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Meteorological Office

REPORT FOR THE YEAR
ENDING
31 DECEMBER 1964

LONDON
HER MAJESTY'S STATIONERY OFFICE
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Met.O.769

ANNUAL REPORT
ON THE
METEOROLOGICAL OFFICE

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

FOR THE YEAR
1 JANUARY TO 31 DECEMBER 1964

LONDON
HER MAJESTY'S STATIONERY OFFICE
1965

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METEOROLOGICAL COMMITTEE

Terms of reference:

(*a*) to keep under review the progress and efficiency of the Meteorological Service and the broad lines of its current and future policy;

(*b*) to keep under review the general scale of effort and expenditure devoted to the meteorological services;

(*c*) to ensure the maintenance of adequate contacts between the Meteorological Service and those who use its services.

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Members: Sir Austin Anderson
Mr. S. Earl
Professor J. Proudman, F.R.S.
Chairman, Meteorological Research Committee (*ex officio*)

Secretary: Mr. W. J. B. Crotch (Secretary, Meteorological Office)

The Committee met three times in 1964.

METEOROLOGICAL RESEARCH COMMITTEE

Terms of reference:

The Meteorological Research Committee will advise the Secretary of State for Air on the general lines along which meteorological and geophysical research should be developed within the Meteorological Office and encouraged externally. It shall review progress and report annually.

It is empowered to appoint sub-committees, one of which shall be responsible for advising on the usage of monies allocated annually from Air Votes for research projects conducted outside the Meteorological Office. The Committee will be responsible for co-ordinating the work of its sub-committees.

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Sir Graham Sutton, C.B.E., F.R.S. (Director-General, Meteorological Office)
Mr. A. E. Woodward-Nutt (Ministry of Aviation)

Secretary: Mr. F. E. Dinsdale

The Committee met three times in 1964 and its sub-committees eight times.

ADVISORY COMMITTEE ON METEOROLOGY FOR SCOTLAND

Terms of reference:

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(*b*) to submit to the Meteorological Committee any proposals in connexion therewith.

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Secretary: Mr. R. Cranna

The Committee met on 21 May 1964.

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(on 31 December 1964)

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SECRETARY, METEOROLOGICAL OFFICE
W. J. B. Crotch, M.A., A.K.C.

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FUNCTIONS OF THE METEOROLOGICAL OFFICE

The Meteorological Office is the State Meteorological Service. On 1 April 1964, as part of the former Air Ministry, it became a part of the new Air Force Department of the Ministry of Defence. The Director-General then became responsible to the Secretary of State for Defence through the Minister of State for Defence (RAF) and the Second Permanent Under Secretary of State (RAF).

The general functions of the Meteorological Office are:

(i) Provision of meteorological services for the Army, Royal Air Force, Civil Aviation, the Merchant Navy and Fishing Fleets.

(ii) Liaison with the Naval Weather Service and provision of basic meteorological information for use by that Service.

(iii) Meteorological services to other Government Departments, public corporations, local authorities, the Press and the general public.

(iv) Organization of meteorological observations in Great Britain and Northern Ireland, and in certain colonies.

(v) Collection, distribution and publication of meteorological information from all parts of the world.

(vi) Maintenance of certain British observatories and publication and distribution of geomagnetic and seismological information obtained from them.

(vii) 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.

Except for the common services provided by other Government Departments as part of their normal function (e.g. accommodation by the Ministry of Public Building and Works; stationery by Her Majesty's Stationery Office) the cost of the Meteorological Office is borne by Defence Votes.

The gross annual expenditure by the Exchequer for the Meteorological Office, including that on the common services, is of the order of £6,900,000. Of the amount chargeable to Defence (Air) Votes, about £4,500,000 represents expenditure associated with staff and £2,100,000 expenditure on stores, communications and miscellaneous services. Over £1,500,000 is recovered from other Government Departments and outside bodies in respect of special services rendered, sales of meteorological equipment and the like.

FOREWORD BY THE DIRECTOR-GENERAL

During the year under review the work of the Meteorological Office proceeded smoothly. There were, however, some features that call for special comment. In the Foreword to the Annual Report for 1963 I drew attention to the decision to publish, regularly, long-range forecasts. The series of 30-day 'weather prospects' with mid-monthly supplements began on 1 December 1963, so that at the time of writing rather more than a year's experience has been gained. The analysis of the forecasts is not yet complete but it is evident that the overall level of success was consistent with experience in the trial period and at times slightly better, especially in the summer and winter. An investigation also showed that many of the subscribers to the series considered that the forecasts had been useful to them.

Although it is gratifying to record a modest level of success at this early stage, it is also necessary to reiterate that long-range forecasting is the most difficult problem in meteorology for which, as yet, there is no secure physical basis. It would be over-optimistic to expect a steady improvement in the reliability and precision of the forecasts until research has disclosed the prime causes for and mechanism of transient climatic fluctuations. Work on this aspect of the science is proceeding actively in the Office but progress is necessarily slow.

Another event with far-reaching consequences for the Office was the decision to incorporate mathematically derived forecast charts of pressure and temperature into routine short-range forecasting. This is the outcome of a decade of intensive research and trials coupled with the creation of a new enlarged computing laboratory incorporating the *English Electric-Leo* KDF9 computing system. It is expected that the installation will be in full operation in the spring of 1965 and that routine forecasts will begin later in the year. At the same time, trials will be made of automatic methods of chart plotting and construction in order to eliminate some of the tasks now done laboriously by hand.

These changes, and others that are described in the main body of the Report, reflect the undoubted fact that meteorology is now well set on the road to becoming an exact rather than a descriptive science. Although it is not to be expected that the mathematical formulation of atmospheric processes will ever be as precise and complete as that of astronomy, there is no doubt that studies undertaken since the end of the war in this country and elsewhere are bearing fruit and that meteorology is now predominantly a mathematical science. It is also encouraging to report that international co-operation, an essential factor in the advancement of atmospheric sciences, is increasing. The World Meteorological Organization, of which the United Kingdom is a very active Member, is now at the planning stage of the World Weather Watch, a co-ordinated system of observation, by satellite and other means, designed to cover the whole globe. With all the facilities now available there are excellent prospects for meteorology in the second half of this century.

I attended the 16th Session of the Executive Committee of the World Meteorological Organization from 26 May to 12 June 1964 in my capacity as a member.

O. G. SUTTON

Meteorological Office,
Bracknell, Berks.

THE DIRECTORATE OF SERVICES

1. Special Topic—Meteorological Communications

With few exceptions, all countries of the world are Members of the World Meteorological Organization (WMO). Membership carries with it the obligation to make an agreed series of weather observations and to arrange that these observations shall be made available to other countries within a reasonably short time. Such organized programmes of observations are the basis of all weather forecasting. All countries, and particularly those with a large interest in aviation, prepare regular weather charts, which display observations made both by eye at ground level and by balloon-borne instruments in the upper atmosphere. The main chart used in the Central Forecasting Office at Bracknell, for example, extends from Asiatic Russia to the western coasts of North America and from the north pole nearly to the equator. This chart normally carries some five hundred plots—land stations and ships—and is fully plotted four times daily. Subsidiary charts are completed at four intermediate hours and, twice daily, upper air charts at five levels, each with some three hundred plots, are also prepared. Similarly representative charts are now plotted in most countries of the world. The bulk of data necessary in any one place to permit this charting programme is clearly large and the total traffic in meteorological data over the whole world is probably larger than that entailed by any other single subject. Since the principal aim of the weather chart is the production of forecasts, the time interval between observations and completion of the chart must be small compared with the period covered by any forecast. At present, for aviation, the period of a forecast is normally about 12 hours; for public forecasting the period may extend to some days. Clearly speedy and extensive international telecommunications are essential to the preparation of useful weather forecasts. No attempt to forecast weather usefully could have been made prior to the invention of the electric telegraph and the subsequent development of forecasting has been closely linked with the development of telecommunications. Increasing density of telegraph networks on land, the introduction of submarine cables, radio-telegraphy, the teleprinter and the increasing refinement of transmission systems, including the development of the pictorial transmission of charts and diagrams by radio and line have been successive stages in this development.

The World Meteorological Organization is responsible for formulating the plans for making and exchanging synoptic observations. It recommends the kind of observations to be made, the instruments to be used, the hours of observation, the code forms and the means of distribution. WMO has, however, no funds for financing international communications; every link must be financed and operated by a national government acting on WMO's advice. This scheme is surprisingly effective—WMO schemes are universally accepted although for financial reasons they cannot always be fully implemented.

As a matter of convenience, WMO is based upon six Regional Associations of Members, corresponding roughly with the continents of the world. Each Association has appointed a working group of experts to formulate recommendations on the problems of telecommunications within its own Region. On a world scale, commissions appointed by WMO study the different aspects of its work; in the present context, the operative commission is that for 'Synoptic Meteorology'. This in turn appoints a working group to study and recommend action on a world scale in the field of meteorological communications. The Congress of WMO is the final authority in all world meteorological matters.

The general flow of meteorological data falls into the following basic pattern. First a national assembly is made of all reports prepared at any hour. These collected reports, or a selection of them, are then transmitted to neighbouring countries as one or more messages or bulletins, and arrangements must be made by which they reach selected sub-regional and regional centres. Sub-regional centres assemble reports from an allocated portion of a WMO Region and make a radio broadcast which can be received over the whole Region. The regional centre in turn makes a radio broadcast which can be received in neighbouring WMO Regions and which contains a representative selection of reports for the whole Region. Subject to the uncertainties of radio propagation, this arrangement is designed to permit the receipt at any location of the data for three or four WMO Regions using a similar number of receivers. This basic pattern is adopted within the European Region, in North America, and in part in the Asian Region. It is followed less closely in the southern hemisphere and in Africa. In general, radio reception conditions are seldom perfect and the system falls short of the effectiveness desired. The radio broadcast system has therefore been supplemented by a system of point-to-point circuits, using both radio and line; the additional cost of such arrangements is justified by the necessity for a continuous flow of data, particularly for aviation forecasting.

A still broader representation of the current weather situation has been rendered possible in the northern hemisphere by a twice-daily interchange of data between the five centres New York, Offenbach (Federal Republic of Germany), Moscow, Delhi and Tokyo. Each sends to both its neighbours a programme of data, such that all receive enough to complete charts for the hemisphere, both surface and upper air. Finally each centre makes the collected data available by radio broadcast or by land-line teleprinter over an allocated area. In the southern hemisphere a similar interchange is being implemented between Brasilia, Nairobi and Melbourne.

European organization. Let us now see how these arrangements are applied in the European Region—WMO Regional Association VI. "Subregional" radio-teleprinter broadcasts, audible over the whole Region, are made by Moscow, Rome, Paris and Bracknell, each containing reports from an allocated area. The Regional collective broadcast for the whole European Region is made from Bracknell. The principal meteorological centres within most of the nations in Europe are however linked by a land-line teleprinter system, known as the International Meteorological Teleprinter Network in Europe, and reception of European radio broadcasts is used only by those nations not exploiting the teleprinter network, by ships at sea, at isolated locations remote from any telegraph system, or, in cases of land-line or apparatus failure, as a reserve channel. National centres on the network transmit their own collected reports to one of seven principal transmitting centres. These are Bracknell, Moscow, Offenbach, Paris, Prague, Rome and Stockholm. National centres not on the network make corresponding scheduled radio broadcasts and, by agreement, one or other of the seven main centres receives them. Thus seven composite programmes jointly containing the observations for the whole Region are assembled and transmitted over agreed circuits. The programmes are so arranged that, at any national centre not originating one of the seven collectives, four receiving teleprinters will deliver an adequate coverage of the Region within

1 hour of the time of observation in the case of surface charts and within 3 hours for upper air charts. A fifth receiving teleprinter linked to an additional Paris transmission will ensure reception of North American data. These reach Europe over three independent routes, Montreal–Bracknell and New York–Offenbach over cable circuits, and New York–Paris over a point-to-point radio-teleprinter circuit using a relay point in the Azores. The European terminals of these transatlantic routes send European data to North America. The circuits between Offenbach and New York also carry data from Asia collected by Tokyo, New Delhi and Moscow. Offenbach incorporates these in its land-line programme within the Region and in a radio-teleprinter broadcast which also includes selected North American data and can be received over the whole of Europe. Countries not connected to the European teleprinter network are Portugal, Turkey, Greenland and Iceland. These still operate radio broadcasts for reception at sub-regional centres and elsewhere but their reports are, at as early a stage as possible, incorporated in the teleprinter programme of one of the main centres. A recent arrangement for the use of a cable circuit serving civil aviation now permits Bracknell to receive the reports of both Iceland and Greenland by teleprinter. Included also in national collectives are weather reports from ships at sea. Coastal radio stations receive these and teleprint them to national collecting centres. Ocean Weather Ships, with meteorologists aboard, transmit to allocated shore stations. Within the United Kingdom, the Meteorological Office mans the radio terminal for communication with three Ocean Weather Ships stationed on the Atlantic. Domestically, each nation controls directly the collection of reports from its own territory. This is made by any sufficiently speedy means. Within the United Kingdom the teleprinter is widely used, but where this is unsuitable, fixed-time telephone calls and, in a few cases, meteoro-radio-telephony are used.

An entirely independent teleprinter network, called the Meteorological Operational Teleprinter Network in Europe, has been set up, primarily to make available to civil aviation pilots and operators reports and forecasts of weather at airfields, and information on conditions that may be hazardous to aircraft in flight. Forecasters at most civil airfields have access to the system and make use of the information it brings them but the system was not designed for meteorologists and will not be discussed in detail here.

The teleprinter and its use. The teleprinter has proved a very convenient instrument for meteorological communication. It is robust, needs little servicing, and is cheap to buy and maintain. The message is very clearly typed by the machine (with two or three copies if required) and the maximum speed of about 66 words (or about eight observations) per minute, though not quite as fast as could be wished, is greater than the speed at which one assistant can plot by hand on a chart. The teleprinter moreover lends itself to a very quick and convenient method of relaying information. The received message can be recorded not only as a page copy for local use, but also on a punched paper tape, and the message can be relayed by feeding this tape into a 'tape relay', suitably connected. The tape system enables a great number of messages to be collected in a communications centre, edited, sorted into a prescribed order and retransmitted very quickly and with very little labour.

The procedure will be best understood from a description of what happens in the United Kingdom at every main hour of observation. There are about 140 observing stations, and, at 10 minutes to the hour, each station makes an observation which includes barometric pressure, wind speed and direction, weather, temperature, humidity, visibility and cloud conditions. The observation is put into a coded form containing from 6 to 10 or even more five-figure groups and this is passed by teleprinter to a collecting centre. There are 12 such centres in this country and thus, on average, each centre collects about a dozen observations which are sent to Bracknell.

Up to this point transmission is by hand, and as the operators are usually meteorological staff, not teleprinter specialists, it is rather slow, but each centre has its own line or lines to Bracknell and all transmit simultaneously, so that all the messages can reach Bracknell by 10 minutes past the hour. At Bracknell each collecting centre's message is recorded on tape by a separate receiver and these tapes, which are punched by the incoming signals, are used to broadcast the complete observations to meteorological stations at home. The broadcasts also include observations from Greenland, Iceland and Eire and reports from merchant vessels and Ocean Weather Ships. However, retransmission is virtually complete by about 35 minutes past the hour.

Meanwhile, observations from Europe are already arriving at Bracknell. The teleprinter tapes, which are rapidly scrutinized by staff trained to read them directly, are divided up according to a fixed programme, and then fed into the various transmissions for which Bracknell is responsible. These transmissions are the domestic broadcasts to stations in the United Kingdom, the two radio-teleprinter broadcasts, and agreed programmes over the cable link to Montreal and direct radio-teleprinter links to Cyprus, Aden and Malta.

Some traffic originates at Bracknell itself. For example, because Bracknell is the Master Analysis Centre for the European Region it must broadcast coded versions of the analysis of certain charts. Such messages are normally transmitted automatically by a manually punched tape.

The other European centres work on similar principles. The schedules are so arranged that in many cases the incoming signal can simply be switched through, and tape relay is used only where this method is impracticable.

WMO recommendations on signals procedure cover not only the content but the format of messages—the headings of various classes of message, the proper use of spaces, the arrangement of groups in the line. Incorrect format adds greatly to the difficulties of plotters, and even more to those of signals staff who edit tapes in the way described in the last paragraph. The importance of format has increased in recent years as a result of the use of computers for preparing meteorological charts. Teleprinter tapes may be fed directly to the computer which relies heavily on correct format for the identification of the incoming data. With the encouragement of WMO considerable improvements in standards have been achieved lately, and automatic data extraction is now nearly as efficient as manual extraction. It must be admitted however that this is only achieved by very elaborate computer programmes which can cope with a wide range of errors in format and even in content.

Traffic volume. On average there are 8 five-figure groups in the coded report of a single observation. Ship reports contain some 10 groups because they include the co-ordinates of the ship's position. For a complete upper air sounding some 120 groups are needed, though a shorter form is much used. The routine completion of four main surface charts and two families of upper air charts at Bracknell requires about 75,000 five-figure groups daily. But these are only the principal charts. The total daily traffic through the Bracknell centre caters for hourly surface charts of the British Isles, twice-daily circumpolar charts of the northern hemisphere, analyses and prognoses in coded form transmitted to dependent outstations and to and from other countries, reports and forecasts of direct use to aviation and, in recent years, coded cloud analyses derived from earth satellites. Moreover the data actually received from other countries comply with a programme jointly agreed between all recipients, and such joint agreements usually express a requirement larger than any individual need. The total volume of incoming traffic is therefore much greater than that actually used for plotting, and on a representative day in January 1964, Bracknell received some 400,000 five-figure groups. The number transmitted, 550,000, was even more remarkable at first sight since Bracknell is responsible internationally only for the transmission of data from the European Region; but as already explained a single observation may be transmitted in several different programmes.

Facsimile transmission. Although techniques for transmitting pictures by telegraphy have been known for a century, it is only recently that they have been applied to meteorological purposes. In the United Kingdom a land-line facsimile system was set up in 1954 and has been gradually extended until it now serves almost all forecasting offices in the country, that is about a hundred. The installation has two main purposes. In the first place there are many charts and diagrams which are required by every forecaster but which can be effectively prepared only in a large central office having access to all the necessary data. (Upper air charts, both actual and forecast, are the most important group.) It is therefore necessary to have some means of distributing such charts to the smaller offices. A coded message can be prepared, and sent by teleprinter, which will enable the recipient to reproduce the original chart, and this method has in fact been used for many years, but it is laborious and not very accurate. Facsimile on the other hand allows such charts to be distributed automatically without distortion.

The second purpose of facsimile is to avoid the great waste of labour which occurs when precisely the same set of observations is plotted at a hundred different forecasting offices. Formerly many offices plotted a chart for the British Isles every hour, and one assistant was almost continuously engaged on this task at each station. Now, the hourly chart is plotted only at Bracknell, and is broadcast by facsimile for use in all other offices. A chart covering most of western Europe is similarly broadcast every three hours.

Many countries now have domestic facsimile systems used in much the same way as the British one just described; but there is no properly co-ordinated international facsimile system comparable with the international teleprinter system. Many countries make meteorological broadcasts by radio-facsimile, but each decides its own programme. However, WMO has made recommendations, in general terms, as to the contents of such broadcasts, and these recommendations are usually respected. A more important fact is that technical groups working under WMO have been able to ensure a wide measure of technical standardization of equipment, so that one receiver may intercept any required broadcast. A radio-facsimile broadcast has been in operation from this country since 1953 and, though it was planned mainly for British bases in the Mediterranean, it is well received over most of Europe and the programmes conform to WMO recommendations. The programme consists of current and forecast charts, both surface and upper air, together with some thermodynamic diagrams, and is in fact the same as that used domestically but without the plotted charts and with the addition of certain charts prepared at London (Heathrow) Airport for aviation.

At Bracknell, facsimile transmissions are regularly received from New York, Washington, Offenbach, Moscow and Tokyo. The American transmissions are by far the most valuable to the forecaster because they include a wide range of charts produced by electronic computer at the Numerical Weather Prediction Unit of the United States Weather Bureau, charts of special application to aviation over the western Atlantic and North America, and cloud observations made by weather satellites. In Europe the Offenbach transmission has the advantages of high power and low frequency; it is successfully received throughout the Region and includes analyses for the greater part of the northern hemisphere.

Administration. The responsibility for the planning and provision of telecommunications to meet the requirements of the Meteorological Office rests formally with the Director-General of Signals of the Air Force Department of the Ministry of Defence. The great indebtedness of the Office to this Directorate is most gratefully acknowledged. Within the Meteorological Office, the co-ordination and formulation of requirements rests with the Assistant Director (Observations and Communications). The communications centre at Bracknell is air-conditioned and occupies practically the whole of the sixth floor in the Headquarters Building. It is manned continuously by Meteorological Office staff consisting of signals officers, radio operators and teleprinter operators. The radio-teleprinter and radio-facsimile transmitters and receivers are provided by the RAF and are at some distance from Bracknell, but transmissions are keyed from Bracknell. The small amount of traffic in Morse code still received is taken at Dunstable, the former home of the Central Forecasting Office. Coded reports and facsimile copy received by radio are relayed by land-line into Bracknell. Communications equipment is when possible obtained from the RAF and, as with the RAF, all teleprinters and lines are rented from and maintained by the Post Office. Direct acquisition of equipment by the Meteorological Office is resorted to only in the case of requirements unique to the Meteorological Office. The largest item under this head is facsimile equipment.

2. General Description of the Services Directorate

The function of this directorate is to satisfy, as far as possible, the demands of the community for meteorological services. Largely, but not wholly, these demands are either for forecasts of weather or for climatological information. For this reason some assistant directorates are concerned directly and almost exclusively with services in one or other of these two categories. Others are concerned primarily with the provision of data and facilities without which the forecaster and climatologist could not do their jobs. The general pattern of the organization of work in the Services directorate is as shown in Appendix I.

In the following paragraphs of this section an outline of the work of each element is given, dealing with the forecasting branches first, climatological branches second and other branches last. A greatly amplified account of one category of work in the Services directorate is given in Section 1, the subject this year being 'Meteorological Communications'. Important events and innovations during the year are described in Section 3, and Section 4 contains notes on the weather of 1964. Finally the statistics in Section 5 provide some measure of the volume of work.

Central Forecasting (Met.O.2). The Central Forecasting Office (C.F.O.) has a dual function. Firstly it is, by international agreement, a Master Analysis Centre, with an output designed to help other forecasting offices both domestic and foreign. The material for this purpose is broadcast over the meteorological communication system (described in Section 1) and consists mainly of actual and forecast charts, both surface and upper air, supplemented by written commentaries. Secondly the C.F.O. is responsible for the preparation of forecasts and 'warnings' which have a nation-wide application. These forecasts fall into three main categories, general forecasts for land and sea areas for dissemination by the Press and by broadcasting, forecasts for some public utilities such as the Central Electricity Generating Board and certain special forecasts for periods up to three or four days ahead. Parallel services in the first two categories are provided by local meteorological offices which prepare more detailed forecasts applicable to smaller areas.

The Central Forecasting Office is also responsible for the preparation of the Meteorological Office daily publications, namely, the *Daily Weather Report* with its *Overseas Supplement* and *Monthly Summary* and the *Daily Aerological Record.*

Aviation Services (Met.O.6). The meteorological organization for civil aviation in the United Kingdom consists of a principal forecasting office at London (Heathrow) Airport, main offices at air traffic control centres, subsidiary offices at civil aerodromes of intermediate importance and observing offices at some minor civil aerodromes. At civil aerodromes where there is no meteorological office, meteorological services are usually provided by telephone or teleprinter from a suitable meteorological office in the vicinity. To meet the need for observations from the aerodromes, air traffic control staff are trained in the making and reporting of weather observations. The functions of the main meteorological offices include not only the supply of forecasts to captains of aircraft before a flight, but also the provision of forecasts, warnings and observations to aircraft in flight.

Overseas, meteorological services for civil aviation are provided at a number of joint user (i.e. RAF and civil) aerodromes in the Near and Middle East Commands.

The pattern of outstation meteorological service for the Royal Air Force largely conforms with the RAF organization. There is a principal forecasting office at the Headquarters of Bomber Command, and main offices, functioning throughout the 24 hours, are located at the Headquarters of some RAF Groups and control and advise subsidiary offices at RAF stations in the Group. At these subsidiary offices a forecaster is available at times which depend on the needs of the Royal Air Force. At observing offices there is no forecaster and the duties comprise the making and issue of weather observations. At RAF Command Headquarters the meteorological unit usually consists of a senior officer of the Meteorological Office who acts as an adviser to the Air-Officer-Commanding-in-Chief and as a liaison officer between him and the Director-General of the Meteorological Office. The same general pattern applies both in the United Kingdom and overseas in Western Germany and the Mediterranean, Middle East and Far East areas.

General Services (*Met.O.7*). This assistant directorate has a triple function. First, it co-ordinates and in some cases supervises the supply of services for the general public through many different channels, e.g. the Press, broadcasting (sound and vision), the automatic telephone weather service, offices on airfields and weather information centres. Weather information centres, established to meet non-aviation inquiries from the public, are now available in London, Manchester, Glasgow and Southampton. The London centre continues to provide the staff for the routine weather presentation on the BBC sound and television channels, though, in this matter, they are acting largely as the mouthpiece of the Central Forecasting Office.

Second, basic climatological investigation into meteorological matters of concern to agriculturists, and special investigations into the relation between meteorological and agricultural parameters, are carried out at Headquarters. Staff are also engaged on the application of meteorology to the problems of agriculture at stations at Bristol, Cambridge, Leeds and Edinburgh. Contact with research and advisory workers in agriculture is maintained through the National Agricultural Advisory Service, research stations, experimental farms, universities and farm institutes.

Third, the assistant directorate is responsible for liaison with the Army Department of the Ministry of Defence on meteorological services for the Army. Ballistics work involves maintaining meteorological offices at a few establishments (Army Department and Ministry of Aviation) where the information supplied is of a specialist nature.

Climatological Services (*Met.O.3*). The function of this assistant directorate is to collect, examine, analyse and preserve meteorological data from surface and upper air observations and to supply answers to queries to which these data are relevant. The area of collection is world-wide though obviously the work carried out is far more detailed in respect of observations made at stations in the United Kingdom, and at places abroad where the observing stations are maintained by the Meteorological Office, than in respect of observations made under the supervision of other meteorological services. The data collected and preserved cover all the usual meteorological elements. The inquiries answered are mainly, but by no means exclusively, concerned with climate in the United Kingdom. These inquiries cover an extraordinarily wide field, ranging from problems of water supply to the sale of ice cream, from the building of power stations to the location of convalescent homes. Data for the United Kingdom are published mainly in the *Monthly Weather Report* and the *Annual Summary* and in the yearly publication *British Rainfall*. Met.O.3 is responsible also for the preparation of occasional publications dealing with climatological statistics.

Much of the data collected comes from voluntary co-operating stations maintained by private individuals, local authorities, river boards, private firms, schools, public utilities, etc. this being particularly so in the case of rainfall observations (see Table XVII). The Meteorological Office sets the required standards for sites, instrumentation, and observational procedure and arranges for periodical inspections of the stations.

This Assistant Directorate also engages in investigational work, including field experiments, mainly of a character relevant to the provision of climatological services.

To a large extent the office at Edinburgh deals in climatological services insofar as Scotland is concerned and an office in Belfast carries out a similar function for Northern Ireland. In such matters these two offices act on behalf of, and are supported by the Assistant Directorate.

Marine Branch (*Met.O.*1). The main functions of the Marine Branch are to organize the supply of meteorological reports by the British Merchant Navy and Ocean Weather Ships, to arrange for meteorological services to the Merchant Navy and to deal with marine inquiries.

Meteorological observing by the British Merchant Navy is entirely voluntary and unpaid; nevertheless nearly 700 ships participate. An analysis of the Voluntary Observing Fleet is given in Section 5.

The United Kingdom co-operates with France, Holland and Norway in maintaining a constant watch at five Ocean Weather Stations in the North Atlantic. For this purpose the Meteorological Office operates four Ocean Weather Ships, of which two are always 'on station'. These ships make hourly observations of surface weather, but their most important function is the measurement of wind, temperature, humidity and pressure in the upper atmosphere. In addition to their meteorological duties the ships also provide the following services:

(i) Air–sea rescue service
(ii) Communications services and navigational aid to transatlantic aircraft
(iii) Other scientific observations (usually at the request of other Government scientific branches).

The Marine Branch publishes monthly charts based on ships' reports, showing the distribution of sea ice in the northern hemisphere. Ocean currents are also calculated from ships' reports and the results used in the preparation of ocean current atlases; the publications section arranges (through HMSO) for the printing of these and also of meteorological and climatological atlases of the oceans. This section also arranges for the correction and printing of various technical books, code cards and forms used by the Voluntary Observing Fleet, Ocean Weather Ships and Port Meteorological Officers. The *Marine Observer*, a journal of maritime meteorology, is published quarterly.

Observations and Communications (*Met.O.*5). About 110 meteorological offices in the United Kingdom make surface observations, but there is also a similar number of auxiliary reporting stations, manned by members of the Coast Guard, Trinity House and Northern Lighthouse Board organizations and other authorities. To obtain information about the upper air, a network of combined radiosonde and radar wind stations is also maintained both in the United Kingdom and overseas. A network of stations equipped with radio direction finders locates thunderstorms over Europe and nearby regions. There are four of these stations in the United Kingdom and three in the Mediterranean —at Gibraltar, Malta and Cyprus.

The communications system by which observations are collected and redistributed to the forecasting offices, is fully described in Section 1 of this report.

Computing and Data Processing (*Met.O.*12). The Meteorological Office has used punched-card machines for data processing since 1921. In 1959 an electronic computer was acquired primarily for research into numerical methods of weather forecasting but it was early realized that the computer would be of enormous value in other work and it has been much used by the Research and Climatological Services branches of the Office. Electronic computing methods proved so successful that in 1963 it was decided to order a powerful new electronic computing system, the *English Electric-Leo* KDF 9 computer. The new computer will be named COMET and the whole electronic computing organization the COMET computing laboratory. The punched-card installation and the original computer were formerly in the charge of a section of Met.O.18 but the imminent arrival of COMET has rendered it advisable to set up a special branch. The new Met.O.12 was accordingly formed on 1 December 1964. Its duties are defined as "Control of computing laboratory and punched-card system. Development of data processing and automation". The branch is equipped to operate and programme COMET and the punched-card machinery, to care for data libraries on magnetic tape and punched cards, and to punch the necessary cards and paper tape. It is responsible for producing general programmes, such as input /output and library routines, for use with COMET. Many specialist programmes will, however, be written by the branches concerned assisted as necessary by Met.O.12 programmers. In addition the branch will be responsible for developing the use of automation in general in the work of the Office.

Forecasting Techniques (*Met.O.8*). Met.O.8 is divided into two sections. Met.O.8a was formed on 1 December 1964 to develop high-speed computer routines for the preparation of actual and forecast synoptic charts. The other section, Met.O.8b is responsible for the surveillance of forecasting techniques, for general guidance on their improvement and for keeping under review manuals of operational forecasting. It also co-ordinates researches and investigations carried out by local meteorological offices.

The staff of such offices are encouraged to undertake research and indeed there are many problems of local forecasting that are best tackled by the man on the spot. But almost any worthwhile investigation needs to be carried out at a number of different stations, according to a fixed plan. Some central co-ordination is therefore necessary and is provided by Met.O.8. The branch also, as a rule, takes charge of the analysis of the results, because it has access to the Headquarters computer and punched-card machinery.

The organization of such local investigations is carried out through two working groups, one concerned with statistical and the other with synoptic problems.

Defence and International (*Met.O.17*). The international character of meteorology inevitably leads to a number of international conferences each year. Most, but not all, of these are held under the auspices of one or other of three organizations. The World Meteorological Organization (WMO) deals with matters of pure meteorology. This organization is composed of six regional associations (one for each continent) and also sponsors a number of technical commissions each of which deals with a particular branch of meteorology. The International Civil Aviation Organization (ICAO) deals with all international questions affecting civil aviation and also has geographical component parts and specialist panels. Many of the ICAO meetings are concerned either directly or indirectly with the meteorological aspects of civil aviation. Thirdly, various aspects of meteorological support for the armed forces of the North Atlantic Treaty Organization (NATO) are discussed at meetings of committees and working groups organized for that purpose. There are also meteorological committees associated with the other international military organizations in which the United Kingdom is concerned.

Delegates from the Meteorological Office to these various meetings are drawn from all parts of the Office but the administration and co-ordination is carried out by Met.O.17. An account of the principal meetings attended will be found in the 'International Co-operation' section (p. 60).

Considerations of the national meteorological wartime policy are closely connected with agreements reached in NATO Meteorological Committee (and other similar) meetings and properly fall within the province of Met.O.17.

The Ministry of Defence (Defence Secretariat, Air Force and Army Departments) and other Government Departments regularly require advice or comment on administrative, financial and technical aspects of meteorological matters which arise in the International and Defence fields. These matters are dealt with, in co-operation if necessary, with other appropriate branches of the Office.

The Assistant Director (Defence and International) also assists the Director-General as Permanent Representative of the United Kingdom with the World Meteorological Organization and in his personal capacity as a member of the Executive Committee of that Organization.

3. Major Events and Changes in the Services Directorate

Central Forecasting (*Met.O.2*). Improved techniques, which have resulted in quicker transmissions, have allowed the Central Forecasting Office to increase very considerably the quantity of processed meteorological data disseminated by facsimile. Broadcast schedules now include actual surface and 500 millibar charts for most of the northern hemisphere and, for Europe and the North Atlantic, actual and forecast charts for all standard pressure levels up to 100 millibars. A useful ancillary chart, now issued for the first time, shows, once a week, the distribution of sea surface temperatures around the British Isles and in the eastern Atlantic Ocean.

Aviation Services (*Met.O.6*). There has been little change in the pattern of meteorological services for aviation during the year; these services cater for all types of flying, from the high-speed, high-altitude flight over long distances to slow flights by comparatively unsophisticated aircraft. The number of forecasts issued for civil flights was again higher than that in the previous year.

Attention has been paid to the meteorological requirements of aircraft under development or planned for the future, in particular the Concord project. Forecasts are now prepared regularly at London (Heathrow) Airport for hypothetical supersonic flights to New York to give forecasters and operators practical experience of the new techniques and requirements.

Services were provided for many RAF exercises in various parts of the world, sometimes in co-operation with Commonwealth and foreign meteorological services. Arrangements were made to provide services for a number of flights by members of the Royal Family; several of the flights were to destinations overseas. An officer was temporarily attached to the Caribbean Meteorological Service for liaison and advisory duties in connexion with a tour of the Caribbean by H.R.H. The Prince Philip, Duke of Edinburgh.

Meteorological visibility for the purposes of civil aviation is now specified in metric units. This is a further step towards international standardization of units.

RAF flying units have been withdrawn from Aldergrove, but the main meteorological office is being retained there to advise civil aviation and to control other meteorological units in Northern Ireland.

Arrangements have been made for the collection of reports of turbulence encountered by aircraft flying above 20,000 ft and reports have been received from civil and RAF flights. These arrangements are in support of the International Civil Aviation Organization's World-Wide Programme of Investigation into the incidence of high-level turbulence.

General Services (*Met.O.*7). The public's interest in weather information, stimulated by the severe winter of 1962–63, was maintained throughout 1964 and, despite the quieter and less eventful weather, non-aviation inquiries totalled 967,265, an increase of 6 per cent on the 1963 figure (itself a record). The outstanding change was in inquiries for weather affecting road transport; these, totalling 145,573, were about 50 per cent up on the 1963 figure, and were 15 per cent of the total of all non-aviation inquiries. Watnall, an aviation office, handled nearly 7000 road inquiries in December alone, and over the year as a whole handled about 50 per cent more non-aviation inquiries than in 1963.

Glasgow Weather Centre moved to new premises in August. The accommodation is now adequate for all facets of the work of the Centre and includes display windows and an inquiry desk to meet the needs of personal callers. The Port Meteorological Officer is also accommodated at the Centre. The move of London Weather Centre, planned for 1964, was delayed, but a firm date was fixed for the move to Penderel House, High Holborn in January 1965. Accommodation at Manchester Weather Centre was somewhat enlarged and rearranged in preparation for a 24-hour service and installation of weather radar.

Close liaison was maintained with BBC Sound and Television. The daily 'Metcast' sound broadcast, presented direct from the London Weather Centre by 'Weathermen', was continued throughout the year. Personal presentation of sound broadcasts by Weathermen was extended late in the year to cover the national forecasts in the 0655 and 0755 Home Service weather bulletins and the forecast at 0830 in the Light Programme. The extension of Light Programme hours demanded more forecasts from the Central Forecasting Office and there was also a consequential change in the schedule of shipping forecasts. Earlier in the year the style of shipping forecasts was changed after discussions with the BBC and shipping interests.

Special broadcasts were made on sound radio, including the overseas service, and on various television channels. Among the topics of the broadcasts were the work of the Meteorological Office in general, the functions of Weather Centres, long-range weather forecasts, auxiliary observing stations, Ocean Weather Ships and weather reconnaissance flights, as well as snippets on current and past weather.

The automatic telephone weather service attracted a grand total of 6,926,013 calls. A new service covering the North Wales coast was introduced in March and is so far available only in Manchester and Liverpool and surrounding areas. Forecasts are obtainable in 16 G.P.O. Information Service Centres throughout the country, and plans for considerable expansion of the service in 1965 are well advanced.

Questionnaires were sent to some 2600 subscribers to *Monthly Weather Survey and Prospects*, to farmers and growers subscribing to the fine spell service, and to Local Authorities using the snow and icy road warning service. Answers to the questionnaires on monthly forecasts provided information on their adequacy and usefulness, and revealed the need for such forecasts in a wide variety of industrial and commercial activities, farming, education, scientific research and private life. Following the questionnaire on fine spells, modifications are being introduced to the service for 1965; and changes have been incorporated in the 1964–65 snow and icy road warning service to meet the needs of subscribers.

Routine forecasts and warnings are now being supplied by the London Weather Centre for drilling operations in the search for oil and natural gases under the North Sea. Plans are afoot to introduce a similar service for boring operations in the English Channel in connexion with the Channel tunnel scheme.

The Army Department and a number of establishments engaged in ballistic work were provided with the necessary meteorological services. As many as 3982 radar wind and/or radiosonde ascents and 761 theodolite ascents were made for ballistic purposes. Assistance and advice in the training of Army personnel on specialized meteorological duties continued. Considerable progress has been made in the theoretical and practical study of the meso-scale variability of wind using a number of radars.

Investigational work concerned with agricultural meteorology continued throughout the year, and a number of memoranda have been prepared dealing with a variety of subjects such as milk production, the distribution of cattle, sheep, cereals and grasslands, barley yields, optimum dates for sowing winter wheat, the sugar beet yellows virus and the codling moth. As a contribution to the growth problems of Corsican pine, a frost investigation is in progress in Thetford Forest in association with the Forestry Commission.

Further advice and assistance have been given on the new town plan for Cumbernauld. Notifications of 'Beaumont' and 'Smith' periods were provided on the same scale as in 1963 and advice given as necessary on the irrigation needs of farmers and growers. Close liaison was maintained with the Pathology and Veterinary Laboratories on disease problems.

Climatological Services (*Met.O.*3). Under the heading of hydrology the year was characterized and to a large extent, dominated by preparation for two forthcoming major events, one national, the other international.

Nationally, the Water Resources Act of 1963 is to be implemented in its organizational aspects by 1 April 1965. As part of this process the appointment of the Water Resources Board and the setting up of river authorities, ready to replace the river boards of England and Wales, provided a great stimulus to increased hydrological activity and its counterpart in hydrometeorological activity within the Office. The Meteorological Office is of course also associated with further developments in the work linked with the Committee on Hydrological Research and the Hydrological Research Unit, and whilst the organizational pattern with regard to hydrology in the U.K. remains very complex, there were important steps towards closer co-ordination of all aspects, including hydrometeorology. In parallel with developments for England and Wales particular attention was given to improving some aspects of basic hydrometeorological work in Scotland and Northern Ireland.

Internationally, preparations for the International Hydrological Decade, planned by UNESCO to begin on 1 January 1965, provided the main stimulus. The British delegation to the international meeting at Unesco House, Paris, in April 1964 included Mr. A. Bleasdale who is also a member of the British National Committee which prepared the British Programme for the Decade. Another international meeting of great importance was the second session of the

WMO Commission for Hydrometeorology (CHy) at which Mr. R. H. Clements was the principal British delegate. This session concerned itself with a very wide range of topics some of which were directly relevant to the International Hydrological Decade which WMO, through CHy, is supporting to the full.

Towards the end of the year the Climatological Services Assistant Directorate was becoming involved in a further study on probable maximum precipitation for the basin of the Ofin river, near Kumasi, Ghana. One officer has now been allocated full-time for work of this nature.

On the land surface climatological side further preparations were made for a full scale trial of collection by teleprinter of climatological data from meteorological offices. Inquiries received ranged over the usual wide field but perhaps special mention should be made of one relating to the frequency of various types of weather to be expected in Morecambe Bay (the Morecambe Bay barrage proposal) and another which involved a comprehensive analysis of Kew daily mean temperatures to provide statistics of use in planning fuel requirements. On the marine climatology side the branch provided the WMO representative at a meeting of an international working party to consider the preparation of a Mediterranean synopsis for the use of all those concerned with the fishing industry.

Marine Branch (*Met.O.*1). In 1964 the British Ocean Weather Ships completed their 17th year of service in the North Atlantic. The 'Castle' class frigates, which between 1958 and 1961 gradually replaced the former 'Flower' class vessels, are continuing to show themselves suitable and reasonably economical for their present duty. Their maintenance and repair costs, for example, at an average of about £11,000 per ship per annum, are little different from the average in 1955, despite rising shipyard costs.

Routine hourly surface observations and six-hourly upper air observations have continued aboard these ships throughout the year—the sea-going meteorologists have again shown their determination to launch their upper air balloons no matter how violent the wind and sea. Tracking the balloon by radar in rough seas is also no mean feat, and requires much skill and concentration on the part of the technicians who operate the radar. The Master of 'Weather Reporter' reported at the end of a recent voyage that "winds reached gale force during each of the 24 days on station".

'Weather Reporter' and 'Weather Monitor', when on duty at Station Juliett, took part in the Military Oceanographic Month in the Eastern Atlantic in September. A letter from the responsible Naval Authority reads "These ships by their cheerful co-operation and high standard of their navigation made a notable contribution to the success of the survey."

Total short-wave solar radiation and radiation balance observations were continued by all four ocean weather ships, by two survey ships of the Royal Navy and by the Royal Research Ships 'Discovery', 'Shackleton' and 'John Biscoe'. Observations to check the accuracy of the Beaufort Scale of wind force were completed during the year aboard the Ocean Weather Ships.

On 31 May a boiler room fire at sea aboard 'Weather Adviser' resulted in fatal injuries to two firemen and fairly extensive damage to the ship. But for prompt action in smothering the fire the consequences would, without doubt, have been very much more serious. Certain additional safety precautions have been taken.

On 9–10 June 'Weather Reporter', on duty at Station Juliett, was involved in an air–sea rescue incident, in which the pilot of a U.S. fighter aircraft ejected into the sea about 20 miles away from the ship. Unfortunately the pilot was dead when he was taken aboard ship.

On 8 May, 'Weather Reporter', on Station Juliett assisted a Swedish ship for nine hours in an unsuccessful search for a man lost overboard. The Ocean Weather Ships had the distinction of winning two awards during the year for their services to aviation—the Hunt Trophy, an inscribed silver tray, awarded annually by the Guild of Air Traffic Control Officers to the individual or organization considered to have made the most outstanding contribution to Air Traffic Control, and the Distinguished Service Citation of the Flight Safety Foundation Inc. of New York, awarded to the personnel of Ocean Weather Ships of all nations for what is described in the citation as "services of immense benefit to the safety of over-ocean transportation".

British shipping has had a recession over the last few years but the situation seems to have improved during 1964. Nevertheless, instruments had to be withdrawn from some 43 voluntary observing ships on account of lay-up or sale to foreign buyers or shipbreakers. But 60 ships were recruited to replace them and the strength of the Voluntary Observing Fleet has remained at about 500 selected and 50 supplementary ships throughout the year.

During the year, 1081 meteorological log-books were received from ships of the Voluntary Observing Fleet. Examination of these books shows that the standard of observations has been generally very creditable and most of the observations are successfully transmitted by radio to the appropriate authority on a world-wide basis. Books were presented to the Masters and officers submitting the 100 best meteorological log-books. Barographs were awarded to four shipmasters who each had an outstanding observing record.

Efforts were continued to secure more radio weather messages and more synoptic observations for climatological purposes from the areas of the world where observations are sparse and 177 of the special forms devised for this purpose were received from the auxiliary ships concerned, each form usually containing about 50 observations.

The interest of scientific associations outside the Meteorological Office in the additional remarks pages of the meteorological log-books has continued, and the circle of the Marine Branch's contacts has widened until we now have people who between them are willing to deal with virtually every natural phenomenon observed at sea. The National Institute of Oceanography has started an investigation into the incidence of marine bioluminescence throughout the world. The Institute has been given access to an index of all such observations recorded in ships' meteorological log-books going back to 1854. During the year log-books have included observations of unusual radar propagation, volcanic ash, moths, water snakes and earth satellites! Many observations of aurora are now received from merchant ships and weather ships on behalf of the Aurora Survey in Edinburgh and as these are often the only reports that are received from oceanic areas they are very valuable.

The increasing importance of Hull as a port and the need to secure the goodwill of the distant water fishing fleets operating from the Humber made it desirable to station a full-time Port Meteorological Officer there. The death of the Marine Branch's former part-time agent in Hull created an opportunity to effect this and during the year the Port Meteorological Officer from Southampton took up full-time duty in Hull whilst Southampton reverted to a part-time agency as it was before 1948. The new arrangement makes it possible to devote more time to those trawlers operating in the high latitudes which have shown themselves particularly adept at sending radio weather messages of non-instrumental observations during the past few years; these trawlers are gradually being equipped with instruments as full observing ships.

The number of inquiries dealt with during the year was slightly larger than that in 1963, and the inquiries covered the usual wide variety of interests. Those from solicitors, insurance and shipping companies far outnumber other classes of inquiry. A considerable number of requests for wave data were again received from engineers interested in drilling for oil and gas in the North Sea. Similar information was provided relating to the Persion Gulf and Western Australia in connexion with the operation of hovercraft. Engineers engaged in offshore construction work in the Mediterranean, Adriatic, the west coast of India and the Persian Gulf, as well as in home waters, were also provided with wave data. The Ministry of Transport was supplied with weather information on 12 occasions for presentation at Courts of Inquiry into shipping casualties. Information about gales and tropical storms in various parts of the world was provided in connexion with the preparation of the new International Loadline Convention for Shipping.

Work continued in co-operation with the Ocean Weather Ships, H.M. survey ships and merchant ships to improve methods of measuring surface ocean currents, and steady progress has been made in punching ocean current data on to Hollerith cards for rapid processing by the electronic computer in due course.

Surface ocean current and sea ice data for six volumes of *Sailing Directions* were reviewed during the year, and surface current and ice data were supplied to the Hydrographic Department of the Navy for the revision of navigational charts.

Observations and Communications (Met.O.5). After 23 years' almost continuous operation, meteorological reconnaissance flights by RAF aircraft ceased on 31 July, when No. 202 Meteorological Reconnaissance Squadron was disbanded. There were several such squadrons operating during the last war, but since 1950, No. 202 Squadron has been the only one still in service. In the 18 years that it was engaged on this work, the Squadron flew over 4000 sorties, nearly all over the Atlantic, and established a fine reputation both in this country and in Western Europe for regularity and reliability.

Reporting stations within the United Kingdom at the end of December totalled 220. Only one-half of these are manned by the Meteorological Office. The remainder are maintained by this office but manned by voluntary observers from many walks of life. A fruitful source of such volunteers is found among television audiences when a recruiting appeal is linked with a weather forecast presentation. It is possible to give a small number of these volunteers a short period of training at the Meteorological Office Training School.

At upper air land stations, revised observational techniques were introduced which, combined with an extended use of larger balloons, afforded observations at greater heights than were formerly possible. A height of 100,000 feet has frequently been exceeded. Table XVIII in its final column gives some indication of the success achieved by the largest balloon.

A new wind-finding radar is being supplied to the Meteorological Office. This possesses a greater range and is more easily operated than the equipment used hitherto. Installation was completed at four stations during the year.

Upper air observations at the Seychelles began during 1963 in support of the International Indian Ocean Expedition, and were terminated in December, 1964.

In the field of communications, a reorganization of the International European Meteorological Teleprinter Network was effected. Certain circuits were abandoned and new ones adopted. Together with a revision of transmitting schedules this distributed the work load among a greater number of nations and everywhere speeded up the receipt of data.

Dunstable, already the shore radio station for Ocean Weather Stations India and Juliett to north-west and west respectively of the British Isles, was designated to replace Washington as shore radio station for O.W.S. Alfa, which, lying between Iceland and south Greenland, has been manned by European weather vessels for some years.

Facsimile equipment to serve meteorological offices with the RAF in Germany has been delivered and is being installed; radio-facsimile reception from other countries was transferred in January from Dunstable to RAF control at the Radio Receiving Station, Bampton; experiments were conducted to reveal the possible usefulness of facsimile communication with our ocean weather vessels. The introduction of alternate line scanning, which halves transmission time for suitable charts, led to an increase of the material supplied to our outstations over the domestic land-line network and an amplified radio-facsimile programme.

Computing and Data Processing (*Met.O.*12). As already mentioned, this Branch was created on 1 December 1964 and then took over from Met.O.18 responsibility for control of the computing laboratory and punched-card installation, and for the development of data processing and automation. The following paragraphs deal with work in this field carried out under both régimes.

The Annual Report for 1963 reported the ordering of an *English Electric-Leo* KDF 9 computer to replace the *Ferranti Mercury* METEOR which had been in use since 1959. It was expected at the end of 1964 that the KDF 9, which will be named COMET, would be installed and accepted for use by mid-February 1965.

METEOR was removed in October to allow work to begin on preparing the COMET computing laboratory and was transferred to the Chemical Defence Experimental Establishment, Porton, near Salisbury. During its five and a half years' service METEOR was used in actual computing for 15,347 hours, performing highly important computations in research, notably numerical forecasting, and in services, notably rainfall data processing. During 1964 METEOR's hours of computing averaged 88 per week. Operational and other urgent computing during the period when no computer was available at Bracknell was done mainly at night on the Mercury computer at the Royal Aircraft Establishment, Farnborough by kind permission of the Head of the Mathematical Services branch there.

The new computer will have about twenty times the capacity for work of METEOR and, unlike the latter, will be capable, over much of the time, of running up to four programmes simultaneously on a 'time-sharing' basis. It will be used to provide twice daily, to the Central Forecast Office, a computed forecast of the pressure distribution and will also be used for research, for climatological data processing, and for trials of the automatic editing of synoptic weather transmissions. An early task will be the compilation, largely by conversion from punched cards, of a library of meteorological data on magnetic tape for use in the computer. Training of staff in the programming and operating of COMET was pressed vigorously forward and by the end of the year a number of programmes for meteorological work were ready for use in acceptance trials. These programmes included the majority of the routines involved in operational numerical forecasting which were prepared by Met.O.11, and others prepared in Met.O.12 for processing rainfall data and converting meteorological punched cards to magnetic tape.

Work in the development of automation was concerned with the acquisition of an automatic chart plotter and a line-drawing apparatus to give a graphical output, e.g. of the contours of an isobaric surface, from COMET. A contract was placed during the year for the chart plotter, which is designed to plot each hour, a British Isles synoptic chart of quality suitable for transmission by the facsimile system. The chart will be plotted with the usual international symbols and differ only slightly in appearance from a hand-plotted one. The chart will be plotted in about 15 minutes as compared with about 40 minutes by hand. Tenders for the purchase of line-drawing equipment were under consideration at the end of the year.

Forecasting Techniques (*Met.O.*8). On 1 December 1964, responsibility for the training within the Meteorological Office was transferred from Met.O.8 to Met.O.18; an account of training appears on p. 57. At the same time a new section was created to develop high-speed computer routines for the preparation of actual and forecast synoptic charts and the title of the branch was changed from 'Techniques and Training' to 'Forecasting Techniques'.

The new section (Met.O.8a) is engaged exclusively on the development of the numerical forecasting programme for the new computer (COMET). Hitherto this work has been carried out by Met.O.11 (Dynamical Research), although it was not strictly appropriate to a research branch. Most of the staff of Met.O.8a have been drawn from Met.O.11 and are therefore already familiar with this highly complex and specialized work. The immediate task is to complete the writing of the basic forecasting programme so that it is ready for testing as soon as the computer is installed, and next, to assist in bringing numerical forecasting into regular use. Thereafter, the programme will have to be developed to cater for a wide range of operational requirements—in particular, for aviation forecasting it must provide explicitly the required information on winds and temperatures in the upper atmosphere. Modifications will also be needed to extend both the area and period covered by the forecast as well as to enable the computer to operate a line-drawing machine and so avoid the loss of time entailed in drawing by hand, and to take account of additional information such as observations of upper wind velocities by aircraft. It may also be necessary to write the programme in an alternative version suitable for use on another computer when the Bracknell one is unserviceable. Tasks of this nature are expected to occupy the section for several years.

Met.O.8b is responsible for the co-ordination of local research and investigation, and for general guidance on forecasting techniques. Several courses of action have been taken as a result of the survey (mentioned in last year's Annual Report) of forecasting methods and techniques in use at outstations. Arrangements have been made with the Independent Television Authority for instruments to be mounted on a high mast (1000 ft) at Lichfield to provide more detailed information on the lowest layers of the atmosphere than is at present available from routine radiosonde reports. (Information from the lowest layer is of great importance for the forecasting of fog and low stratus cloud.) Original radiosonde records are being examined to see whether more detail of the lower layers can usefully be supplied than can be deduced from the radiosonde reports as coded at present. Also as a result of the survey, a study has been made of methods in current use for forecasting the type, intensity and duration of precipitation. Co-operation is being sought from operational outstations in testing recently published techniques for forecasting various elements.

There has been a need for some time past to review current techniques for the forecasting for aviation of winds and temperatures near the tropopause. Additional staff have been appointed to Met.O.8 for this purpose.

Work continues on a number of statistical and synoptic investigations and in co-ordinating and in advising on similar investigations which are being conducted at outstations. Studies include the following: local variations of fog within the valley of the upper Thames, variation of cloud base according to geostrophic wind, the depth of the katabatic wind, and the objective forecasting of visibility at London (Heathrow) Airport using current data to predict the visibility three or six hours ahead.

A. C. BEST
Director of Services

4. Notes on the Weather of 1964

According to available records two successive very cold winters are rare in Britain, and the number was not increased in 1964. January and February 1964 were relatively mild compared with the very cold winter of 1962–63. But perhaps the majority of people in the southern half of the country will remember the year for its fine summer weather once June was out. Meanwhile March had been very wet, as it was in 1963, possibly a comfort to some water undertakings after another dry winter, but a discomfort to many other people by giving the coldest and dullest Easter for many years. The changeable nature of April, May and June provided good growing weather for many crops, but June unfortunately was to provide too much of its rain on one Royal Ascot day. Even fine summers have their rainy days and Bolton's 2·2 inches of rain in 15 minutes in July was a record fall for such a period. The autumn was drier than usual in England and Wales and by the end of November the previous 36 months had been the driest this century, taking averages over England and Wales as a whole. December was a mixture of mild and cold periods, giving floods in Wales in the second week and a white Christmas morning in many northern and eastern parts of the country.

Table I gives for England and Wales, for Scotland and for Northern Ireland highest and lowest temperatures recorded at stations published in the *Monthly Weather Report* each month, the mean daily maximum and mean daily minimum temperatures over each division of the country based on a number of representative stations (with long-period averages for comparison), monthly sunshine expressed as a percentage of the 1931–60 average and monthly rainfall as a percentage of the 1916–50 average together with these long-period averages. Corresponding annual values are added.

Figure 1 shows the distribution of rainfall over the country expressed as a percentage of the average.

Tables II–XIII give for the twelve stations shown in Figure 2 (p. 23) similar details for each month of temperature (highest and lowest and mean daily maximum and minimum), sunshine (the percentage of average and the 1931–60 average) and rainfall (the percentage of average and the 1916–50 average) as in Table I together with a statement for each station of the number of days when temperature fell below 0°C in the screen (frost), when thunder was heard by the observer at any time during the 24 hours of the day (thunder), when snow or sleet was observed to be falling sometime during the day (snow falling), when at least half the ground in sight of the observing station appeared at 0900 GMT to be covered with snow (snow cover), when visibility was below 220 yards at 0900 GMT (fog) and when wind rose to 34 kt or more over a period of ten minutes at any time during the 24 hours (gale).

TABLE I—CLIMATOLOGICAL DATA FOR 1964

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
ENGLAND AND WALES													
Highest maximum temperature °C	13·9	15·0	15·6	22·2	27·2	27·2	28·9	32·8	27·8	23·3	16·7	15·0	32·8
Lowest minimum temperature °C	–13·3	–13·9	–8·9	–6·7	–1·7	–1·2	0·0	–1·7	–2·8	–7·2	–11·0	–15·5	–15·5
Mean daily maximum temperature °C	5·8	6·9	6·6	12·1	17·4	17·6	20·3	20·1	18·9	12·7	10·5	6·5	12·9
1931–60 average maximum temperature °C	6·3	6·7	9·5	12·5	15·7	18·9	20·4	20·3	17·8	13·8	9·8	7·4	13·3
Mean daily minimum temperature °C	1·1	2·2	2·0	5·2	8·9	10·2	12·1	11·4	9·7	5·4	5·0	0·9	6·2
1931–60 average minimum temperature °C	1·2	1·3	2·5	4·5	7·0	10·1	12·1	11·9	10·1	7·0	4·3	2·5	6·2
Percentage of average sunshine	89	86	53	79	104	74	103	112	135	115	105	114	97
1931–60 average sunshine (hours/day)	1·57	2·38	3·69	5·20	6·15	6·61	5·73	5·44	4·35	3·12	1·81	1·31	3·95
Percentage of average rainfall	29	48	170	111	95	139	63	64	43	66	56	111	83
1916–50 average rainfall (inches)	3·69	2·67	2·30	2·42	2·56	2·23	3·20	3·25	3·06	3·71	3·84	3·53	36·46
SCOTLAND													
Highest maximum temperature °C	13·9	14·4	13·3	18·9	25·0	23·9	26·3	27·8	25·0	20·6	15·6	13·3	27·8
Lowest minimum temperature °C	–11·1	–11·7	–8·3	–6·7	–2·2	–4·4	–0·6	–2·7	–4·4	–7·0	–8·9	–15·6	–15·6
Mean daily maximum temperature °C	7·1	6·8	6·8	11·0	14·1	15·6	17·0	16·2	15·1	11·5	9·1	5·8	11·3
1931–60 average maximum temperature °C	5·6	6·2	8·1	10·6	13·5	16·2	17·6	17·3	15·3	12·0	8·7	6·8	11·5
Mean daily minimum temperature °C	2·5	2·0	2·1	4·3	7·3	8·2	10·0	9·6	8·2	5·5	3·7	0·6	5·3
1931–60 average minimum temperature °C	0·9	1·1	2·1	3·5	5·8	8·5	10·5	10·4	8·7	6·3	3·6	2·2	5·3
Percentage of average sunshine	98	95	66	83	84	97	103	96	106	93	102	111	95
1931–60 average sunshine (hours/day)	1·26	2·30	3·21	4·68	5·86	5·76	4·55	4·38	3·66	2·47	1·48	0·95	3·37
Percentage of average rainfall	43	48	83	113	116	102	79	126	116	69	85	114	91
1916–50 average rainfall (inches)	5·66	3·93	3·30	3·30	3·20	3·19	4·19	4·50	4·71	5·81	5·29	5·29	52·37
NORTHERN IRELAND													
Highest maximum temperature °C	13·3	13·7	13·0	17·6	22·8	22·2	23·4	24·4	22·2	17·2	15·0	13·3	24·4
Lowest minimum temperature °C	–4·4	–7·2	–6·1	–3·9	0·0	–1·1	2·2	–1·1	0·0	–2·5	–6·1	–5·6	–7·2
Mean daily maximum temperature °C	7·8	7·6	8·3	12·5	16·2	16·6	18·3	18·1	16·7	12·3	10·3	6·8	12·6
1931–60 average maximum temperature °C	6·5	7·3	9·6	12·1	15·1	17·7	18·5	18·5	16·3	12·9	9·5	7·5	12·6
Mean daily minimum temperature °C	3·0	2·8	2·2	4·8	8·0	9·3	11·4	10·4	9·5	5·7	3·9	1·4	6·0
1931–60 average minimum temperature °C	1·7	2·2	2·9	4·2	6·5	9·5	11·3	11·0	9·4	6·9	4·2	2·9	6·0
Percentage of average sunshine	62	84	62	86	88	80	77	104	119	78	125	102	89
1931–60 average sunshine (hours/day)	1·53	2·31	3·34	4·97	6·14	5·83	4·40	4·39	3·62	2·71	1·91	1·15	3·53
Percentage of average rainfall	47	44	131	90	92	107	56	105	89	126	78	107	89
1916–50 average rainfall (inches)	4·23	2·93	2·56	2·60	2·76	2·76	3·73	3·94	3·73	4·32	4·02	4·32	41·90

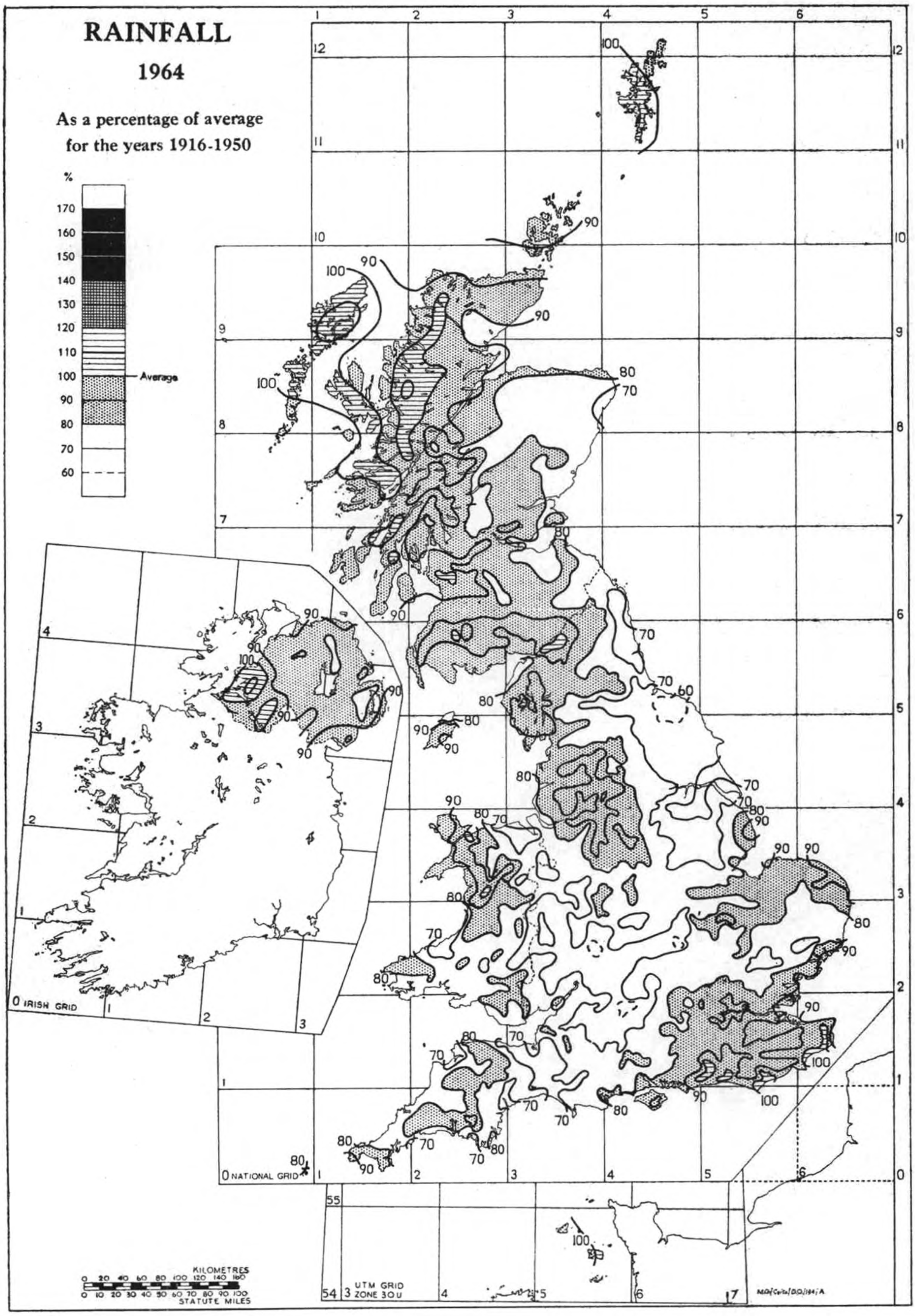


FIGURE 1—Rainfall 1964

FIGURE 2—Stations included in Tables II–XIII

TABLE II—JANUARY 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	11·8	−3·1	5·8	2·3	81	46	25	2·14	6	0	4	2	1	0
Gorleston	10·0	−2·0	4·6	1·0	93	54	19	2·21	7	0	3	0	4	1
Boscombe Down	9·8	−5·1	4·9	1·0	54	56	16	2·90	9	0	3	2	1	0
Plymouth	11·9	−1·5	7·4	3·7	63	60	19	4·33	3	0	2	2	0	0
Elmdon	11·4	−11·6	5·2	0·7	87	44	30	2·51	14	0	4	2	1	0
Valley	11·3	−3·9	7·9	4·1	80	58	27	3·60	5	0	0	0	0	2
Manchester Airport	11·0	−3·5	6·0	1·8	128	34	30	3·00	9	0	2	0	0	0
Tynemouth	11·2	−3·0	6·3	2·9	127	43	25	2·34	2	0	0	0	0	0
Renfrew	11·7	−5·0	7·0	2·5	78	35	38	4·66	8	1	2	0	2	0
Dyce	11·4	−6·5	6·7	1·3	97	54	25	3·14	9	0	1	0	0	0
Stornoway	12·0	−3·6	8·5	4·5	104	35	56	4·18	4	0	1	0	0	4
Aldergrove	10·7	−2·3	7·2	2·8	61	45	53	3·68	3	0	2	0	0	2

Very dry

The dry weather of December 1963 continued throughout January 1964, but the month was not nearly so cold. The first three days were mild and mainly dull and dry except for some sunny periods in the south-east on the 1st and some heavy rain in the Hebrides on the 3rd.

Fog became widespread and dense in parts of central and southern England on the 4th as winds became light and variable, and this proved to be the beginning of a dull foggy period which lasted nearly a week, but with light rain or drizzle at times.

On the 10th easterly winds spread over southern England bringing a progressive fall of temperature during the next few days. Snow and sleet showers fell in southern England and spread to most other districts on the 12th and 13th.

Fog and drizzle returned to southern England on the 14th as mild southerly winds cleared the thin covering of snow from most districts. There was a temporary improvement with long periods of sunshine nearly everywhere on the 16th and 17th, as winds backed towards the south-east, but fog returned on the 18th and spread to most districts during the night. Extensive fog persisted over much of central, eastern and southern England from the 19th to about the 24th (apart from a temporary lifting on the 23rd) but in western districts and in Scotland weather was changeable with south-westerly winds.

Increasing westerly winds cleared the fog from most districts on the 26th, and the last few days of the month were generally mild and unsettled with widespread rain on the 27th, 29th and 30th.

TABLE III—FEBRUARY 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	12·3	−2·0	7·5	3·3	98	64	45	1·55	4	0	4	1	1	0
Gorleston	12·5	−1·1	6·4	2·6	102	69	54	1·60	2	0	6	0	1	2
Boscombe Down	11·8	−5·7	6·9	1·8	62	74	42	2·05	10	0	3	0	4	0
Plymouth	12·0	−4·8	8·2	3·6	82	80	103	3·11	5	0	1	0	0	0
Elmdon	12·5	−7·0	7·0	1·8	73	65	37	1·90	9	0	4	2	1	0
Valley	14·5	−5·5	8·2	3·4	101	79	25	2·29	6	0	3	0	0	1
Manchester Airport	13·4	−4·8	7·0	2·5	114	55	27	2·37	7	0	4	0	1	0
Tynemouth	12·0	−4·0	6·5	3·0	75	66	39	1·65	4	0	3	0	2	1
Renfrew	13·5	−6·9	7·4	2·4	104	60	32	3·19	7	0	6	0	0	0
Dyce	11·2	−3·5	6·6	1·6	80	80	86	2·36	10	0	5	3	1	1
Stornoway	11·8	−6·0	7·7	2·6	115	62	74	2·68	8	0	5	0	0	4
Aldergrove	12·4	−4·4	6·9	2·1	95	65	33	2·39	8	0	3	0	0	0

Continuing dry

The very mild windy weather at the end of January continued into February with gales, severe at times, in northern Scotland. Sunny periods during the first two days gave place to widespread rain on the 3rd. Cooler showery weather in a north-westerly airstream followed the rain but the 6th was a quiet day with prolonged sunshine and with widespread and severe frost at night.

Weather during the next week became increasingly more cloudy but was mainly dry with temperature a little above average.

Easterly winds brought a sharp fall in temperature on the 16th. All districts had some snow during the next few days and there were moderate falls on high ground from the Peak district northwards. At Forest in Teesdale (Durham) level snow lay 10 inches deep. The 20th and 21st were fine sunny days but rain from the Atlantic reached extreme western districts late on the 21st.

Mild wet weather, preceded in places by snow, spread to all districts during the 22nd and 23rd, the rain being heavy at times. The remainder of the month was generally dull and misty, overnight fog in many southern and eastern districts persisting for much of the 26th and 29th but there were good sunny periods on the 27th and 28th.

TABLE IV—MARCH 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	13·9	−1·4	7·4	3·1	62	113	225	1·46	3	1	8	1	0	0
Gorleston	9·0	−0·6	4·7	1·9	40	125	176	1·35	6	0	7	0	0	2
Boscombe Down	12·5	−2·7	7·1	1·8	55	126	169	1·79	11	0	8	0	1	0
Plymouth	12·2	−2·4	8·2	3·6	67	133	256	2·73	5	0	4	0	0	0
Elmdon	12·4	−5·5	6·4	1·0	53	107	199	1·69	13	0	10	3	0	1
Valley	14·3	−1·4	8·8	3·0	89	128	147	2·09	3	0	4	0	0	0
Manchester Airport	11·8	−3·0	6·7	2·0	63	99	170	1·77	10	0	6	1	0	0
Tynemouth	7·1	0·5	4·8	2·9	30	100	205	1·54	0	0	8	0	1	5
Renfrew	11·0	−4·3	7·7	1·8	66	91	76	2·51	6	0	5	1	1	0
Dyce	9·8	−4·9	5·7	1·9	28	108	183	2·12	6	0	7	1	0	1
Stornoway	10·9	−2·7	8·7	3·6	110	108	40	2·29	5	0	1	0	0	0
Aldergrove	10·6	−3·4	7·6	2·3	66	104	169	2·01	7	0	4	0	0	0

Cold. Dull and wet generally

The exceptional dryness of the previous three winter months continued until 10 March. Weather was generally dull with snow and sleet showers, mainly light, which became progressively more frequent during the first week. On the night of the 6th/7th 3 inches of snow fell on the higher ground in Kent and Sussex and 4 inches in Guernsey. Heavy and widespread rain on the 12th–14th brought monthly totals at many stations well above the average rainfall for March.

A wintry spell began over the weekend 14th–15th as winds backed to east. The 14th was a generally wet day but the rain turned to snow during the night and snow continued in most districts, except the extreme west and north, throughout the 15th. On the higher ground it accumulated to a depth of 6 inches in the Home Counties and to 12 inches in parts of Yorkshire.

The cold spell was broken on the 19th by about a week of mild wet weather. Rain was heavy in southern England on the 19th while a belt of moderate to heavy rain moved north-east from the Midlands to southern Scotland. Heavy falls were also recorded in many parts of England on the 24th and in eastern Scotland on the 25th when 2·13 inches fell at Dyce in about 32 hours.

Easterly winds set in again on the 27th and during the remainder of the month weather was generally dull and became progressively colder with rain at times and some snow in eastern districts.

TABLE V—APRIL 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	19·7	−0·3	12·6	6·2	81	160	175	1·81	1	3	1	0	0	0
Gorleston	15·6	0·2	10·9	5·4	86	166	160	1·67	0	3	0	0	1	0
Boscombe Down	18·7	−1·2	12·1	4·6	85	167	80	1·96	2	0	2	0	0	0
Plymouth	16·2	0·9	11·3	6·2	72	182	98	2·20	0	0	0	0	0	0
Elmdon	20·1	−2·6	12·2	4·5	74	151	90	1·98	4	1	0	0	0	0
Valley	19·0	0·1	11·7	6·1	88	178	94	1·89	0	0	0	0	0	2
Manchester Airport	19·4	−1·2	12·1	5·5	82	138	108	1·89	1	0	0	0	0	0
Tynemouth	16·4	2·0	10·9	6·0	86	147	131	1·62	0	1	0	0	0	0
Renfrew	17·4	−2·5	12·1	5·1	76	142	105	2·32	1	1	0	0	0	0
Dyce	18·6	−1·7	11·5	3·5	81	148	66	2·29	3	0	0	0	0	0
Stornoway	13·6	−2·2	10·3	4·3	91	142	192	2·33	2	0	1	0	0	0
Aldergrove	15·8	−1·5	12·1	4·6	86	149	66	2·19	2	0	0	0	0	0

Dull and showery

The cold dull weather with sleet or snow at times at the end of March lasted over the first four days of April, but on the 5th winds backed to north bringing brighter, less cold, weather to all districts, and this sunny weather continued until the end of the first week.

The second week was generally unsettled. Rain from the Atlantic reached parts of Scotland and northern England on the night of the 7th and spread slowly southwards on the 8th and 9th. There were long sunny periods on the 10th after the rain, and again on the 13th and 14th following widespread rain on the 11th and 12th.

The third week started dull and wet. On the 15th most places had rain which became heavy at times on the 16th as winds backed towards the south and thunderstorms spread from France. Weather became very mild and, on the 18th, temperatures reached 19°C in parts of south-east England. As a result of these high temperatures, thunderstorms broke out in the late afternoon.

There were long sunny periods with occasional thundery showers and scattered thunderstorms on the 22nd, and these increased in frequency on the 23rd. The remainder of the month was generally mild but changeable. The 25th was a dull wet day but temperatures rose sharply on the 26th as an airstream of Mediterranean origin reached the British Isles, and 20°C was recorded at places as far apart as Chivenor (Devon) and Mildenhall (Suffolk). The last four days of the month were showery with scattered thunderstorms but with long sunny periods.

TABLE VI—MAY 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	24·9	5·4	19·1	10·4	105	199	94	1·81	0	4	0	0	0	0
Gorleston	23·5	5·8	16·4	9·2	120	209	76	1·51	0	0	0	0	0	0
Boscombe Down	22·6	2·9	17·7	8·2	98	199	239	1·85	0	2	0	0	0	0
Plymouth	21·4	3·7	15·3	9·7	84	219	109	2·39	0	3	0	0	0	0
Elmdon	24·0	0·1	18·2	8·0	102	185	60	2·22	0	2	0	0	0	0
Valley	23·0	6·5	15·6	9·4	82	223	125	2·26	0	2	0	0	0	4
Manchester Airport	24·3	4·5	17·5	9·5	108	177	106	2·24	0	3	0	0	0	0
Tynemouth	20·8	5·6	14·5	8·6	99	172	37	1·99	0	1	0	0	3	0
Renfrew	22·7	3·8	15·9	8·2	90	185	110	2·63	0	1	0	0	0	0
Dyce	20·8	2·1	14·8	6·2	95	181	53	2·78	0	0	0	0	0	0
Stornoway	17·6	3·1	12·8	7·5	78	195	132	2·29	0	0	0	0	0	1
Aldergrove	21·5	5·0	16·2	7·6	81	196	85	2·46	0	0	0	0	0	1

Changeable; warm spells

The changeable weather continued throughout May. During the first week winds were south-westerly and day temperatures about average; there were long sunny periods and scattered showers but rainfall was more prolonged on the 2nd; winds backed to south on the 6th and there was widespread rain for about 36 hours.

The second week was mainly sunny and dry in southern and eastern England, but with variable cloud and occasional rain or showers elsewhere. Afternoon temperatures reached 27°C locally in the south-east on the 12th.

The weather pattern changed on the 14th as fine quiet weather spread to nearly all districts. Prolonged sunshine led to progressively rising day temperatures; Whit Monday (18th) was fine and warm in the south but rain in the north spread to all districts during the night and continued in south-east England for much of the following day.

After about 36 hours of rain in most districts on the 21st and 22nd an easterly airstream became established over the British Isles on the 23rd–28th. Weather became fine and warm over most of the country except southern England where it remained generally cloudy with occasional rain until the 25th. The period 26th–28th was dry and sunny over most of the country, but overnight fog persisted well into the day in some eastern coastal districts. Thunderstorms with torrential rain, which caused widespread flooding, were reported from many districts during the last two days of the month.

TABLE VII—JUNE 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	25·0	6·2	19·4	11·4	81	213	225	1·72	0	5	0	0	0	0
Gorleston	24·2	5·5	17·4	10·7	83	215	201	1·67	0	4	0	0	0	1
Boscombe Down	24·0	4·0	18·3	9·8	80	208	149	1·62	0	4	0	0	0	0
Plymouth	21·2	7·3	17·0	11·3	85	222	103	2·01	0	1	0	0	0	0
Elmdon	23·2	0·4	17·6	9·5	75	192	227	1·66	0	4	0	0	0	0
Valley	23·0	6·7	15·8	10·4	78	221	134	1·99	0	0	0	0	0	0
Manchester Airport	23·6	3·0	16·7	10·3	66	179	117	2·34	0	3	0	0	0	0
Tynemouth	23·4	5·0	15·9	10·2	91	182	121	1·75	0	1	0	0	0	0
Renfrew	21·3	3·3	16·8	9·3	97	183	133	2·41	0	2	0	0	0	0
Dyce	21·6	−0·1	16·8	7·1	104	181	93	2·15	1	1	0	0	0	0
Stornoway	17·0	3·2	14·1	7·9	93	173	90	2·56	0	0	0	0	0	0
Aldergrove	21·6	4·0	16·7	9·2	86	179	102	2·25	0	0	0	0	0	0

Changeable; very wet in south-east England

The first week was generally wet and unsettled with frequent thunderstorms. The 1st was a cool day with easterly winds and widespread and occasionally heavy thunderstorms. After a wet night the next day was brighter and temperature rose to about normal on the 3rd as winds veered towards west.

The 8th, a fine sunny day, began a spell of warm sunny weather in the south-east with temperature reaching 25°C locally on the 10th. In the west and north, however, weather remained unsettled with rain at times. The warm spell, which had extended to most districts by the 11th, broke up with violent thunderstorms late on the 12th.

During the next ten days weather was mainly cool with scattered showers and sunny periods, but there was widespread rain on the 17th and 18th. Northerly winds on the 19th–21st brought light snow showers to the Scottish Highlands and frequent thundery showers to most other districts.

The remainder of the month was generally drier and warmer. Temperature over the country rose steadily and by the 27th reached 27°C at a number of places. The 28th was rather dull with a little drizzle in central and southern England and the month ended with two mainly dry sunny days with temperatures near average.

TABLE VIII—JULY 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	27·5	9·6	22·8	13·9	113	198	80	2·44	0	3	0	0	0	0
Gorleston	26·2	6·4	19·7	12·7	107	210	65	2·30	0	1	0	0	0	0
Boscombe Down	27·5	6·1	21·9	11·4	113	191	31	2·48	0	1	0	0	0	0
Plymouth	22·7	6·5	19·4	12·5	112	198	77	2·58	0	0	0	0	0	0
Elmdon	24·0	8·2	20·6	11·7	113	178	61	2·60	0	1	0	0	0	0
Valley	22·6	8·2	17·8	12·3	85	187	87	2·52	0	1	0	0	0	0
Manchester Airport	23·8	6·7	18·9	12·0	94	154	104	3·09	0	4	0	0	0	0
Tynemouth	23·0	7·4	18·1	12·0	108	169	37	2·97	0	3	0	0	0	0
Renfrew	21·5	5·7	17·8	11·1	89	159	57	3·10	0	0	0	0	0	0
Dyce	26·3	1·1	18·3	9·7	116	157	41	3·45	0	1	0	0	0	0
Stornoway	19·8	3·8	15·2	9·5	102	128	124	3·08	0	1	0	0	0	1
Aldergrove	21·9	6·0	18·5	11·1	72	136	47	3·05	0	1	0	0	0	0

Dry. Warm in the south during the latter half of the month

The dry weather at the end of June continued until 6 July. Afternoon temperatures reached 25°C locally in south-east England on the 2nd but following a little rain on the 3rd, freshening north-westerly winds kept temperatures well below average.

A deepening depression skirting the north of Scotland on the 7th and 8th gave record low pressure readings for the British Isles for July. Gales were widespread and many places in the north registered their highest gust ever recorded in July. Associated troughs brought an end to the dry spell with about 24 hours of rain in most places. After two or three bright showery days further rain reached western districts on the 10th and continued throughout the 11th and for much of the 12th. Rain was renewed in the west and north on the 14th but did not reach south-east England.

The third week was warm and thundery with temperatures over England and Wales progressively increasing until the 17th. Thunderstorms broke out in many places on the 18th and the latter part of the week was rather cloudy and cooler with further thunderstorms on the 19th and 21st.

During the remainder of the month weather continued changeable and cool in Scotland, but in south-east England it was generally sunny and warm with temperature reaching 28°C on the 25th and 26th.

TABLE IX—AUGUST 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	28·1	6·6	21·6	12·8	117	188	82	2·24	0	3	0	0	0	0
Gorleston	27·0	6·5	19·9	12·7	111	189	107	2·01	0	4	0	0	0	0
Boscombe Down	29·1	3·6	21·2	10·8	116	184	10	2·31	0	0	0	0	0	0
Plymouth	24·4	6·7	19·2	12·4	102	198	46	2·88	0	1	0	0	0	0
Elmdon	27·2	3·0	20·1	10·2	105	173	79	2·43	0	1	0	0	0	0
Valley	22·1	5·4	18·0	11·9	109	183	113	2·90	0	0	0	0	0	1
Manchester Airport	25·0	4·8	19·3	11·3	124	151	89	3·19	0	2	0	0	0	0
Tynemouth	26·0	5·8	17·4	11·7	112	147	99	3·03	0	3	0	0	0	1
Renfrew	22·7	2·4	17·7	10·4	97	137	155	3·33	0	3	0	0	0	0
Dyce	26·8	1·7	16·9	9·4	83	147	142	3·10	0	1	0	0	0	0
Stornoway	18·0	2·5	14·0	8·5	109	133	152	3·35	0	0	0	0	0	5
Aldergrove	24·2	3·5	18·0	10·5	102	135	88	3·29	0	1	0	0	0	0

Dry with very warm spells in the south-east. Cool and changeable in the north

Fresh north-westerly winds on the 1st moderated on the 2nd as a belt of drizzle spread over the country from the west. Weather was fine and warm during the next few days especially on August Bank Holiday (3rd) when 10 hours of sunshine was fairly general.

Rain on the 6th, the first measurable rainfall for nearly two weeks in many districts, was followed by two or three days of rather cool weather with scattered showers in a north-westerly airstream.

Pressure rose generally on the 10th, and weather from the 10th to the 15th, except in sheltered western districts, was rather cloudy with easterly winds and average temperature; eastern coastal districts, however, were rather cool with occasional drizzle.

The 16th and 17th were stormy with widespread rain and gales, but north-westerly winds brought a sharp drop in temperature on the 18th with frequent thundery showers; day temperatures in parts of eastern England were as much as 7°C below normal. The next two or three days were dry and sunny but further rain reached Scotland on the 22nd and the Midlands on the 23rd; rain became widespread and heavy at times that night.

A very warm spell with light southerly winds and almost unbroken sunshine began on the 25th. Afternoon temperatures rose to 32°C at a number of places. Although the 28th was cooler with thundery rain the month ended warm and sunny.

TABLE X—SEPTEMBER 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	24·8	5·1	20·3	10·7	154	142	21	1·98	0	0	0	0	0	0
Gorleston	25·2	6·0	18·8	11·3	126	152	15	2·23	0	1	0	0	0	0
Boscombe Down	25·3	3·5	20·4	9·0	145	137	42	2·36	0	1	0	0	0	0
Plymouth	24·6	5·2	18·6	11·9	130	152	60	2·88	0	1	0	0	0	0
Elmdon	23·6	-1·0	19·5	7·7	145	127	24	2·17	1	0	0	0	3	0
Valley	22·3	4·5	17·7	11·2	121	139	64	3·16	0	1	0	0	1	0
Manchester Airport	22·6	0·8	17·9	9·8	125	116	64	2·68	0	2	0	0	1	0
Tynemouth	21·8	3·5	16·3	10·6	124	124	76	2·31	0	2	0	0	2	0
Renfrew	21·9	-1·2	16·4	8·7	118	111	128	3·57	1	1	0	0	0	1
Dyce	18·8	-0·3	15·1	7·5	92	129	90	3·17	1	0	0	0	0	2
Stornoway	18·7	-0·4	13·8	7·9	68	111	184	3·75	1	0	0	0	0	3
Aldergrove	20·9	2·2	16·5	9·5	122	107	109	3·02	0	1	0	0	0	0

Mainly sunny and dry

The first two days of September were dry and sunny with light easterly winds. Winds became light and variable on the 3rd but there was little change in the general weather apart from patches of fog in some coastal districts. Days were rather warm except in foggy areas, but night temperatures inland were below average.

Rain reached western Scotland on the 5th spreading to all districts by evening; in parts of south-east England it was the first measurable rain for 17 days. The 6th was showery with north-westerly winds, but rain was again widespread on the 7th.

During the next few days a series of troughs and ridges from the Atlantic brought variable cloud and rain at times to Scotland, but central and southern districts of England (apart from the extreme west) were generally sunny and warm. The fine warm weather extended to the whole of the British Isles on the 12th but was brought to an end on the 14th by widespread rain from the west which continued for much of the 15th.

A rather cool period with thundery showers followed. Gales were widespread and the showers were frequent on the 16th, but were rather scattered with good sunny periods during the next four days.

Another spell of fine sunny weather began over southern England on the 21st, and lasted, apart from rather a cool dull day on the 27th, until the end of the month. On the 25th afternoon temperatures reached 25°C in some eastern districts including the London area. In the north weather remained dull and unsettled with rain at times until the 28th. The month ended with two fine sunny days in most districts.

TABLE XI—OCTOBER 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	20·0	−0·2	13·3	5·9	135	98	54	2·25	1	1	0	0	2	0
Gorleston	17·3	2·0	12·3	6·6	109	111	149	2·43	0	5	0	0	2	0
Boscombe Down	18·8	−0·7	12·9	4·8	128	103	62	2·93	2	2	0	0	1	0
Plymouth	18·8	1·6	13·7	8·0	98	114	95	3·83	0	4	0	0	0	1
Elmdon	19·4	−4·8	12·7	4·0	128	92	65	2·51	4	0	0	0	2	0
Valley	18·2	−0·3	13·3	7·6	82	102	90	3·84	1	2	0	0	0	2
Manchester Airport	18·7	−1·6	12·5	5·7	142	85	92	3·22	2	3	0	0	1	0
Tynemouth	16·7	1·0	11·8	7·2	112	92	26	2·47	0	1	0	0	0	0
Renfrew	16·5	−1·4	12·2	4·9	97	72	48	4·70	3	0	0	0	0	0
Dyce	16·8	−1·6	11·8	4·6	78	96	37	3·74	4	0	0	0	0	0
Stornoway	15·1	−0·6	11·7	5·5	107	76	87	4·38	2	0	0	0	0	0
Aldergrove	15·8	−0·8	11·9	5·5	74	81	119	3·60	2	2	1	0	1	1

Dry and rather cold

The dry sunny weather at the end of September continued during the first few days of October, but an unsettled period began on the 5th as rain, the first in many places for nearly two weeks, spread in from the Atlantic. The rain, heavy at times in the west, did not reach south-east England until the late evening. After a mainly fine day on the 6th rain again spread from the west to most districts during the night, slowly giving place to cooler showery weather the next day. On the 9th a small depression moving eastwards off the north coast of France brought stormy weather to the English Channel; a gust of 94 kt was recorded at Jersey Airport.

During most of the following week weather remained generally cold with outbreaks of rain and scattered thunderstorms; there were, however, good sunny periods, especially in the south.

Pressure rose generally over the country on the 16th and most of England was sunny and dry during the next four days, but in Scotland and Northern Ireland it was rather cloudy with rain at times. Temperatures were above average nearly everywhere.

Another cold period began on the 21st as rainbelts moved south-east over the country. On the 23rd a northerly airstream brought thundery showers of rain, hail or snow to most areas. The showers continued on the 24th but there were long sunny periods in south-east England.

Temperature returned to normal on the 25th as winds backed towards south-east. From then until the 27th it was dry over most of England with broken sunshine, but in the north and in Scotland weather was dull with occasional rain.

During the last four days of the month a ridge of high pressure extended from the southern Baltic over the British Isles and weather became generally dull and cooler with occasional drizzle chiefly in coastal districts.

TABLE XII—NOVEMBER 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	15·1	−3·3	11·0	6·7	103	53	54	2·49	2	0	0	0	3	0
Gorleston	14·6	−2·0	10·3	6·8	142	58	43	2·74	2	0	0	0	0	0
Boscombe Down	14·2	−5·0	10·4	4·8	94	62	73	3·19	5	0	1	0	0	0
Plymouth	14·8	0·5	11·4	7·5	92	67	77	4·48	0	0	0	0	0	3
Elmdon	15·1	−4·3	10·2	4·4	103	50	36	2·68	4	0	3	0	2	0
Valley	14·0	−2·7	11·6	6·1	141	59	81	3·60	3	1	0	0	0	4
Manchester Airport	14·2	−6·2	9·6	4·5	116	43	73	3·03	4	0	3	0	3	0
Tynemouth	14·9	−1·1	9·5	5·8	131	49	40	2·50	1	0	1	0	0	0
Renfrew	13·2	−4·4	8·9	3·8	80	42	73	4·12	6	0	3	0	5	0
Dyce	14·1	−4·1	9·2	2·1	126	59	20	3·67	13	0	0	0	0	0
Stornoway	12·4	−2·3	9·5	4·8	62	45	105	4·50	5	2	5	0	0	4
Aldergrove	13·4	−2·4	9·9	3·8	144	53	74	3·19	6	0	3	0	2	0

Mild and dry

The predominantly dry weather at the end of October continued well into November. For most of the first week temperatures were about normal, and after a foggy start to the week there were good sunny periods with scattered showers in an easterly airstream about mid-week. The 7th–10th was rather cold with light variable winds; extensive fog covered much of northern England and southern Scotland, but elsewhere there were long sunny periods.

On the 11th mild westerly winds from the Atlantic cleared the fog and brought rain to all districts. From then until the 17th weather was less settled with periods of rain, mainly slight, broken by sunny spells. The wettest day was the 13th with some heavy rainfall in south-west England. Winds veered to north-west on the 16th and it became temporarily cooler in Scotland with scattered snow showers.

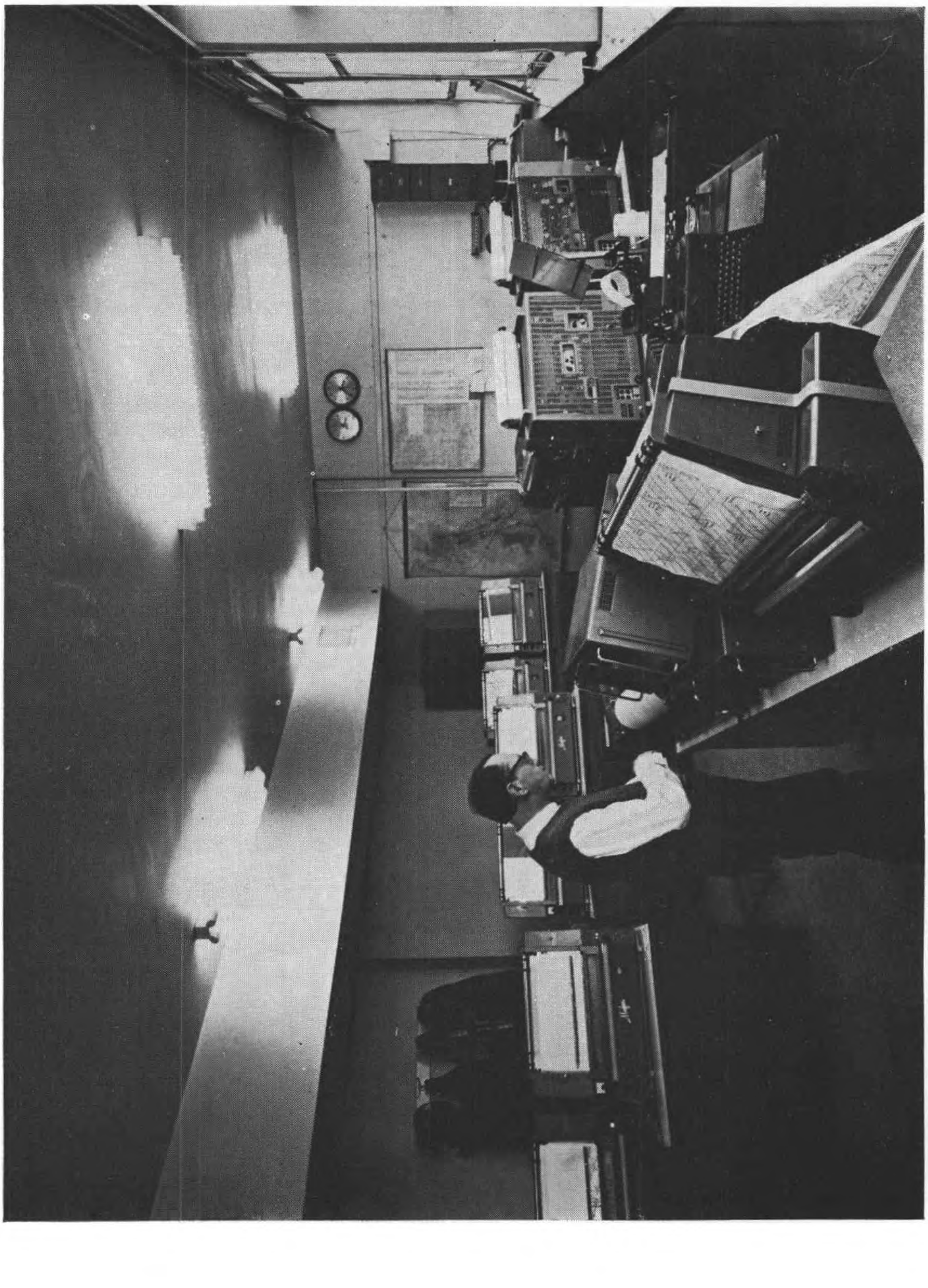
From the 18th to the 25th an anticyclone covered the Bay of Biscay or northern France, and westerly winds brought mild weather back to all districts of the British Isles. It was generally dull with rain or drizzle at times but with little measurable rainfall in the south or Midlands.

Heavier rain spread to western and northern districts during the evening of the 26th and weather became colder the next day as winds veered towards north-west. Wintry showers spread south over the whole country on the 28th and 29th—snow lay on high ground for a time as far south as Devon and Kent. The month ended cold and rather wet with the higher ground being snow-covered in parts of the north and with widespread freezing fog in the south.

PLATE I

One position in the Bracknell Teleprinter Room. The operator is transmitting into the European Teleprinter Network.

PLATE II



Crown copyright

Bracknell Facsimile Room. General view showing receiving recorders on left and transmitters and monitoring recorders on right.

PLATE III

Crown copyright

The receiving console of the Type 1 automatic weather station at Bracknell; the sensors are on the Experimental Site three miles away.

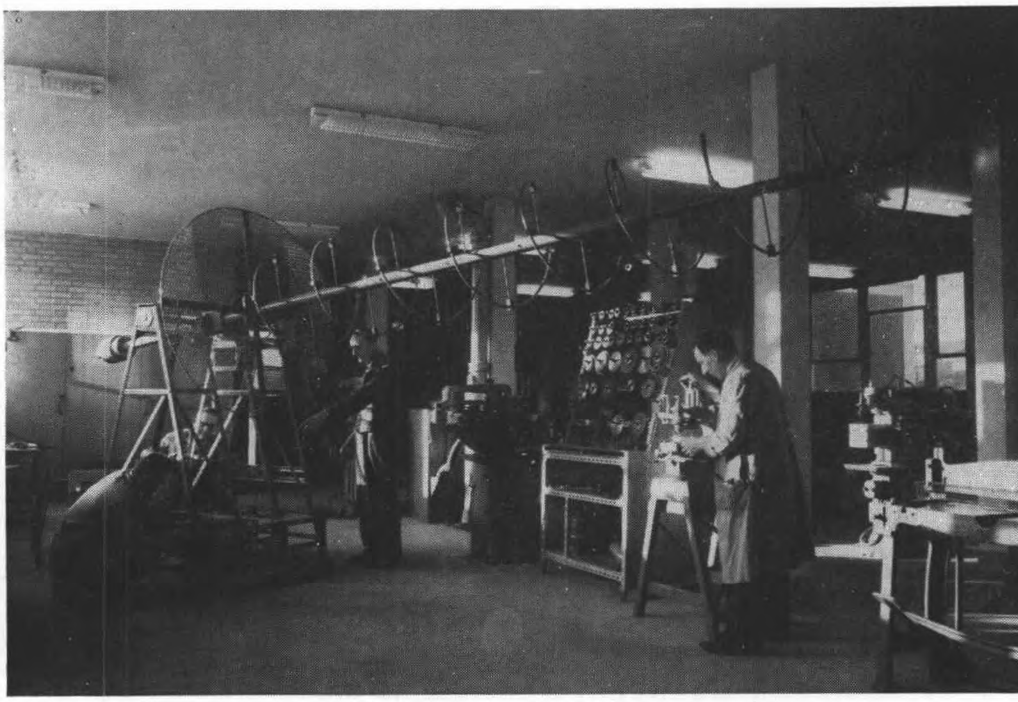
PLATE IV

Crown copyright

Meteorological studies using satellites. As a satellite passes through the shadow of the earth's atmosphere the intensity of solar radiation reaching the satellite decreases. By measuring this variation in specific wavelength regions, the vertical distribution of specific gases can be determined.

The ultra-violet monochromator and high-vacuum chamber, shown above, are used for testing and calibrating equipment designed to determine the vertical distribution of molecular oxygen, at levels between 100 and 200 km, in this way.

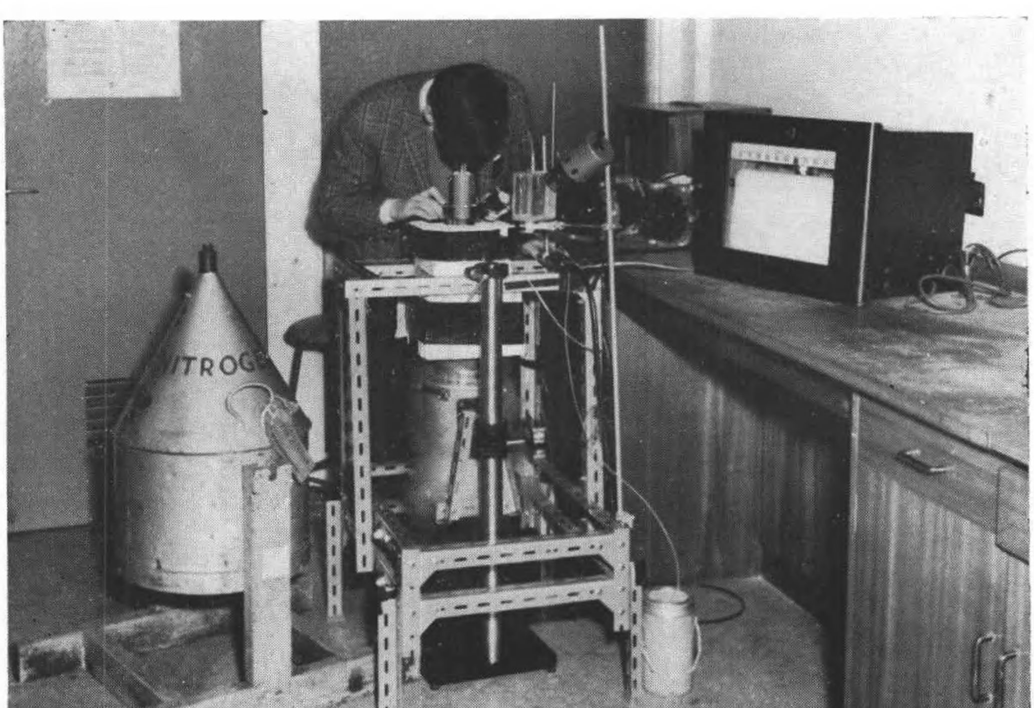
PLATE V



Crown copyright

The workshop at Bracknell for producing experimental models and laboratory equipment.

PLATE VI



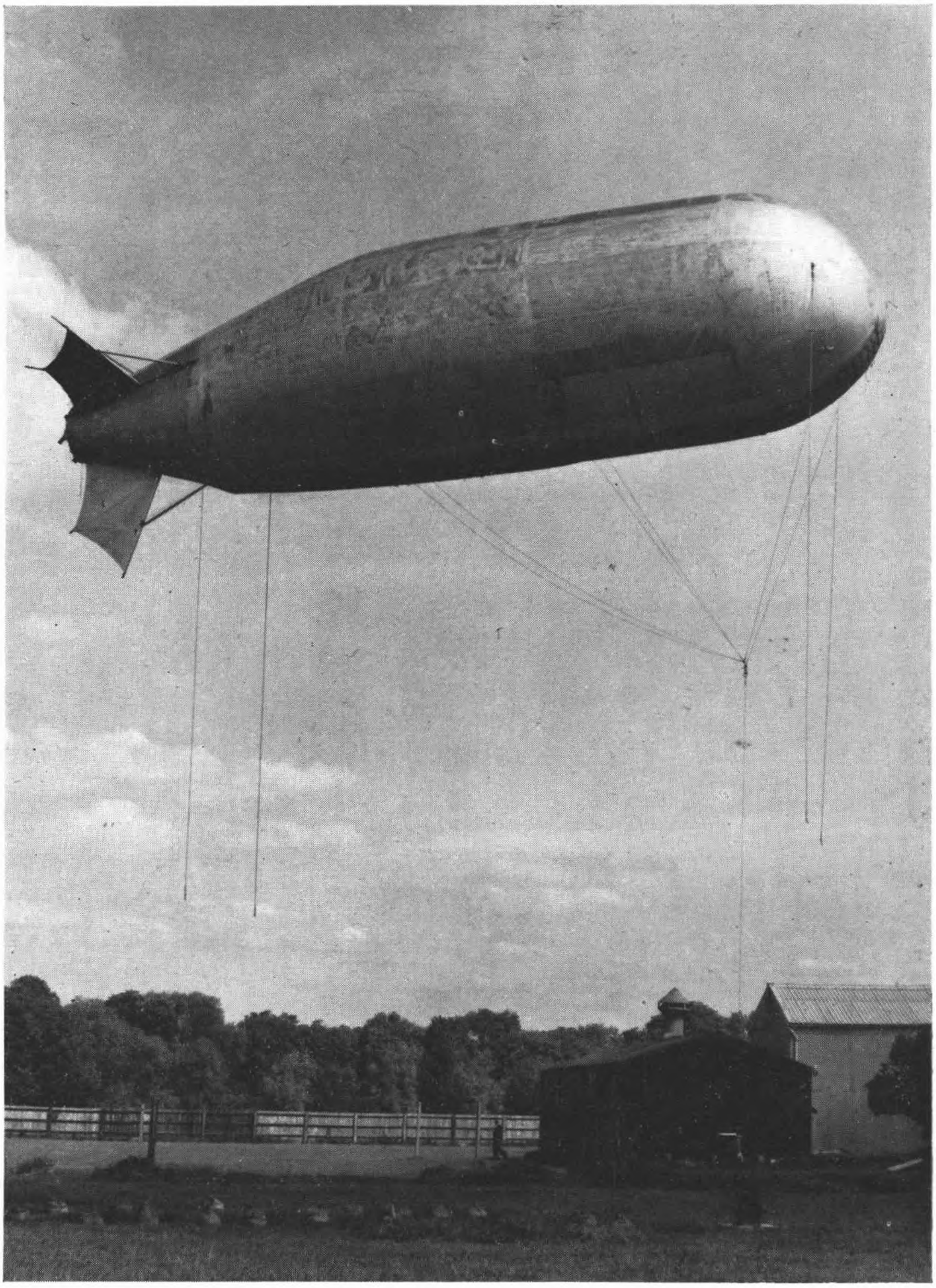
Crown copyright

An experiment in progress to test a method of measuring the concentration of ice nuclei in the atmosphere.

Porton: Measurement of turbulence. The dispersion of particles and gases emitted into the atmosphere depends mainly on the variations of wind velocity. Here, the sensitive wind-vane and cup anemometer are being mounted on a portable mast to measure these variations.

Porton: Analysis of wind records. Special electrical systems have been evolved for recording the essential wind data in a form which can be almost directly to estimating particle diffusion. Here, the traces, which are being analysed, indicate turbulence at 16 metres for a period of two days.

PLATE IX



Crown copyright

This captive balloon is used at Kew to measure the slant visual range to different heights in fog. This is a matter of great importance to aircraft coming in to land.

The long-range forecasting unit has a series of conferences, firstly to select analogues from the records of the past 90 years and secondly, as here, to consider all the relevant information and decide on the forecast for the next month.

TABLE XIII—DECEMBER 1964

	Temperature °C				Sunshine		Rainfall		Number of days with					
	Highest	Lowest	Mean maximum	Mean minimum	Percentage of average	Average (hours)	Percentage of average	Average (inches)	Frost	Thunder	Snow falling	Snow cover	Fog	Gale
Kew	14·1	−6·1	6·7	3·0	126	40	65	2·06	9	0	2	0	0	0
Gorleston	14·0	−6·2	6·4	2·6	77	46	171	2·16	7	0	7	6	1	2
Boscombe Down	13·2	−10·0	6·2	1·3	114	49	78	3·02	14	0	3	2	1	4
Plymouth	13·1	−5·7	8·4	3·5	118	52	73	4·51	8	0	2	0	2	3
Elmdon	13·3	−9·8	5·4	0·4	118	40	103	2·41	15	0	5	3	3	1
Valley	12·6	−4·4	7·8	4·2	112	43	199	3·53	4	0	3	0	0	11
Manchester Airport	13·8	−7·3	5·8	0·9	206	32	153	2·75	12	0	5	3	1	0
Tynemouth	12·7	−5·7	5·8	1·7	121	33	77	2·39	10	0	6	3	0	2
Renfrew	12·1	−8·0	6·3	1·1	153	26	118	4·19	10	0	7	2	0	0
Dyce	12·1	−11·7	4·7	−0·5	99	45	38	3·28	17	0	9	6	0	1
Stornoway	10·9	−6·3	6·0	1·6	74	26	140	4·06	11	1	13	2	0	5
Aldergrove	11·3	−5·6	5·9	1·1	104	35	120	3·54	10	1	10	4	0	0

Changeable; wet in western districts

The first four days of the month were rather cold with northerly winds; a rather wet day on the 2nd was followed by two days of wintry showers and sunny periods.

Weather became milder on the 5th as an airstream from the Atlantic, spreading round the north side of an anticyclone in our south-west approaches, brought rain to all districts. A rapidly deepening depression approaching Ireland on the 7th brought severe gales to the south-west and heavy rain and widespread floods to Wales and the Lake District. Further disturbances from the Atlantic brought renewed heavy rain to the west on the 8th and to the south-east on the 9th. After two days of rather foggy weather another depression deepened considerably as it approached Ireland. In North Wales the rain associated with this depression was more or less continuous for 36 hours; renewed floods resulted.

A cold period began on the 14th with easterly winds bringing sleet and snow to parts of southern England followed by freezing fog which persisted throughout the 15th and 16th in many places. Weather during the next week was dominated by an anticyclone over or near northern districts; it was generally dry and cold with some good sunny periods during the first three days of the week.

A cold northerly airstream brought wintry showers to most northern and eastern districts on the 24th and 25th, and on the 26th snow spread eastwards across the country reaching the London area during the evening. The cold spell lasted another two days with snow at times on the 27th but with long sunny periods on the 28th.

On the 29th rain spread across the country from the west; it continued in most districts throughout the night and on the 30th with temperatures well above the average. The last day of the month was fine and sunny with scattered showers in western districts.

5. Statistics

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 XIV

NUMBERS OF OFFICES OF VARIOUS TYPES STAFFED BY METEOROLOGICAL OFFICE STAFF AND OPERATING ON 31 DECEMBER 1964

	Within U.K.	Overseas
Principal forecast offices associated with the RAF	1	—
Main meteorological offices associated with the RAF ...	7	6
Subsidiary offices associated with the RAF	48	15
Observing offices associated with the RAF	6	5
Principal forecast offices associated with civil aviation ...	1	—
Main meteorological offices associated with civil aviation ...	3	1
Subsidiary meteorological offices associated with civil aviation	12	1
Observing offices associated with civil aviation	6	—
Upper air observing offices	8	8
Public service offices	4	—
C.R.D.F. offices	5	3
Port meteorological offices	5	—
Offices associated with National Agricultural Advisory Service	3	—
Other offices	29*	7

Notes

A principal forecast office meets the needs of aircraft flying over very 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 meteorological 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.

C.R.D.F. offices form the network for thunderstorm location.

Port meteorological offices are maintained at the bigger ports.

* Eight of these stations are administered by D.R.Met.O.

Table XV

OCEAN WEATHER SHIPS

To meet its obligation under the ICAO North Atlantic Ocean Station Agreement the United Kingdom operates four Ocean Weather Ships which work in rotation with two ships from France, two ships from the Netherlands and two ships operated jointly by Norway and Sweden. The British ships serve at four of the five Ocean Weather stations in the eastern North Atlantic; each vessel makes, on average, eight voyages a year and spends 24 days on station during each voyage. Some statistics for 1964 for the British Ocean Weather Ships are shown below.

Total number of days on station	700
Total number of days on passage	156

	Station A	Station I	Station J	Station K
	Average number per voyage of 24 days			
Aircraft contacted	189	487	1361	322
Radar fixes to aircraft ...	209	289	977	349
Weather messages to aircraft	34	146	156	1

TABLE XVI
MERCHANT NAVY SHIPS

A total of about 4000 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 these, including British ships, do this on a voluntary basis. Ships which report in full at four specified times daily are known as 'selected' ships; ships which report at the same times daily, but in a less complete form are known as 'supplementary' ships. A number of coasting vessels, lightships, distant-water trawlers and auxiliary ships also make and transmit meteorological observations. On 31 December 1964, the number of British ships reporting was:

Selected ships	499
Supplementary ships	52
Coasting vessels	124
Lightships	13
Trawlers	12
Auxiliary ships	57
Total	757

The British Voluntary Observing Fleet includes ships of over 100 shipping companies; and the numbers on the various routes are shown below:

U.K. to Australia	107
U.K. to Far East	85
U.K. to Persian Gulf	31
U.K. to South Africa	44
U.K. to North America	91
U.K. to West Indies	30
U.K. to South America	40
U.K. to Pacific Coast of North America	12
U.K. to European ports	39
U.K. to Falkland Islands and Antarctica	2
World-wide 'tramping'	70

During two typical days, one in June and one in December, the numbers of reports from ships received in the Central Forecasting Office were as follows:

		Reports June	Reports December
Direct reception from	British ships in eastern North Atlantic	84	82
	Foreign ships in eastern North Atlantic	41	23
	British trawlers in North Sea	2	7
	British merchant ships in North Sea	3	4
	Total (direct reception)	130	116
Reception via other European countries	Ships in eastern North Atlantic	370	357
	Ships in Mediterranean	101	71
	Ships in North Sea	37	32
	Ships off north Russia	4	9
	Ships in other European waters	49	43
	Grand Total (eastern North Atlantic and European waters)	691	628
Via U.S.A.	Ships in Western North Atlantic	497	418
	Ships in North Pacific	412	494

TABLE XVII

CLASSIFICATION OF STATIONS WHICH RENDER CLIMATOLOGICAL RETURNS

A large amount of meteorological data is obtained for climatological purposes from stations which are not part of the Meteorological organization. The following table shows how the sources of climatological information in the United Kingdom (including Meteorological Office stations) were distributed on 31 December 1964.

	Stations					Autographic Records		
	Observatories	Synoptic	Agro-meteorological	Climatological	Rainfall*	Sunshine	Rainfall	Wind
Scotland, north	1	9	0	27	314	24	8	9
Scotland, east	0	11	9	61	607	49	17	12
Scotland, west	1	13	3	43	505	30	20	13
England, north-east	0	12	4	25	441	27	18	4
England, east	0	13	12	16	480	25	23	11
England, Midlands	0	12	19	47	1269	59	49	8
England, south-east (including London)	1	17	20	55	847	68	96	17
England, south-west	0	8	8	28	525	33	13	5
England, north-west	0	5	4	19	475	22	14	12
Wales, north	0	2	2	17	237	10	13	2
Wales, south	0	3	9	14	312	23	5	5
Isle of Man	0	2	0	1	17	3	1	2
Scilly and Channel Isles	0	3	0	3	19	6	1	2
Northern Ireland	0	10	3	37	293	15	7	5
Total ...	3	120	93	393	6341	394	285	107

* Includes stations in earlier columns.

TABLE XVIII

HEIGHTS REACHED IN UPPER AIR ASCENTS

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

Observations of temperature, pressure and humidity

	Number of observations	Percentage of all ballons reaching 100 mb 53,000 ft (approx)	50 mb 67,000 ft (approx)	30 mb 78,000 ft (approx)	10 mb 100,000 ft (approx)	Percentage of largest balloons reaching 10 mb 100,000 ft (approx)
Eight stations in United Kingdom	5831	93·2	75·1	35·3	3·6	39·8
Seven stations overseas ...	5052	95·9	78·5	40·5	2·4	33·5
Four Ocean Weather Vessels	1340	88·2	61·6	28·1	0·2	—

Observations of wind

	Number of observations	Percentage of all balloons reaching 100 mb 53,000 ft (approx)	50 mb 67,000 ft (approx)	30 mb 78,000 ft (approx)	10 mb 100,000 ft (approx)	Percentage of largest balloons reaching 10 mb 100,000 ft (approx)
Eight stations in United Kingdom	11,371	87·8	61·6	17·1	2·5	45·2
Seven stations overseas ...	7971	88·7	70·0	29·8	3·2	55·6
Four ocean weather vessels	2660	87·5	60·1	19·1	0·1	—

TABLE XIX

THUNDERSTORM LOCATION

Number of thunderstorm positions reported by C.R.D.F. network ... 81,303

TABLE XX

METEOROLOGICAL COMMUNICATION TRAFFIC

Almost all the national and international exchange of meteorological data which are used in the construction of synoptic charts and the production of forecasts is effected by either coded messages or facsimile charts. The coded messages are composed of groups of five figures and there may be three to thirty such groups in one message. The messages are exchanged by radio and teleprinter. The following figures give an analysis of the traffic through the Meteorological Office Communications Centre for one typical day (24 hours) taken near the end of December 1964 and, for comparison, some corresponding figures for one day near the end of 1963.

Communication traffic for one day

	Number of groups in one day			
	In	Out	Total	Total in 1963
Land-line teleprinter ...	326,880	360,720	687,600	719,572
Radio	92,221	221,121	313,342	306,953
Facsimile Charts	Number of charts in one day			
Land-Line	0	77	77	68
Radio	96*	61	157	135

* Received at Bampton by radio and passed to Met.O. by land-line.

TABLE XXI

SPECIAL SEASONAL FORECASTS

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

	Year	No. of customers	Year	No. of customers
Fine spell notifications (a summer service primarily for farmers)	1963	723	1964	744
Weekend temperature forecasts (a winter service primarily for industrialists) ...	1963–64	49	1964–65	46
Snow and icy road warnings (primarily for Local Authorities)	1963–64	251	1964–65	257

TABLE XXII

FORECASTS FOR AVIATION

Forecasts for aviation constitute the primary function of many of the offices. The Central Forecasting Office is almost solely concerned with analysis of the weather situation, the issue of guidance in outline to other offices and the issue of forecasts to the BBC and the national Press. Thus the volume of work in the Central Forecasting Office shows little variation from year to year. The following figures indicate the numbers of forecasts issued for aviation and the numbers of meteorological briefings which took place during 1963 and 1964. They do not include warnings and routine general forecasts.

	1963	1964
Number of meteorological briefings for		
aviation in United Kingdom	372,764	370,119
aviation at overseas stations	55,190	63,809
Number of aviation forecasts issued for		
aviation in United Kingdom	877,948	908,767
aviation at overseas stations	180,896	235,385

TABLE XXIII
NON-AVIATION INQUIRIES

Non-aviation inquiries are handled by four weather centres specially established at London, Manchester, Glasgow and Southampton to meet the needs of the general public for forecasts for special purposes. Many of the forecast offices are established primarily to meet aviation requirements but also answer telephone requests for forecasts and other weather information from the general public, public corporations, Press, commercial firms etc. (the *Post Office Guide* lists the telephone numbers of 39 such offices). All but an insignificant proportion of these inquiries refer to current or future weather and are categorized according to the purpose of the inquiry in the figures below. Climatological inquiries are dealt with in Table XXV.

	1963	1964
Grand total of inquiries (all offices) ...	912,751	967,265
Percentage of inquiries connected with		
agriculture, etc	12·1	10·2
holidays	15·2	16·1
public utilities	9·0	8·5
road transport	10·3	15·0
Press	10·5	9·5
marine	19·3	17·7

TABLE XXIV
AUTOMATIC TELEPHONE WEATHER SERVICE FORECASTS

The total number of calls made on the service during the year, although less than that for 1963 (which had been inflated during the abnormal winter early in the period) nevertheless maintained the steady increase shown since 1960. During 1964 a forecast service for the North Wales coast (so far obtainable only by subscribers in Liverpool and Manchester) was started bringing up to 14 the total areas available for 16 GPO Information Centres. The figures below are supplied by courtesy of the Post-master-General.

Information Service Centre	Forecast area	Number of calls 1963	Number of calls 1964	Remarks
London	London	4,060,454	3,277,757	
London	Essex Coast	173,365	184,647	
London	Kent Coast	144,651	155,893	
London	Sussex Coast	215,513	237,294	
Colchester	Essex Coast	93,915	101,109	
Brighton and Hove	Sussex Coast	110,475*	159,744	
Birmingham	Birmingham	389,228	391,303	
Liverpool	South Lancashire and North Cheshire	246,115	209,175	
Liverpool	Lancashire Coast	51,630	100,295	Started March 1963
Liverpool	North Wales Coast	—	22,492	Started March 1964
Manchester	South Lancashire and North Cheshire	249,369	255,443	
Manchester	Lancashire Coast	39,470	49,394	Started March 1963
Manchester	North Wales Coast	—	18,211	Started March 1964
Cardiff	Cardiff	256,606	202,368	
Belfast	Belfast	272,689	203,035	
Glasgow	Glasgow	393,657	283,697	
Edinburgh	Edinburgh	241,064	249,409	
Bristol	Bristol	233,067	219,343	
Portsmouth	Southern Hampshire	112,202	117,040	
Southampton	Southern Hampshire	292,031	230,739	
Canterbury	Kent Coast	116,351*	113,706	
Blackpool	Lancashire Coast	66,120	105,857	Started May 1963
Southport	Lancashire Coast	20,551	38,062	Started May 1963
	Total	7,778,523	6,926,013	

(Totals in 1961—5,546,479
in 1962—6,090,954)

*Estimated.

TABLE XXV

CLIMATOLOGICAL INQUIRIES

Met.O.3, Edinburgh and Belfast receive a number of inquiries relating to past weather or to climatology. Met.O.7 receives a number relating to the application of meteorological data to agriculture. Most of the inquiries dealt with by the offices outside Headquarters refer to current weather or to forecasts. The following figures give the total number of such inquiries and the percentage of this number relating to the main types of inquiries.

	1963	1964
Total number of climatological inquiries ...	8616	8521
Percentage relating to		
agriculture (farming, market gardening and forestry)		14·9
building and design (including siting)		8·8
commerce (sales, marketing and advertising) ...		7·0
education and literary		6·6
industrial and manufacturing activities		6·8
legal (damage, accidents, insurance)		15·4
medical and health		2·8
Press and information centres		4·6
research		5·6
water supply		9·0

TABLE XXVI

DATA PROCESSING

Punched-card installation

Number of cards punched by the Meteorological Office installation ...	1,087,300
Number of cards punched elsewhere on behalf of the Meteorological Office	473,416
Number of cards converted to paper tape	312,450
Number of non-routine investigations completed	194

Computer installation

The electronic computer METEOR was used for computing during 3506 hours before it was removed in October to the Chemical Defence Experimental Establishment, Porton.

THE DIRECTORATE OF RESEARCH

1. Special Topic—Micrometeorology

Micrometeorology is concerned with the detailed physical properties and processes in the air, especially in the layers near the ground. The movement of the air in these lower layers is rarely as simple as the laminar or streamlined flow dealt with in aerodynamic theory, but rather tends mostly to be irregular and fluctuating in both speed and direction as is immediately evident from a typical record of an anemometer. This quality of the motion, in which it is impossible to distinguish any steady or regular pattern of streamlines, is called turbulence. Turbulent motion is of course not entirely confined to the lowest layers of the atmosphere—as is well known it is also encountered by aircraft at higher levels in the atmosphere—but it is in the lowest layers that conditions are especially favourable for the setting up of turbulence, and here it is of special importance not only in meteorological science itself but in other sciences and problems of economic and human interest.

The outstanding feature of this turbulent motion is its diffusive quality, as a result of which properties are transferred and redistributed through the air. Thus the heat which is received from the sun at the earth's surface is transported upward by this process to the air layers above, as is also the moisture from stretches of water, damp soil and transpiring crops. Associated with these vertical transfers there is a characteristic fall-off with height of the temperature and humidity of the air. By exactly the same process the momentum which the air loses in its contact with the rough surface of the ground is replaced by downward transfer of momentum from the unaffected layers higher up, and so a characteristic wind profile is established with velocity increasing with height. Apart from its meteorological significance in providing clouds and rain the evaporation of water is of direct interest in plant biology, horticulture and agriculture and in hydrology, and this forms one of the main 'user' interests. The problem is in essence to be able to estimate the rate of loss of water from the surface from a knowledge of the strength of the wind and the temperature and humidity of the air.

In addition to the redistributing action on the natural heat and moisture content of the air, wind and turbulence also play an important role in transporting and dispersing gases and particles of various kinds. These may be natural in the form of radioactive emanations from the ground, seeds and pollens from plants and spores from fungus growths, or they may be artificial in the form of smoke and sulphur dioxide from combustion processes and radioactive material from nuclear reactors. In the latter instances, where a nuisance or toxic effects may be involved, the problem amounts to estimating, from meteorological data, the way in which the windborne material is spread in the horizontal and the vertical and so diluted to a level of concentration which may or may not be troublesome or harmful.

In the context of classical physics the notion of diffusion of gases and vapour by the random motion of molecules is familiar. This type of diffusion would apply if the airflow were laminar, but it is very easily seen that such diffusion is incomparably slower than that which normally occurs in natural winds. The difference is consistent with the idea that in such natural airflow the irregular motion of molecules over minute distances is completely overshadowed by an irregular motion of volumes of air over considerable distances. This is the basis of the earliest theory of turbulent or eddy motion, in which *eddies* were conceived as small discrete volumes of fluid moving about at random over distances which were called mixing lengths, analogous to the free paths of molecules. This idea was soon realized to be a grossly simplified and crude basis on which to consider turbulent motion and over the last half century the description and understanding of turbulent motion and its effects have developed on increasingly sophisticated lines. Throughout, the aim has been the twofold one of improving the basic description and understanding of the complex physical processes involved and of applying this knowledge in the fields of practical interest already referred to.

General history. The history of micrometeorological research within the Meteorological Office began effectively with the specialized investigations of the dispersion of smoke and gas in connexion with research into chemical warfare problems soon after the First World War. At the War Office Experimental Station, at Porton on Salisbury Plain, a programme was laid down in 1921 which over the next 15 years was to provide a permanent basis of knowledge of the diffusion of windborne material over short distances and of the relevant temperature and wind structure in the first few metres above the ground.

The diffusion experiments were carried out on unobstructed, relatively level terrain and with artificial sources of smoke, the resulting crosswind and vertical distributions of smoke being explored by special air-sampling apparatus. Besides providing accurate statistics of these distributions in the specially selected conditions of steady mean wind direction and overcast sky (so-called neutral conditions) these experiments also clearly showed the dominant effect of the thermal stratification of the air which occurs as a result of the heating of the surface by the sun during the day and the cooling under clear skies at night.

The daytime clear sky régime is characterized by a fall or lapse of temperature with height which is especially intense near the ground. The lapse rates are such that the air density correspondingly increases upwards and this unstable condition encourages vertical motion and intensifies turbulence, with the effect that material is dispersed more rapidly both vertically and sideways. On clear nights the reverse condition applies. Temperature increases and density decreases with height, so providing a stabilizing force which suppresses the vertical motion, reduces the turbulence and correspondingly diminishes the rate of dispersal of material.

The recognition of this controlling influence of the vertical gradient of temperature promoted an intensive exploration at Porton, and elsewhere, of the details of the temperature field in the lower atmosphere, and as a result of this the magnitudes of the vertical temperature gradients and their variations with time of day, season and state of sky are now well established. At the same time, temperature-gradient observations became established as an essential ancillary observation in any field studies involving diffusion and transfer processes.

In addition to the experimental and observational studies a good deal of original theoretical and mathematical work was carried out by the Porton team of meteorologists in the 1920's and 1930's. There were two main approaches to the problem, one in which the rate of turbulence transfer was specified by a so-called eddy diffusivity, analogous to but greater by several orders of magnitude than the molecular diffusivity. The other approach did not specifically involve the notion of diffusivity but was a development of the statistical lines which were then emerging in the general theory of turbulence. Both approaches had certain features in common which continue to be exploited in estimating vertical diffusion near the ground. The first of these features is that the form of the vertical profile of wind velocity reflects the rate at which momentum is transferred in the vertical. The second is that the transfer of matter follows exactly the same laws as that of momentum. On this basis methods were developed for predicting the diffusion of smoke from sources, and the evaporation of liquid from the ground, from measurements of the vertical gradient of wind speed. In turn this led to much further study of the properties of the wind profile in an effort to refine the description and understanding of this basic micrometeorological feature.

To sum up, the period up to the Second World War was one in which the importance of the vertical profiles of temperature and wind velocity was clearly recognized and methods were devised by means of which the profile data could be used to estimate features such as rate of evaporation and concentration of smoke downwind of a source over a limited range of conditions.

Post-war developments. In the years since the end of the Second World War, developments have occurred in a number of directions.

The problem of natural evaporation was taken up by a Meteorological Office Research Unit established at the School of Agriculture at Cambridge University. In this work an extension of the principles followed in the researches at Porton quickly led to a method of estimating natural evaporation from measurements of the profile of wind speed and humidity near the ground. For an extensive reasonably uniform surface which is bare or covered with grass or low crops the method as originally evolved is capable of providing accurate estimates when the airflow is not greatly complicated by thermal stratification. Less accurate but useful estimates can be provided in thermally stratified conditions and the improvement of these is the practical aim of the study which continues at Cambridge. In this respect the central feature is a recording soil-balance with which direct measurements of the rate of evaporation can be obtained for comparison with estimates made from the meteorological measurements.

The early Porton work on the diffusion from sources of smoke at ground level was limited to distances of travel of about 1 km. In the 1950's interest in the diffusion of material at distances beyond about 1 km was stimulated by the possibility of hazard from releases of radioactive material and by proposals to seed clouds for precipitation by releasing suitable nuclei at the ground. As a consequence experiments were carried out at Porton using a fluorescent particulate tracer to provide a broad specification of the crosswind and vertical spread of the material at distances up to about 100 km. In particular the effective continuation of the crosswind spreading at shorter ranges was confirmed and the dependence of vertical spreading on the convective and turbulent state of the atmosphere away from the ground was demonstrated. Despite the greater complexities as compared with the short-range behaviour it appeared that useful estimates of diffusion could be made partly with the aid of data on wind fluctuation, using principles which will be explained later. The estimates made in this way have been used in a number of applications outside the Meteorological Office, notably in the detailed considerations given by the U.K. Atomic Energy Authority to the possibilities of hazard from accidental releases of radioactive material from their nuclear installations.

One of the most interesting and productive developments comes from the stimulation of interest in the actual details of the structure of turbulent flow. Hitherto the tendency had been to side-track the evidently complicated features of the turbulent motion itself and, as noted, to relate diffusion to the average effects reflected in the vertical gradients of temperature and wind velocity. Much of the reluctance to deal in the more direct terms of the turbulent fluctuations was a consequence of instrumental difficulties and of the considerable labour involved in reducing and analysing the volume of numerical data which observations would provide. With these obstacles largely removed by improvements in instrumental technique and developments in high-speed computing, the measurement of the detailed structure of atmospheric turbulence is now relatively commonplace in research investigations, and a steady effort is now being applied in this field in the Meteorological Office in work at Porton and Cardington.

In the theoretical framework within which the measurements of turbulence can be analysed and interpreted in relation to diffusion problems, the central concept is that of the spectrum of turbulent energy. Mathematically the fluctuating velocity which is observed in turbulent motion can be subjected to a form of harmonic analysis, in which the mean-square fluctuation of velocity (in effect the total turbulent energy) is divided up into contributions from a continuous range of frequencies (just as the intensity of light can be expressed as a function of frequency or wavelength). In the turbulence spectrum the mechanical analogy is that there are eddies of different 'sizes' ranging, say, from millimetres to kilometres. The physical importance of this concept lies in the realization that diffusion and transfer processes are controlled not only by the intensity of turbulence but also by the eddy sizes which can be effective in the particular example of diffusion concerned. Thus the growth of an isolated cloud of material of given dimensions can be affected only by eddies of comparable or smaller size. The same applies to a particular section of the plume from a continuous source. Bigger eddies merely move the cloud or section of plume bodily without significantly affecting its internal distribution. The latter process is however effective in determining the average concentration produced at a fixed position downwind of a source from which material is continuously emitted. For short intervals of time a relatively narrow front is affected by the plume, at a correspondingly intense level of concentration. As the exposure time is extended the plume meanders over a wide angle, in effect as bigger eddies come into play, and a wider front is affected but at a generally lower level of concentration.

The precise details by which the measurements of turbulence can be used to calculate the spread of a cloud or plume of material cannot be gone into in full here, but two points deserve emphasis. The most difficult part of the problem on the theoretical side is concerned with the precise way in which eddies exert their diffusive effect, as compared with the nature of the velocity fluctuations which are registered by a wind instrument in the normal way. The feature which determines the diffusion is the fashion in which the velocity of a particular small element of air fluctuates as it travels along in the main stream, and in the mathematical analysis this system of considering velocity fluctuations is known as Lagrangian. On the other hand a wind instrument responds to the fluctuations of velocity which are associated with different elements of air as they pass by. This system of considering the velocity fluctuations is known as Eulerian. The problem is to bridge the gap between the Lagrangian fluctuations which are not easily measurable and the Eulerian fluctuations which can be measured, and the crucial point is the difference in the characteristic frequencies at which the two series of fluctuations occur. The problem is far from being satisfactorily solved but the indications of the theoretical and observational work so far are that the Lagrangian frequencies are smaller (i.e. the fluctuations are generally slower) than the Eulerian by a scale factor which is in the range 1 to 10 according to the particular conditions.

For the ultimate practical application of the ideas of the preceding paragraph formulae have been derived to give the crosswind or vertical spread of the material in an isolated cloud or continuous plume of an air pollutant, or the factor (the eddy diffusivity) from which for example the rate of evaporation from a natural surface can be derived, given the vertical gradient of humidity. The important point is that these formulae are entirely in terms of the level of turbulence (as represented by the root-mean-square velocity fluctuation) and the scale ratio referred to above. The information on the level of turbulence can either be obtained from special measurements on the particular occasion and site, or interpolated from data assembled from previous measurements into the form of a climatological summary in terms of broad specifications of the meteorological conditions.

The current position and future prospects. The current position may be said to be one in which, given certain essential meteorological measurements useful estimates can be made of such practical features as the likely concentration of an air pollutant downwind of a specified source or the rate of evaporation from a sheet of water or a natural surface. The accuracy of the prediction will vary widely according to the nature of the source and the surface and according to the quality of the meteorological data available, and in some instances the estimates are necessarily rough. Improvements of the accuracy of these estimates can only come with progressive elimination of the remaining gaps and uncertainties in the understanding of diffusion processes and in the measurement and compilation of the special meteorological information demanded. These gaps in knowledge are the subject of attention in the current programme of research in the Meteorological Office and this article concludes with a brief reference to the more important items which are now under investigation.

In the hope of making further progress in the rather difficult problem of the Lagrangian/Eulerian relations experiments are now being conducted with floating balloons which, in effect, give Lagrangian measurements. These are superpressured plastic balloons called tetroons because of their roughly tetrahedral shape. The technique was invented in the U.S.A. and introduced here some time ago by a Weather Bureau Research Officer working in collaboration with the Meteorological Office. These measurements are being made at Cardington at a height of about 1000 m, the balloons being tracked by radar, and the Eulerian statistics required for comparison are obtained from effectively stationary instruments carried on the cable of a captive balloon. From such experiments it is expected that the statistics concerning the Lagrangian/Eulerian scale ratio will be usefully extended.

Although a fairly satisfactory empirical description is available for the fall-off in concentration at long distances (100 km) from an isolated source the precise details of the physical processes which determine this fall-off are still lacking in certain respects. When material has been transported over such long distances and, in the process, has been spread over some considerable height range (hundreds or thousands of metres) the plume or cloud is then subject to the effects of the gradual variations of wind speed and direction with height (the wind at 1000 m may have more than double the speed of that near the surface and may have a direction differing by 30° or more). The interesting point is that through the vertical interchange which proceeds continuously in the cloudy material the gradual changes of wind with height produce the effect of horizontal spreading. This presents the rather difficult theoretical problem of determining the extent to which such a process adds to the horizontal spread already in existence as a result of the turbulence in a horizontal plane. This theoretical problem is being studied at Porton and elsewhere. At Porton the main effort is applied to an extension of classical mathematical methods, by high-speed analogue and digital computing techniques, and from this investigation useful theoretical estimates will be available for the shear effect, as it is called, in a variety of meteorological conditions. There are rather deep physical problems also involved which require to be unravelled before the shear effect can be properly taken into account in estimating long-range diffusion.

The finer details of the structure of turbulence are also a subject of continuing investigation at both Porton and Cardington. Instrumentation and recording techniques as applied to atmospheric turbulence measurements have been developed to a very high degree, and this aspect has played a prominent part in the Porton programme. Accordingly the measurements of the statistical properties of turbulence, required in the practical applications which have been described, can proceed at a greatly increased rate, and examination of the structure of the airflow as revealed by the velocity fluctuations in both time and space can be attempted much more effectively than was possible a few years ago. At Cardington, where captive balloons are available for carrying instruments, the emphasis is on the examination of the properties of atmospheric turbulence at heights greater than those attainable with masts and towers. The properties at heights up to 1000 m or so are of practical interest in long-range diffusion of pollutants as well as in the meteorological problems of heat and vapour transfer throughout deeper layers of the atmosphere. These measurements also have become possible only through elaborate instrumental and recording techniques, in which the special difficulties associated with using instruments carried some hundreds of metres aloft on a swaying balloon have had to be overcome. At both Porton and Cardington these basic studies of turbulence are necessarily of long-term value, and as such can be expected to continue the process of extending the foundations on which problems of diffusion and turbulent transfer must be tackled if accurate advice is to be given in many practical matters.

Finally, in relation to the demands for practical advice, the most important requirement is the availability of 'climatological' information on turbulence, from which estimates of the various quantities of interest can be provided for various heights in the atmosphere and various conditions of weather and terrain. Such data are for example required in the consideration of long-term plans for tall chimneys at modern power stations from which effluent will be released at a considerable height in the atmosphere. Although adequate instrumental and recording techniques are available their use has so far been confined largely to occasional special experiments and short spells of observation. Rapid progress in building up a climatology of turbulence requires much more than this. With this requirement in mind a system of more regular observations is now under trial, in association with the daily readings of wind speed and temperature which are made at heights up to 1200 m at Cardington.

To sum up, in general it can be seen from the topics considered above that the problems arising from the turbulent and diffusive nature of the atmosphere continue to attract interest in a wide range of meteorological investigations. Despite the complexities, advances in the elucidation of the subject are evident, useful practical applications have been made, and lines of further work have been opened up which should yield further progress in both of these directions.

2. Organization of the Research Directorate

In broad terms the organization of research continued on lines which have taken shape gradually over the past ten years or more. The primary division is into two deputy directorates responsible respectively for "physical research" and "dynamical research", conventional terms having a widely accepted usage in meteorology. Physical meteorology covers the constitution of the atmosphere and the basic physical processes, especially turbulence and diffusion, radiation, condensation and precipitation, whereas dynamical meteorology is taken to connote the study of the large-scale phenomena of weather and climate as dynamical and thermodynamical systems, and so includes most of the problems of weather forecasting and climatic variation.

The Deputy Directorate for physical research naturally takes care of the scientific design and development of instruments for use throughout the service and also controls the work of the research outstations and observatories, including geophysical research in seismology and geomagnetism. In this way the senior staff in physical research tend to have many contacts outside the Meteorological Office with government laboratories and university departments having interests in atmospheric problems much wider than those of weather forecasting. Institutions which have common interests of this kind and with which we have been fortunate to co-operate include the Royal Aircraft Establishment, the Royal Radar Establishment, the Radio Research Station, the Chemical Defence Experimental Establishment and the Atomic Energy Authority. The many scientific committees organized by the Royal Society also make a considerable demand upon the time of the directorate.

The work within the deputy directorate for dynamical research, directed to the more immediate problems of weather and climate, has the aim of adding sooner or later to the scientific efficiency of the service to the public; weather forecasting takes a prominent place. It has been found convenient to bring within the ambit of this deputy directorate the branch which is responsible for all Meteorological Office training as well as for the Library and official publications.

The branch and outstation structure permits most research projects to be carried out by small teams each of a few scientists with supporting staff and headed, in most cases, by a senior principal scientific officer who is both scientific leader and administrative head of his group. The arrangement seems to have considerable merit for meteorological research.

Acknowledgement is again most gratefully accorded to the outside members, from the universities and other Government departments, of the Meteorological Research Committee and its Sub-Committees. A total of nine meetings were held in the course of the year, allowing most of the problems of research to be discussed in some detail.

3. Physical Research

High atmosphere. The Anglo-American research satellite ARIEL II was successfully launched on 27 March, carrying two experiments designed by Meteorological Office staff to measure the distribution of ozone concentration in the atmosphere above a height of about 30 km. Data have been obtained from both experiments, but the sensitivity of one set of equipment deteriorated quickly. The second experiment worked well and is expected to yield many hundreds of ozone profiles when the heavy calculations, using an electronic high-speed computer, have been carried out. A few chosen cases have, in the meantime, been examined by approximate computation using desk machines, and some preliminary results were communicated to a meeting at the Royal Society on 3 December. The indications are that the amount of ozone at heights above 70 km is much smaller than has previously been supposed but measurements in different parts of the world seem to confirm that above 35 km the vertical distributions everywhere are very similar. These preliminary results have not yet revealed any significant difference between the ozone values at sunrise and sunset. The cause of loss of sensitivity in the first experiment is not yet known but the question is being examined because the facts are causing concern to scientists, particularly astronomers, planning to employ a similar technique for certain experiments in future satellites. It seems highly probable that the aluminium coating of the exposed mirrors had been damaged by impact with molecules at high speed, not by meteorites or cosmic rays. To assist calibration of the satellite instrumentation two Skylark rockets with Meteorological Office equipment were launched from Woomera. Both these soundings were successful.

A similar experiment is planned for inclusion in the next satellite to be launched in the Anglo-American co-operative programme; this will measure the distribution of molecular oxygen at levels where it is partially dissociated by ultra-violet sunlight. Design and testing of this equipment was in progress in the Bracknell laboratories throughout the year. The mirrors were being constructed of solid aluminium with a protective coating and it is planned to use a much higher orbit. In this way it is hoped to avoid the loss of sensitivity.

Firings of the Skua meteorological rocket from South Uist in January and February suggested the need for modifications of the rocket vehicle. These were made and a further series of trials was carried out at Aberporth in August and September. In the course of these trials measurements of temperature were made to heights over 70 km, with winds up to 65 km. Internal evidence suggests that the temperatures are reliable below a height of not less than 65 km, which is believed to be the greatest height at which direct thermometry has been successfully applied. The sondes with which these results were obtained were designed and made in the Meteorological Office. It is expected that firings with the modified rocket will be resumed at South Uist in January 1965.

Meteorological Research Flight. After a lapse of two years, following an accident early in 1962, a high-altitude aircraft—a modified Canberra PR-3—again became available to the Meteorological Research Flight, making its first sortie on 7 April. Its major task has been to seek turbulent flying conditions at high levels in clear air and thin cloud layers and to examine the nature of the air motions. Measurements of the water, ozone and radioactive dust content of the air were made on most flights. The operational ceiling of this aircraft is below 50,000 feet and it is unable to provide answers to some of the questions raised in planning the operations of supersonic transport aircraft at heights up to 65,000 feet. A programme of meteorological investigation has been drawn up in case a higher-performance aircraft should become available.

The other aircraft of the Flight—a Hastings and a Varsity—have been used mainly in an investigation of air motion at lower levels, below and around cloud. In the course of this work a radio-refractometer, built by staff of the Radio Research Station, has been carried as it provides the best known method of measuring small-scale variations in the water content of the air. Some flights were also made to sample ice particles in clouds, and to measure the absorption and reflection of solar radiation by cloud. Between mid-November and mid-December the Hastings was in Singapore engaged in an investigation of tropical cumulus cloud and the wind-field of the intertropical convergence zone. Further convincing evidence was obtained of the development of heavy rain showers with cloud tops not reaching the level where the temperature was below freezing-point. Experiments in the same equatorial region will be resumed in July when the cloud and wind conditions will be radically different.

Radio-meteorology. Collaboration continued with the Radio Research Station in measurements of the refractive index of the air, using instruments carried by barrage balloons at Cardington, Bedfordshire, and on aircraft of the Meteorological Research Flight. The radio-refractometers, operated by scientists of the Radio Research Station, are providing hitherto unobtainable data on the small-scale variations of humidity which complement those of air motion and temperature made by the meteorologists. This fine structure on the scale of tens of centimetres is particularly noticeable near the base of subsidence inversions.

The Director of the Royal Radar Establishment continued to allow Meteorological Office staff the use of two advanced radar installations at Malvern. Use of a pulsed Doppler radar to investigate the size distribution of raindrops and the vertical currents in shower-clouds and thunder-clouds was continued. There was good evidence that the size distribution in the free atmosphere does not differ greatly from that near the ground. Computations were made, using readings from the Doppler radar, of the horizontal convergence of the wind in an extensive rain area, with interesting results. Further experiments on the same lines are planned. The narrow-beam 8-mm radar was used in an experiment to determine attenuation of the radiation in rain. The meteorologist's interest in this investigation arises from the problem of estimating rainfall amounts over an area, but it is also one of importance to engineers, particularly in assessing the performance of communication satellite systems. An extensive paper study of the problem of rainfall measurement by radar methods, with particular reference to conditions in the British Isles, was completed and will be published. The possibility of using the back-scattered radar signal from the raindrops themselves for the quantitative measurement of rainfall amount has been discussed for many years but the accuracy likely to be attainable, even with specially designed radar, may not prove to be sufficient to justify a costly development programme for the Meteorological Office, and work on this aspect of the problem is now under review.

Micrometeorology. An extensive investigation of turbulence and diffusion in the lower atmosphere, involving staff at Bracknell, Porton, Cambridge and Cardington, forms the subject of a special article in this report.

Some years ago, study at Kew Observatory of the properties of fog led to a suggestion that a method of fog clearance by spraying a solution of a hygroscopic material deserved further investigation. (It had been tried in America before World War II, with some success, but a particularly unpleasant chemical was used there.) Following small-scale experiments by Meteorological Office staff in the laboratory and the open air the method was examined and the cost of installation and operation on airfields estimated by Ministry of Aviation engineers. The installation costs proved very high and work on the project has ceased.

Instrument development. Much attention was given to automatic observation and new methods of data recording. Refinements were incorporated in the automatic weather station designed for connexion to the G.P.O. telephone network. During a short trial period, the station was located at Aberdeen and interrogated from Bracknell. A second complete equipment is being manufactured.

Following examination of available systems, a specification of requirement was drafted covering a versatile magnetic tape recorder for use with several meteorological instruments, to allow unattended operation for periods of a month or more.

Cloud pictures transmitted by the American NIMBUS A satellite were recorded at Bracknell using equipment assembled and in part constructed in the Meteorological Office workshops. The area covered during the trials stretched from the Levant to beyond Iceland. The satellite transmissions ceased before the end of the year but are expected to be resumed during 1965.

A laboratory model of a new radiosonde was completed. It has a fine-wire resistance element as thermometer to minimize errors on exposure to solar radiation. Action was initiated to secure manufacture of a trial batch of these instruments.

Instrument supply and maintenance. Six sets of the new wind-finding radar were delivered and installed. This equipment, a Cossor Type 353 10-cm radar, 750 kW peak power, is giving complete satisfaction. It successfully follows a standard radar target to distances of more than 200 km and permits winds to be measured regularly to heights greater than 100,000 feet. The same radar has been used to follow a rocket drop-sonde from heights greater than 200,000 feet.

Three weather-radar equipments were completed by the manufacturer but installation is deferred because of building delays.

There was a considerable increase during the year in the number of instruments and components tested and calibrated, much of the work being for other authorities on repayment terms. More than 130,000 balloons of various sizes were tested by sampling, and almost 20,000 radiosondes were calibrated. By agreement with the World Meteorological Organization the "Interim Reference Sunshine Recorder" is manufactured only in this country and 116 specimens were inspected and approved before installation throughout the world.

4. DYNAMICAL AND SYNOPTIC RESEARCH

Research related to short-range weather forecasting. Research over recent years has demonstrated that useful calculations can be made from the physical and dynamical laws which control atmospheric movements in order to predict the future distribution of atmospheric pressure near the ground and in the upper air. Such charts computed for 24 to 48 hours ahead can form a valuable guide to the weather forecaster, and have been shown to be more accurate in several respects than those drawn by a forecaster on the basis of experience and extrapolation. Experience in performing the calculations on the Meteorological Office electronic computer METEOR which had been employed for the research had, however, demonstrated that this machine lacked the speed and capacity to enable forecast charts to be prepared regularly within the short time interval required by the forecaster. A decision was therefore taken during 1963 to install a faster machine of greater capacity, the *English Electric-Leo* KDF 9.

During 1964 much effort was devoted to preparing the computing programmes needed to carry out numerical forecasts regularly when the new computer is installed early in 1965. These programmes provide for the extraction by the computer of the data required to start a numerical forecast. These data are taken from the paper tapes punched by the teleprinter equipment from incoming observations. Subsequently the programmes provide for the examination of the data for errors and the interpolation to points at which there are no observing stations, before the prediction calculations are started. Advantage is being taken of the capacity of the new computer in order to extend the area over which predictions will be made to include the whole of Europe and the Atlantic north of latitude 30°N. The calculations will be based upon values of atmospheric variables at three levels interpolated to 1927 points of a regular network extending over a large area. The methods of calculation will be the same as those employed during 1963 in extended trials over a small area.

In addition to the preparation of the computation programmes for the new computer, there have been research studies towards the extension of the prediction technique to additional levels in the atmosphere with a view to the direct application of the calculated pressure charts to the provision of forecast winds for aviation. Encouraging success has been achieved in respect of a level about 30,000 feet above MSL, much used by modern aircraft, where the strong winds of the jet stream are found. The extension to levels in the stratosphere at which supersonic transport aircraft will fly has also been studied.

Research has also included the examination of the fundamental way in which the problem of meteorological prediction is presented for computation and experimental calculations have been made from the so-called 'primitive equations' which express directly the dynamical laws operating. This is an alternative to the current procedure in which additional simplification and approximation enters before the problem is posed to the computer.

Studies have also been directed to applying similar dynamical calculations to the more detailed structure of weather systems by using a considerably finer grid of points on which to base the computations. The first objective is to achieve an understanding of atmospheric motion within rain-producing systems. For this purpose the large ATLAS computers have been used, first at Manchester University and later at the National Institute for Research in Nuclear Science. The calculations are still at a preliminary stage.

Although these calculations will open the way to a quantitative understanding of the formation of rain, it is not to be expected that the successful prediction by numerical computation of weather phenomena with dimensions of a few hundred miles or less will be easily achieved. Much weather of practical importance is organized on this scale and it is necessary to continue descriptive studies of such phenomena on the basis of the regular network of weather observation. Such studies serve both to formulate the problems of importance for later attack by numerical methods and to improve and codify the knowledge available to the forecaster by which he can relate his prediction of rain, snow, fog and other weather phenomena to the distribution of pressure. Considerable attention has been given to the distribution of rain in various types of weather systems, and the variation of the rainfall amount with factors which can be determined from the weather map. The problem of ascertaining the distribution of rain is made difficult by the considerable variations in rainfall amount over distances of a few tens of miles, but this difficulty can be overcome by the use of radar and the processing on an electronic computer of the many rainfall measurements by voluntary observers.

Empirical studies have also been made on the conditions under which hail occurs, the factors leading to snow and to dry spells of a few days' duration. Some relations of practical use in forecasting have been obtained. The distribution and intensity of showers are also being examined in relation to larger-scale aspects of the weather situation.

Research related to long-range weather forecasting. Weather forecasts have been prepared twice a month throughout the year to cover the ensuing 30 days and the issue to the public, which commenced in December 1963, has continued. The degree of success has been somewhat greater than that achieved during the preceding trial period.

The basic method employed is that of seeking periods in the past ninety years when weather developments over a large area were similar to those of recent weeks. The forecast is then based on the expected similarity between ensuing weather situations and those subsequent to the analogue period. However, the technique is still experimental and several different ways of selecting analogous periods have been examined and tested during the year. The Meteorological Office electronic computer has been used to make comparisons between distributions of temperature over Europe and the Atlantic for different periods. Similar comparisons have been made for pressure and also in respect of weather sequences. The facility to enable such comparisons to be made rapidly and objectively has permitted past data to be used in the testing of various methods of comparison.

During the preparation of the long-range weather forecasts various physical processes which may give rise to weather anomalies are considered. This requires consideration of anomalies of the condition of the land surfaces and oceans which may affect the supply of heat and water vapour to the atmosphere. Consideration of the magnitude of such possible effects has indicated that variation of the temperature of the oceans from year to year and season to season is one of the potentially significant causes of large-scale changes in the atmospheric circulation, and facilities for the regular examination of observations of ocean temperature have been extended.

General circulation of the atmosphere. A quantitative understanding of the large-scale air circulation over the whole globe is fundamental to the proper understanding of climate, and is of direct practical importance if a physically based system of long-range weather forecasting is to be developed, or climatic changes are to be understood or anticipated. It is also a prerequisite before any proposals for large-scale weather modification can be considered.

A significant attack on the problem has been mounted by attempting to simulate the large-scale behaviour of the atmosphere mathematically by the numerical solution on an electronic computer of the controlling dynamical equations. In contrast to similar but more elaborate experiments in the United States of America only a very limited number of the factors involved have been considered and the mathematical description is limited to a few aspects of the problem which are however important aspects. Computations which simulate the large-scale motions of the atmosphere over a period of 100 days or more provide a basis on which the statistical properties of the motion can be examined and their causes sought. Such calculations have presented many new problems of mathematical technique but, as these are solved, it is hoped to introduce additional physical effects which will render the mathematical formulation more realistic. Preliminary results have reproduced some important effects of the large mountain barriers.

Alongside this attempt to describe mathematically the general circulation of the atmosphere, a number of descriptive studies of the observational data have been made in order to improve the available description of the large-scale behaviour of the atmosphere. These have included studies of the large-scale changes in the winds up to 13 km during the rapid changes of the monsoon circulations of the tropics, studies of the average circulation of air at about 20 km and studies of the geographical distribution of the principal areas of heating and cooling of the atmosphere over the northern hemisphere.

Another aspect of the general circulation of the atmosphere which has received theoretical study is that of the slow exchange of air between latitudes in the stratosphere. This is important for the redistribution of radioactive dust injected into the stratosphere by atomic explosions, and the studies have been directed to determining whether there is a net poleward movement of air which can account for the observed transfer of radioactive material towards the pole or whether this is best regarded as a mixing process.

Theoretical studies have also clarified some aspects of the curious variation of winds in the equatorial stratosphere which go from mainly westerly to mainly easterly and back again over a 26-month period. Nevertheless, the phenomenon, which was discovered some five years ago, remains unexplained.

Regional climatology. The first volume of a substantial study of the climate of the eastern North Atlantic and adjacent waters was published under the title *Weather in Home Fleet Waters. Volume I Northern Seas Part I.* This publication is intended primarily for naval use and work continued during the year on the preparation of subsequent volumes.

Climatic trends. The collection and co-ordination of data on past weather régimes was continued in order to improve the picture of the variations of climate of the British Isles during the historical period, and of the changes in the larger-scale circulation which occurred with them. Meteorological Office staff took part in a number of discussions of climatic trends and their significance. The subject appears to be arousing increased public interest as its economic significance is realized.

Special investigations. The scientific staff engaged upon the main research projects have given advice when necessary to Government departments and other bodies on meteorological problems related to their research. However, a number of requests for information are received which are outside the main lines of research and which call for urgent investigation. The following are examples of such special studies:

Transport of radioactive material after atomic explosions.

Atmospheric pollution to be expected at various distances from proposed chimneys.

Wind structure near the ground in relation to the landing and take-off of aircraft.

Numerous inquiries for climatological information with particular reference to the effect of weather on aviation.

Through membership of a number of departmental and inter-departmental committees, advice was also given on atmospheric pollution, atmospheric turbulence and climatic extremes.

5. GEOPHYSICAL RESEARCH

Seismology. The Gassiot Fellowship in Seismology remained vacant throughout the year. The installation of the standard teleseismic equipment supplied by the U.S. Coast and Geodetic Survey was completed at Eskdalemuir in March and it has since functioned satisfactorily. Recording by the Galitzin seismographs at Kew Observatory ceased on 31 December. These instruments, originally installed by Prince Galitzin himself, have given remarkably good service, first at Eskdalemuir and later at Kew Observatory, for more than fifty years.

Geomagnetism. The Gassiot Fellow in Geomagnetism resigned at the end of August to take up a post at the University of Queensland. During the year he published theoretical work on rock magnetism and the 'seismomagnetic effect' and began an investigation on the correlation of magnetic pulsations using three specially constructed proton magnetometers spaced about 20 miles apart. On completion of these observations the proton magnetometers were installed at Hartland, Eskdalemuir and Lerwick Observatories where their suitability as routine instruments is under investigation.

(It was announced early in 1965 that the scientific and financial responsibility for the work in geomagnetism and seismology carried out in the Meteorological Office would pass to the newly-formed Natural Environment Research Council. It was accordingly decided to defer the filling of the vacancies for Gassiot Fellowships until the new Council could consider the matter.)

6. INTERNATIONAL RESEARCH ACTIVITY

In the 1963 Annual Report attention was drawn to the many ramifications of international arrangements for the co-ordination of research and to the contributions made by the Meteorological Office to international projects. The position does not change very ràpidly and it is unnecessary to repeat the survey on this occasion but it is well to recall that co-ordination is achieved only by the expenditure of much effort in those national and international committees on which Meteorological Office representation is required. The following is a list of some of the international bodies and projects with which the Office is connected:

International Years of the Quiet Sun (IQSY)

International Indian Ocean Expendition (IIOE)

International Hydrological Decade (IHD)

Programmes of the Scientific Committees of the International Council of Scientific Unions

- Committee on Space Research (COSPAR)
- Scientific Committee for Oceanic Research (SCOR)
- Scientific Committee for Antarctic Research (SCAR)

In addition to these there is a growing interest in the development of some kind of world research programme specifically for meteorology. Towards this end machinery has been set up by both the World Meteorological Organization, as the inter-Governmental body, and the International Union of Geodesy and Geophysics (IUGG) as the non-Governmental association of national academies. The first meeting of the WMO Advisory Committee, of which the Director of Research is a member, was held early in the year (in February 1965 a second meeting established liaison with the IUGG committee). By the nature of the case the scope for international co-operation in the study of world weather and climate is exceptionally wide but the part which United Kingdom scientists in general and Meteorological Office staff in particular may be called upon to play in a world programme cannot be judged until the programme begins to take a more definite shape. The United States has, so far, taken a prominent lead in discussions with its remarkable scheme of earth-orbiting satellites for meteorological purposes as impressive evidence of serious intentions. The U.S.S.R. is also showing a full interest in collaboration. Bearing in mind the possible rewards in better long-range weather forecasting, in providing helpful weather services for the many developing countries of low latitudes, and even ultimately in weather control, one may look for the project to gather momentum in the coming years.

7. Library and Publications

On 1 December the control of the Library and Publications passed from the Directorate of Services to the Directorate of Research. The departments involved were the National Meteorological Library and Archives, the Editing Section and the Cartographic Drawing Office, which were combined into an Assistant Directorate (Publications and Training).

The Library provides an information service on the literature of meteorology and those other branches of geophysics within the scope of the office. The library services are available not only to the professional meteorologist but to anyone who wishes to use them, whether he be a research worker, an industrialist or simply an interested member of the public. Of the inquiries from outside the Meteorological Office during the year, one was concerned with a survey on North Sea weather in connexion with drilling for oil and natural gas. Another related to a study of the influence of weather on man's activities, and a third to the history of theories of rain formation. The increasing use that is made of the Library is shown by a 25 per cent rise, as compared with recent years, in the number of loans in 1964. Library statistics are given in Table XXVII on page 58.

The Archives occupy a building about half a mile from the main Office. These archives, like those at Edinburgh (for Scotland) and Belfast (for Northern Ireland), are appointed under the Public Records Act of 1958 as repositories for original meteorological observations and other records of the Meteorological Office. The existence of nearly two miles of shelving in the Bracknell building is an indication of the capacity of the Archives and, even now, nearly three years after they were established, the task of checking, cataloguing and binding the contents is less than half finished. Research workers in the Meteorological Office are the most frequent users of the records in Archives, but there has been a steady increase in outside inquiries. Requests are made by correspondence or in person, and photo-copies of past records have been provided for various bodies in this country and abroad.

The Editing Section prepares for printing most of the Meteorological Office publications. The *Meteorological Magazine* is issued monthly, but most other publications appear at irregular intervals. *Geophysical Memoirs* and *Scientific Papers*, for example, are two series which consist of research papers by Meteorological Office staff. A noteworthy publication in 1964 was the 4th Edition of the *Meteorological Glossary*, a valuable reference book which first appeared in 1916 and which has now been entirely re-written.

The Cartographic Drawing Office is responsible for the preparation for printing of all diagrams for publication by the Meteorological Office. These include many charts used by forecasters for various areas of the world and which are frequently altered to meet changing forecasting needs. Many hundreds of diagrams are produced during each year.

8. TRAINING

Responsibility for training also passed to the Directorate of Research on 1 December.

The main Training School is at Stanmore, where a variety of courses are conducted by a staff of 16, supplemented from time to time by visiting specialist lecturers. The most advanced course is that for Scientific Officers, which aims to provide not only practical training in forecasting, but also the general background knowledge required by the potential researcher in meteorology. At a lower level there are shorter courses for newcomers to forecasting, and a third type of course is designed for assistants, who constitute the largest single body of trainees. There are in addition training courses for forecasters of limited experience and refresher courses for the more senior forecasters, at which there is discussion of recent developments in techniques. A few courses at Stanmore deal with specialized branches of meteorology, but the main one of this type, in radiosonde work, takes place at the Radiosonde Training School at Hemsby, on the Norfolk coast, where one of the regular upper-air sounding stations is situated. As many as 48 students, most of them on the introductory course, were trained at Hemsby during 1964.

Training is not confined to formal professional instruction. During the year 24 meteorologists attended courses for meteorological Officers-in-Charge, specially arranged by the Civil Training and Education branch of the Air Force Department. Another facet of training is external study, a scheme whereby staff are helped to follow courses in science subjects while continuing their normal duties. At the end of the year 310 students, mostly young, were obtaining benefit from these concessions.

An important aspect of the training organization is that each year about 50 of the students come from Commonwealth and foreign meteorological services in all parts of the world. The distribution of their countries is shown in Table XXVIII on page 58.

During the year new editions of the *Pocket book for forecasters* and *Notes for Scientific Assistants in the Meteorological Office* were prepared by the Training School staff.

R. C. SUTCLIFFE
Director of Research

Table XXVII

LIBRARY STATISTICS

Items received including duplicates but excluding daily weather reports ...	8486
Individual books, pamphlets, articles, microfilms classified and catalogued...	6549
Transparencies acquired	910
Publications lent (excluding daily weather reports and internal 48-hour loans) ...	12,923
New agreements for exchange of publications	13
Total number of exchange agreements	418
Total number of pages translated by Library translators	
Russian ...	2119
German ...	28
French ...	8
Icelandic ...	16
Total...	2171

ARCHIVES

Number of loans ...	841

Table XXVIII

TRAINING

The following figures give details of courses which were completed during 1964 at the Meteorological Office Training School at Stanmore, the Radiosonde Training School at Hemsby, and the Air Force Department Civil Training and Education establishment in London.

	Number of courses	Length of course in weeks	Number of students
Scientific Officers ...	1	23	6
Senior Forecasters ...	3	3	32
Forecasters (Advanced) ...	5	4	40
Forecasters (Initial) ...	2	17	54
Assistants ...	11	9	141
Climatology...	1	4	7
Mediterranean Meteorology ...	2	2	11
Tropical Meteorology ...	1	3	5
Voluntary Observers ...	2	1	26
Auxiliary Observers (Coastguards)	2	1	35
Assistants (Background Course) ...	2	1	30
Special Course for Antarctic Observers ...	1	1	1
Advanced Instrument Maintenance	4	3	23
Instrument Theory and Interpretation ...	1	1	7
Radiosonde (Initial) ...	5	8	33
Radiosonde (Refresher) ...	3	4	7
Radiosonde (Advanced) ...	3	4	8
Special Course for Antarctic Observers (Radiosonde) ...	1	8	6
Course for Officers-in-Charge ...	2	1	24
		Total	496

Students from the following territories attended courses:

Country	Number of students
Austria	4
British Antarctica	7
Channel Islands	2
East Africa	5
Egypt	1
Ecuador	1
France	1
Hong Kong	1
India	1
Iran	3
Libya	2
Mauritius	1
Nigeria	4
Pakistan	1
Switzerland	6
Syria	4
Total	44

INTERNATIONAL CO-OPERATION

1. WORLD METEOROLOGICAL ORGANIZATION

There were several sessions of constituent bodies of the Organization during 1964. From 26 May to 12 June, the Executive Committee met at the Headquarters of WMO* in Geneva for its sixteenth session, which was attended by the Director-General, Sir Graham Sutton in a personal capacity and he was assisted by Mr. C. W. G. Daking, the Assistant Director (Defence and International). Probably the outstanding subjects discussed were the World Weather Watch and the Development Fund, matters which are interrelated. A schedule for completion of the various phases of planning for the World Weather Watch was drawn up. With regard to the Development Fund, a plan for utilization and operation of the Fund was prepared and agreed for submission to Members of WMO for their approval by postal ballot. A majority of Members gave their approval and projects for support from the Fund for the year 1965 were selected at a session of an Executive Committee Panel, which met in November.

The Commission for Hydrometeorology met in Warsaw from 29 September to 16 October. The United Kingdom delegation was led by Mr. R. H. Clements, Assistant Director (Climatological Services) who was assisted by Dr. J. Ineson of the Geological Survey on ground water matters and by Mr. J. F. Glennie of the Hydrological Section of the Water Resources Board on surface water matters. The International Hydrological Decade including participation by WMO and its Members was among the important items dealt with at the session.

The Commission for Maritime Meteorology held its Fourth Session in Geneva at the Headquarters of the WMO from 23 November to 8 December. This was the first session of a WMO Technical Commission to be held in Geneva. As the arrangements for the session were admirable and appreciated by all who took part a useful precedent has been set. Commander C. E. N. Frankcom, Marine Superintendent, was the Principal Delegate of the United Kingdom. He was assisted by Instructor Captain G. P. Britton, R.N., Director of the Naval Weather Service and Mr. N. Bradbury (Met.O.3). Among the items discussed were the organization of meteorological networks at sea and climatological information for sea areas.

A joint WMO/IUGG symposium on research and development aspects of long-range forecasting held in Boulder, Colorado, U.S.A. from 29 June to 4 July was attended by Dr. R. C. Sutcliffe, Director of Research, and Mr. J. S. Sawyer, Deputy Director (Dynamical Research).

2. CENTRAL TREATY ORGANIZATION

A meeting of the Sub-Committee of the Central Treaty Organization Economic Committee was held in London from 22 to 30 October. Mr. A. A. Worthington (Met.O.6) attended as a member of the United Kingdom delegation.

3. NORTH ATLANTIC TREATY ORGANIZATION

Dr. A. C. Best, Director of Services, United Kingdom member of the Standing Group Meteorological Committee, attended the 21st meeting of the Committee in Paris from 23 to 25 June. Mr. L. H. Starr, Assistant Director (Observations and Communications) and Mr. R. A. Buchanan (Met.O.17) were also present.

* A list of all abbreviations used in this section, and their meanings is given on page 64.

The two Working Groups of the Standing Group Meteorological Committee, on Weather Plans and Weather Communications, held two meetings during the year, in Athens from 10 to 19 March and in Bonn from 13 to 21 October. Mr. L. H. Starr and Mr. R. A. Buchanan represented the United Kingdom. Mr. Starr is also Chairman of the Working Group on Weather Communications. Mr. R. A. Buchanan represented the Meteorological Office at the 13th meeting of the SHAPE Meteorological Committee held near Paris from 13 to 15 May.

The Meteorological Committee of Channel Command met in London on 13 and 14 February. Mr. R. A. Buchanan attended on behalf of the Meteorological Office.

Mr. J. Crabtree (Met.O.7) was a member of the United Kingdom delegation at a meeting of the External Ballistics Group of the Armaments Committee in Paris from 25 to 29 May and also at meetings of sub-groups in Bonn from 19 to 22 May and in the United Kingdom from 28 October to 4 November.

On 27 and 28 January Dr. R. C. Sutcliffe, Director of Research, attended a meeting in Brussels of the NATO Science Committee's *ad hoc* Advisory Group on Meteorology. He also attended a meeting in Rome on 4 and 5 May of a NATO Consultative Group for Research on "Cyclogenesis to lee of the Alps—North Italy and the Gulf of Genoa". At this meeting Dr. Sutcliffe was accompanied by Mr. E. Knighting, Assistant Director (Dynamical Research).

4. South East Asia Treaty Organization

Mr. D. H. Johnson, Chief Meteorological Officer, Far East Air Force, was the principal United Kingdom delegate at a meeting of the Meteorological Committee of SEATO in Bangkok from 14 to 17 December.

5. International Civil Aviation Organization

The Meteorology and Operations Divisions of ICAO held a joint meeting simultaneously with the Third Session of the Commission for Aeronautical Meteorology of the World Meteorological Organization, in Paris, from 20 January to 15 February. Mr. P. J. Meade, Deputy Director (Outstation Services) headed the United Kingdom delegation which included Mr. A. A. Worthington (Met.O.17) and Mr. D. G. Harley (Met.O.6). During the session Mr. J. Briggs (Met.O.15) presented a paper on 'Low-level atmospheric turbulence in relation to aircraft'.

Mr. A. A. Worthington (Met.O.17) attended, as a member of the United Kingdom delegation, the ICAO Informal Meeting on Snow and Slush Problems at Aerodromes in Europe, held in Paris from 27 April to 2 May.

The ICAO Meteorological Operational Telecommunications Network (Europe) Development/Implementation Panel held a meeting in Paris in November. Mr. J. A. Pattinson (Met.O.6) attended from 10 to 12 November as adviser to United Kingdom Panel Member (Ministry of Aviation).

The ICAO Fourth Africa–Indian Ocean Regional Air Navigation Meeting was held in Rome from 23 November to 18 December. Mr. D. G. Harley (Met. O.17) attended as a member of the United Kingdom delegation.

6. Other International Meetings

Below is a representative list of other international meetings and symposia attended by members of the Office during the year. The list read in conjunction with Sections 1–5 demonstrates the wide variety of meteorological and allied disciplines which are the concern of the Meteorological Office in the international field.

Mr. E. J. Bell (Met.O.5c), Chairman of a Special Panel of the Working Group on Meteorological Transmissions of WMO Regional Association VI (Europe) attended a session of the Panel in Geneva from 20 to 30 October for study and development of an advanced telecommunications plan for the Region.

From 28 September to 10 October Mr. L. P. Smith (Met.O.7) attended a technical conference in Beirut on "Agrometeorology in the Middle East" for discussion of a joint FAO/UNESCO/WMO inter-Agency project in agro-meteorology in semi-arid and arid zones. Mr. Smith also attended a seminar held in Cairo from 13 October to 3 November to discuss agrometeorological problems in Africa.

As WMO representative, Mr. N. Bradbury (Met.O.3), attended a session of a Joint Working Party of FAO, the General Fisheries Council for the Mediterranean and the International Commission for the Scientific Exploration of the Mediterranean Sea, to consider the preparation of a synopsis of the Oceanography of the Mediterranean. The session was held in Monaco from 26 to 29 October.

Mr. A. A. Worthington (Met.O.17) participated in the Franco-Anglo-United States meeting on supersonic transport aircraft requirements held in Paris from 1 to 9 June.

At the request of the Department of Technical Co-operation, Mr. D. G. Harley (Met.O.6) visited the West Indies from 9 June to 18 July to report, in consultation with the Director, Caribbean Meteorological Service, on the meteorological requirements of the British Windward and Leeward Islands and British Guiana.

Mr. D. G. Harley (Met.O.17) was in Iceland from 27 October to 2 November at the invitation of the Icelandic Meteorological Service, to discuss international civil aviation matters of mutual interest, in particular those related to the 1965 ICAO Special North Atlantic Regional Air Navigation Meeting.

Mr. G. W. Hurst (Met.O.7) attended as WMO observer an FAO/IUFRO symposium on internationally dangerous forest diseases and insects. The symposium was held in Oxford in July.

Mr. W. H. Hogg (Met.O.7) attended an international conference on cereal rust held in Cambridge in July.

In July Dr. R. W. Gloyne (Met.O.7) attended a NATO Soil Conference in Cambridge and also an International Botanical Conference in Edinburgh.

Dr. A. G. Forsdyke, Assistant Director (Special Investigations) was a member of the United Kingdom delegation which attended a session of a Quadripartite Working Party (U.K., U.S.A., Canada and Australia) on the standardization of climatic stress specifications for military equipment. The session was held in London from 27 to 30 October.

Mr. A. F. Crossley (Met.O.9) attended a tripartite British, French and German Institutes of Navigation conference at Eastbourne from 12 to 14 May during which the safety and reliability of sea and air transport from the stand-point of navigation was discussed.

Dr. G. D. Robinson, Deputy Director (Physical Research) attended the 1964 World Conference on Radio Meteorology, held in Boulder, Colorado, U.S.A.

from 14 to 18 September. Dr. Robinson was accompanied at this conference by Dr. P. G. F. Caton (Met.O.15) who presented a paper on 'Raindrop size distribution in the free atmosphere'.

Dr. Robinson also attended a UNESCO inter-governmental meeting in Paris, from 21 to 30 April to discuss seismology and earthquake engineering.

Dr. W. T. Roach (Met.O.15) attended a NATO summer school course on Radiometeorology held in Athens in September by the Advanced Study Institute.

Commander C. E. N. Frankcom, Marine Superintendent, attended meetings of constituent bodies of IMCO, as WMO observer, in February, April, July and November. He also attended, as Chairman, the annual meeting in Bergen, from 20 to 21 May of the Unofficial Advisory Committee of European States on North Atlantic Ocean Stations.

Mr. L. Jacobs, Assistant Director (Observatories and Micrometeorology) attended a symposium of the Radiation Commission of IAMAP held in Leningrad, U.S.S.R., from 4 to 16 August. Mr. Jacobs read a paper on 'The operation of a network of ship-borne radiation instruments'.

Mr. R. A. Hamilton (Met.O.14) attended an IAMAP symposium on Atmospheric Ozone held in Albuquerque, New Mexico, U.S.A. from 31 August to 5 September.

Mr. R. H. Collingbourne (Met.O.14) took part, on behalf of the Meteorological Office, in the regional comparisons of working standard pyrheliometers held at Davos, Switzerland from 14 to 26 September. The standard Kew Ångström pyrheliometer was used for the comparisons.

Mr. H. H. Lamb (Met.O.13) attended the annual meeting of the Geologische Vereinigung (an international Geological Union) held in the University of Cologne from 5 to 7 March and read a paper on 'Climatic changes and variations in the atmospheric and oceanic circulations'.

Dr. R. Frith, Assistant Director (High Atmosphere), and Mr. J. R. Bibby (Met.O.19) attended a joint IUGG/WMO symposium on ozone research and its applications to atmospheric physics held in Albuquerque, New Mexico, U.S.A. from 31 August to 5 September.

Dr. Frith also attended a symposium organized by COSPAR at Florence from 11 to 19 May, and sessions of the working groups of ESRO in Munich on 2 February and in Paris on 23 April and 30 July.

Mr. A. Bleasdale (Met.O.3) was a member of the United Kingdom delegation at the inter-governmental Meeting of Experts, convened by UNESCO and held in Paris from 7 to 17 April, on the International Hydrological Decade 1965/74.

Mr. B. F. Westwater (Met.O.6) visited the West Indies from 28 October to 19 November for liaison meteorological duties in connexion with the Royal Flights by H.R.H. The Prince Philip, Duke of Edinburgh, to the Windward and Leeward Islands.

Five members of the staff were released during the year to take up appointments under United Nations Technical Co-operation programmes, or British programmes of the same kind.

Mr. R. Frost, Principal Scientific Officer, was appointed as WMO Adviser to the Malawi Government on national and international meteorological commitments and organization.

Mr. F. E. Lumb, Principal Scientific Officer, was appointed to the East African Meteorological Department under the OPEX scheme of the United Nations, for administrative and scientific work in the Headquarters of the Department in Nairobi.

Mr. A. Elliott, Senior Experimental Officer, was appointed as Senior Meteorological Officer, New Hebrides Condominium, under arrangements made with the Department of Technical Co-operation.

Mr. F. J. Smith, Experimental Officer, was appointed as a Meteorological Officer with the Nigerian Meteorological Service under arrangements made by the Department of Technical Co-operation.

Mr. R. Eden, Senior Scientific Assistant, was released for duties with the Meteorological Service of Nyasaland (now Malawi) under arrangements made by the Crown Agents.

LIST OF ABBREVIATIONS USED IN THIS SECTION

WMO	— World Meteorological Organization
IUGG	— International Union of Geodesy and Geophysics
NATO	— North Atlantic Treaty Organization
SHAPE	— Supreme Headquarters Allied Powers Europe
SEATO	— South-east Asia Treaty Organization
ICAO	— International Civil Aviation Organization
FAO	— Food and Agriculture Organization
UNESCO	— United Nations Educational Scientific and Cultural Organization
IUFRO	— International Union of Forest Research Organizations
IMCO	— Inter-Governmental Maritime Consultative Organization
IAMAP	— International Association of Meteorology and Atmospheric Physics
COSPAR	— Committee on Space Research
ESRO	— European Scientific Research Organization
OPEX	— Operational and Executive

STAFF

The Meteorological Office Headquarters organization is shown in the diagram on p. 67 and the names of the principal officers are listed on p. iv. At the end of the year 1964, the total number of posts of all grades was 3586. The strength was made up as follows:

Scientific Officer Class	
Chief Scientific Officer	3
Deputy Chief Scientific Officer	4
Senior Principal Scientific Officer	26
Principal Scientific Officer	79
Senior Scientific Officer	21
Scientific Officer	21
Administrative Class	
Assistant Secretary	1
Experimental Officer Class	
Chief Experimental Officer	20
Senior Experimental Officer	231
Experimental Officer	386
Assistant Experimental Officer	199
Scientific Assistant Class	
Senior Scientific Assistant	269
Scientific Assistant	1270
Marine Staff	
Nautical Officer Class	8
Ocean Weather Ships and Base	
Officers	53
Crew	126
Technical and Signals Grades	296
Executive and Clerical Grades	164
Typing and miscellaneous non-industrial grades	121
Industrial employees	90
Locally entered staff and employees overseas	198

Recruitment of honours graduates was sufficient only to replace losses, and vacancies persisted throughout the year. It was also not possible to fill all the posts graded within the Experimental Officer class and an increased resignation rate marred the excellent position in respect of Scientific Assistants which was reported last year.

Seven Assistant Experimental Officers shared the year between the Office and Colleges of Advanced Technology where they were taking Sandwich Courses. Study concessions were granted to 310 members of the staff. From many applicants 14 University undergraduates were chosen to work in the Office as Vacation Students. Four college-based Sandwich Course students spent their extra-college periods with the Meteorological Office.

Dr. R. C. Sutcliffe, C.B., O.B.E., F.R.S., was awarded the Silver Medal by the Council of the Royal Society of Arts for his paper, 'Advances in Weather Forecasting'.

Her Majesty the Queen approved the award of the Polar Medal to Mr. M. J. Blackwell, M.A. for service with the British Antarctic Survey.

In the New Year's Honours List Mr. J. Bell, B.Sc., was appointed a member of the Most Excellent Order of the British Empire.

Mr. A. L. Henson was awarded the Imperial Service Medal.

APPENDIX I

METEOROLOGICAL OFFICE HEADQUARTERS ORGANIZATION

- Director-General
  - Director of Services
    - Deputy Director (Central Services)
      - MET.O.1 (Marine)
      - MET.O.2* (Central Fore-casting)
      - MET.O.5* (Obsns. and Commns)
      - MET.O.8* (Fore-casting Tech-niques)
      - MET.O.12* (Data Process-ing)
    - MET.O.17* (Defence and Inter-national)
    - Deputy Director (Outstation Services)
      - MET.O.3* (Climat. Ser-vices)
      - MET.O.6* (Aviation Ser-vices)
      - MET.O.7* (General Ser-vices)
  - Secretary's Division
    - MET.O.4
    - MET.O.10
  - Director of Research
    - Deputy Director (Dynamical Research)
      - MET.O.9* (Special Investi-gations)
      - MET.O.11* (Fore casting Re-search)
      - MET.O.13* (Synop. Climat.)
      - MET.O.18* (Publica-tions and Trng.)
      - MET.O.20* (Dynam. Climat.)
    - Deputy Director (Physical Research)
      - MET.O.14* (Obser-vatories and Micro-met.)
      - MET.O.15* (Atmos. Physics)
      - MET.O.16* (Instru-ment Develop-ment)
      - MET.O.19* (High Atmos.)

*Assistant Directorates

APPENDIX II

PUBLICATIONS

The publications prepared by the Meteorological Office are generally issued by Her Majesty's Stationery Office as official publications. A complete list, with the prices at which they can be purchased through any of the sales offices or usual agents of Her Majesty's Stationery Office, is sent free to any applicant.

The following official publications were issued during the period of this Report:

PERIODICAL

Daily Aerological Record, containing information respecting meteorological conditions in the upper air over the British Isles (to 20 December 1964).

Daily Weather Report, containing weather maps for the northern hemisphere, British Isles, etc., and data (to 31 December 1964).

Daily Weather Report, Overseas Supplement, containing surface and upper air data (to 12 August 1964).

Meteorological Magazine (to December 1964).

Monthly Weather Report (to August 1964).

Seismological Bulletin. A diary of seismological disturbances recorded on the Galitzin aperiodic seismographs at Kew Observatory, Richmond (to May 1964).

Marine Observer (quarterly) (to October 1964).

The Observatories' Year Book, comprising the geophysical results obtained from autographic records and eye observations at Lerwick, Eskdalemuir and Kew Observatories (1962).

Monthly Weather Survey and Prospects, a monthly publication containing climatological data for Britain, the weather of the past month, a general survey and inference, and weather prospects for the coming month in Britain; a supplementary document, containing survey, inference and prospects only, is published in mid-month (December 1964).

British Rainfall 1959/1960.

SERIAL

Scientific Papers:

19. Some further observations from aircraft of temperatures and humidities near stratocumulus cloud, by J. G. Moore, B.Sc.
20. The Interannual Variability of Monthly Mean Air Temperatures over the Northern Hemisphere, by J. M. Craddock, M.A.

OCCASIONAL

Weather in the Mediterranean Vol. II, 2nd Edition.

Weather in Home Fleet Waters Vol. 1, Part I.

Ships Code and Decode Book—6th Edition.

Hygrometric Tables Part II, 2nd Edition. Stevenson Screen readings in degrees Celsius.

Hygrometric Tables Part III, 2nd Edition. Aspirated psychrometer readings in degrees Celsius.

Meteorological Glossary, 4th Edition.

APPENDIX III

BOOKS OR PAPERS BY MEMBERS OF THE STAFF

The following books or papers by members of the staff were published during the year ending 31 December 1964:

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