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INVESTIGATIONS RELATING TO CIRRUS CLOUD

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Summary.—Some 200 reports by aircraft observers on the presence or absence of cirrus cloud have been analysed. Some statistical relationships between the occurrence or non-occurrence of cirrus cloud and synoptic variables are shown to be significant, in particular a large proportion of the reports of extensive cirrus sheets is associated with advection of cyclonic vorticity at 300 mb. About 30 observations were of cirrus cloud in the stratosphere.

Introduction.—This paper analyses cirrus cloud observations which were made by Royal Air Force aircraft between August 1952 and December 1954. Reports were also obtained from aircraft of the Meteorological Research Flight based at Farnborough, and were made during their routine high-level ascents. It was hoped that any ascent to cirrus levels by aircraft from these stations would yield a report of "cirrus observed" or "no cirrus observed", but in the early stages of the investigation a certain reluctance was shown to make a report of the latter type.

In order to facilitate simple analysis of the reports, the reporting stations were issued with forms which were so designed that an observer was only required to tick whether cirrus cloud had been observed, and if so to give the distribution and type of the cloud, and the heights and temperatures of bases and tops. Amplifying remarks were also invited.

Altogether about 220 reports for 180 separate days were available for analysis. The majority of these cases were reports of the presence or absence of cirrus cloud at a particular place, though several were reports made on long-distance flights, sometimes as far as North Africa. There were approximately twice as many reports of cirrus observed as no cirrus observed, but it was thought that sufficient observations had been obtained to permit a statistical examination of the reports.

Although a request was made that visibility in and through cirrus cloud should be reported, very few such estimates were made, and no statistical analysis was possible.

Analysis of observations.—Murgatroyd and Goldsmith¹ made an analysis of cirrus cloud observations obtained from routine high-level ascents by aircraft of the Meteorological Research Flight, and also from several selected synoptic reporting stations. With the greater number of observations available for the present investigation, it was thought worth while re-working some of the histograms presented in the earlier paper.

Fig. 1 shows the distribution of observations of the tops of cirrus cloud relative to the tropopause. It can be seen that a maximum occurs between 2,000 ft. and 4,000 ft. below the tropopause, and that rather more than 50 per cent. of the observations of cirrus tops occur from the tropopause down to 6,000 ft. below. Altogether 29 observations were made of cloud in the stratosphere. Of these latter, 10 were more than 6,000 ft. above the tropopause, the greatest reported height (estimated) being 20,000 ft. above. The occurrence of a maximum just below the tropopause is consistent with the results presented by Murgatroyd and Goldsmith, although a peak of more than 50 per cent. was found by those authors to be from 0 to 2,000 ft. below the tropopause.

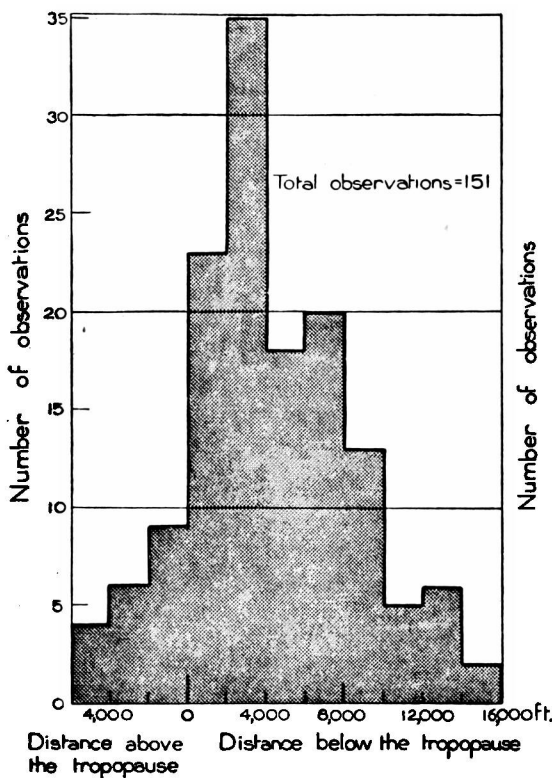


FIG. 1—DISTRIBUTION OF CIRRUS TOPS RELATIVE TO THE TROPOPAUSE
10 observations were from 6,000 to 20,000 ft.

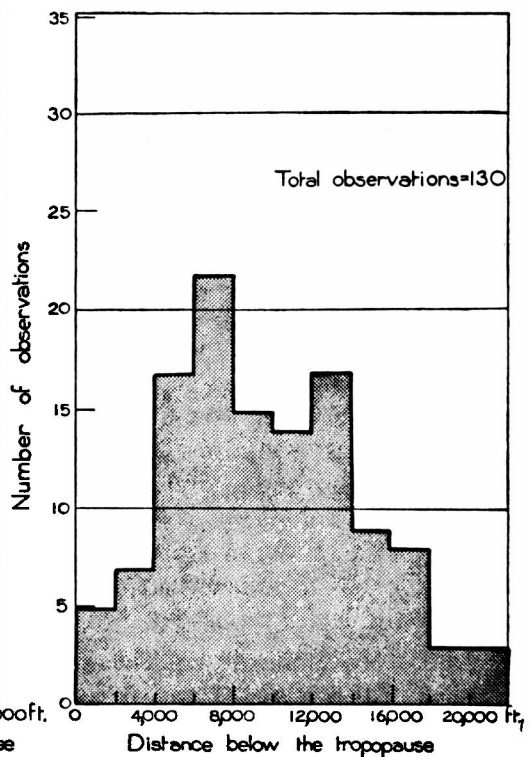


FIG. 2—DISTRIBUTION OF CIRRUS BASES RELATIVE TO THE TROPOPAUSE
10 observations were above the tropopause

Fig. 2 presents a histogram of the frequency distribution of the distance of bases of the cirrus clouds below the tropopause. No well marked peak is evident, but more than 50 per cent. of the observations give a cloud base between 4,000 ft. and 12,000 ft. below the tropopause.

The frequency distribution of the heights of cirrus cloud bases is shown in Fig. 3, where maxima are evident at about 20,000 ft., 25,000 ft. and 30,000 ft. It was thought that these maxima may well be due to a preference for estimating and reporting heights to the nearest 5,000 ft., though a maximum was also obtained by Murgatroyd and Goldsmith between 25,000 and 30,000 ft. Ten cases were reported when the base of the observed cirrus was above 40,000 ft.

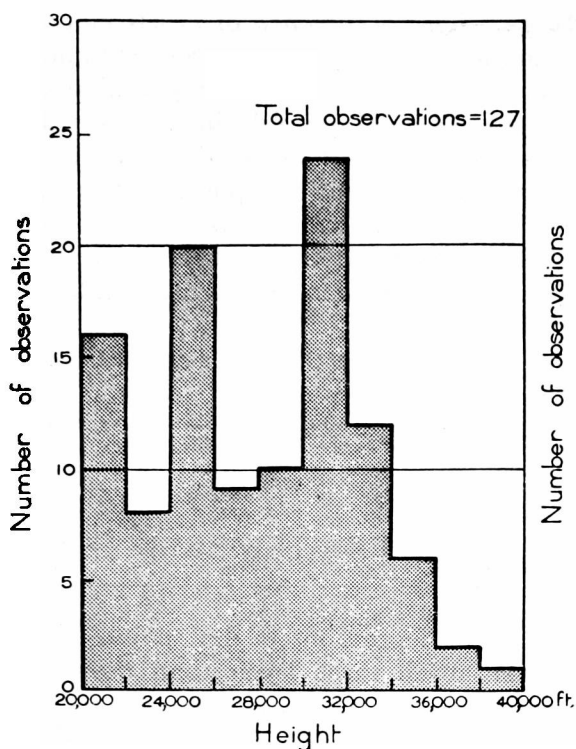


FIG. 3—DISTRIBUTION OF HEIGHTS OF CIRRUS BASES

9 observations were < 20,000 ft.
10 observations were > 40,000 ft.

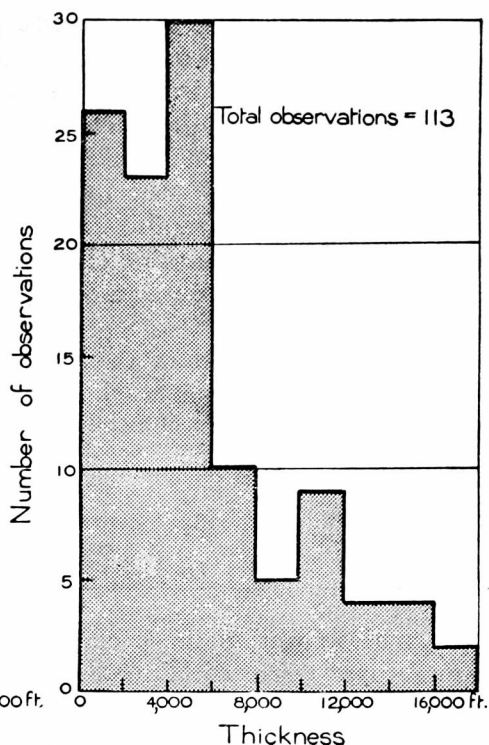


FIG. 4—DISTRIBUTION OF CLOUD THICKNESS

Fig. 4 presents the frequency distribution of the thicknesses of cirrus cloud. About 70 per cent. of the cirrus reported had thicknesses in the range from a few hundred feet to 6,000 ft., though thicknesses of up to 17,000 ft. were reported.

Analysis of surface charts.—It is well known that cirrus cloud is frequently observed in association with a frontal boundary between air masses. However, it is equally apparent from analysis of surface synoptic charts that extensive cirrus cloud is observed in situations other than those exhibiting surface frontal features. Examination of the distances of points of observation of the cirrus cloud from surface fronts showed that about half of the cirrus reports lay from 0 to 200 miles ahead of a surface front, while less than a tenth of the no cirrus reports lay in this range. However, there were more than one quarter of the cirrus reports which could not be associated with any well marked surface front.

Similarly, analysis of the distances of the points of observation from surface-pressure maxima and minima indicated that rather more than half of the no cirrus reports, and rather less than a third of the cirrus reports, occurred in association with a ridge or high-pressure centre.

Although the above analysis seems to indicate that extensive cirrus cloud is more commonly found in association with well marked fronts and isobaric troughs than elsewhere, this is already common knowledge among forecasters, and makes no additional contribution to the cirrus-forecasting problem.

Analysis of upper air soundings.—The occurrence of cirrus cloud is undoubtedly associated with moist air in the upper troposphere. Since humidity observations are not normally available at these heights, an examination was made of the dew-point depressions at 500, 450 and 400 mb. in the hope that a significant increase in humidity might be apparent below the usual cirrus levels. Table I presents the mean depressions of the dew-point at 500, 450 and 400 mb. and the significance levels of the differences between the means for occasions of cirrus and no cirrus. It can be seen that at all three levels the differences between the means of dew-point depression are highly significant.

TABLE I—DRYNESS OF AIR IN ASSOCIATION WITH REPORTS OF CIRRUS AND NO CIRRUS

	500 mb.			450 mb.			400 mb.		
	Dew-point depression	No. of obs.	Significance	Dew-point depression	No. of obs.	Significance	Dew-point depression	No. of obs.	Significance
Cirrus	°F. 18	164	} Better than 0·1 %	°F. 18	152	} Better than 0·1 %	°F. 17	156	} Better than 0·1 %
No cirrus	26	80		26	74		25	72	

An analysis was made of cases when the depressions of dew points below temperatures were simultaneously lower at all three levels than the mean depressions for cirrus reports at these levels, and also when the depressions were simultaneously greater at all three levels than the means obtained for no cirrus reports. This included rather more than half of the total cases. The results are presented in Table II from which it is seen that if these criteria had been used as a basis for forecasting, the “useful effort” (Crossley²) and forecast accuracy for forecasts of cirrus cloud would have been 84 per cent. and 80 per cent. respectively. This would undoubtedly be of some assistance to a forecaster in assessing the distribution of cirrus cloud from radio-sonde observations.

TABLE II—CIRRUS AND NO CIRRUS WHEN THE DEPRESSIONS OF DEW-POINTS AT 500, 450 AND 400 MB. WERE SIMULTANEOUSLY (i) LESS THAN THE MEANS FOR CIRRUS REPORTS (HUMIDITY FAVOURABLE) AND (ii) GREATER THAN THE MEANS FOR NO CIRRUS REPORTS (HUMIDITY UNFAVOURABLE)

	Cirrus	No cirrus	Total
	<i>number of reports</i>		
Humidity favourable	70	18	88
Humidity unfavourable	13	32	45
Total	83	50	133

Kimachi³ suggests that cirrus cloud over Japan is observed only when the temperature at 500 mb. falls within discrete limits and has a maximum frequency of occurrence between temperatures from 0° to −20°F. Analysis of observations in the present investigation showed that the temperatures at 500 mb. when cirrus cloud is reported range from +20° to −30°F. with a flat maximum between +10° and −15°F. Furthermore, no significant difference was found between the distributions of temperatures at 500 mb. for reports of cirrus and no cirrus.

Kimachi also suggests that the lapse rate of temperature with height may well be important in the cirrus-forecasting problem. This is consistent with

the work of Bannon, Frith and Shellard⁴ who obtained a correlation coefficient of 0.80 between the temperature at 500 mb. and the frost point at 300 mb. as measured from aircraft of the Meteorological Research Flight engaged on high-level ascents.

Table III presents the means of the temperature lapse rates at 100-mb. intervals from 500 mb. at times of reports of cirrus and no cirrus. The means at each interval are not significantly different, and are of little use for assessing the presence or absence of cirrus cloud.

TABLE III—MEANS OF TEMPERATURE LAPSE RATE

	500-400 mb.	400-300 mb.	300-200 mb.
	<i>degrees Fahrenheit per thousand feet</i>		
Cirrus	3.90	4.06	2.07
No cirrus	4.02	4.02	1.47
"Student's" <i>t</i>	1.86	0.06	1.00

Murgatroyd and Goldsmith¹ suggest that cirrus cloud is most frequent when the wind at 300 mb. is in the south-west to west sector, and least when the wind is in the east sector. No significant differences were found between the means of the wind strengths at any level up to 200 mb. for reports of cirrus and no cirrus. Table IV presents the frequencies of the winds in various sectors at levels from 500 mb. to 200 mb. for observations of cirrus and no cirrus. Considerable variation is observed in the distribution of the winds for these two classes of reports at all levels up to 200 mb., and application of the χ^2 test indicates that the differences are most significant at 400 mb. It can be seen that the large values of χ^2 at most levels result from an excess of no cirrus reports in the east-south sector and an excess of cirrus reports in the south-west to west sector. These results are in good agreement with those of Murgatroyd and Goldsmith¹.

TABLE IV—DISTRIBUTION OF WIND DIRECTIONS AT VARIOUS PRESSURE LEVELS FOR REPORTS OF CIRRUS AND NO CIRRUS

Pressure		N.-NE.	NE.-E.	E.-SE.	SE.-S.	S.-SW.	SW.-W.	W.-NW.	NW.-N.	Total	χ^2	Significance
mb.												%
200	Cirrus	13	17	0	5	11	39	34	29	148	36.1	<0.1
	No cirrus	9	4	2	3	9	8	16	12	63		
300	Cirrus	17	13	2	7	14	35	29	26	143	24.0	0.1
	No cirrus	7	6	4	4	11	11	10	14	67		
400	Cirrus	15	13	3	4	22	31	36	22	146	45.7	<0.1
	No cirrus	8	4	7	5	11	6	12	13	66		
500	Cirrus	17	11	6	5	19	30	40	19	147	23.3	0.3
	No cirrus	11	5	7	2	8	8	13	12	66		

It has further been suggested by these authors that warm-air advection at cirrus levels is frequently observed when cirrus cloud is reported. This is supported by a report issued by the Washington Air Weather Service⁵, where it is claimed that warm-air advection between 700 mb. and 300 mb. may be used for forecasting cirrus cloud. Table V presents frequencies with which warm-air or cold-air advection are found at times of reports of cirrus and no cirrus at intervals from 500 mb.

TABLE V—CIRRUS ASSOCIATED WITH ADVECTION OF WARM OR COLD AIR

		Warm advection	Cold advection	Neither	χ^2	Significance
mb.		<i>number of cases</i>				%
300–	Cirrus	50	42	42	15.46	0.1
200	No cirrus	16	30	18		
400–	Cirrus	53	31	48	13.67	0.1
300	No cirrus	20	26	21		
500–	Cirrus	52	41	42	3.92	20
400	No cirrus	20	23	22		
500–	Cirrus	70	37	35	21.40	0.1
300	No cirrus	23	30	14		

These frequencies were obtained by examining the winds reported from routine upper air soundings at the times and in the neighbourhoods of the reports. A veering wind with height was taken to indicate warm-air advection between the two levels considered, and conversely. In numerous cases the change in direction was slight within the height interval, and all instances where this change was less than 5 degrees were classified as “neither”. Also under this classification were reports of wind strengths less than 5 kt. The distributions of frequencies in these classes were significantly different for reports of cirrus and no cirrus at the 0.1-per-cent. level or better for all intervals considered except 500–400 mb. Reports of clouds in the stratosphere were not included in these analyses. The association between the occurrence of cirrus cloud and warm-air advection in the upper troposphere is thus confirmed.

Analysis of 1000–500-mb. thickness charts.—Although time differences of up to six hours occurred between the times of observation and the times of the thickness chart used in this analysis, for the purpose of comparison with the thickness charts it was thought justifiable to neglect the changes in the thermal pattern in this interval. In fact, most of the reports were made on afternoon flights and the average time interval was probably of the order of one to two hours. No significant difference was found between the means of the thickness value for the two classes, cirrus observed and no cirrus observed, though significant differences were evident in the means of the thickness gradients. This is shown in Table VI, where the means of the thermal winds are given for cases of cirrus and no cirrus. The means are 21 kt. and 16 kt. respectively, and application of “Student’s” t test indicates that they are significantly different at the 0.5-per-cent. level.

TABLE VI—ASSOCIATION OF CIRRUS WITH THE THERMAL WIND SPEED

	Cirrus	No cirrus
Mean thermal wind (kt.)	21	16
No. of observations	174	79
Standard deviation	11.4	12.3
Standard error of mean	0.9	1.4

An attempt was made to relate the point from which an observation was made to a trough–ridge pattern in the 1000–500-mb. thickness field. To allow simple classification, an idealized wave-length was divided into six equal parts along its axis, and the frequencies obtained for each class of reports of cirrus or no cirrus. Only about half the observations allowed of a reasonable degree of confidence in this classification. Fig. 5 presents the ratios of the

frequency of observations of cirrus to no cirrus in each section of the ideal wave-length. It is clear that this ratio is greatest in and near a thermal ridge and least near a thermal trough, and is consistent with surface observations of the association of cirrus cloud with warm fronts.

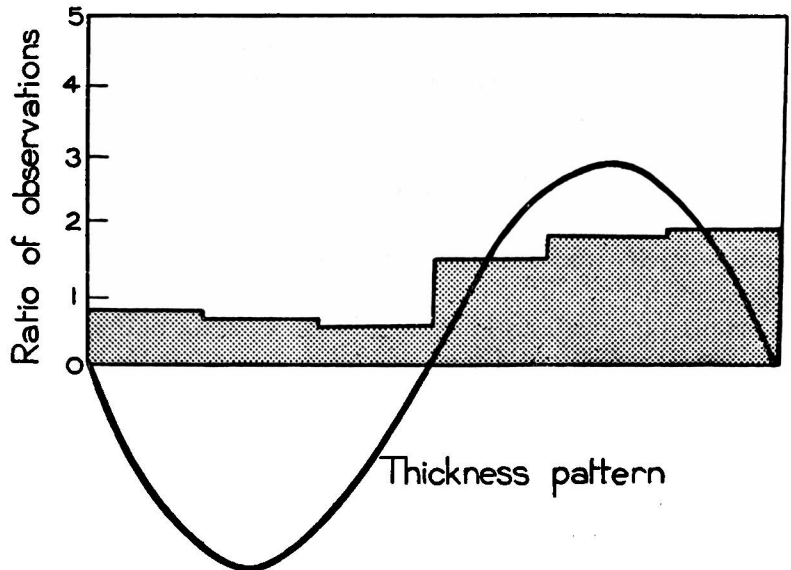


FIG. 5—RATIOS OF THE NUMBER OF OBSERVATIONS OF CIRRUS TO NO CIRRUS IN RELATION TO AN ASSUMED WAVE-FORM IN THE TOTAL THICKNESS PATTERN

Since only about half the observations were used in the above analysis, an attempt was made to classify types of thickness pattern over the area from which reports were obtained, in terms of the curvature of the thickness lines. The thickness patterns were labelled as cyclonic or anticyclonic according to the sign of the curvature of the thickness lines. If these were straight, or the gradients very weak, the observation was assumed to belong to a third class, neither cyclonic nor anticyclonic. Table VII presents the frequencies of these observations in these three classes.

TABLE VII—ASSOCIATION OF CIRRUS WITH CURVATURE OF THICKNESS LINES

	Cyclonic	Anticyclonic	Neither	Totals
	<i>number of cases</i>			
Cirrus	59	54	49	162
No cirrus	31	15	35	81

A χ^2 test applied to the distributions showed that they were significantly different at a level which was better than 0.1 per cent., and the individual χ^2 values indicate that there is a tendency for cirrus cloud to be most frequent when the curvature of the isotherms is anticyclonic.

Cirrus cloud and vorticity advection at 300 mb.—French and Johannessen⁶ attempted to relate the presence of extensive layers of cirrus cloud to patterns on the 300-mb. contour chart. For their analysis observations were obtained from high-flying aircraft engaged on routine navigation flights over extensive areas of the United States. Their observations were classified according to the sign of the advection of cyclonic vorticity at 300 mb.

Theoretical considerations indicated that if the vertical motion at the tropopause was zero or very small compared with the vertical motions at lower levels, then the sign of the vorticity advection at 300 mb. gave the direction of the mean vertical motion through a layer which had its top at the tropopause and its base somewhere below 300 mb.

The authors found that 86 per cent. of the mileage flown through extensive cirrus by the aircraft corresponded with a positive sign of the vorticity advection at 300 mb. at the same time implying, on the above assumption, upward vertical motion at 300 mb. Further, cirrus cloud sheets were always to be found when the absolute vorticity at 300 mb. was negative.

Using a finite difference approximation to the geostrophic wind it is possible to express the vorticity and also the advection of vorticity at a point in terms of known contour heights at a set of points on a grid centred on the given point, the Coriolis parameter and the magnification factor of the grid. Although the preparation of vorticity and vorticity advection charts is possible by hand computation, with a large number of cases considerable time and labour is saved by using an electronic computer.

A grid of 12 by 11 points was adopted covering an area bounded approximately by longitudes 40°N. and 60°N. and latitudes 15°E. and 35°W. To conform with the limited capacity of the machine—the MEG computer at Manchester University was used—mean values along a line of latitude of the Coriolis parameter and magnification grid were used. These were shown to be justifiable approximations by comparison of several charts analysed fully by hand with and without these limitations. A total of 180 charts was subjected to analysis by the computer, and the field of vorticity advection at 300 mb. obtained for the times of the charts. The distribution of absolute vorticity at the same level was also evaluated for some 40 charts.

Sixteen charts were analysed for occasions when reporting aircraft were engaged on long-distance flights generally at altitudes in excess of 40,000 ft. On two of these flights the cirrus cloud was reported as being well above the aircraft and consequently well into the lower stratosphere. These were not included in the statistical analysis at this stage.

TABLE VIII—ASSOCIATION OF CIRRUS WITH SIGN OF VORTICITY ADVECTION AT 300 MB. FOR POINTS AT 100-MILE INTERVALS ALONG AIRCRAFT TRACK

Cirrus	Sign of advection			Total
	+	—	o	
	<i>number of cases</i>			
Thick	23	7	0	30
Patchy	18	16	0	34
Nil	19	39	3	61

Considering first these observations made during long-distance flights, points were taken every 100 miles of the aircraft track, and Table VIII presents the frequencies of the sign of the vorticity advection at 300 mb. for cases of cirrus and, no cirrus. The cirrus observations have been further divided into two classes, namely thick and patchy. The former includes all observations of cloud sheets thicker than 1,000 ft., whilst the latter includes all observations of wisps, bands and tufts, generally believed to be 3–6 oktas. Reports of anvil

cirrus alone were not included. Table VIII shows that 77 per cent. of all thick cirrus cloud reported on long-range flights were in areas where the vorticity advection at 300 mb. was positive, indicating upward vertical motion in the upper troposphere.

Table IX presents corresponding figures obtained from the remaining 164 cases, namely point observations, the cases of cirrus cloud in the stratosphere again being excluded. Several observations were made independently on individual days, and all have been included in Table IX.

TABLE IX—ASSOCIATION OF CIRRUS WITH SIGN OF VORTICITY ADVECTION AT 300 MB. FOR SPOT REPORTS

Cirrus	Sign of advection			Total
	+	—	o	
	<i>number of cases</i>			
Thick	69	19	3	91
Patchy	27	28	5	60
Nil	18	40	2	60

Table X is obtained by combining Tables VIII and IX, i.e. assuming that an observation every 100 miles of aircraft track is equivalent to a spot observation. Thus 76 per cent. of the observations of thick cirrus cloud were found in areas where the advection of cyclonic vorticity at 300 mb. was positive, whilst 66 per cent. of the cases of no cirrus were found in areas where the term was negative.

TABLE X—SIGN OF VORTICITY ADVECTION AT 300 MB. COMBINING TABLES VIII AND IX

Cirrus	Sign of advection			Total
	+	—	o	
	<i>number of cases</i>			
Thick	92	26	3	121
Patchy	45	44	5	94
Nil	37	79	5	121

Little difference was found between the means of the absolute vorticities for the two classes cirrus and no cirrus, although the number of cases available for analysis was not sufficient to give any statistical accuracy. French and Johannessen⁶ state that extensive sheets of cirrus cloud were found in areas where the absolute vorticity at 300 mb. is negative. Since this implies dynamical instability at 300 mb., a phenomenon which is thought to be rare and in any case confined to small areas only, it is not surprising that no cases were found in the charts analysed when the absolute vorticity was negative. Hence no additional evidence is available for comparison with the claims of the above authors.

Analysis of 300-mb. contour charts.—Sawyer and Illett⁷ described an investigation into the frequency distribution of type and amount of cirrus cloud in relation to the jet stream at 300 mb. Later, Murray⁸ in an analysis of flights through jet streams made by aircraft of the Meteorological Research Flight drew similar conclusions concerning the distribution of high and medium layer cloud with respect to the jet stream. Fig. 6 (a) shows the frequency distribution of cirrus reports of the present series with distance from the jet-

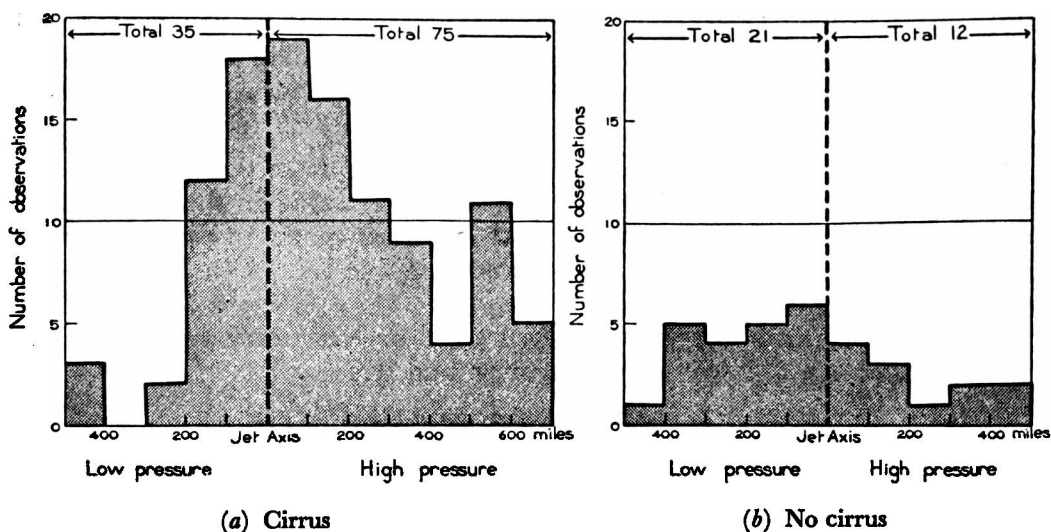


FIG. 6—RELATION BETWEEN FREQUENCY OF REPORTS AND DISTANCES FROM JET-STREAM AXIS AT 300 MB.

stream axis at 300 mb. In spite of the difficulty in placing the jet axis to within ± 100 miles it is clearly seen that the majority of cirrus reports lie on the high-pressure side of the axis, very few being more than 200 miles on the low-pressure side. The division of reports of no cirrus shown at Fig. 6 (b) is not so well marked, but even so about two thirds of the reports occur on the low-pressure side. These figures show good agreement with the conclusions of the above authors, although many reports of cirrus or no cirrus were rejected as having no apparent association with a jet stream at 300 mb.

It has been shown above that there is a significant connexion between the presence of cirrus cloud in the upper troposphere and the sign of the vorticity

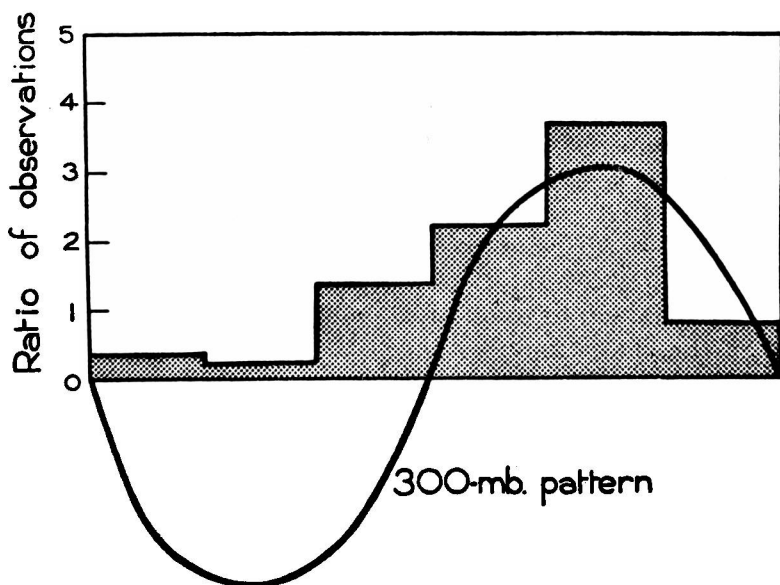


FIG. 7—RATIOS OF THE NUMBER OF OBSERVATIONS OF CIRRUS TO NO CIRRUS IN RELATION TO AN ASSUMED WAVE-FORM IN THE 300-MB. CONTOUR PATTERN

advection at 300 mb. Considering only the curvature of the contours, the advection term $(V'\partial\zeta/\partial s)_{300}$ is positive to the rear of a ridge and forward of a trough in the contour pattern. Fig. 7 shows the ratios of the percentages of observations of cirrus to no cirrus in relation to an idealized wave pattern in the 300-mb. flow. It is clearly seen that this ratio is a maximum in and to the rear of a ridge and a minimum in and to the rear of a trough. At first sight this does not appear fully consistent with the conclusion above, since we should expect upward vertical motion in the layer immediately below the tropopause to be taking place through the region forward of the trough line and to the rear of the ridge line at 300 mb. However, it is thought that although the air may commence to ascend immediately forward of the trough, some little time must elapse before the rising air becomes saturated, and hence before the appearance of cirrus clouds. Thus it is not surprising that the maximum frequency of reports should occur just in and to the rear of the ridge, as shown in Fig. 7.

Cirrus clouds in the stratosphere.—Some 30 cases were reported when the bases or tops of cirrus cloud were above the tropopause obtained from analysis of neighbouring upper air ascents. In eight of these cases, the clouds had been definitely below the tropopause reported from neighbouring stations, and extended upwards above the tropopause. These cases are not surprising since local variations in height of the tropopause could permit reported tops of cloud to extend above the tropopause height reported by the nearest radio-sonde ascent.

Some of the remaining reports were discussed by Jacobs⁹ who concluded that the extensive layer clouds observed over southern England on July 27–29, 1953 were in fact dust clouds which originated from a volcanic eruption in Alaska on July 9, 1953. The clouds reported in this case were estimated to be at heights in excess of 50,000 ft. at times. It seems highly improbable that the remaining 18 cases could be attributed to similar disturbances, and in all probability there were genuine ice-crystal clouds, at times as much as 10,000 ft. above the tropopause.

Little can be said concerning the existence of these very high clouds; the sample is too small to permit a statistical investigation, even if the relevant data were known at these heights. However, vorticity advection charts at 300 mb. were constructed for these occasions, and the results were remarkable in that for all cases of extensive cirrus sheets in the stratosphere, the sign of the advection of cyclonic vorticity at 300 mb. was negative (Table XI).

TABLE XI—SIGN OF VORTICITY ADVECTION AT 300 MB. FOR CIRRUS CLOUD IN THE STRATOSPHERE

Route flights and spot observations included				
Cirrus	Sign of advection			Total
	+	—	o	
	number of cases			
Thick	o	17	1	18
Patchy	3	5	o	8

The theory postulated by French and Johannessen associates upward vertical motion in the upper troposphere with a positive value of vorticity advection at 300 mb. assuming little or no vertical motion at the tropopause. A negative value of the vorticity advection would imply downward vertical motion below

the tropopause, which would thus be a region of horizontal convergence. If this is so then it is possible that upward vertical motion was occurring in the lower stratosphere, and hence if the air were sufficiently moist at these levels the formation of cirrus cloud might result. Obviously, this is far from being anything but a tentative suggestion, and considerably more cases need to be reported of these high clouds which undoubtedly do exist in the stratosphere.

Conclusions.—

(i) The observations confirm the work of earlier writers on the association of cirrus cloud in the troposphere with the area ahead of surface fronts, the high-pressure side of the jet stream at 300 mb., and with thermal ridges. Considerable agreement is obtained with the statistical results presented by Murgatroyd and Goldsmith¹ regarding the distribution of bases and tops of cirrus cloud in relation to the tropopause.

(ii) A strong association is found between the presence of cirrus cloud and the humidities at 500, 450 and 400 mb. Some assistance to the fore-caster is possible in assessing the distribution of cirrus cloud from radio-sonde ascents if the humidities at all three levels are taken into consideration.

(iii) At all levels from 500 mb. to 300 mb. the winds between S. and W. were most frequently accompanied by cirrus cloud, and winds between S. and E. had the lowest frequency of cirrus reports.

(iv) Consideration of the winds at 500 and 300 mb. confirms that cirrus cloud is associated with warm-air advection at these levels. Also, cirrus cloud has an association with strong thermal contrasts as indicated by the 1000–500-mb. thickness pattern.

(v) Cirrus cloud in the troposphere is associated with positive values of the advection of cyclonic vorticity at 300 mb., implying upward vertical motion in the upper troposphere.

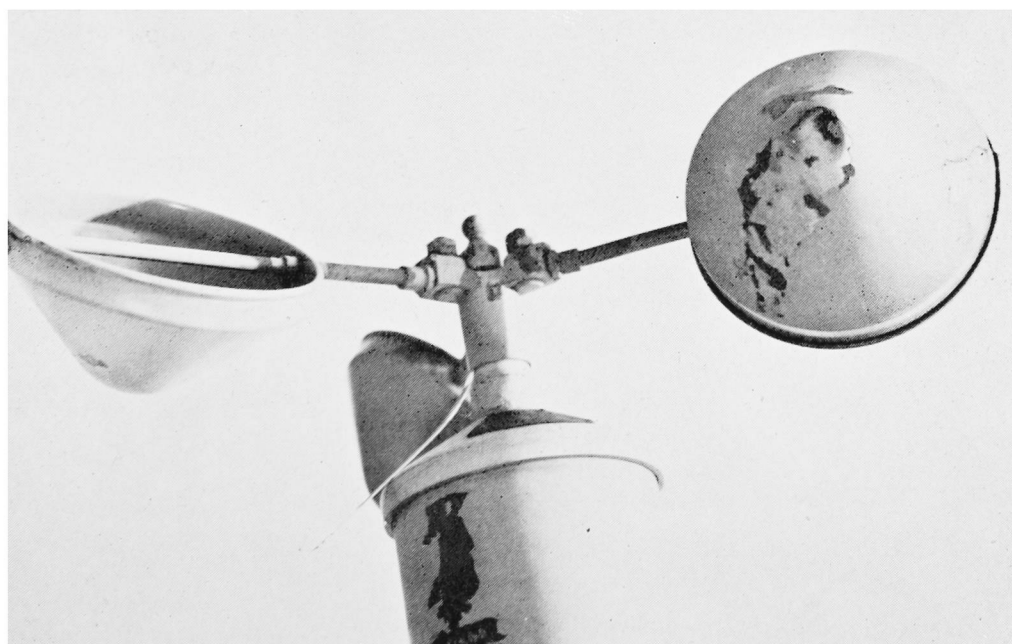
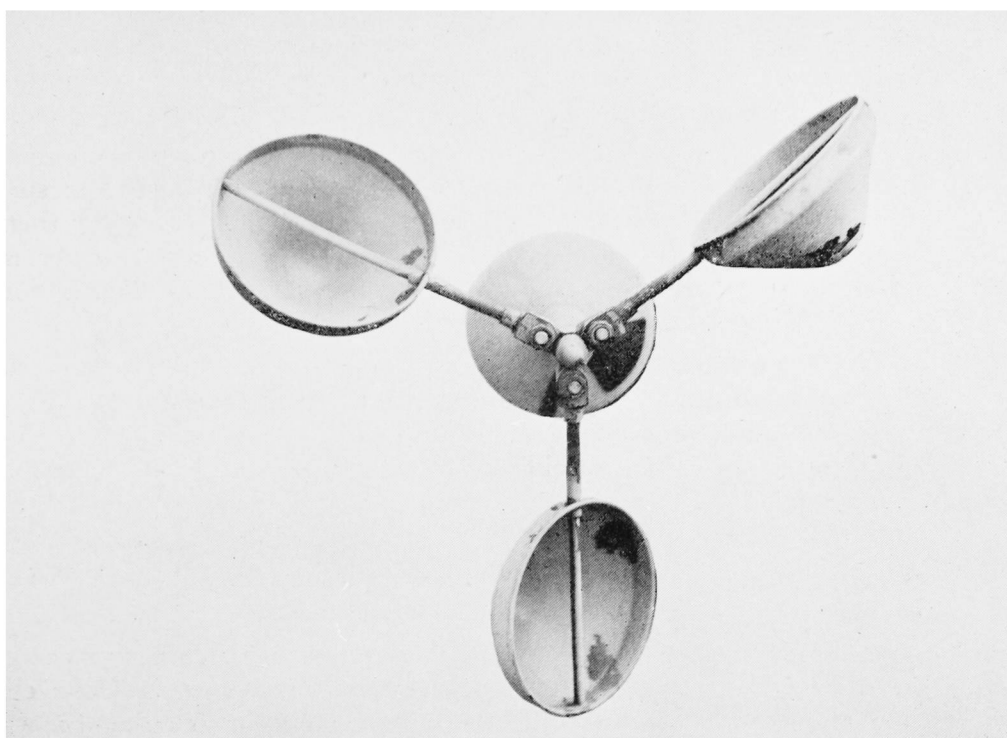
(vi) Reports of cirrus cloud in the stratosphere were comparatively few, but are sufficient to confirm that high clouds at these levels do exist.

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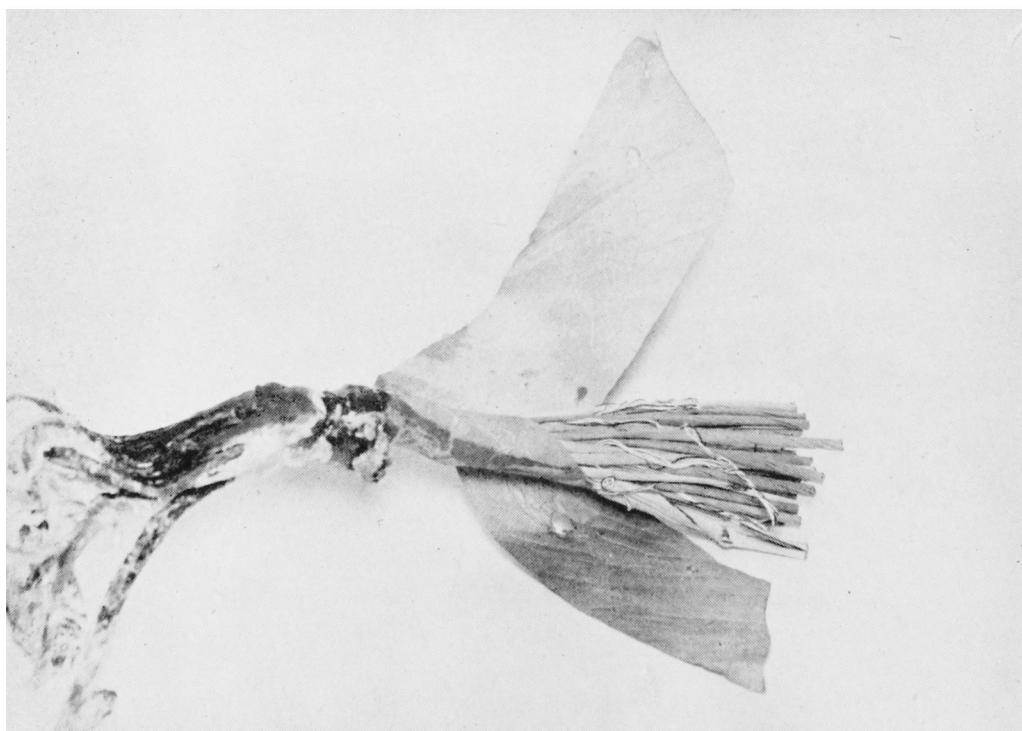
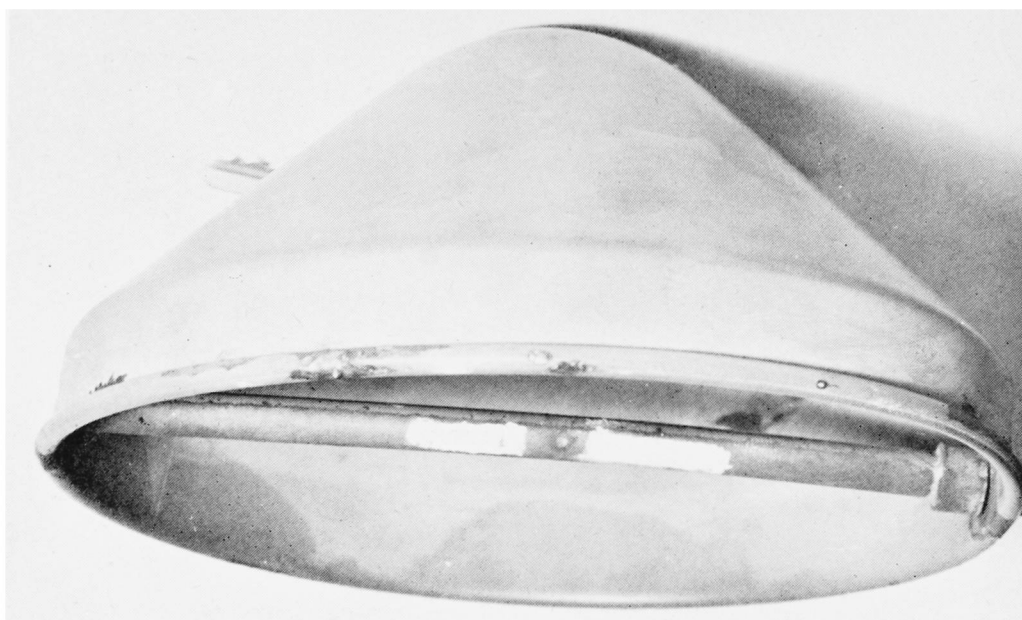
ERRATUM

NOVEMBER, 1956, PAGE 352. Rainfall of September 1956, Station Compton, Compton Ho., Per cent. of Av.; for "49" read "169".



LIGHTNING DAMAGE TO ELECTRIC-CUP-GENERATOR ANEMOMETER
(See p. 25)

To face p. 13]



LIGHTNING DAMAGE TO ELECTRIC-CUP-GENERATOR ANEMOMETER AND INSTALLATION
(See p. 25)

HETEROGENEITY IN THE MEASUREMENTS OF HUMIDITY MADE BY THE RADIO-SONDE NETWORK OF EUROPE

By A. H. HOOPER

In the course of an investigation into variations in radio propagation at metre wave-lengths, the results of radio-sonde ascents over a large part of the European region were used to study the radio-refractive-index structure of the lower troposphere. In a well mixed atmosphere a steady lapse, i.e. a decrease, of radio-refractive index with height is developed, and propagation conditions are normal. The presence of thin but extensive layers in which the lapse is markedly greater than normal was found to be associated with extensions of radio range. Estimates were made on each occasion of the occurrence and intensity of these discontinuities in lapse, based on rules in which the moisture structure played a predominant part, for each of the upper air soundings made over Europe. While there was good general agreement over the region, it was found that the estimates for certain stations were not in accord with the results of the network as a whole, and could not easily be explained meteorologically. There are grounds, therefore, for suspecting instrumental causes, particularly in regard to the humidity observations of certain individual stations and of certain types of radio-sondes.

Limitations of data and method.—The method employed was to estimate from tephigrams, by examining primarily the hydro-lapse, the occurrence of discontinuities of radio-refractive index of various intensities. Search was made specifically for layers with a marked decrease of water vapour with height. As most radio-sondes sample the atmosphere discontinuously, an increased hydro-lapse must extend over several hundred feet to be detected, thereby implying considerable changes of water-vapour content. Changes of the required magnitude are usually associated with horizontal stratification of the subsidence type in which a large and rapid decrease with height of moisture content is maintained. Such structures tend to extend over considerable areas and to be observed simultaneously at several upper air stations.

A given temperature imposes an upper limit on the water-vapour content and hence imposes a corresponding limit on the maximum change in radio-refractive index due to a change from saturated to dry conditions. An additional limiting factor arises from the lag in response of the radio-sonde humidity sensing devices. With the slow response associated with low temperatures, a sharp discontinuity of sufficient magnitude may be reported in stages over several successive readings. In such circumstances the indicated change in hydro-lapse could be taken, wrongly, as being insignificant. Thus at low temperatures, humidity discontinuities are both restricted in magnitude and are less well recorded. A latitude effect is, therefore, to be expected.

A further limitation arises from the procedure used for compiling the messages containing the radio-sonde observations. As a sufficiently large hydro-lapse cannot be maintained over the height intervals between the International Standard Levels for which humidity is invariably reported, the reporting of these discontinuities is dependent upon adequate use of additional levels in the reported message. There was no reason, however, to attribute the discrepancies discussed below to any deficiency on this score. It is probable, therefore, that a radio-sonde which fails to indicate the full extent of a humidity change from wet to dry, or which has either a slow sampling rate or slow

response, will introduce discrepancies between the observed radio effects of the atmosphere and the measured lapse rates for humidity and temperature.

From a daily scrutiny of tephigrams plotted from radio-sonde messages, the presence of any discontinuity in radio-refractive index lapse over the European region was assessed in the following steps:—

- (i) an estimate by inspection of the Hemsby upper air sounding,
- (ii) a computation of radio-refractive-index structure of the Hemsby sounding to check the validity of the estimates,
- (iii) an estimate by inspection of all other available upper air observations.

The intensities of all discontinuities were assessed on a four-point scale from “Nil” to “Strong” and their heights noted. The degree of validity of 515 estimations of the incidence of “Strong” discontinuities for Hemsby, when compared with the subsequent computations, was found to be 96·1 per cent. Estimations for all other stations have been corrected on this performance. The broad conclusions of this report do not, however, depend upon this uncertainty, as the magnitude of the correction is too small.

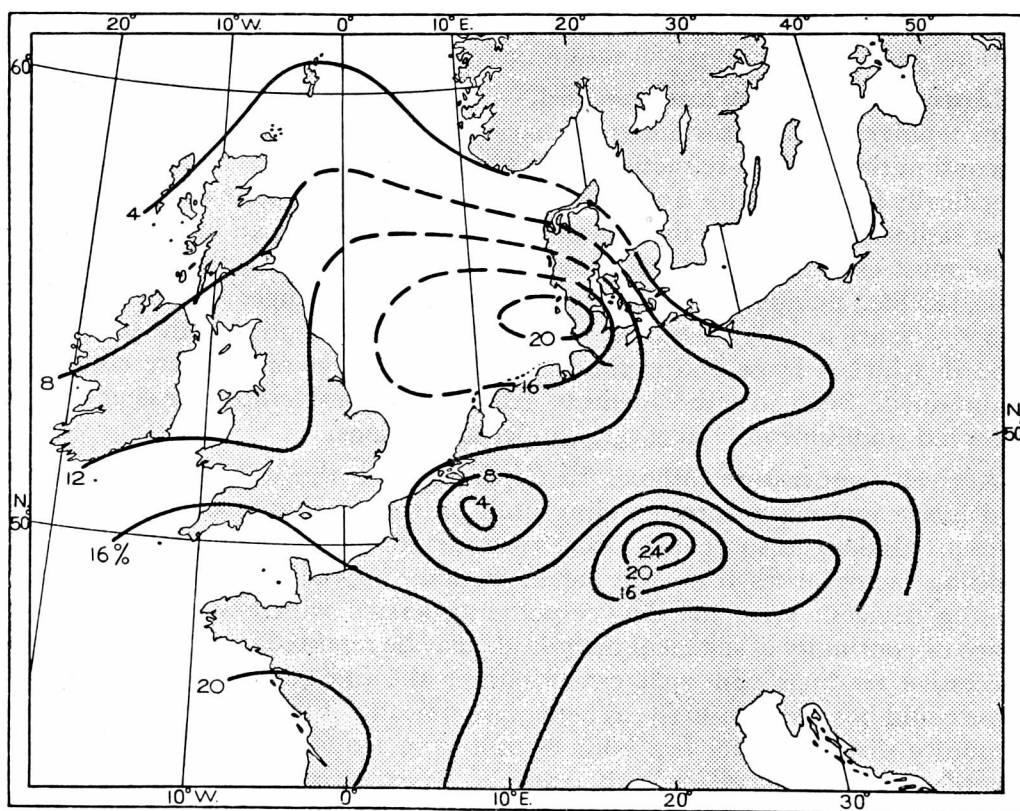


FIG. 1—OCCURRENCE OF STRONG RADIO-REFRACTIVE-INDEX DISCONTINUITIES
MID JULY, 1953—MID OCTOBER, 1954
Surface to 10,000 ft.

Geographical and seasonal distribution of results.—Fig. 1 shows for each station the percentage frequency of occurrence of a strong radio-refractive-index discontinuity, assessed and corrected in the above way, during the 455 days commencing July 17, 1953.

In the western half of the chart the frequency is seen to decrease from south-east to north-west. In so far as the condition is mainly associated with subsidence and is limited by temperature this result could be attributed to the occasional north-eastward extension of the Azores anticyclone and to the general variation of temperature with latitude.

Four other features are apparent:

- (i) a very low frequency over Belgium
- (ii) a very low frequency over Scandinavia
- (iii) a relatively high frequency over Flensburg
- (iv) a relatively high frequency over Erlangen.

In case these features were real geographical variations arising from the modification of the lower layers of the troposphere by varying surface conditions, the figures were separated into successive 1,500-ft. intervals above ground level.

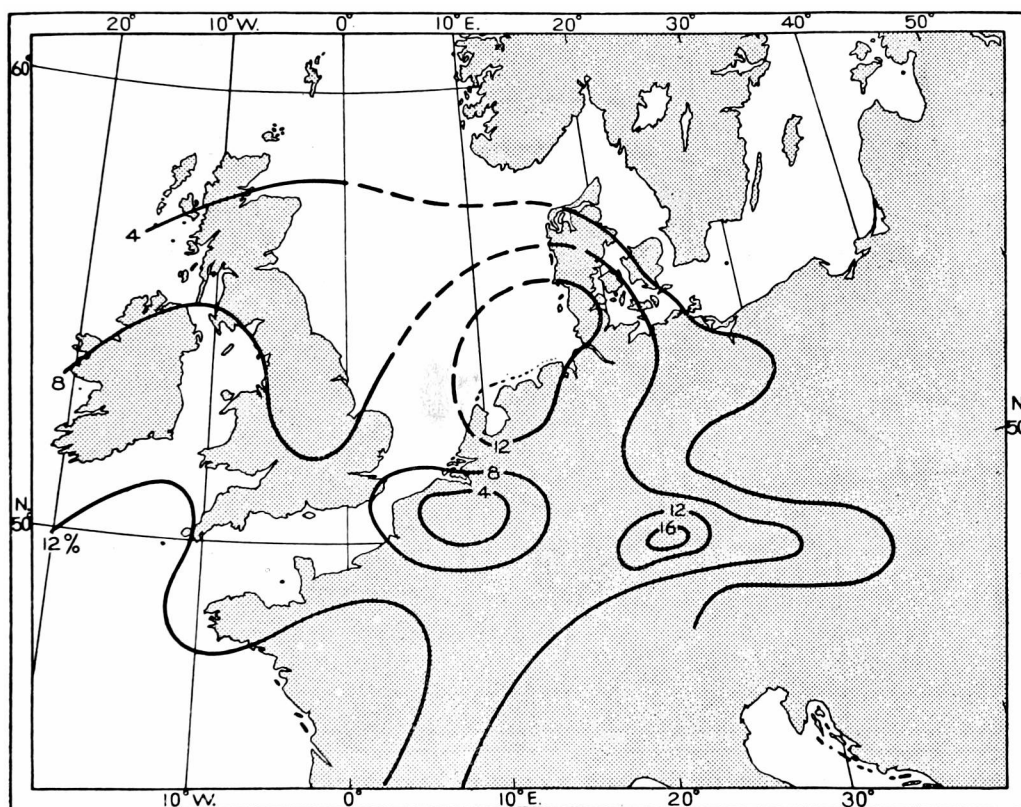


FIG. 2—OCCURRENCE OF STRONG RADIO-REFRACTIVE-INDEX DISCONTINUITIES
MID JULY, 1953—MID OCTOBER, 1954
3,000 ft. above ground to 10,000 ft.

It was found that in each layer the general pattern remained. Fig. 2 shows the percentage frequencies when the height-range surface—3,000 ft. is excluded and it is seen that the isopleths are substantially unchanged in pattern. The possibility remains, however, that geographical variations in surface conditions, while not causing variations in incidence at low levels, may affect the instrumental performance by governing the conditions of storage and preparation before use.

In winter, the limitation set by temperature on saturation-vapour-pressure results in radio-refractive-index discontinuity of the required magnitude being infrequent, despite the occurrence of extensive subsidence. The figures have been examined on a seasonal basis. It was found that during the three-month period mid-June to mid-September 1954 the frequency of occurrence was much higher than average at certain stations. These were the southern British, the French stations, Erlangen, Friedrichshaven and Payerne. This effect could possibly be due to the extension of the Azores anticyclone bringing warm moist air more frequently to these areas than to the remainder. Fig. 3 shows, therefore, the percentage frequency of discontinuity for the six months from mid-December 1953 immediately preceding the season of increase. It can be seen that while the last of the four peculiarities has been excluded the other three still remain to be explained. They occur in all the periods examined.

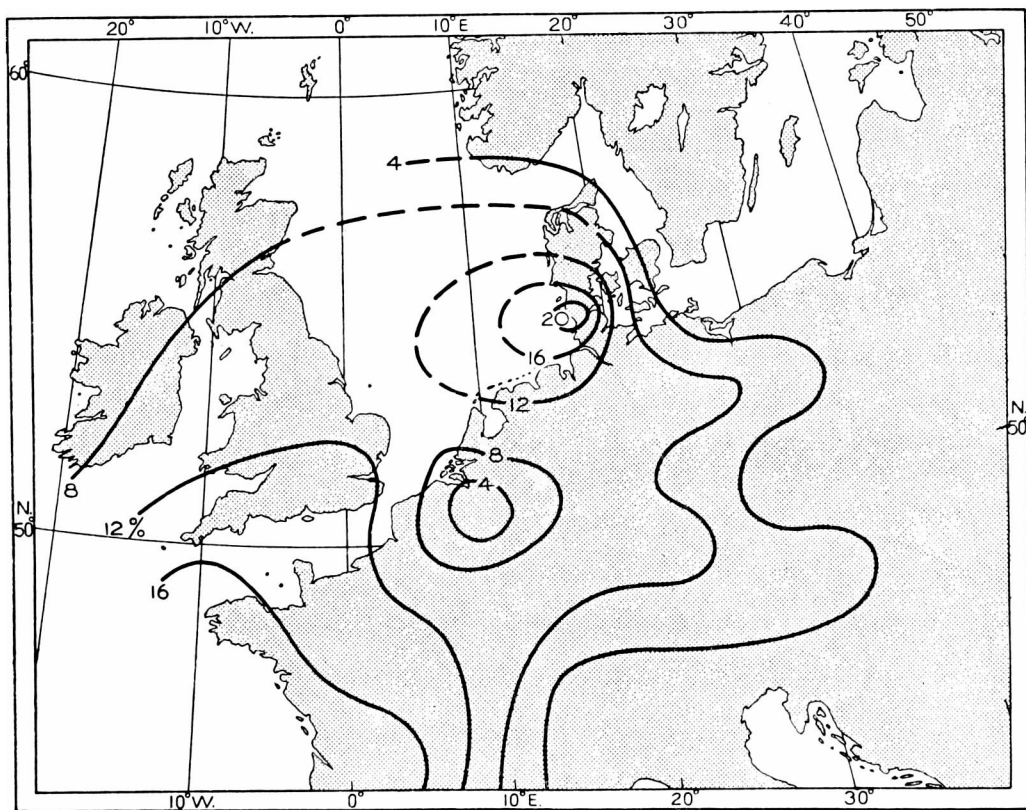


FIG. 3—OCCURRENCE OF STRONG RADIO-REFRACTIVE-INDEX DISCONTINUITIES
MID DECEMBER 1953—MID JUNE 1954
Surface to 10,000 ft.

Examination of heterogeneities.—In the examination of the heterogeneities shown by this method no evidence is submitted as to the absolute accuracy of the various forms of radio-sonde humidity-measuring devices. The results as they are presented herein suggest that at certain radio-sonde stations a marked change in the vertical humidity-structure is observed with greater or less frequency than at other stations, to a degree which cannot be explained by meteorological considerations alone. The variation in the frequency with which this type of humidity structure is observed thus suggests

a variation between stations in the accuracy of response to change of humidity, but external evidence, which might be obtained from observations of radio propagation, would be necessary to judge which response was the most accurate.

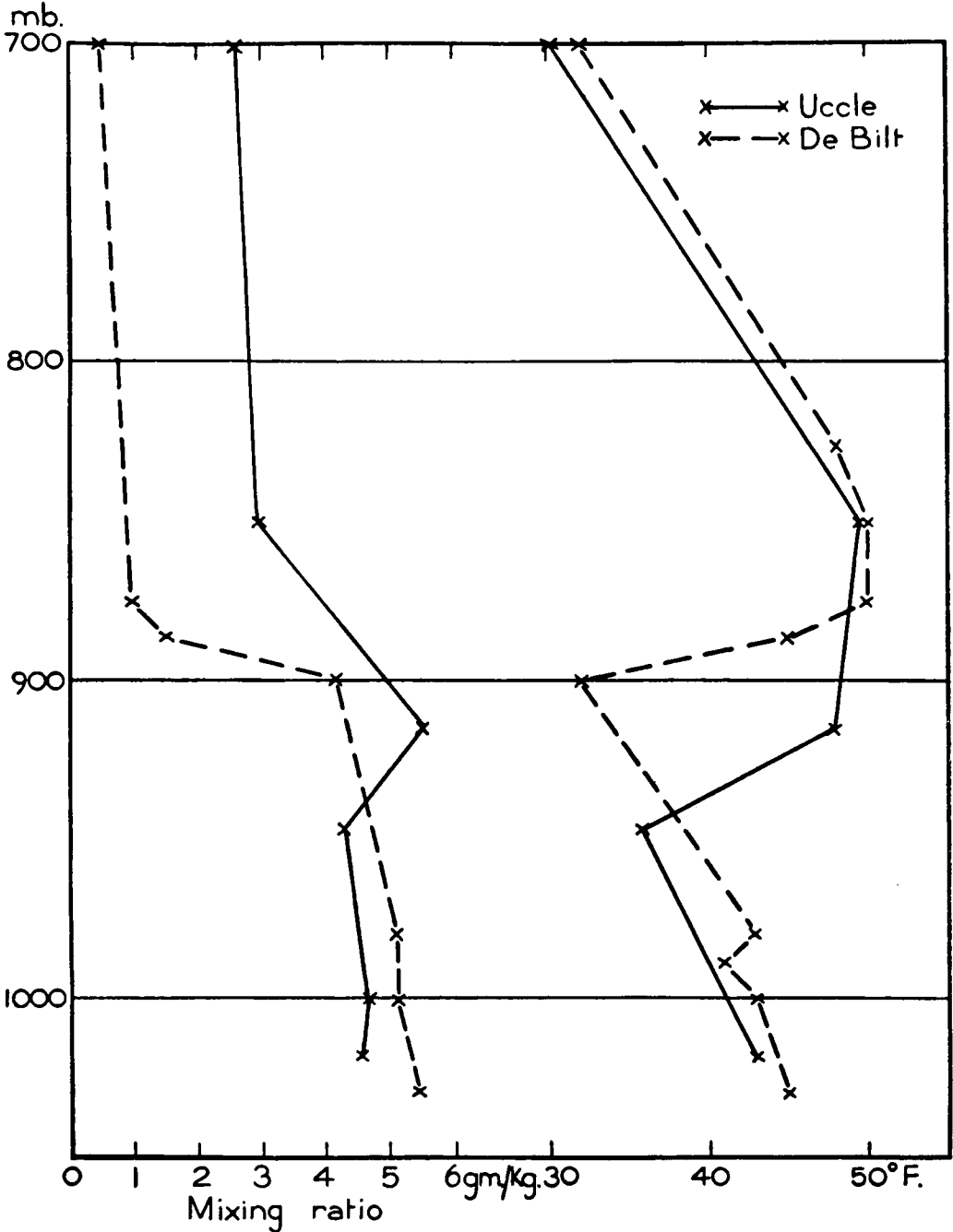


FIG. 4—RADIO-SONDE DATA FROM UCCLE AND DE BILT FOR AN OCCASION WHEN SURROUNDING STATIONS SHOWED SIMILAR SUBSIDENCE STRUCTURES
The radio-refractive-index discontinuity implied is “strong” at De Bilt but merely “average” at Uccle.

The first feature, the Brussels “low”, depends upon the one station Uccle which is surrounded by stations experiencing frequencies of occurrence many times greater. This is especially curious in that the British radio-sonde is in

use both there and at De Bilt and these, together with the British stations, should form a homogeneous network. Gold-beater's skin is used as the humidity-sensing element and it has been reported¹ that this material exhibits a hysteresis effect below about 70-per-cent. relative humidity. British practice is to expose the material to a near-saturated atmosphere for about 1 hr. immediately before use so that subsequent operation is largely over the curve given by calibration, from wet to dry. The sondes used at Uccle and De Bilt are supplied uncalibrated and it is suggested that calibration and/or subsequent treatment at Uccle differs in some way from British practice. The procedure at De Bilt yields results that are comparable with those of the United Kingdom in the respect examined. Again it is stressed that the results considered herein give little or no indication as to which procedure is the more reliable.

A search was made for specific occasions when the report from Uccle differed from those from surrounding stations, and there was reasonable assurance that the air mass was homogeneous. Fig. 4 shows the reports from Uccle and De Bilt on such an occasion while Fig. 5 shows their reports on an occasion of agreement. Specific occasions of reasonable assurance were, in fact, rare

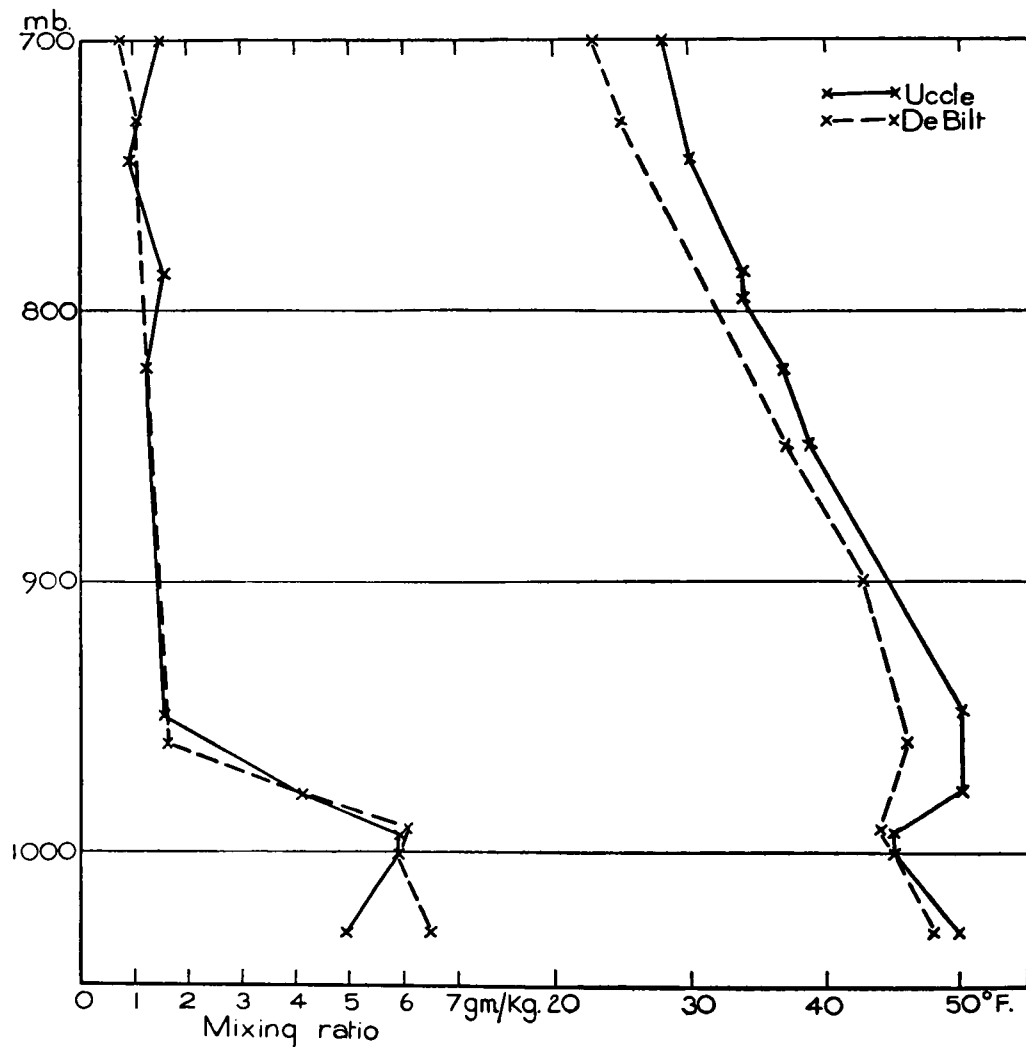


FIG. 5—RADIO-SONDE DATA FROM UCCLE AND DE BILT FOR AN OCCASION WHEN SUBSIDENCE WAS PRESENT

The humidity structure results in a "strong" radio-refractive-index discontinuity.

owing mainly to not all of the surrounding stations showing the required condition. As Fig. 1 shows, however, the surrounding stations agree closely as to long-term frequency of occurrence and it is on this result that the conclusion of network heterogeneity is based.

The second feature of very low incidence over Scandinavia arises from the results reported by stations using the Väisälä radio-sonde. While a gradual reduction northward in frequency is to be expected, as experienced 9 per cent. to 4 per cent. over the British Isles, the difference in frequency of occurrence between Flensburg and Copenhagen, for example, is very great. The sudden reduction from the high incidence at Flensburg and Emden to the very low incidence at Copenhagen, Gothenburg and Sola is most unlikely from climatological considerations. This, together with the fact that in this region the demarcation between stations with frequencies of more than 10 per cent. and stations with frequencies of 1 per cent. or less coincides exactly with the use of a particular type of radio-sonde, again suggests an instrumental origin.

The humidity-sensing element in the Väisälä sonde is of hair and is calibrated at each station several days before use, room humidity and 97 per cent. being used. It is then seasoned in a near-saturated atmosphere for 48 hr. It has since been reported² that in July 1954 the Swedish stations changed to the use of hair treated by the Frankfurter process, for which a greatly reduced lag is reported.

Table I shows the incidence of strong discontinuities at stations in this region for successive 3-month periods, ending mid-October 1954.

TABLE I—OCCASIONS OF STRONG DISCONTINUITIES

3-month period ending	Norway		Sweden		Denmark—Germany	
	Sola	Gardemoen	Torslanda	Stockholm	Copenhagen	Flensburg
Mid-January	0	1	1	1	1	15
Mid-April	1	0	2	0	0	15
Mid-July	1	0	2	2	1	14
Mid-October	0	4	1	6	2	11

In the last period examined, when "Frankfurter" hair was being used, the incidence at Stockholm suddenly increased, at a time when the general incidence at the north-west German stations decreased. Although several extraneous reasons can be advanced to explain the absence of a corresponding change at Torslanda, there is insufficient evidence to associate this increase with the introduction of "Frankfurter" hair.

The area of relatively high incidence over north-west Germany is due to reports from Flensburg, supported in part by the reports from Emden. While this geographical distribution is meteorologically plausible the impression was gained, during consideration of radio propagational effects observed in the area, that the increase in incidence is unreal. The radio-sonde in use at these two stations and at Hanover was the standard type H.50 using Frankfurter hygrometers. From the difference in incidence between these stations it appears that differences in treatment before use can modify the characteristics of "Frankfurter" hair.

The high incidence over southern Germany is due only to one station—Erlangen. This station, too, uses the type H.50 radio-sonde. It is at a relatively high level, 909 ft., however, and may well be subject to marked local effects which either modify the lower tropospheric structure or, as earlier envisaged,

the radio-sonde performance. As during the six-month period shown on Fig. 3 the incidence was not exceptional, and the radio-propagation effects observed in the area were limited, it is not possible to suggest an explanation.

It is of interest to note that at Wiesbaden and Munich, American equipment with yet another humidity-sensing material, lithium chloride, was employed. The results from these stations are seen to fit in smoothly with those from neighbouring stations e.g. Payerne.

General Discussion.—Direct comparisons between many types of radio-sonde were carried out at Payerne in 1951. They comprised a series of ascents in which radio-sondes were carried aloft in pairs. The differences between each pair of sondes and the change of these differences with height has been examined. Comparing each radio-sonde type in turn with the average of the remainder, it is inferred that with a decrease of relative humidity with height between the pressure ranges 900–800 mb. and 600–500 mb., there is a slight tendency for the German and Finnish instruments to under-estimate the decrease while the French and British sondes give an over-estimate. The geographical distribution implied by this is not wholly in accord with that now found and it is concluded that the effect now described is not associated with the type of humidity performance observed at Payerne.

A study of radio-sonde observational homogeneity has just been published by the World Meteorological Organization³. In the method⁴ adopted, changes with time of the observed thickness between various pressure surfaces are examined. Such thicknesses depend mainly on temperature, humidity playing only a small part. For example, the total contribution of water vapour in a pressure/height evaluation in the British Isles seldom exceeds 50 ft., and in conditions of marked subsidence a contribution of 20 ft. is usual. Changes of the type considered in the humidity structure of shallow layers would thus be unobservable as a change in thickness.

It can be seen from the relation customarily used⁵ that for radio-refractive-index discontinuities the situation is reversed, and although temperature plays a part, it is the humidity contribution that predominates. It can be shown that no reasonable differences in the measurement of temperature between radio-sondes of different types could account for the features discussed here.

The discrepancies shown in this paper in regard to radio-sonde humidity observations are thus unlikely to be detected by any of the standard methods of radio-sonde comparison in use at present, or to affect the main meteorological purpose of radio-sonde ascents in providing temperature and height information. At the same time, accurate humidity observations have great importance in meteorology and other spheres and are among the most difficult of the required data to obtain reliably. It is probably true to say that no other meteorological measuring device is as sensitive to changes both of design and of handling technique as the radio-sonde hygrometer. This is instanced at Uccle, where by comparison with United Kingdom results, the British radio-sonde, possibly due to some difference in calibration or sounding technique, apparently causes a rapid moisture change from wet to dry either (i) to be incompletely observed, or (ii) to be observed with a large lag. Over-all, however, the upper air humidity data over western Europe are surprisingly homogeneous.



Photo by J. E. Gittens



Photo by J. E. Gittens

FENLAND "BLOW", JULY 5, 1956
(See p. 21)



Photo by J. E. Gittens

FENLAND "BLOW", JULY 5, 1956
(See p. 21)

With the attention being given at the present time to tropospheric humidity on a regional scale it is hoped that at future international trials closer study of humidity comparisons will be made and that ultimately the remaining differences will be eliminated.

Conclusions.—The homogeneity of the European upper air network has been indirectly examined in respect of magnitude and speed of response to low-level moisture discontinuities of large magnitude. It appears:

- (i) that instrumental differences existed at the time of the comparison
 - (a) between the British radio-sonde as used in Great Britain and Holland and as used at Uccle, probably due to differences in technique.
 - (b) between the British, French, German, American and Swiss radio-sondes together and the Vaisala sonde with standard hygrometer, attributable to a large difference in properties between goldbeater's skin, "Frankenburger" hair, and lithium chloride on the one hand and "ordinary" hair on the other.
- (ii) that smaller differences existed between certain stations using the H.50 radio-sonde, possibly due to variations of surface conditions.
- (iii) that the British sonde, as normally used, and the French sonde gave directly comparable results, as regards the aspect of humidity examined, and that both agreed well with results from the American and Swiss instruments.

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[Prof. Dr. J. van Mieghem, President of the World Meteorological Organization Technical Commission for Aerology, who saw the above article before publication, has commented as follows:

L'étude de Mr. Hooper révèle incontestablement qu'il existe à la station d'Uccle une anomalie que l'on ne peut justifier par des arguments météorologiques. Je crois que l'étalonnage est hors cause, et qu'il faut attribuer cette anomalie à une trop grande vitesse ascensionnelle et peut-être aussi à ce que les prescriptions relatives à la préparation de l'hygromètre avant le lancer ne sont pas toujours scrupuleusement suivies.

Les travaux dans le genre du celui de Mr. Hooper sont fort utiles, car ils montrent les efforts que nous devons encore accomplir pour que le réseau aérologique ne représente plus que les seules phénomènes météorologiques.]

SOIL BLOWING IN THE FENS IN 1956

By M. T. SPENCE, B.Sc.

Storms which lift the top soil and fill the air with soil particles, reducing visibility to a few yards, occur in the Fens from time to time; they are known locally as "blows". Farmers suffered heavy losses of soil, seeds and fertilizers over a wide

area in the severe "blow" of May 4-5, 1955, previously described in this Magazine¹.

In 1956, the "blows" were less severe and more localized. A small amount of surface drifting was seen in March 1956, but the first "blow" came on May 10. It was confined to particularly vulnerable areas, notably one of some 800 acres of black fen 8-10 miles north-east of Cambridge. Most of the stricken fields in this fen were re-sown with carrots though a small acreage was re-drilled with sugar beet. From May 11 to July 4, the wind was never strong enough to cause "blowing" but on July 5 and again on July 29-30, the mean hourly wind reached or slightly exceeded 25 kt.; the direction on both occasions was south-west to west. The maximum gust recorded on the 5th was 37 kt. and on the 29th-30th, 43 kt. It is unusual to have such strong winds in July and exceptional to have fields with bare soil exposed to the strong winds if they do occur. Normally fields are covered by vegetation at this time of the year and so are protected from loss of soil. However, in July 1956, those fields which had "blown" in May were still vulnerable and it was upon these fields that most of the damage occurred. Many acres of carrots and sugar beet were lost. The photographs facing pp. 20 and 21 were taken during the "blow" of July 5 and show how great the loss of soil can be. The low level of the top of cloud confirms that the storm is analogous to a sandstorm rather than a dust-storm—a view expressed previously in connexion with the storm of May 1955¹.

There is a tendency to regard drought as essential for soil erosion by wind. This is not borne out by conditions in the Fens in July 1956. Rain preceded the "blow" of July 5; on the previous night 0.02 in. fell at Mildenhall and not long before that the ground had been thoroughly moistened (0.34 in. in the last week of June). Again, in the case of the "blow" of July 29-30, light rain had fallen continuously on the morning of the 29th (0.02 in.) and copious rain had fallen (0.32 in.) on the two previous days. It seems that the earth clods, when drying after rain, tend to break up into small particles thus increasing the liability to wind erosion.

I am indebted to Mr. N. J. Sneesby of the Agricultural Land Service, Eastern Province, for information about the areas affected by the "blows".

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NOTES AND NEWS

Universal Decimal Classification^{1,2}

551.5 Meteorology

One of the most important tasks of the World Meteorological Organization's Commission for Bibliography and Publications is to keep the meteorology section of the Universal Decimal Classification up to date. Meteorology is more fortunate than some sciences as regards classification of the literature because of the existence of such an international body as the Commission for Bibliography and Publications.

The Commission held its first session in Paris during November and December 1953 and agreed on a number of revisions of 551.5. The revisions were later agreed by the Executive Committee and the International Federation for Documentation—the central governing body dealing with Universal

Decimal Classification—and are announced in “W.M.O. Technical Regulations Volume 1” as to come into force on January 1, 1957. Annexe V of Volume 1 gives the complete revised classification for meteorology.³

The major changes from the classification in force since January 1, 1950, are as follows:—

551.501.6 : 551.511.1 *Thermodynamical diagrams*. New number added under 551.501.6 *graphical methods of representation—isopleths*.

551.508.765 *Instruments for measuring ice accretion*. New number added under 551.508 *meteorological instrumentation*.

551.509.313 *Dynamics (hydrodynamics and thermodynamics) applied to forecasting*. New number added under 551.509 *weather forecasting, artificial action on weather*. This new number will be used for literature on numerical methods of forecasting.

551.509.314 *Statistical methods of forecasting*. New number added.

551.509.32 *Forecasting of specific elements and phenomena*. New number added. This number is sub-divided to cover individual elements (e.g. 551.509.325 covers *forecasting of visibility*.)

551.510.522 *Layer in contact with the Earth's surface*. New number added under 551.510.52 *troposphere*. This new number will be used for papers on the general meteorology of the atmosphere at breathing level and heights accessible by fixed instruments.

551.510.528 *Tropopause*. New number added. Previously there was no number for the tropopause as such and the device of using 551.510.52/551.510.53 i.e. *troposphere/stratosphere* had been used in the Meteorological Office Library.

551.510.53 *Atmosphere above the tropopause (highest tropopause if there is a multiple arrangement)*. The title of this number was changed from *stratosphere in general* in recognition of the increase in complexity of the known structure of the higher atmosphere.

551.511 *Mechanics and thermodynamics of the atmosphere in general*. This number is used for papers dealing with the mechanical and thermodynamical processes in air, regarded from the theoretical or physical point of view, without reference to the place of the air in any specific circulation, such as a depression. There is another number, 551.515, with suitable sub-divisions for classifying papers on the dynamics of depressions and anticyclones. It has for long been recognized that 551.511 needed sub-division to permit easier finding of papers on specific parts of theoretical dynamical meteorology and the first session of the Commission for Bibliography and Publications produced one as follows:

551.511.1 *Statics and quasi-statics*.

.12 *Hydrostatics. Standard atmospheres*.

.13 *Static and quasi-static thermodynamic states and processes. Thermal equilibrium*.

.2 *Kinematics*

.3 *Dynamics*.

.32 *Hydrodynamics*. This number will be used for theoretical papers on such subjects as the general equations of motion, variation of wind with height, geostrophic relation, and the conservation theorems of hydrodynamics.

.33 *Thermodynamics*. This number will be used only for papers on subjects in which variation in time plays an essential part.

.6 *Turbulence and diffusion*. This number will be used only for papers which are wholly or mainly theoretical. Papers which are wholly or partly observational will be given either 551.551 *turbulence, gustiness, turbulent diffusion* or both 551.551 and 551.511.6.

551.521.326 *Radiation from the night sky*. New number under 551.521.32 *terrestrial and atmospheric radiation* in place of 551.521.4 which has been deleted.

551.547.5 *Distribution in space (of upper air pressure), isohypses, isobars*. New number added under 551.547 *upper air pressure*.

551.551 *Turbulence, gustiness, micro-variations of wind, turbulent diffusion in the atmosphere* has been renamed from *wind structure, micro-variations, gustiness, turbulence*, and is sub-divided as follows

551.551.2 *Turbulence in the lower layers defined as the region accessible by instruments mounted on the ground, on masts, towers, and fixed balloon cables*.

.21 *Turbulence in the layers up to normal anemometer height*.

.25 *Turbulence in the lower layers above normal anemometer height*.

.5 *Turbulence in the free atmosphere*.

.8 *Turbulent diffusion of momentum, heat, water vapour and aerosols*.

551.556.6 *Wind pressure on buildings*. New number added under 551.556 effects of wind, in place of 551.556:69 which has been deleted.

551.556.81 *Effects of wind on water surfaces*. New number added.

551.557.5 *Specific large-scale winds (e.g., jet stream, anti-trades)*. New number added under 551.557 *upper air wind*.

551.589.6 *Quasi-periodic phenomena (e.g. Ice-Saints' Days)*. New number added under 551.589 *synoptic climatology*.

551.593.653 *Noctilucent clouds*. Name changed from luminous clouds.

The revised classification will be brought into use in the Meteorological Office library for classifying books and papers received on and after January 1, 1957.

This note is published with the agreement of the British Standards Institution, copyright holders of the Universal Decimal Classification in the United Kingdom. A list of the relevant B.S.I. publications is given^{4, 5, 6}.

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Royal Society International Geophysical Year Expedition to Antarctica

Since early January 1956 the advance party of the British International Geophysical Year Expedition¹ has been established at a site a mile and a half inland on the ice shelf in Coats Land on the eastern side of the Weddell Sea. The base is known as the Royal Society Base, Halley Bay. The revised co-ordinates are $75^{\circ} 31'S.$, $26^{\circ} 36'W.$ The main party of the International Geophysical Year Expedition and that of the Trans-Antarctic Expedition sailed from London on November 15, 1956 in the m.s. *Magga Dan* (2,000 tons). The Trans-Antarctic Expedition base is at Shackleton, $77^{\circ} 57'S.$, $37^{\circ} 16'W.$, about 250 miles south-westward of Halley Bay.

The Expedition's main party of 20 under the leadership of Col. R. A. Smart, R.A.M.C., includes 11 scientific members who will be responsible for the observational programme of the aurora, geomagnetism, glaciology, the ionosphere, meteorology, radio-astronomy and seismology until the end of 1958. The component for work in meteorology, geomagnetism, glaciology and seismology consists of the following members of the Meteorological Office, Messrs. J. MacDowall, A. Blackie, J. M. C. Burton, D. T. Tribble and D. G. Ward; all of whom, along with several other of their Office colleagues, volunteered for this enterprise more than a year ago. They will be joined, for 1957, by another colleague, Mr. P. H. Jeffries, who has been with the Trans-Antarctic Expedition advance party at Shackleton throughout 1956. Having accomplished their indispensable mission during 1956 of establishing the base at Halley Bay, instituting preliminary scientific observations and carrying out other essential pioneer work, the advance party, which includes Mr. D. W. S. Limbert of the Meteorological Office, will return to the United Kingdom early in 1957.

An immediate preoccupation of the new arrivals at Halley Bay will be to erect, on the ice shelf, the instrument and observation huts (including those for the geomagnetic instruments and for filling radio-sonde balloons) and additional aerial arrays, and to install equipment with minimum delay so that everything shall be fully operational well before the beginning of the International Geophysical Year, July 1, 1957.

The general nature of the work in meteorology and geomagnetism, to be undertaken at Halley Bay in 1957-8, has been outlined previously¹. One of the important features will be upper air soundings twice daily. For the measurement of upper winds to 80,000-100,000 ft., it is hoped 3-cm. radar equipment very recently developed by Decca Radar Ltd is to be used. A three-component Willmore-seismograph assembly is to be used for recording earthquakes which may occur at moderate distances from the base.

Our best wishes for complete success go to the whole party at Halley Bay, and to the several other similar parties in the far South, in their endeavours to achieve significant contributions to the general International Geophysical Year programme for Antarctica.

REFERENCE

1. ABSALOM, H. W. L.: International Geophysical Year. *Met. Mag., London*, **85**, 1956, p. 33.

Lightning damage to an electric-cup-generator anemometer

The electric-cup-generator anemometer at the R.A.F. station at Wyton, Huntingdonshire was struck by lightning at 1546 G.M.T. on July 18, 1956 during

a severe thunderstorm. Some of the damage to the anemometer and installation is shown in the four photographs facing pp. 12 and 13.

The lightning struck the revolving-cup assembly. The top photograph facing p. 11 shows the assembly with twisted cups, the lower photograph an indentation at the apex of one of the cups and the upper photograph, facing p. 13, beads on the rim of a cup, produced by local fusing of the metal. This local fusing effect was produced on the rims of two of the three cups. This photograph also shows a mark on the supporting arm of the cup, due apparently to sparking between rim and arm. Finally, the lower photograph facing p. 13 shows the fusing in the 14-pair cable leading out of the mains terminal box. The cable was fused to the inside of the terminal box and the insulation wax melted off the cable wires. The outer wrapping of the cable shows perforations caused by fusing points on individual wires.

S. F. COLEMAN

BOOK RECEIVED

Indian Journal of Meteorology and Geophysics. 7, 1956, No. 4, India Meteorological Department. 9½ in. × 7¼ in., pp. ii + 414 + vi. Manager of Publications, Delhi, 1956. Price: Rs. 3/- or 5s.

REVIEWS

Equatorial weather with particular reference to Southeast Asia. By I. E. M. Watts. 8½ in. × 5½ in., pp. xvi + 224, *Illus.*, University of London Press Ltd, London, 1955, Price: 25s.

This is a brief and elementary outline of the theory and practice of synoptic meteorology in equatorial regions together with the essential background of climatology and physical principles. After reading it the enthusiastic amateur and the not too advanced student will feel that they have acquired some worthwhile knowledge of the subject, but the expert in tropical meteorology will find much to criticize. However it is evident that the book was not written for the expert and it would be improper to judge it entirely from his standpoint.

Little fault can be found with the scope of the book, but considered as a whole the work does not hang well together. The order of treatment is somewhat confusing and the standard of knowledge assumed for the reader varies greatly from one section to another. It begins with a brief and somewhat facile account of the general circulation of the atmosphere with special reference to low latitudes. There follows a rather digressionary chapter dealing with the differences between tropical and temperate latitudes as regards meteorological observations and their interpretation. The following chapter on the vertical distribution of temperature is of very patchy quality; for example the terms "lapse rate" and "adiabatic" are introduced without explanation, neither is any inkling given of why a rising parcel of air cools. In the brief theoretical explanation of the tephigram it is by no means evident that temperatures used in formulae are on the absolute scale. On the other hand the explanation given of stability and instability is a most elementary one.

There are next three descriptive chapters on the formation of fog and cloud, precipitation and other phenomena associated with strong convection, and the seasonal and geographical distribution of rainfall in Southeast Asia. The last is a useful and well written summary, illustrated by clear diagrams. However the statement on p. 67 that the maximum frequency of precipitation over the sea normally occurs in the early morning will not pass without question; this is known to be true only for coastal waters.

The kinematics and kinetics of air movements near the equator are dealt with in the next block of four chapters. The treatment is mostly descriptive though now and again there are appeals to the minimum of mathematical background, for example the Rossby long-wave formula and the Petterssen kinematic formulae for the motion of pressure systems. The basic physics and dynamics are skimmed over rather lightly. The restrictive conditions under which the Rossby formula applies are not mentioned, while on p. 86 there is a statement implying that movement of air along the isotherms contributes to its changes of temperature. Frequent reference is made to convergence as an active factor in producing weather but it seems that confluence in the flow patterns is too easily accepted as an indicator of convergence. If shortcomings of this kind occurred only here and there they could be tolerated but similar, though perhaps less glaring ones, characterize much of the book.

The remaining chapters deal for the most part with the practical aspects of weather analysis in Southeast Asia. Inevitably there are the usual comparisons with temperate latitudes (one wonders how synoptic meteorology would have developed in low latitudes alone) and emphasis is rightly laid on air streams and their boundaries. Some practical examples are given. These chapters are the best in the book and make a useful introduction for the forecaster going to the tropics for the first time.

A. G. FORSDYKE.

The atmosphere. By N. C. Gerson. *Air Force Surv. Geophy. Cambridge Mass.* No. 73. 10 $\frac{3}{4}$ in. \times 8 $\frac{1}{4}$ in., xii + 76, *Illus.*, Air Force Cambridge Research Center, Cambridge Mass., 1955.

It is still probably true to say that for the ordinary synoptic meteorologist the atmosphere ends just above the tropopause. The aurora, ionised layers, meteors and other upper atmospheric phenomena are considered the province of workers in other scientific fields, if not as mere physical curiosities. The pace of development in aviation, both service and civil, suggests, however, that meteorologists may soon be called on for information and advice on conditions in the ozonosphere, and eventually in the ionosphere.

This survey, prompted by the approaching International Geophysical Year programme, is intended to provide for the meteorologist a brief review of the properties of the 5 per cent. of the atmosphere lying beyond 20 Km. The author lists four fields of research from which information has been obtained: auroral physics, ionospheric physics, geomagnetism and cosmic rays. He gives a concise and readable account of the contributions each of these can make, with a note on their historical development.

Mr. Gerson deals then with the structure and composition of the higher atmosphere, following with a brief discussion of atmospheric motions. The remaining sections are concerned with the ionic layers, air glow and auroral statistics, and terrestrial magnetism. Despite the simplification and condensation required by a short survey there are few statements with which one could quarrel. Some controversial points, such as the seasonal variations in ozone concentration, the validity of methods of wind measurement and connections between high- and low-level phenomena are touched upon, but not discussed.

Fully half of the survey is taken up by diagrams relating to a wide range of phenomena. They include: energy-level diagrams for oxygen and nitrogen,

neutral and ionized; the local, vertical and latitudinal variations of ozone concentration, the geographical and diurnal variation of the ionic layers, with illustrations for individual locations; absorption wave-bands for various atmospheric gases, and emissions in the air-glow and auroral spectra; and charts of auroral frequency, and of geomagnetic intensity. Several of these are taken from other sources, but it is convenient to have them assembled in this fashion.

The question of nomenclature is one that will shortly require to be settled, if confusion is not to arise. The simplicity of referring to only three atmospheric layers, troposphere, stratosphere and ionosphere, will need to be weighed against the desirability of incorporating words such as mesosphere, chemosphere, thermosphere and exosphere into meteorological literature.

P. GRAYSTONE

OBITUARIES

Mr. Arthur John Lander, M.B.E. It is with deep regret that we record the sudden death of Mr. A. J. Lander, Head of M.O.4, on November 5, 1956, at the age of 57. He entered the Office in 1920 as a Technical Assistant and began his career at the Royal Aircraft Establishment, Farnborough. Rather less than a year later he was transferred to the newly formed Meteorological Department at the Chemical Warfare Experimental Station, Porton, where micrometeorological research was starting under N. K. Johnson. Lander remained at Porton for 15 years. During this period he developed a remarkable talent for designing and making intricate unconventional meteorological instruments, and the pioneer work at Porton owed much to his skilled hands. In 1936 he went to Kew, where he played a considerable part in making the radio-sonde a satisfactory instrument for routine use.

His practical knowledge of this new tool was of great value in 1939 when the setting up of a network of upper air stations became a matter of the highest importance. After visiting Finland and France to obtain first-hand knowledge of the Väisälä and Bureau systems, Lander gave his personal supervision to the task of setting up the radio-sonde stations including those as far afield as the Scilly Isles and Shetland. His efforts ensured the firm foundation of a good aerological service and they were followed by his assuming responsibility for the calibration of all the thousands of radio-sondes that were to be issued in the ensuing years. For this work he was awarded the M.B.E. in 1945.

From 1952 to 1954 Lander's earlier experience of micrometeorological work was put to good use when he collaborated with G. D. Robinson in research into the convective heat flux near the ground. The results of this work formed the subject of two valuable Meteorological Research Papers. In 1955 Lander was made head of the Branch (M.O.4) concerned with the supply and testing of instruments and was promoted to the grade of Chief Experimental Officer.

Lander was a born engineer, and he made no secret of the fact that he preferred the workshop bench to the desk. He will be missed, not only for his professional abilities, but also for his friendliness and good nature. Our deepest sympathies go to his widow and daughter.

O. G. SUTTON.

Mr. S. E. Ashmore, B.Sc., A.Inst.P., F.R.Met.Soc.—The news of the death on October 14, 1956, of Mr. Ashmore, Physics Master at Grove Park School, Wrexham, was received with deep regret.

Mr. Ashmore had maintained a climatological station at the school since 1943, submitting to the Meteorological Office unbroken records of the highest standard. Moreover, so infectious was his enthusiasm for meteorology and so ready his willingness to help and advise, that several others in the area were stimulated into making climatological or rainfall observations.

Nor was his interest limited to observing, but included the physical and geographical interpretation of meteorological phenomena and climatological data. Many of his articles and letters were published in the *Quarterly Journal* of the Royal Meteorological Society, the *Meteorological Magazine*, *British Rainfall*, and *Weather*. The subjects covered by them ranged from the geographical distribution of the annual variation of the diurnal range of temperature, the physics of meteorological optical phenomena, evaporation and percolation, to the semi-permanent snow beds of the British Isles. He was awarded the Darton Prize by the Royal Meteorological Society in 1955.

By his personal efforts and also his example and encouragement to others, Mr. Ashmore made a valuable contribution to the records from voluntary observers—records on which the study of climatology in this country so much depends. It is gratifying to learn that the station which he established at Grove Park School, in particular, is to be continued; there could be no more appropriate memorial to S. E. Ashmore.

Mr. Thomas Walton.—It is with deep regret we learn of the death, at the age of 36, of Mr. T. Walton, as a result of a road accident on the night of November 15, 1956. He joined the Office in May 1948 as a Meteorological Assistant after service in the Meteorological Branch of the Royal Air Force Volunteer Reserve from 1940 to 1948. He served successively at a number of aviation outstations, including a tour of duty in Malta and El Adem. He was promoted Assistant Experimental Officer in 1949 and Experimental Officer in 1954. At the time of his death he was serving at Basingbourn.

He is survived by a widow and a daughter to whom the sympathy of all who knew him in the Office is extended.

AWARD

Prize of the International Meteorological Organization

The first recipient of the Prize of the International Meteorological Organization is Dr. H. T. Hesselberg, formerly Director of the Norwegian Meteorological Institute, who was President of I.M.O. from 1935 to 1946. The prize, which consists of a gold medal, a diploma and the sum of \$1,200, was presented to him in Oslo on September 21, 1956 by M. André Viaut, President of the World Meteorological Organization. The Prize, created by the World Meteorological Organization to perpetuate the memory of its predecessor, is presented annually by the Executive Committee of W.M.O. for contributions to meteorological science combined with devotion to the cause of international meteorology.

METEOROLOGICAL OFFICE NEWS

Retirement.—Mr. A. J. Tabor, Senior Experimental Officer, retired on August 10, 1956, after 45 years' service. He joined the Office in December 1911 as a Boy Clerk in the Marine Division. In 1917 he was posted to the

Forecast Division and in April 1918 he joined the Royal Garrison Artillery as a gunner. On demobilization in February 1919 he returned to the Forecast Division. In April 1920 he was transferred to the Marine Division where he remained for 28 years. Since 1948, until his retirement, he worked in the Civil Aviation (Home) Branch on administrative duties.

Courses of training for climatological observers.—Two courses, each lasting four and a half days, were held in October 1956 at the Meteorological Office Training School, Stanmore, and 36 observers attended. Instruction and discussions covered the exposure and maintenance of instruments, the making of observations, and the completion of returns. Films and slides were shown, and talks given on some of the applications of climatological data. Special attention was paid to the work at Crop-Weather and Health-Resort Stations. Visits were made to the forecasting branch at the Air Ministry and to Harrow, where the work of the British Climatological Branch, the recording of data on punched cards in the Marine Branch, and the testing of instruments were seen and discussed. The courses are designed to help the observers with their specific work, to broaden their interests in meteorology, and to give them an insight into the ultimate purpose of the observations. It is hoped to arrange similar courses in October 1957.

WEATHER OF NOVEMBER 1956

The main cyclonic activity in the Atlantic was again north of its usual path and was probably unusually concentrated all month along the east coast of Greenland. This gave mean pressure values for the month 8 mb. below normal about Scoresby Sound in 70°N. Temperatures were 4° to 5°C. above normal from Iceland to Spitsbergen, and precipitation was very excessive on the windward southern slopes of Iceland and eastern slopes of north-east Greenland (excesses up to 600 per cent. of normal, these being unusually high figures for such a region).

As in October, the Azores anticyclone was shifted north, towards the British Isles, the monthly pressure anomaly reaching + 10 mb. near south-west Ireland.

The North-Pacific depressions appear also to have been north of normal, but not notably intense, whereas the north-east extension of the Pacific anticyclone over the central Rockies was remarkably intense and persistent. Mean pressure for the month was 8–10 mb. above normal over a wide area of western North America between 40° and 55°N., with peak values of 1030 mb.

The Siberian anticyclone was rather above normal intensity and its centre shifted somewhat north and north-east. The system had sufficiently increased extent to cover all central Asia in spite of the shift of centre.

Temperatures were slightly above normal in the broad south-westerly air stream from central Asia to the Arctic. Bigger excesses occurred in the south-westerly winds reaching the Canadian Rockies and in the Chinook region on the lee side, where anomalies reached +4°C. There was another region of temperatures 1° to 3°C. above normal between the Great Lakes and the Atlantic seaboard of the United States and Canada from 35° to 50°N.

The month was cold over most of Europe, except the British Isles; the anomaly pattern culminating with –6°C. over Finland was rather reminiscent of November 1955. There were also regions of negative anomaly

-1° to -3°C . over most of northern and central North America, over the central Rockies and in far-eastern Siberia. Locally over north Labrador, over Baffin Land, and north of Irkutsk, anomalies of -5°C . for November were reported.

In the British Isles this unusually dry November was dominated by anti-cyclones over north-west Europe or the eastern Atlantic.

The month opened with an intense anticyclone over Scotland with pressure at Benbecula 1044.5 mb., a new high November record of pressure in the British Isles. During most of the first week an anticyclone was situated to the west or north-west of the country and weather was cloudy with slight rain or drizzle and moderate north-westerly winds. As the anticyclone crossed southern England to the continent on the 6th and 7th, early morning frost and fog became widespread; at some places fog persisted most of the day but at others there were good sunny periods. On the 7th temperatures rose generally to the upper fifties as strong southerly winds spread into the western part of the country. The next four days were changeable with rain at times, and although some heavy falls occurred for short periods, rainfall was not substantial anywhere. A period of quiet, rather foggy weather followed with slight local rain, mainly in the north, and frost at night, as an anticyclone from the Azores moved north and then crossed England to the continent. On the 19th winds increased from the south-east ahead of an Atlantic trough; temperature began to fall steadily, and by the 21st cold continental air had spread over much of the British Isles. Frost was widespread; at Cardington a temperature of 18°F . was recorded in the screen on two successive nights. The cold spell was brought to an end by a frontal system which moved south-east into Scotland on the 24th, and as the associated warm front crossed the country the following day temperatures rose above 50°F . everywhere. Severe gales occurred in northern districts as very cold air again swept southwards over the British Isles on the 25th; wind rose in gusts to 70–90 kt. in Scotland. Strong, cold northerly winds persisted until the 29th and there were frequent snow showers in the north and scattered snow showers as far south as the Home Counties.

The main feature of the month was the low rainfall. Over the country as a whole it was the driest November since records began in 1869 apart from 1945 and also the driest month of 1956 so far. The mean temperature was only slightly below normal despite the severity of the two cold spells.

The mainly dry weather has enabled most farmers to catch up with their routine work and good progress has been made. The first general frost of the autumn was severe but later than usual so that its effect was not very great.

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

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Per-centage of average	No. of days difference from average	Per-centage of average
	$^{\circ}\text{F}$.	$^{\circ}\text{F}$.	$^{\circ}\text{F}$.	%		%
England and Wales ...	63	17	1 0.6	37	—5	99
Scotland	60	16	+ 1.2	62	—4	78
Northern Ireland ...	56	24	+ 1.4	70	—3	66

RAINFALL OF NOVEMBER 1956

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
<i>London</i>	Camden Square ...	0·38	16	<i>Glam.</i>	Cardiff, Penylan ...	1·45	36
<i>Kent</i>	Dover ...	0·69	22	<i>Pemb.</i>	Tenby ...	1·33	31
	Edenbridge, Falconhurst	0·88	25	<i>Radnor</i>	Tyrmynydd ...	3·34	50
<i>Sussex</i>	Compton, Compton Ho.	1·01	27	<i>Mont.</i>	Lake Vyrnwy ...	2·83	49
	Worthing, Beach Ho. Pk.	0·69	22	<i>Mer.</i>	Blaenau Festiniog ...	4·47	42
<i>Hants.</i>	St. Catherine's L'thouse	0·94	30		Aberdovey ...	2·69	59
	Southampton (East Pk.)	0·82	26	<i>Carn.</i>	Llandudno ...	1·43	49
	South Farnborough ...	0·72	27	<i>Angl.</i>	Llanerchymedd ...	1·71	41
<i>Herts.</i>	Harpenden, Rothamsted	0·80	30	<i>I. Man</i>	Douglas, Borough Cem.	1·48	31
<i>Bucks.</i>	Slough, Upton ...	0·41	18	<i>Wigtown</i>	Newton Stewart ...	2·17	44
<i>Oxford</i>	Oxford, Radcliffe ...	0·77	33	<i>Dumf.</i>	Dumfries, Crichton R.I.	1·02	28
<i>N'hants.</i>	Wellingboro' Swanspool	0·66	31		Eskdalemuir Obsy. ...	2·81	48
<i>Essex</i>	Southend, W. W. ...	0·42	19	<i>Roxb.</i>	Crailing... ...	0·80	34
<i>Suffolk</i>	Felixstowe ...	0·55	27	<i>Peebles</i>	Stobo Castle ...	1·42	43
	Lowestoft Sec. School ...	1·13	48	<i>Berwick</i>	Marchmont House ...	0·89	30
	Bury St. Ed., Westley H.	0·72	31	<i>E. Loth.</i>	North Berwick Gas Wks.	0·61	28
<i>Norfolk</i>	Sandringham Ho. Gdns.	1·17	47	<i>Mid'l'n.</i>	Edinburgh, Blackf'd. H.	0·65	29
<i>Wilts.</i>	Aldbourne ...	0·93	30	<i>Lanark</i>	Hamilton W. W., T'nhill	1·23	34
<i>Dorset</i>	Creech Grange... ...	0·87	21	<i>Ayr</i>	Prestwick ...	1·30	40
	Beaminster, East St. ...	0·70	18		Glen Afton, Ayr San. ...	3·34	61
<i>Devon</i>	Teignmouth, Den Gdns.	1·04	33	<i>Renfrew</i>	Greenock, Prospect Hill	2·65	44
	Ilfracombe ...	1·68	43	<i>Bute</i>	Rothsay, Ardenraig
	Princetown ...	5·11	58	<i>Argyll</i>	Morven, Drimnin ...	6·08	90
	Werrington Park ...	2·39	52		Poltalloch ...	4·05	72
<i>Cornwall</i>	Penzance ...	2·38	52		Inveraray Castle ...	5·29	63
	St. Austell ...	2·73	55		Islay, Eallabus ...	3·68	68
	Scilly, Tresco Abbey ...	1·57	46		Tiree ...	3·64	75
<i>Somerset</i>	Taunton ...	0·62	23	<i>Kinross</i>	Loch Leven Sluice ...	0·62	17
<i>Glos.</i>	Cirencester ...	0·81	26	<i>Fife</i>	Leuchars Airfield ...	0·76	33
<i>Salop</i>	Church Stretton ...	1·50	48	<i>Perth</i>	Loch Dhu ...	3·45	40
	Shrewsbury, Monkmore	0·76	34		Crieff, Strathearn Hyd.	0·92	21
<i>Worcs.</i>	Malvern, Free Library...	0·68	27		Pitlochry, Fincastle ...	1·30	35
<i>Warwick</i>	Birmingham, Edgbaston	0·87	33	<i>Angus</i>	Montrose, Hospital ...	0·90	34
<i>Leics.</i>	Thornton Reservoir ...	0·96	42	<i>Aberd.</i>	Braemar ...	1·22	32
<i>Lincs.</i>	Boston, Skirbeck ...	0·79	40		Dyce, Craibstone ...	1·78	55
	Skegness, Marine Gdns.	1·01	47		New Deer School House	2·78	82
<i>Notts.</i>	Mansfield, Carr Bank ...	1·02	42	<i>Moray</i>	Gordon Castle ...	1·82	63
<i>Derby</i>	Buxton, Terrace Slopes	1·85	40	<i>Nairn</i>	Nairn, Achareidh ...	1·45	64
<i>Ches.</i>	Bidston Observatory ...	1·39	56	<i>Inverness</i>	Loch Ness, Garthbeg ...	3·19	76
	Manchester, Ringway...	1·22	47		Loch Hourn, Kinlochourn	9·85	83
<i>Lancs.</i>	Stonyhurst College ...	2·27	50		Fort William, Teviot ...	7·96	97
	Squires Gate ...	1·26	38		Skye, Broadford ...	7·27	85
<i>Yorks.</i>	Wakefield, Clarence Pk.	0·55	26		Skye, Duntulm ...	5·58	93
	Hull, Pearson Park ...	0·73	33	<i>R. & C.</i>	Tain, Mayfield... ...	2·15	73
	Felixkirk, Mt. St. John...	1·63	67		Inverbroom, Glackour...
	York Museum ...	0·65	31		Achnashellach ...	11·74	136
	Scarborough ...	1·69	68	<i>Suth.</i>	Lochinver, Bank Ho. ...	5·42	107
	Middlesbrough...	0·98	46	<i>Caith.</i>	Wick Airfield ...	3·67	117
	Baldersdale, Hury Res.	1·41	39	<i>Shetland</i>	Lerwick Observatory ...	3·61	85
<i>Nor'l.d.</i>	Newcastle, Leazes Pk....	0·65	28	<i>Ferm.</i>	Crom Castle ...	2·26	65
	Bellingham, High Green	1·09	32	<i>Armagh</i>	Armagh Observatory ...	2·24	79
	Lilburn Tower Gdns. ...	0·68	20	<i>Down</i>	Seaforde ...	2·34	62
<i>Cumb.</i>	Geltsdale ...	2·30	70	<i>Antrim</i>	Aldergrove Airfield ...	1·30	40
	Keswick, High Hill ...	2·51	44		Ballymena, Harryville...	2·39	59
	Ravenglass, The Grove	1·50	34	<i>L'derry</i>	Garvagh, Moneydig ...	3·16	80
<i>Mon.</i>	A'gavenny, Plás Derwen	1·37	33		Londonderry, Creggan	3·94	96
<i>Glam.</i>	Ystalyfera, Wern House	2·38	36	<i>Tyrene</i>	Omagh, Edenfel ...	2·88	78

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