveal the underlying performance of products, such as their response to promotions. With particularly sensitive goods such as ice cream, improvements in market share due to marketing activity, or demographic trends, can be completely obscured if weather effects are not removed from sales figures.




*Courtesy Wall's Ice-cream*

A new consultancy, Metstar (Met. Scientific and Technical Advice and Research) was introduced during the financial year to make available the skills of Met. Office research staff to industry and commerce. The service enables Met. Office experts to contract out some of their time to particular projects and seeks commissioned research and development mainly in the fields of hydrometeorology, nowcasting, remote sensing, atmospheric dispersion and climate change. Contracts were won during the year from EUMETSAT, the States of Jersey Public Services Department, Thompson–CSF, Logica and Scicon.

*Harlaw Academy, winners of a weather observing project sponsored by Aberdeen Weather Centre to raise awareness of meteorology in the community.*

### Education.

The appointment of a new Education Business Development manager during the year has enabled us to apply more resources to improving the educational materials available to schools. Teachers' resource packs are planned for the National Curriculum Key Stage 1 (5- to 7-year olds) and Key Stage 2 (7- to 11-year olds). The packs are designed to be cross-curricular, and are scheduled to be available in October 1992. The Office is also taking part in a joint project with the BBC and Educational Publishing to produce a schools weather video programme and teacher resource pack suitable for National Curriculum Key Stages 3 and 4.

### Sport and leisure.

Essential to the Met. Office's success is the regional Weather Centres' local knowledge. Nowhere is this more true than in sporting activities, such as racing, tennis, rugby and football. West Ham United Football Club obtains a 24-hour forecast from London Weather Centre, which enables them to forecast attendances and give ample notice to the police, so that the club does not incur unnecessary charges and saving the public unnecessary travelling.

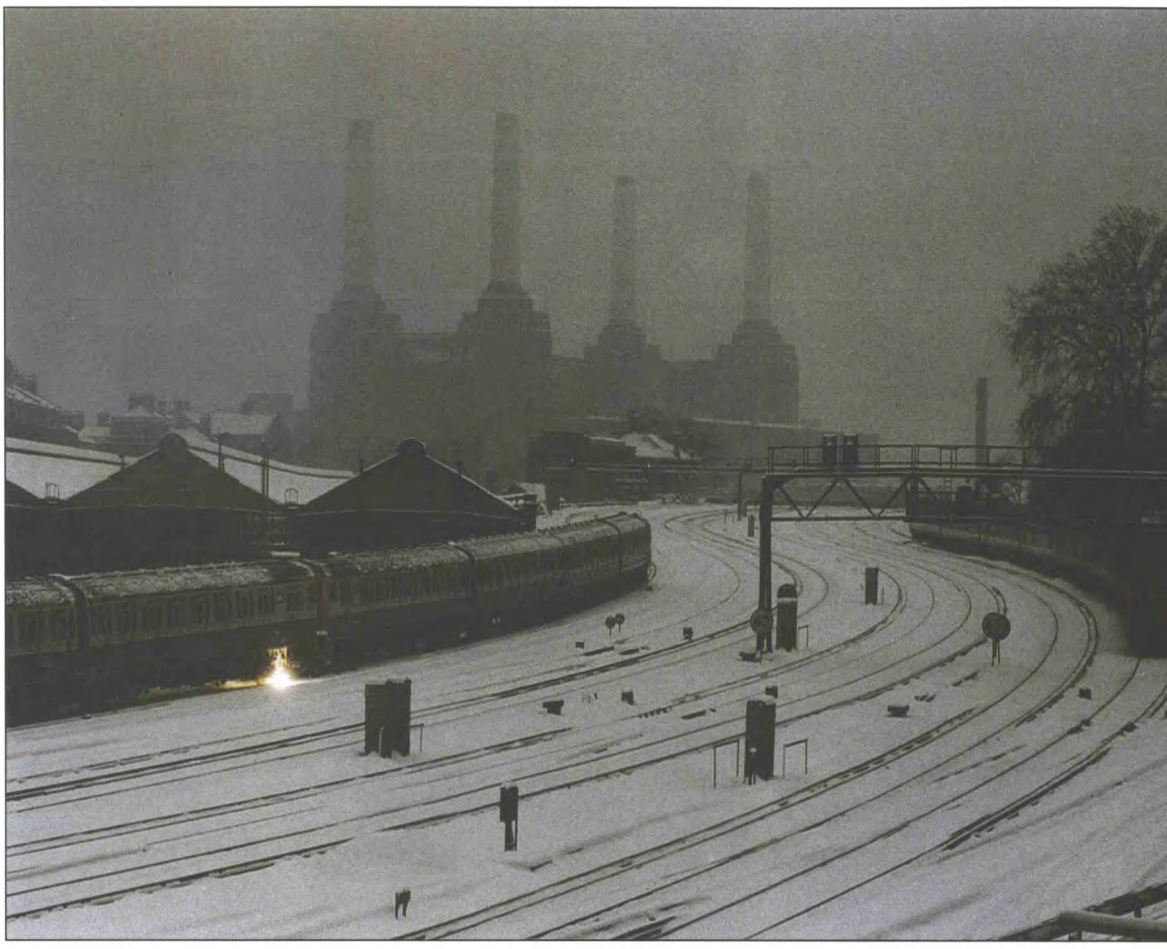
## SERVICES TO THE PUBLIC

Although many of the services to the public are provided on a commercial basis, some are funded by the Government and provided in the national interest. These Public Meteorological Services are mainly concerned with the provision of warnings and advice in emergency situations.

### The National Severe Weather Warning Service.

This service provides a comprehensive warning system for emergency authorities and the public in the event of severe weather. Early warnings, in some cases issued three or four days in advance, are sent out to emergency authorities, and these are kept up to date on a daily basis. The public are kept informed through scheduled weather forecasts and issues of News Releases. Within a few hours of the event 'FLASH' warning messages are issued to the emergency authorities and for public broadcast by the media. These give as much detail as possible about areas to be affected and likely severity.

Unlike the previous winter, 1991/92 was generally mild and this was reflected by the issue of only one early warning and one 'FLASH' message in relation to snow conditions. Severe gales were generally confined to the north with the main hazard in the south being provided by foggy spells in mid-December and late January. Although not damaging in itself, widespread and



*The severe cold of February 1991 was not repeated this winter.* *Courtsey Richard Watt*

dense fog can cause more disruption and risk to life through its effect on human activities than the more dramatic conditions associated with severe gales or snow.

## Storm Tide Warning Service.

This service provides information to the relevant authorities on the expected heights of wind-driven storm surges, with forecast wave-height data now also provided for many regions. Warnings are issued when danger levels are likely to be exceeded, but the winter season 1991/92 was relatively uneventful with the lowest number of east coast warnings for at least 20 years.

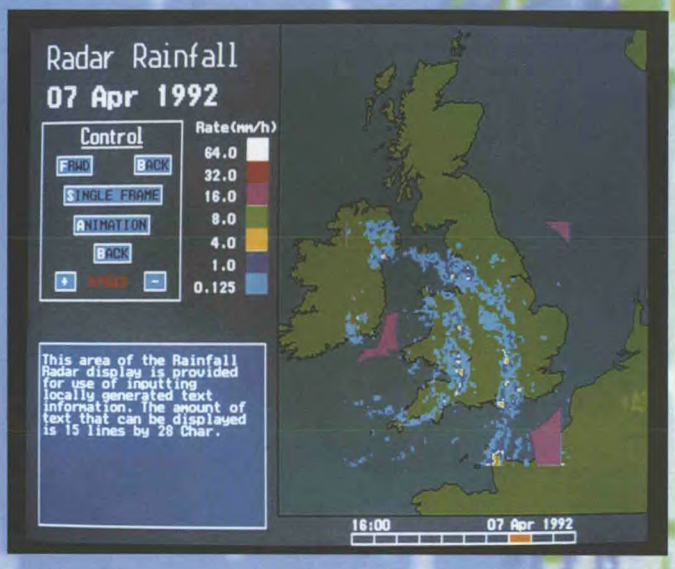
## Pollution Emergencies.

Weather advice is provided to the relevant authorities to assist them in dealing with pollution incidents. These might be connected with the release of toxic chemicals, volcanic debris, or radioactive material into the atmosphere, or with the spillage of oil onto the ocean. Forecast tracks of atmospheric pollutants can also be provided, and a nuclear accident model (NAME) is available to predict the movement and deposition of radioactive material globally and regionally. The nuclear incident at Sosnovyy Bor, near St. Petersburg, in March 1992 provided an opportunity to test the model in an operational context.

## Shipping.

Forecasts and warnings for the North Atlantic and coastal waters around the British Isles are provided within the requirements of the international Convention for the Safety of Life at Sea, and are a long-established part of the Public Met. Service. In February 1992 the Global Maritime Distress and Safety System regulations came into operation, and associated forecasts and warnings were supplied for distribution by satellite and land-based radio services.

*Rough Sea!*




*MIST*
*A frame taken from an animated sequence of radar-derived rainfalls. The sequence gives the speed and direction of rainfall movement as well as rainfall intensity.*

# Technology transfer

Even in meteorology, there are opportunities to transfer some technologies whose development have been driven by the needs of Defence, into the public sector and, eventually the private sector. New technologies also provide a driving force to transfer existing services from one delivery medium to another, with corresponding improvements in customer service.

## MIST — PC delivery of services.

At least 10 years ago, Defence Services saw the need to be able to communicate with their military customers using computers. The prototype PC-based system, developed in-house, was the Meteorological Information System (MIST). This was tested to wide acclaim at RAF Marham, where it continues to operate following numerous upgrades. The RAF decided to incorporate MIST into a wider-ranging scheme, the Automated Low Flying Enquiry and Notification System (ALFENS).
This was conceived to help avoid mid-air collisions in the congested UK low-level airspace, providing pilots with the appropriate details to plan and complete their low-level sorties safely.

The potential of MIST was then recognized by the CAA, who approved its use for the Offshore Helicopter Operations Centres in Scotland, with tailored software providing colour text and graphic displays of critical information. To bring this technology into the private sector two collaborative projects are now underway with British Aerospace. The first is to develop MIST on a PC with a variety of communications adaptors, using satellite, PSS (packet switched system), dial-up fax and leased lines. The second is to investigate an interactive system to provide MIST data for public access in shopping malls, museum displays, travel agents, and so on.

## Fax — the new popular medium.

The introduction of the Group 3 standard for facsimile transmission was arguably one of the main driving forces behind the explosion in the use of fax as a communications medium.
Fax has taken over as an indispensible aid to business, where it is mostly used for the transmission of text, even though its greatest advantage is as the cheapest and quickest method of communicating graphical information.

Meteorological charts provide far more information, and more rapidly, than textual descriptions and are an obvious candidate for delivery by fax. To this end, a new system was installed last year for coping with increased fax traffic (ARTIFAX), and new services have been introduced tailored to customers' requirements (MetFAX and Weatherfax).

ARTIFAX (Automatic Routine Transmission of Information by Facsimile) processes text and graphics produced either manually or from computer, for multiple transmission as a fax broadcast over the public telephone network to a large number of customers. Many of these are aviation customers, benefiting from a commercial agreement with the CAA to improve flight documentation services.

A new premium-rate dial-up fax service (MetFAX) was launched this year, also for aviation and for marine users. Faxes from ARTIFAX and Weather Centres are sent to the MetFAX database stored in a remote audiotex system, managed by Vodata Services. The service has been extremely successful and will be broadened to cover educational and general weather products.

Weather Centres can now offer subscribers a direct fax service (Weatherfax) of local weather parameters for five days ahead. Data are compiled on a local PC database, before being automatically sent to customers each day. The service is particularly popular with farmers, and anyone who needs to keep a regular watch on local weather.

## Telephone services.

Increasing demands for forecasts to be delivered to a steadily increasing number of subscribers cannot be met simply from human resources. This has led to development effort being put into methods to generate text and voice reports directly from numerical outputs. A current project is to provide hourly weather reports from around the United Kingdom using computerized speech. This is being done jointly with Telephone Information services (TIS) who manage the premium-rated telephone forecast services for the general public and who provide a substantial proportion of Commercial Services' revenue.

Courtesy British Gas

# Quality and Timeliness

*Demand for gas rises sharply as temperature drops. Six times as much gas may be required on a cold winter day as in summer. The supply of gas is matched to demand at the Central Control Department. The demand forecast is made using a computer model based on temperature and wind speed forecasts.*
*Forecasts of temperatures for British Gas were within the required accuracy of 3 °C on 97.6% of occasions last year. The success rate for gale warnings for shipping was 85% with fewer than 15% false alarms.*


*The research showed that 90% of the population obtain weather information from television, 25% from radio and 14% from newspapers. There was a strong preference for forecasts to be presented by professional meteorologists. This has influenced the current policy to ensure that all Met. Office presenters, not just those on BBC TV, have meteorological qualifications.*
*The picture shows a student on a forecasting course at the Met. Office College.*

# Quality assurance

The Met. Office attaches considerable importance to the quality of its services. Each step is important, from basic observational input, through numerical modelling processes and forecasters' interpretation, up to monitoring the quality of the resulting outputs and ensuring that customers are receiving the information that they need, on time, and in a form which is readily understandable. This needs to be achieved at the same time as keeping control of costs.

## Keeping the machine well oiled.

For observations, considerable effort is made to eliminate sources of error by monitoring performance, visiting sites, discussing problems with observers and arranging training if required. All Met. Office manned sites, one third of all other manned sites and one half of the automatic stations are inspected each year. In the Central Forecasting Office observations from every part of the world are scrutinized closely. With the aid of interactive computer terminals, erroneous data (perhaps because of errors in transmission) are weeded out. This can be a difficult matter of professional judgement in remote areas where there are very few observations; satellite imagery plays an important role here.

Then there is the computer model. Although improvements in the model are always being developed, great care is needed to make sure that these are incorporated operationally only after considerable testing. The question of reliability is of major concern; customers (like the world's airlines) need the information routinely, without fail. In the event of a major computer outage, arrangements are in place to provide the best forecast available, either from an earlier run of the model or from another National Met. Service. Despite improvements in computer forecasting, human forecasters remain a vital part of the set-up. Recruitment of skilled staff and regular professional training are key factors, as are experience and an intuitive understanding of the subject.

## Assessing accuracy.

Verification of the forecast is an essential procedure which is carried out not only for the benefit of customers, but also in order to help forecasters to improve their performance and to give an objective assessment of the way in which the computer models behave.

The model is relatively easy to verify and this is carried out automatically for every run. Statistics are assembled for different forecast parameters (wind, temperature, precipitation, etc.), for different forecast periods and for different parts of the world. These highlight aspects where the models need improvement. Particular forecasts are also investigated closely to identify why an individual forecast has gone wrong.

Of particular concern to the aviation sector is the forecast of winds near the tropopause. Results for the 24-hour forecast of winds at flying levels have shown accuracy improvements every month since the introduction of the Unified Model. During the year verification of Terminal Aerodrome Forecasts (TAFs) suggest that about 90% of these forecasts are correct.

More difficult to assess are the worded forecasts issued to the public and to customers. Nevertheless many forecasts are verified routinely. Some sample figures: the 1755 Radio 4 forecast for the next day has consistently achieved an 84% score in recent years. Road temperature frost forecasts for the highway authorities were correct on 89% of occasions.

## Responding to customers' needs.

There are two areas in which we now monitor our customer's requirements. Firstly we check our customer's perception of the accuracy of the products and levels of service we supply, and secondly we use market research to identify areas in which we could usefully develop and improve services.

Objective assessments of accuracy and skill, presentation and timeliness of services are now routinely assessed by our customers in the public, defence and commercial sectors. Almost 50 organizations, covering all market sectors, completed returns this year containing a six-point marking system for services they receive over a seven-day period every three months. In 1991 we conducted two public attitude surveys. The first was to investigate the image of the Met. Office and the second to obtain some feedback on what the public preferred in TV broadcasts. The results have proved that monitoring public attitudes should now be undertaken regularly.

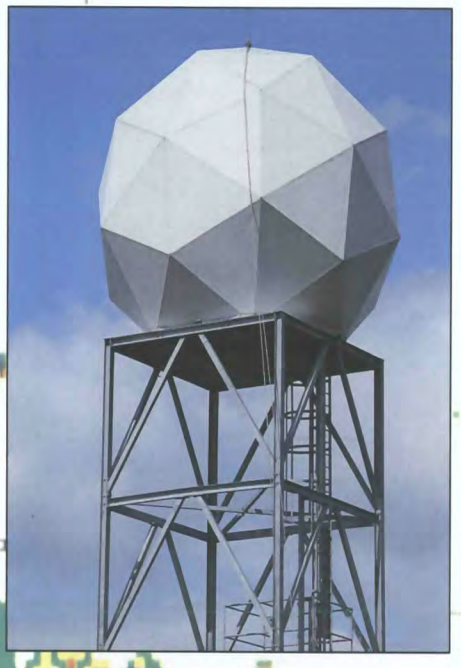
Some of the most striking features of these surveys are that the satisfaction level for BBC and ITV forecasts were both over 90%; 80% of the public felt that the forecasts were useful to them; 67% thought the accuracy of the forecasts had improved over the last 5 years, compared with 5% who thought there had been a deterioration.

Other feedback on the style and content of presentations will be taken into account in making further improvements to the service.

Courtesy estec

*ERS-1*

*Sensor detects waves on the sea surface from which wind speed and direction can be calculated. Another can provide data on wave height and the third sea surface temperatures and ocean colour. Low-level wind and sea wave data will benefit wave prediction in particular, and sea surface temperature data will assist in climate monitoring.*



*Three new weather radars in Scotland were opened formally on 13 December by the Scottish Office Minister for Home Affairs and the Environment and, with the addition of data from radars in Ireland, qualitative weather radar data are now available for the whole of the British Isles. Observations of precipitation are made every 15 minutes on a 5 km grid for use by forecasters in the United Kingdom for short-period forecasting ('nowcasting').*

*The UK-run weather ship* **Cumulus** *and about twelve North Atlantic container ships (one funded by the United Kingdom) also make upper-air soundings by radiosonde balloons.*
**Cumulus** *is also employed as a floating classroom for training in meteorological and oceanographic studies.*

# The Global Observing System

The Met. Office inputs data into the Global Observing System, from the United Kingdom and overseas territories, to standards and formats agreed with the WMO. For some applications data are required at fairly coarse resolution, while for others detailed data are required, for example when producing forecasts for the British Isles.

## Surface Observations.

A network of approximately 300 synoptic stations is maintained around the United Kingdom. About 60 sites are now fully automated and a further 150 manned by Auxiliary Observers, such as coastguards and oil-rig personnel. Automatic and semi-automatic observing systems inland and marine networks are a key element in increasing efficiency and effectiveness. Introduction of these is phased over several years, and major achievements have been:

- Seventeen systems have been installed, of which fifteen became operational during the year.
- Five synoptic automatic weather stations were enhanced to provide climatological data, and works services were completed for a further twenty-four out of the total of about forty stations.
- The offshore buoy network of five stations (on the edge of the continental shelf west of the British Isles) was completed together with increased deployments of drifting buoys in the North Atlantic.
- Many auxiliary observers have now been equipped with lap-top PCs into which they enter the observed weather. Each PC performs checks and then codes the data before automatically transmitting message into Bracknell.

Reports from merchant ships provide valuable weather data over the oceans with about 500 UK ships forming part of the 7000-strong WMO Voluntary Observing Fleet. By exchange with other responsible members under the WMO agreement the global archive of marine data has now reached 71 million observations, dating back to 1854.

## Upper-air Observations.

A major step forward in aircraft observations was made during the year with the successful operation of ASDAR – an automatic data acquisition system installed on board civil aircraft. Observations are transmitted every seven minutes at cruising level, and at predetermined intervals during climb and descent. ASDAR produces much good quality data over data-sparse areas. The project is being carried out as part of an international consortium, through the WMO. The Met. Office has so far funded three of the six systems in service.

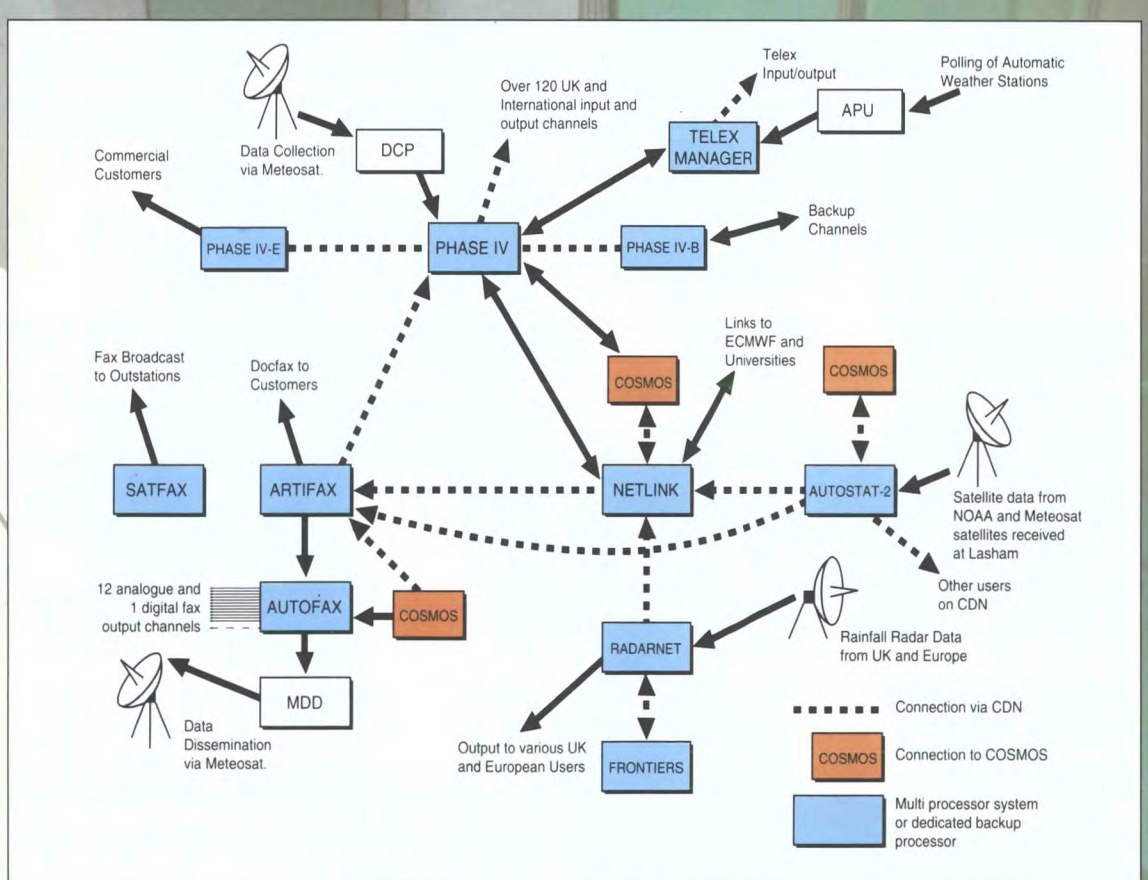
## Satellite information.

Polar and geostationary orbiting satellites have complementary roles in the observing system. Geostationary satellites provide half-hourly visible and infrared images with resolution of 5 to 10 km but do not cover the polar regions. Cloud top and sea surface temperatures are obtained as well as the distribution of water vapour. The United Kingdom helps to fund the satellite over the equator at 0 deg longitude through the European consortium, EUMETSAT.

Polar satellites occupy a much lower orbit, and so provide higher-resolution imagery, less frequently than the geostationary satellites, but with cover over the poles. Their most important role is to provide information which can be turned into vertical profiles of temperature and humidity for input into numerical forecast models. Calculation of these from raw satellite data is not a trivial matter and Office scientists are working on the problem, which will be eased somewhat by the next generation of sounding instruments.

The United Kingdom contributes to the polar satellite system by designing and building advanced sounding instruments. The last of eight Stratospheric Sounding Units is now due for launch in 1992. The first of these was flown in 1978 and they are still carried on NOAA satellites. The new, Advanced Microwave Sounding Unit for the following NOAA satellites is being provided jointly with the US and is being built by British Aerospace under contract to the Office, whose contribution is the measurement of humidity profiles. The instrument is under test at the Defence Research Agency space facility.

On 17 July 1991 the first European Remote-Sensing Satellite, ERS-1, was successfully launched. It carries three instruments of meteorological interest. A particularly significant contribution comes from the C-130 aircraft operated by the Met. Research Flight.
Its measurements, along with other aircraft and a network of buoys, have been used to calibrate the satellite instrumentation.




*The Met. Office computer systems have many external inputs and outputs as well as internal links.*

# Maintaining the information flow

Information is at the heart of the Met. Office's activities.

The Meteorological Telecommunications Centre (Met. TC) at Bracknell operates round the clock, gathering and disseminating the weather observations and forecasts which are essential to meteorological services. Almost all the messages (roughly 100 000 in, 600 000 out per day) are switched completely automatically. Staff in Met. TC monitor the flow and correct faulty messages, ensuring a very high level of services. The Met. TC also supports reception, processing and distribution of radar and satellite imagery, and transmits products by radio and satellite broadcasts.

Large-scale scientific processing, such as the Unified Model, is performed on two Cray Y-MP8 machines. The task of numerical weather prediction is performed on one machine. The second, funded by the Department of Environment (DoE), is used for climate studies. A general-purpose computing service is provided by an Hitachi Data Systems EX100 machine, which also acts as a front end to the Cray machines. The workload on this machine has increased by around 40% during the year, reflecting the increase in work generated by the two Crays, and as a direct consequence of bringing into operation the new, higher-resolution models.

A new graphical display system, HORACE, is under development to provide powerful workstations at Headquarters RAF Strike Command and the Central Forecasting Office. This will, over the next few years, enable the weather forecast to be produced entirely on a screen.

Additions and improvements continue to be made to the range of products available to forecasters through the computer-based ODS (Outstation Display System). For example, Defence Services' programme neared completion with 25 systems installed during the year, including 7 in Germany. Five existing systems were upgraded and plans are well advanced for extension to the Mediterranean; all of which has greatly assisted improving quality of service and efficiency.

No less important is automation of the Office's administrative functions. Phase 1 of an office automation system has been installed, and access to it will be made widely available in the next few years. A personnel management system is being procured which will allow Personnel Management Branch to save considerable staff time on routine tasks and use this time to significantly increase the range and quality of services they provide. Similarly, completion of the Financial and Management Information System will provide a wide variety of reports on the financial performance of the Office, and allow better and more consistent decision making.

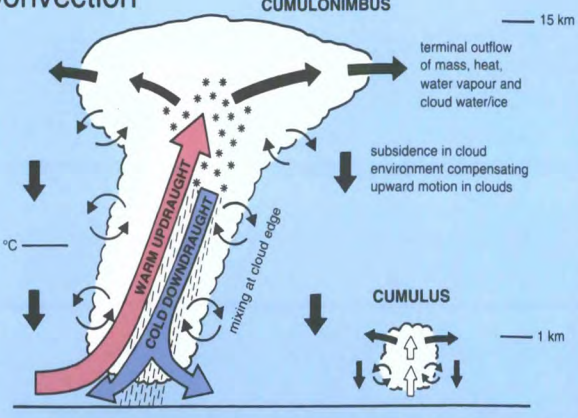
There are growing requirements for management and storage of data. With the increase in available scientific computing power, much larger volumes of data are being generated in support of operations and research.

*Control station for the main Met. Office computer system COSMOS*

Several terabytes (million million bytes) of data which need to be retained are now being generated each year. In order to cope with this in an effective way, high-capacity storage media are required, together with appropriate systems for their control and management. The necessary hardware and software will be procured next year.

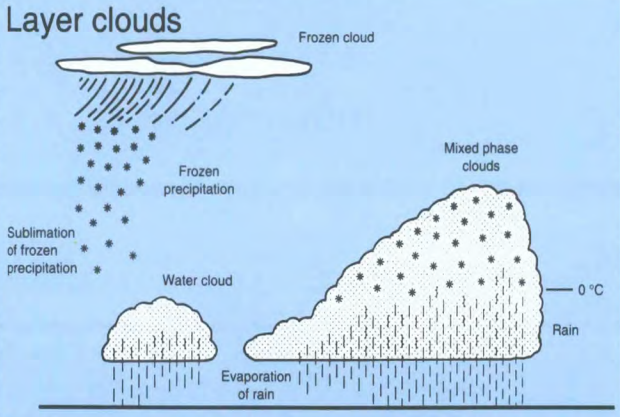
At present observations and products are collected and disseminated around the United Kingdom by a variety of techniques ranging from teleprinter and facsimile broadcasts to computer networks. The aim is to replace this diversity with an integrated digital network running an international-standard message service. Good progress has been made in testing the hardware and software network and implementation is planned over the period 1993–95. A large effort is also going into the modernization of the systems in the Met. TC, notably the main message switch, to give greater capacity and keep up with the demand for new facilities to support the growth in activity.

## Convection



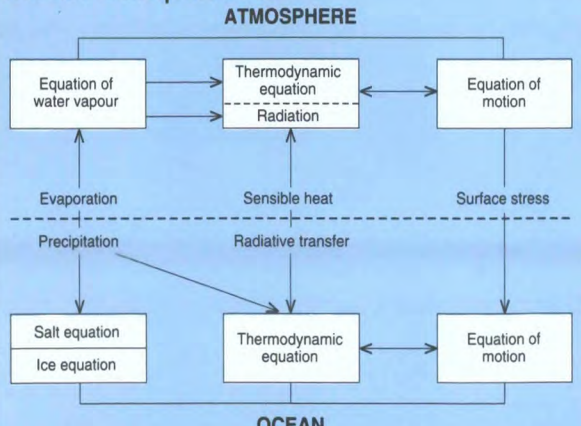

Simple cloud microphysics scheme included to calculate precipitation rate.
Convective activity related to stability of initial convecting layers.

## Layer clouds



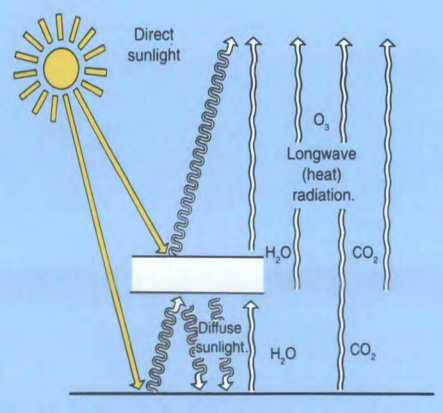

Fractional cloud amount and cloud water content predicted.
Rainfall formed by accretion and collection of cloud water.
Separate treatment of frozen precipitation.

## Model Components




The processes of a coupled Atmosphere—Ocean model

## Radiation




Sunlight treated in four frequency bands, long-wave radiation in six.
Effects of clouds depends on their fractional cover, height, condensed water and phase.

# Weather forecasting models

Over the year, adoption of the new Unified Model for numerical weather prediction and climate studies has had an impact on virtually all our operations. Use of the same model for both applications has already led to rapid improvements in the performance in each. The new model brings together atmosphere and ocean processes, and opens up many opportunities for future development. It was introduced for operational global and regional forecasting over the North Atlantic and Europe in June 1991. It is planned to introduce it for mesoscale forecasting over the UK area at the end of 1992.

In addition to introducing the Unified Model, the system for processing observations for use in the model has been replaced. Assimilation is a technique for adjusting the model's initial conditions to give, subject to constraints imposed by model physics, an optimal fit to actual observations. New types of data, for instance those supplied by the ERS-1 satellite, are being assimilated on an experimental basis, and higher-resolution satellite data are now included operationally. Use of the Unified Model for mesoscale forecasting opens up the possibility of assimilating mesoscale upper-air data for the first time. Work has also begun on assimilating satellite cloud data.

## Products.

The Unified Model produces forecasts up to 48 hours ahead over the North Atlantic and Europe, at 50 km resolution. Rain and snowfall are the most important products from this version. It is also run to produce global forecasts for up to six days ahead. The unification of the model has greatly increased the range of products available, particularly from the global model. Cloud forecasts are now possible, and forecasts of surface weather conditions, which usually depend critically on cloud, can be greatly extended.

The mesoscale version of the Unified Model will replace an older model at the end of the year. This model, with 16 km resolution, is designed to produce detailed forecasts of cloud and surface weather over the United Kingdom, up to 30 hours ahead. Initial trials of the new model have been very promising.

The United Kingdom is a member state of the European Centre for Medium-range Weather Forecasts (ECMWF), and so has access to the forecasts produced from their models. These are run in delayed mode, to ensure that the initial analysis is of the highest possible quality. The forecasts form a major input to predictions in the four- to ten-day range.

The Unified Model and the ECMWF model are used experimentally to produce guidance on forecasts up to 30 days ahead. On this time-scale, direct prediction is impossible, and it is necessary to assess the probability of particular types of weather. Early results with the Unified Model have shown a much greater ability to capture the variability of the atmosphere than with the previous Met. Office model.

In addition to atmospheric forecasts, a separate set of models is run to predict the sea-state to provide guidance for shipping. A storm surge model is also run to provide guidance for coastal authorities.

## Model development.

A major part of the Office's research programme is devoted to improving the performance of data assimilation and the forecast model, including representation of unresolved processes. Diagnostic models, which are used to infer weather details from model output are also a subject of study. This research concerns detailed investigation of atmospheric structure and processes, including radiative transfer, clouds and turbulence.

A more accurate radiation scheme is being developed, which can be used to test changes to the simpler schemes which, for reasons of computational expense, are used in the Unified Model. Comparison with satellite data and direct observations with the MRF C-130 aircraft are used to test and develop this new scheme.

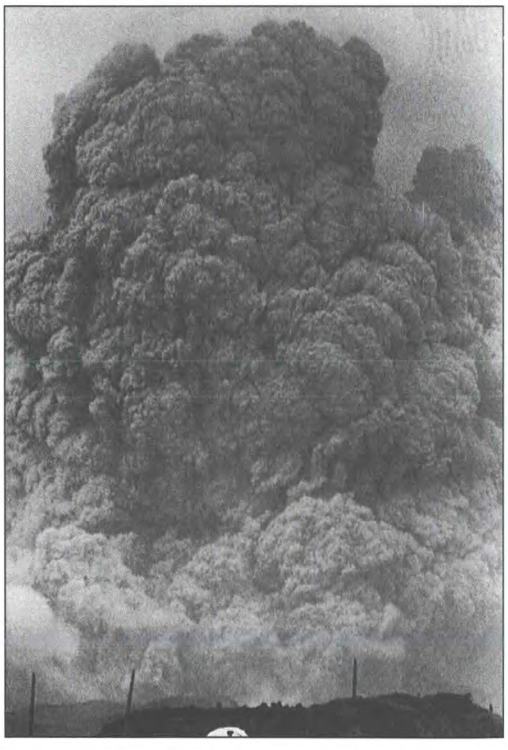
Improvements to the representation of convective clouds are a priority because of their influence on rainfall. Better allowance for downward movement of air, which inevitably accompanies convective updraughts, has led to better rainfall forecasts. Longer-term work concerns development of very-fine-scale models, which require all of the computer resources needed to do a global weather forecast, in order to deal with an area with dimensions of tens of kilometres or less. These turbulence-resolving models are now starting to be used to help improve representations of small-scale physical processes in large-scale models. Rather than replace observations, they enable detailed point-wise observations made by the C-130 aircraft to be used more effectively, to produce the average properties needed by the Unified Model.

On their smallest scale of application, these turbulence-resolving models are used to describe turbulence, clouds and diffusion in the lowest kilometre of the atmosphere (the atmospheric boundary layer). On these scales, observational data are obtained with both the C-130 aircraft and also the tethered-balloon facility at Cardington, Bedfordshire. The C-130 sees its main use over the sea, while the Cardington facility is used to study the characteristics of heterogeneous terrain and flow over small-scale hills. Hills and mountains are also important on larger scales when they generate wave motions within the atmosphere. Improved representations of such wave motions have been tested using a three-kilometre-resolution version of the mesoscale forecast model.

The use of observations, theory and diverse models in combination, continues to give a most effective approach to improving the content and performance of our wide range of weather forecasting and climate prediction models.

## CLIMATE PREDICTION

The Hadley Centre is the main centre for research on climate change in the United Kingdom and is funded jointly by the Met. Office and the DoE. Its long-term objective is the achievement of reliable predictions of the regional distribution of the magnitude and rate of onset of climate change. This work requires a state-of-the-art climate version of the Unified Model, which has both atmospheric and ocean components.



Courtesy Associated Press.

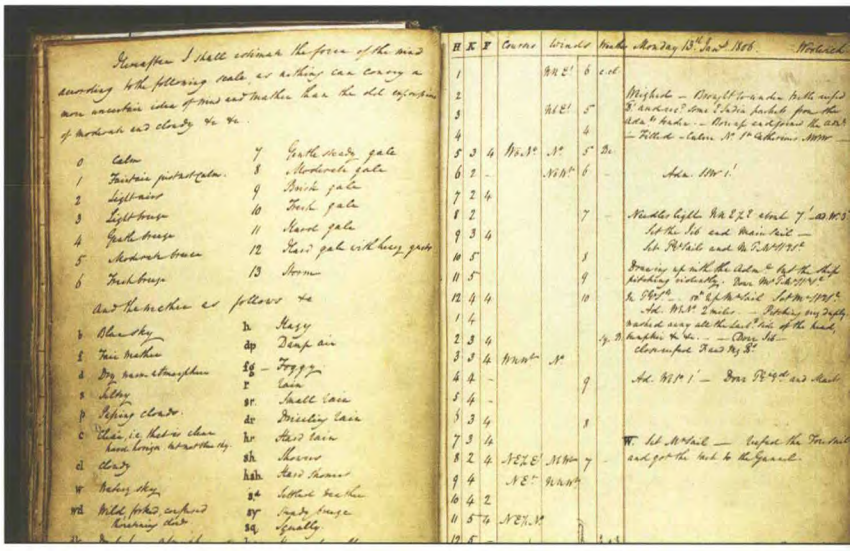
*The eruption of Mt. Pinatubo in June 1991 put a vast amount of dust into the higher reaches of the atmosphere (the stratosphere) and may have caused a little cooling, as well as making it difficult for some satellites to measure the sea surface temperature (SST) correctly.*

### Observed climate change.

Use of all the surface data available has now revealed continuing evidence for global warming, with 1990 and 1991 being the two warmest years, and the last decade the warmest, so far.

### Assembling data for the past.

Detection of climate change requires accurate knowledge not only of the present climate but also of the past. Working in collaboration with the University of East Anglia's Climatic Research Unit, quality controlled global land surface temperature and rainfall data are kept up to date on a monthly basis. We have also constructed a more reliable set of daily temperatures for Central England going back to 1772. Accurate sea surface temperatures are vital for climate monitoring, as



*Admiral Beaufort's original scale of wind force.*

are observations of sea-ice. Many millions of hitherto inaccessible marine observations dating back to the late nineteenth century are slowly being added to archives abroad, and plans are being made to include them in ours. Unfortunately, past data are not only very incomplete, they are also not entirely trustworthy and difficult corrections must be made to allow for differences in measuring techniques.

### Prediction of climate change.

Until recently, research on prediction of climate has focused on the response of models of the atmosphere and a shallow ocean to an instantaneous doubling of $CO_2$ concentration. It is now possible to assess the effects of more realistic emission scenarios, such as an increase of $CO_2$ at 1% per year. Little warming happens in the first twenty or so years (which may be an artefact of the experimental method) but thereafter warming is at a rate of about 0.3°C per decade. As in the real atmosphere, there are fluctuations from decade to decade, but broadly speaking, winters get wetter and summers drier in mid-latitudes. This differs significantly from

previous experiments in that there is hardly any warming of the sea in the north-west North Atlantic and around Antarctica – both regions where the ocean is mixed much more deeply than elsewhere.

## Rainy season forecasting.

In many parts of the world, rainfall is affected by sea surface temperatures (SSTs). The known connections are usually statistical in character, with some extending over enormous distances (for example, the effects of the Pacific's El Niño are believed to span the globe). The Met. Office now issues forecasts for the rainy seasons in the northern Nordeste of Brazil and the Sahel region of Africa, based on anomalies of global SST. Forecasts for Nordeste have been issued since 1987 and all have been useful. However, those for the Sahel are more difficult as they require forecasts of SST. In particular, the Sahel forecast in 1988 was wrong because of unforeseen large and rapid changes in SST anomalies in the tropical Pacific and elsewhere.

## Physical processes.

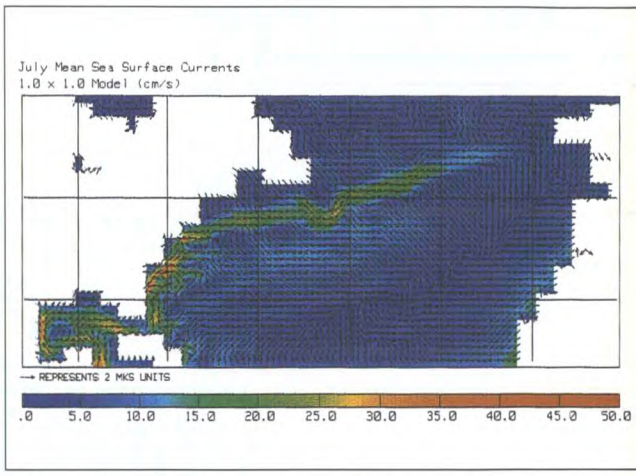
The climate is generated by interaction of radiative forcing with the dynamical and physical processes of the ocean and atmosphere, modified by the Earth's geography. Just as in operational forecasting models, these processes must all be represented realistically in climate models.
In particular, climate change studies are very sensitive to how clouds are represented. Another important aspect of radiative processes, now being included in the model, is the effect of trace gases such as methane, nitrous oxide and the CFCs, which are known to contribute to the greenhouse effect.

Changes in climate are also expected to have important effects on vegetation, which, as well as being directly important for human activity, may in turn affect the climate. The first steps are therefore being taken to model vegetation, which will allow modelling of the carbon cycle on land.

## Modelling the oceans.

The ocean and atmosphere comprise a coupled system – the atmospheric circulation being largely driven by the sea surface temperature distribution which, in turn, is determined by the interaction of ocean currents and fluxes of momentum, heat and water across the ocean surface.
Consequently, for climate studies, a primary requirement is development of a coupled atmosphere–ocean version of the Unified Model.

If the model grid over the ocean is the same as that used at present for the atmosphere, important finer-scale features like the Gulf Stream




*Higher-resolution model of oceans can resolve detail of the Gulf Stream.*

cannot be resolved, so a higher-resolution model has been developed. Such a model is very time consuming and costly to use, even on today's supercomputers. A limited-area model has been developed, therefore, on which it is quicker and cheaper to do tests, such as trying to reproduce the intermittent warming of the tropical Pacific, known as El Niño. Other processes that are needed in the coupled models include the flow of fresh water from rivers into the oceans and the seasonal blooming of oceanic algae, which can change what happens to sunlight reaching the sea surface, and also affects the efficiency of surface exchanges of $CO_2$.

## Stratospheric ozone.

In response to concern about the ozone layer, the US space agency, NASA, led a project to develop an Upper Atmosphere Research Satellite (UARS) which was launched from Cape Canaveral in September 1991. Its instruments probe the atmosphere between about 8 to 80 km above the surface, measuring temperature, wind and the concentrations of a range of trace chemicals including ozone and chlorine-containing compounds. For its contribution to the project, the Met. Office undertook the challenge of combining all the available meteorological data from UARS and other sources, and some of the chemical data to produce a 3-D view of the changing state of the middle atmosphere.
A special version of the Unified Model was developed for the project. Theoretical investigators, at the Met. Office and elsewhere, are now using the data to study features of the dynamics, photochemistry and chemical transports of the middle atmosphere.

Regular twice-weekly balloon-borne ozone sounding flights were made from Lerwick during the Winter. This work, funded by the DoE, is a part of the European Arctic Stratospheric Ozone Experiment (EASOE). These measurements are being used in conjunction with other data from EASOE and UARS to investigate the possibility of stratospheric ozone depletions in the northern hemisphere.

*Crawley upper-air station was host to teams from Switzerland and the USA early this year. Six different types of sonde were flown in groups to find a new standard.*

*The Met. Office College runs courses for overseas meteorological technicians.*

*Installing the wind-finding radar in Lusaka.*

# The International dimension

The weather and climate do not recognize national boundaries. Because these are global phenomena, there is a long tradition of active international co-operation between national meteorological services, for example in sharing data, observations and research. Now, with the approaching elimination of trade barriers within the European Community, a careful balance needs to be struck between maintaining this free interchange of information, while enabling nations to provide competitive commercial services.

As one of the national meteorological services most advanced in developing commercial services for the private sector, it was natural for the Met. Office to take a key role in opening up opportunities for commercial collaboration in Europe.

As a result of this initiative, in December 1991 seventeen countries agreed in principle to create an Economic Interest Grouping (EIG), whose proposed name is ECOMET. ECOMET's aims are to enhance collaboration between European national meteorological services in the supply of observational data, forecast products and value-added weather services to professional users, independent weather companies and the public, so that any member's weather services could be sold in other member's countries, creating a wider choice for industry.
It is planned to reach final agreement on ECOMET's formation by the end of 1992. Meanwhile, commercial agreements with other European national meteorological services have been negotiated by the United Kingdom, including provision of substantial marketing consultancy, commercial training and collaboration in European TV services.

Another major international event was the Eleventh World Meteorological Congress. This meeting takes place every four years and was attended by representatives of 134 Member States or territories. The United Kingdom delegation, led by Sir John Houghton, played an important role, including chairing the Programme and Budget Committee. This committee produced a new four- year budget based on zero real growth and initiated a change in policy to one of full budgeting, to anticipate and account for inflation. Also high on the agenda was reorganization of the World Climate Programme and establishment of the Global Climate Observing System (GCOS). In future, GCOS will play a crucial role in providing data on world climate and climatic trends such as those associated with global warming.

The Office contributed to the Voluntary Co-operation Programme (VCP) by installing refurbished windfinding radars in Nadzab (Papua New Guinea), St Brandon (Mauritius) and Lusaka (Zambia). Other major donations were made to Bangladesh in order to replace basic observing equipment lost during the April 1991 tropical cyclone, and five climate computing systems to be installed in Czechoslavakia, Papua New Guinea, Nepal, Cape Verde and Hungary. This year fourteen students from nine countries were given fellowships through the VCP to study in the United Kingdom on courses ranging from initial forecasting training to PhD studies. Fellowship funds were also given to various Regional Meteorological Training Centres in developing countries to help local training of staff.

There were many overseas visitors to the Office, including a delegation from the People's Republic of China led by Mr Zou Jingmeng who is the current President of WMO. This visit followed the signing of a Memorandum of Understanding between the two meteorological services and agreement was reached on a number of areas of future co-operation.

As part of the DoE-funded Climate Prediction Programme there is also an active programme of exchange visits with other institutes throughout the world engaged in climate prediction research. Visits were made to the USA, France, Germany, China and Japan and, together with information obtained from visitors to the Hadley Centre, a report was prepared summarizing the international work on this topic.

The opportunity was taken to establish and build on existing collaboration. During 1991 eight scientists, representing Australia, Kenya, Poland, Spain and the USA, made extended visits to the Hadley Centre and a further ten visitors are planning to come for periods of a month or more during 1992.

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| | |
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| Birmingham Weather Centre | 021- 717 0571 |
| Bristol Weather Centre | 0272 279272 |
| Cardiff Weather Centre | 0222 390420 |
| Edinburgh Climate Office | 041- 248 7272 |
| Glasgow Weather Centre | 041- 248 7272 |
| Leeds Weather Centre | 0532 457753 |
| London Weather Centre | 071- 696 0574 |
| Manchester Weather Centre | 061- 477 1017 |
| Newcastle Weather Centre | 091- 232 3808 |
| Norwich Weather Centre | 0603 630164 |
| Nottingham Weather Centre | 0602 384094 |
| Plymouth Weather Centre | 0752 251861 |
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