M.O. 567 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 82, No. 967, JANUARY 1953

CHARTS OF UPPER AIR TEMPERATURE AND ISOBARIC HEIGHT

By D. DEWAR, B.Sc.

Not many years ago a research worker contemplating a study of upper air climatology would have found that he could make little progress owing to lack of data; now he may well find that his first problem is how to use the wealth of observational material that has been collected as a result of the introduction of daily radio-sonde observations by most of the meteorological services of the world. The broadcasting since January 1949 of CLIMAT TEMP messages giving, at five standard pressure levels, monthly mean values of temperature, dew point and height of the isobaric surface provides valuable summaries of some of these observations.

After the formation of the Upper Air Climatology Branch of the Meteorological Office, it was realized that a useful contribution to the study of the general circulation of the atmosphere could be made by tabulating and plotting these monthly mean values as part of the routine work. Some account of the development of the work and the present procedure is given below.

Preparation of charts.—After discussion with other branches of the Meteorological Office it was decided that the charts should give isopleths of temperature and height on the isobaric surfaces for 700, 500, 300, and 200 mb. A Mercator projection was adopted for the base maps so that the monthly charts could be compared with the charts of average height of isobaric surfaces, published in *Geophysical Memoirs* No. 85. The units chosen were metres and degrees Centigrade in preference to British units of feet and degrees Fahrenheit.

Up to December 1950 the charts were drawn on reproductions of the base maps used for the charts of *Geophysical Memoirs*, No. 85[1], to which had been added the location of upper air stations broadcasting CLIMAT data. The boundary of these maps was at 100°W. and divided the United States roughly in two, a division which, while very satisfactory for the Admiralty chart on which the maps had originally been based, was not so convenient for drawing isopleths over America. A revised map was brought into use in January 1951 with the boundary of the map changed to 180°, and a circumpolar map for the northern hemisphere, extending to 55°N., was added to get a better idea of the run of the isopleths in high latitudes and to allow stations outside the northern limit of the Mercator map to be plotted.

Data used for the charts.—For the early charts the data used for plotting were obtained from teleprinter messages supplied by the Central Forecasting Office at Dunstable, and the values published by the United States Weather Bureau

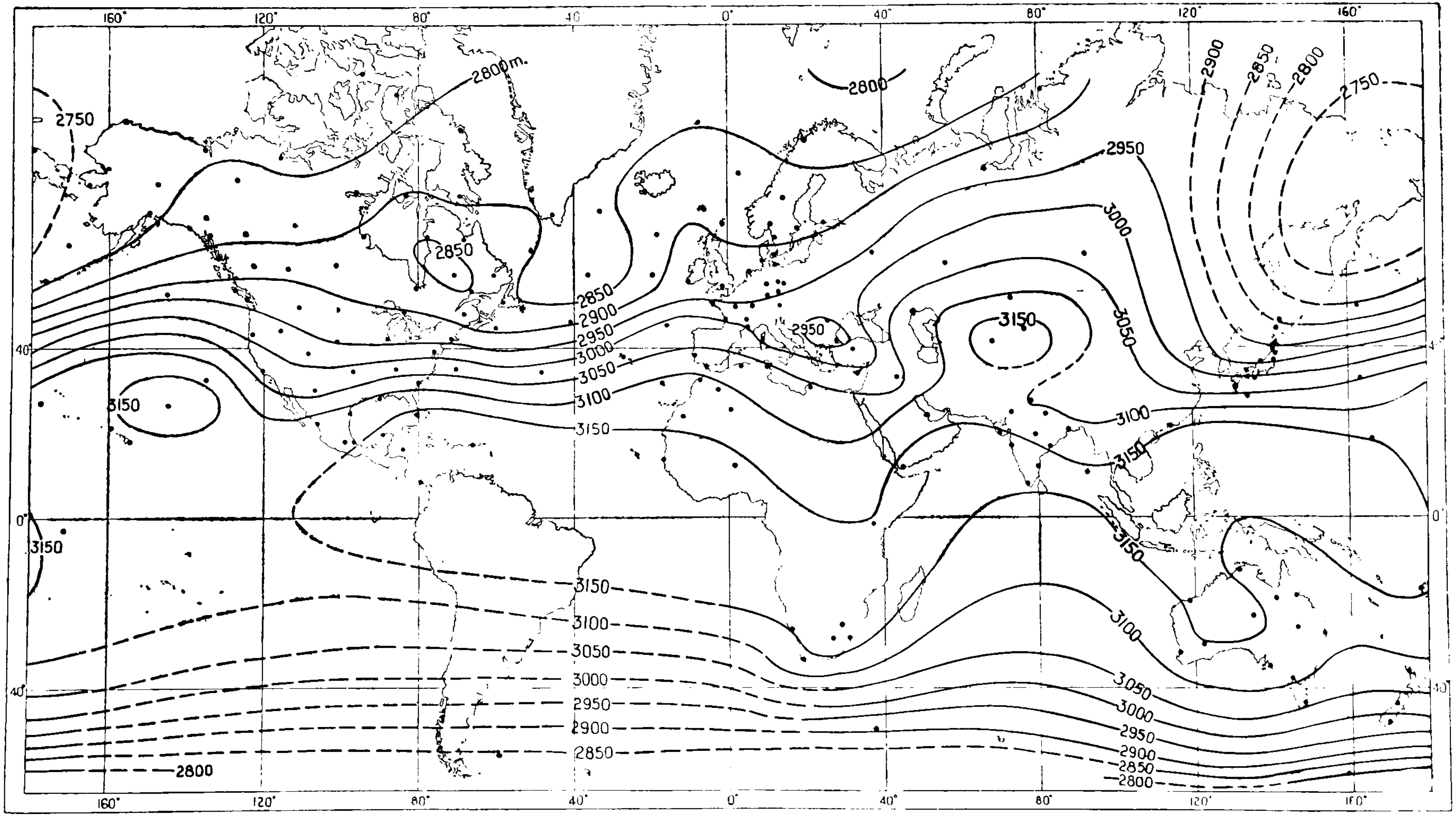


FIG. I—CONTOURS OF MEAN HEIGHT OF 700-MB. PRESSURE SURFACE, MARCH 1952
(Tropical and temperate zones)

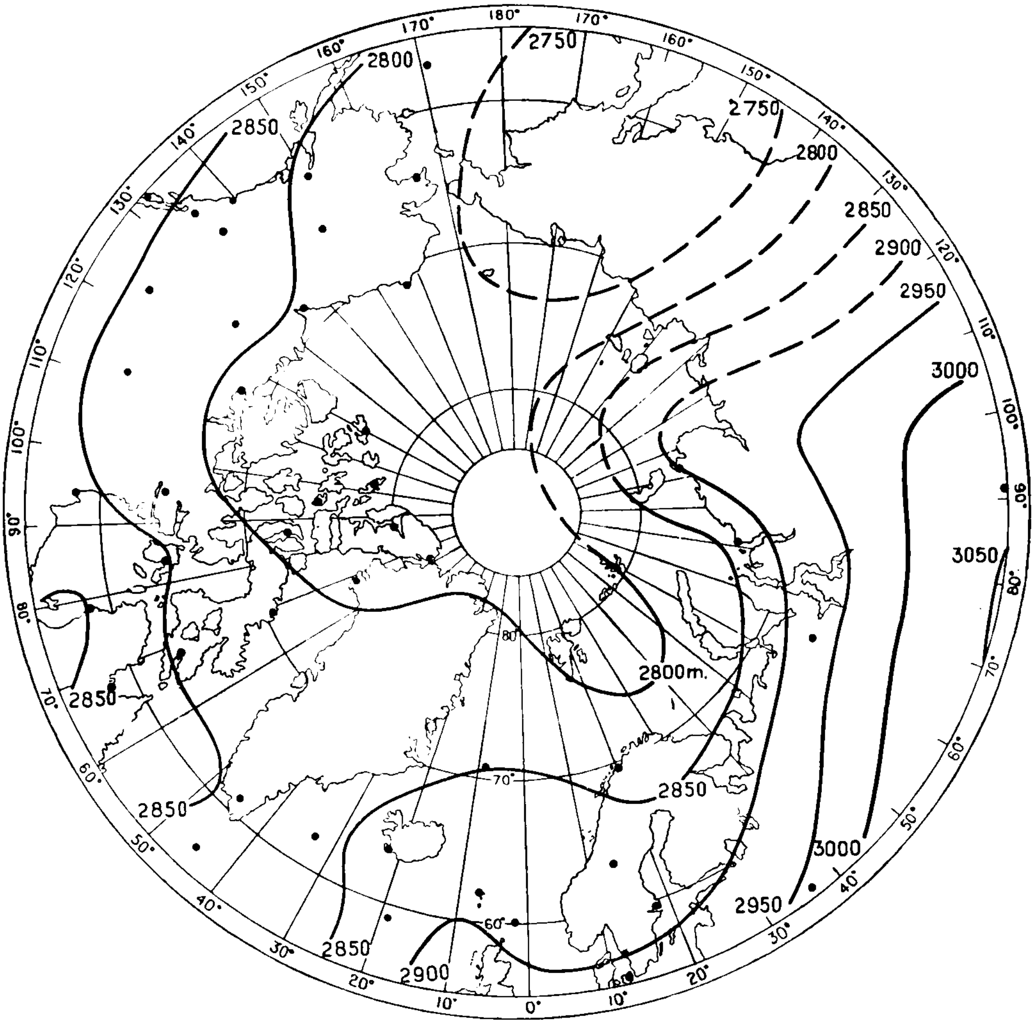


FIG. 2—CONTOURS OF MEAN HEIGHT OF 700-MB. PRESSURE SURFACE, MARCH 1952
(Arctic region)

in "Monthly climatic data for the world", supplemented by values worked up from data sent to the Upper Air Climatology Branch from British radio-sonde stations overseas. No data were received for Russia, Japan, South America and New Zealand and these early charts now seem very incomplete. Through the co-operation of the Directors of the South African and New Zealand Meteorological Services and the Director of the Royal Observatory, Hongkong, it was arranged that copies of CLIMAT data for those countries would be sent by air mail, and these enabled more complete charts to be drawn. More recently values for about twelve Russian stations have been added by working up monthly means from daily values extracted by the Central Forecasting Office Dunstable from the upper air data broadcast for Russian radio-sonde stations. The number of stations for which values are given in "Monthly climatic data for the world" has steadily increased, and it is now possible to draw a fairly complete chart over the world up to the 300-mb. level. Data for South America are still unfortunately non-existent, and there seems to be little hope of being able to do more than draw tentative lines over this region for some time to come. The 700-mb. charts for March 1952, reproduced as Figs. 1 and 2, show stations now being received and the latest type of chart.

Accuracy of data.—Each chart usually shows a few values that have to be rejected as being either obviously wrong or decidedly at variance with adjacent stations. Frequently values cannot be made to fit in with a smooth run of the isopleths, and, as it is difficult to know whether these departures are minor errors or real departures due to local topography, the policy adopted has been to follow the values as far as possible rather than to draw smooth curves.

Values given in the "Monthly climatic data for the world" are plotted in preference to the data received through interception of the broadcast messages, as more stations are given and values for the American stations probably have fewer transmission errors. For the British (home and overseas) stations and for South Africa, Hongkong and New Zealand the values given in confirmatory messages sent by post are used. This system ensures that the best data are used, but unfortunately it entails a delay of about six weeks before charts can be plotted.

Some rather peculiar discrepancies between values for stations in the same area have been found. For the charts up to April 1950 the only station in west Africa giving CLIMAT values was Dakar, and these values were accepted though both heights and temperature were lower than would have been estimated for this area. In May 1950 two other stations in the same latitude (Sal and Niamey) were received, and confirmed the suspicions felt about the Dakar values. Taking Sal and Niamey as correct led to a temperature correction of roughly +2°C. being required for Dakar with height corrections ranging from about 100 m. at 700 mb. to 400 m. at 200 mb. By early 1951 the differences had become smaller, and from June 1951 onwards Dakar values are in fair agreement with Niamey (Sal reports having ceased).

Values for Gibraltar and neighbouring stations were often found to be conflicting in 1950. On the whole the values for Gibraltar appeared high in relation to those for Portela, Casablanca, Colomb-Béchar and Maison Blanche, but differences were not consistent either from level to level, station to station, or month to month. These differences, which it was thought might have arisen through the use of different types of radio-sonde instruments, became less in 1951, and charts for the latter part of that year show generally good agreement between the different stations.

The differences in monthly means that can arise through the use of two types of radio-sonde at Canadian stations are discussed in a paper by T. J. G. Henry[2] and are shown to be appreciable.

Average values.—In addition to plotting the monthly data on charts the values have been entered on special summary forms which allow all the data broadcast to be entered month by month, and provide for monthly and seasonal averages to be computed after five years' data have been entered. When the charts indicate that a value is wrong, a probable value read from the charts is entered in brackets. These five-year averages, when available, will be very useful for the revision of the average charts of temperature over the world being prepared from data now available.

Major features of the charts.—This note has been written primarily to describe the production of the charts. They are being used in the research section for a study of upper air climatology, but in the meantime a brief description of some features noted while they were being drawn may be of interest.

Although in their diversity of detail they are reminiscent of daily synoptic charts certain features are often well marked. Considering first the contour charts, three "waves" extending around the northern hemisphere are frequently recognizable; one crest is normally to be found over the west of the American continent, another over the central Atlantic and another over central Russia. Of the corresponding troughs, that to the north of Japan is the most marked and often it is linked by a region of low isobaric height to the trough in the Labrador region giving, on the circumpolar chart, the impression roughly of a figure eight stretching across the pole.

It is more difficult to generalize for the southern hemisphere as the charts are less complete and features of the distribution less prominent, but the impression obtained is one of a mainly latitudinal run of the lines with a tendency for troughs to be indicated over the oceans and crests over the continents.

The temperature charts up to the 300-mb. level show, as might be expected, warm air in equatorial regions with warm ridges corresponding to the isobaric-height crests. In the northern-hemisphere summer the warmest regions as a rule are over Mexico (at the lower levels) and in a belt extending from India over southern Arabia to central Africa. The high-temperature region over Mexico is most evident at 700 mb. and at 300 mb. the temperature is definitely lower than that over India. During the northern winter the high-temperature area moves southwards to form a broad belt centred roughly over the equator, showing a definite bias for greater warmth in the northern hemisphere.

Of the localized features noticed, the most prominent is the steep gradient over Japan between the area of greater height of the isobaric surfaces over the western Pacific and smaller height to the north of Japan. Though not so striking, the contours from west Africa to India on the 300-mb. and 200-mb. charts suggest that there is a sweep of strong westerly winds over this region between about 20°N. and 40°N. from October to March, and this is borne out by the vector mean winds recently computed for Habbaniya for the period 1948–50. The speeds are given below together with the corresponding values for Larkhill:—

	October	November	December	January	February	March
			knots			
200 mb.						
Habbaniya	64	50	68	73	77	85
Larkhill	35	36	26	33	32	24
300 mb.						
Habbaniya	48	39	59	63	68	70
Larkhill	36	37	27	37	38	24

Another feature often noticed is the steep horizontal temperature gradient over Australia; an example of this is shown in the 500-mb. temperature chart for August 1951, reproduced as Fig. 3, where the intense thermal gradient is particularly noticeable.

The 200-mb. temperature chart deserves special mention; it is the most difficult chart both to draw and to understand and, probably for these reasons, the most interesting. Fairly complete charts are unfortunately only available for about a year, as data for high-latitude stations were not received for earlier charts and the drawing of the charts is still in arrear. Some of the following comments may therefore not apply generally.

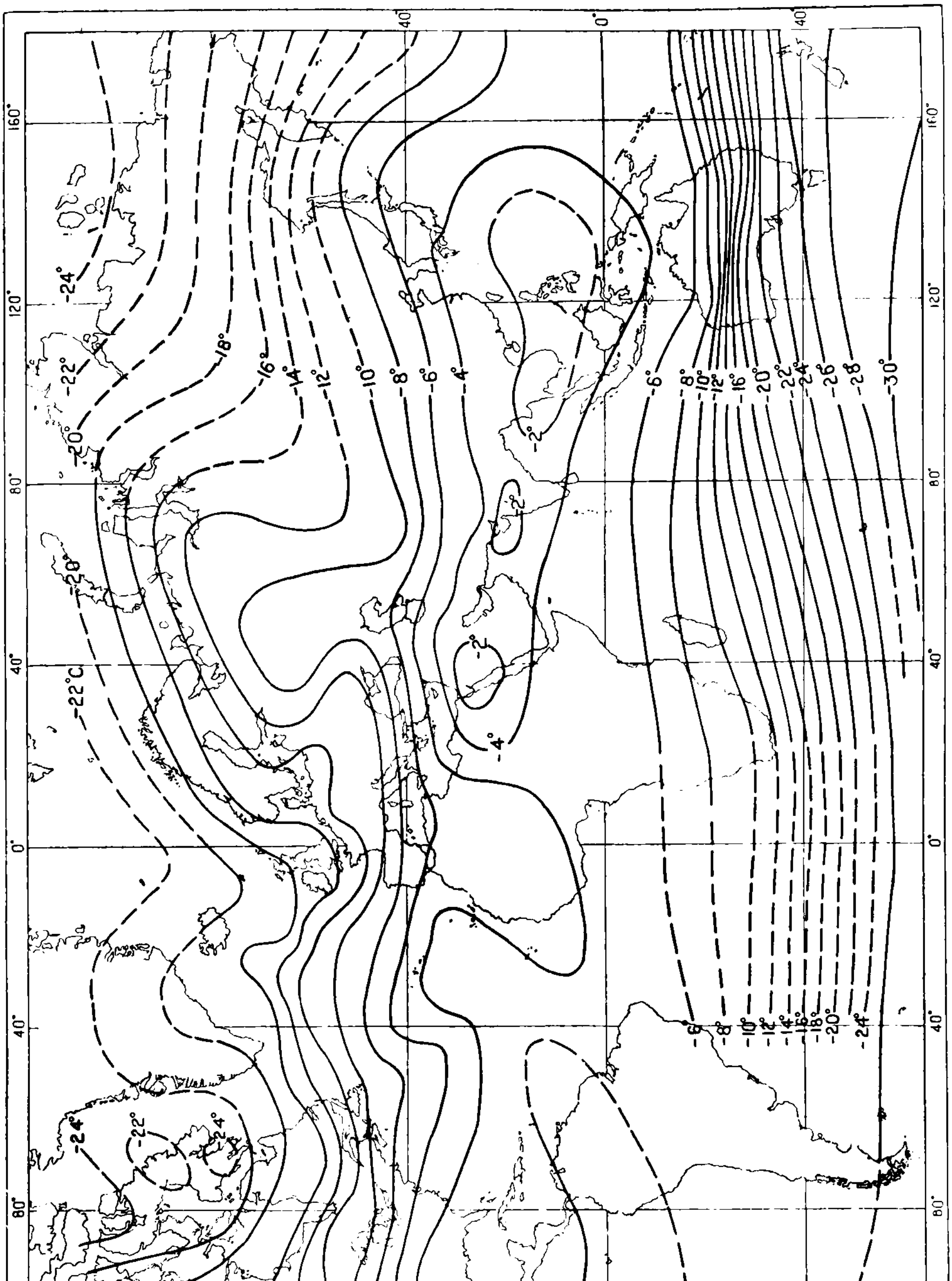


FIG. 3—MEAN TEMPERATURE AT 500 MB., AUGUST 1951
(Tropical and temperate zones)

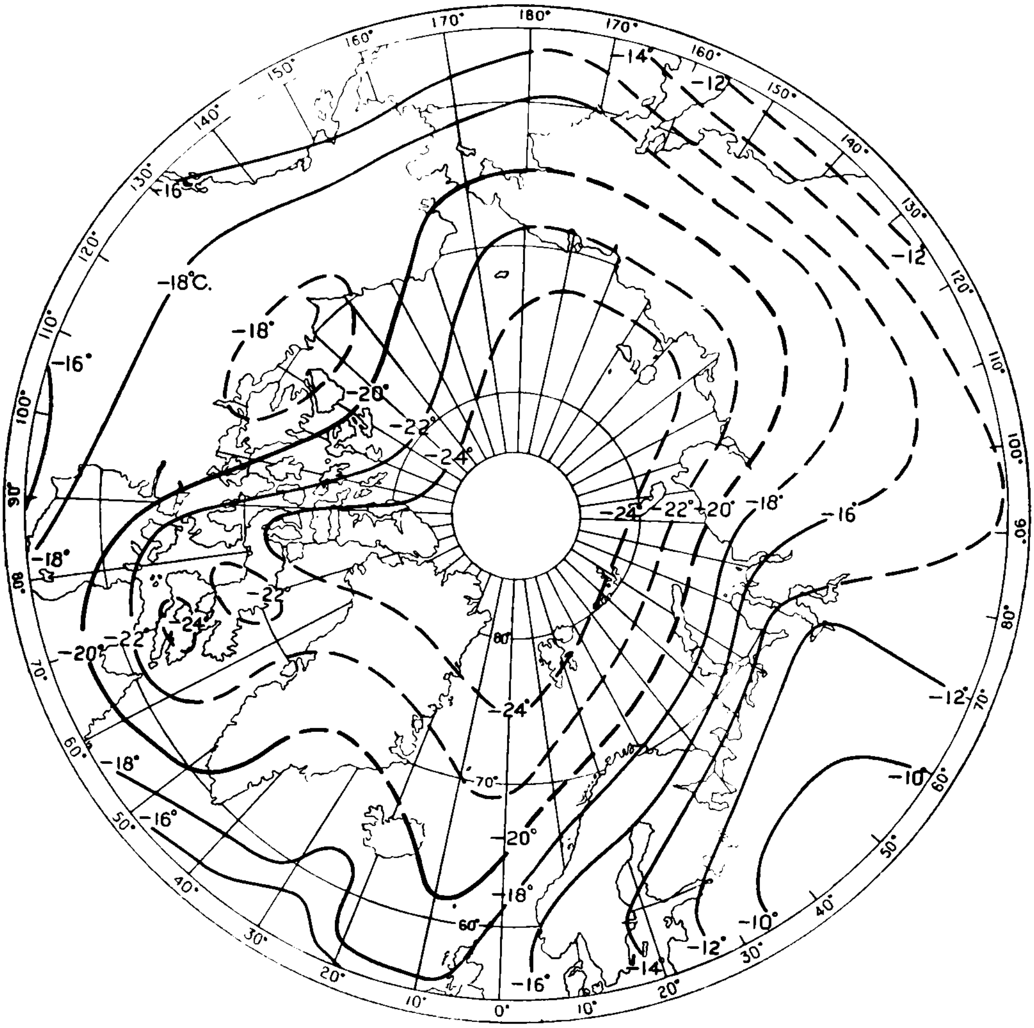


FIG. 4—MEAN TEMPERATURE AT 500 MB., AUGUST 1951
(Arctic region)

The temperature distribution changes almost completely at this level from the pattern shown by successive lower-level charts, and becomes very confused with many warm and cold patches appearing in different parts of the chart, owing to some regions being now in the stratosphere while others are still in the troposphere. The pattern varies considerably from chart to chart with seasonal changes superimposed on these variations; the following paragraph attempts to present the dominant features.

From May to October, generally, the arctic regions show the highest temperature and the antarctic regions the lowest. Equatorial regions have about the same temperature as arctic regions, but are sometimes colder; still colder air is usually found in a belt in the region of 40°N. From November to January the polar regions of the northern hemisphere become the coldest parts of the chart while the antarctic regions become warm; at the beginning of this period a belt of warm air extends from South America to South Africa and then sweeps north-east towards Japan. During February and March this warm belt moves into the equatorial zone with a cold belt to north and another

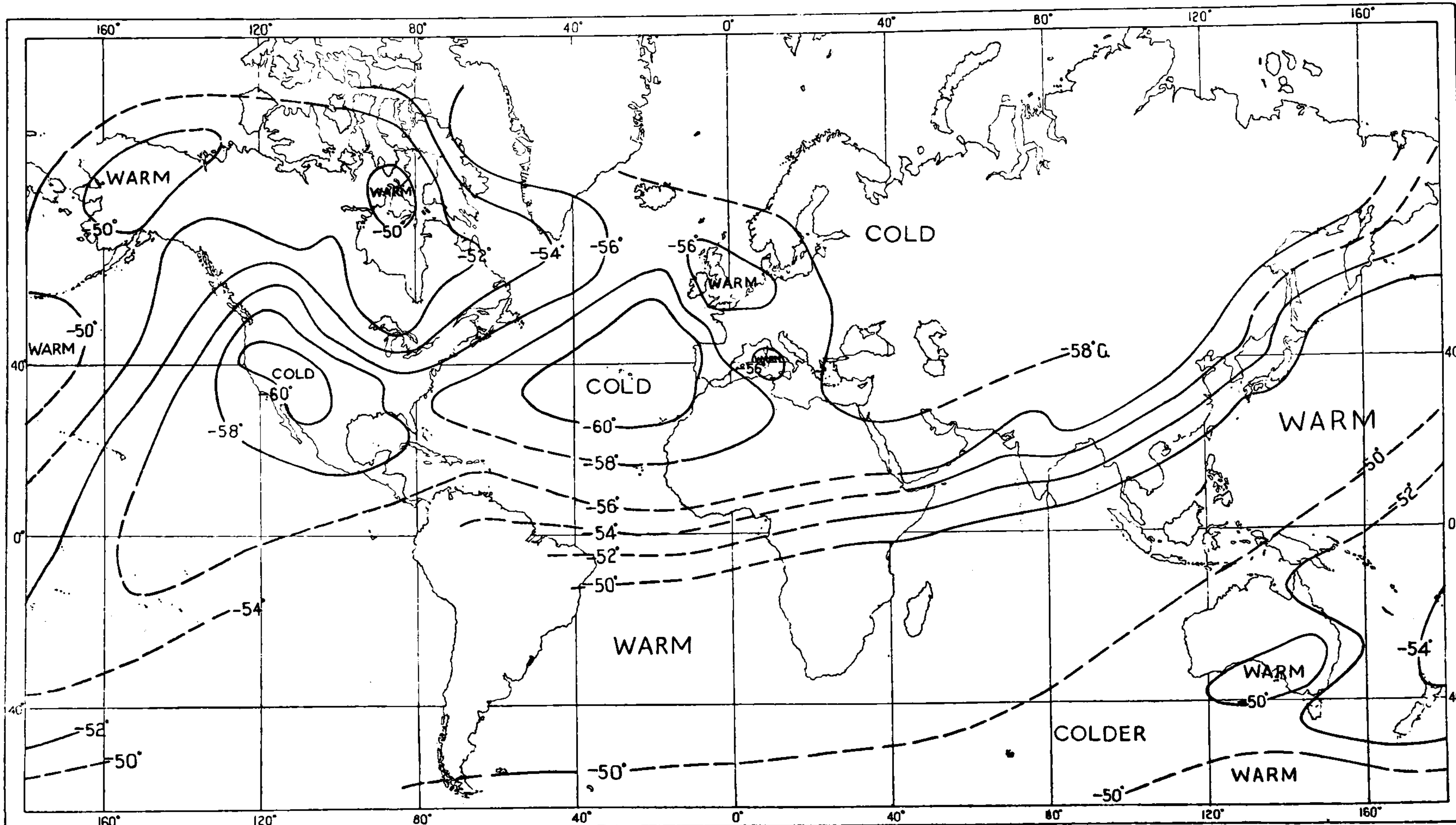


FIG. 5—MEAN TEMPERATURE AT 200 MB., DECEMBER 1950

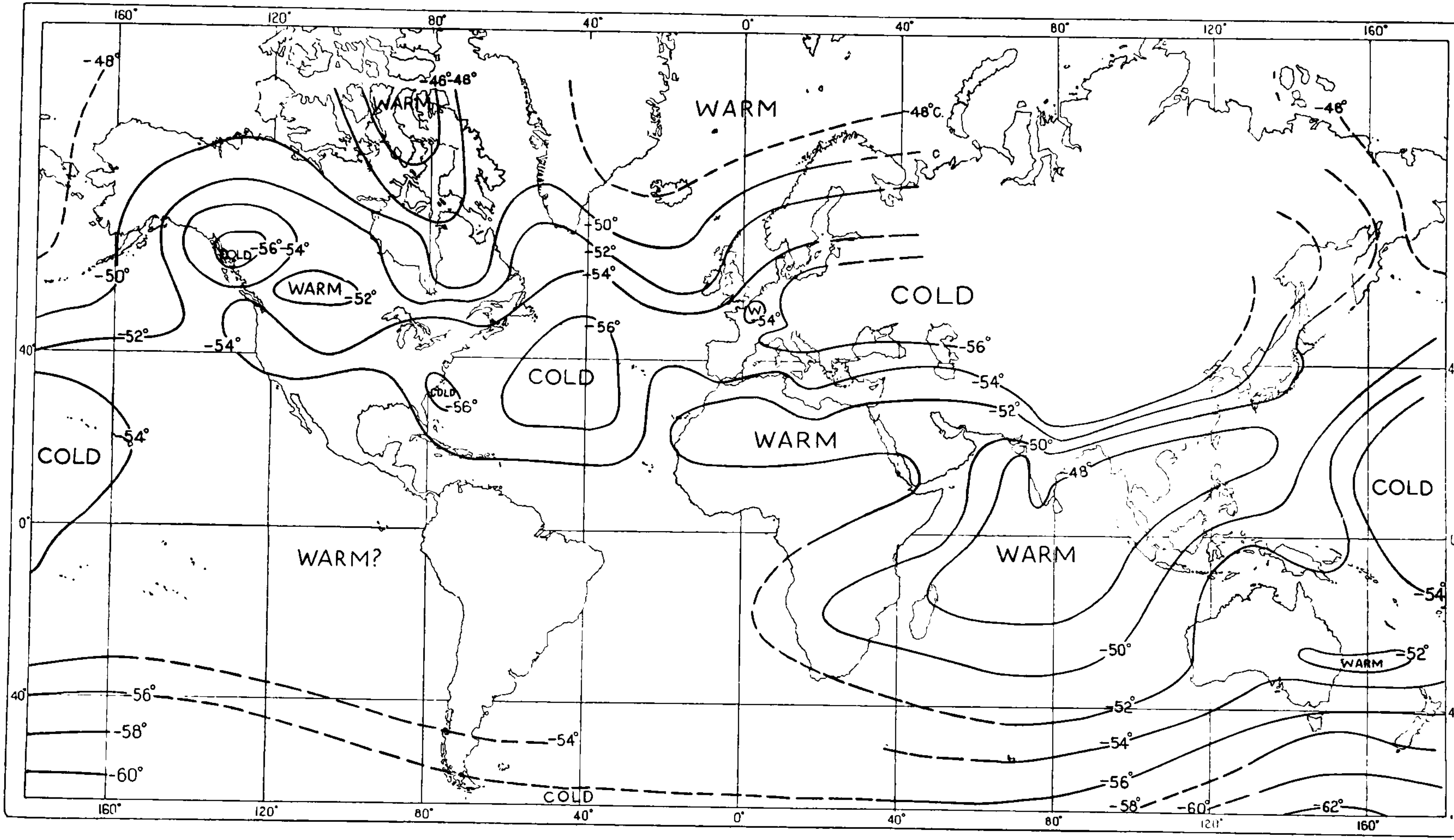


FIG. 6—MEAN TEMPERATURE AT 200 MB., SEPTEMBER 1951
(Tropical and temperate zones)

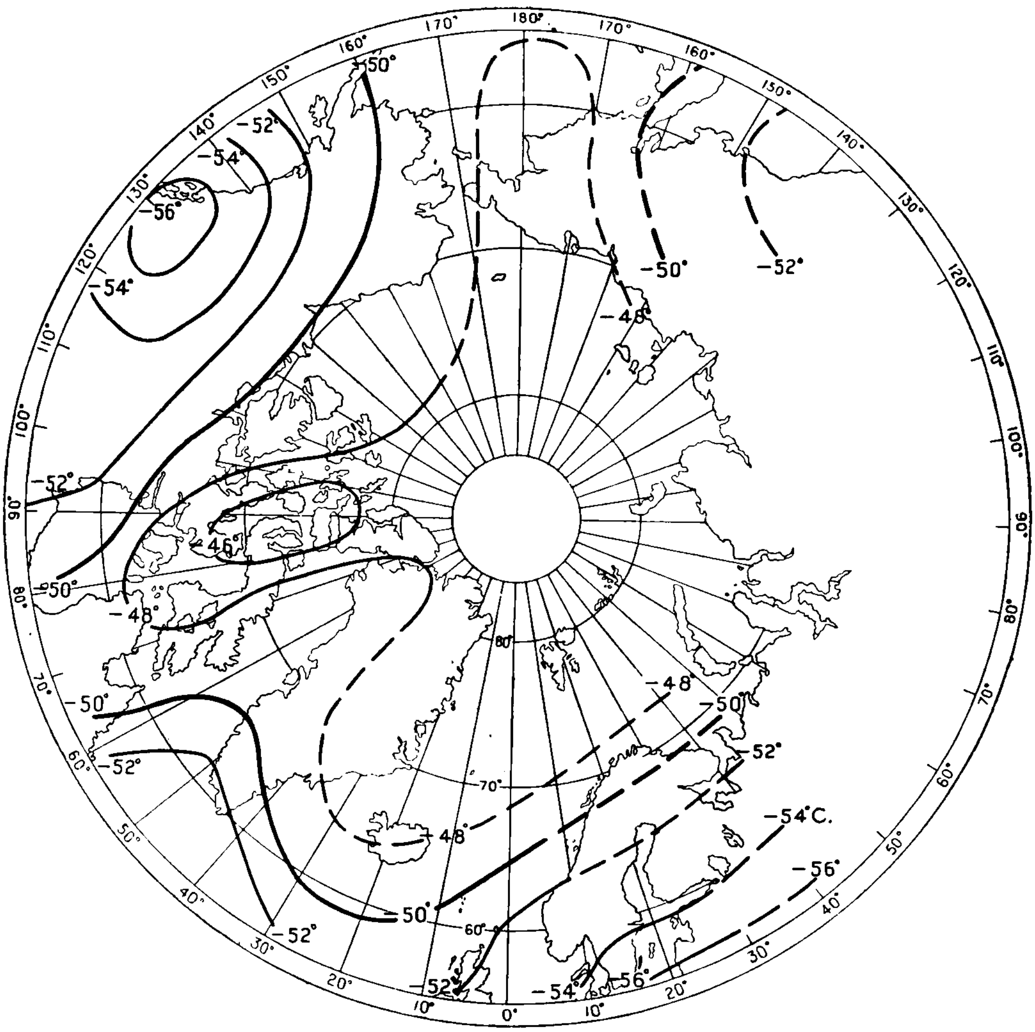


FIG. 7—MEAN TEMPERATURE AT 200 MB., SEPTEMBER 1951
(Arctic region)

to south of it but with warm air again further south. By April the arctic regions are becoming warm again and the antarctic regions cold, and the coldest air is now found in a belt between about 30° and 40°N.

Some of these features are illustrated by the chart for December 1950 (Fig. 5) and the charts for September 1951 (Figs. 6 and 7).

It is worth noting that the 200-mb. charts suggest that at this level the mean position of the thermal equator is south of the geographical equator—a reversal of its position in the lower troposphere.

In this brief description it has only been possible to deal with a few of the many interesting features of the charts; a detailed study of them may lead to the discovery of facts of both theoretical and practical importance.

REFERENCES

1. BROOKS, C. E. P., DURST, C. S., CARRUTHERS, N., DEWAR, D., and SAWYER, J. S.; Upper winds over the world. *Geophys. Mem., London,* **10**, No. 85, 1950.
2. HENRY, T. J. G.; A comparison of mean temperatures obtained with Canadian and American types of radio sondes. *Circ. met. Div., Toronto,* No. 2041, Tec.–103, 1951.

SOLAR AND TERRESTRIAL RELATIONSHIPS

By D. H. McINTOSH, M.A., B.Sc.

In the daily publication, *Wetterkarte*, of the Meteorological Service of the United States Zone of Germany for March 14, 1952, Professor Scherhag[1] described remarkable meteorological and ionospheric effects which he associated with the occurrence of an intense solar eruption in the early hours of February 24. The temperature on February 24 at 27 Km. over Berlin rose from −83°F. (−64°C.), which is normal for the season, at 0900 G.M.T. to −53°F. (−47°C.) at 1500 G.M.T. and to °1F. (−17°C.) by next morning. The increase in temperature extended downwards, the temperature at 20 Km. rising from −76°F. (−60°C.). on February 26 to −38°F. (−39°C.) on February 29. The wind at 18 to 30 Km., normally almost always westerly in winter, changed direction to east and increased in speed by the afternoon of the 29th to the remarkable value of over 60 kt. The wind change is considered to have been produced by the development of an intense high-pressure area in the stratosphere over northern Europe. The temperature measurements were made with special American balloons and with radio-sondes of a new type described as having higher accuracy than any others. The ionospheric effects were shown by world-wide interference with radio transmission.

The assumption in this article of a direct link between the solar and meteorological events was made with a degree of certainty which does not appear to be justified. Here, the general problem of solar and terrestrial relationships is reviewed, and comment made on Professor Scherhag's article.

Geomagnetic and ionospheric phenomena.—There is ample visual evidence that the sun passes through a marked cycle of activity of approximately 11 years. These solar variations are reflected in corresponding changes in the earth's magnetic field and in the electron density of the upper atmospheric layers. In both these phenomena the effects of two distinct types of solar radiation are distinguishable: an ultra-violet "wave" radiation, moving with the speed of light, responsible for ionizing the atmospheric layers and giving rise, in conjunction with the tidal motions of the atmosphere, to geomagnetic diurnal variations depending on both solar and lunar time; and a slower-moving "particle" radiation consisting of electrified solar particles whose close approach to the earth causes geomagnetic and ionospheric storms. Both types of radiation are directly correlated with the sun's activity, as measured by the relative sun-spot number. The relations are close for annual mean values, but become increasingly vague as the time interval shortens, so that it is rarely possible to interrelate the respective day-to-day changes. An exception is provided by the occurrence of an intense solar flare. About four minutes after such a flare is first observed there often occurs, over most of the sunlit hemisphere, a characteristic variation of the earth's magnetic field and a radio fade-out, resulting from a sudden intensification of the ionizing wave radiation. The magnetic effect may, exceptionally, last about an hour, and the radio fade-out two or three times as long. If the flare is centrally situated on the sun's disc, there is a much greater than random probability of it being followed after about a day by an intense and world-wide magnetic storm of sudden onset, assumed to be caused by the arrival in the vicinity of the earth of slower-moving solar "particle" radiation emitted simultaneously with the "wave" radiation. This probability by no means amounts to certainty; intense flares have occurred in apparently favourable positions without subsequent storms, while conversely the occurrence of an intense storm in the absence of a flare, or even a sun-spot, has been known. H. W. Newton[2] has demonstrated a statistical connexion between intense flares and "very great" magnetic storms. The "lesser" storms are not associated with flares and have, in contrast to the "very great" storms, a marked recurrence tendency of 27 days, corresponding to the solar rotation period. Because of a lack of close association with visible sun-spots, these storms were attributed by J. Bartels[3] to hypothetical magnetically effective solar emitting areas, which he termed "M-regions". Our knowledge of magnetic and ionospheric variations may perhaps be summarized by the statement that, while a solar origin of their greater part is not in doubt, there remains a good deal of mystery in the phenomena, and their day-to-day changes can rarely be related directly to corresponding solar changes.

Solar and meteorological connexions.—Since we regard the sun as the driving force in all that constitutes weather, it is natural to expect that changes in the condition of the sun will be reflected in corresponding weather variations, and attempts have been made by many authors to confirm this expectation. C. G. Abbott, who has been largely responsible for the increased accuracy of solar-constant measurement achieved in the past 50 years, holds to the opinion that the constant is subject to small variations which cause small weather changes. It is more widely held, however, that the small differences found in the constant result from variations in the transparency of the atmosphere, these being associated with weather anomalies which are therefore the cause, and not the effect, of the measured variations of the constant. Support for this view appears to be contained in Abbot's own finding[4] that there is no sun-spot cycle variation of the solar constant. Changes in the atmospheric transmission properties would be expected to average out over a long period to give such a result, while on the other hand the existence of day-to-day changes in the value of the constant with no long-period change corresponding to sun-spot epoch would be very difficult to explain.

Much of the work in the field of solar and meteorological relationships has recently been reviewed by C. E. P. Brooks[5] who reached the conclusion that a connexion does most probably exist. It is my opinion, having regard to the dependent nature of successive sun-spot numbers, to the properties of both time and space coherence displayed by meteorological data, and to the lack of independence of different meteorological elements, that none of the relations so far claimed carries real conviction. On the analogy of the relationships discussed in the preceding paragraph, it is likely that the use of solar and meteorological data meaned over a fairly long period would have the best prospect of establishing a relationship, and most of the workers have used such material. Recently B. and G. Duell[6], working with daily values, have claimed positive results which appear to have received fairly general acceptance. Their method consisted essentially of finding mean values of barometric pressure under conditions of varying intensity of solar "particle" and ultra-violet radiation. The means were calculated, for instance, at a large number of stations in the series of days extending from 3 days before to 11 days after magnetically disturbed days (5 per month), these means being contrasted with corresponding values round magnetically quiet days. A similar procedure was adopted with days of intense solar flares, and the resulting variations attributed to the influence of the additional ultra-violet radiation associated with flares. Before we can assume that the resulting variations are uniquely, or even partly, related in a direct way to the variations of solar radiation, it is necessary to determine how successfully other random influences have been eliminated by the averaging process. This is readily done by finding the standard error either of the means themselves or of the differences between means, and is a very necessary precaution in an investigation of this nature. The results of such tests which I have applied to the findings of B. and G. Duell are as follows:—

(*a*) The maximum difference found between the means associated with magnetically disturbed days and those round magnetically quiet days was about 4 mb., each of the means being derived from 320 cases. Magnetically quiet and disturbed days tend to occur in separate successions, and calculation shows that only about one in three of either type of day makes an independent contribution to the "true" pressure mean. The standard deviation of the difference of two means, each given by n independent values is $\sqrt{2}\sigma/\sqrt{n}$, where σ is the standard deviation of the individual daily values (about 12 mb. in this case—central Europe in the four winter months November to February). Thus the difference of 4 mb. was only $2\frac{1}{2}$ times the appropriate standard deviation. If such a difference were obtained in a single random sample it would be no more than suggestive of a relationship. Since, however, it was the maximum difference in a series of days at a number of stations in a specially selected season and grouping of years, it must be considered quite insignificant.

(*b*) For stations over north-west Europe, the departures associated with magnetic disturbance from long-period pressure means were represented on charts by the authors. Maximum departures of $+2\cdot5$ mb. occurred in west Iceland and of $-2\cdot5$ mb. near Riga, both on the second day following the selected days of magnetic disturbance; the appropriate values of σ are about 15 mb. in each case, so that these maximum departures are each less than twice the standard deviation of the means, derived from 320 cases as in (*a*). There is thus no reason to believe that the intensification and slackening of the pressure gradient over north-west Europe following days of magnetic disturbance is due to any cause other than insufficient averaging.

(*c*) Examination in a similar way of the variations in the mean surface pressure following days of intense solar flares shows that they also fail to attain a level of significance; in this case, all 51 cases can be counted independent. However, the corresponding pressure variations at upper levels suggest a possible significance. From the day of an intense solar flare to the succeeding day, the level of the 500-mb. surface in Ireland was found by B. and G. Duell to fall, in the average of 51 cases, by about 130 ft. Examination of a year chosen at random shows that the standard deviation of the difference on successive days of the 500-mb. level at Aldergrove is 300 ft. Thus the standard deviation of the mean of 51 independent cases is about 42 ft., and the actual mean departs from zero by just over three times this amount. Although it must again be noted that this is a maximum value over a wide area, the contrast with the very small changes over the preceding 24 hr. is striking when account is taken of the normal coherence of such changes. The suggestion of a real effect was considered strong enough to warrant testing with fresh data. The mean 500-mb. contour level at Aldergrove was determined for each day from 3 days before to 11 days after 29 Class 3 or 3+ flares occurring between 0900 and 1500 G.M.T. during 1942–51. The variations of these means were found to be insignificant, and the substantial change round the flare day, which occurred in the data used by B. and G. Duell, did not reappear here. The variations in surface pressure at Mauritius in the series of days round 40 intense flares, occurring between 0800 and 1600 L.M.T., were also examined, but again with negative result. Mauritius was chosen because of the small range of random fluctuations there, and because it seems likely that any effect associated with solar flares should be biggest where the distance from the subsolar point is least.

Geomagnetic storm of February 24, 1952.—The description by Scherhag[1] of the geomagnetic, ionospheric and solar disturbances of February 24, 1952, contains some puzzling features which have a bearing on his assumption of a direct link between these events and the accompanying stratospheric rise of temperature. A world-wide geomagnetic storm commenced suddenly at 2126 G.M.T. on February 23, 1952 and continued with varying intensity till February 25. At no time was the magnetic storm, or accompanying ionospheric storm, of more than moderate intensity; periods equally or more disturbed had already occurred in February and occurred again in March. Evidence appears to be lacking of a big solar disturbance in the form of an intense flare on February 24; no visual flare was reported, and the absence of any of the geophysical effects which usually accompany a large flare makes it almost certain that none did occur. The storminess of February 24 was obviously of corpuscular origin and could not be linked with any flare or other solar disturbance which may have occurred that day.

The reported rise of temperature at about 27 Km. over Berlin, amounting to nearly 85°F. in 24 hr. seems very large and apparently is quite exceptional at this level since it received special comment. The intermediate observation, showing a rise of 30°F. in 8 hr. serves both to confirm the observation made later and to show that the rise of temperature took place gradually. It is natural to seek for an explanation of this temperature rise, but a too ready linking of this exceptional event with other events which were not exceptional appears unwarranted, and may only serve to divert attention from the true explanation.

Conclusion.—The present lack of clear proof of a direct link between solar and surface meteorological changes does not necessarily mean that no such link exists, but makes it certain that any direct tropospheric effect of solar variations is very small. There may, however, yet be an achievement in this field of investigation comparable to that of Professor Chapman[7], who, following the failure of many previous investigators, was able to prove the existence at Greenwich of a lunar atmospheric tide of total amplitude only a small part of the error of the individual values used.

Since there are very probably no variations in the solar constant measurable at the ground, the variable part of the sun's radiation must be removed in the upper atmosphere. The influence of such variations is apparent in the regular ionospheric layers (100 Km. and upwards), while it is known by direct observation that the additional ultra-violet radiation associated with solar flares penetrates to the D layer, at a height of about 80 Km. The pressure at 80 Km. is of the order of only 5×10^{-2} mb., and it seems hardly possible that any pressure variations occurring at this level would be apparent at the surface, even if transmitted in full. If the variable component of radiation can penetrate beyond the D layer to the ozone layer, at a height of 20–40 Km., the chance of visible reactions in the troposphere increases proportionally to the greater pressure at these levels. The failure of the ozone content of the atmosphere to show a solar cycle variation or to increase at the time of an intense solar flare may be considered indirect evidence that no effective variation of solar radiation reaches this level. These facts are capable of other interpretation, but it seems certain that the ozone layer represents the only possible link between the sun's variations and surface weather reactions. It should be possible to answer some of these problems with the help of the direct observations at very high levels now becoming available, but it is important that these observations should not be interpreted too hastily or in the light of preconceived theories.

REFERENCES

1. SCHERHAG, R.; Einfluss von Sonneneruptionen auf Stratosphärenwetter nachgewiesen. *Wetterkarte, Bad Kissingen*, Nr. 74, March 14, 1952.
2. NEWTON, H. W.; Sunspots, bright eruptions and magnetic storms. *Observatory, London*, **62**, 1939, p. 318.
3. BARTELS, J.; Twenty-seven day recurrences in terrestrial magnetic and solar activity 1923–33. *Terr. Magn. atmos. Elect., Baltimore Md.*, **39**, 1939. p. 201.
4. ABBOT, C. G., ALDRICH, L. B. and HOOVER, W. H.; *Annals of Astrophysical Observatory of the Smithsonian Institution, Washington D.C.*, **6**, 1942.
5. BROOKS, C. E. P.; The relations of solar and meteorological phenomena. Septième Rapport de la Commission pour l'étude des relations entre les phénomènes solaires et terrestres. *Conseil International des Unions Scientifiques, Paris*, 1951, p. 183.
6. DUELL, B. and DUELL, G.; The behaviour of barometric pressure during and after solar particle invasions and solar ultra-violet invasions. *Smithson Misc. Coll., Washington D.C.*, **110**, No. 8, 1948.
7. CHAPMAN, S.; The lunar atmospheric tide at Greenwich 1854–1917. *Quart. J. R. met. Soc., London*, **44**, 1918, p. 271.

RELATIVELY HIGH STRATOSPHERE TEMPERATURE OF FEBRUARY 1951

By F. J. SCRASE, Sc.D.

In an article on atmospheric reactions to solar corpuscular emissions H. C. Willett[1] reported what he described as "the first instance of the direct measurement of thermal effects produced in the higher atmosphere by a sudden solar disturbance". He stated that during the 24-hr. period, February 24–25, 1952, the regular twice daily high-altitude soundings taken by the German Weather Service in the western zone of Berlin recorded a rise of temperature of 72°F. (40°C.) at the 20–10-mb. levels in the stratosphere. This sudden heating effect diffused slowly downwards to the 50-mb. level where there was a 22°F. (12°C.) increase a few days later. During the following week a slow return to near normal temperature occurred at all levels. These observations have since been discussed in more detail by R. Scherhag[2] who claims to have confirmed the connexion between the high temperature and solar eruptions by a statistical investigation of the correlation between the daily magnetic activity and the temperature of the upper stratosphere.

Since Willett assumed that the Berlin observations of abnormal heating in the stratosphere were the first of their kind, it may be of interest to report that a similar occurrence had, in fact, been noted a year previously by the writer from the results of high-altitude soundings made at Downham Market (52°36′N., 0°24′E.) and Lerwick (60°08′N., 1°11′W.). About 150 of these soundings to levels between 20 and 30 Km. were made in 1950 and 1951. Temperature was measured by the Meteorological Office radio-sonde, and wind and height by radar. The soundings were all made at night (2200) so

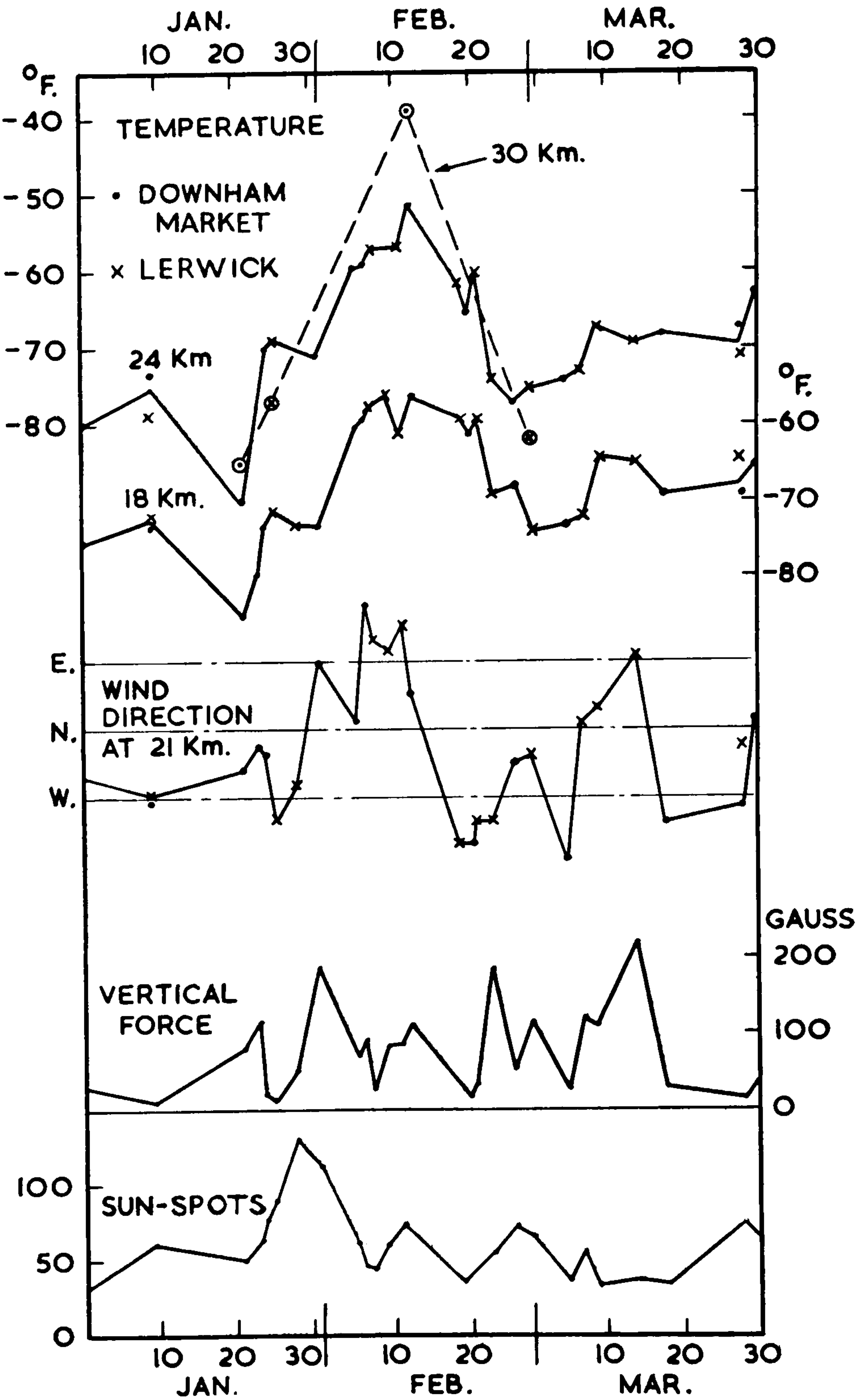
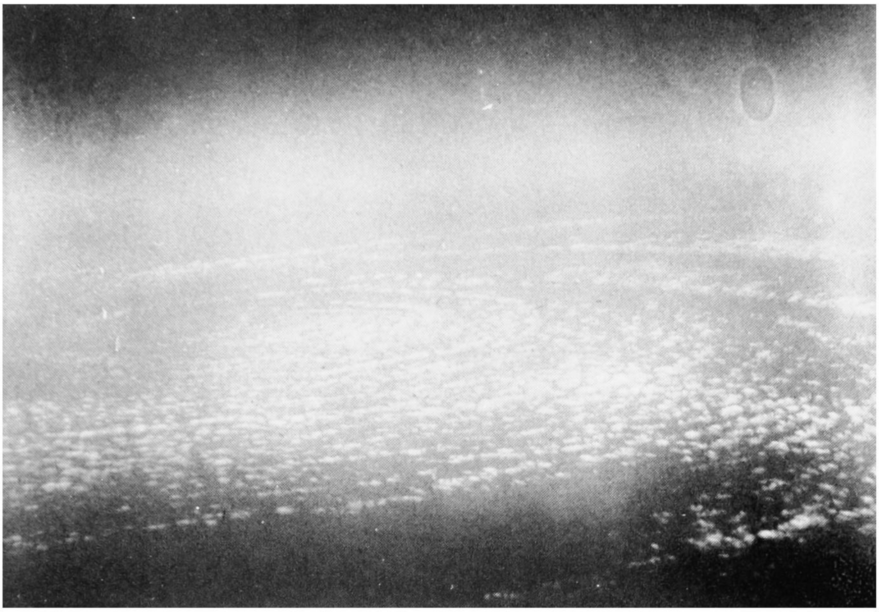
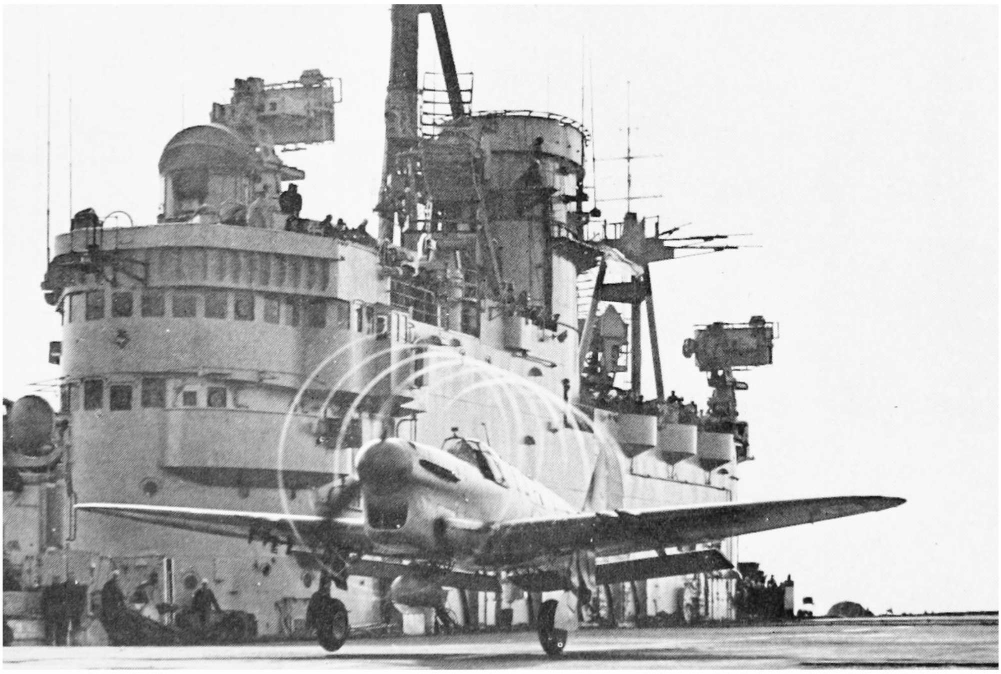


FIG. 1—STRATOSPHERIC TEMPERATURE AND WIND DIRECTION, MAGNETIC ACTIVITY (RANGE OF VERTICAL FORCE AT ESKDALEMUIR) AND SOLAR ACTIVITY DURING THE FIRST QUARTER OF 1951



Reproduced by courtesy of R. Noble

CLOUD PATTERN NEAR CAPO CARBONARA, SARDINIA, FROM 35,000 FT.
(See p. 28)



Reproduced by courtesy of "The Aeroplane"

PROPELLER-TIP CONDENSATION TRAILS

The Firefly aircraft was just taking off from H.M.S. *Eagle* whilst she was steaming off the Isle of Wight, on March 8, 1952. (see p. 29.)

FIG. 1—A FRESHLY FORMED PIECE OF CONTRAIL

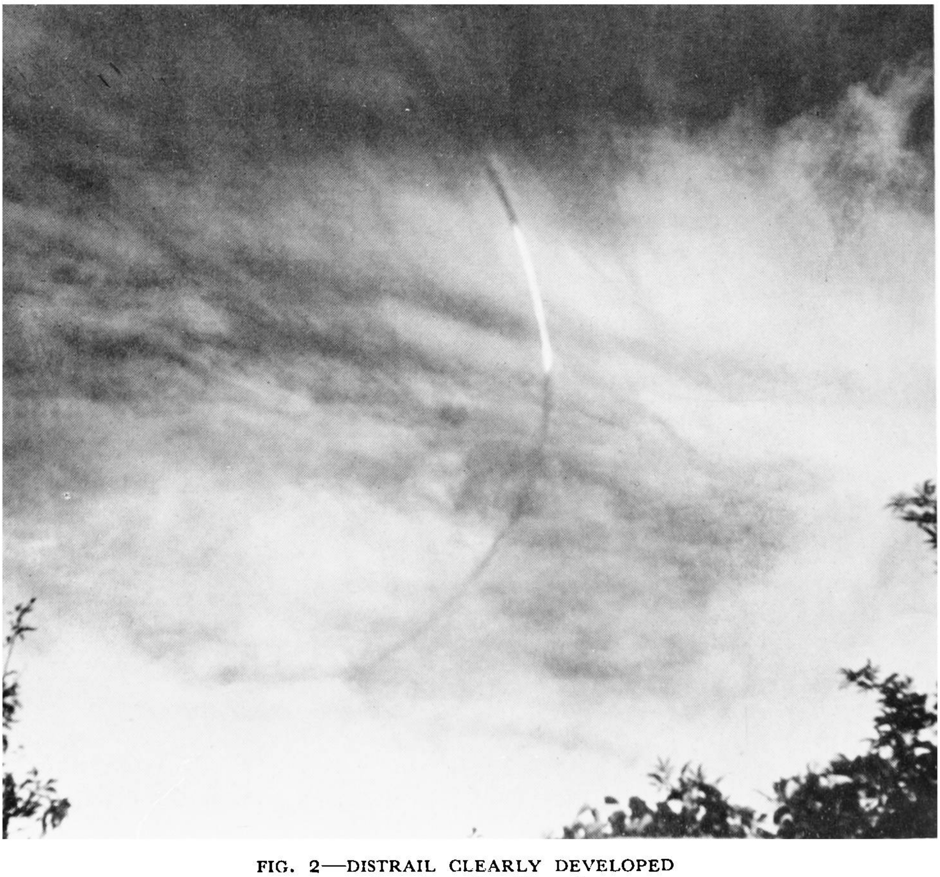


FIG. 2—DISTRAIL CLEARLY DEVELOPED
(1 min. after Fig. 1)

FIG. 3—DISTRAIL BREAKING UP INTO A ROW OF HOLES
(2 min. after Fig. 1)

FIG. 4—HOLES WELL DEVELOPED
(4 min. after Fig. 1. This picture is incomplete because the film ran out)

CONTRAILS AND DISTRAILS

Condensation trails (contrails) and evaporation trails (distrails) were formed by an aircraft over Wimbledon Common about 10.30 a.m. on September 23, 1952. Photographs were taken looking northwards. The aircraft was passing just behind the tree on the left of Fig. 1; it was in cloud and cannot be distinguished in the photograph.

(see p. 27)

Photographs reproduced by courtesy of R. S. Scorer

SANDSTORM OR HABOOB FROM THE GARDEN OF A HOUSE IN KHARTOUM

(See p. 26)

Photographs reproduced by courtesy of J. Fleming as to eliminate solar-radiation errors. A preliminary survey of the results has been published[3], and a more detailed account, which is to include occurrences of the type now under discussion, is in course of preparation.

The point of immediate interest is that the stratospheric temperatures observed in these soundings during the period February 5–20, 1951, were relatively high compared with the general run of the temperatures before and after this period. The observations at 18, 24, and 30 Km. for the first three months of 1951 are plotted in the upper part of Fig. 1. At the peak of the warm period on February 12, the temperatures at the three heights were about 20°, 25° and 40°F. higher than those outside the period. The differences at specified pressure levels would be still greater. The changes were practically simultaneous at all the stratospheric heights but there were no similar changes in the tropospheric observations.

The soundings during the period February 1–12 were also noteworthy in showing the appearance of an easterly air stream at the levels above 18 Km. It was followed by a reversion to the westerly stream before the summer régime finally set in. The observations of wind direction at 21 Km. are shown in Fig. 1. The changes from the westerly flow of the winter months to the summer easterlies does not usually take place until nearer the vernal equinox.

Possible connexion of the abnormal temperature with solar phenomena was investigated by examining the sun-spot numbers published by the International

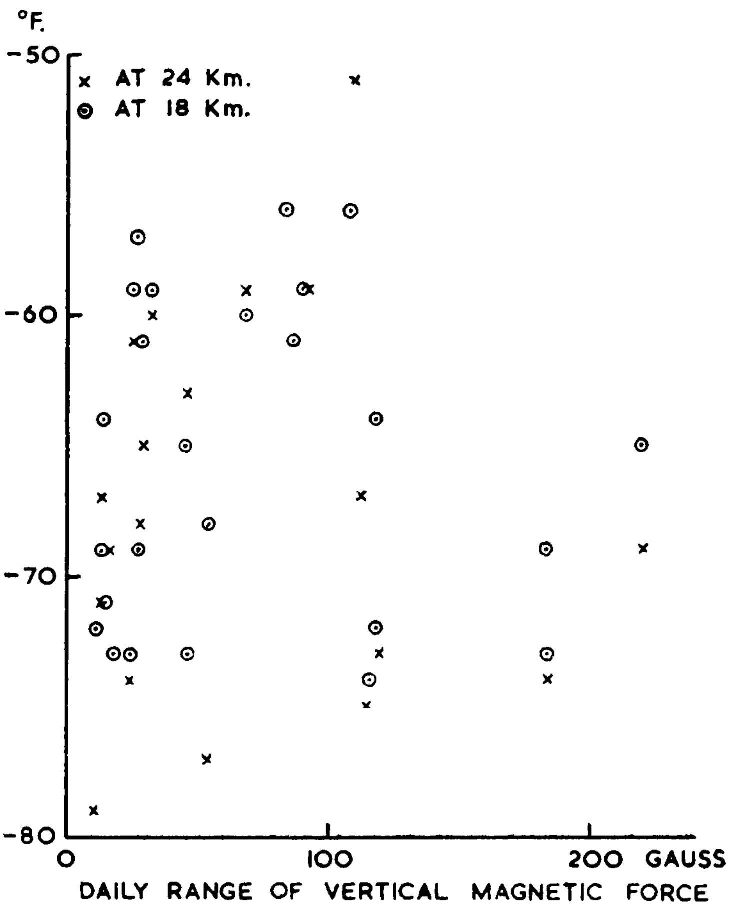


FIG. 2—STRATOSPHERIC TEMPERATURE AND MAGNETIC ACTIVITY

Astronomical Union[4] and the daily range of vertical magnetic force recorded at Eskdalemuir Observatory (55°19′N., 3°12′W.). The range of vertical force may be taken as giving a good indication of solar corpuscular activity. The data for the days of the high-level soundings are plotted in the lower part of Fig. 1. There is clearly little or no connexion with the sun-spot number or the magnetic activity, neither of which was abnormally high. The lack of correlation is, perhaps, more evident in Fig. 2 in which the temperatures are plotted against the daily range of vertical force; the sun-spot data gave a similar result. According to the *Quarterly Bulletin on Solar Activity* for the first quarter of 1951 the only solar eruptions large enough to be estimated as 3 on a scale 1 to 3 of increasing intensity and size occurred on February 19 and 25, and March 24. There is little evidence to indicate that these eruptions caused relatively high temperatures in the stratosphere. Neither does there appear to be any evidence of ionospheric activity to correspond with the high temperatures.

The weather over the British Isles during February 1951 was decidedly abnormal in two respects, namely very low sea-level pressures and high rainfall. The mean pressures were between 10 and 14 mb. below average, and the exceptionally low readings at some places broke previous records. Rainfall over south-east England was nearly double the average, and again at some places records were broken.

For most of the month a westerly type of weather prevailed, with depressions passing over or close to the British Isles. Temperatures were remarkably uniform.

REFERENCES

1. WILLETT, H. C.; Atmospheric reactions to solar corpuscular emissions. *Bull. Amer. met. Soc., Lancaster Pa.*, **33**, 1952, p. 255.
2. SCHERHAG, R.; Die explosionsartigen Stratosphärenerwärmungen des Spätwinters 1951/1952. *Ber. dtsch. Wetterdienstes, U.S. Zone, Bad Kissingen*, No. 38, 1952, p. 51.
3. SCRASE, F. J.; Radio-sonde and radar wind measurements in the stratosphere over the British Isles. *Quart. J. R. met. Soc., London*, **77**, 1951, p. 483.
4. WALDMEIER, M.; Sunspot relative-numbers. *Quart. Bull. solar Activ., Zurich*, No. 93, 1952, p. 197.

METEOROLOGICAL OFFICE DISCUSSION

Orographic effects on wind with special reference to the safety of aircraft

The first discussion of the 1952–53 series, held at the Royal Society of Arts on October 20, 1952, dealt with orographic effects on wind with special reference to the safety of aircraft. It was opened by Mr. L. Jacobs who based his statement on the following papers:—

FIELD, J. H. and WARDEN, R.; A survey of air currents in the Bay of Gibraltar 1929–30. *Geophys. Mem., London*, **7**, No. 59, 1933.

ABE, M.; Mountain clouds, their forms and connected air currents. *Bull. cent. met. Obs., Tokyo*, **7**, No. 3, 1941.

BROOKS, F. A.; Mountain top vortices as causes of large errors in altimeter heights. *Bull. Amer. met. Soc., Lancaster Pa*, **30**, 1949, p. 39.

ROUSE, H.; Model techniques in meteorological research. "Compendium of meteorology", Boston Mass., 1951, p. 1249.

It has long been known that air in passing over hilly or mountainous country is uplifted on the windward slopes but that the airflow to the lee can be very irregular, often with violent up-and-down currents. Over fairly rough high ground, with winds of any intensity, marked eddies can form in the lee, either breaking off irregularly and travelling downstream, or remaining in regularly spaced positions, the so called "rotors" first described in detail by Küttner[1,2] from sailplane and other investigations.

In stable air and with a moderate increase of wind with height, standing waves can be set off in the lee of high ground, and with moisture present lenticular cloud is shown at the up currents of the waves. These clouds have long been observed in various parts of the world. Manley[3] has pointed out in his detailed account of the helm wind that observations of the helm bar in Cumberland were made as early as 1777. Local names have been given to these lenticular clouds such as moazagotl in the Riesengebirge Mountains in Germany and turusi on Mount Fuji in Japan.

Many attempts have been made to calculate theoretically the disturbance of the air flow by high ground. Scorer[4,5] has pointed out the inadequacies in the earlier theoretical treatments by Lyra and Queney, and has himself put forward a suitable mathematical theory to explain the formation of the lee waves, assuming dry, isentropic, inviscid, stream-line flow in which the disturbance is only a small proportion of the wind velocity. He has given diagrams of the air flow to be expected over a mountain ridge, showing extension of the lee waves to great heights, and has pointed out that the lee clouds such as helm bar and Küttner's rotors indicate the waves at low levels, while, at the other extreme, the mother-of-pearl clouds observed by Størmer show the lee waves at 70,000–100,000 ft. His theory fits in very well with observations of the lee waves as shown, for example, by the sailplane flights described by Yates[6] in this country and by light-aircraft flights by Radok[7] in Australia. Turner[8,9] has recently given many examples of the effect of the vertical currents of these waves on aircraft in western Europe, sometimes 60–80 miles from the high ground, with up-and-down currents sometimes greater than 2,000 ft./min.

For very disturbed flow to the lee of a mountain an attempt can be made to study the flow round a model placed in a wind tunnel, such studies being supplemented by investigations on the site. This approach to the problem has been made in the four papers which form the basis of this discussion.

Field and Warden started their experiments in 1929 with a 1 : 5,000 model of the Rock of Gibraltar, after many accidents had occurred with seaplanes attempting to land in Gibraltar Bay, in the lee of the Rock (top 1,396 ft.), when an easterly wind, the levanter, was blowing.

To study the air flow around the model in the wind tunnel the motion of either flags—short fine silk fibres—or streamers—long woollen strands—were observed and sketched. The flags of equivalent length 800 ft. and equivalent spacing 2,000 ft. were fixed on wires at various equivalent heights up to 7,000 ft., and the positions of the streamers could be adjusted until they illustrated the major eddies. By skewing the model results were obtained with winds from between NE. and SE.; repetition of the experiments with or without a change of observer showed no material differences.

There was good agreement between the flag and streamer methods—as shown by plots on some twenty diagrams. At all levels up to at least 3,000 ft. an area of vortices and eddies extended westward of the Rock for about a mile and a half over the Harbour and Bay and was succeeded further west by a wide region of turbulent winds on a decreasing scale.

Following the model experiments, measurements were made of the horizontal and vertical currents at Gibraltar, by double-theodolite pilot-balloon ascents, from November 1929 to March 1930. In spite of weather difficulties and a lack of easterly winds, 138 balloons were sent up of which 77 were in winds between 72° and 120°, the extreme easterly range found during the period.

In comparing model and site results it must be remembered that the tunnel wind is uniform while winds on the site are liable to vary appreciably with height and time. In spite of this the model observations did, as Field and Warden report, "forecast in a very remarkable way the real winds on the site. In a total of 360 plottings of balloons there were only some 24 instances of discordance, many of them slight."

Vertical velocities calculated from the pilot-balloon ascents, which were mostly made with surface winds of force 3, reached nearly 800 ft./min., and they considered that these velocities probably reached 1,500 ft./min. or more for a short time even on days when the free wind did not exceed force 6. Down currents are stronger than up currents and are considerably more frequent.

While at Gibraltar they made a short study of the banner cloud which forms to the lee of the Rock, and noted that the period of breakaway of small cumulus cloud from the end of the banner (4–5 min.) agreed well with a theoretical estimate of 3 min. previously given by Relf of the National Physical Laboratory.

Abe in his 1941 paper continues to describe work he commenced in the 1920's on the ciné and stereo photography of clouds round the conical-shaped Mount Fuji (12,390 ft. high) in Japan, using his results to judge the associated air currents. He is careful to point out that the first ciné photographs of cloud were taken by Sir Napier Shaw[10] in 1911. His work on cloud photography is voluminous—an earlier 1937 paper contains 500 pages—but the opener pointed out that, in interpretation, there is always the difficulty of allowing for the growth or decay of the clouds. He gives many examples of rotating clouds with vertical, horizontal and inclined axes saying "they are certainly generated by vortices induced on the lee mountainside."

The important feature of Abe's work is his wind-tunnel experiments, using a 1 : 50,000 model of Mount Fuji. He made his first model experiments in 1932[11] but the series of experiments in 1939–41 are more detailed. Abe points out the desirability of equating the Reynolds number for the flow over Mount Fuji with that over the model. He does this by making the assumption that eddy viscosity is applicable to the flow over Mount Fuji and molecular viscosity to the model. By assuming a velocity of 22 m.p.h. for flow over Mount Fuji and adopting a velocity of 2 m.p.h. for the air flow in the wind tunnel he calculated a Reynolds number for both cases of around 4,000. This is a definite assumption and, as mentioned below, it was criticized by Rouse.

To make the air flow visible Abe used smoke of an incense stick in normal experiments, and occasionally little wind vanes. To get a wind shear the air flow was partly interrupted or an extra blower was introduced into the chamber. To simulate a lapse rate the heavy white smoke of "dry-ice" cloud could be introduced into the bottom of the tunnel. He took photographs of the air flow past the model under varying conditions and obtained rough qualitative agreement with the movements and shapes of mountain clouds he had observed on Mount Fuji. In particular he was able to imitate a wing-shaped turusi (lee cloud) in his wind tunnel, with its associated up-and-down currents.

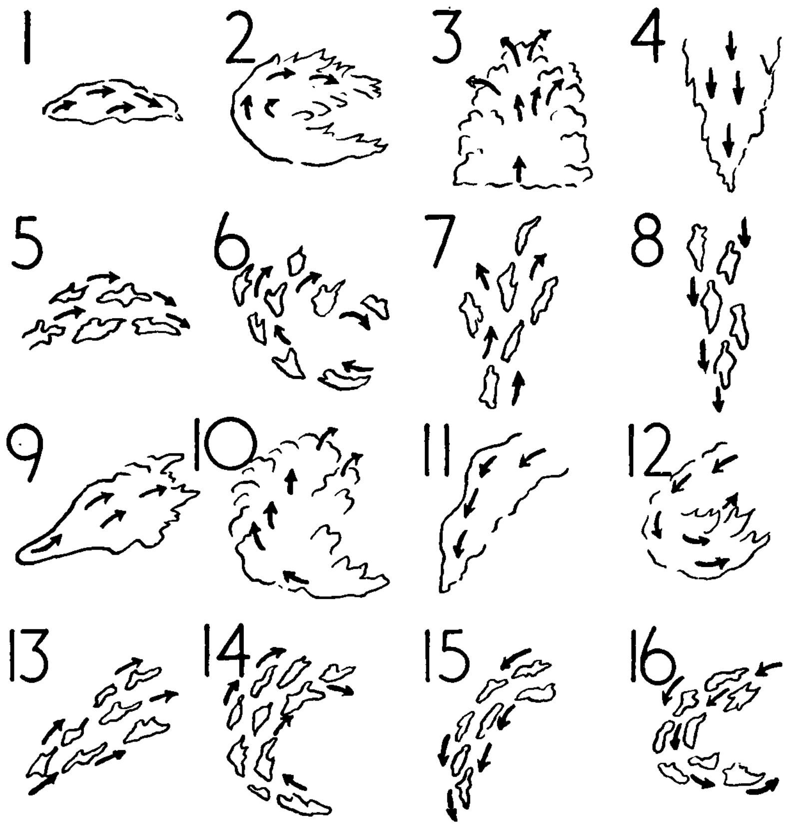


FIG. 1—ABE'S CLASSIFICATION OF MOUNTAIN CLOUDS

He points out that, while the cloud forms generated by Mount Fuji are simple compared with those of other mountains, as its shape is very simple, a classification of the various peculiar types observed might well form a useful foundation for an international classification, as he was convinced that the various shapes gave a good guide to the vertical currents. His main classification is shown in Fig. 1.

Brooks is only indirectly concerned with model experiments in that he applies the well known results of wind-tunnel tests of pressure drop on the camber of aerofoils to get some idea of the equivalent pressure drop likely over a mountain top. With a free stream velocity of 100 m.p.h. over a 14,000-ft. mountain this gives an altimeter error of 700 ft., assuming a double velocity head. He points out that this error is not large enough to explain some of the errors of 2,000–3,000 ft. which he claims have been reported directly by aircraft and indirectly by large pressure changes observed on the tops of mountains and by vortex cloud spouts descending below the main cloud level.

These large pressure changes could arise as the pressure drop in intense vortices (analogous to tornadoes) stemming from the bluff edges of the mountains. He calculated that the tangential velocity of the core of a vortex, of which the outer part was irrotational, would have to be 135 m.p.h. to give a pressure fall at the centre sufficient to bring the total altimeter error on top of the 14,000-ft mountain to 2,000 ft., but stated that this inner velocity could be set up on the outer edge of the vortex by quite moderate winds. He suggests wind-tunnel experiments, possibly using the free surface of a water channel to simulate the natural gradient of density, be carried out to check this theory, followed by investigation by aircraft and smoke generators on the site.

Dr. Rouse, Director of the Iowa Institute of Hydraulic Research, the author of the fourth paper, commenting on Brooks's work, states that he did not doubt that pressure intensities within the eddies were fully as low as Brooks estimates. He did not understand, however, how the velocities involved would permit the altimeter error in an aircraft to occur without the velocity effect becoming even more disastrously apparent. Moreover, measurements he had made indicated that the velocities in the lee of abrupt boundary irregularities, such as walls and cliffs, were invariably lower than that of the deflected wind.

It was as a result of Brooks's work and the discussion on it that the project of research "Theoretical and observational study of air flow over mountain ranges" was initiated by the United States Air Force's Air Research and Development Command in 1950 and is still proceeding.

In Rouse's own paper he points out the use of dimensional analysis and in particular the Π theorem in planning model experiments. For mechanical flow dimensionless parameters, such as the Euler, Froude, Reynolds and Mach numbers, have to be equated for model and site, and normally temperature would also have to be considered. However, if gravitational, viscous or thermal effects are to be neglected, only the Reynolds number need be considered. Rouse criticizes Abe's assumption regarding the viscosity, since Abe was dealing with fairly smooth high ground, but he points out that where the ground is rough—as in Field and Warden's case—the flow is essentially independent of the Reynolds number. The opener mentioned that Abe's 1942 experiments[12] with bluff models satisfied this condition.

Rouse refers to unpublished war-time work using large mountain models in hangars, the air flow being produced by blowers or aircraft propellors, but gives no details. He gives suggestions for future model work pointing out that pitot heads or hot-wire anemometers can be used for measurement and chemical smoke for display of the flow. To simulate thermal stratification experiments could be carried out in water using salt solutions of different concentrations.

It is rather surprising that, in view of Rouse's general recommendation of the use of model experiments, the United States Air Force Research project decided, after preliminary experiments, to discontinue model work owing to lack of dynamic similitude. Only preliminary notes have so far been published on the general work of the research project[13,14]. Measurements are being made at Bishop, California (between the Sierra Nevadas and White Mountains which range up to 10,000–14,000 ft.) using radio-sondes, radar equipment and double-theodolite pilot-balloon measurements. Performance-calibrated sailplanes are being tracked and vertical currents of 4,000 ft./min. have been recorded.

The Bishop lee waves are used by sailplane pilots to climb to record heights of over 40,000 ft. Lee clouds are common at 25,000–35,000 ft. with higher lee clouds estimated at 60,000–80,000 ft. (It should be noted that Austin[15] has reported that in this country wave clouds can be set off to 32,000 ft. over hills less than 800 ft. high, and Ludlam[16] has emphasized that this hill cirrus is indeed quite common in the British Isles, with vertical currents inside the clouds up to 2,000 ft./min.)

These four and other papers appeared to the opener to indicate that the use of models is feasible with heights up to say 2,000–3,000 ft. near very rough terrain, but that such experiments should be supplemented, and, in the case of higher levels and higher ground, superseded by investigation on the site.

Gliders have been increasingly used in recent years for investigation on the site and descriptions of such work have been given by Förchtgott[17-21] in Czechoslovakia, Raspet[22] in the United States and by Yates[6], Bell[23], Fyfe[24], Ludlam[25] and Scorer[26] in this country. Scorer[27] has given a summary of the theoretical and glider work discussed during the July 1952 meeting of the Organization Scientifique et Technique Internationale du Vol à Voile at Madrid.

The opener mentioned that Raspet[28] had detected well marked windward waves as well as lee waves, and that, apart from recent theoretical work by Ringleb[29], he had been unable to trace any other reference to these waves.

The Director said that this discussion is very topical and coincides with the publication of the report of the air crash on January 10, 1952, in the Snowdon area. This is the first public inquiry on aircraft accidents to have a meteorologist on the Board and Mr. Gold with his wide knowledge of meteorology was a most admirable choice. Two general effects on aircraft have to be considered, turbulence and the effect of the flow on altimeter readings. Like other critics of Brooks's paper he was puzzled about his altimeter errors, as these would be fluctuating widely with the movement of the vortices, and velocities as great as Brooks estimated would be enough to break up any aircraft.

Dr. Scorer, Imperial College, emphasized that there was a great deal to be said on this subject so he would restrict his remarks to describing three of the latest results, which he expected to publish shortly.

It is now well recognized that static stability in an air stream extends the effect of a mountain to greater heights than when the lapse rate is adiabatic. It is evident therefore that wind-tunnel experiments must take account of the relationship between kinetic energy and buoyancy energy expressed in the number

$$S = g\beta\frac{d^2}{U^2}$$

which must take the same value in model and full scale ; β represents the static stability ($= dT/Tdz$), d is a representative length and U is the wind. This number is of paramount importance and the Reynolds number is a secondary consideration. In typical cases we find that very slow running speeds, such as 70 cm./sec., are required, and this makes the control of velocity and temperature profiles extremely difficult. He had abandoned the construction of a projected wind tunnel through lack of time and resources.

To give point to the importance of this stability number it is desirable to distinguish types of flow in the atmosphere. It is thus called aerodynamic flow if it is analogous to ordinary wind-tunnel flow, that is when the lapse rate is adiabatic, and barostromatic if the stratification is stable.

A special result, of great importance, is that if an adiabatic layer, such as a layer of nimbostratus for instance, is sandwiched between two stable layers the flow over a hill cannot be steady and laminar. It is therefore unsteady or contains overturning, but the nature of these disturbances is unknown, and cannot be evaluated by perturbation theory (this theorem may be relevant to the air crash in Snowdonia).

The wavy motions produced by mountains can affect the readings of radiosonde balloons for they drift downwind through the waves as they ascend. In passing from a crest to a trough a fictitious inversion may be recorded.

One of the difficulties of research in the field is in obtaining the right weather. A research team will have to be ready to go to a site at short notice when a suitable forecast is given. There is no need to go outside Great Britain for this, nor to fly at great altitudes, for the nature of the flow near the ground determines the effective shape of the mountain as regards disturbances at great heights. The problem at high levels is simple in comparison with the study of standing and moving eddies in the lee of a hill.

Abe's demonstration in a wind tunnel of how to produce a wing-shaped cloud in the lee of a mountain is not conclusive, for a similar-shaped banner cloud can be explained by perturbation theory with no eddies or vortices in the lee.

Mr. H. S. Turner said that he had been collecting reports in the last 4 years at Northolt of standing waves observed by aircraft pilots, and now had 30 reports indicating that appreciable up-and-down currents, sometimes associated with marked turbulence, can be experienced by aircraft—in one case the aircraft was descending at 1,000 ft./min. over the Rhône Valley when it should have been ascending at 500 ft./min. In every case there was a shallow unstable layer recorded near the ground with a stable layer above. Cases were recorded in all months except June and July, and the most frequent areas were, in descending order, the Rhône Valley, north England and south Scotland, north Wales and the north Irish Sea. He gave a detailed account of the upper air picture on October 6, 1952, when Gloucester reported moderate or severe turbulence at 18,000–25,000 ft. in the Cheltenham area, and he was able to confirm the existence of standing waves by questioning a pilot at Northolt.

Mr. Gloyne mentioned that the flow round hills and valleys was of great importance in agricultural meteorology, and, for example, that hills and valleys of certain angles were self cleaning when snow fell and drifted. The same Brooks mentioned by the opener had also pointed out that orographic flow caused the forward flagging of trees on the tops of hills and the reverse flagging of trees in the reversed flow at the lee foot of the hills. Mr. Gloyne emphasized that the curvature in models was always greater than that on full scale.

Mr. Illsley described the effect of south-westerly winds on landing on the east-west runway at Gibraltar, pointing out that the south-westerly sea breeze was shallow and caused no difficulty but that with deep south-westerly currents the turbulence caused by the Rock made conditions very dangerous. Pilots had been forbidden to turn in the lee of the Rock owing to the danger of stalling in the eddies.

The effect of obstacles on the readings of anemometers was of course well known but he had found some very marked effects with two anemometers, one on the windward and the other on the leeward side of a building at South Cerney, and similar effects due to high ground at Plymouth.

Mr. Bannon very much doubted if Brooks's altimeter error in a vortex is important, for an aircraft would pass through the vortex before the altimeter could be read at all. He wondered if the opener had found any references in the literature to the size or distribution of the vortices to which Brooks was referring. Mr. Jacobs said that Brooks is very careful to avoid giving any idea of the size of the vortices but suggests that the intense ones are confined to near the mountain. He could find no other reference to the size of this "Brooks" vortex although Field and Warden found 6,000 ft. diameter for those in the lee of the Rock of Gibraltar. Dr. Scorer thought that the effect of the descending currents on aircraft in the lee was far more important than any possible altimeter error.

The Director mentioned that the Meteorological Office was in close touch with the United States Air Force project and has pointed out the importance of considering the wind shear and lapse rate.

Mr. Gold wondered if Dr. Scorer could give a description of the physical principles of the formation of the standing waves. He presumed the waves had a small effect on altimeter readings. He would like to know whether there had been any comparative readings of aircraft accelerations and altimeters. In connexion with Mr. Illsley's remarks on anemometers, he pointed out that similar difficulties were found long ago at the Lizard[30]. There was no doubt about the importance of flow over mountains, and he was surprised that there had in fact been so few aircraft accidents—he attributed this to the skill of the pilots. Dr. Scorer referred to the differences between aerodynamic and barostromatic flow, and said it was difficult to give the short physical explanation of the height distribution of wave motion asked for by Mr. Gold. He did not think aircraft accelerations and altimeter errors had been considered, or would be a worth-while investigation, but comparison of actual and altimeter readings of heights of gliders near hills was a profitable investigation, which he had already undertaken in north Wales, and he suggested could be repeated in the lee of the Isle of Man.

Dr. Stagg asked "Where do we go from here?" He pointed out the difficulties of waiting till conditions were just right in nature, e.g. for standing waves, and suggested that large model experiments in hangars as mentioned by Rouse might be the answer using the S number proposed by Dr. Scorer. Dr. Scorer thought the answer was to have mobile teams of meteorologists and glider pilots available to go to sites at short notice.

Mr. Wallington considered that more meteorologists should take up gliding. He mentioned that the late Terence Horsley had reported that on one occasion when he had landed after soaring in standing waves, to the lee of the Sidlaw Hills, he found that there had been such intense turbulence at ground level that trees had been uprooted.

The Director asked Mr. Gold how the Court of Inquiry had decided on the exact figures in their recommendations that the safety height over hills be increased so that when, for example, the wind had increased to 60 kt. the clearance should be 4,000 ft. Mr. Gold said that the figures seemed reasonable in the light of evidence available to the Court. There was no doubt whatever that 1,000 ft. is inadequate clearance in conditions that may arise over mountains of 3,000 ft. or more.

REFERENCES

1. KÜTTNER, J.; Moazagotl und Föhnwelle. *Beitr. Phys. frei. Atmos., Leipzig*, **25**, 1939, p. 79.
2. KÜTTNER, J.; Zur Entstehung der Föhnwelle. Untersuchung auf Grund von Wellensegelfügen und Beobachtungen an der Moazagotl-Wolke. *Beitr. Phys. frei. Atmos., Leipzig*, **25**, 1939, p. 251.

3. MANLEY, G.; The helm wind of Crossfell 1937–1939. *Quart. J. R. met. Soc., London*, **71**, 1945, p. 197.
4. SCORER, R. S.; Theory of waves in the lee of mountains. *Quart. J. R. met. Soc., London*, **75**, 1949, p. 41.
5. SCORER, R. S.; Air flow over mountains. *Sci. Progr. Twent. Cent., London*, **40**, 1952, p. 466.
6. YATES, A. H.; Standing wave exploration by sailplane. *Weather, London*, **4**, 1949, p. 40.
7. RADOK, V.; Report on a flight investigation of lee wave disturbance near Melbourne. *Res. Bull. met. Bur. Aust., Melbourne*, No. 15, 1950.
8. TURNER, H. S.; Standing waves and powered flight. *Met. Mag., London*, **81**, 1951, p. 106.
9. TURNER, H. S.; Severe turbulence over the Inner Hebrides. *Met. Mag., London*, **81**, 1952, p. 239.
10. DINES, W. H.; The free atmosphere in the region of the British Isles. Second report. *Geophys. Mem., London*, **1**, No. 2, 1912.
11. ABE, M.; The formation of cloud by the obstruction of Mt. Fuji. *Geophys. Mag., Tokyo*, **6**, 1932, p. 1.
12. ABE, M.; An effort to make visible the mountain air current. *J. met. Soc. Japan, Tokyo*, 1942, p. 69.
13. KÜTTNER, J. and THOMPSON, P. D.; Observations and theory of flow over long ranges. *Bull. Amer. met. Soc., Lancaster Pa*, **31**, 1950, p. 168.
14. COLSON, DEVER; Results of double-theodolite observations at Bishop, Cal., in connection with the "Bishop-Wave" phenomena. *Bull. Amer. met. Soc., Lancaster Pa*, **33**, 1952, p. 107.
15. AUSTIN, A. R. I.; Wave clouds over southern England. *Weather, London*, **7**, 1952, p. 50.
16. LUDLAM, F. H.; Orographic cirrus clouds. *Quart. J. R. met. Soc., London*, **78**, 1952, p. 554.
17. FÖRCHTGOTT, J.; Viditelné príznaky vertikálních pohybu v orzdusí (Les symptômes visibles des mouvements verticals dans l'atmosphère). *Bull. Mét. tchécosl., Praha*, **3**, No. 1, 1949, p. 11.
18. FÖRCHTGOTT, J.; Vlnové proudeni v závetrí horskych hrebenu (Le courant ondulatoire sur côte sous le vent des crêtes montagneuses). *Bull. mét. tchécosl., Praha*, **3**, No. 3, 1949, p. 49.
19. FÖRCHTGOTT, J.; Aplikace Kármánovy cesty vírú na pomery v atmosfére (L'application de déplacement du tourbillon de Kármán sur les conditions dans l'atmosphère.) *Bull. mét. tchécosl., Praha*, **3**, No. 4–5, 1949, p. 57.
20. FÖRCHTGOTT, J.; Transport drobnych cástic nebo hmyzu pres Krusné hory (Transport des microparticules ou des insectes au-délà de Krusné hory). *Bull. mét. tchécosl., Praha*, **4**, No. 1–2, 1950, p. 14.
21. FÖRCHTGOTT, J.; The air flow round a conical hill. *Gliding, London*, **2**, 1951, p. 147.
22. RASPET, A.; The sailplane as a meteorological probe. *Res. Rep. Off. naval Res., Washington D.C.*, No. 1, 1948.
23. BELL, G. J.; Some meteorological aspects of soaring flight. *Weather, London*, **5**, 1950, p. 8.
24. FYFE, A. J.; Lee waves of the Ochils. *Weather, London*, **7**, 1952, p. 137.
25. LUDLAM, F. H.; A meteorological investigation using gliders. *Weather, London*, **6**, 1951, p. 345.
26. SCORER, R. S.; The pressure field in front of a hill or that sinking return. *Gliding, London*, **2**, 1951, p. 70.
27. SCORER, R. S.; O.S.T.I.V. 1952; meteorology and gliding. *Quart. J. R. met. Soc., London*, **78**, 1952, p. 635.
28. RASPET, A.; The air flow over an extended ridge. *Org. Sci. Tech. Int. Vol a Voile, Den Haag*, 1951, p. 7.
29. RINGLEB, F. O.; Basic atmospheric flow problems. *Res. Rep. Off. naval Res., Washington D.C.*, 1948.
30. THOMAS, M. J.; Notes on the behaviour of the anemograph at Lizard. *Prof. Notes met. Off., London*, **5**, No. 73, 1936.

LETTERS TO THE EDITOR

Sandstorms in the Sudan

It was interesting to compare Mr. D. W. Johnston's notes on the relation of visibility to wind in Cyrenaica[1] with corresponding effects on the other side of the Sahara. The haboobs or sandstorms of the Khartoum area are well known; they are associated with line-squalls moving north-westwards from Abyssinia and the eastern Anglo-Egyptian Sudan. Immediately prior to the arrival of a haboob the surface wind is calm, but in a matter of seconds it accelerates to 50–60 kt. and the visibility in blowing sand can fall below 10 yd. During the day-time a haboob can be seen approaching as a wall of sand. The mechanics of blowing sand have always been vaguely associated with instability in the line-squalls. Since the publication of the report on the American thunderstorm project[2] it is now thought that it is the leading edge of the cold down-draught from a thunderstorm cell which actually raises the loose sand. An average drop in temperature of about 20°F. on the arrival of a haboob is a confirmation of this theory.

Mr. Johnston also mentions the effect of vegetation on the initiation of blowing sand, this corresponds to another effect in the Sudan. A large area to the south-east of Khartoum known as the Gezira is now artificially irrigated and forms a large cotton plantation. Older inhabitants in Khartoum are convinced that present-day haboobs are not nearly so heavily sand-laden as those of earlier years.

The two photographs facing p. 17 are of a sandstorm or haboob; they were taken from the garden of my house in Khartoum about 1445 G.M.T. (1645 local time) one afternoon in June 1950.

J. FLEMING

Northolt Airport, March 10, 1952

REFERENCES

1. JOHNSTON, D. W.; Relation of visibility to wind in Cyrenaica. *Met. Mag., London,* **81,** 1952, p. 8.
2. BYERS, H. A.; Structure and dynamics of the thunderstorm. *Weather, London,* **4,** 1949, pp. 220 and 244.

Duststorm near Mafraq

In the issue of the *Meteorological Magazine* for August 1952 there is a short note referring to two fine photographs of a duststorm near Mafraq. As it is thought that the note may give the impression that a duststorm is solely a frontal phenomenon, I would like to point out that this is not always the case. My own experience both in India and the Middle East is that many duststorms are associated with the squalls which accompany thunderstorms. The parent thunderstorm may have developed locally and the duststorm may or may not be followed by rain from the associated cumulonimbus cloud especially as the precipitation may evaporate before reaching the ground.

It is significant that, on the occasion in question, thunderstorms were reported in the area and in one of the two photographs there appears to be some cumulonimbus in the vicinity of the duststorm.

R. G. VERYARD

Stanmore, September 10, 1952.

Contrails and distrails

A phenomenon similar to that described by your correspondent H. G. Hopkins in the *Meteorological Magazine* for October was observed over west Wimbledon at about 10.30 a.m. on September 23, 1952. An aircraft caused a condensation trail (contrail) for a short distance in a cloud (there was no shadow, or relative motion of the cloud and the contrail) and on either side was a channel cleared of cloud (distrail). I fetched my camera but a lower cloud intervened before I could record it and the distrail was not visible about five minutes later when the contrail, now very diffuse, was again seen. However, after about two minutes, a second aircraft followed on a similar track—approaching from the south-west, turning to the left over Wimbledon Common and returning towards the south-west. A small length of contrail again appeared (Fig. 1) in about the same place, with a distrail on either side. The distrail developed into a row of holes in the course of the next five minutes (Figs. 2, 3, 4). The motion of the cloud cannot be judged from the position of the trees in the photographs because the camera was not fixed. Unfortunately the film ran out and the last picture is incomplete, but shows clearly the distrail holes. Lower cloud again intervened after a further 1½ minutes. The photographs are reproduced in the centre of this magazine.

A tentative explanation is suggested: the part of the cloud in which the distrail occurred was water cloud which was evaporated by the exhaust heat but did not reform immediately because of this heating and because of the downwash of the aircraft or simply because the surrounding air was not saturated with respect to water; the part in which the contrail formed was ice cloud at the same temperature and because the frost point was not exceeded, except perhaps in a small part of the wake of the aircraft, the cloud was not evaporated but the ice crystals grew through the addition of water vapour by the aircraft. The appearance of the cloud is, if anything, in favour of some explanation of this sort because the contrail part is more fibrous, the distrail part more woolly.

R. S. SCORER

Imperial College, London, S.W.7, November 13, 1952.

[At the time of Dr. Scorer's interesting observation an anticyclone was centred to the west of the Bay of Biscay and a depression to the north of Scotland. A warm front had passed over south-east England during the previous night. The surface isobars over south-east England were curved anticyclonically.

The tropopause height and temperature were about 41,000 ft. (190 mb.) and −80°F. The tropopause was reported by Larkhill as Type II (no inversion but a sharp discontinuity with lapse rate above), less than or equal to 1°F./1,000 ft. at 0300 G.M.T. and Type I (definite inversion) at 1500 G.M.T.

The Mintra level was about 29,700 ft. (320 mb.) at a temperature of −35°F. The vertical temperature distribution as shown by the Larkhill observations had no unusual features in the region between 20,000 and 40,000 ft. The difference between dry-bulb and dew-point readings at the highest level recorded, 350 mb., was 22°F. at 0300 G.M.T. and 16°F. at 1500 G.M.T. The wind above Larkhill at 0900 G.M.T. was 280° 36 kt. at 24,000 ft., 289° 38 kt. at 40,000 ft., and 308° 20 kt. at 50,000 ft.—Ed. *M.M.*]

NOTES AND NEWS

Unusual Cloud Pattern

We are indebted to Mr. R. Noble, 24 Norman Grove, Longsight, Manchester 12, for the aerial photograph of cloudlets arranged in a series of roughly concentric rings which is produced facing p. 16.

The photograph was taken at 38°50′N., 10°00′E., a little to the east of Capo Carbonara, the south-east point of Sardinia, between 0945 and 1015 G.M.T. on August 11, 1952. The photograph was taken from 35,000 ft. and the estimated height of the clouds is 3,000 ft. Mr. Noble estimated the clouds occupied a circle of 20 to 30 miles diameter. No other cloud was visible.

The cloudlets appeared to be stratocumulus just forming but may have been small cumulus.

The general wind direction was NE. on the west side of a trough of low pressure which moved eastwards across the Mediterranean. The clouds appear to have formed in a horizontal eddy presumably produced topographically.

There was apparently no general vertical motion in the eddy as the clouds show little vertical development. They probably formed in a shallow unstable layer, and but for the presence of the eddy would have been in a series of straight lines.

Propeller-tip condensation trails

The lower photograph facing p. 16 was taken aboard H.M.S. *Eagle* on March 18, 1952, and shows a typical example of propeller-tip condensation trails produced by the propeller of a Firefly aircraft. H.M.S. *Eagle* was, at the time, steaming near Nab Tower in the English Channel just to the east of the Isle of Wight.

The air mass over the area was old polar maritime air in the rear of an occlusion which moved north-eastwards along the Channel during the morning of March 16, 1952. This occlusion became stationary and frontolysed over Scotland and the North Sea in the face of an anticyclone which developed over Scandinavia, whilst the air over southern England became stagnant with a slight easterly drift on the 18th. It was very humid, relative humidities being more than 90 per cent. throughout the day at Calshot.

After a clear night the day at Calshot began with fog which cleared between 0700 and 0800, became cloudy with showers in mid afternoon, and again became foggy after dark. Thunder was heard during the afternoon.

Tornado in Northern Ireland

We are indebted to Mr. J. Porter of Garvagh for drawing attention to reports in the *Belfast News Letter* of October 25, and *Northern Constitution* of November 1, concerning a tornado at Upperlands, Co. Derry at 6.15 p.m. on Thursday, October 23, 1952. Considerable damage was done on the farm of Mr. M'Kinistry. A beech tree 4 ft. in diameter was uprooted and sheets of corrugated iron were later found suspended from tree branches 50 ft. above the ground. A metal pot weighing over 1 cwt. was moved nearly a quarter of a mile and corrugated iron roofing half a mile. Men repairing the tower of the church at Tamlaght, two miles distant, saw wreckage flying through the air. One witness spoke of seeing a "mass of something like smoke inside which leaves etc. were swirling". This was probably the funnel of the tornado.

On October 23, there was a very unstable south-westerly air stream over Ireland giving showers and local thunder.

METEOROLOGICAL OFFICE NEWS

Radio-sonde display.—At the exhibition organized by the Radio Industries Council held at Earl's Court at the end of the summer, an exhibit of radio-sonde equipment was staged, in conjunction with Messrs. Whitely's of Mansfield. The complete assembly, consisting of balloon, parachute and radio-sonde transmitter was shown, with ground receiving equipment in console form designed by Messrs. Whitely's for overseas sales. Signals from the radio-sonde could be seen on the cathode-ray tube and measurements taken by members of the public. Office staff attended to answer technical questions, to demonstrate the operation of the instruments and explain the purposes to which upper air observations are applied. The display attracted considerable attention and was valuable in bringing this branch of our work to the attention of the general public. The Office is indebted to Messrs. Whitely for allotting so large a part of their exhibit to meteorological apparatus.

Ocean weather ships.—Following an accident to the Second Engineer in *Weather Watcher*, the Master of the Ship consulted Dunstable Hospital by radio and carried out the treatment prescribed. On the ship's return to the Shore Base, the Medical Officer at Greenock Royal Infirmary stated that the treatment "could barely have been improved on, any refinements being merely academic".

Social and sports activities.—*Party at Harrow.*—On the evening of November 26, the staff of the Climatological Division at Harrow held a birthday party to celebrate the 60th birthday of Mr. R. H. Mathews, O.B.E., Assistant Director (Climatology). The party was planned by the staff as a demonstration to him of their very sincere appreciation of his efforts on their behalf, and of their affection for him. Over 120 past and present members of his Division attended. Mr. Mathews in a short address said how appreciative he was of the means taken by his staff to launch him into old age and how he would treasure the memories of their work and play together during the last four years.

Lawn tennis.—In the Air Ministry lawn tennis championships, the Office staff gained the following successes:

Ladies' Singles: Winner — Miss N. Edwards
Men's Singles: Runner Up — Mr. J. M. Lain
Mixed Doubles: Runners Up — Mr. J. M. Lain and Miss N. Edwards

Cross-Country Running.—The Office won the team race in the Air Ministry Cross-Country Championship held at Hayes, on Saturday, November 29, 1952. Mr. W. R. Bird was second, Mr. I. P. McDonald third in the individual event, and Mr. P. D. Dench second in the handicap.

The running of Messrs. McDonald and Bird did much to enable the Air Ministry Harriers to win the London Business Houses Intermediate Championship held at Parliament Hill Fields earlier in the month.

WEATHER OF NOVEMBER 1952

Mean pressure was above normal over the North Atlantic, north of 45°N., and Scandinavia, and below normal over central Europe. The mean pressure to the west and south-west of Ireland reached 1018 mb., which was as much as 13 mb. above normal in places; mean pressure at the Azores (1017 mb.) was 5 mb. below normal. Over Scandinavia and central Europe mean pressure was between 1010 and 1015 mb. and in the latter region it was 5 mb. below normal.

Mean temperature over the whole of Europe, except Spain, was about 2–5°F. below normal. The values of mean temperature varied from 20°F. in the north of Scandinavia to 35–45°F. in central Europe and 50–60°F. in the Mediterranean region.

In the British Isles the weather was exceptionally cold, particularly during the latter half of the month. As far as can be estimated at present it was the coldest November over Great Britain as a whole since 1925. Snowfall was the heaviest in November since 1919 and in some southern districts for a much longer period; for example at Oxford for 72 years. Less than the average sunshine occurred in Ireland but over most of Great Britain there was an excess; at Southport it was the sunniest November since records began in 1896.

The first week was unsettled generally, and rather mild in the south and west. On the 2nd a small disturbance moved from north of Ireland to the southern North Sea giving rain in most places. On the 4th another depression off north-west Ireland and associated troughs moved east; rain occurred generally and was heavy locally (3·04 in. at Blaenau Festiniog, Merionethshire, and 3·63 in. at Borrowdale, Cumberland). On the 5th a depression south of Iceland moved east-south-east and troughs moved across the British Isles giving further rain, with gales at exposed places in the north-west. Thereafter a deep depression moving south over the North Sea gave widespread severe north-westerly gales; gusts up to 80 kt. occured in the north-west Midlands and considerable damage occurred in some places. The north-westerlies persisted until the 11th but temperature was still not very low. By the 13th a ridge of high pressure extended from the Atlantic across Scotland to Russia; this distribution was temporarily broken on the 14th and 15th by a small depression moving south to south-west England and giving some rain in most places and a thunderstorm at Guernsey. A good deal of fog occurred from the 14th to the 16th. During the 17th and 18th another weak disturbance moved south-south-west from the north of Scotland giving showers, wintry in some parts. Thereafter a depression over France moving west gave considerable rain in the south and on the 20th and 21st a complex depression moving eastward over the country gave substantial rainfall and some wet snow. In the rear of this disturbance there was an outbreak of northerly winds of Arctic origin followed by a ridge of high pressure; snow lay 5 in. deep at Dyce, near Aberdeen, on the 23rd and exceptionally hard frost for November was registered on the mornings of the 24th and 25th. Air temperature fell to 17°F. at Midleton, near Cork on the 24th and to 5°F. at Dalwhinnie, 7°F. at Moor House, Westmorland (1,830 ft.), and 10°F. at Kielder Castle on the 25th. Subsequently a depression moved east-south-east from south-west Ireland and later turned east-north-east along the English Channel to west Germany giving considerable precipitation in southern districts. Heavy rain in Sussex (2·04 in. at Heathfield in the 24 hours to 0900 on the 28th) caused serious flooding. In the closing days a trough of low pressure over northern France spread a little north giving further precipitation in the south on the 29th. In a belt across the country covering parts of East Anglia, the Midlands, the hills in the south-west and most of south Wales, during the last four days there were successive falls of sleet or snow which lay on the ground. Snow lay 10 in. deep at Whipsnade, in the Chilterns on the 30th, with drifts up to 8 ft. in the the vicinity. At Tredegar, Monmouthshire (1,028 ft. above M.S.L.), it lay 6 in. deep from the 27th to the 30th and on the evening of the 29th a train travelling from Merthyr Tydfil to Abergavenny ran into a 10 ft. drift at Pen-y-Wern. In the north severe frost and valley fog occurred; on the morning of the 29th air temperature fell to 10°F. at Moor House and 12°F. at Eskdalemuir, while the maximum temperature at Renfrew on that day was only 24°F., the lowest maximum there in November since records began in 1921.

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

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	62	10	−3·2	118	−1	116
Scotland	57	5	−3·3	77	−1	123
Northern Ireland ...	57	20	−2·3	85	−3	85

RAINFALL OF NOVEMBER 1952

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	3·85	163	*Glam.*	Cardiff, Penylan ...	4·00	99
Kent	Folkestone, Cherry Gdn.	4·54	140	*Pemb.*	Tenby, The Priory ...	3·86	89
"	Edenbridge, Falconhurst	4·46	126	*Radnor*	Tyrmynydd	4·73	71
Sussex	Compton, Compton Ho.	5·09	134	*Mont.*	Lake Vyrnwy	4·25	74
"	Worthing, Beach Ho. Pk.	4·12	129	*Mer.*	Blaenau Festiniog ...	7·46	70
Hants.	Ventnor Cemetery ...	6·08	185	"	Aberdovey	4·21	93
"	Southampton, East Pk.	3·71	118	*Carn.*	Llandudno	2·47	85
"	Sherborne St. John ...	3·74	131	*Angl.*	Llanerchymedd ...	3·77	90
Herts.	Royston, Therfield Rec.	3·74	161	*I. Man*	Douglas, Borough Cem.	3·60	76
Bucks.	Slough, Upton	2·93	132	*Wigtown*	Newton Stewart ...	2·94	59
Oxford	Oxford, Radcliffe ...	3·81	166	*Dumf.*	Dumfries, Crichton R.I.	2·13	58
N'hants.	Wellingboro' Swanspool	2·91	135	"	Eskdalemuir Obsy. ...	3·96	68
Essex	Shoeburyness	4·23	199	*Roxb.*	Kelso, Floors	4·08	177
"	Dovercourt	4·45	207	*Peebles*	Stobo Castle	2·95	89
Suffolk	Lowestoft Sec. School ...	4·21	179	*Berwick*	Marchmont House ...	3·41	114
"	Bury St. Ed., Westley H.	4·12	179	*E. Loth.*	North Berwick Res. ...	2·32	104
Norfolk	Sandringham Ho. Gdns.	3·27	132	*Midl'n.*	Edinburgh, Blackf'd. H.	2·07	92
Wilts.	Aldbourne	4·76	163	*Lanark*	Hamilton W. W., T'nhill	2·15	60
Dorset	Creech Grange... ...	4·64	113	*Ayr*	Colmonell, Knockdolian	2·54	51
"	Beaminster, East St. ...	4·95	125	"	Glen Afton, Ayr San. ...	3·66	67
Devon	Teignmouth, Den Gdns.	5·15	161	*Renfrew*	Greenock, Prospect Hill	2·16	36
"	Cullompton	3·91	114	*Bute*	Rothesay, Ardencraig ...	2·61	51
"	Ilfracombe	4·53	115	*Argyll*	Morven (Drimnin) ...	2·72	40
"	Okehampton Uplands...	6·06	114	"	Poltalloch	2·54	45
Cornwall	Bude, School House ...	4·45	125	"	Inveraray Castle ...	3·50	41
"	Penzance, Morrab Gdns.	6·60	144	"	Islay, Eallabus	2·69	50
"	St. Austell	5·78	117	"	Tiree	2·06	43
"	Scilly, Tresco Abbey ...	6·01	174	*Kinross*	Loch Leven Sluice ...	2·11	59
Glos.	Cirencester	3·81	128	*Fife*	Leuchars Airfield ...	1·99	87
Salop	Church Stretton ...	3·67	118	*Perth*	Loch Dhu	2·82	32
"	Shrewsbury, Monksmore	2·34	104	"	Crieff, Strathearn Hyd.	2·02	47
Worcs.	Malvern, Free Library...	3·30	131	"	Pitlochry, Fincastle ...	1·97	53
Warwick	Birmingham, Edgbaston	2·54	107	*Angus*	Montrose, Sunnyside ...	2·04	77
Leics.	Thornton Reservoir ...	2·00	88	*Aberd.*	Braemar	3·06	80
Lincs.	Boston, Skirbeck ...	2·79	139	"	Dyce, Craibstone ...	3·55	109
"	Skegness, Marine Gdns.	2·55	118	"	New Deer School House	4·29	133
Notts.	Mansfield, Carr Bank ...	2·51	103	*Moray*	Gordon Castle	4·09	142
Derby	Buxton, Terrace Slopes	3·66	78	*Nairn*	Nairn, Achareidh ...	2·55	113
Ches.	Bidston Observatory ...	2·44	98	*Inverness*	Loch Ness, Garthbeg ...	3·27	78
"	Manchester, Ringway...	2·13	82	"	Glenquoich	8·28	68
Lancs.	Stonyhurst College ...	2·46	55	"	Fort William, Teviot ...	4·27	52
"	Squires Gate	1·96	59	"	Skye, Duntuilm ...	4·40	73
Yorks.	Wakefield, Clarence Pk.	1·21	57	"	Skye, Broadford ...	5·60	65
"	Hull, Pearson Park ...	3·08	141	*R. & C.*	Tain, Tarlogie House ...	2·81	95
"	Felixkirk, Mt. St. John...	1·71	70	"	Inverbroom, Glackour...		
"	York Museum	1·48	71	"	Achnashellach	7·93	92
"	Scarborough	4·09	166	*Suth.*	Lochinver, Bank Ho. ...	6·90	137
"	Middlesbrough... ...	3·37	159	*Caith.*	Wick Airfield	3·57	114
"	Baldersdale, Hury Res.	2·34	64	*Shetland*	Lerwick Observatory ...	2·88	68
Norl'd.	Newcastle, Leazes Pk....	3·23	137	*Ferm.*	Crom Castle	1·70	49
"	Bellingham, High Green	3·81	111	*Armagh*	Armagh Observatory ...	2·47	87
"	Lilburn Tower Gdns. ...	4·32	129	*Down*	Seaforde	2·86	75
Cumb.	Geltsdale	3·42	104	*Antrim*	Aldergrove Airfield ...	3·01	93
"	Keswick, High Hill ...	3·21	57	"	Ballymena, Harryville...	3·59	89
"	Ravenglass, The Grove	1·68	38	*L'derry*	Garvagh, Moneydig ...	4·27	109
Mon.	Abergavenny, Larchfield	3·87	101	"	Londonderry, Creggan	3·71	90
Glam.	Ystalyfera, Wern House	5·36	82	*Tyrone*	Omagh, Edenfel ...	3·23	85

Printed in Great Britain under the authority of Her Majesty's Stationery Office
By Geo. Gibbons Ltd., Leicester

Wt-33. K15.