M.O. 482 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 76. NO. 897. MARCH, 1947

THE INTERNATIONAL METEOROLOGICAL ORGANIZATION

National meteorological services grew up in many countries during the nineteenth century, and began to exchange their observations. The need for standardising the methods was soon felt, and for observations at sea international co-operation was sought by a Conference on Maritime Meteorology at Brussels in 1853, but no discussion of land stations was held until 1872. In that year Dr. C. Bruhns, Director of the Leipzig Observatory, invited a number of well-known meteorologists to a conference at Leipzig, of whom 52 attended, including one representative of America. This Congress was recognized as filling an urgent need, and was quickly followed by another, at Vienna in September 1873, at which a permanent " International Meteorological Committee " was formed; this Committee met in London in 1876 and Utrecht in 1878. The latter meeting laid down a constitution for the " Second International Meteorological Congress " at Rome in 1879, and may be considered as the birth-place of the International Meteorological Organization, which, apart from interruptions caused by wars, has functioned continuously ever since. The Members of the Organization are Directors of Meterological Services. The " I.M.O." aims at perfecting and co-ordinating the various meteorological activities of the world, including the standardization of meteorological procedures, the publication and exchange of meteorological observations and statistics and the application of meteorology to aviation, marine navigation, agriculture, etc. Upon its activities depends the ability of each country to obtain promptly and accurately from other countries the reports which are plotted on synoptic charts, and on which weather forecasts are based. The I.M.O. comprises the Conference of Directors, the International Meteorological Committee, various Regional Commissions, a number of Technical Commissions and a permanent Secretariat.

The Conference of Directors is composed of the Directors of State Meteorological Services of practically all nations and Directors of certain other independent meteorological organizations and institutes. At present it has about 100 members representing 84 countries and colonies. It is presided over by the President of the International Meteorological Committee, who is at present Sir Nelson K. Johnson, K.C.B., D.Sc., Director of the Meteorological Office of Great Britain. Before 1939 it met every six years or less to approve standard methods of observation and analysis and to decide generally upon measures of international co-operation between meteorological services. A Conference was held in London in 1946 to pick up the threads of international co-operation broken by the war; the next will be in Washington this year.

The International Meteorological Committee consists of 25 members elected by the Conference of Directors, together with the Presidents of the Technical Commissions. It acts for the full Conference during the interval between meetings of the latter; it is empowered to receive recommendations from the Technical Commissions and to approve them for universal adoption and to initiate any necessary measures for the development or improvement of international meteorology. The President of the Committee (Sir Nelson Johnson) is the chief executive officer of the Organization. The Committee normally meets every three years; the last meeting was in Paris in 1946.

International meteorology is truly world-wide, and from 1935 onwards local interests have been in the hands of a series of "Regional Commissions", which co-ordinate the activities of all the meteorological services within their regions, and link up with neighbouring regions. There are six Regional Commissions, representing respectively Africa, Asia, South America, North and Central America, south-west Pacific and Europe.

The Technical Commissions are formed to consider and make recommendations upon any technical questions referred to them by the Conference of Directors or the International Meteorological Committee. They exist to prepare the ground in matters concerning international co-operation in the various branches of applied meteorology. There are at present ten Technical Commissions, dealing with: aerology, aeronautical meteorology, bibliography and publications, agricultural meteorology, climatology, projection of meteorological charts, instruments and methods of observation, maritime meteorology, hydrology and synoptic weather information; meetings take place at intervals not exceeding three years.

The Secretariat is located in the permanent headquarters of the Organization at Lausanne, Switzerland. It is responsible for organizing meetings of the Conference, Committee and Commissions, and arranges for the publication of their approved resolutions, minutes and reports. It also serves as a centre for information on world meteorological services, and, in consultation with the Presidents of the Committee and Commissions, conducts the day-to-day work of the Organization. The Secretariat is maintained by annual contributions from the various national services, the contribution of a major service being 5,400 Swiss francs, that for a medium service 2,700 Swiss francs, with correspondingly lower contributions from smaller services. The financial affairs of the Organization are managed and the Secretariat is administered by an Executive Council of six members, which meets every year under the President of the International Meteorological Committee.

The I.M.O. collaborates with other international organizations whose work is related to meteorology, such as the Provisional International Civil Aviation Organization (P.I.C.A.O.), the International Union of

Telecommunications and the International Ice Patrol Service. The character of the collaboration usually consists in inviting the other bodies to send delegates to meetings of the Commissions with which they are primarily concerned.

The relationship between the I.M.O. and the United Nations is under discussion with a view to exploring the possibilities of the Organization becoming linked to U.N.O. without losing its world-wide character and independence. The present status of the I.M.O. is little more than that of a voluntary association. Steps are being taken to place the Organization upon a more official footing, and the draft of an International Convention has been prepared and is expected to be finally agreed and signed at the Conference of Directors in Washington next September. The adoption of the Convention will not affect materially the aims, functions or the internal structure of the Organization.

During the 1939–45 war, the activities of the I.M.O. were necessarily much curtailed. With the return of peace it became necessary to resume its activities and to restore the international procedures which had been in operation prior to 1939. The task confronting the Organization was rendered more complicated by two factors. The first was the development of long-range flying and the consequent demand for a corresponding development in the meteorological arrangements for aviation. The second new factor was the introduction of improvements in the field of scientific and technical meteorology. These advances in meteorology had been made by a few countries to meet the demands of war. It was now necessary to spread the new knowledge universally, and to apply it to meet the requirements of peace.

An extraordinary meeting of the Conference of Directors was held in London between February 25 and March 2, 1946 (see photograph facing p. 60), to set the machinery of the Organization into immediate operation again, at the same time adapting its internal organization to meet the changed world conditions. Meetings of the Commission for Aeronautical Meteorology, of the Commission for Synoptic Weather Information and of the European Regional Commission were held in Paris during June and July, 1946, and were immediately followed by a meeting of the International Meteorological Committee.

A further meeting of the European Regional Commission was held in Paris in January, 1947, whilst the remaining Regional Commissions will hold meetings during the first half of the year. Meetings of all the Technical Commissions are to be held at Toronto during August and the first half of September, 1947, and will be followed by a Conference of Directors in Washington D.C. during the latter half of September.

THE SEVERE WINTER OF 1946 TO 1947

BY C. K. M. DOUGLAS, B.SC.

Though the really notable cold spell only developed late in the winter, there were two earlier severe spells of relatively short duration, both due to the westward movement of Russian anticyclones. The first was from December 15 to 21, while the second only lasted from January 5 to 7, but gave considerable snowfall in the east and Midlands, and continuous frost for 48 hours over a substantial area. Both spells were naturally longer and much more severe on the continent, and even the second one lasted for ten days in north Germany. There followed a spell of unusual mildness (rare in the middle of a severe winter) and temperatures reached 57°F. locally on January 16. On January 18 there was a pronounced anticyclone over Brittany and deep depressions over Finland and south Greenland. Temperature was relatively high over Europe generally, including all European Russia except the north-east, and there was nothing to suggest that a severe spell was approaching, but nevertheless it was the last mild day over a large part of Great Britain until nearly the middle of March, and even later in the north. The anticyclone over Brittany declined, and an initially weak wedge of high pressure to northward built up, until on the 21st the highest pressure was off north-west Norway. From the 19th to 22nd temperature remained below 40°F. at many places and there was some night frost. Really wintry weather commenced in the south-east on the 23rd, with the onset of a very cold NE. wind, supplied by a NNE. current over Finland, which had come round the north side of the depression mentioned previously. Snowfalls with severe drifting began in Kent and Sussex and part of East Anglia on the 23rd and continued for some days, and slighter snowfalls occurred over a larger area.

The developments between the 24th and 26th, which finally established the wintry spell and extended it over the whole country, were of great interest from the synoptic standpoint. By 0600 on January 24, the anticyclone which had formed off north-west Norway had moved south-west to Scotland with central pressure 1040 mb. and the col over Finland between this high and the Siberian high had a pressure of only 1031 mb. Mild air from the north-west formed a warm sector over the north Baltic, and a small depression formed there and moved rapidly south-west to England as a trough of low pressure, under the influence of a strong NE. " thermal " wind aloft over the whole area. The combination of the fall of pressure in the British Isles with a renewed rise in Finland resulted in a very cold easterly current over England and Wales on the 26th, giving continuous frost which extended over most of Scotland and Ireland two or three days later. The upper air charts were very useful to forecasters during this period.

From the above account it is clear that the development which started the long cold spell was wholly different from those associated with the short earlier spells, and there is no definite evidence of any connexion between them.

On January 28 a trough of low pressure over Russia separated the Siberian high from the more westerly high, but this high extended far enough east to give a protracted cold spell.

Throughout most of February pressure remained high over Scandinavia and was even higher round north and central Greenland. At times there was a belt of high pressure from Greenland to Siberia. The Greenland anticyclone undoubtedly played an essential part in the maintenance of the easterly type throughout most of February, and was entirely responsible for the prolongation of the severe weather for a fortnight after the Scandinavian anticyclone had given way, and for three weeks in the north. The Greenland system extended to a higher level than the more easterly one. The radio soundings from the American ship off the south-east coast of

Greenland (about 61°N., 32°W.) showed that the average height of the 500 mb. surface in February was about 300 ft. higher than over Scandinavia at the same latitude, and NE. winds at 500 mb. were frequently observed by the ship. There was also high pressure in the Greenland area in February 1895 and in January 1940.

The winds from some easterly point which began on January 22 lasted in most districts without a break until February 22, giving one of the longest (if not actually the longest) spells of E. wind ever recorded in this country. It was an exceptionally dull period except in west Scotland, and at Kew there was no sunshine from February 2 until the 22nd, the longest sunless period since records began. February was the dullest on record and duller than any month since December 1890. Under these circumstances it was naturally the day temperatures rather than the night temperatures which were the outstanding feature. At Greenwich the mean maximum for February was the lowest of any month since before 1841. Frost was continuous from February 11 to 23 over a large area. There were ice floes in the North Sea, and the exceptionally low sea temperature intensified the later phase of the cold period, especially in March.

There were only brief periods when conditions favoured severe night frost. Late in January exceptionally cold air came over from the south-east behind a west-moving trough, and there were two extremely cold nights in the south, even in areas where the night was partly cloudy and where the wind was appreciable. Further north there was only one very cold night. A weak wedge of high pressure gave the lowest temperatures of the winter over most of the country on the 23rd to 25th, in places the lowest since 1895, and a similar ridge on March 1 to 3 gave further severe frost especially in the north. Over most of Scotland severe night frost continued until March 9, and intermittently until the 15th, and there was another severe frost over the greater part of England and Wales on the night of March 5 to 6.

There can be little doubt that the winter was the snowiest of which we have any precise knowledge. Snow fell every day down to a low level in some parts of Great Britain from January 22 till at least March 17, and over the major part of Great Britain and Northern Ireland the ground was continuously snow covered from January 27 until March 13, and for a few days longer in some northern regions. Level depths exceeded 2 ft. in some areas, and heavy drifting occurred at times at all exposed places throughout the British Isles, with dislocation of rail and road traffic on an unprecedented scale. Even Cornwall suffered severely and Scilly had two considerable falls. North-west Scotland was the least affected part of Great Britain. In the north-east there was perhaps no single snowstorm as bad as that of February 18 to 20, 1941, but the six weeks' aggregate must have been greater at most places.

The conditions associated with individual snowstorms can only be dealt with briefly. A trough of low pressure which moved west from the continent covered virtually the whole of Great Britain with a coating of dry snow on January 27 to 28, and a depression which formed out of this trough became centred over the western English Channel and prolonged the snowstorm in south-west England, resulting in the isolation of many villages and the blocking of railways.

The four other main storms in southern and central districts were associated with complex depressions from the Atlantic, which were deep off our south-west coasts but partly filled as they moved away, the first two south-east and the other two east-north-east. In all four cases the belts of snow were associated with occlusions, but moved to northward of the sea-level position of the occlusion, from which they were separated by belts of light or occasional precipitation. In the March case a second belt of precipitation came up from south-west. The area chiefly affected only extended as far north as south Lancashire and Yorkshire. In the first case (February 2 to 4) the snow was followed by a three days' thaw in the south-west and a two days' thaw over a considerable area in the south, which much reduced the depth of snow. There was prolonged snow without thaw from Lincolnshire to north Wales, heaviest in the east and on high ground. The second storm on February 8 to 9 was somewhat similar, but the subsequent thaw only lasted for 48 hours in the south-west and 24 hours in the south-east. The third storm on February 21 gave very dry powdery snow even in the extreme south. The fourth major storm in the southern and central areas, that of March 4 and 5, was the worst of the winter, though in the south-west and extreme south the precipitation was mainly rain, with glazed frost in places. The level depth of this fall exceeded a foot over a large area, and drifting was exceptionally severe (see photographs between pp. 60 and 61). The failure of the thaw to spread so far as it did after the earlier February storms was interesting from the synoptic standpoint and illustrates the difficulties with which forecasters have to contend. The motion of the occlusion on February 8 to 9 was approximately that of the component of geostrophic wind at right angles to it, while on March 4 to 5 there was a large difference, as much as 40 m.p.h. for one 6-hour period. The large ageostrophic motion of the cold air low down both held up the front and added substantially to the intensity of the snowfall.

It is well known that depressions in the English Channel area give the worst snowstorms in the south, and notable examples occurred in January 1881, March 1891, April 1908, December 1927 and January 1939. These all had different features, especially as regards the preceding conditions, and none resembled that of March 4 to 5, 1947, sufficiently to be of any use to the forecaster.

In the north the most notable February snowstorm occurred on the 26th, when a polar-air depression moved north-east from south-west Ireland across south-east Scotland. That day was brilliantly fine in south-east England, and the mildest of the month. During the severe period as a whole, much of the snow in the north-east district was of the showery type, and the totals showed marked local variations, but were very large in some areas. There was another severe general snowstorm in north England, south Scotland and north Ireland (the worst of the winter in some areas) on March 12 to 13, with bad drifting. A warm front became stationary near the Scottish border and then retreated.

The final thaw commenced in the south on March 10, but in Scotland only on March 16. For nearly a week conditions were very changeable in the south, with more frost and very cold days and occasional snow, alternating with thaw and considerable rain. In spite of the interruptions in the thaw there was very serious flooding, the worst in the Thames Valley since 1894. The end of the wintry spell over the country as a whole can be taken as March 16, 7½ weeks after its onset. There was an exceptionally severe gale in the south on the evening of that day, affecting much of England and Wales. The synoptic developments for March 3 to 14 showed certain features which were unique in our area, not so much in their general nature as in their speed. Deep occluded depressions to westward filled up at an astonishing rate as new systems formed further east, and the cold air swept quickly southward again.

Though large accumulations of snow in March are frequent on high ground, there is no precedent to recent conditions over the country as a whole for a long time past. In the last week of February and in early March 1895 the mean maximum temperature was up to or slightly above 40°F. over practically the whole country.

Some other points of contrast with other severe periods are worth noting. There is no record of such a long spell of bleak E. wind and dull weather as occurred this year, but short spells are fairly common. Dullness is rather characteristic of E. winds in winter, partly owing to the North Sea and partly to clouds already existing on the continent. If the geostrophic wind is E. rather than NE., continental clouds are the commonest cause of dullness in south-east England, though stratocumulus sometimes forms when the air crosses a short stretch of sea.

Though dullness is the typical feature of easterlies, there are also bright spells, and the two coldest previous Februaries, 1895 and 1929, both had long bright periods and both were associated with much lower continental temperatures, drawn from the heart of Siberia. In the earlier part of the 1929 spell there was a considerable depth of cold air, and later the continental anticyclone was further south and there was marked subsidence in the SE. current, an ideal situation for clear skies. In the recent severe spell there was never enough subsidence to clear the clouds except in the brief periods which gave severe frost. The very cold air was always shallow, generally with a marked temperature inversion somewhere between 3,000 and 5,000 ft., favouring persistent clouds. The air supply did not come from so far east as in the earlier periods, and the trajectories were often complex. Even when the lower air had come from north Russia only a shallow layer reached our area. Sometimes the supply was from the Black Sea area, and was affected during transit by precipitation falling into it from warmer Mediterranean air aloft.

On the average over many years the largest number of severe night frosts occur in arctic air, originally from north or north-north-east. This seldom gives a long cold spell unless easterlies follow, but there was a 10-days severe spell in January, 1945, and a 16-days spell in January, 1881, this being the longest spell of this type of which we have any knowledge. During the blizzard of January 18 to 19, 1881, there was a ridge of high pressure from Denmark to Austria, and the air over southern England came back from east France and west Germany, its original source being northerly arctic.

The conditions at the onset of the recent severe period have been described in detail, and it is worth mentioning that the long cold spells of 1890, 1895 and 1917 also originated with the advance of a ridge of high pressure from west or north-west towards Scandinavia. Westward movements of Siberian anticyclones resulted in eight days of severe cold and twelve consecutive night frosts in February 1929, and in eight days of severe cold in the south-eastern area in December 1938, but no really long spell of continuous severe cold originated in this way. The problem presented by long cold spells is on a hemispherical, possible even a global scale, and the Siberian anticyclone alone does not provide an adequate explanation of them. It does not appear to be the primary factor in most cases, though from some aspects a Scandinavian anticyclone can be regarded as a kind of western extension or outpost of the Siberian system.

THE NUMERICAL BASIS OF CLIMATE

BY C. E. P. BROOKS, D.SC.

Part III. Significance Tests and the Analysis of Variance

It often happens that in the course of an investigation we have to decide whether or not a certain hypothesis is consistent with the data. A suitable test for this purpose was designed by K. Pearson in 1900 and is known as the " chi-square " test; it consists simply in forming the sum :—

$$\chi^2 = \Sigma \frac{(O-E)^2}{E}$$

where O is the observed frequency and E the expected frequency in each cell, the only proviso being that E must be at least 5. We also need to know the number of " degrees of freedom " in the table, i.e. the number of cells which can be filled up arbitrarily before the remainder are fixed by the total number of observations, and by the other features of the distribution which are used in computing the expected values. Suppose for example that we have 100 observations classified into six frequency cells. We can fill up five cells arbitrarily, but then the number in the sixth cell is fixed by the total. If we now fit a normal frequency curve to this distribution, we are using two other properties of the distribution, namely the mean and the standard deviation. Consequently the degrees of freedom are $6-1-2=3$.

In this imperfect world there is rarely if ever complete agreement between expectation and observation, and we must frame our judgment of the soundness of a hypothesis on a comparison of the actual measure of disagreement with that to be expected by the operation of chance errors. Two main levels may be distinguished :—

(i) if χ^2 is so large as to give a probability of less than 5 per cent., i.e., so large that it would only arise by chance once in more than 20 trials, we regard the hypothesis as not consistent with the facts.

(ii) if χ^2 is so small as to be above the 95 per cent. level of probability, the inference is that we have accumulated sufficient observations almost to eliminate the results of chance errors. The hypothesis fits the facts very well, but this does not mean that the hypothesis is necessarily true; that is a matter for physical reasoning or further experiment.

Most good textbooks of statistics contain in some form or other a table of values of χ^2 corresponding to different levels of probability for various numbers of degrees of freedom. A convenient table is included in " Industrial Experimentation " (Ministry of Supply, 1946) published by H.M. Stationery Office at the modest price of two shillings.

As a simple example, we will test the popular belief that a solar or lunar halo is a prognostic of rain. Table 5 has been reconstructed from some data given by H. Neuberger for central Pennsylvania. The figures not in brackets show the actual observations classified into four groups—halo followed by precipitation ; halo not followed by precipitation ; day without halo followed by precipitation ; day without halo not followed by precipitation. The figures in brackets give the distribution which would be expected if there were no tendency for a halo to be followed either by precipitation or fine weather, the 2,284 days being divided in accordance with the frequency of haloes, no haloes, rain and no rain. Thus the number of days with haloes, 646, is divided in the ratios 1,316/2,284 and 968/2,284 ; similarly for the number of days without haloes.

TABLE V. HALOES AND SUBSEQUENT PRECIPITATION

	Precipitation within 48 hours		
	Yes	No.	Total
Halo	497(372)	149(274)	646
No halo ..	819(944)	819(694)	1,638
Total ..	1,316	968	2,284

In this example we have

$$\chi^2 = \frac{(125)^2}{372} + \frac{(125)^2}{274} + \frac{(125)^2}{944} + \frac{(125)^2}{694} = 138$$

There is only one degree of freedom, because the total numbers of days of rain and haloes are fixed, so that after one cell is filled, the remainder can be filled in only one way. The value of χ^2 is very large, and from a table of χ^2 for one degree of freedom we find that the probability of such a distribution occurring by chance is much less than 0·01 per cent. In other words the odds are more than 9,999 to 1 that there is a real tendency for haloes to be followed by precipitation within 48 hours. Note that this is not the same as the probability that any individual hàlo will be followed by precipitation, which can be seen from the table to be less than 4 to 1.

In this example the figures were actually given as percentages, and it took some trouble to estimate the number of observations. The latter is vitally important however, for if we had taken the original table at its face value, and assumed that there were only 100 observations, we should have calculated χ^2 as 6·1, and the odds against this value occurring by chance are only 69 to 1 ; still significant but not so overwhelming as with 2,284 observations.

This significance test can also be applied to a frequency distribution, in order to see whether it is consistent with some particular assumption as to the type of distribution. For example, we have the following frequencies of numbers of days with screen frost at Greenwich in January, 1841–1905 :—

Number of frosts	0–4	5–9	10–14	15–19	20–24	25–30
Number of months	10	16	15	12	10	2

From these figures we calculate the mean frequency as 12·2 per month, $\sigma = 6 \cdot 8$.

If there were no connexion between the weather of one day and the next, the frequency distribution would follow a well known law due to Bernouilli.

Suppose we had a drum containing millions of discs, some white (representing frosts), and the remainder black (no frost), and took out 65 sets of 31 each. We do not know the proportion of white to black in the drum, but we find that the average number of white discs in a set of 31 is 12·2. The best assumption we can make as to the proportion is that there are 122 white to 188 black discs, i.e., the probability p of drawing a white disc on any one trial is 12·2/31 or 0·4, and the probability q of drawing a black disc is 0·6. The numbers of white and black discs actually drawn will vary from one set of 31 to another, and a little consideration will show that this is another case of the binomial series described in Part II. The expected frequency distribution of the numbers of white discs will be given by the expansion of $65(0\cdot4+0\cdot6)^{31}$, 65 being the number of sets and 31 the number in each set. The theoretical frequency distribution given by this series is as follows :—

Number of frosts ..	0–4	5–9	10–14	15–19	20–24
Number of months ..	0	6	40	18	1

Comparison with the observed figures shows a wide discrepancy, and this is confirmed by the significance test. Grouping the figures to obtain at least five in each cell we have :—

Frequency	0–9	10–14	15–31
Observed	26	15	24
Expected	6	40	19

$$\chi^2 = 67\cdot2$$

There is only one degree of freedom, because the mean value as well as the total of 65 has been used in computing the " expected " distribution. The probability that the observed distribution is consistent with the expected distribution is less than ·001, or in other words the odds that it is not consistent are more than 999 to 1.

The reason for this discrepancy must be that our hypothesis is at fault, in other words that the numbers of frost days are not distributed according to chance. To investigate the question we can adopt another useful technique known as the " analysis of variance ".

The assumption with which we began was that all the 65 sets of 31 discs were drawn from the same drum. Bernouilli showed that in such a case the standard deviation of numbers of either white or black discs would be given by $\sigma_B=\sqrt{(npq)}$. In our example n is 31, $p=0\cdot4$ and $q=0\cdot6$, so that $\sigma_B=2\cdot7$. But suppose that each set of 31 was drawn from a different drum, in which the proportions of white and black discs varied from drum to drum. In this case the standard deviation σ of the observed series is compounded of the Bernouilli standard deviation σ_B and the standard deviation of the proportions in the different drums, multiplied by 31, which we will call σ_D.

We cannot combine standard deviations directly, but we can combine their squares, or variances. Thus

$$\sigma^2 = \sigma_B{}^2 + \sigma_D{}^2.$$

We do not know σ_D directly, but we know σ and have an approximation to σ_B based on the observed mean frequency $[\sigma_B=\sqrt{(31\times\cdot4\times\cdot6)}]$, and so we can calculate σ_D. This gives

$$\sigma_D{}^2 = 6\cdot8^2 - 2\cdot7^2 = 46\cdot2 - 7\cdot3 = 38\cdot9.$$

From this we infer that the character of the month accounts for more than four-fifths of the variability in the number of frosts from one January to another, and the variability due to chance to less than one-fifth.

This gives us a useful method of estimating the frequency distribution of phenomena when we know only the mean frequency. It happens that for any one phenomenon the ratio of the observed standard deviation σ to the Bernouilli standard deviation σ_B is almost independent of the frequency of the phenomenon, the average values being about 1·5 for thunder, 2 for fog, gale and rain and 3 for frost and snow.

If we know the average frequency, we can calculate σ_B from $\sqrt{(npq)}$, and multiplying by the appropriate ratio (in this case taken as 3), find an approximate value of σ. If p lies between about 0·25 and 0·75, the distribution is sufficiently normal to use the normal frequency table given in Part II. In this way the following frequency distribution of frosts at Greenwich was computed :—

Number of frosts ..	0–4	5–9	10–14	15–19	20–24	25–30
Observed ..	10	16	15	12	10	2
Expected ..	10	13	16	14	8	4 ·

Grouping the last two cells together, we find that $\chi^2 = 1 \cdot 0$, with 3 degrees of freedom. This corresponds with a level of probability of about 70 per cent., so that the differences between the observed and expected figures can reasonably be attributed to chance.

When p is less than 0·25 or more than 0·75, the distribution is not sufficiently normal for this method to be used. A discussion of this case would be beyond the scope of these articles, but it can be said here that there is no simple solution.

The latter part of this article is based on some work by Miss N. Carruthers and myself in 1944, but we subsequently found that F. Baur had covered much the same ground in 1930 (see *Met. Z., Braunschweig*, **47,** 1930, p.381).

In these three articles I have dealt with only a few of the many possible applications of statistical methods to climatic data, but sufficient I hope to illustrate the general principles and to show how interesting and fruitful the subject can be.

Errata, Part I.

PAGE 10, Table I, Scilly, column headed 41° ; *for* " 0 " *read* " 2 ".

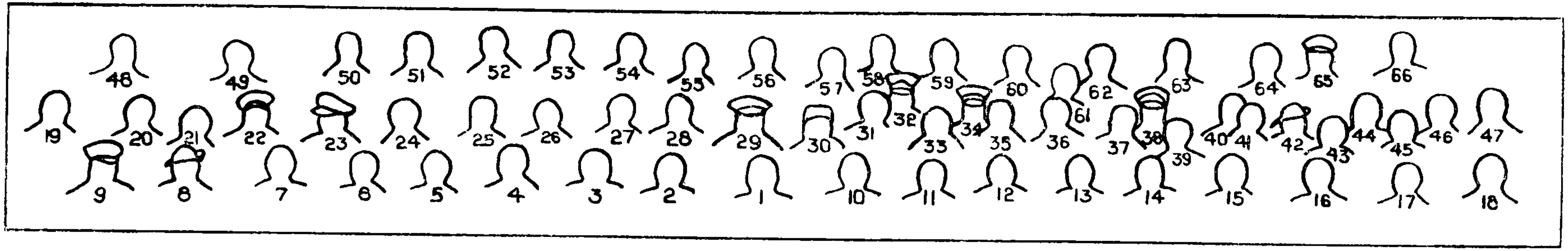
PAGE 11 ; *for* table following line 12, *substitute* the following :—

TABLE II

	Mean	Quartiles		Deciles		Median	Mode
			degrees Fahrenheit				
Scilly	51·38	49·4	53·5	47·3	55·2	51·5	51·7
Birmingham ..	49·42	45·1	53·7	42·0	56·9	49·1	48·5

PAGE 13, line 6 ; *for* " Mean ± ·6745 " *read* " Mean ± ·6745 σ ".

PAGE 14, line 11 ; *for* " $(0 \cdot 67/0 \cdot 05)^2$ or 4,356 years " *read* " $(0 \cdot 67\ \sigma/0 \cdot 05)^2$ or more than 2,000 years ".



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34. Guiraud (Allied Control Authority, Berlin)
35. Sutton (Egypt)
36. Sellick (Rhodesia)
37. T'u (China)
38. Grimes (Malaya)
39. Krishna Rao (India)
40. Sekera (Czechoslovakia)
41. Gregor (Czechoslovakia)
42. Miss Van den Linde (Secretariat, I.M.O.)
43. Ferreira Vaz (Portugal)
44. Rivet (France)
45. Feige (Palestine)
46. Ducasse (France)
47. Slettenmark (Sweden)
48. Entwistle (Great Britain)
49. Azcarrage (Spain)
50. Gillen (Luxemburg)
51. Hagen (U.S.A.)
52. Petersen (Denmark)
53. Mundell (U.S.A.)
54. Little (U.S.A.)
55. Koulakov (Russia)
56. Sobolev (Russia)
57. Grigoriev (Russia)
58. De Boer (Netherlands East Indies)
59. Rossby (U.S.A.)
60. De Vincenti (Italy)
61. Bleeker (Holland)
62. Musikic (Yugoslavia)
63. Mladenovic (Yugoslavia)
64. Thellier (France)
65. Bodart (France)
66. Nagle (Eire)

EXTRAORDINARY CONFERENCE OF DIRECTORS OF THE INTERNATIONAL METEOROLOGICAL ORGANIZATION, LONDON, 1946

(see p. 51)

THE ALFRETON—MATLOCK ROAD ABOUT ½ MILE EAST OF WESSINGTON, MARCH 15, 1947, ABOUT 1300 G.M.T.

The drifts are approximately 12 to 14 ft. high. This part of the road is about 400 ft. above M.S.L.

THE ALFRETON—MATLOCK ROAD ABOUT ½ MILE EAST OF WESSINGTON, MARCH 15, 1947, ABOUT 1300 G.M.T.

The drifts are just forming during the blizzard. The drift against the telegraph pole is about 12 ft. high.

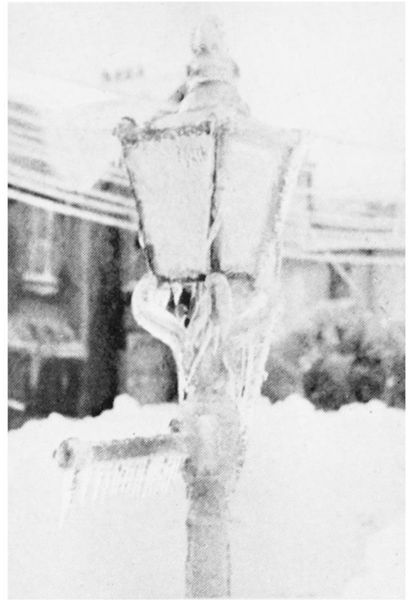
THE ALFRETON—MATLOCK ROAD ABOUT 1,000 YARDS EAST OF WESSINGTON, MARCH 16, 1947, AT 0900 G.M.T.

The 5-ft. drifts along the road ahead completely blocking it.

These photos are reproduced by the courtesy of Mr. F. Tomlinson

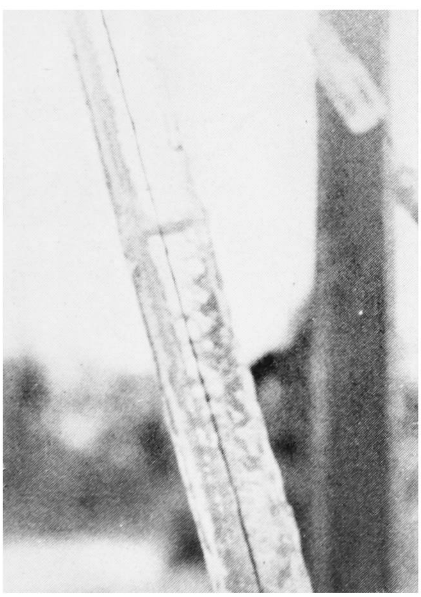
RIME AND SNOW, PRINCETOWN, FEBRUARY 14, 1947

Glazed frost occurred on February 11, and rime commenced forming on the 12th and was cumulative up to the 16th.



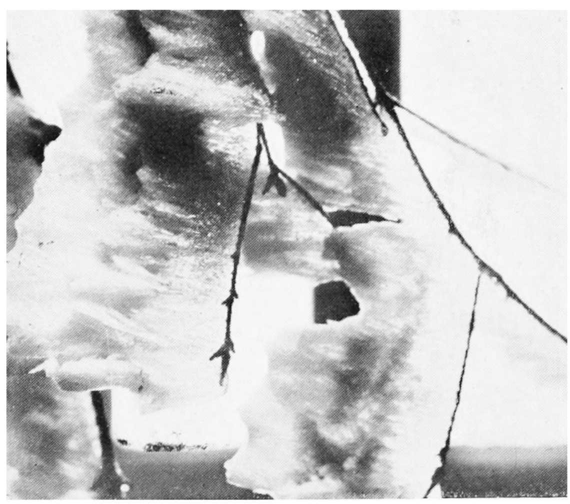
GLAZED FROST, PRINCETOWN, MARCH 6, 1947

Weather clear (no mist) but no sunshine.



GLAZED FROST, PRINCETOWN, MARCH 6, 1947

Single telephone wire showing thickness of ice. The wire can be seen as a thin black line down the centre and the mark half way up is where the ice has cracked when the wire fell down.



RIME, PRINCETOWN, FEBRUARY 16, 1947

Rime formation on ¼ in. diameter twigs feathered out to 4 in. This was no doubt due to the continuous easterly winds from the 11th to 16th. The rime formation was cumulative from the 12th to 16th.

These photos are reproduced by the courtesy of Mr. J. Hyde

To face p. 61]

Official U.S. Navy photograph

WATERSPOUT IN THE GULF OF TONKIN, AUGUST 8, 1945
(see p. 63)

METEOROLOGICAL OFFICE DISCUSSIONS

The Monday evening discussion held at Victory House on March 3 was devoted to the consideration of a paper in the *Journal of Meteorology* on " Insolation in Relation to Cloudiness and Cloud Density " by Bernhard Haurwitz of Harvard University, U.S.A.*

Introducing the paper for discussion, the Director emphasised the importance of work of this nature to agricultural meteorology, a section devoted to the study of which has recently been incorporated in the Climatological Branch of the Meteorological Office, and also outlined certain developments in direct measurements of insolation planned by the Meteorological Office in this country.

The discussion was opened by Mr. L. G. Cameron who first of all made it clear that the author was only seeking a general climatological relationship between the elements mentioned, and that he was thinking in terms of total radiation from the sun and the sky on a horizontal surface. In view of the scarcity of data on insolation, the author declares his intention of attempting to establish a relationship between insolation, cloudiness and cloud density since observations of cloudiness are far more numerous throughout the world than are records of the duration of sunshine, which however, if available, are better indicators of insolation, especially with broken skies, than is total cloudiness.

Using observations of cloudiness, cloud density and air mass (secant of the zenith distance of the sun) related to the insolation, all recorded at the Blue Hill Meteorological Observatory, Boston, Mass., the equation

$$T = \frac{a}{m} e^{-bm}$$

was chosen to express the insolation (T) as a function of the optical air mass (m) ; a and b being constants for each cloudiness and cloud density. Least square curves for the insolation at the various air masses with different degrees of cloudiness and cloud density were obtained which clearly showed the increasing importance of density in limiting insolation, at a given air mass, with the higher degrees of cloudiness. A comparison of the insolation for a number of air masses at given cloudiness and cloud density with that from a cloudless sky established the fact that the ratio of insolation decreases as a rule with increasing air mass. Finally annual and monthly mean values of insolation have been computed, and the results used to construct a series of annual curves which illustrated the fact that with increasing cloudiness the differences between the insolation at different densities become more pronounced and the annual amplitudes become smaller.

In the course of the general discussion which followed the summary of the paper Dr. Stagg, announcing that the work at Kew was now approaching the stage when a study on similar lines could be attempted with some confidence, went on to describe how the various types of radiation were measured. Mr. Sumner considered that the chief defect in the paper was that atmospheric turbidity is not taken into account. Using the results given in the paper, he had found that the amount of insolation getting through to the ground on

* *J. Met., Milton Mass.* **2,** 1945, p.154.

a cloudless day at Kew corresponded to that with a cloud cover of 8–9 tenths of density $2\frac{1}{2}$ according to the Haurwitz method. Dr. Brooks expressed the opinion that the paper was of considerable value especially if the expressions found within it were used to construct a much needed map of the radiation received over this country. He also called attention to an interesting application of the work to geological problems by citing the case of the permo-carboniferous glacial deposits in South Africa and India. According to Wegener the glacial conditions necessary for the deposition of this conglomerate were brought to South Africa as a result of a re-orientation of the earth's axis which put the south pole into the region of South Africa. Without any such alteration however the necessary glacial conditions might have been produced by permanent monsoon conditions with a continuous cover of 10-tenths cloud of density 4, during permo-carboniferous times.

Some criticism was levelled at the coarse grouping of the total cloudiness especially in the 4–7-tenths group which in itself embraces quite a wide range of solar radiation, whilst Mr. Swinbank and other speakers, in criticising the crude definitions of cloud density (0–4 according to the "International Cloud Atlas"), thought that the data available deserved a more accurate classification. Mr. L. H. G. Dines was inclined to think that the effect of atmospheric turbidity was at times over-estimated since his work on clear days with very good visibility at Kew had revealed that even under those conditions only 2 thirds of the possible insolation was received. Dr. Scrase asked, but was answered in the negative, whether the paper made any reference to the effects of cloud height since Dr. Atkins had found that the amount of illumination for the same thickness of cloud was directly proportional to the cloud height. Mr. B. C. V. Oddie raised the interesting point that, when considering insolation in relation to plant growth, it was not the total insolation which mattered so much as the amount received at the various wave-lengths.

METEOROLOGICAL RESEARCH COMMITTEE

The 46th meeting of the Meteorological Research Committee was held on January 30, 1947.

At this meeting a revised research programme was considered and adopted. The new programme contains more problems than the old programme but fewer of the problems have been allotted priority PX.

Further consideration was given to the question of exploration of the constitution of the upper atmosphere by the use of projectors using pulsed light. Certain preliminary steps to test the feasability of this were decided upon. Other matters considered by the Committee included meteorological research by the School of Agriculture, Cambridge, and a paper dealing with the height of the tropopause over monsoonal regions.

LETTERS TO THE EDITOR

Unusual Wet-bulb Reading

On Sunday morning, March 9, the dry-bulb thermometer in the screen in my garden read 30°F. and the wet-bulb 32°F. These were the readings when I opened the door of the screen. Neither thermometer had been touched in any way. I was very surprised and I naturally verified the readings. It was a fine morning and the temperature must have been lower during the night. The wet bulb was covered with ice. If this had been newly formed, the temperature would have been 32°F., but if the water round the wet bulb had frozen earlier in the night one would have expected the wet bulb even when covered with ice to have read at least as low as the dry bulb. There was no fog or mist.

E. GOLD

March 10, 1947.

Supercooled water on pond ice

At 1530 on January 24, 1945, I visited the large pond at Pantyrochain, which is two miles north-north-east of the weather station at Wrexham, and there partook of what might have passed as skating had the ice not been so rough and bumpy. The pond is roughly circular, and several hundred yards across. Near the middle I found a patch, about a quarter of an acre in extent, which from a distance appeared brownish, and covered in places with a little snow. I travelled at speed to investigate, and on reaching the edge of the patch, the skates sank their full depth into soft material and I was precipitated headlong into about two inches of very liquid slush. Its appearance was that of the slush produced on roads after municipal authorities have applied salt to the snow, and it was of a brownish tint, and contained much liquid water. The dry bulb at Wrexham twenty minutes before was 22°F., and the temperature on the snow surface about 16°F., moreover the temperature at ground level had been below freezing point (and at times below zero) for about 116 hours previously. It was therefore a matter of no little surprise to me to find liquid water on the surface of the ice, which was at least 5 inches thick.

S. E. ASHMORE

11, *Percy Road, Wrexham*

[It would be interesting to have a chemical analysis—there was possibly some soluble substance which lowered the freezing point.—Ed. M.M.]

NOTES AND NEWS

A waterspout in the China Seas

The photograph facing p. 61 was obtained by a U.S. Navy Typhoon reconnaissance plane on August 8, 1945, in the Gulf of Tonkin between Hainan and the south China coast. The storm in which it occurred developed on the "equatorial front" on August 4, intensified and moved north-westward across northern Luzon and developed into an intense typhoon in the South China Sea, finally dissipating along the China–Indochina border on August 11. It was followed throughout its history by search planes, some of which flew directly into the "eye".

The storm lacked the usual symmetry and towards the close of its life gave indications of developing a frontal structure. By the 9th the storm had moderated, but a violent squall line or front had developed, extending north-north-east to south-south-west east of Hainan for over 100 miles. The clouds in the photograph are probably part of this developing squall line.

Although the waterspout itself is not very well shown in the photograph, other interesting features stand out clearly. Note the wind shear shown by the band of rougher water parallel to the line of cloud drawn into a spiral eddy system around the base of the waterspout. Other eddies or atmospheric wave motion also appear along the line of shear which may possibly develop into other waterspouts.

This photograph appeared with a number of others in a U.S. Navy publication "Typhoon Reconnaissance June through September 1945". We are indebted to Mr. R. A. Buchanan for calling our attention to it and obtaining a copy for reproduction, and to the U.S. Navy for permission to reproduce.

Small tornadoes or whirlwinds in the British Isles

We are indebted to the Rev. T. L. Jackson of Ampleforth College, Yorkshire, for the following description of a small whirlwind observed at Ampleforth on May 31, 1946.

"About 7 p.m. on Thursday, May 31, one of our workmen and his family were in their cottage; it had been raining heavily—very heavily—and was beginning to slacken off, when the attention of the family was attracted by the sound of a violent wind. Running to the window at the back of the cottage which looks out on the hillside, they were just in time to see a small black cloud, about the size of a cottage, with its base at the ground level, approach from the south-east at about 'cycling speed'. Two horses grazing in the field saw the cloud coming and bolted. The cloud approached the remains of an overgrown hedge, which mainly consisted of a few medium size oak trees (about a foot and a half in diameter), and as it passed snapped one of them off at ground level, though it left the trees about ten yards farther up the hill intact. The cloud then passed off in a north-westerly direction and, crossing over the public road, passed over the hedge on the other side of it. Here it uprooted two good-sized elm trees, though here again trees quite close (about five yards) were left intact. The cloud then passed on up over the hill and disappeared." The wife and child in the cottage both said they thought there was a twisting motion inside the cloud.

Mr. Jackson goes on to say that the disturbance was evidently a very small one, as there is no trace of any effect on the barogram at the College. Also he can find no evidence of any damage other than the three trees.

The synoptic charts show that at approximately 1800 G.M.T., that is 7 p.m. B.S.T., on May 31, the time at which the phenomenon was observed, a cold occlusion passed over Ampleforth. Conditions were suitable, therefore, for such developments. Small tornadoes or whirlwinds are not so unusual in Great Britain as might be expected from the normal temperate, equable climate usually experienced in this country. As recently as September 20 during a widespread gale in England, a gust of 100 m.p.h. was registered at Scilly, and Mr. L. G. Howes, of Rhode House, Colyford, Devon, writes that "the north-north-west hurricane line of progression appeared to pass close by as I could see trees being blown down in a line as it progressed. One tree was picked up bodily and turned round." The last sentence suggests the whirling movement of the small tornado. These exceptionally heavy gusts occurred in the turbulent NW. wind which occurred after the passage of an occlusion associated with a vigorous complex depression moving east from St. George's Channel. Then there were the destructive tornadoes at Whipsnade Zoological Gardens and Sheepcot Farm, Berkshire, on Jan. 18, 1945. These developed with the passage of a line squall associated with a vigorous depression and a trough moving in a south-easterly direction over the country; a gust of 113 m.p.h. was registered at St. Ann's Head. Again on October 24 of the same year, a whirlwind occurred at Wivelsfield and Newtimber in mid Sussex causing considerable damage. A very disturbed spell of weather occurred from October 24 to 26 and on the 24th a depression moved north-east from the west of Ireland to east Scotland. The whirlwind is often preceded or accompanied by heavy rain or thunderstorms demonstrating the high degree of turbulence associated with the phenomenon.

L. F. LEWIS

An account of the damage caused by the storm of January 18, 1945, in Berkshire was received from Mr. A. R. Maxwell Hyslop, who writes as follows:—

" I have just returned from Berkshire where I was told of and saw the traces of a very extraordinary storm which took place some weeks ago. You may have full particulars of it already, but in case you have not (and this seems possible because of its curiously limited range) I think it worth writing. It seems to have been a kind of tornado in miniature. I have seen traces of the damage, from Sheepcot Farm, lying south of the main Reading–Wantage road in the civil parish, Abelicoz, of Aston Upthorpe, in a straight line across the back of Lokingdon Hill to near Cholsey Station, G.W.R. I don't know whether it did damage on either side of that stretch; but within it it lifted a large wood and corrugated iron barn off its birch foundations (at Sheepcot Farm), blew down two other solidly built barns, blew down a solid garden wall, and, which seems most surprising of all, not only uprooted a large number of trees of all sizes near Lokingdon but actually snapped off the trunks and branches—some as thick as a man's body—at heights of from 10 to 30 ft. above the ground. No lives, I believe, were lost. Apparently it happened on a stormy, but not noticeably wild day and lasted only about 2–3 minutes, and the width of the destructive passage was not more than 200–300 yards at most; some people say less ".

The date of the storm was verified by Mr. F. J. K. Cross, of Aston Tirrold Manor, who adds: " It took my farm buildings by the Reading–Wantage Road, then it devastated Lokingdon farm buildings and swept by Westfield and took the garden wall. The shearing off of the trunks and branches at roughly one height was most noticeable."

Boston Flood, 1810

The *Lincolnshire Standard* of January 1, 1944, gave some details of the great flood on November 10, 1810, at Boston, Lincs. Knowledge of the rainfall of such early years is limited, but at South Kyme, some 10 miles west-north-west of Boston the total for November 1810 was 5·94 in., which is not a very arresting figure. The graphic account describes how an extraordinarily strong ENE. gale, accompanied by continuous rain, gathered up strength in the course of the day. It was the day before full moon and a high tide was expected in the evening, but by five in the afternoon the storm was at its height and it raged for two hours. " Vessels lying in the river Witham between the bridge and Skirbeck Quarter rolled gunwhale under ",—a circumstance never before witnessed there and all the more significant when one remembers that this part of the river is about four miles from the sea. Several vessels off the coast were lost with all hands, and the flood-tide brought havoc on land. For nearly an hour the flood-tide appeared to be stationary as the waters surged relentlessly forward up the river and over the sea walls. Nothing like it within living memory had been seen before on that coast. About 8 p.m. it began to ebb. The force of the water broke down not only the ancient sea banks, but also newly constructed sea banks, inundating farm lands and buildings and dwelling houses. Many people sought refuge in the rafters of their houses until rescuers came by boat.

Mr. H. W. Wheeler, in " History of the Fens ", published in 1868, quotes a fuller account of this disaster, together with notes on earlier and subsequent floods. The description adds that the whole extent of coastal country from Wainfleet to Spalding (some 10 miles to the north and to the south of Boston) suffered considerable damage, and attributes much of the blame to " an impetuous ESE. wind that rose to a hurricane ".

M. SHIRLEY

St. Elmo's Fire in Shetland

The following report of an unusual electrical phenomenon experienced on January 5, 1943 has been received from the Keeper of the remote Whalsey Skerries Lighthouse in Shetland.

" From 5.30 to 6.30 a.m. from the tower balcony, the top of the flagpole and gutter around the dome were seen to be illuminated. An effect was also felt at finger tips, which glowed and hissed, especially if one's arm was extended over the balcony rail."

The description suggests the brush-like discharges of electricity sometimes seen on masts and yards of ships at sea known as St. Elmo's Fire.

REVIEWS

Forecasting Weather. By Sir Napier Shaw; 3rd edition, with a supplementary note on sixteen years' progress in forecasting weather, by R. G. K. Lempfert. 8vo, $8\frac{1}{2}$ in. $\times$ $5\frac{1}{2}$ in., pp. xliii + 644. London, Constable and Co. 1940. *Illus.* Price 42*s.* net.

In January, 1940, there appeared in this Magazine a review of a new treatise on terrestrial magnetism and electricity. The reviewer said " It is an imposing work (794 pages), but what makes the greatest impression on me is that practically everything described in this volume has been done since I became interested in terrestrial magnetism and atmospheric electricity in 1903 ". Yet terrestrial magnetism as a science is old, at least as old as meteorology. What was known about terrestrial magnetism and atmospheric electricity before 1903 was substantial, though it now seems small in relation to the advance made since that time.

And if we must be candid how different is the position in meteorology. The appearance of a third edition of Sir Napier Shaw's " Forecasting Weather " provides an excellent means of measuring the corresponding rate of progress. In this edition of 644 pages some 60 pages cover the " sixteen years' progress in forecasting weather " since 1923. The 1923 edition had grown by 200 pages over the 1911 edition, but in this case the change was accounted for in large measure by revision and the inclusion of additional subjects rather than by entirely new knowledge. Van Everdingen in reviewing the 1923 edition commented on the slow rate of progress of the science despite " an enormous increase in the number of reporting stations, of observed data and of wireless messages " and thought it had gained little by these crowded data for the lower strata.

The new matter in the third edition is from the pen of Mr. R. G. K. Lempfert and brings the work up to date with a clear and compact account of synoptic developments, structure of depressions, air masses and fronts. Upper air observations in forecasting, practical applications of forecasting and forecasting for long periods. Approximately half of this can be regarded as connected with the collection and distribution of information, terminology and the charting of data, and the remaining half as representing proportionately the advance in fundamental knowledge of the science. To quote Sir Napier it becomes more and more " obvious that we must not only have the pile of observations . . . but we must also find the skill to compile and co-ordinate the facts in some general description which gives the effective results and disregards the unimportant details ".

A.H.R.G.

Light and Colour in the Open Air, by M. Minnaert. Translated by H. M. Kremer-Priest and revised by K. E. Brian Jay. 8vo, $8\frac{1}{2}$ in. × $5\frac{1}{2}$ in., pp. viii + 362. London, G. Bell and Sons, Ltd. 1940. Price 15*s*. net.

This is a most delightful book which will equip the attentive reader to derive greatly enhanced enjoyment from his walks abroad, whether by noonday, evening or night, on the hill-top, the sea-shore or by pond and stream. Many of the phenomena described are of everyday occurrence, so that we scarcely give them a thought, and yet when they are pointed out they are a never-failing source of pleasure ; examples are the curious tricks of shadow cast by the sun, described in the chapter on " Sunlight and Shadows ", and of reflection, especially from slightly moving water, in " Reflection of Light ". Sunlight shining through shallow water also produces some strange effects by refraction. The reviewer has already tried many of the experiments or observations suggested, sometimes with success, sometimes without, the failures no doubt being due to lack of experience.

The finest effects arise in the atmosphere : mirages caused by the curvature of light, distortion of the setting sun, the green ray, scintillation, rainbows, haloes and coronae, the light and colour of the sky, and the illumination of clouds. These will be of especial interest to meteorologists, both for the descriptions and the theory ; in particular, the detailed account of twilight phenomena is very welcome. Some of these atmospheric phenomena are rare, but others are much more common than is generally supposed, as is shown by the records published by the Dutch Meteorological Institute.

The observer must carefully distinguish between optical phenomena which have a real existence in the outer world, and those which originate in the eye of the beholder—hence the chapter " The Eye ", which sets out some of the weaknesses and irregularities of human vision. Other subjective phenomena are dealt with in " After-images and contrast phenomena ", such, for example, as the apparent blue colour of shadows in moonlight, beats in railings and the curious effects of rotating wheels.

It is often thought that observations of optical phenomena require expensive apparatus, but the author shows that this is not so. For most purposes the eye alone is enough, though it must be trained in observation, and especially in the discrimination of fine shades of light and colour, and in the estimation of angles. For most other purposes the simplest aids are sufficient, gadgets that are available in every home or that can be made in a few minutes. Even the polarization of light, for example in a rainbow, can be seen with an ordinary piece of blackened glass, though of course a Nicol prism is better.

The book covers such a multitude of subjects that it is impossible to mention a tithe of them. Though the treatment is simple, it is quite scientific, and where necessary the author does not hesitate to use elementary trigonometry or algebra. The value of the book is greatly increased by the numerous photographs, many of them of considerable meteorological interest. Plate Vb, " Mirage along a Sunlit Wall ", showing the triple image of a boy, is one of the oddest (it reminds one of Browning's " Setebos and Setebos and Setebos "), but perhaps most remarkable is the frontispiece photograph of the Spectre of the Brocken.

C.E.P.B.

An Investigation into the variation of the lapse rate of temperature in the atmosphere near the ground at Drigh Road, Karachi, by S. Mal, B. N. Desai and S. P. Sircar. Memoirs of the India Meteorological Department. Vol. XXIX, Part 1, 4to., 12-in. × 9¼-in., pp. i+53. *Illus.* Delhi, 1942. *Rs.* 2-2 or 3*s.* 6*d.*

During October 1929, observations were commenced at Drigh Road, Karachi, to obtain records of the behaviour of temperature in the lowest layers, up to 260 ft., of the atmosphere. These observations were continued until April 1933, but unfortunately, owing to certain gaps in the work, only the period between August 1930 and July 1931 was sufficiently continuous to be of value. The data obtained during this period form the basis of this memoir, which sets out to discuss the diurnal, seasonal and annual variations of temperature and lapse rates and their fluctuations on clear and cloudy days and nights. In addition, careful attention has been given to the growth and decay of nocturnal inversions and the characteristics of the lapse rates associated with the formation of fog.

A wireless mast, offering excellent exposure, at the airship base, Drigh Road, was chosen for the investigation and louvred screens containing the thermographs erected at 4 ft., 56 ft. and 156 ft. It is most unfortunate that the additional thermographs erected at 16 ft. and 256 ft. failed to produce a sufficient continuity of records to be of any value. Especially is this so in the case of the lower instrument since it is in the very lowest layers of the atmosphere that the most rapid temperature changes are recorded.

After a clear and very concise description of the instruments used, their installation and the observation technique adopted, the memoir proceeds to present a large amount of data either as observed or reduced to a form more suitable for the purposes of the work. Detailed records are thereby made available, but in some cases, as in the presentation of graphical data the months of January, April, July and October only are chosen since they are considered representative of the winter, pre-monsoon, monsoon and post-monsoon seasons.

Commencing with the hourly values of temperature at different heights, the work proceeds to careful and instructive analyses of the mean hourly lapse rates, the extreme values of the lapse rates and the frequency of the occurrence of lapse rates of various magnitudes. Some very definite and almost startling illustrations of the well known fact that lapse rates near the ground bear little or no relation to the lapse rates in the free atmosphere are given.

Whilst the various elements analysed have in most cases been related to conditions on cloudy and cloudless days, it is felt that much more of the data could have been correlated with more of the atmospheric elements.

The discussions regarding the development of stratus cloud over Karachi during the monsoon months and the lapse rates associated with the development of fog are illuminating and should prove of immediate practical value.

The memoir contains much useful data which will no doubt prove of interest to any investigator conducting research in the same field.

L.G.C.

Methods in climatology, by Victor A. Conrad. 8vo., 9 in. × 6 in., pp. xx + 228. *Illus.* Cambridge, Mass. Harvard University Press and London, Oxford University Press. 1944. 4 dollars.

Because climatological observations are so easy to make and—superficially—so easy to discuss, climatologists have in the past been for the most part content with a superficial study of them by means and extremes. Frequency tables, even of individual elements, are relatively rare in climatological literature ; this may be due to the space they occupy, but even that simple index of variability, the standard deviation (see *Met. Mag., London*, **76**, 1947, p. 12) has been very slow to make its way. In the last few years however climatologists have become more statistically minded, and an evident need has grown up for a textbook on the application of statistical methods in climatology.

Dr. V. Conrad has now covered the whole field in a rapid and vigorous survey. He begins with the nature and organization of meteorological observations ; then follow two chapters on the simpler statistical devices—means, quartiles, standard deviation, coefficient of variation and relative variability. The last mentioned, defined as 100 × mean deviation/mean, has been widely used in British work on variability of rainfall. The account of random sampling is of interest, though the method when applied to duration of rainfall in temperate latitudes does not give such good results as in the example quoted for Batavia. The chapter on curve fitting includes the straight line, logarithmic and exponential curves and the second order polynomial. The author regards the calculation of constants by the method of least squares as unnecessarily laborious and gives instead a method of approximation, but the reviewer thinks that if common sense is applied to the arithmetic, the least-square method is little if any more laborious, while it is definitely preferable on technical grounds. This section ends with a chapter on harmonic analysis especially as applied to monthly and hourly data.

The second part of the book describes methods of representing some of the characteristics of different elements, either for practical applications, as accumulated temperatures or " degree-days ", or for purposes of study. The proposed method of computing resultant winds from directions only, by assuming that the mean velocities from different directions are proportional to the frequencies, is interesting but unsound. The reviewer found that if the distribution of winds is normal, the theoretical relationship between frequency and velocity is approximately that mean velocity from any one direction is proportional to the frequency raised to the power of 0·3. The frequencies and mean velocities of surface winds at Sealand in January showed the same relationship. This does not differ very much from the assumption that the mean velocity is the same from all directions. Rather curiously, in his example for Batavia (p. 104), the author, while implying that he uses the frequency-velocity relation, actually calculates the resultant on the basis that the mean velocities from all directions are the same, which is probably why the result comes out so well. On p. 105 it is stated that the number of calms should be excluded in deriving the resultant wind; surely this is incorrect even though in an extreme case, such as an Alpine valley, it may appear to have some purpose. It should be made clear that the velocity equivalents quoted for the Beaufort scale refer to anemometers at a height of 6 metres.

Part III deals with the comparison of neighbouring stations and reduction to standard periods. Of interest here are the criteria of " relative homogeneity " for testing whether either of two synchronous series which it is proposed to compare is affected by some non-natural factor such as a change of site. This leads on to a chapter on total and partial correlation, various graphical methods of representation such as streamlines of wind, and numerical methods of characterising different climates. Finally the author sets out briefly his views on how a monograph on the climate of a region or a place should be written.

The book will be of great value as a simple non-technical introduction to the statistical treatment of climatological data, and it is supplemented by extensive footnote references (in which, however, British authors are rather conspicuously few; E. G. Bilham, for example, has made some quite important contributions to the subject, but his name does not appear). Each specialist will think that the treatment of his particular subject is too brief but on the whole the balance is fairly maintained. There is, however, one important detail, namely, the sequence of weather, which is almost entirely neglected, and this at least should be remedied in a future edition.

C.E.P.B.

RAINFALL OF JANUARY, 1947

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	1·48	80	*Glam.*	Cardiff, Penylan ..	3·32	90
Kent	Folkestone Cherry Gdns.	2·44	108	*Pemb.*	St. Ann's Head ..	5·96	171
,,	Edenb'dg, Falconhurst	3·44	140	*Card.*	Aberystwyth	2·87	89
Sussex	Compton, Compton Ho.	4·01	126	*Radnor*	Bir. W.W., Tyrmynydd	6·16	98
,,	Worthing, Beach Ho.Pk.	2·51	108	*Mont.*	Lake Vyrnwy.. ..	6·68	121
Hants.	Ventnor, Roy. Nat. Hos.	3·10	121	*Mer.*	Blaenau Festiniog ..	10·16	124
,,	Fordingb'dg, Oaklands	3·32	120	*Carn.*	Llandudno	5·42	225
,,	Sherborne St. John ..	2·48	106	*Angl.*	Llanerchmedd ..	5·46	173
Herts.	Royston, Therfield Rec.	1·49	86	*I. Man*	Douglas, Boro' Cem...	4·91	147
Bucks.	Slough, Upton ..	1·74	94	*Wigtown*	Pt. William, Monreith	5·20	159
Oxford	Oxford, Radcliffe ..	1·37	76	*Dumf.*	Dumfries, Crichton R.I.	6·00	186
N'hant	Wellingboro', Swanspool	1·79	97	,,	Eskdalemuir Obsy. ..	6·53	121
Essex	Shoeburyness	2·30	170	*Roxb.*	Kelso, Floors	1·87	107
Suffolk	Campsea Ashe, High Ho.	1·90	104	*Peebles*	Stobo Castle	5·54	185
,,	Lowestoft Sec. School	1·95	117	*Berwick*	Marchmont House ..	2·42	108
,,	Bury St. Ed., WestleyH.	1·69	94	*E. Loth.*	North Berwick Res. ..	2·04	119
Norfolk	Sandringham Ho. Gdns.	1·95	100	*Midl'n.*	Edinburgh, Blackfd. H.	2·22	126
Wilts.	Bishops Cannings ..	1·94	84	*Lanark*	Hamilton W.W., T'nhill	3·25	98
Dorset	Creech Grange ..	3·77	116	*Ayr*	Colmonell, Knockdolian	4·84	112
,,	Beaminster, East St...	4·07	117	,,	Glen Afton, Ayr San.	6·70	131
Devon	Teignmouth, Den Gdns.	4·17	143	*Bute*	Rothesay, Ardencraig	5·78	128
,,	Cullompton	5·05	156	*Argyll*	Loch Sunart, G'dale..	7·78	110
,,	Barnstaple, N. Dev. Ath.	3·24	99	,,	Poltalloch	5·39	107
,,	Okehampton, Uplands	5·96	117	,,	Inveraray Castle ..	7·36	90
Cornwall	Bude School House ..	2·92	96	,,	Islay, Eallabus ..	4·17	89
,,	Penzance, Morrab Gdns.	5·24	138	,,	Tiree	3·80	89
,,	St. Austell, Trevarna..	4·69	110	*Kinross*	Loch Leven Sluice ..	4·15	132
,,	Scilly, Tresco Abbey..	4·57	146	*Fife*	Leuchars Airfield ..	3·43	188
Glos.	Cirencester	2·26	90	*Perth*	Loch Dhu	12·09	133
Salop	Church Stretton ..	..	..	,,	Crieff, Strathearn Hyd.	5·83	145
,,	Cheswardine Hall ..	1·85	84	,,	Blair Castle Gardens..	5·48	164
Staffs.	Leek, Wall Grange P.S.	2·02	70	*Angus*	Montrose, Sunnyside	3·83	192
Worcs.	Malvern, Free Library	2·15	97	*Aberd.*	Balmoral Castle Gdns.	3·38	122
Warwick	Birmingham, Edgbaston	2·11	104	,,	Aberdeen Observatory	4·56	209
Leics.	Thornton Reservoir ..	1·77	89	,,	Fyvie Castle	3·97	168
Lincs.	Boston, Skirbeck ..	1·95	120	*Moray*	Gordon Castle ..	1·69	84
,,	Skegness, Marine Gdns.	1·56	90	*Nairn*	Nairn, Achareidh ..	..	..
Notts.	Mansfield, Carr Bank	2·49	116	*Inv's*	Loch Ness, Foyers ..	3·07	73
Ches.	Bidston Observatory	1·93	91	,,	Glenquoich	9·25	67
Lancs.	Manchester, Whit. Park	2·31	92	,,	Ft. William, Teviot ..	8·55	88
,,	Stonyhurst College ..	3·65	85	,,	Skye, Duntuilm ..	3·56	67
,,	Blackpool	3·26	119	*R. & C.*	Ullapool	2·43	54
Yorks.	Wakefield, Clarence Pk.	2·67	139	,,	Applecross Gardens ..	4·95	90
,,	Hull, Pearson Park ..	2·06	114	,,	Achnashellach ..	5·89	65
,,	Felixkirk, Mt. St. John	2·67	133	,,	Stornoway Airfield ..	2·75	56
,,	York Museum ..	2·47	140	*Suth.*	Lairg	2·49	76
,,	Scarborough	1·99	100	,,	Loch More, Achfary ..	4·79	66
,,	Middlesbrough ..	·99	62	*Caith.*	Wick Airfield ..	2·96	120
Norl'd	Newcastle, Leazes Pk.	1·48	75	*Shet.*	Lerwick Observatory	3·77	88
,,	Bellingham, High Green	4·17	146	*Ferm.*	Crom Castle	1·91	57
,,	Lilburn Tower Gdns.	2·79	135	*Armagh*	Armagh Observatory	1·51	60
Cumb.	Geltsdale	2·34	84	*Down*	Seaforde	5·10	162
,,	Keswick, High Hill ..	7·05	140	*Antrim*	Aldergrove Airfield ..	2·95	109
,,	Ravenglass, The Grove	4·41	132	,,	Ballymena, Harryville	3·70	100
West.	Appleby, Castle Bank	4·28	134	*Lon.*	Garvagh, Moneydig ..	5·01	146
Mon.	Abergavenny, Larchfield	4·09	121	,,	Londonderry, Creggan	3·14	87
Glam.	Ystalyfera, Wern Ho.	5·46	86	*Tyrone*	Omagh, Edenfel ..	3·78	107

WEATHER OF JANUARY, 1947

January was an unusually stormy month in the Atlantic, especially during the first half, when deep depressions followed irregular tracks south of Greenland and Iceland. Pressure fell below 948 mb. south-west of Reykjavik on the 3rd and in the Atlantic west of the British Isles on the 5th and 8th, and below 940 mb. south-west of Greenland on the 10th, in the centre of an enormous depression which filled almost the whole North Atlantic. Later in the month the depressions became smaller and less deep, and at the same time an intense anticyclone moved from northern France to Scandinavia where it remained until the end, extending its influence over Great Britain most of the time. On the 24th and 25th it was actually centred over northern Scotland, where pressure exceeded 1040 mb. on the 24th. By the 27th a definite easterly current had developed over England and very cold weather set in. Taking the month as a whole, mean pressure exceeded 1025 mb. over Finland and northern Russia, and was below 990 mb. over southern Greenland and the ocean to the south-east. Pressure was more than 15 mb. above normal over northern Norway and more than 10 mb. below normal over much of the North Atlantic.

The weather was characterised by frequent gales from the 1st to 17th, a very mild spell around the middle of the month and severe conditions during the last week. On the 15th temperature rose to 56°F. at Prestwick airport on the west coast of Scotland and on the 16th to 57°F. at numerous inland stations in England, while minimum temperatures did not fall below 50°F. at a number of places on the 15th and 16th. On the 20th pressure became high over Scandinavia and high pressure persisted there until the end of the month. From the 25th onwards depressions passed east to the south of the British Isles and cold easterly winds set in over the United Kingdom, with snow at first in east and south-east England, later extending over much of the country. At the Scilly Isles level snow lay to a depth of 7 in. on the morning of the 30th, a most unusual occurrence in these islands. The cold was intense over England and Wales during the last week; the deviation from the average for the week beginning on the 26th was −11·6°F. On the morning of the 30th temperature in the screen fell to −5°F. at Writtle in Essex.

The general character of the weather is shown by the following table:

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days, difference from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F.	%		%	%
England & Wales	57	−6	−3·7	113	−1	103	20
Scotland ..	56	8	−1·7	116	−2	108	17
Northern Ireland	54	18	−2·5	103	−1	82	16