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TRAINING IN THE METEOROLOGICAL OFFICE

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Training has always formed a lively subject for controversy. While some regard it as an essential preparation for efficient work, others believe that systematic training merely postpones the day when the individual can begin to learn his job properly in the exacting school of experience. Sympathy can be felt with the latter point of view, and indeed there are many qualities of a good workman which can only be acquired in the responsible performance of his duty—by becoming operational as it were—and which formal training can make little attempt to provide. As far as the Meteorological Office is concerned, however, the question hardly arises. In nearly all the educational institutions of Great Britain meteorology is either excluded or an intruder. Most of the staff on joining the Office are therefore confronted with meteorology as a separate subject for the first time, and it is thus imperative to provide courses of instruction for them.

Although it is regrettable that meteorology is not more widely taught at schools and colleges, it must be conceded that the subject would be an awkward one to fit into the general curriculum. The trouble is that a number of other subjects have to be mastered first. Meteorology is the science of the atmosphere, and the task of the meteorologist is to observe and describe as accurately as possible the many different phenomena that occur. He therefore applies the methods of physics and mathematics to account for the various elements which in their aggregate constitute the weather, and he also uses the summaries and speculations of geography to supply a background of average conditions. The student, therefore, who wishes to understand even the elementary processes of the atmosphere will find himself severely handicapped if he has neglected physics, mathematics and, perhaps in a less degree, geography. The importance of these subjects as a stepping stone to the study of the atmosphere illustrates the practical difficulty in schools of devoting more attention to meteorology. It could hardly be expected that progress in fundamental studies should be arrested so that the large amount of time necessary could be spent on their application to the weather.

The preceding remarks have been made in the full knowledge that for some years past some elementary meteorology has been included in practically every geography syllabus. This development, though welcome in many respects, gives rise to a tendency for meteorology to be treated from the wrong angle. The analysis of past weather from the climatological standpoint—average rainfall, the world distribution of temperature from season to season, the identification of prevailing winds—falls conveniently within the scope of geography, but it is to physics and mathematics that we must look for the explanation of how these elements occur or how they vary—the formation of rain, changes in temperature caused by the ascent or descent of air, why the wind blows and so on. In case this statement may appear to magnify the difficulties of meteorology, it should be stated at once that, although there is still a lot to be learnt about every atmospheric process, much of what goes on may be described in a general way in quite straightforward terms. But the explanation will be a physical one, and, however simple, not readily grasped by those with no knowledge of physics.

To many this insistence on the importance of the application of physics and mathematics to meteorology may seem rather unnecessary, but it is not made without good reason. A number of young people while still at school become fired with an intense interest in meteorology and assume that if they concentrate on geography they will be taking the best possible steps to fit themselves for careers as meteorologists. Since meteorology has appeared only in their geography lessons, the assumption is a reasonable one. Some of these enthusiasts, however, proceed to neglect mathematics and physics if not to give them up altogether. Eventually they discover that their preparations for a meteorological career have been ill planned, and that much time has been wasted at a period of their lives when the study of physics and mathematics might have presented least difficulty.

Historical.—Systematic centralized training did not begin in the Meteorological Office until late in 1935. Before that time the Office was comparatively small, and new staff were engaged at irregular intervals as and when vacancies arose. These recruits were posted immediately to the offices where they were required to serve, and there they were regarded as under training until, after a few months as a general rule, they were declared to be efficient in their grade by their Officers-in-Charge. This type of training, although apparently of an *ad hoc* nature, had a number of advantages. The new member of staff received personal tuition over a lengthy period from an officer of many years' experience of the work; the latter had a vested interest in the successful outcome of the training because the future efficiency of his own office was involved.

Towards the end of 1935 the rate of recruitment to the Meteorological Office increased suddenly, and a number of Technical Officers were appointed within a short space of time. It is interesting to recall that this increase in strength was made necessary not by military expansion but by the ripening of plans for the development of civil air routes overseas. The Short "C" class flying boats, forerunners of the R.A.F. Sunderlands, were under construction and were to be used for speeding-up the Empire Air Mail Service and for transatlantic flights. The latter were to be experimental at first because in those days the idea of regular commercial flights across the Atlantic Ocean was little more than an act of faith.

The weather was naturally one of the most important factors to be taken into account, and, as a preliminary to the flights, the Meteorological Office undertook an intensive examination of the weather that might be encountered from season to season over the 2,000-mile flight from Foynes to Newfoundland. Accordingly a special section in the Overseas Division of the Meteorological

Office was formed at Croydon airport with a Senior Technical Officer, Mr. S. P. Peters, in charge. The new batch of Technical Officers was posted to the section, and Mr. Peters was given the dual responsibility of training them as forecasters and then of carrying out, with their assistance, the Atlantic investigations.

While this work was proceeding the level of recruitment rose once again, this time because the meteorological requirements of the R.A.F. were beginning to increase as the effects of the expansion programme were seen in the opening of new airfields. There was then every indication that for some time to come more and more staff would be needed by the Office. It was therefore decided to centralize the training of forecasters as much as possible. The special section of the Overseas Division formed the obvious foundation for such a project, and, until its transfer to Foynes in the summer of 1937, it received and trained all newly appointed Technical Officers. The move did not, however, disturb the continuity of training. As an additional measure to the appointment of staff from outside, steps had been taken within the Office to increase the number of forecasters available, and suitable Technical Assistants with long experience had been selected to attend a forecast course. A new training element, working in close association with the Overseas Division, was formed at Croydon, and it was able, when the necessity arose, to take over the responsibility for all forecasting courses including those for Technical Officers.

A further aspect of training had to be considered in 1939 when the formation of a Meteorological Branch of the R.A.F.V.R. was sanctioned, and the recruiting of officers and airmen began. It was originally intended that the volunteers should be trained by means of evening classes arranged at various centres throughout the United Kingdom, but the war started before these proposals could be carried out, and the problem then became one of providing full-time instruction for officers and airmen who had been mobilized.

The airmen were required for assistants' duties, and they were posted in small parties to Royal Air Force stations where the local meteorological offices could provide the training.

For the officers more elaborate arrangements were necessary, and a school was opened for them at Berkeley Square House, London. Professor (now Sir David) Brunt was released temporarily by the Imperial College of Science to take charge of the training programme, and about 40 officers who were awaiting courses were posted to the new school. At the same time the training classes for civilian forecasters were moved into Berkeley Square House, and so Professor Brunt became responsible for the training of all forecasters, service and civilian, for the Meteorological Office. These arrangements came into existence on September 15, 1939. The date is an important one for the record because it marks the official opening of the Meteorological Office Training School. Thus, although training courses had been quite a normal activity of the Office for the preceding four years, the organization under which they flourished had never been given a separate title.

With the formal setting up of a training school on a more or less permanent basis, the advantage of centralizing the instruction of assistants as well as forecasters was soon appreciated, and classes for synoptic assistants, airmen and civilians, were arranged.

Recruitment to the Meteorological Office was stopped for a few months in the summer of 1940, and the Training School accommodation at Berkeley Square House was released for other purposes. Towards the end of the year it became necessary to resume training and the School was re-opened at Barnwood, Gloucester, Mr. C. J. Boyden, a Senior Technical Officer being appointed Chief Instructor. After about a year it was found more convenient to hold the assistants' classes which then contained civilians, airmen and airwomen, in the London area. The School was therefore divided, the forecast classes remaining at Gloucester, but, in August 1943, accommodation difficulties also forced their removal to London and the two sections were reunited at Kilburn. Since then the Training School has had several moves within the London area, the final one taking place on August 22, 1951, when it was moved to Stanmore, its permanent location.

At Stanmore the School is accommodated in a plain, single-storey building. Apart from the usual classrooms and administrative offices, an instrument display room and a cinema are provided and there is also a suitable exposure for the Stevenson screens and other outdoor equipment. The surroundings are quite pleasant, and from the technical point of view Stanmore is a very suitable place for a meteorological training school compared with, for example, central London with its smoke-laden atmosphere. The photographs between pp. 144 and 145 show the type of classroom provided, the instrument enclosure and the space available for pilot-balloon work.

Present training organization.—In 1948 when the general reorganization of the Meteorological Office took place the training of staff became the responsibility of a separate branch which was created for the purpose. This Branch is responsible not only for imparting the knowledge and skill which staff need to carry out their meteorological duties but also for supervising external training, that is studies taken outside the Office in order to improve scientific qualifications. External studies are important because they enable staff to keep abreast of modern developments in meteorology and also help to fit them for more responsible work. Concessions are made to staff taking approved courses externally.

Before a description is given of the various types of course provided at the Training School, it might be useful to refer to the principles on which the recruitment of staff are based. Owing to the nature of its work the Meteorological Office forms a part of the Scientific Civil Service and its personnel consists almost entirely of scientific staff. These are divided into three classes—Scientific Assistants, Experimental Officers and Scientific Officers—and entry to a class is largely determined by the standard of qualification attained in physics and mathematics. Assistants must normally have reached the ordinary level of the General Certificate of Education in these subjects. Experimental Officers require at least Intermediate B.Sc. or its equivalent, and for Scientific Officers a good honours degree in either physics or mathematics is essential.

On joining the Meteorological Office the new member of the staff is first of all posted to a station for a week or two so that he may at first hand obtain a general impression of the work that has to be done. After this brief but useful introduction he is sent to the Training School and formal instruction begins.

Since the large majority of the staff of the Meteorological Office are employed in some way or other on synoptic meteorology, the basis of weather forecasting, this aspect of meteorology receives most attention during training. In the courses arranged for each class a primary objective is to do more than merely impart to each trainee the ability to carry out his duties in a routine manner. A fair proportion of the time in every course is therefore devoted to the theory of meteorology, and in this way staff acquire a good understanding of the scientific background to their work and an appreciation of its importance in relation to the general international arrangements for promoting the efficiency of meteorological services. While the amount of theory and the detail of its treatment in each type of course must naturally take account of the academic qualifications of the trainees, the scope of each course is made as wide as possible, and an underlying motive is to encourage further reading in meteorology so that each trainee will maintain a lively interest in the subject throughout his career.

Courses for Scientific-Assistant Class.—The courses provided for assistants at the Training School last for eight weeks. A revision of basic physics, especially heat and properties of matter, prepares the way for some meteorological theory, and the assistant is then introduced to ideas on air masses and fronts, the life histories of depressions and anticyclones, the meaning of Buys Ballot's Law and the formation of cloud and rain through the ascent of air. In addition to these lectures, instruction and practice are given in technical procedures in force at outstations such as the making of weather observations, both visually and with instruments, the use of meteorological codes and the plotting and drawing of synoptic charts.

The main syllabus of the course is completed in six weeks, and the final fortnight is spent on intensive practical work in which conditions at outstations are reproduced as closely as possible. By the end of his course the new assistant should have a good grasp of all his duties but naturally he would not have the facility, or speed, in carrying them out that is the hallmark of an experienced assistant. However, speed is acquired with long practice and at the Training School the main emphasis is upon accuracy and neatness. The importance of these two qualities is repeatedly stressed because the observations made by an assistant are transmitted far and wide and therefore must be absolutely reliable, and the charts which he plots are the first and perhaps the most vital steps in the preparation of forecasts.

When the course at the Training School ends the assistant is posted to a station, and there, working under the guidance of an expert colleague, he develops in proficiency and confidence until he is fully competent to fill a vacancy on the establishment. This period of further training varies in duration between one assistant and another, but on the average it last about 2 months and seldom exceeds 3 months.

After his initial training is completed the assistant has not finally severed his connexion with the Training School. It is intended that after several years spent on routine duties at stations, he should return to the School for a three-week refresher course during which he would be able to revise and extend his knowledge of the basic theory of meteorology. The first of these courses was held in February 1950, and six more have taken place since then; in fact, they are arranged whenever it is possible to obtain the release of assistants from their offices in sufficient numbers. The courses so far held have been most successful, and there is no doubt that they have served a useful purpose.

Courses for Experimental-Officer Class.—In the past four years new entrants to the Experimental-Officer Class have been drawn largely from assistants who, by means of further studies as well as general efficiency, have qualified for promotion. As such staff are already conversant with the fundamental duties of observing and plotting they go straight to a forecasting course which lasts for 12 weeks. Staff who are recruited externally to the Experimental-Officer Class and who have had no previous experience of meteorology, are first of all given three weeks' preliminary training, mainly on assistants' duties, before their forecasting course begins.

The syllabus of the course includes a study of the dynamics and thermodynamics of the atmosphere, including a detailed consideration of the tephigram, and of the application of radiation principles to special phenomena such as fogs and frosts. Lectures are also given on upper air analysis, general climatology and on the forecasting techniques used in tropical areas. Among other subjects treated are ice formation, thunderstorms and turbulence cloud.

The practical work of the forecasting course is based first of all on the analysis of simple situations, and the trainees then pass on to a study of selected sequences of past weather. These have been chosen for their instructive features, and are useful examples of weather situations frequently encountered. Each sequence contains from 4 to 7 consecutive charts which are printed with the basic data already plotted. Trainees are provided with the charts of a sequence one at a time, and they analyse and draw up each chart and forecast from it before receiving the following one. The main advantage of using sequences in this way is that they contribute to completeness, whereas a reliance on current weather throughout a course would entail the risk of experiencing too few interesting situations, and the slow trainee would find his answers by gazing out of the window as the actual weather overtook his pedestrian efforts.

Current weather is not scorned, however, and the final 3 weeks of a course are occupied with forecasting as nearly as possible in accordance with an office routine and, when practicable, in conjunction with a class of assistants. Groups of forecasters and assistants then become responsible for the operation of "stations" with a working programme which includes written forecasts, telephone and personal inquiries and routine observations.

On completing their course the forecasters go to offices where, for the following 3 months, their practical training is continued with the object of developing those qualities, such as briefing ability, which cannot be fully imparted at a training school.

The initial training of a forecaster is thus spread over six or seven months at the outset of his career. He then spends several years on routine forecasting duties working under the direction of senior and far more experienced forecasters. During this period he inevitably extends his practical knowledge of the weather and its ways, and this, combined with his understanding of the physical processes that take place in the atmosphere, helps him to become a reliable forecaster with the confidence that results from the scientific application of accumulated experience. At this stage he will be regarded as ready to return to the Training School for a course in preparation for more responsible forecasting duties.

Advanced forecasting courses for members of the Experimental-Officer Class were started in March 1949. Before that time the officers to be trained were sent to major forecasting offices where instruction and operational experience in higher duties were provided simultaneously. The scheme worked very well, but it was considered that greater benefit would accrue if the technical instruction were given by means of organized courses at the Training School to be followed immediately by practical training at a major forecasting office.

The syllabus of the advanced forecasting courses, which last for four weeks, is concerned mainly with the application of upper air data. A study is made of Sutcliffe's development patterns, of Rossby's theory of waves in a barotropic atmosphere, and lectures are also given on jet streams.

Courses for Scientific-Officer Class.—A scientific officer is regarded as under training during the first two years of his career, although during much of that period he is in fact doing useful and responsible work. Since high qualifications in mathematics or physics are an essential condition of entry to the Scientific-Officer Class, its members are recruited with the intention that they should undertake original research in order to extend existing knowledge in one or more branches of meteorology. Their training is therefore planned so that they may acquire a wide knowledge of the subject, and also a keenness to investigate some of the many problems that still remain to be solved.

The first part of the two-year training period is spent on a course at the Training School which lasts for 18 weeks. The annual intake of scientific officers is small—not more than 10—and, as they all join at about the same time shortly after they leave the University, only one course is required each year. This is concerned primarily with synoptic meteorology, the ground covered being similar to that for the initial and advanced courses for members of the Experimental-Officer Class except that the treatment is more theoretical, and original papers, such as those of Sutcliffe, Petterssen and Rossby, are discussed in detail.

Following this course at the Training School a scientific officer is given two main attachments for the balance of the two years, one to an important forecasting unit and the other to a meteorological centre which is not engaged in forecasting work. During the former attachment, besides gaining a great deal of practice in the technique of forecasting, he is also given time to read research papers and may take part in any investigations which are in progress. The second attachment, for which account is taken of the individual's special aptitudes, may be to an observatory or to Harrow where the Instrument Development and Climatology Divisions are situated, or to a centre established for a particular project such as the Meteorological Research Flight.

To supplement this training programme, short visits of a few days or a week are made to other centres whenever convenient. Thus, by the end of the two-year training period, the young scientific officer should have become well acquainted with the work of the Office as a whole, and will have acquired a good knowledge of forecasting and of at least one other branch of meteorology.

Miscellaneous courses.—At intervals during each year the normal routine of the Training School is pleasantly varied by the arrangement of a special course. About twice a year, normally in the late autumn or early spring, short courses lasting four days are provided for observers from climatological and crop weather stations. The former are maintained by private observers or by municipal and other local authorities, while the latter are situated at agricultural colleges and research institutions for the study of the relation between the weather and growing crops. These stations make valuable contributions to the weather records from which statistics and summaries are compiled for the benefit of the community generally. The courses are arranged in conjunction with the Climatology Division of the Meteorological Office, and the primary objects are to perfect the observers' technique in reporting the weather and in the maintenance of their equipment, and to give them an opportunity to raise questions of technical procedure with experienced instructors. Since they were first started in March 1950, six very stimulating courses have been held.

Another interesting course was held early in 1950 for instructors at nautical schools, whose duties include the teaching of meteorology to officers of the Merchant Navy studying for their Master's and Extra-Master's Certificates. This course was arranged at the request of the Ministry of Education, and it is probable that it will be repeated in a few years' time.

With the re-forming of the Meteorological Branch of the Royal Air Force Volunteer Reserve some special problems arose in connexion with the training of officers. Many of them had been forecasters during the war, and this experience, together with that obtained in post-war reserve training, had qualified them to receive training for higher duties. Short courses, on the lines of the advanced forecasting courses provided for officers of the Experimental Class, were therefore arranged and were given during the period of 15 days' continuous training for which reserve officers are liable. Two of these courses were held in 1951 and three more have been arranged for the summer of 1952.

Among others for whom courses are arranged whenever necessary are Merchant Navy Officers recruited to the Marine Branch of the Meteorological Office for duty at Headquarters, at port meteorological offices or on ocean weather ships.

Students from overseas.—Since the war a number of overseas meteorological services have asked for vacancies on forecasting courses at the Training School to be reserved for selected members of their staffs. Such requests have always been complied with, and in consequence there have been few forecasting courses in the past few years which have not included among their members at least one student from abroad. Within the Empire, Ceylon, Nigeria, Hongkong and the Sudan have sent locally recruited staff to England for training, and other countries that have been represented on forecast courses include Belgium, Greece, Iraq, Persia, Siam and Peru.

After their forecasting courses these visitors from overseas spend two or three months at offices adding to their practical experience, and some also continue their training by going to centres such as Eskdalemuir Observatory where they learn about terrestrial magnetism or to Hemsby where the operation of radio-sonde and radar wind equipment is taught.

Although not strictly under the present heading, it should be mentioned that the Colonial Office and the Crown Agents for the Colonies recruit a number of staff within the United Kingdom for duty in colonial meteorological services. Such staff are invariably sent to the Training School for a course before they go abroad.

External training.—In 1944 the Assheton Committee published its report on the training of civil servants. One of its recommendations was that Departments should encourage their staff to obtain external qualifications in subjects related to their official work. Accordingly shortly after the end of the war, the Treasury circulated a memorandum laying down the general principles on which the further studies of staff should be approved and specifying the material help that should be given.

The application of the scheme in the Meteorological Office is concerned with the study of physics, mathematics and geography, and staff are encouraged to study these subjects in order to obtain qualifications above the basic minimum required for entrance to their particular class. Thus the objective of Scientific Assistants would be Intermediate B.Sc., and members of the Experimental Officer Class who wished to participate in the arrangements would study for a full science degree. Facilities granted to those whose course of study is approved include the payment of fees and time-off with pay to attend classes and sit for examinations.

Since its inception the scheme has proved very popular among the staff of the Office and the numbers availing themselves of its provisions are usually in the neighbourhood of 200 or nearly 10 per cent. of the total. The scheme is also proving worth while in that a satisfactory number of examination successes have been gained and, a point of particular importance, assistants taking external studies have presented a fruitful field for recruitment to the Experimental-Officer Class.

ESTIMATION OF WEEKLY FROST RISK USING WEEKLY MINIMUM TEMPERATURES

By E. N. LAWRENCE, B.Sc.

Summary.—The following note describes a method of estimating the weekly frost risk in spring, and may be used for sites with only a short period of observations providing there is a meteorological station of long standing in the same climatic region.

It is necessary to find the average weekly mean daily minimum temperature of the site, and also either the average weekly absolute minimum temperature or the value of the "spread coefficient". The latter is a measure of the scatter of minima about the average minimum temperature and may be calculated from the two minima mentioned or estimated from an examination of the site characteristics. For flat country, it is possible to construct maps showing the lines of equal spread coefficients, which may be used to obtain the spread coefficients of any site within the area.

It is shown how the two minima mentioned may be obtained graphically from brief records of observations.

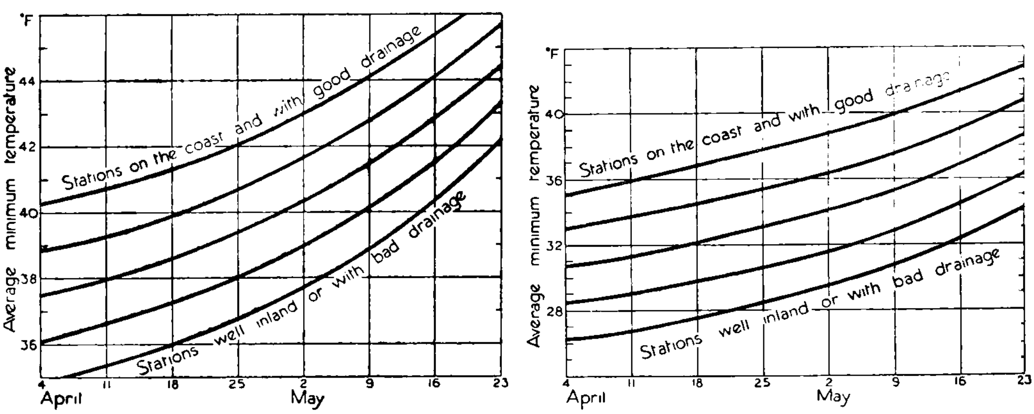
Finally, using the resulting values of the average weekly mean daily minimum temperature and the spread coefficient, the frequency of frosts for threshold temperatures 32°, 30° and 28°F. may be read from the graphs of Fig. 3.

Assumptions.—It has been found[1] that the curve of distribution of minimum temperature exhibits a negative skew in winter, and that of maximum temperature shows a positive skew in summer. For the spring months considered in this note, it is assumed that minimum temperature follows the normal distribution curve. Thus the frequency of minimum temperature below a given value depends on the average minimum temperature and a measure of the spread of minimum temperature about the average.

Generally, with normal distributions, spread is measured in terms of the standard deviation, which may be expressed as the quotient of the range and a range parameter[2]. The latter depends on the number of independent minima, and may be expected to be approximately constant for all stations within a limited area of similar climate. Hence the standard deviation is proportional to the range, which therefore also represents a comparable measure of the scatter. The spread is here conveniently calculated in the form of the average half range or spread coefficient (S), expressed as the difference between the weekly mean minimum temperature and the weekly absolute minimum temperature.

Stations on exposed coasts are greatly susceptible to the moderating influence of the sea and may be expected to show some tendency towards a negative skew distribution of minima. This phenomenon may be the cause of disagreement between observed and calculated values of the very low frost frequencies.

Method.—As an aid to the estimation of the weekly mean minimum temperature at a site for which long-term measurements are not available, graphs showing its mean rates of increase with time have been constructed [see Fig. 1(*a*)]. The top curve is typical of a coastal station and the lowest curve corresponds to a station well inland. Curves for stations with good drainage lie towards the top of the chart and curves for sites with bad drainage tend to lie near the bottom.



(*a*) Weekly mean minimum (*b*) Weekly absolute minimum

FIG. 1—RATE OF INCREASE DURING APRIL AND MAY OF AVERAGE WEEKLY MINIMUM TEMPERATURE

When estimating the weekly mean minimum temperature, Fig. 1(*a*) may be used as follows:—

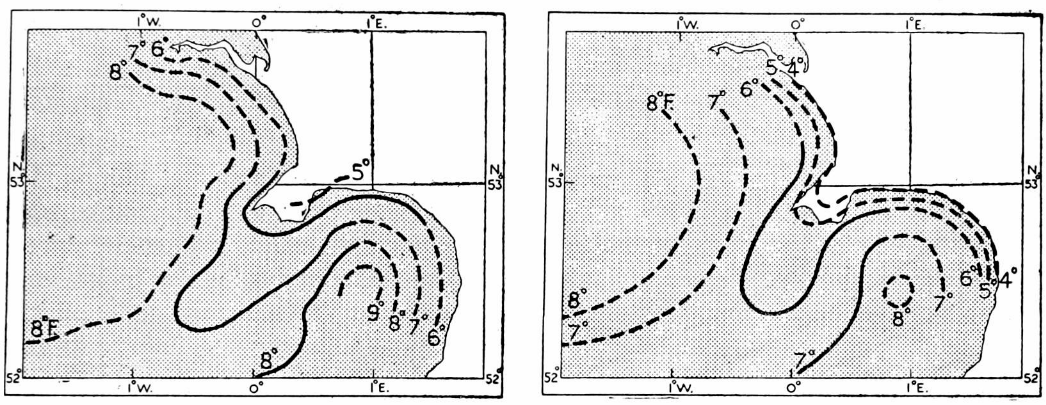
(i) Obtain a series of weekly mean minimum temperatures for a period of at least one spring.

(ii) Examine the observations for this period of the nearest meteorological site of long standing and calculate the differences of the latter from their long-term averages.

(iii) Correct the weekly mean minimum temperatures of (i) using the differences calculated in (ii), plot the results on Fig. 1(*a*) and draw the curve which best fits these points and lies parallel to the adjacent curves. This curve gives the average minimum temperature of the site during April and May.

A further set of curves [Fig. 1(*b*)] has been constructed for weekly absolute minimum temperature and is similar to that of Fig. 1(*a*) regarding topography and use.

For flat country, a good estimate of the spread coefficient may be simply computed from a map based on the network of meteorological stations. Fig. 2 shows the lines of equal spread coefficients for the northern part of eastern England for April and May respectively. Unfortunately, the spread coefficients of sites in hilly country cannot be obtained by reference to a chart, because orographic features would make a chart over-complex. In order to calculate such spread coefficients, it is necessary to know or estimate (by the method above) the average weekly absolute minimum temperature in addition to the average weekly mean minimum temperature. The difference between these two values is the spread coefficient.



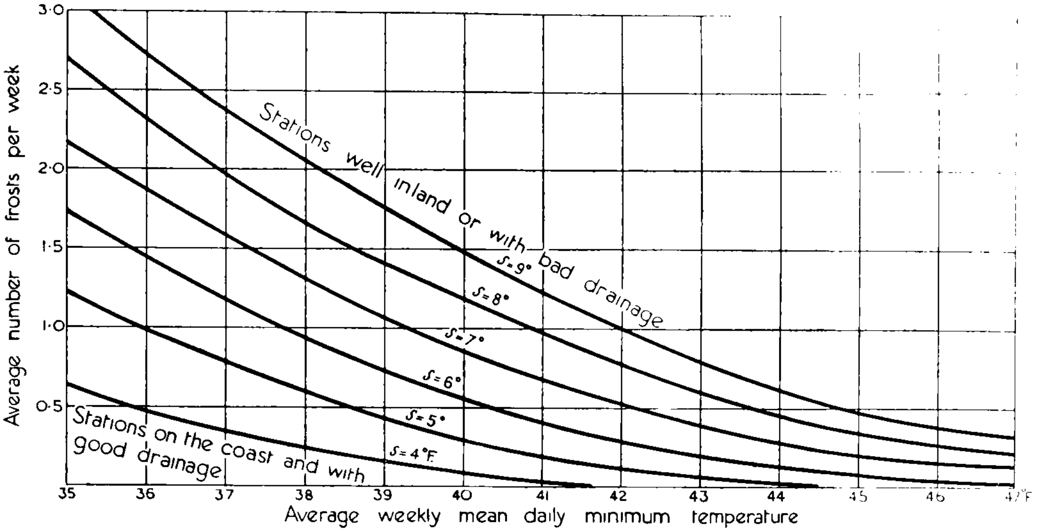
(*a*) April (*b*) May

FIG. 2—LINES OF EQUAL SPREAD COEFFICIENT OF MINIMUM TEMPERATURE

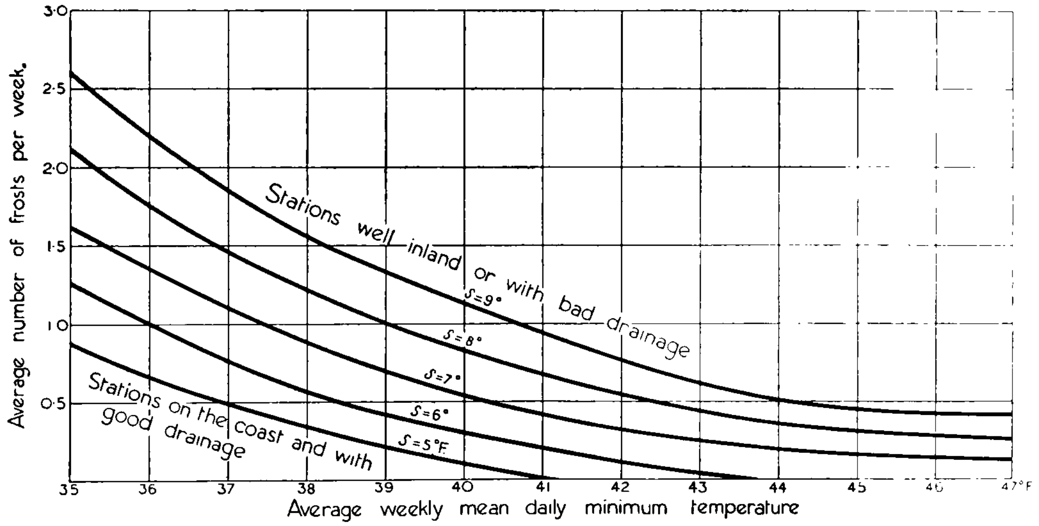
Having found the value of the average minimum temperature of any particular week during April or May, and the corresponding spread coefficient of a particular site, by reference to a chart or otherwise, the weekly frost risk may be read from the graph of Fig. 3(*a*). The closeness of fit of the spread-coefficient lines of Fig. 3(*a*) is acceptable statistically, and the agreement between observed and forecast frost frequencies is satisfactory for all stations with periods of observation exceeding fifteen years. Stations with shorter periods exhibit strong sampling errors. It should be emphasized that estimates of frost frequencies cannot be expected to agree with observed frequencies over periods of less than fifteen years.

So far this note has dealt with frequencies of frosts with temperature of 32°F. or below. Figs. 3(*b*) and 3(*c*) give forecast frequency graphs for threshold temperature of 30° and 28°F. respectively. In these cases to obtain reasonable agreement between the estimated frost risk and observed frequencies, it was found necessary to take a period of the order of at least 20 years. In all cases good agreement is not obtainable for frequencies of the order of one per month or less.

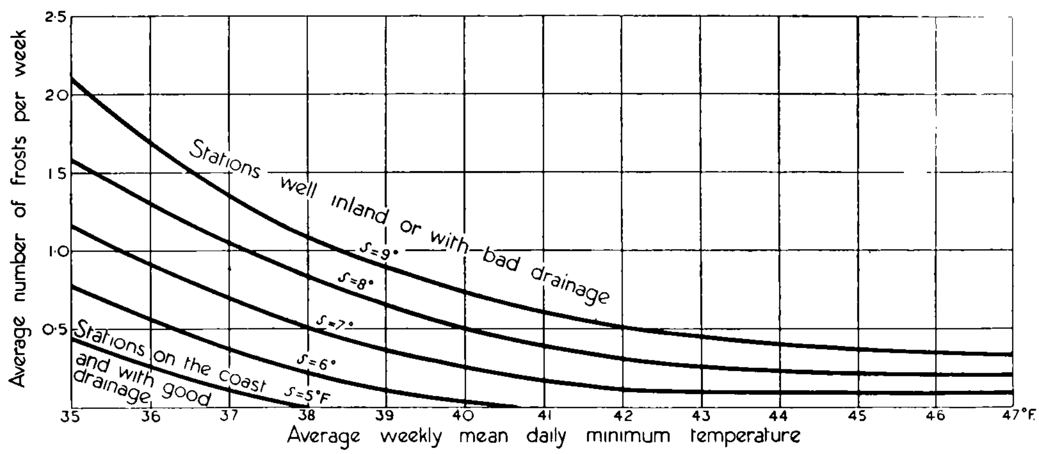
It may be seen from the graphs of frost frequencies (Fig. 3) that for high average minimum temperature (e.g. the Wash district in May) the weekly



(*a*) Threshold temperature 32°F.



(*b*) Threshold temperature 30°F.



(*c*) Threshold temperature 28°F.

FIG. 3—RELATION OF FREQUENCY OF TEMPERATURE AT OR BELOW VARIOUS THRESHOLD VALUES TO THE AVERAGE WEEKLY MEAN DAILY MINIMUM TEMPERATURE AND THE SPREAD COEFFICIENT (S)

frost frequency changes slowly with change of temperature, so that a very rough estimate of the average minimum temperature will give an approximation to the frequency, provided that the country is flat and that spread-coefficient charts are available for the area.

Distribution of spread coefficients in relation to topography and soil.—The value of the spread coefficients is usually about 5°F. in April and of the order 4–5°F. in May for coastal sites and stations with extremely good drainage of cold air, i.e. stations on steep slopes well above valley floors. Malvern, Worcestershire, is situated on a steep slope well inland and has an average value of 5·0°F. for the April–May period.

The value of the spread coefficient is about 8°F. in April and 7–8°F. in May for stations well inland (about 40–70 miles from the open sea), though stations less than about 40 miles inland with some impediment to free drainage of cold air may have high spread coefficients. Parkend, Gloucestershire, where woodlands impede the drainage, has values of 7·4° and 6·8°F. respectively.

For the remaining stations, i.e. those less than about 40 miles inland but not near coasts and without major orographical features, the spread-coefficient value is about 7° in April and about 6–7°F. in May.

It should be noted here that all these values for the spread coefficient are approximations and that they are influenced by soil type, as may be seen from Fig. 2, where the values appear to be lower along the belt of lias (clay), oolites (limestone) and alluvium which extends roughly from the Cotswolds to near the Wash. This means that frost frequencies tend to be lower for example over clay than over sandy soil, a fact borne out by a previous investigation[3].

Owing to paucity of data, the spread-coefficient lines of Fig. 2 were estimated in places (shown by broken lines) by extending the exhibited tendency of these lines to lie parallel to coasts and their less marked tendency to be parallel to certain soil boundaries.

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METEOROLOGICAL RESEARCH COMMITTEE

The 19th and 20th meetings of the Physical Sub-Committee of the Meteorological Research Committee were held on February 22 and 29, 1952, respectively.

The technical papers discussed at these two meetings included one by Mr. Durst and Mr. Gordon[1] on the distribution of humidity at sea. Miss Carruthers[2] presented a paper dealing with the use of probability paper in upper air climatology, the use of this type of graph being illustrated with data regarding tropopause heights. Upper air climatology was also considered in a paper by Mr. Frost[3] entitled "The upper air circulation in low latitudes and its relation to certain climatological discontinuities".

The influence of the size of condensation nuclei on the development of radiation fog was considered in a paper by Mr. Best[4].

Cloud physics was represented by two papers, one by Mr. Jones[5] dealt with aircraft observations of the nature of cloud particles above the freezing level in cloud from which a radar response is obtained. The other paper described some laboratory experiments by Mr. Palmer[6] on the reproduction of ice crystals by splintering.

The Committee also considered recommendations regarding changes in Part III of the research programme for the forthcoming twelve months.

ABSTRACTS

1. DURST, C. S., and GORDON, A. H.; The distribution of humidity at sea. *Met. Res. Pap., London,* No. 665, S.C.III/106, 1951.

At ocean weather station JIG (53°50′N., 18°40′W.) October–December, 1947, vapour pressure differences, sea surface (assumed saturated at sea temperature) to 28–30 ft., were compared with wind direction and force. Decrease greatest with N.–E. winds and force 2–3, least with S.–SW. winds. Relative humidities at bridge height from all data at JIG and ITEM were expressed as mode, 10 and 80 percentiles against wind direction and force, showing a minimum at force 2.

2. CARRUTHERS, N.; Probability paper—an application in upper air climatology. *Met. Res. Pap., London,* No. 711, S.C.III/124, 1952.

The use of probability paper for examining frequency distributions is described. The results of combining two normal distributions differing in mean or standard deviation and of plotting platykurtic and leptokurtic distributions are illustrated. The method is then applied to tropopause pressures at Habbaniya (Iraq), giving (except in July) combinations of two distributions. From discontinuities in upper air temperatures it appears that the total frequency distribution of tropopause pressure is made up of 10 normal distributions.

3. FROST, R.; The upper air circulation in low latitudes and its relation to certain climatological discontinuities. *Met. Res. Pap., London,* No. 706, S.C.III/122, 1952.

The author discusses the abrupt changes of tropopause in Iraq in late May and October, and corresponding discontinuities in surface temperature. Sections of temperature and east-west component in 40°E., 0–60°N., up to 130 mb. in January, April, July and October show a westerly jet stream in 26°N. (January) to 40°N. (July), crossing Iraq at time of tropopause change, and an easterly jet stream in July in 15°N. at 100 mb. Causes of the jet streams and relation to surface conditions and sudden onset of Indian monsoon are discussed.

4. BEST, A. C.; Condensation nuclei and the development of radiation fog. *Met. Res. Pap., London,* No. 698, S.C.III/118, 1952.

The paper traces the effect of condensation on hygroscopic nuclei (sea salt) on visibility as humidity increases. Opacity (extinction coefficient) is discussed as a function of drop size and the latter as a function of mass of nucleus and relative humidity. With assumed distributions of nucleus size, opacity and liquid water are calculated for humidities 80–99·9–100 per cent. Assuming all nuclei of same size, equations are solved for growth of droplets and decrease of visibility in cooling air after saturation; visibility is found to depend on water content, total salt content and size of nuclei.

5. JONES, R. F.; Aircraft observations of radar reflecting particles above the freezing level. *Met. Res. Pap., London,* No. 683, S.C.III/113, 1951.

Observations of character of precipitation, temperature and icing on 8 flights in cloud in and above freezing level, in conjunction with ground radar, are discussed. Echoes from above freezing level are associated with numerous ice crystals 0·5 mm. or more long, the bright band occurring at the change to raindrops. Other observations describe flights through cumulus and cumulonimbus above freezing level, with columnar echoes from supercooled water and usually icing.

6. PALMER, H. P.; The reproduction of ice crystals by 'splintering'. *Met. Res. Pap., London,* No. 702, S.C.III/120, 1952.

A layer of hoar frost was formed by sublimation on under surface of a cooled block at 0° to −25°C. from an air stream in a cloud chamber. When surface was 6° colder than air, hoar frost grew dendritically and ice splinters were released (10/min./cm.^{2}) probably by fracture of dendrites. With difference less than 6°, tabular plates were formed without splintering. Release of splinters during freezing of deposited water is also discussed; it occurs only with contaminated water.

ROYAL METEOROLOGICAL SOCIETY

Meteorology and the operation of jet aircraft

At the meeting of the Society held on February 20, the President, Sir Charles Normand, in the chair, there was a discussion on meteorology and the operation of jet aircraft.

The proceedings opened with statements by Air Cmdre G. Silyn Roberts (Ministry of Supply), Capt. A. M. Majendie (B.O.A.C.). Gp. Capt. C. G. Lott (H.Q., Fighter Command R.A.F.), Mr. G. J. W. Oddie (Meteorological Office) and Mr. C. S. Durst (Meteorological Office).

Air Cmdre Roberts gave an outline of meteorological phenomena of significant interest in the flying and design of jet aircraft. He pointed out that the thrust of jet engines decreased more rapidly with increasing temperature than that of piston engines and that jet-fuel consumption was very high at low levels. Jet aircraft could fly at greater heights and speeds and climb more rapidly than piston-engined aircraft. While low-level meteorology was as important as ever, the operation of jet aircraft called for consideration of meteorological conditions at greater heights than before.

Turning to individual meteorological elements he pointed out first that forecasts of visibility for landing were very important because the jet aircraft uses a great deal of fuel if it has to loiter at low levels waiting to land.

Turbulence was probably the most important meteorological phenomenon for jet aircraft because their higher speed made its effects more violent. The gustiness which can occur in clear air at great heights was serious for transport and bomber aircraft, for the risk of stalling it brings. Much more information was needed about the structure of gusts at all heights for use in aircraft design, and ability to forecast occurrence of clear-air turbulence was highly desirable if not essential for the comfort of airline passengers.

As regards ice accretion, the higher speed of jet aircraft caused the rate of accretion to be more rapid, but this effect was mitigated by the temperature rise associated with the higher speed and the fact that their high cruising altitude enabled jet aircraft to spend more of the flight above clouds. Jet engines very quickly lost power if the air intake was throttled by ice accretion. Accurate forecasting of icing regions was very important. Hail might cause severe damage because of the high speed, and hail drawn inside the jet engine might be serious for axial compressor engines though centrifugal compressor engines have been unaffected by quite large lumps of ice. It was difficult to protect the intake against hail without making it more liable to throttling by ice accretion.

Temperature was very important because of the loss of thrust as temperature increased, and it was a critical factor in taking off from tropical airfields. Air Cmdre Roberts concluded by stating that he considered the advent of jet aircraft had made flying safer, and it was particularly to assist in more economical operation that further meteorological information was required.

Capt. Majendie, who had piloted a Comet aircraft on several proving flights to the tropics, discussed the operation of jet air liners. He pointed out that to obtain maximum range for the fuel carried the jet air liner climbed rapidly to the operating height of 30,000–40,000 ft. and descended rapidly at the destination. The major meteorological requirements in flight planning were airfield temperature for deciding maximum load at take-off, cloud, mean wind and temperature for climb, wind and temperature at operating height and the landing forecast. The elements for which the most improvement in forecasting was necessary were wind at operational height and the areas in which turbulence was likely to occur. He quoted instances of departure of wind at operational height from the forecast value. The landing forecast was very important because it was essential for a jet pilot to decide, while still at operating height, to fly to an alternative airfield if the intended destination were unfit. This was because of the high rate of fuel consumption at low levels. Capt. Majendie also considered more information was needed about the heights to which cumulonimbus cloud reached in the tropics because of the serious risks of turbulence and ice accretion associated with these clouds.

Gp Capt. Lott said the problems of military jet aircraft were similar to those encountered in civil operation, but were more acute or different because military aircraft were necessarily operated to the limits of endurance and because attainment of the aim was more important than safety.

First, in poor visibility there would be a very serious air-traffic-control problem in landing large numbers of jet aircraft in a short time. This was especially acute for fighters. Another point about visibility was that at heights of the order of 40,000 ft. it was more difficult to sight other aircraft than it was at lower levels unless the other aircraft were making condensation trails. As regards condensation trails, there was now evidence that they could form at greater heights than thought likely in the past and the sighting problem increased the importance of trail formation. Temperature was important in bomber and fighter operations because of its relation to range and rate of climb respectively; the director of fighter operations was thus much concerned with the height of the tropopause. The strong winds at great heights were of obvious importance for the range of bomber aircraft and for fighter interception because the higher the ground speed of bombers the less time there was for interception. Turbulence was important in Service flying for its effects on bombing accuracy and on the manœvrability of fighters.

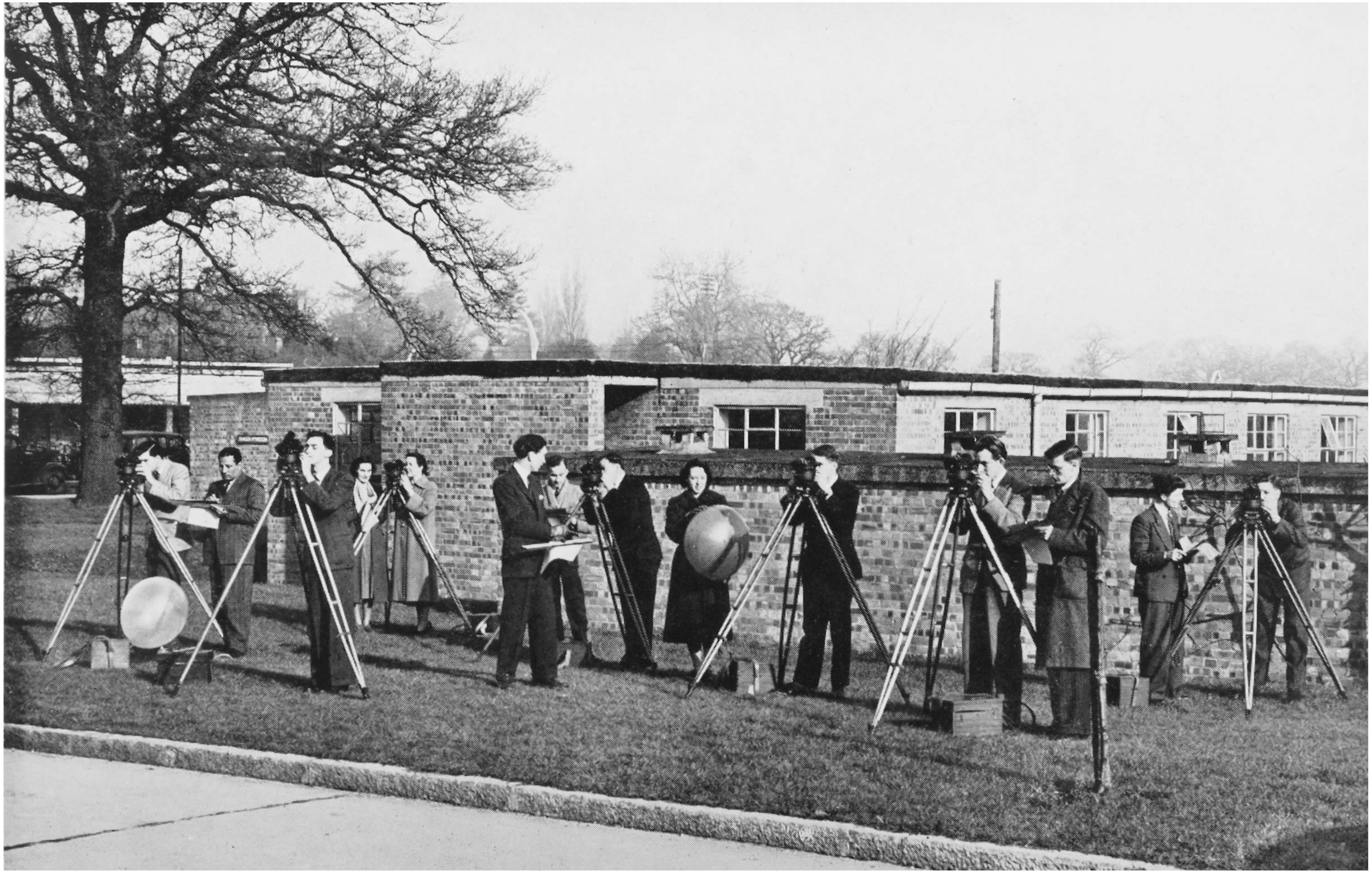
Mr. G. J. W. Oddie outlined the forecasting of winds at 30,000–40,000 ft. by contour and isotach analysis, and discussed with the aid of a diagram due to Mr. J. K. Bannon[1] the distribution of turbulent areas around a jet stream. Mr. Oddie called for more reports from pilots of jet aircraft about the winds and meteorological phenomena encountered at great heights.

Mr. C. S. Durst described the correlation method of predicting wind at great heights developed in the Meteorological Office since 1945. For fuller information on the forecasting of winds at 30,000–40,000 ft. dealt with by Mr. Durst and Mr. Oddie reference should be made to the report of the Meteorological Office Discussion of January 14 in the *Meteorological Magazine*[2].

Capt. S. W. C. Pack and Lt-Com. F. G. Christie of the Naval Weather Service described the Navy's problem in forecasting for the operation of jet aircraft from aircraft carriers as no diversion at all was possible. The forecaster on a carrier in mid ocean had little information, and Captain Pack observed that Mr. Durst's charts of the standard deviation of wind showed highest values over the oceans. Lt-Com. Christie said that at a naval shore station he had been able to forecast sufficiently accurately to enable jet fighters to fly when cloud base was as low as 300 ft., and he had found that condensation trails did not form at a temperature above −55°F.

[To face p. 144

METEOROLOGICAL OFFICE TRAINING SCHOOL
Assistants taking the readings in the instrument enclosure

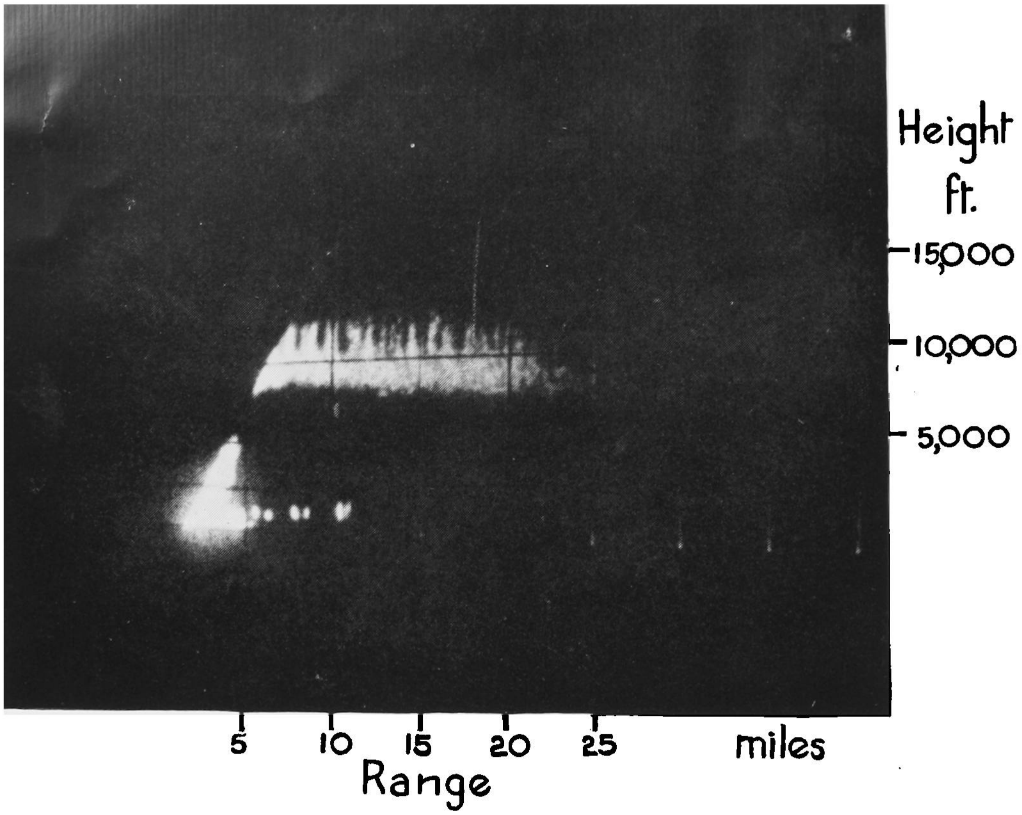


METEOROLOGICAL OFFICE TRAINING SCHOOL
A class of forecasters measuring upper wind by pilot balloon

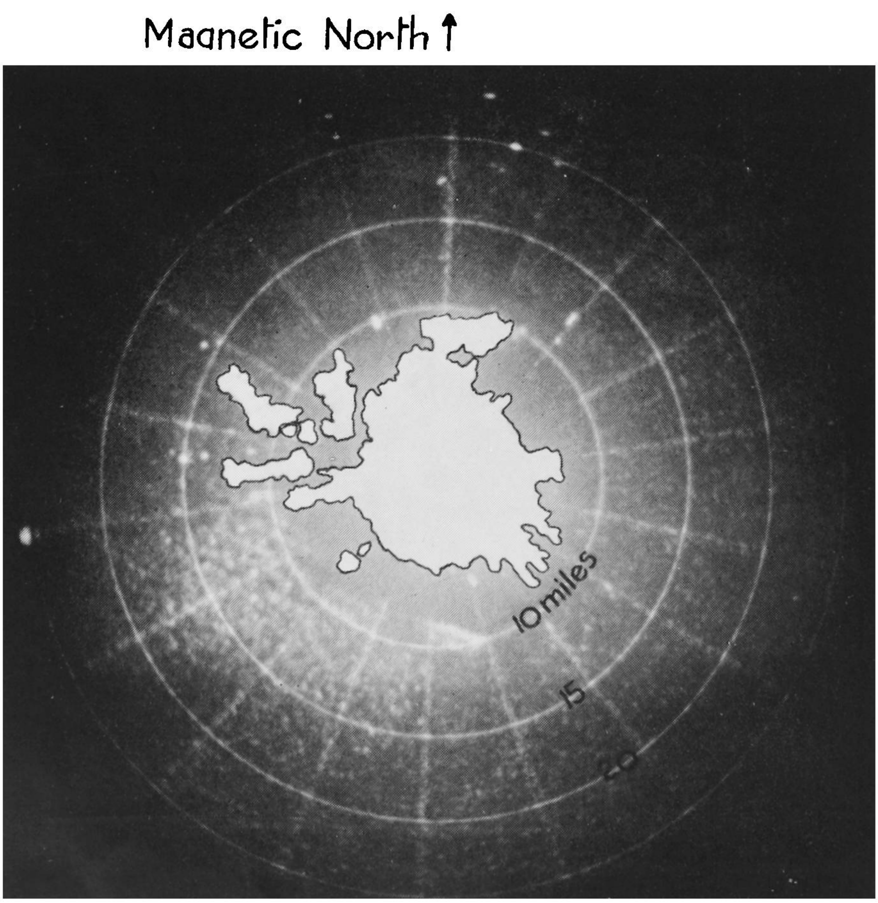
METEOROLOGICAL OFFICE TRAINING SCHOOL

A class of Scientific Officers analysing a weather map in one of the class rooms

To face p. 145]



H.R.T. Photograph at 17h. 00m. 00s. on a bearing of 240° magnetic



P.P.I. photograph at 17h. 28 m. 15s. The permanent echoes are surrounded by firm lines

RADAR PHOTOGRAPHS FROM EAST HILL, BEDFORDSHIRE, ILLUSTRATING BÉNARD-CELL CLOUD ECHOES, DECEMBER 31, 1951

See p. 152

Mr. J. Durward pointed out that the requirements of jet aircraft had not outstripped information over areas for which the British Meteorological Office was responsible. He thought Capt. Majendie's example of a wind of 50 kt. from west when it was forecast to blow from east referred to a change expected on the Cairo–Nairobi route which did not take place precisely at the latitude indicated in the forecast. He stressed the need for in-flight reports of measured winds.

Dr. R. S. Scorer said the requirements of jet aircraft had outstripped the theory of turbulence and high-level cloud formation. He suggested high-level turbulence might be partly explained by orographically produced vertical currents.

Mr. J. D. Hastings said he had five years' experience of forecasting for jet aircraft. First, he queried the seriousness of icing damage to jet engines on the basis of flight trials with a sprayer ring whereby cones of ice 6 in. long and 2 or 3 in. in diameter went into the air intake but caused no damage. He doubted the importance of the V^2 law for rise of temperature in reducing icing risk because a Meteor aircraft flown at 40,000 ft. at an external temperature of −60°C. for three-quarters of an hour at presumably maximum cruising speed had an external panel temperature only 16°C. above air temperature. No instances of ice accretion on the airframe of jet fighters had however been reported to him. He was not surprised at the observations made from jet aircraft of cloud above 30,000 ft. because the tropopause can be at a greater height than 40,000 ft. even over Great Britain. With regard to tropical clouds Spitfire aircraft sometimes reported cumulus cloud extending up to 50,000 ft. during the monsoon over Burma, and he thought monsoon cloud could be quite extensive at the Comet's operating level. Finally he had found that for forecasting condensation trails critical temperatures of −51°F. for polar air and −61°F. for tropical air worked well in practice.

Dr. J. S. Farquharson referred to the successful forecasting by the Central Forecasting Office of winds for the flight of Canberra aircraft across the Atlantic, and claimed that this Office's forecast of high-level turbulence for research flights at South Farnborough had been successful on 22 occasions out of 24. He said that isotach charts were being drawn experimentally at the Central Forecasting Office for study.

Dr. A. W. Brewer confirmed the difficulty of sighting other aircraft, even at an agreed rendezvous, in the bright sun and dark sky of great heights. His experience was that condensation trails do not form in the stratosphere unless the air is exceptionally cold and more than 15°C. below MINTRA value*, when they were inevitable.

Mr. J. K. Bannon did not consider high-level turbulence could be set up by orographic effects alone as it had been observed with no high ground up-wind for hundreds of miles and very few instances had been noted of turbulence in conjunction with general up- and down-currents. He gave instances of the relation of turbulence to the jet stream of which the main feature is the small frequency of turbulence below the level of the jet axis and on the anticyclonic side[1]. With regard to condensation trails he strongly advised caution in the use

*The MINTRA temperature is that above which for a given pressure condensation trails are not likely, on the basis of the theory in "Condensation trails from aircraft"[3], to occur.

of the temperature criteria given by previous speakers as he knew of observations which contradicted all of them.

Flt-Lt Allen, of the Royal Aircraft Establishment, Farnborough, confirmed Dr. Farquharson's statement of forecasting for flights to examine high-level turbulence, but added that on a number of other occasions when turbulence was forecast it had not been possible to fly to investigate it.

Gp Capt. S. W. R. Hughes considered forecasting in all areas was not yet good enough. An unexpected difficulty, which had recently occurred with jet fighters, was icing on the cockpit canopy in clear air during descent which seriously impaired the pilot's vision. He was not satisfied that there was little risk of internal damage by ice to jet engines.

Capt. Majendie, replying to the discussion, said he was grateful to know meteorologists were putting so much effort into these problems. It was difficult for jet-air-liner crews to measure and report winds accurately as yet because of inadequate navigational aids, but as regards forecasting accuracy there had certainly been occasions, even over Europe, when there had been a large drift angle in the opposite direction to the forecast one. He reiterated the need to know when clear-air turbulence was likely, to enable precautions to be taken, and his concern at the possible dangers of climbing through ice-forming cloud in the tropics.

Professor P. A. Sheppard concluded the proceedings with a general summing up of the discussion.

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1. BANNON, J. K.; Weather systems associated with some occasions of severe turbulence at high altitudes. *Met. Mag., London,* **81,** 1952, p.97.
2. London, Meteorological Office. Meteorological Office Discussion. *Met. Mag., London,* **81,** 1952, p.79.
3. London, Meteorological Office. Condensation trails from aircraft. London, 1943.

ROYAL ASTRONOMICAL SOCIETY

Thunderbolts: The electric phenomena of thunderstorms

Mr. E. Gold took the chair at the geophysical discussion held at the Royal Astronomical Society on January 25, 1952, on the subject of "Thunderbolts: the electric phenomena of thunderstorms".

Mr. Gold opened the proceedings with an interesting and amusing statement on literary references to "thunderbolts" from Lucretius to the *Meteorologische Zeitschrift* which emphasized the unexpectedness and violence of the electric discharges of thunderstorms, their tendency to strike the higher places, and the appearance on rare occasions of ball lightning.

Dr. Wormell indicated the major results of past research employing the two techniques of direct photography of the lightning stroke, and instrumental measurement of the field-changes at ground level associated with lightning flashes. After describing the well known stepped-leader picture of the lightning stroke due to Schonland, he showed that recent field-change studies at Cambridge by Dr. Pierce revealed the time-scale of Schonland's picture to be characteristic of only very few discharges. The majority of flashes had a leader which came down to earth much more slowly than Schonland's stepped leaders. In between successive discharges along a given channel a new leader developed. Sudden changes in the electric field occurred with the return stroke up the channel and between successive such strokes the changes were, in comparison, slow or zero. When the field-change intervening between return strokes was zero the charged leader in the cloud was progressing towards another cloud charge at the same level, because field-change was a measure of change in the electric moment; if there was an appreciable positive change the new charge tapped was at a greater height. Intervening zero field-changes were three times as frequent as intervening positive field-changes; intervening negative field-changes were very rare. Dr. Wormell gave figures, derived from the Cambridge field-change records, which showed that 90 per cent. of flashes to earth brought down negative electricity.

Finally, Dr. Wormell spoke of the work at Cambridge by Mr. Browne on reflection of a vertical radar beam in thunderstorms and especially of the very intense low-level echo changing rapidly in intensity with height found to occur in very heavy thunderstorm rain. The intense concentration of raindrops producing this echo could only be explained by supposing that there was a violent updraught in the cloud at the level in question. Attempts to interpret the effect, however, in terms of the breaking-drop hypothesis and the consequent generation of the lower positive charge found by Simpson and Scrase in the Kew altielectrograph results, encountered considerable difficulties in connexion with the observed rate of rainfall, size of the charge produced, etc.

Dr. R. H. Golde spoke of the topographical, geophysical and geological conditions which have been claimed to determine points where lightning flashes may be concentrated. There were some areas, often quite small, called lightning nests which received more than their share of strokes, and it had been suggested that these might be associated with regions of high gradients of soil conductivity. Here Dr. Golde turned to consider what might cause a lightning leader stroke coming down from the cloud actually to strike a particular point of the ground. He pointed out that the leader stroke constituted a "self-propagating" or "incomplete" discharge, and that, even for the most intense stroke, the field strength below the leader required for complete breakdown would not be reached until the tip was within about 100 m. of the ground and, for an average stroke, within about 15 m. This was supported by photographic evidence of upward streamers developing from the earth to meet the down-coming leader. It had been suggested that geological faults of high conductivity or underground water courses surrounded by high-resistivity soil would be liable to attract lightning because of the local field concentration produced at the earth's surface. Calculations of the attractive effects of buried metal cables or lightning conductors showed, however, that the attractive effects extended only to distances of under 200 m., so that the presence of a highly conducting feature in high-resistivity soil would explain the concentration of discharges in small "nest" areas only.

Mr. J. Durward described two instances when he saw what appeared to be ball lightning. The first was in Scotland in 1934, when a ball of fire came out of an adjacent wood in a thunderstorm to strike an iron gate over a road, and the second was in an aeroplane over southern France when a ball of light exploded with a loud bang in a doorway after causing damage in the pilot's cabin.

Mr. Logan defended the existence of ball lightning because of the large common measure of agreement in the observations made by rural people having little or no knowledge of it before seeing it. He suggested the ball was a volume of little pressure containing a number of charged particles moving at very high speed.

Capt. Brown, an airline pilot, described his observation of a ball of blue fire which struck his aeroplane over India in a thunderstorm and damaged the wireless system.

Dr. Pierce, of Cambridge, discussed the development of leader strokes. He said it seemed most likely that they originated in the main negative charge in the cloud. An arc régime existed within the leader channel, and, as the leader moved out into areas differing in potential, corona discharge occurred from the sides. From the Cambridge field-change records, a value of the corona constant had been derived which appeared to be characteristic of the gaseous channels involved; using this value, the calculated currents for upward leaders from the Empire State Building were in excellent agreement with those measured experimentally by McEachron.

Dr. Allibone referred to a photograph showing lightning striking a beach very close to the sea, which was against the theory of attraction by high conductivity areas. Mr. Shipley described seeing, when a schoolboy, from a bus top in London, a ball of fire during a thunderstorm. He suggested ball lightning might be an incandescent volume produced at the end of a lightning streamer which remained more or less stationary for a time. Dr. Allibone said that suggestion had already been made, and described laboratory observation of long sparks which supported it.

Dr. F. J. Scrase described the thundercloud charge distribution found before the war in the Kew alti-electrograph soundings which revealed a positive charge in the highest part of the cloud at a temperature below $-15°$C., a negative charge just above the freezing level, and a positive charge in the base of the cloud. The existence of the lower positive charge had since been confirmed by observations from aircraft and on the Zugspitze, as well as by the increase in frequency of positive fields below the centre of an active thunder cell. Dr. Scrase said he regarded the essential difference between thunderclouds and shower clouds was that in the latter the lower positive charge was absent or less well developed. This idea was supported by the field-changes which take place as the clouds pass over and by the fact that thunderstorm rain is predominantly positively charged and shower rain predominantly negatively charged. The Kew alti-electrograph data and the Zugspitze observations show that thunderstorms have their bases well below freezing level, where conditions are most favourable for breaking drops while shower clouds do not. The Kew data show that the negative charge extends over a greater depth in thunderclouds than in shower clouds, and recent radar-echo observations show a much bigger echo in thunderclouds which is probably due to the increase in drop size.

BOOK RECEIVED

Jaarboek A. Meteorologie (Yearbook, A. Meteorology) 1949, Koninklijk Nederlands Meteorologisch Instituut. $13\frac{1}{4}$ in. × $9\frac{1}{2}$ in., pp. xii + 96, Staatsdrukkerij-en Uitgeverijbedrijf, 's-Gravenhage, 1951. Price: *fl.* 5.00.

LETTERS TO THE EDITOR

Abrupt seasonal temperature changes at the tropopause and at the surface at Habbaniya

In the *Meteorological Magazine* for November 1951, Mr. Dewar describes the abrupt change which occurs in the temperature of the stratosphere in June and October at Habbaniya. I do not know whether it has ever been pointed out, though it must be well known to those who have served in Iraq, that similar changes occur at the surface in May–June and September–October. Thus a curve of maximum temperature is not "smooth" because of an abrupt rise at the beginning of the summer and an abrupt fall at the end. The latter was of course the change which one noticed most because it provided a welcome relief from the heat of the summer.

Mr. Dewar considers three years, 1948–1950. He gives the date of change in 1948 as October 9, in 1949 as October 23, and in 1950 as October 20. In 1948 and 1950 the fall in surface maximum temperature was marked about one day later than the fall at the tropopause. Thus the mean maximum for the period October 6–10, 1948, was 99°F., and for the five days October 11–15, 79°F. In 1950 the mean for the period October 17–21 was 93°F., and for the five days October 22–26, 81°F.

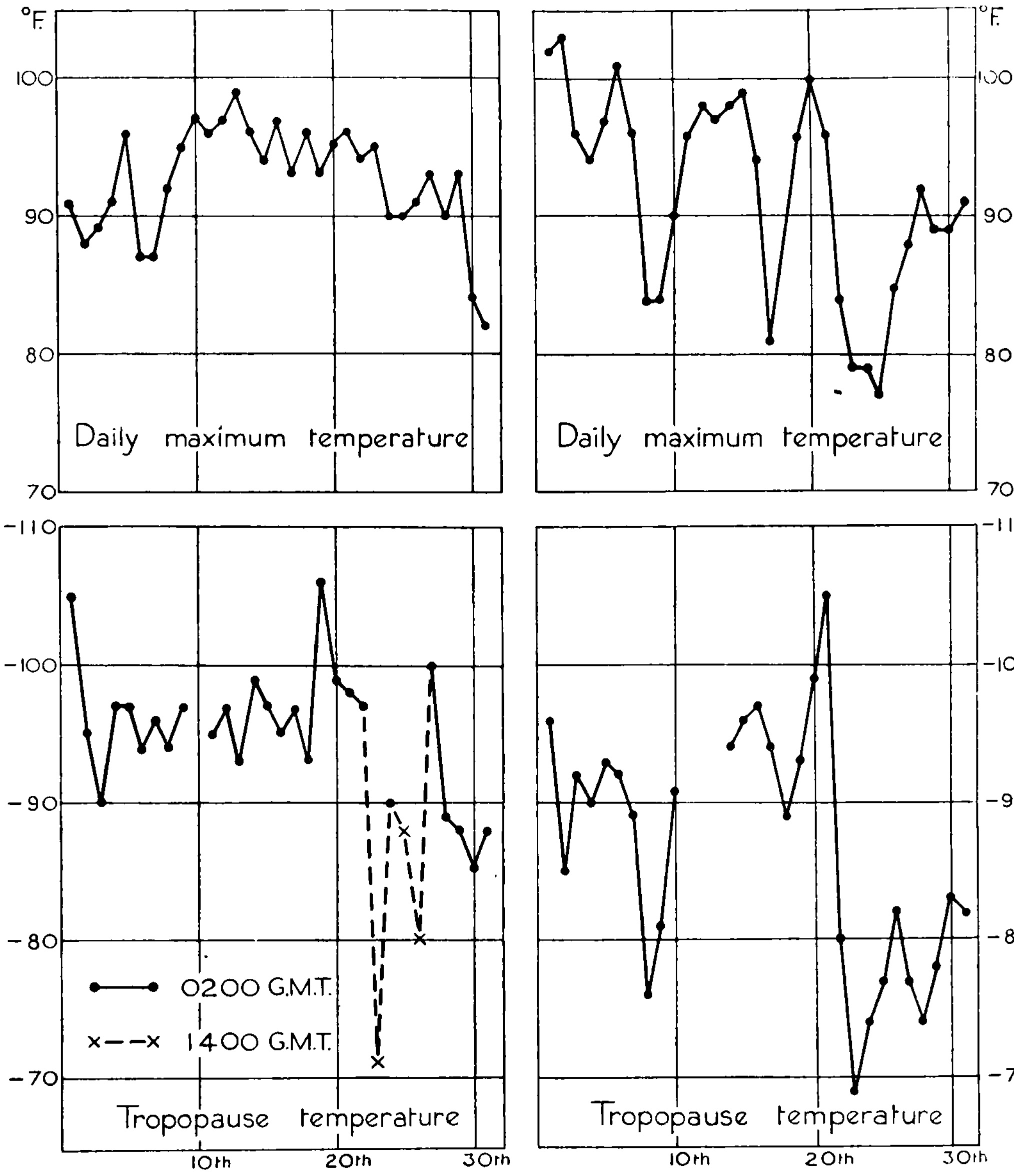
The fall in surface maximum temperature in 1949 was not so pronounced on the date given by Mr. Dewar. Thus the five-day mean October 19–23 was 95°F. and for October 24–28, 91°F. A pronounced fall did not take place until October 30 (93° to 84°F.). October 1949 was in fact rather different from other months. The maximum temperature was much more constant and lower at the beginning of the month than in 1948 or 1950; the mean maximum for the first ten days of 1949 being 91°F. compared with 99·5°F. in 1948 and 95°F. in 1950.

January 14, 1952 J. DURWARD

[Mr. Durward's letter drawing attention to the connexion between the seasonal change in tropopause temperature over Habbaniya and the change in surface daily maximum temperature is very interesting, and, in order to examine the changes more closely, graphs have been drawn for each transition period during the years 1948–50. Those for October 1949 and October 1950 are reproduced in Fig. 1. In order to simplify the comparison only the 0200 G.M.T. values* for the tropopause temperature have been plotted (apart from some 1400 G.M.T. values around October 24, 1949, where 0200 G.M.T. values were not available) and the appearance of the graphs differs somewhat from those published before.

From Fig. 1 (*b*) it will be seen that the most pronounced change of temperature in both graphs occurs between the 21st and the 22nd. The reason why they do not show the 24-hr. lag referred to by Mr. Durward is that the dates May 19 to October 20 given in the previous article refer to the period for which the tropical régime persisted; the transition started on the following day after a tropical régime value at 0200 G.M.T. The same relation holds for the change in October 1948. It is, indeed, sometimes difficult to say precisely when the change occurs, and it would be unwise to regard them as well defined changes which might be used to forecast changes in the surface maximum temperature.

*It would probably have been better to use 1400 G.M.T. temperature readings but these were not as complete as the 0200 G.M.T. readings.



(*a*) October 1949 (*b*) October 1950

FIG. 1—DAILY MAXIMUM SURFACE TEMPERATURE AND TROPOPAUSE TEMPERATURE AT HABBANIYA

Except where otherwise stated the time of observation is 0200 G.M.T. (0500 L.T.)

This is well illustrated in Fig. 1(*a*) by the graphs for October 1949. As Mr. Durward remarks, this year was rather different from the others, and the fall in the surface maximum temperature did not occur until October 30 though the change in tropopause temperature began on October 23.

In addition to the main fall of temperature referred to by Mr. Durward there is also, on many occasions, a marked similarity between large fluctuations of surface maximum temperature and of tropopause temperature around the transition period. In Fig. 1(*b*) these fluctuations are most evident during the tropical régime but the other graphs show, in general, the reverse. The resemblance appears to be most marked when the seasonal change is well defined.—D. DEWAR].

Föhn effect over Scotland

Every meteorologist knows the theory of the föhn effect, but probably very few meteorologists, at any rate in this country, have seen an example actually worked out from data for the British Isles.

On January 23, 1952, the gradient wind over central Scotland was south-south-easterly and about 15 kt.; it remained so sufficiently long for air from Leuchars to travel up to Kinloss. The distance between the two places, as the crow flies, is about 90 miles so that it would take about six hours for a parcel of air to make the journey.

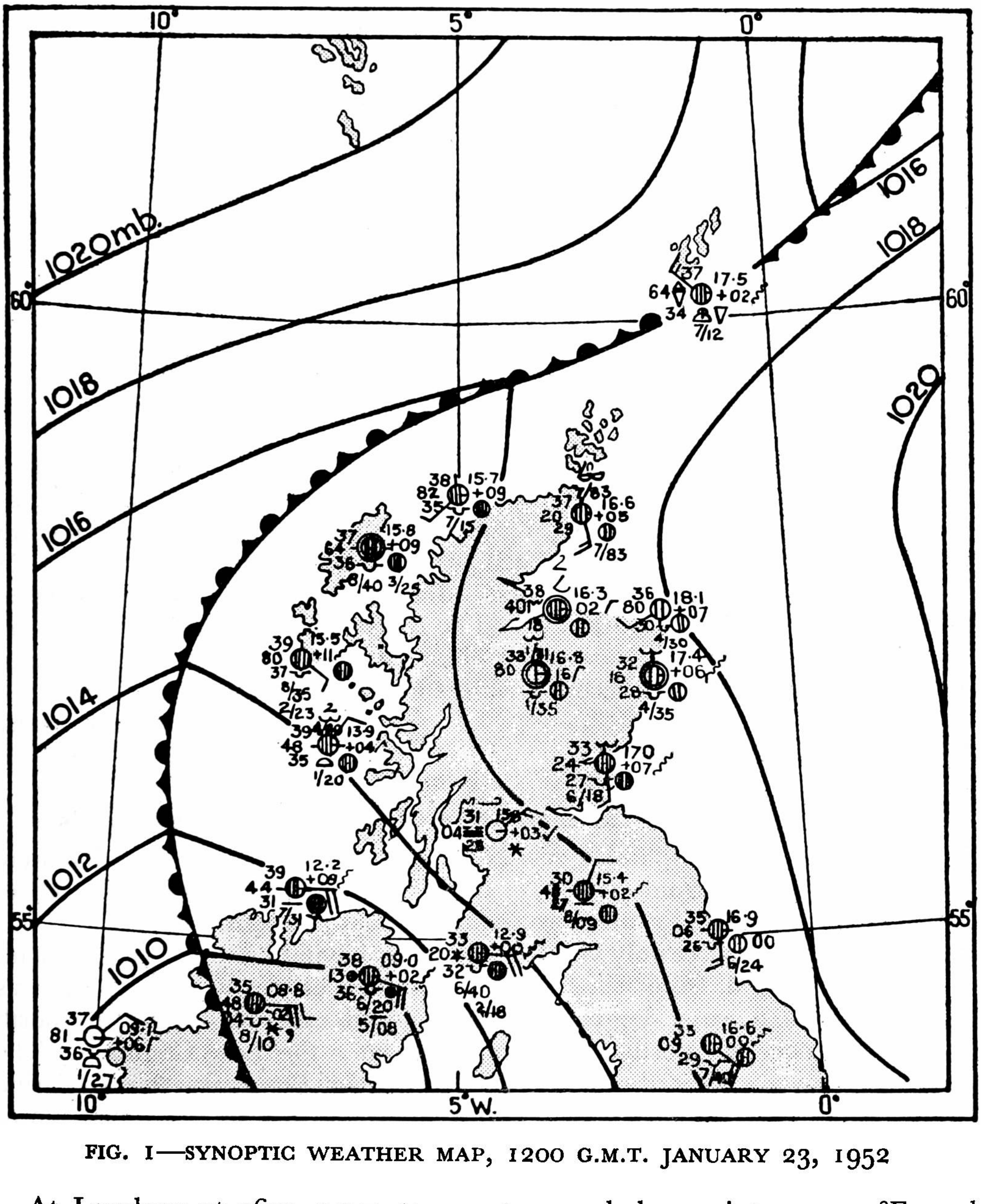


FIG. 1—SYNOPTIC WEATHER MAP, 1200 G.M.T. JANUARY 23, 1952

At Leuchars at 0600 G.M.T. temperature and dew point were 33°F. and 28°F. respectively, and they remained practically constant throughout the morning. At Kinloss at 1200 G.M.T. temperature and dew point were 38°F. and

18°F. respectively. The cloud cover over the track was sufficient to preclude the difference between these figures being explained by insolation at this time of the year. The only possible explanation is therefore föhn effect over the Cairngorms, the peaks of which rise above 4,000 ft.

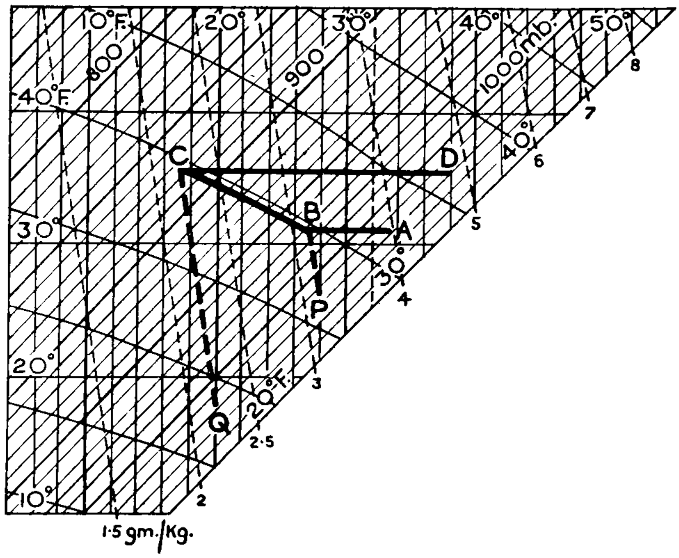


FIG. 2—TEPHIGRAM SHOWING ASCENT OF AIR AT LEUCHARS AND DESCENT AT KINLOSS

It is reasonable to assume that, in crossing the Cairngorms, the air was lifted mechanically an average of 3,500 ft., or about 135 mb., and that, after saturation was reached, further lifting resulted in precipitation. The tephigram shows that air at Leuchars at a surface pressure of 1017 mb. would ascend via the path represented by ABC, and descend to Kinloss via the path represented by CD; the dew point at Kinloss would be represented by Q. The theoretical values of temperature and dew point obtained by this process are 37°F. and 20°F. respectively, in close accord with the actual observations at Kinloss.

W. D. S. McCAFFERY

Pitreavie, January 23, 1952

Radar evidence of the formation of Bénard convection cells

On December 31, 1951, radar echoes from medium-level precipitation were received at East Hill from 1100–1730 G.M.T. For most of the period the echoes took the form of a band centred at about 10,000 ft., and generally some 2,000–4,000 ft. thick, and were only visible on bearings having a southerly component. The medium cloud, from which the precipitation echoes were received, was associated with a wave depression which moved eastwards along the north coast of France into north-east France and later the Low Countries. The centre of the wave, according to the *Daily Weather Report*, was on a bearing of about 225° magnetic from East Hill at 1200 and about 155° magnetic at 1800. The radar echoes were strong in the late morning and early afternoon but became very weak and diffuse in mid-afternoon (about 1430–1530). About dusk (sunset 1600 G.M.T.) the echo intensity increased rapidly, and, as seen in the H.R.T. photograph (opposite p. 145) taken at 1700, the echo showed a marked cellular structure. The P.P.I. photograph (opposite p. 145) taken at 1728 suggests the presence of very many tiny cells which had a tendency to form into lines with an orientation of about 290–110° magnetic (280–100° true). The winds in this layer appear to have been somewhat variable about this time (Larkhill, 1500, 208° 14 kt. at 700 mb. to 289° 14 kt. at 600 mb.), but the probability is that the lines of cells were parallel to the wind direction in the top of the layer. Overhead at 1730 the cloud appeared to have broken to a cellular type of high stratocumulus but appeared thicker to the south and south-west.

It is thought that this intensification of echo and tendency for cellular structure were brought about by the cooling of the top of the cloud layer by radiation after sunset at this level, producing cells of the Bénard type. If this were the case the distance apart of the individual echo columns (if one column indicates the up-current of one cell) should give the diameter of the cells, and hence, approximately, the depth of cloud affected by the cells*. The spacing of the individual columns on the H.R.T. photograph and of the lines of echo columns on the P.P.I. photograph averaged about 4,500 ft., suggesting a depth of air taking part in the cell movement of about 1,100–1,500 ft. The distance suggested by the H.R.T. photographs—the vertical extent of the columns—is 1,750 ft. The Larkhill upper air ascent at 1500 showed that a very small cooling effect (less than 1°F.) at 12,700 ft., supposing this echo-top height to be the cloud top, would be sufficient to make the 1,300-ft. layer beneath unstable for saturated air, while a cooling of 2°F. would make this layer unstable even if unsaturated.

Presumably this effect of layer cloud breaking into cellular cloud may occur quite frequently around dusk, the present case being unique only in the accident of having large naturally formed ice crystals present already as radar "tracers" for the cellular motion.

It is also of interest to note that, although ice crystals of considerable size must have been present in this layer, the base of the echo did not fall over several hours, implying that as the ice crystals fell from the layer their reflectivity decreased very rapidly. This decrease was probably occasioned by rapid evaporation, since the air at 750 mb. (8,000 ft.—the echo base was about 8,250 ft.) was very dry (dry bulb 17°F., dew point −7°F. at Larkhill) at 0900 and still far from saturated (dry bulb 17°F., dew point 11°F.) at 1500. On the other hand the upper air ascents at Larkhill do not indicate saturation at any time or any height, even in the layer from which echo was received. Only a trace of precipitation was recorded between 0900 and 2100 at Kew, London Airport and Boscombe Down.

East Hill, near Dunstable, Bedfordshire, January 14, 1952 R. F. JONES

NOTES AND NEWS

Vertical air motion over northern England and southern Scotland November 27, 1951

Strong vertical air motion was experienced by three Wellington aircraft flying at 13,000 ft. over northern England and southern Scotland between 1700 and 1900 G.M.T. on November 27, 1951. Their route was from southern England to Newcastle, north to Berwick, west across southern Scotland to near Stranraer, and finally southwards.

*See BRUNT, D.; Physical and dynamical meteorology. London, 2nd edn, 1939, p. 219.

One of the pilots, Flt-Lt Stansfield, reports that near Newcastle rising air currents of the order of 750 ft./min. were encountered, and persisted for between 10 and 15 min. The speed of the aircraft was 140 kt. which indicates the rising current was encountered from Newcastle to a point off the north-east end of the Cheviot Hills. From that point to the turning point near Stranraer a series of up- and down-currents, mostly down ones, was encountered. The down-currents had a speed of 400–500 ft./min. The aircraft were flying in clear air in a wind of about 270° 70 kt. and did not experience any bumpiness.

A well marked jet stream, with its axis at about 300 mb. and axial speed of at least 120 kt., was situated at the time just to the north of the line Berwick to Stranraer. During the occurrence of the strong up-currents the aircraft were flying roughly at right angles to the axis of the jet stream, and during the period of variable but mainly down-currents were flying roughly parallel to it. It is however doubtful if the vertical currents encountered were associated with the jet stream.

It seems more probable that they were vertical currents produced by the strong winds over the mountains. It is known that, notably to the lee of mountains, up- and down-currents can occur at considerably greater heights than the top of the mountains. The theory of these currents, the so-called "lee-wave" phenomena, has been discussed by Queney[1] and Scorer[2,3] amongst others. The available upper air information shows that, at the level of flight, the wind was increasing with height and the lapse-rate of temperature was large—about 4°F./1,000 ft.—and larger than at lower levels; these conditions are favourable, according to Scorer, for the formation of lee-waves though his theory does not seem definitely to allow for them at a height so great in proportion to the height of the mountain tops.

REFERENCES

1. QUENEY, P.; A problem of air flow over mountains: a summary of theoretical studies. *Bull. Amer. met. Soc., Lancaster Pa.*, **29**, 1948, p. 16.

2. SCORER, R. S.; Theory of waves in the lee of mountains. *Quart. J. R. met. Soc., London*, **75**, 1949, p. 41.

3. SCORER, R. S.; Forecasting the occurrence of lee waves. *Weather, London*, **6**, 1951, p. 99.

Extreme tropopause pressure

The values of extreme tropopause pressure and corresponding heights given in the table below were extracted for an inquiry. It has been suggested that they are of sufficient interest to be published in spite of the reservations appended to them as far more conservative values are usually quoted.

The outstandingly low maximum pressure over Larkhill in March has been critically examined and it appears that the tropopause is usually high over southern England during this month. The next lowest pressure for 1948–50 was 350 mb. and in March 1951 the lowest pressure was 358 mb.; tropopause pressures below 200 mb. were frequently recorded.

These extremes have been obtained by taking the extreme tropopause pressures given on returns to the Upper Air Climatology Branch and then obtaining the heights from the *Upper Air Section* of the *Daily Weather Report* or *Daily Aerological Record* (as the corresponding heights were not entered on the forms used in 1948–50). These forms gave the station's assessments of the tropopause, and these do not always agree with the assessments published by

EXTREME TROPOPAUSE PRESSURE AND CORRESPONDING HEIGHTS AT LARKHILL AND LERWICK, 1948–50

	Larkhill (51°11′N., 1°48′W.)				Lerwick (60°08′N., 1°11′W.)			
	Maximum pressure	Corresponding height	Minimum pressure	Corresponding height	Maximum pressure	Corresponding height	Minimum pressure	Corresponding height
	mb.	ft.	mb.	ft.	mb.	ft.	mb.	ft.
Jan.	392	22,500	150	45,600	457	18,700	143	46,000
Feb.	450	19,400	145	45,800	440	19,800	161	43,100
Mar.	357	25,500	152	45,400	490	17,800	147	44,800
Apr.	**494**	17,700	164	43,300	**550**	14,500	187	40,200
May	370	25,100	167	43,700	386	23,400	187	40,800
June	400	22,800	142	47,300	400	22,900	164	43,800
July	340	27,400	130	49,100	350	26,300	170	43,700
Aug.	380	24,300	150	46,700	350	26,200	177	42,400
Sept.	350	26,200	**115**	51,800	470	18,900	119	49,800
Oct.	379	23,700	**115**	51,300	400	21,900	**109**	50,300
Nov.	414	24,500	130	47,700	455	18,500	138	46,100
Dec.	448	19,700	154	44,100	450	19,300	158	43,800

the Central Forecasting Office. When it appeared that the station's value was doubtful the next highest (or lowest) value was adopted. The values given may not be extreme heights, but this is not considered to be of practical significance in view of the uncertainty attached to these extreme values. They should be treated with reserve.

D. DEWAR

REVIEWS

General astronomy. By Sir Harold Spencer Jones. 8½ in. × 5½ in., pp. x + 458, *Illus.*, Edward Arnold & Co., London, 3rd edn, 1951. Price 30*s.* 0*d.*

"General astronomy" is written for the elementary student of astronomy knowing simple algebra and trigonometry and Intermediate B.Sc. physics. It deals with the observations and the inferences that can be directly drawn from them and avoids the more speculative parts of recent astronomical theory. For a meteorologist wishing to acquire a broad knowledge of astronomy it is quite the best book. It is, however, regrettable that no references are provided to more specialized books for further reading in any part of the subject in which the reader may be particularly interested.

The book has been revised throughout for this third edition. Subjects of very recent discovery such as the solar radiation in the radio part of the spectrum and the use of radar for the detection of meteors are described.

The book is particularly recommended to meteorologists for the account of sun-spots and bright solar eruptions, and the associated radiations of great importance in terrestrial magnetism, radio propagation, and the production of auroræ.

In discussing the maintenance of the sun's radiation the author says the existence of ice ages in the past makes it reasonably certain there have been variations in the radiation, without mentioning that there are serious theories of ice ages which do not require any change in the radiation emitted by the sun.

The reproduction of the photographs is excellent. There is a very good index.

G. A. BULL

The Egyptian climate: an historical outline. By G. W. Murray. *Geogr. J., London,* **117**, 1951, pp. 422–434.

The December 1951 number of the *Geographical Journal* contains an interesting article by Mr. G. W. Murray, "The Egyptian climate: an historical outline". Mr. Murray's data are the rate of erosion of softer rocks of the Sahara, the rate of growth of the western dunes and the flint implements and remains of tree trunks on the surface. He concludes that, except during two brief rainy interludes, the Egyptian deserts have been dry for three-quarters of a million years. The rainy interludes occurred about 20,000 years ago and again from about 8000 to 4000 B.C. His paper includes evidence of a fall in the level of the subterranean water of the Sahara which is supplied from the Sudan rainfall.

G. A. BULL

On the microclimatic properties of sheltered areas: the oak-coppice sheltered area. By R. J. Van der Linde and J. P. M. Woudenberg. *Meded. ned. met. Inst., De Bilt, A*, No. 56, 1950, pp. 151. Staatsdrukkerij-en Uitgeverijbedrijf 's-Gravenhage. Price: *fl.* 3.00.

This book is a welcome addition to the growing number of studies of climate experienced in the first two metres or so over natural surfaces of the type actually encountered in agriculture. The first 40 pages consist of an excellent critical review of existing knowledge on the subject in the course of which most, but not all, of the various sources have been tapped. Particular attention is drawn to the work of the Russian, Bodrov, who, in a paper in 1936, stressed that, especially when temperature is being investigated, separate consideration should be given to observations from sunrise to early afternoon (when there is a net gain of heat at the surface) and to those obtained during the rest of the day.

The body of the work (some 70 pages) is a detailed account of experimental studies during some ten periods, each covering from two to five days, scattered over the months April to November (inclusive) in 1943–47. The experiments were carried out in a flat area near Oldebroek—some 6 Km. from the east bank of the IJssel Lake (the Zuider Zee)—which had been divided, by strips of oak coppice 4 to 5 m. high, into a series of long narrow fields rarely more than 50 m. wide running approximately south-east to north-west. There were also a number of secondary barriers perpendicular to the main system. In most of the ten series of observations, frequent readings were recorded from shielded thermometers 2 cm. from the surface, at a number of points 10 m. or less apart in a line perpendicular to the belt, but in one case the heights were 10 cm. and 25 cm., and in another the vertical temperature profile to $1\frac{1}{2}$ m. was examined at two points supplemented by readings in a standard screen 40 cm. above the surface. In general the surface was one of bare soil. Other observations were a series of readings of soil temperature at 10 cm. depth, twice daily readings of water loss as indicated by Piché evaporimeters with the evaporating surface 10 cm. from the ground and some observations of humidity (at 30 cm.). The observations in each series, which are set out graphically, are prefaced by a detailed account of the weather prevailing at the time—an essential procedure when considering phenomena whose interrelationships vary significantly between different types of weather. To estimate the extent of the shadow thrown by the barrier a diagram from an earlier paper by the same authors is reproduced.

The experimental data are analysed and appraised in the light of similar studies by other workers, in particular C. G. Bates of the U.S.A. and Bodrov, in a section of 20 pages. A 7-page summary and bibliography complete the book.

One novel result is the specification of four different temperature zones within the protected area which become most evident on sunny days with light or moderate winds (i.e. Beaufort force 3 or less). These are

(i) a narrow shaded strip on the north-east side of the barrier with temperatures lower than anywhere else in the area

(ii) a zone a few metres wide with high temperatures

(iii) a zone some 20–30 m. wide where temperatures are noticeably lower than in zone (ii) and fairly uniform

(iv) a final zone, again 20–30 m. wide, where the temperature gradually increases towards the next barrier.

Some of the highest early-afternoon temperatures were recorded in zone (iv) and would be sufficient to cause "sun-scald" to many types of crop. In contrast to the generally accepted ideas, the zone of maximum temperature (i.e. zone (ii)) did not coincide with the region of greatest air stagnation, but appeared to move as the position of the edge of the midday shadow varied from month to month. Nor did the temperature maximum by day coincide in position with that of lowest minimum at night, as is usually stated. A partial explanation of some of these findings is suggested in terms of local circulations within the protected area. Other interesting results are the evidence that the effect of these barriers on temperature extended up to $1\frac{1}{2}$ m., and the statement that in the conditions of intermittent sunshine, so characteristic of the climate in western Europe, temperature by day will generally be higher in the protected zone than in the open.

It is essential when studying the results to bear in mind that successive belts followed each other so closely that cumulative effects must have been operative, and to note the authors' conclusion that the oak coppice when in full leaf must be regarded as a "dense" barrier. It is not clear to what extent the writers consider their findings influenced by the peculiarities of the shelter-belt network and of its orientation, and it would perhaps have been an advantage if they could have provided rough numerical values for the temperature differences to be expected in given conditions—if only to prevent the reader drawing his own, possibly unsound, conclusions from the diagrams.

It is unfortunate that the number of occasions of sunny weather with moderate or fairly strong winds perpendicular to the main belts were very few, and hence the influence of such barriers whilst acting in their most characteristic fashion cannot be assessed. It would have been helpful if horizontal distances had been expressed, as customary, in multiples of barrier height as well as in absolute measures.

In conclusion, this volume is of considerable value and interest—the critical review with which it begins would alone commend it to a wide public—and we look forward to those further related studies which the authors hint at more than once.

R. W. GLOYNE

METEOROLOGICAL OFFICE NEWS

Gale damage at Bristol.—On the night of Friday, March 28, during a gale with gusts of 50–60 m.p.h., a large beech tree was uprooted and fell on to the meteorological office at the National Agricultural Advisory Service Headquarters, Bristol. The office, which was a one-storey prefabricated hut, was completely wrecked, the centre branches of the tree falling in the middle of the building. A night-watchman and a postman, who were sheltering in the small store-room on the side of the office furthest away from the tree, were trapped and hurt but escaped serious injury. Display material, papers and furniture were destroyed but the instruments held in stock were in a steel cupboard and remained intact. Luckily an oil-stove in the storeroom was extinguished by the crash.

Award.—We congratulate Mr. J. M. Craddock on the award to him by the Royal Meteorological Society of the First Darton Prize for 1951, an annual prize for the most meritorious paper on instrumental meteorology published by the Society during the year. The paper dealt with "An apparatus for measuring dewfall" and it was published in *Weather* for October 1951.

Sports.—The Air Ministry Harriers held a 3½-mile cross-country race at Cranford on March 15, 1952. Mr. P. D. Dench was first man home, with Mr. M. D. Dobson third. A sealed handicap was won by Mr. Dobson.

Mr. S. W. Lewis has been selected to represent the Civil Service at water polo against Cambridge University.

Marriage.—We offer our best wishes to Dr. A. H. R. Goldie, Deputy Director of Research, and Miss N. Carruthers, known for her statistical work in the Office, on the occasion of their marriage on April 5, 1952.

WEATHER OF MARCH 1952

Pressure was generally low in the North Atlantic, west Europe and the Mediterranean, and high in Scandinavia and the Arctic Ocean. The lowest mean pressure of 999 mb., about 10 mb. below normal, occurred in the North Atlantic about 50°N., 25°W.; mean pressure in the Azores, about 1009 mb., was 14 mb. below normal. Mean pressure in west Europe and the Mediterranean was mainly between 1010 and 1015 mb. generally 3–6 mb. below normal. In Scandinavia and to the northwards, mean pressure was between 1014 and 1019 mb., generally 4–8 mb. above normal.

Temperature was generally high for March in south-west Europe and low in Scandinavia and central Europe. Mean temperature in France, Spain and the western Mediterranean was generally between 50° and 60°F., about 5°F. above normal. In Scandinavia and central Europe mean temperature was well below freezing in most places, the lowest being in Finland and Lapland, where it was between 7° and 14°F., which was 5–10°F. below normal.

In the British Isles the weather was very mild until the 25th apart from a temporary cold spell from the 13th to the 15th. The last week was cold, particularly from the 27th onwards. An unusually severe snowstorm occurred in south-east and east England and the Midlands on the 29th.

During the opening days a depression south-westward of the British Isles moved north-east and caused rain in the west and north. On the 2nd another depression developed on the Atlantic and moved to a position north-westward of Ireland, where it remained, with little movement but becoming less deep, for several days. Meanwhile troughs of low pressure moved north-east or north over the British Isles giving rain at times. On the 6th another depression approached our south-west coasts and associated troughs of low pressure moved north over the country; rain fell generally on the 6th and 7th and was heavy locally (2·61 in. at Maesteg Park, Glamorgan, and 2·08 in. at Ulpha, Cumberland on the 6th). In the early hours of the 9th a small secondary depression moved north-east along the English Channel giving considerable rainfall in southern England. More settled sunny weather, apart from local fog, set in on the 10th when a ridge of high pressure crossed the British Isles. Between the 12th and the 15th an anticyclone moved from a position north-east of Iceland to central Europe and maintained fair weather over most of the British Isles, with variable amounts of sunshine but long bright periods in many places. On the 15th and 16th a depression off the south of Ireland moved north and filled; scattered rain occurred in England and southern Ireland. Except in south-west England and west Ireland, good records of bright sunshine were obtained in most areas on the 15th and in the Hebrides on the 16th (10·7 hr. at Waddington and 10·6 hr. at Finningley on the 15th and 10·5 hr. at Stornoway on the 16th). The period 13th–15th was rather cold (maximum temperature 39°F. at Elmdon on the 13th and minimum 20°F. at Eskdalemuir on the 15th) but temperature rose considerably on the 16th. A very mild unsettled spell ensued, with relatively high pressure over Scandinavia and troughs of low pressure crossing the British Isles. Scattered rain or showers occurred on the 17th and 18th and local thunderstorms were recorded in the south-east of England. On the 19th and 21st rain fell generally, and was heavy locally, but on the intervening days, the 20th and 22nd, it was mainly very slight and scattered. On the 17th–19th there was much morning fog, which persisted locally on the coasts. A depression approached south-west Ireland on the 23rd and a trough crossed southern England causing rain generally in England and Wales. On the 24th the depression moved a little south-east and a trough lay over southern England and was associated with more rain. Thereafter a wedge of high pressure extending south from an anti-cyclone centred east of Iceland lay over the British Isles and cold north-easterly winds prevailed. The anticyclone subsequently moved slowly south-westward, while pressure became very low west of Portugal and later over the Bay of Biscay also. In consequence the north-easterly winds strengthened and very cold air spread from Russia to the British Isles giving an exceptionally cold spell for late March. Snow fell widely from the 27th onwards, the fall being substantial with severe drifting in the southern and midland districts of England on the 29th.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	63	16	+1·9	115	0	78
Scotland	61	15	+1·5	94	−2	97
Northern Ireland ...	59	27	+2·2	61	−7	101

RAINFALL OF MARCH 1952

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	2·97	162	*Glam.*	Cardiff, Penylan ...	2·66	84
Kent	Folkestone, Cherry Gdn.	3·96	182	*Pemb.*	Tenby	2·72	88
„	Edenbridge, Falconhurst	3·32	134	*Mer.*	Aberdovey	2·72	82
Sussex	Compton, Compton Ho.	3·67	132	*Radnor*	Tyrmynydd	3·04	57
„	Worthing, Beach Ho. Pk.	2·71	141	*Mont.*	Lake Vyrnwy	3·40	76
Hants.	Ventnor Cemetery ...	4·15	198	*Mer.*	Blaenau Festiniog ...	12·21	141
„	Bournemouth	...	...	*Carn.*	Llandudno	0·86	42
„	Sherborne St. John ...	2·76	123	*Angl.*	Llanerchymedd ...	2·25	76
Herts.	Royston, Therfield Rec.	3·13	171	*I. Man*	Douglas, Borough Cem.	2·85	96
Bucks.	Slough, Upton	2·55	145	*Wigtown*	Newton Stewart ...	2·96	86
Oxford	Oxford, Radcliffe ...	2·40	145	*Dumf.*	Dumfries, Crichton R.I.	2·52	84
N'hants.	Wellingboro' Swanspool	2·93	164	„	Eskdalemuir Obsy. ...	3·91	80
Essex	Shoeburyness	2·76	204	*Roxb.*	Kelso, Floors	0·82	42
„	Dovercourt	2·87	186	*Peebles*	Stobo Castle	1·34	46
Suffolk	Lowestoft Sec. School ...	2·38	148	*Berwick*	Marchmont House ...	1·58	60
„	Bury St. Ed., Westley H.	3·10	164	*E. Loth.*	North Berwick Res. ...	1·33	71
Norfolk	Sandringham Ho. Gdns.	2·72	143	*Midl'n.*	Edinburgh, Blackf'd. H.	0·95	48
Wilts.	Aldbourne	3·00	135	*Lanark*	Hamilton W. W., T'nhill	2·15	77
Dorset	Creech Grange... ...	3·96	140	*Ayr*	Colmonell, Knockdolian	2·15	64
„	Beaminster, East St. ...	4·02	137	„	Glen Afton, Ayr San. ...	3·23	77
Devon	Teignmouth, Den Gdns.	2·77	107	*Renfrew*	Greenock, Prospect Hill	4·61	99
„	Cullompton	3·65	133	*Bute*	Rothesay, Ardencraig ...	4·10	114
„	Ilfracombe	3·71	129	*Argyll*	Morven (Drimnin) ...	5·71	118
„	Okehampton Uplands...	4·85	117	„	Poltalloch	4·04	105
Cornwall	Bude, School House ...	3·18	130	„	Inveraray Castle ...	6·82	108
„	Penzance, Morrab Gdns.	3·98	124	„	Islay, Eallabus	3·62	95
„	St. Austell	4·30	125	„	Tiree	4·71	141
„	Scilly, Tresco Abbey ...	3·25	124	*Kinross*	Loch Leven Sluice ...	3·58	120
Glos.	Cirencester	3·19	138	*Fife*	Leuchars Airfield ...	1·78	91
Salop	Church Stretton ...	2·06	85	*Perth*	Loch Dhu	...	...
„	Shrewsbury	1·25	75	„	Crieff, Strathearn Hyd.	3·63	113
Worcs.	Malvern, Free Library...	2·24	115	„	Pitlochry, Fincastle ...	2·35	85
Warwick	Birmingham, Edgbaston	2·49	130	*Angus*	Montrose, Sunnyside ...	3·33	160
Leics.	Thornton Reservoir ...	2·87	156	*Aberd.*	Braemar	1·93	65
Lincs.	Boston, Skirbeck ...	2·35	151	„	Dyce, Craibstone ...	3·86	146
„	Skegness, Marine Gdns.	2·55	154	„	New Deer School House	2·03	78
Notts.	Mansfield, Carr Bank ...	2·00	96	*Moray*	Gordon Castle	1·84	79
Derby	Buxton, Terrace Slopes	3·16	77	*Nairn*	Nairn, Achareidh ...	1·38	75
Ches.	Bidston Observatory ...	1·63	86	*Inverness*	Loch Ness, Garthbeg ...	·78	53
Lancs.	Manchester, Whit. Park	2·40	106	„	Glenquoich	9·00	93
„	Stonyhurst College ...	2·22	60	„	Fort William, Teviot ...	5·86	87
„	Squires Gate	1·71	76	„	Skye, Duntuilm ...	4·37	99
Yorks.	Wakefield, Clarence Pk.	1·58	88	„	Skye, Broadford ...	6·68	110
„	Hull, Pearson Park ...	2·53	139	*R. & C.*	Tain, Tarlogie House ...	2·66	48
„	Felixkirk, Mt. St. John...	1·90	96	„	Inverbroom, Glackour...	3·13	63
„	York Museum	2·24	133	„	Achnashellach	5·06	75
„	Scarborough	1·70	94	*Suth.*	Loch More, Achfary ...	...	...
„	Middlesbrough... ...	1·20	76	*Caith.*	Wick Airfield	2·80	123
„	Baldersdale, Hury Res.	1·61	56	*Shetland*	Lerwick Observatory ...	6·15	195
Norl'd.	Newcastle, Leazes Pk....	1·05	51	*Ferm.*	Crom Castle	2·24	72
„	Bellingham, High Green	2·46	84	*Armagh*	Armagh Observatory ...	1·42	60
„	Lilburn Tower Gdns. ...	1·57	59	*Down*	Seaforde	1·41	48
Cumb.	Geltsdale	1·26	45	*Antrim*	Aldergrove Airfield ...	1·42	57
„	Keswick, High Hill ...	2·38	53	„	Ballymena, Harryville...	2·08	66
„	Ravenglass, The Grove	2·45	79	*L'derry*	Garvagh, Moneydig ...	2·09	67
Mon.	Abergavenny, Larchfield	2·06	68	„	Londonderry, Creggan	2·00	63
Glam.	Ystalyfera, Wern House	5·65	105	*Tyrone*	Omagh, Edenfel ...	2·05	65