

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

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FOREWORD

BY THE DIRECTOR OF THE METEOROLOGICAL OFFICE

The publication of the Meteorological Magazine ceased with the issue for June, 1940. The deciding factor was not so much the need for saving paper as the urgent necessity at that time of conserving manpower. The nation could not afford the time of the type-setters and other operatives involved in producing a journal of this kind.

It was not until publication had actually stopped that the value of the *Meteorological Magazine* was fully realised. We had not appreciated the important part it played as a means of keeping us informed of technical developments, as a link between Headquarters and outstations, and as a forum for the discussion of interesting technical points.

The zeal of the Editor, Dr. Brooks, did not allow the *Meteorological Magazine* to suffer complete eclipse, and a typescript edition, complete with diagrams and photographs, maintained a limited circulation. Some of the most interesting features which appeared in the "emergency" edition will be reproduced in the early numbers of this 1947 volume.

With the resumption of normal publication it is hoped not only to regain the original advantages which the magazine provided, but to make it of even greater value and interest than before the war. Articles will be included from time to time dealing with international meteorological matters, which will enable the meteorologist to appreciate how his own work fits into the general world pattern. There will be authoritative articles in simple non-technical language on the work of different sections of the Meteorological Office, and on interesting phenomena which occur from time to time. Regular accounts will also be given of the activities of the Meteorological Research Committee with an outline of the more important papers discussed at its meetings. It is further proposed to include a certain number of original papers on investigations carried out in the Meteorological Office, although the longer papers of this type will continue to be published as *Geophysical*

Memoirs and *Professional Notes* as in the past. Articles will be given describing important developments, such as the recent decision to establish a network of weather reporting ships in the North Atlantic, and explaining the part which the Meteorological Office will play in the scheme.

Although the *Meteorological Magazine* has hitherto been intended primarily for the staff of the Meteorological Office and its collaborators, it is hoped that it will find many regular readers amongst those who worked with us for the first time during the war, and also amongst those members of the community at large who, while having no official connexion with the office, are yet interested in the weather and the State weather service.

N. K. JOHNSON

PRESTWICK ATLANTIC TERMINAL

BY C. V. OCKENDEN, B.SC.

“ . . . Well, that’s about all, Skipper. Apart from the cold front in Zone 4 it should be a pretty good trip tonight. Oh ! while I think of it, would you mind asking Montreal if they could let us have three or four purple pencils ? ” Trivial if you like, but typical of Prestwick airport during the war. Complete understanding existed between the meteorologist, the captain of the B.O.A.C. Liberator and the terminal on the other side of the Atlantic. And one knew that within 36 hours there would be a little parcel in the “ debriefing ” office, containing purple pencils which it would have taken months to obtain from stationery stores in Great Britain.

So great was the volume of air traffic at Prestwick that there were in fact three meteorological offices within the boundary of the airport. One was located in the Terminal building to give reports and forecasts to the local flying control, to “ debrief ” arrivals and do the normal observational, pilot-balloon, and climatological work associated with an outstation ; another was with the Air Transport Auxiliary Headquarters and had to provide route forecasts at a moment’s notice for almost any route to almost any airfield in the British Isles (for every “ delivery ” aircraft arriving from Canada had to be flown away to the place where it was most required at the earliest moment) ; whilst the third office was housed with Signals and Transatlantic Control in a small country mansion called “ Redbrae ” a few hundred yards from the main Terminal building. The three offices were of course linked by ’phone and teleprinter so that their activities could be easily controlled by the senior forecaster on duty. In the following account it is to the work of the “ Redbrae ” Type I office that reference will usually be made.

In 1940 the need for more and yet more aircraft in order to win the war became very obvious. The Battle of Britain was on, production of aircraft in this country was far from sufficient and there was a serious shortage of shipping for transporting crated aircraft and spares across the Atlantic whilst losses by enemy submarine activity were mounting. Thus, despite the fact that up to that time the crossing of the North Atlantic had been considered an exceptional feat of airmanship, it was decided to start a regular

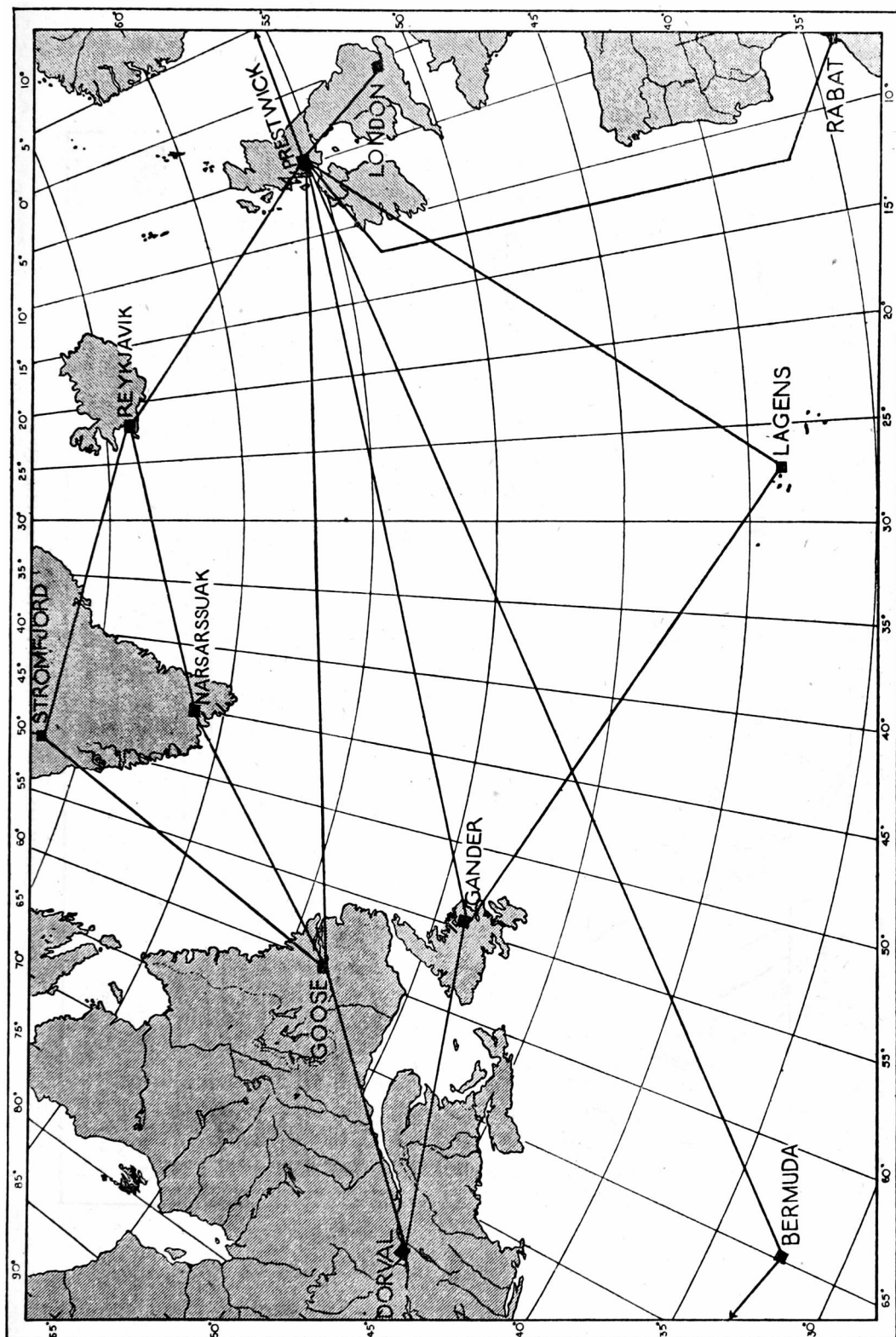


FIG. 1—CHART SHOWING ATLANTIC AIR ROUTES (1944)

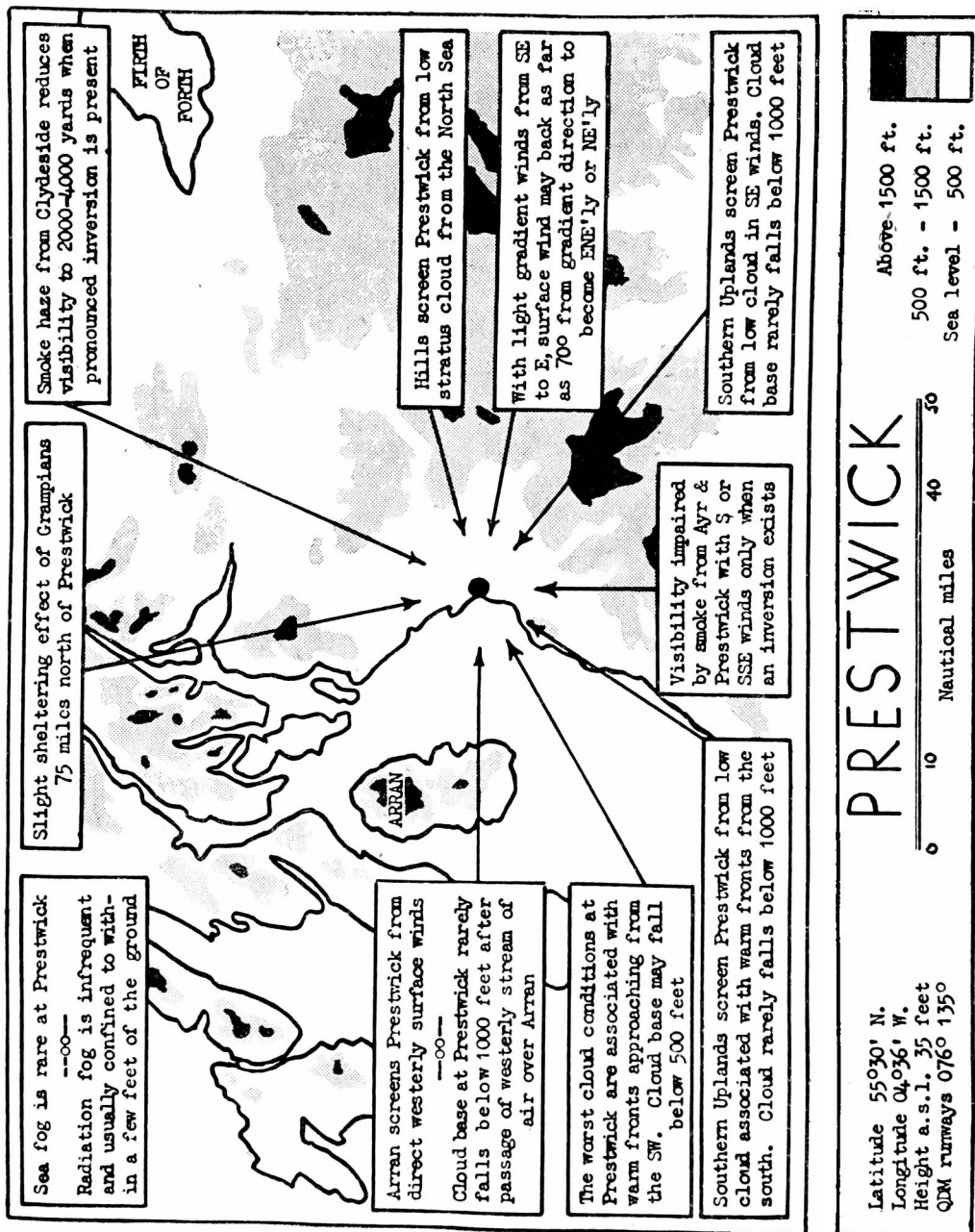


FIG. 2—CHIEF METEOROLOGICAL FEATURES OF PRESTWICK

air ferry service and to deliver by air to this country the much needed aircraft which were being built in the United States, in particular, Lockheed Hudsons required for Coastal Command. The organization built up was known as ATFERO and the first delivery flight of seven Hudson aircraft was made on November 10, 1940. Flying the Atlantic soon became a daily occurrence; in November 1943, 100 Fortresses were flown over in one day, and in one week in the summer of 1944, 525 aircraft from overseas (either direct from Canada or Bermuda or via Iceland or north-west Africa) were controlled from Prestwick. The main terminals for the direct crossing were Gander in Newfoundland and Prestwick on the Ayrshire coast. The advantages of Prestwick as the eastern terminal were threefold. It was out of the way of bomber and fighter bases, it involved no crossing of high ground and the number of occasions when it becomes unfit for flying because of bad weather is lower than at almost any airfield in the British Isles. In particular, fog is very rare. Fig. 1 shows the positions of Prestwick and Gander as terminals of the Atlantic Air Routes and Fig. 2 shows diagrammatically the chief meteorological features of Prestwick. It need hardly be said that the location of the terminals was a military secret during the early phases of the war, but the ban was lifted in October 1943.

It was in December 1940 that it was decided to deliver Catalina aircraft to this country by flying them from the States to Bermuda and thence to Greenock (later Largs was used, because visibility was better, there was no balloon barrage and it involved a much shorter journey to Prestwick for passengers and freight). The Battle of the Atlantic had made it necessary for us to have a large number of these long-range seaplanes for convoy duty and to hunt out enemy submarines. These flights, involving a non-stop ocean crossing of about 3,400 miles, were controlled by Prestwick T.A.C. (Transatlantic Air Control), and as the actual time of flight was not less than 20 hours and sometimes amounted to 24-26 hours it will be appreciated that the advisory route forecast sent to Bermuda from Prestwick called for a lot of hard thinking. A forecaster was usually sent to Greenock to interview incoming crews and pass the information by telephone to "Redbrae".

Until the summer of 1941 crews which brought over delivery aircraft returned to Canada by boat, taking anything from 10 to 14 days, with the result that aircraft were being held up because of shortage of pilots, navigators and radio men. It was, therefore, decided to institute the Return Ferry Service (R.F.S.) and seven Liberators (three of which had already been flown over as deliveries) were put into operation by British Overseas Airways; thus was started the first regular two-way all-the-year-round cross-Atlantic air service for passengers and freight. In the autumn of 1941 a new airport at Dorval near Montreal was completed, and in a relatively short time Prestwick and Dorval came to be the main terminals for the B.O.A.C. service, short stops at Gander being made when necessitated by adverse weather or by strong head winds on the Atlantic. By 1942 the idea of flying short- and medium-range bomber and fighter aircraft to this country was developed using Greenland and Iceland as stepping-stones and the great new airfield near the mouth of Goose River in Labrador was completed. This base was soon to become one of the busiest airports in the world, and on account of its clearer skies it became a most useful alternative terminal for B.O.A.C. east-west flights from Prestwick. An enormous

amount of traffic grew up on the northern route, and Prestwick was at times hard put to it to supply forecasts for, and to receive, all the aircraft which arrived from Iceland as well as from Gander, Goose and Montreal. It may be of interest to recall that on March 1, 1943 a glider towed by a Dakota made the flight from Montreal to Prestwick over this route, and thus set up a world record for distance for a glider carrying freight. Special forecasts had to be supplied for the flight because of the importance of vertical currents and temperature changes, and the accuracy of the forecast of upper winds for the last leg was such that the glider touched down at Prestwick from Iceland almost exactly on schedule. In addition to the weather hazards which in winter were often very great, especially on the Labrador to Greenland and Greenland to Iceland legs, communication difficulties were fairly frequent owing to radio "black outs" associated with aurora: in fact at times it was impossible to obtain vital weather information reliably for periods of two or three days at a time. The Americans set up radio-teletype links between Goose, Narsarssuak (Greenland), Meeks Field (Iceland) and Prestwick and the close co-operation which existed between both services ensured that all data was exchanged regardless of the route by which it was received.

Prestwick was by now (1942) despatching aircraft to north-west Africa—to Rabat/Sale, Marrakesh or Ras-el-ma; delivery Liberators and Fortresses were being flown on to the Middle East and India and a regular mail service was established between Prestwick and Rabat and later extended to Lagens. This involved forecasters at "Redbrae" studying conditions in the Mediterranean as well as the Atlantic, and a daily exchange of forecasts with Rabat had to be instituted. For security reasons the route to north-west Africa lay along 12° W.; forecasting for a southbound aircraft was a much easier proposition than for a westbound, because in general the trip could be made without having to ascend to any great height to avoid icing. However it meant that attention had to be paid every evening both to snow blizzards in Newfoundland and the possibility of sandstorms in Africa—for in the event of the African terminal being affected, there existed no nearby alternative airfield.

When Transatlantic Air Control was set up it was little thought that its activities would include looking after a route to Moscow, but on October 21, 1942, a B.O.A.C. Liberator took off on the first flight eastbound. A large amount of organizational work had been performed in the way of explaining our codes and procedure to our Russian allies, and, since it was too dangerous to fly direct, the route chosen took the aircraft as far north as the Arctic Circle. A point-to-point W/T channel was opened up with Moscow, daily forecasts were exchanged for a considerable time and many flights in both directions were carried out before it became strategically possible to open up the longer but meteorologically more favourable route through the Mediterranean. The reception hall of the airport was indeed one of the most cosmopolitan places in the world about this time, and in December 1942 their Majesties the King and Queen made a visit of inspection. The King was particularly interested in the meteorological briefing of a crew setting off for Montreal, and the photograph reproduced in Fig. 5 is probably unique, in it Her Majesty is being shown the pilot-balloon method of obtaining upper winds.

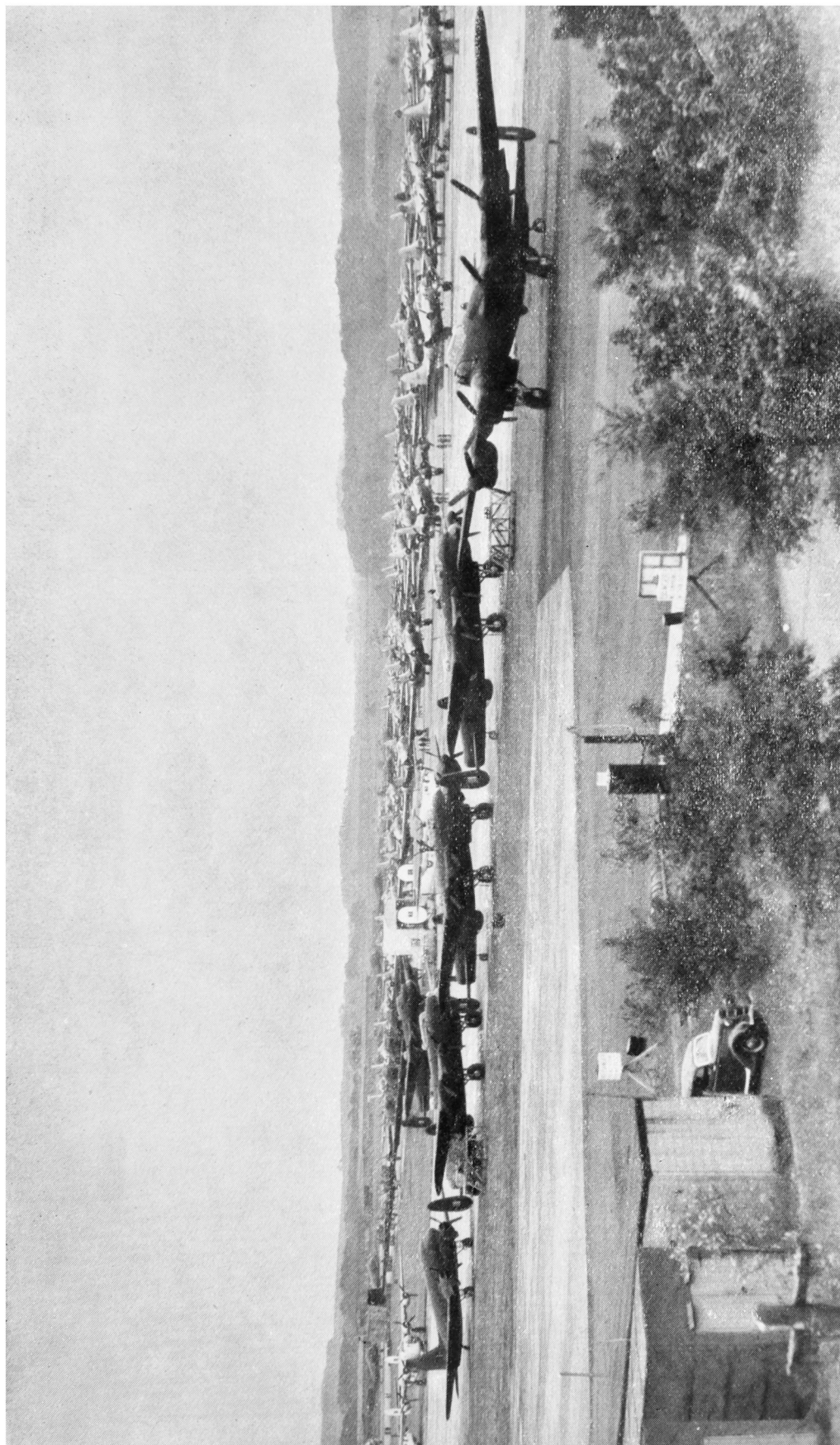
Late in 1943 aircraft began to arrive at Prestwick from Lagens in the Azores as a result of operation "Alacrity" in which a temporary runway consisting of about 1,000 tons of metal Summerfelt tracking was laid down in the incredibly short time of 48 hours. Within a few months B.O.A.C. westbound aircraft were being despatched from Prestwick via Lagens on occasions when strong head winds over the Atlantic and bad weather in Iceland made both the direct crossing to Gander and the northern route inadvisable.

Thus, by 1944 aircraft of almost every type—Hudsons, Fortresses, Mitchells, Marauders, Bostons, Venturas, Skymasters, Dakotas, Lightnings, were pouring into Prestwick airport from Dorval, Gander, Goose, Reykjavik or Meek's Field, Bermuda, Lagens, and north-west Africa, and Controllers and Met. forecasters were saddled with the tremendous task of ensuring the safety, as far as it lay within their powers to do so, of all aircraft flying these diverse routes. In one sense the meteorologist benefited by the numbers because each machine in flight represented a potential "reporting station", and, with the dearth of surface weather reports, the logs handed in by captains and the few reports they were allowed to send by W/T whilst in flight were invaluable. By their aid it was possible for the terminals to correct the estimated positions of fronts in mid Atlantic and to follow pretty closely any changes in speed and characteristic from one synoptic chart to the next. Needless to say, the "first-timer" pilot on an eastbound flight was often not over scrupulous about turning-in a good description of the weather experienced during his flight, but the logs received from the regular Liberators on the B.O.A.C. Ferry service were most complete and included observations made every hour with notes of any unusual phenomena. The close co-operation given by some of the veterans of the R.F.S. will always be a pleasant memory; although they can be numbered on both hands, they had made altogether 1,000 Atlantic crossings by September 1944, and several Captains had individually completed, or were coming up to, 100 crossings by Christmas 1944. In 1942 one crew flew the Atlantic five times in nine days in the same Liberator aircraft.

Whatever the route, the procedure for supplying meteorological information was the same and was known as MOOF—Meteorological Organization for Overseas Flights. The Atlantic was divided into zones of 5 degrees of longitude; Prestwick terminal supplied an advisory forecast for the five zones from 5°W. to 30°W. whilst Gander did the same for the five zones between 30°W. and 55°W. In general, flights were made by night so that stellar navigation could be used, and every morning coded forecasts giving anticipated conditions for the following night were exchanged by direct W/T point-to-point channel; this channel, incidentally, also carried the fundamental synoptic data forming the basis of complete synoptic charts prepared four times daily. The forecast, which was of an "advisory" nature, was in a 5-figure code and gave anticipated weather, cloud base and tops, icing information and winds for 5,000, 10,000, 15,000 and 20,000 ft. for each "zone" in the sender's control, together with expected conditions at the terminal airfield and four or five alternative airfields. By about noon the forecaster at Prestwick was able to have ready a complete rough draft of expected conditions for the whole flight together with a pictorial diagram, and the Captain, Second Pilot, Navigator and W/T Officer of the westbound

Liberator attended the office with the B.O.A.C. representative for a "preliminary briefing". The heights at which it seemed best to fly in various zones were discussed and a rough estimate of the time of flight worked out. An average head wind of 30 knots meant very careful consideration being given to the weather expected at Gander and Goose; if these could not be forecast as being "fit" with a fairly high degree of confidence, the Captain would usually decide against a direct flight and go via Iceland or the Azores (Lagens). On many occasions, however, it was possible to recommend a rhumb line course from Prestwick to Halifax or a "composite" course via a point about 60°N. 40°W. to Goose, depending on the position of an Atlantic depression. A great deal of attention was paid to the construction of upper-air charts and, with the increase of data derived from radio-sonde ascents in Great Britain, Iceland, Greenland and three or four U.S. cutters at more or less fixed positions in the Atlantic, it was possible at a fairly early stage to produce a chart for 10,000 ft., which proved extremely useful. Later, contour charts for 750 mb. and 500 mb. were substituted, and by 1944 the confidence of R.F.S. pilots in the upper winds given for the crossing was increased to such an extent that an additional 2,000 lb. pay-load was being carried whilst delays on schedule were reduced to a very small percentage. The actual route and time of take-off having been decided at the midday conference, a signal would be sent to Dorval requesting any amendments to their forecast to reach Prestwick by a stipulated time, and on receipt of any amendment which might cause a radical change of plan, the B.O.A.C. representative was informed and arrangements made for another briefing. Any minor amendments were incorporated in the typed documents handed to the Captain at the final briefing which took place one hour before take-off. These consisted of 15 or so sheets (giving forecasts for zones and terminals), a tracing of the "actual" synoptic chart for 1200 G.M.T. and a "composite" chart, all stapled together in a stout cover. The "composite" chart was very popular amongst transatlantic pilots for it portrayed the positions of lows and highs and fronts in each zone as they were expected to be positioned by the time the aircraft reached that zone. It was realised that there are obvious theoretical objections to this method of presentation, but there is no doubt that it helped the pilot to get a better appreciation of the development of the situation between time of take-off and touch-down than an ordinary "preparatic" chart drawn for a fixed hour.

Immediately the Liberator aircraft was airborne, a signal was flashed to the Canadian terminal giving the E.T.A. (expected time of arrival) and "point of no-return" (the furthest point from which the aircraft could if necessary return to its base of departure having regard to the quantity of fuel carried, the load and the winds it would encounter) and the forecaster compiled a coded message to the meteorologist at the destination giving details of the forecast carried by the aircraft. The purpose of this was to enable the Canadian service to send any important amendments to the aircraft on the last half of the 10-hour (approx.) crossing; for instance, if the wind at 5,000 ft. was given as 270° 35 knots and it became evident that in the last two zones a more probable value was 300° 28 knots, a simple code introducing "add 30 subtract 7" indicated to the pilot that he should add 30° to the direction and subtract 7 knots from the speed, whilst it gave no information which could be of much use to the enemy. It must be remembered



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FIG. 3—PRESTWICK LANDING FIELD ON A BUSY DAY



Reproduced by the courtesy of Scottish Aviation Ltd.
FIG. 4—GENERAL VIEW OF PRESTWICK AND THE AIRPORT

that every single figure of all meteorological coded messages exchanged by wireless had to be encyphered or decyphered, and this added enormously to the work of assistant staff on both sides of the Atlantic, also, radio fade-outs being fairly frequent at some periods, a good deal of skill was often called for in patching up corrupt messages especially if there happened to be an inexperienced W/T operator on duty at the sending or receiving signals office. When conditions became really bad, messages were cabled. Soon after the nightly departure of the westbound return Ferry aircraft (frequently three or more took off at intervals of half an hour), the forecaster would begin to receive advices from Dorval, Gander or Goose of the departure of batches of eastbound delivery aircraft and so throughout the night he was kept busy drawing up and analysing current charts, sending routine messages to other North Atlantic bases, advising Controllers of probable developments in regard to conditions at United Kingdom bases, sending amendment messages to aircraft in flight, answering their requests for specific information and keeping an eye on the half-hourly broadcasts of "actual" conditions transmitted from Prestwick for several alternative airfields in Great Britain. Meanwhile, the westbound aircraft, with its load of passengers who had had supper in Scotland and would have breakfast in Newfoundland, was not forgotten, and when, some time after dawn, the signal was received giving its time of arrival the forecaster went off to his breakfast, tired but with a feeling of professional pride that another westbound flight had been accomplished within 20 minutes or so of the estimated flight time.

The full story of the activities of Prestwick airport in wartime would be a long one. "Atlantic Bridge" (H.M. Stationery Office, London, 1945) ends with these words: "The Atlantic air is now mastered: its history is only beginning". During the coming year the establishment by international agreement of several ocean weather stations will be effected and many a wartime pilot will sometimes give a thought to the days when Gander and Prestwick formed the sole supports of the one-span bridge which carried so much vital traffic between two hemispheres.

THE NUMERICAL BASIS OF CLIMATE

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

Part I. The Significance of Averages

The number of meteorological observations even for a single station which has been in operation for many years is so great that it is not humanly possible to comprehend the whole. Hence the practice has grown up of representing them by a few figures, mainly the arithmetical means for the months and year, and, for some elements, the extremes also. In view of the importance which climatologists attach to an "average", it may be of interest to inquire briefly into its meaning.

If we look at a collection of averages of temperature for the British Isles, we find for example that St. Mary's in the Scilly Isles and Birmingham in the heart of England have nearly the same average temperature at 1300 G.M.T., but this does not necessarily mean that the conditions of temperature at that time are the same at these two places—far from it. To bring out the differences which may be masked by similarity of average, Table I shows the

frequency of temperatures at each place in two-degree steps during April in the ten years 1928-37. A glance at the table shows that while temperatures in the Scilly Isles tend to be uniform, clustering closely round the average, those at Birmingham are much more variable—a fact which is of course directly explained by the difference between the thermal properties of sea and land.

TABLE I—TEMPERATURE (° F.) FREQUENCY PER 10 YEARS AT 1300 IN APRIL

Note : “ 37° ” means the step from 36·0° to 37·9° F.

	37°	39°	41°	43°	45°	47°	49°	51°	53°
Scilly	0	0	2	1	10	25	52	76	75
Birmingham ..	5	14	10	26	36	36	39	33	29
	55°	57°	59°	61°	63°	65°	67°	69°	71°
Scilly	45	12	1	1	0	0	0	0	0
Birmingham ..	32	21	6	4	4	4	0	0	1

The range at Scilly is from about 41° to 61° F. or 20°; that at Birmingham from about 37° to 71° F. or 34°, but the latter is obviously greatly extended by the isolated reading of 71° F. As a better, but still rough, measure of variability we may take the range of values within which half the observations lie. These are known as the lower and upper quartiles. We find that at the Scilly Isles there is an even chance that the temperature on any one occasion will lie between 49·4° and 53·5° F., while at Birmingham the corresponding limits are 45·1° and 53·7° F. Similarly, we can calculate the deciles or ten-percentiles, so called because ten per cent. of the values lie below the lower decile and ten per cent. above the upper decile. These are particularly useful when we wish to compare the extremes in series of very different numbers of observations. For example, in marine data we may have a thousand ships' observations in one “square” (of five degrees of latitude by five degrees of longitude) and only a hundred in a neighbouring square. Other things being equal, the extremes of, say, sea temperature in the former are likely to be greater than in the latter simply because there are ten chances to one of picking up an unusually high or low figure. On the other hand the deciles are directly comparable, and they have the additional advantage of ruling out “mistakes”. In an element with a comparatively small range of variation the observed extremes may quite likely be due to errors of observation, and the omission of ten per cent. at each end rules out such errors.

In future, in accordance with the usual statistical procedure, we shall refer to the average as the mean. Other statistical terms in frequent use are the median and mode. The median is simply the middle observation, so that any single reading is as likely to be above as below the median. The mode is the most frequent value. When the observations are symmetrically distributed about the mean, the median and mode coincide with the mean, but if the range extends much further above than below the mean so that the distribution is asymmetric or skew with a long tail to the right, then both median and mode will be below the mean.

The median is readily found by counting,* but it is difficult to find the mode by inspection. Most series of meteorological observations are, by statistical standards, rather short, and the distribution is irregular. In such cases we can plot the frequencies as a graph and draw a smooth curve through them noting the point at which the curve reaches its highest level, but another way in suitable cases is given by the simple expression

$$\text{Mode} = \text{Mean} - 3 (\text{Mean} - \text{Median}).$$

In some distributions there is more than one mode; for example, individual cloud amounts in western Europe have two, at 0 and 10 tenths, and the mean cloud amount is almost the least frequent value.

The various statistical measures in our series for Scilly and Birmingham are as follows :—

Table II

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

The observations are shown graphically in Figs. 1 and 2. In Fig. 1 the

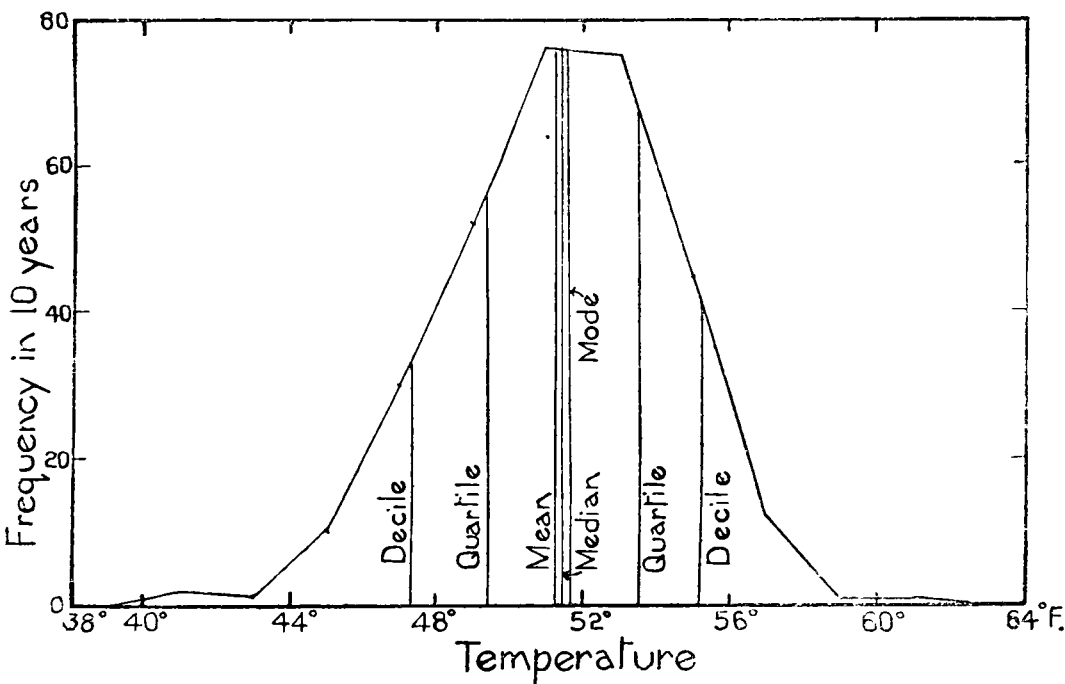


FIG. 1—FREQUENCY DISTRIBUTION 1300 TEMPERATURE, SCILLY, APRIL

* In computing the median, quartiles, etc., from a frequency table such as Table I, the assumption is made that in any one cell the values are uniformly distributed. For example, in 300 observations the median lies midway between the 150th and 151st from the left-hand margin. At Scilly there are 90 observations less than 49·95°F. and 76 from 49·95 to 51·95°F. The figure of 49·95 lies between the 90th and 91st observation and the mean of the 150th and 151st is taken as 49·95 + 2 × 60/76 = 51·5°F.

frequencies for Scilly are plotted as points, the abscissa being the mid temperature of the step and the ordinate the frequency. This type of diagram gives a good representation of the frequency distribution where three or more consecutive plotted points lie near a straight line, but it is liable to give the impression that near the centre of the diagram the frequency is lower than it actually is. For example, if figures had been available for the step 51° – 53° F., they would probably have shown a peak frequency above 80 in 300.

In Fig. 2 the frequency of values in each step at Birmingham is represented by a horizontal line drawn across the width of the step; this is known as a frequency polygon or "histogram". It is a more accurate representation of the statistics than is the type shown in Fig. 1, but since it takes no account of the probable distribution inside each step, it is less suggestive of the true form of the frequency curve.

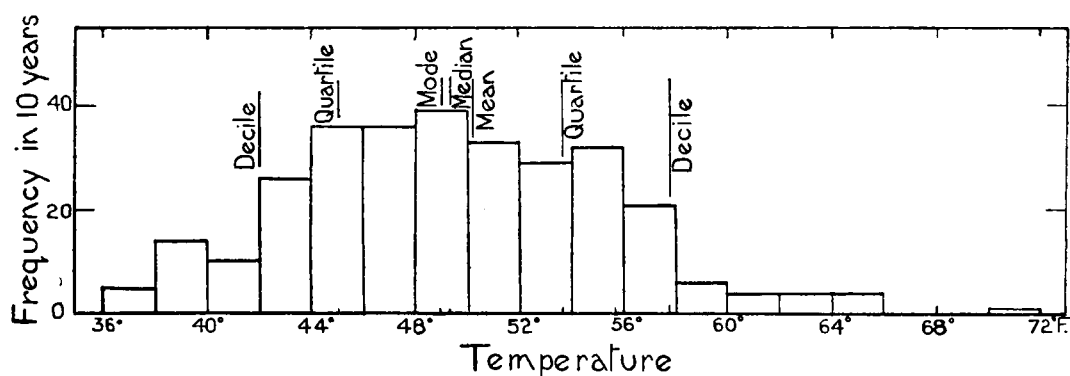


FIG. 2—FREQUENCY HISTOGRAM 1300 TEMPERATURE, BIRMINGHAM, APRIL.

The direct comparison of frequency tables is a cumbersome method of measuring the relative variability of two series of data. Even the quartiles depend finally on the exact values of two individual readings, and neglect both the extremes and near-average readings. It is much more desirable to be able to express the variability by a single figure which takes account of the scatter of all the readings. Two such measures are available: the mean deviation and the standard deviation.

The mean deviation is simply the average difference, taken irrespective of sign, between the individual observations and their mean. This is the simplest possible measure of variability and is frequently used. For various reasons, both theoretical and practical, however, a more convenient measure is the square root of the mean of the squares of the differences between the individual observations and their mean. This is known as the "standard deviation", and is commonly denoted by the Greek letter σ .

In our two examples of temperature, the values of mean deviation and of the ratio of the latter to the former, are as follows:—

	Mean deviation	Standard deviation	Ratio
	°F.	°F.	
Scilly	2.40	3.03	1.26
Birmingham	4.86	6.19	1.27

In series of observations which are fairly symmetrically distributed about a central peak, the standard deviation is about 1.25 times the mean deviation.

In such series also, half the observations will lie inside limits approximately two-thirds of the standard deviation (more accurately, 0.6745σ) on either side of the mean. This value, 0.6745σ , is known as the "probable error" For temperatures at Scilly and Birmingham in Table I, we have the following values :

			Interquartile range	Mean $\pm 0.6745 \sigma$
			$^{\circ}\text{F.}$	$^{\circ}\text{F.}$
Scilly	49.4-53.5	49.4-53.4
Birmingham	45.1-53.7	45.3-53.6

The standard deviation is a very important quantity in considering the significance of a mean value. For statistical purposes an "observation" is one of any series of comparable values. For example, we may have the mean temperature of each of a very large number of Januaries, and we can compute the standard deviation of the mean January temperature from the mean of the whole long series. If now we divide our very long record into a number of shorter series of, say, ten years each, we shall find that the mean of any one ten-year series will not, as a rule, be the same as the long-period mean, and the sum of the squares of the differences between the individual values and the 10-year mean will be less than the sum of the squares of the differences between the individual values and the long-period mean. In other words, the value of σ calculated from only 10 years will generally be too small. If we have only one 10-year series, we do not know the long-period mean, so that we cannot calculate the true value of σ , but we can obtain an approximate measure of the most probable value of σ by dividing by one less than the number of observations. Thus the standard deviation of monthly mean temperatures calculated from 10 observations is obtained by dividing the sum of squares of differences by 9 instead of by 10, and taking the square root. In mathematical language,

$$\sigma = \sqrt{\{\Sigma (T - T_m)^2 / (n - 1)\}}$$

where T is the temperature of individual months, T_m is the mean and n is the number of months ; Σ means the sum of all values.

So far we have been considering the standard deviation of individual "observations", either daily readings or monthly means, which we have denoted by σ . Suppose now we group our observations into successive pairs and take the average of each pair. We can form a new frequency distribution of these means of pairs and calculate their standard deviation, which we may call σ_2 . It can be shown quite simply that if successive observations are independent, i.e. if there is no relation between the mean temperature of January in two successive years, which appears to be sufficiently true for practical purposes, σ_2 will be $1/\sqrt{2}$ times σ , the standard deviation of individual values. Similarly, if we take groups of n observations, the standard deviation of their means will be $1/\sqrt{n}$ times the standard deviation of the individual values.

This enables us to assess the accuracy of a mean or "normal" of a climatological element very simply. Consider the temperature of London in January. Observations for 50 years give a mean value of 38.51°F. , and the standard deviation of the individual values is 3.48°F. Now we can imagine that this 50 years is only one of a large number of possible 50-year

periods which would give a whole series of 50-year means. From the one example which we have, we can assess the standard deviation of these 50-year averages as σ/\sqrt{n} , i.e. $3.48/\sqrt{50}$ or 0.49°F . Half of them would differ from the average of the whole set by at least 0.67×0.49 or 0.33°F ., the "probable error". Hence there is an even chance that the particular 50 years which we have differs from the true mean by as much as 0.33°F ., and the most we can say is that there is an even chance that the true January mean temperature lies between $38.51 + 0.33$ and $38.51 - 0.33$, i.e. between 38.84° and 38.18°F . To obtain a mean which is probably accurate to the nearest 0.1°F ., which is the way mean temperatures are usually quoted, we should need no less than $(0.67/0.05)^2$ or ~~4356~~ > 2000 years of observation !

(To be continued)

THE VELOCITY PROFILE IN THE LOWEST 400 FT.

BY R. FROST, B.A.

Many meteorologists, attracted by the analogy between the flow of liquids in pipes and the flow of air over the ground, have assumed that near the surface the velocity profile could be represented by a power law of the height above the surface. Hellmann,* who set up recording anemometers at heights of 5, 25, 50, 100 and 200 cm. and took continuous readings for nearly three months, found that the mean wind at these heights fitted a power law $V = Az^m$ where $m = 0.27$, and found that the index increased to 0.33 when night observations only were used.

Heywood, who fitted a power law to mean wind velocities at heights of 13 and 19 metres above the ground, the means being taken over a period of two years, found a value of $m = 0.26$.

Giblett fitted a power law to mean wind velocities measured by anemometers at heights of 50 ft. and 150 ft. at Cardington, the winds being grouped according to the temperature difference between 143 ft. and 4 ft., and found that m increased with increasing stability from a value of about 0.01 when the temperature difference was -5°F . to 0.62 when the temperature difference was $+7^\circ\text{F}$. and had a value of 0.143 when the temperature difference was zero.

During the period from October 1943 to November 1944, a series of observations of wind speed, temperature and humidity were carried out at the Royal Air Force station at Cardington in the course of an investigation into the formation of mist and fog by Mr. W. G. Swinbank of the Meteorological Office. The observations were made with instruments suspended from a balloon of the type used in the defence of Great Britain, which was raised to a height of 400 ft., measurements of wind speed, temperature and humidity being taken at heights of 5, 25, 50, 100, 200 and 400 ft.

These observations from Cardington afford the first direct opportunity of investigating the velocity profile of the wind in the lowest 400 ft. of the atmosphere with different temperature gradients. The wind observations

* The list of references is on p. 17.

on each ascent were grouped according to the temperature difference ΔT between 400 ft. and 4 ft., all observations in which the wind failed to reach a speed of 10 m.p.h. at 400 ft. being omitted. Means of wind speeds at each height in each ΔT category were then taken and the results are exhibited in Table I.

TABLE I

No. of Observations	Temperature difference 400 ft.-5 ft.	Mean wind speed (m.p.h.)					
		5	25	50	100	200	400
81	- 2 to 0	6.48	8.98	10.35	12.49	14.50	17.98
130	- 1 to 1	4.45	6.60	7.93	9.42	11.60	15.09
104	0 to 2	5.71	8.02	9.76	11.61	14.68	19.39
53	2 to 4	3.08	4.96	6.60	8.47	11.57	16.66
35	4 to 6	1.87	3.06	4.83	7.20	10.51	15.80
28	6 to 8	1.30	2.54	4.64	7.32	10.66	14.69
15	8 to 10	0.93	2.26	3.80	5.93	8.09	13.33
14	10 to 12	0.79	1.50	3.00	4.79	7.86	13.64

The observations on which the above table is based were made during the evening or night when the lapse rate of temperature with height was in general negative. In order to supplement these observations and to investigate the velocity profile under conditions of positive lapse rate, observations made at Cardington during the day-time, at slightly different heights, were also utilized. Table II, based on these observations, is computed in the same way as Table I.

TABLE II

No. of Observations	Temperature difference 350 ft.-4 ft.	Mean wind speed (m.p.h.)				
		4	30	80	150	350
80	- 4 to - 2	8.60	11.68	13.81	14.96	16.60
57	- 2.5 to - 1.5	7.98	11.26	13.51	14.79	17.23

In Fig. 1 logarithms of the mean wind speeds are plotted against logarithms of the heights, and it can be seen that for each value of ΔT the points lie on a straight line. It follows therefore that the velocity profile in the lowest 400 ft. at Cardington can be represented by a power law of the height above the surface, in which the index of the power is a function of ΔT .

With high stabilities there is a tendency for the mean wind speed at 5 ft. to lie somewhat above the line through the remaining points. This can probably be accounted for by the fact that with high stabilities the majority of the winds at 5 ft. used in this analysis were of the order of 1 m.p.h., at which speeds a cup anemometer is not very reliable.

Values of the index m for each value of ΔT have been calculated by the method of least squares and are given in Table III. Two values of m for each value of ΔT have been derived, the first by using observations at all heights, the second by omitting the readings at 5 ft. The second set of values of m is probably the more reliable, but for most purposes the differences are unimportant.

TABLE III

Temperature difference	-4 to -2	-2.5 to -1.5	-2 to 0	-1 to 1	0 to 2	2 to 4	4 to 6	6 to 8	8 to 10	10 to 12
<i>m</i> , all observations	.145	.17	.23	.27	.28	.39	.50	.60	.61	.67
<i>m</i> , excluding obser- vations at 5 ft.	.145	.17	.25	.29	.32	.44	.59	.63	.62	.77

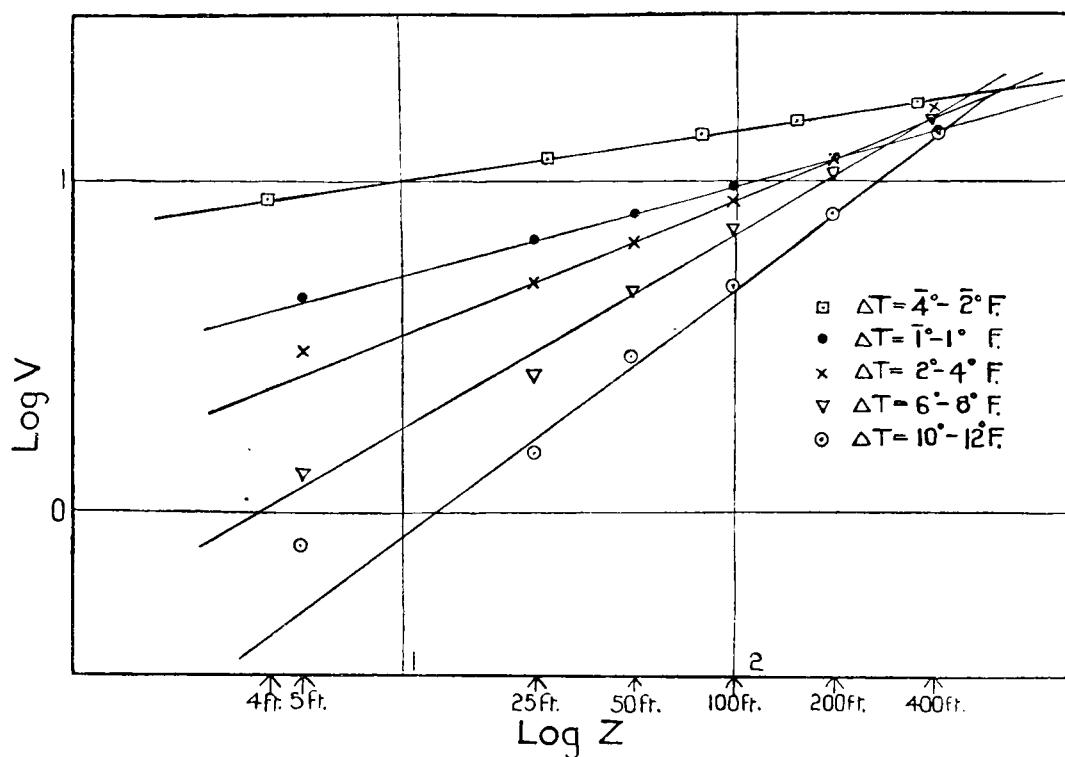
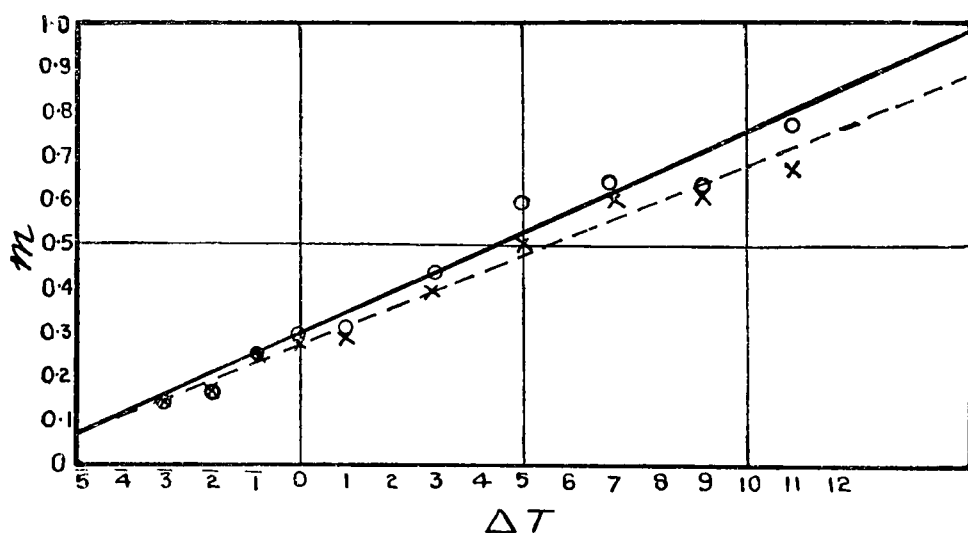


FIG. 1—VARIATION OF WIND WITH HEIGHT FOR VARIOUS TEMPERATURE DIFFERENCES BETWEEN 400 FT. AND 5 FT.

FIG. 2—OBSERVATIONS SHOWING THE RELATIONSHIP BETWEEN THE INDEX OF THE POWER AND ΔT

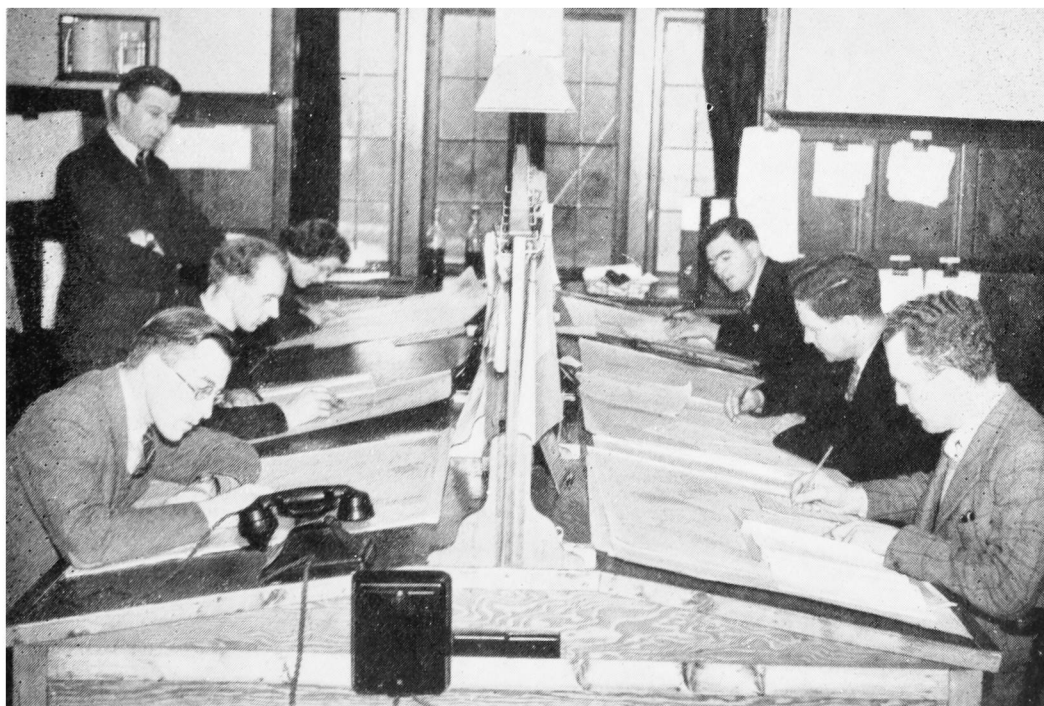
Values of the index calculated from observations at all heights are marked X.

Values calculated with the observations at 5 ft. omitted are marked O.



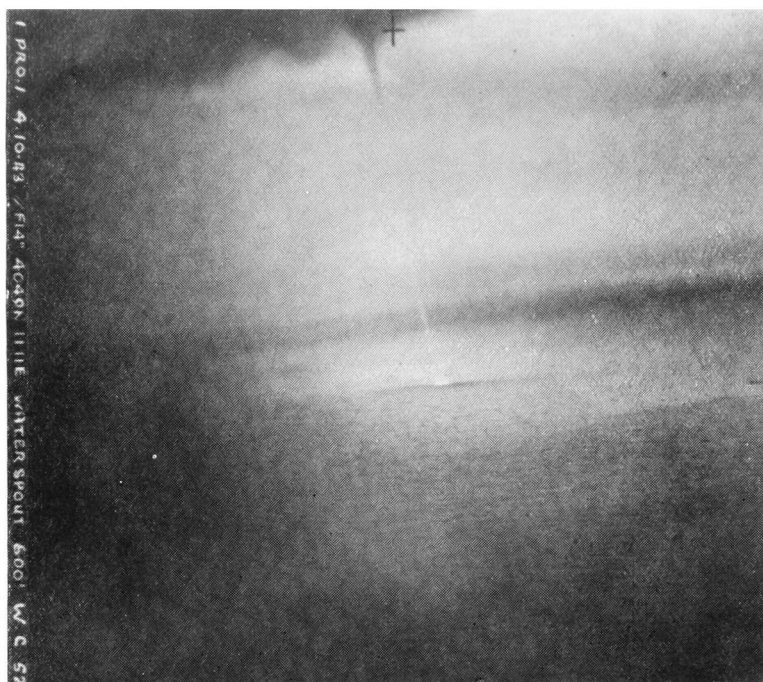
Reproduced by the courtesy of Graphic Photo Union

**FIG. 5—HER MAJESTY THE QUEEN BEING SHOWN THE PILOT-BALLOON
METHOD OF OBTAINING UPPER WINDS**



**FIG. 6—INTERIOR OF METEOROLOGICAL OFFICE AT TRANSATLANTIC AIR CONTROL, PRESTWICK
(see pp. 1-9)**

To face page 17]



WATERSPOUTS IN THE TYRRHENIAN SEA
(see p. 22)

The values of m for each value of ΔT are shown graphically in Fig. 2, and it can be seen that over the range of ΔT discussed which varies from superadiabatic lapse rates to very heavy inversions, the relationship between m and ΔT is very nearly linear.

An important consequence of this is that means of wind observations made under any conditions of temperature lapse rates can also be represented by a simple power law in which the index of the power is the same linear function of the mean temperature differences between 400 ft. and 4 ft. Thus, according to Johnson and Heywood the mean lapse rate in the lowest 100 m. (330 ft.) for all hours of the year is zero. Hence the index of the power law calculated from annual means should, from Fig. 2, be 0.27 to 0.29 in good agreement with Heywood's own value and also Hellmann's.

The discrepancy between the values given by Giblett and those of Table III could be accounted for by the difference in exposures of the two anemometers at Cardington, and will be discussed elsewhere.

I am indebted to the Director of the Meteorological Office for permission to use the unpublished data from Cardington.

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HELLMAN, G. ; *S.B. preuss. Akad. Wiss., Berlin*, 1919, No. 22, p. 404.
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OVERHEAD SMOKE PALLS FROM THE CONTINENT

During the war there were two outstanding examples of smoke palls at a considerable height which drifted to England from the continent. The most remarkable of these was on June 10, 1940, when the pall extended from Essex at least as far west as Stroud and persisted for several hours, drifting into the Midlands. A pilot reported a smell of petrol when flying in the smoke. It evidently originated in burning petrol dumps in north France, especially in the Havre-Rouen area. Its base was at about 6,000 ft. and it must have been of considerable depth. It was carried across in a SSE. upper current of about 15 to 20 knots, and had evidently accumulated over the area of origin on the previous afternoon and evening, when the upper wind was very light and when conditions favoured vigorous convection to a considerable height. At low levels it did not drift to the same area, at least during its most intense phase in the morning, as there was a shallow SW. current during the night and early morning.

Mr. E. V. Newnham wrote the following description of the phenomenon at Stonehouse, near Stroud :—

“ The light reminded me very much of that which accompanied the eclipse of the sun (not quite total in London where I observed it) a few years ago, and from this it seems a fair deduction that the obscuring layer of nearly uniform high-level smoke or haze reduced the sunlight unselectively, i.e. it acted like a shutter. There was certainly no reddening of the light. The intensity was so reduced that the sun even towards noon could be looked at in comfort with the naked eye, yet was sharply defined. A bit more reduction of the light would have given a fair imitation of moonlight (full

moon). At the time I thought the smoke or haze might be the result of big fires in the battle zone, the wind at the time being easterly."

The same unselective effect was noticed at Dunstable. The reduction in the sun's heat seemed large relative to the reduction of illumination, as compared with the effect of a normal smoke pall. At Kew the maximum temperature was only 63°F., whereas the Mildenhall temperature at 1,000 ft. was 67½°F. at 0600 and 70°F. at 1600. The visibility at Kew was below 1,000 yds. at both 1300 and 1800. This is most abnormal in June, and must be unprecedented on a day without appreciable rain. Even at Croydon, which was much less affected by local smoke, the temperature was 63°F. at 1300, and the maximum was 66°F. Cold surface air spreading northward caused a sharp fall of temperature at Mildenhall in the afternoon.

Mr. H. V. Sims observed the phenomenon at Earls Colne (Essex), and at 1330 there was a shower of four or five minutes' duration which spotted everything with black. The shower was from high stratocumulus castellatus clouds which existed in patches over the eastern part of the area of the smoke pall.

The second occasion was on the evening of September 12, 1944. Mr. L. W. Hubbert sent a description of it from Winslow (Bucks). A pilot reported that it extended from 4,500 to 7,000 ft. and was thickest at 5,000 ft., and that the ground was frequently invisible from 6,000 ft. Viewed from the ground, the smoke had a greyish-brown appearance, although in the zenith the sky could usually just be discerned. Ground visibility in the area was 6 to 12 miles. The pall seems to have been about 30 miles wide and 40 miles long, though it was not of uniform thickness and had some clear gaps in it. Some observers confused it with high cloud. The edge of the smoke was in wisps, with some resemblance to cirrus. The composition of the smoke was normal, as the sun's disc appeared red.

Mr. Hubbert traced back the trajectory of the air at the level of the smoke and found that it was over the middle Rhineland at about 2300 to 2400 on the previous night, when there was a concentrated incendiary raid on Darmstadt. There can be little doubt that this was the origin of the smoke.

C. K. M. DOUGLAS

OFFICIAL NOTICES

It is not yet possible to resume the "Climatological Table for the British Empire" which appeared in the *Meteorological Magazine* up to its suspension. Arrangements have been made to collect the information, and it is hoped to publish the values for January 1947 in the course of a few months.

OFFICIAL PUBLICATIONS

The *Meteorological Magazine* is the first of the publications of the Meteorological Office, suspended during the war years, to be resumed. The *Monthly Weather Report* and *Daily Weather Report* were maintained throughout for official use, though for reasons of security they were not available for general issue at the time. Other peace-time publications will be resumed as soon as possible, and it is intended to make a special effort to publish the war-time arrears. In particular, *British Rainfall* will appear in two volumes of three years each, covering the years 1940 to 1942 and 1943 to 1945 respectively.

The text will necessarily be contracted, but all the essential tables and maps will be included. The series of annual volumes will be resumed with that for 1946.

The results of some of the important researches carried out during the war years will appear in the revived series of *Geophysical Memoirs* and *Professional Notes*. The *Annual Report of the Director* will also be revived, but it is not yet possible to take up again the issue of the *Weekly Weather Report*, the *Observatories Yearbook* and the *Réseau Mondial*.

The appearance of new publications of the Meteorological Office will be announced regularly in this column, with brief summaries of their contents.

ROYAL METEOROLOGICAL SOCIETY

At the usual monthly meeting of the Society held at 49, Cromwell Road, on December 18th, Mr. Gordon Manley, President, in the chair, the following papers were read :

F. V. Appleby—A note on the classification of rainstorms.

Approaching the problem from the point of view of the water engineer, the author set out to find a simple measure of the "magnitude" or "significance" of a rainstorm.

Using the total rain R which falls in a storm and the intensity i in inches per hour as variables, a method is described of plotting the data for any storm as a vector of length R making an angle θ with the x -axis such that $\tan \theta = i$. This gives a short line of steep slope for storms of short duration and a longer line of lesser slope for storms of greater duration.

It was found that if falls such as those tabulated by Bilham, the Ministry of Health and others, were grouped in series according to the frequency with which they were likely to occur, e.g. "noteworthy" falls once in 10 years, "remarkable" falls once in 40 years and so on, the ends of the vectors representing any series lay roughly on a semicircle the diameter of which gave a measure of the significance of the storm. If we call this measure of significance μ , μ is given by the equation $R = \mu \cos \theta$, or $\mu^2 = R^2 (i^2 + 1)$. For rates of fall likely to occur once a year in this country, μ is approximately 0.56, and for storms once in 160 years, $\mu = 5.40$.

A relationship $i^2 = (0.25 + \mu^2/t^2)^{1/2} - 0.50$ was obtained for the intensity, and curves were plotted for $\mu = 0.56$ for comparison with the Ministry of Health's standard figures for urban drainage (frequency once per year) and for $\mu = 2.61$ for comparison with Bilham's series of "remarkable" falls (frequency once in 10 years).

A discussion followed in which mention was made of the omission of any reference to the area covered by the storm, a factor of some importance in many engineering problems.

W. Schaffer—Inclined streamline flow.

Professor Sheppard gave at very short notice a clear account of the salient features of Capt. W. Schaffer's paper.

This paper which is mathematical and difficult to summarise (it will occupy 14 pages in the *Quarterly Journal*) gives equations of motion for air currents flowing at an angle to the horizontal; from these an equation is

developed relating the veering or backing of the wind with height to the rate of ascent of the air and the local rate of rise of temperature. The paper is illustrated by simple numerical examples.

Beginning with thermal winds roughly at right angles to the surface isobars and causing winds veering with height, it follows that warmer air is being advected. Next we consider air with a lapse rate less than the dry adiabatic ; if this rises, it cools. Finally, the following equation is produced :

$$\frac{d\alpha}{dz} = - \frac{g}{lV^2T} \left\{ w (\Gamma - \Gamma_1) + \frac{\partial T}{\partial t} \right\}$$

where g , t , w , z have their usual significance,

Γ = adiabatic lapse rate, taken as positive

Γ_1 = actual lapse rate

$l = 2 \sin \phi$

α = angle between the horizontal component, V , of the wind vector and the W.-E. line.

For ascent $d\alpha/dz$ is negative in the northern hemisphere and positive in the southern hemisphere, i.e. for an ascending current the wind veers with height within the rising air stream in the northern hemisphere and backs with height in the southern (unless $\partial T/\partial t$ is negative and numerically large). This agrees with evidence of pilot-balloon results.

For an actual example, take values such as $V = 10^3$ cm./sec., $w = z$ cm./sec., $l = 7.3 \times 10^{-5}$, then the change in direction is about 17° per Km. (when $\partial T/\partial t$ is small). It may be noted that a rising temperature at a fixed point produces the same effect as an upward component in the wind.

One can go on to consider a normal surface trough with warm air, so that isobars aloft form a ridge, and from the foregoing considerations quickly pick out the areas of ascent or descent or alternatively, convergence and divergence.

Among other things, the paper also shows that the fall in pressure along a line in an upper-level surface, this line being the projection on this surface of the sloping trajectory ending at this surface, is

$$\rho g H^2 \left\{ (\Gamma - \Gamma_0) + \frac{1}{w} \frac{\partial T}{\partial t} \right\} / 2T.$$

For an application of this, assume that an upper-level chart is drawn for 3,000 gdm. (about 10,000 ft.) and an intermediate chart is drawn for 1,500 gdm., the difference between the two levels being roughly 1.53×10^5 cm. Let the lapse rate be 7×10^{-5} °C./cm. Then to rise a height $H = 1.53 \times 10^5$ cm. the change of pressure at the upper level comes out to 2.4 mb. Now if D is the distance along the 1,500 gdm. stream line direction for the upper-level pressure to fall 2.4 mb., then the air flow will incline upwards at approximately $1.5 \times 10^5/D$ radians. For example, if $D = 600$ Km., the angle with the horizontal will be

$$\frac{1.5 \times 10^5}{6 \times 10^7} = \frac{1}{400} \text{ radians or } 0.15^\circ.$$

METEOROLOGICAL RESEARCH COMMITTEE

The 45th Meeting of the Meteorological Research Committee was held on December 12, 1946.

Some further consideration was given to the possibility of exploring the constitution of the upper atmosphere by means of searchlight beams.

Two panels were formed ; one to supervise work relating to the meteorological aspects of icing on aircraft and the other to consider how various problems in tropical meteorology can best be tackled.

A proposal to investigate the correlation between temperature and velocity fluctuations due to turbulence in the atmosphere was examined and approved.

The Committee also considered papers on the size distribution of cloud particles, on a comparison between the Mk. V and the M.O. electrical aircraft psychrometer, and on the use of Elsasser's radiation chart.

LETTERS TO THE EDITOR

The Green Flash observed over the Atlantic

I have recently received a letter from Professor Sir Geoffrey Taylor in which he refers to an observation of "green flash" which he made while crossing the Atlantic by air. The following passage is taken from his letter:—

"I saw a very fine green flash as the sun went down behind a huge sheet of cloud extending apparently from 300 miles east of Newfoundland to near Ireland. I had hardly expected a cloud sheet to have a sufficiently definite top to show the green flash, but it was a really fine display."

June 29, 1944.

N. K. JOHNSON

The Blue (?) Flash*

The following description of a curious sunset phenomenon refers to observations made at sunset on August 20th, 1943, from the beach about two miles west of Rhyl. I had gone there on purpose as everything previously had appeared favourable for observation of the green flash. The air was very transparent, and the Isle of Man was visible, which is a rare occurrence. All round was a gorgeous display of colour : it was one of those rare occasions when an artist would be justified in painting the Carnarvonshire mountains in lavish purple. The cirrus near the sun was golden, and in the east it was red. Just as the upper limb of the sun was disappearing, its colour appeared a beautiful blue, a trifle bluer than the deepest sky-blue seen with maritime polar air in spring.

I was viewing it through powerful binoculars, which, at the moment, excluded from the field of view all the coloured mountains and clouds, so I do not think that the unusual colour of the flash was connected in any way with the coloured surroundings. Perhaps it was due to the use of the binoculars themselves.

11, Percy Road, Wrexham, August 22, 1943.

S. E. ASHMORE

* A flash of a vivid blue colour was described by Mr. S. T. A. Mirrlees in the *Meteorological Magazine* for August, 1935.

NOTES AND NEWS

Waterspouts in the Tyrrhenian Sea

The photographs facing p. 22 have been forwarded by Fl/Lt. R. Kennedy. They were taken on October 3, 1943, at 1427 G.M.T. from an aircraft at a height of 600 ft., at a distance of a mile. The sky was overcast to the east, 5-tenths stratocumulus to the west. The weather was calm but the wind freshened to 15 knots from 335° at this point. Two spouts appeared to be stationary and two more were forming; a large area of water was disturbed.

Another waterspout, the photograph of which is not reproduced, was observed two days later at 0720 G.M.T. The wind was 8 knots from 320° increasing in squalls. No movement of the spout was observed. It formed in five minutes from an area of extremely turbulent water, and developed a pronounced kink after 10 minutes. Its total life is not known.

REVIEWS

Geomagnetism, by Sydney Chapman and Julius Bartels. The International Series of Monographs on Physics. 8vo., 9 × 6, Vol. I, pp. xxv + 542, Vol. II, pp. x + 507. Oxford, The Clarendon Press, 1940. Price 63s. net.

For some ten years Professor Chapman and Professor Bartels have had in hand the preparation of an important treatise on Geomagnetism. It appears in print when the countries they represent are at war,* though it is noted that they initial the preface as from London and Washington respectively. In a note acknowledging many facilities received from institutions in Britain, Germany, America and other countries, the authors specially record their indebtedness to Dr. J. A. Fleming, of the Carnegie Institution of Washington. It is fitting that a work of this sort should have a somewhat international flavour because there is perhaps no branch of science in which the world-wide aspect is more patent and the need for world-wide co-operation more clearly recognised.

The book is in two volumes: Vol. I contains Part 1, an account of the observed facts of geomagnetism and the methods by which they are recorded; Vol. II contains Parts 2 and 3—Part 2 indicating how the data are analysed and synthesised and Part 3 being a discussion of the physical causes. This is broadly the plan, but the writers, in the interests of a logical exposition of facts and principles, have not attempted to confine each part strictly to the limits just described.

Brief accounts are given of related phenomena, the leading facts concerning the lunar and solar motions, the disturbances and other properties of the sun's atmosphere, earth currents, aurora and the ionosphere, magnetic prospecting and the relation of magnetism to geology. An indication is given of the many ways in which geomagnetism is now at last actually contributing powerfully to the problems to which its exponents of a generation ago rather vaguely hoped that it might one day contribute, providing avenues of research into the earth's interior, the earth's high atmosphere and the sun's atmosphere. For these reasons, and because of the links of geomagnetism with problems of radio and telegraphic communication and cosmic ray

[continued on p. 24]

* This review was written in 1942.

RAINFALL OF NOVEMBER, 1946

Great Britain and Northern Ireland

Co.	Station	In.	Per cent of Av.	Co.	Station	In.	Per cent of Av.
<i>London</i>	Camden Square . . .	3.49	148	<i>Glam.</i>	Cardiff, Penylan . .	6.83	169
<i>Kent</i>	Folkestone, Cherry Gdns.	4.49	138	<i>Pemb.</i>	St. Ann's Head . .	5.43	136
"	Edenb'dg, Falconhurst	5.99	169	<i>Card.</i>	Aberystwyth . .	4.50	122
<i>Sussex</i>	Compton, Compton Ho.	7.02	184	<i>Radnor</i>	Bir. W.W., Tyrmynydd	12.38	186
"	Worthing, Beach Ho. Pk.	4.22	132	<i>Mont.</i>	Lake Vyrnwy . .	11.10	191
<i>Hants</i>	Ventnor, Roy. Nat. Hos.	4.42	138	<i>Mer.</i>	Blaenau Festiniog . .	13.63	128
"	Fordingb'dg, Oaklands	5.17	151	<i>Carn.</i>	Llandudno . .	2.75	95
"	Sherborne St. John . .	6.28	220	<i>Angl.</i>	Llanerchmedd . .	6.92	164
<i>Herts</i>	Royston, Therfield Rec.	4.50	193	<i>I. Man</i>	Douglas, Boro' Cem.	8.13	173
<i>Bucks</i>	Slough, Upton . .	4.58	206	<i>Wigtown</i>	Pt. William, Monreith	7.19	167
<i>Oxford</i>	Oxford, Radcliffe . .	4.51	196	<i>Dumf.</i>	Dumfries, Crichton R.I.	7.38	201
<i>N'hant</i>	Wellingboro', Swanspool	4.39	204	"	Eskdalemuir Obsy. . .	10.81	186
<i>Essex</i>	Shoeburyness . . .	2.96	139	<i>Roxb.</i>	Kelso, Floors . .	4.37	189
<i>Suffolk</i>	Campsea Ashe, High Ho.	3.46	156	<i>Peebs.</i>	Stobo Castle . .	6.33	191
"	Lowestoft Sec. School	3.66	156	<i>Berwick</i>	Marchmont House . .	5.38	179
"	Bury St. Ed., Westley H.	3.77	164	<i>E. Loth.</i>	North Berwick Res. . .	4.41	197
<i>Norfolk</i>	Sandringham Ho. Gdns.	5.02	203	<i>Midl'n.</i>	Edinburgh, Blackfd. H.	3.29	147
<i>Wilts</i>	Bishops Cannings . .	4.63	162	<i>Lanark</i>	Hamilton W.W., T'nhill	4.46	125
<i>Dorset</i>	Creech Grange . .	5.95	144	<i>Ayr</i>	Colmonell, Knockdolian	6.51	130
"	Beaminster, East St. . .	8.30	209	"	Glen Afton, Ayr San.	8.35	152
<i>Devon</i>	Teignmouth, Den Gdns.	6.30	197	<i>Bute</i>	Rothsay, Ardenraig	6.71	132
"	Cullompton . . .	6.39	186	<i>Argyll</i>	Loch Sunart, G'dale . .	5.64	75
"	Barnstaple, N. Dev. Ath.	5.07	129	"	Poltalloch . .	5.62	100
"	Okehampton, Uplands	11.21	211	"	Inveraray Castle . .	7.54	89
<i>Cornwall</i>	Bude, School House . .	4.59	129	"	Islay, Eallabus . .	4.89	91
"	Penzance, Morrab Gdns.	6.85	150	"	Tiree . .	3.88	80
"	St. Austell, Trevarna . .	6.89	140	<i>Kinross</i>	Loch Leven Sluice . .	6.40	178
"	Scilly, Tresco Abbey . .	4.63	134	<i>Fife</i>	Leuchars Airfield . .	5.69	248
<i>Glos.</i>	Cirencester . . .	5.73	192	<i>Perth</i>	Loch Dhu . .	11.94	137
<i>Salop</i>	Church Stretton . .	6.22	212	"	Crieff, Strathearn Hyd.	6.46	149
"	Cheswardine Hall . .	4.91	190	"	Blair Castle Gardens . .	5.04	144
<i>Staffs</i>	Leek, Wall Grange P.S.	5.77	185	<i>Angus</i>	Montrose, Sunnyside . .	6.46	244
<i>Worcs.</i>	Malvern, Free Library	4.38	174	<i>Aberd.</i>	Balmoral Castle Gdns.	5.79	157
<i>Warwick</i>	Birmingham, Edgbaston	6.57	276	"	Aberdeen Observatory	5.98	203
<i>Leics.</i>	Thornton Reservoir . .	5.28	234	"	Fyvie Castle . .	6.82	197
<i>Lincs.</i>	Boston, Skirbeck . .	4.49	225	<i>Moray</i>	Gordon Castle . .	3.70	128
"	Skegness, Marine Gdns.	3.99	185	<i>Nairn</i>	Nairn, Achareidh . .	2.89	128
<i>Notts.</i>	Mansfield, Carr Bank . .	5.58	230	<i>Inu's</i>	Loch Ness, Foyers . .	2.72	70
<i>Ches.</i>	Bidston Observatory . .	3.83	153	"	Glenquoich . .	10.31	85
<i>Lancs.</i>	Manchester, Whit. Park	4.99	189	"	Ft. William, Teviot . .	5.78	70
"	Stonyhurst College . .	6.82	151	"	Skye, Duntuilin . .	8.67	145
"	Blackpool . . .	4.97	143	<i>R. & C.</i>	Ullapool . .	4.06	79
<i>Yorks.</i>	Wakefield, Clarence Pk.	4.20	198	"	Applecross Gardens . .	6.12	94
"	Hull, Pearson Park . .	5.07	231	"	Achnashellach . .	5.53	64
"	Felixkirk, Mt. St. John	4.38	179	"	Stornoway Airfield . .	5.41	98
"	York Museum . . .	5.39	258	<i>Suth.</i>	Lairg . .	6.28	157
"	Scarborough . . .	3.95	160	"	Loch More, Achfary . .	7.81	91
"	Middlesbrough . . .	3.49	165	<i>Caith.</i>	Wick Airfield . .	4.21	134
<i>Norl'd</i>	Newcastle, Leazes Pk.	4.18	178	<i>Shet.</i>	Lerwick Observatory . .	5.82	137
"	Bellingham, High Green	5.56	162	<i>Ferm.</i>	Crom Castle . .	4.15	119
"	Lilburn, Tower Gdns.	5.05	151	<i>Armagh</i>	Armagh Observatory . .	4.20	148
<i>Cumb.</i>	Geltsdale . . .	5.00	152	<i>Down</i>	Seaforde . .	5.73	151
"	Keswick, High Hill . .	11.30	200	<i>Antrim</i>	Aldergrove Airfield . .	3.53	109
"	Ravenglass, The Grove	7.12	159	"	Ballymena, Harryville	3.94	97
<i>West.</i>	Appleby, Castle Bank	6.12	184	<i>Lon.</i>	Garvagh, Moneydig . .	3.73	95
<i>Mon.</i>	Abergavenny, Larchfield	9.14	239	"	Londonderry, Creggan	3.93	96
<i>Glam.</i>	Ystalyfera, Wern Ho.	14.35	218	<i>Tyrone</i>	Omagh, Edenfel . .	4.19	110

phenomena, there has in recent years been a growth of interest in the subject, so that a comprehensive treatise is particularly to be welcomed.

Some of the primary problems of the earth's magnetism, such as the origin of the main field and the cause of the secular change, have still to be solved ; and though progress has been made in many directions, the writers remark that Part 3 (the physical interpretation) is the part with which they feel least satisfied and the part which, they hope, will be the first to need revision.

A. H. R. G.

THE WEATHER OF NOVEMBER, 1946

Apart from the extreme north-west, the last three weeks of November in Britain were characterised mainly by an excess of rain. For the first few days these islands lay between a depression over the Atlantic and an anti-cyclone over eastern Europe. The latter gradually spread westwards and extended over Britain on the 5th and 6th. On the 7th it split into two parts, one situated over Iceland and the other over eastern Europe, and this distribution was maintained with little change throughout the remainder of November, with a series of deep depressions moving eastwards or north-eastwards across western Europe. The average pressure distribution for the month shows a minimum (below 1004 mb.) over north-west Scotland and an anticyclone (exceeding 1020 mb.) over southern Russia. The abnormal character of the month is more clearly brought out by the differences of pressure from average, which range from -7 mb. over southern Ireland and southern England to +5 mb. over Iceland and the greater part of Russia. The latter country was reported in *The Times* to be suffering from drought.

Rainfall in Britain was especially persistent in the latter part of the month. The heaviest daily fall of which information is so far available was 6·83 in. at Princetown on the 23rd ; at this station the nine days from the 19th to 27th inclusive gave the remarkable total of 16·78 in.

Temperature was generally two to four degrees above the normal, but in England this was brought about mainly by the high night temperatures. There was, however, a very warm spell during the approach of the anti-cyclone on the 3rd to 6th, when record day temperatures for November up to 71°F. were reported. After this the effect of the warm oceanic winds was to some extent reduced by the lack of sunshine, and day temperatures were not remarkable.

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

	AIR TEMPERATURE			RAINFALL		SUNSHINE	
	High- est	Low- est	Difference from average daily mean	Per- centage of aver- age	No. of days' difference from average	Per- centage of average	Per- centage of possible duration
	°F.	°F.	°F.	%		%	%
England & Wales	71	27	+3·5	·178	+5	63	15
Scotland . .	69	16	+2·1	136	+3	78	16
Northern Ireland	65	26	+2·3	116	+1	86	21