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A FEBRUARY CROSS-SECTION ALONG THE GREENWICH MERIDIAN

By R. W. JAMES, M.Sc.

Summary.—Techniques in the construction of meridional profiles of geostrophic westerly wind are briefly discussed. It is shown that computations may be greatly reduced by plotting the contour height of a fixed pressure level against the cosine of latitude. The technique is applied to obtain the mean westerly wind profile for February 1951, considered to be typical of the east Atlantic.

Comparison is made with corresponding profiles drawn for east America. It is suggested that the apparent differences may be attributed to the different boundary conditions involved in a sea and land surface, respectively.

Introduction.—Cross-sections of the mean westerly geostrophic flow have been drawn for the United States (notably by Hess[1]), the Australasian region[2,3], China[4] and India[5]. The northern-hemisphere sections are for broadly similar topographic regions; a land mass to windward with a prominent mountain barrier, the Rockies in the case of the United States, the Himalayas in the Asiatic regions. The Australasian sections, on the other hand, may be regarded as typical of maritime areas.

It would be hazardous to discuss the differences between land and sea profiles by comparing the northern- and southern-hemisphere sections, for, in addition to contrasting boundary conditions, we have to contend with possible inherent differences in the mean flow in the two hemispheres. It would, therefore, be of interest to compare a northern-hemisphere cross-section of windward oceanic aspect with the existing profiles proper to a continental exposure.

The Greenwich meridian has the broad Atlantic to windward, the British Isles presenting a relatively small land mass, so that this cross-section might be taken as typical of a sea exposure. It might appear surprising that no cross-section for this meridian has yet been published, considering the wealth and accuracy of the available aerological material.

It may be that some diffidence arises from doubts as the homogeneity of the available ascents, for the cross-section lies over different countries, with differing sounding equipment. It is true that any definitive cross-section must be based on a critical comparison of the performance of the varying radio-sondes employed, but for a first attempt it seems reasonable enough to dispense with such refinements.

We shall present below a cross-section of geostrophic westerly wind along the Greenwich meridian for February 1951. The data are extracted from *Monthly*

Climatic Data for the World (February 1951)[6]. This publication includes a selection of the mean values of the upper air elements contained in the monthly CLIMAT TEMP broadcasts of many countries. No European country as yet publishes upper air climatological summaries.

The purpose is not merely to present a particular cross-section but rather to indicate how easily such sections can be drawn, given the aerological data in suitable form. The actual labour of drawing the cross-section below occupied less than a day.

"Elimination" of latitude.—The earlier cross-sections[1] were computed from data embodying mean pressures at fixed height levels. Most meteorological services now publish their material in terms of the mean height of specific pressure levels. The advantages of working with contour heights rather than pressures when geostrophic wind speed is required are obvious. Not only is the effect of change of density with height eliminated, but also the smaller influence of the change of density at a fixed level with latitude.

However, with the usual techniques correction must still be made for the change of the Coriolis parameter with latitude. We shall now see how this variation in latitude may be treated in a particularly simple way.

The expression for the westerly component of geostrophic wind speed is

$$U_g = \frac{g}{2\omega \sin\varphi} \frac{\partial Z}{\partial y} \qquad \ldots\ldots (1)$$

where g is the acceleration of gravity, ω is the earth's rotational speed, Z is the contour height of a given pressure level, and y is the distance along a meridian. We may write $y = -a\varphi$, where a is the earth's radius, and eliminating y in equation (1) we find

$$U_g = \frac{g}{2\omega a} \frac{\partial Z}{\partial \cos\varphi} \qquad \ldots\ldots (2)$$

Therefore, we may plot the contour height against the cosine of the latitude instead of the latitude itself, and the slope of the curve at any point is a measure of geostrophic westerly wind speed. Numerically we have, when Z is expressed in hundreds of metres,

$$U_g = 1\cdot06 \frac{\partial Z}{\partial \cos\varphi}$$

$$\simeq 1\cdot06 \frac{\Delta Z}{\Delta \cos\varphi} \text{ m./sec.} \qquad \ldots\ldots (3)$$

where ΔZ is the difference in contour height between two points φ_2 and φ_1, $\Delta\cos\varphi = \cos\varphi_2 - \cos\varphi_1$. A smoothed curve can be drawn through the available data and the slopes read off at any desired number of points, or we may form the differences ΔZ and $\Delta\cos\varphi$ for a pair of stations and so determine the mean U_g between them.

Which method is adopted depends largely on convenience, but the writer prefers to estimate the slope. To use it as a matter of routine one requires paper ruled proportionately to the cosine.

No particular novelty is claimed for this technique. Mr. Radok says that he and Loewe employed it in computing their southern-hemisphere cross-sections[2].

Contour height as a function of latitude.—Table I shows the contour heights of the 850-, 700-, 500-, 300- and 200-mb. levels in February 1951 for the nine stations used in the analysis, ranging from Lerwick (latitude 60°N.) to Dakar (15°N. approximately). All the stations except Dakar are less than 10° from the Greenwich meridian.

TABLE I—MEAN CONTOUR HEIGHT OF SELECTED PRESSURE LEVELS, FEBRUARY 1951

	Position		Pressure levels (mb.)				
			850	700	500	300	200
					metres		
Lerwick	60°11'N.	1°11'W.	1,267	2,769	5,240	8,672	...
Larkhill	51°11'N.	1°48'W.	1,321	2,831	5,319	8,771	11,299
Brest	48°27'N.	4°25'W.	1,329	2,844	5,330	8,789	11,415
Bordeaux	44°50'N.	0°42'W.	1,384	2,909	5,423	8,908	11,517
Gibraltar	36°09'N.	5°21'W.	1,496	3,054	5,636	9,226	11,834
Casablanca... ...	33°35'N.	7°39'W.	1,524	3,083	5,664	9,275	...
Colomb-Béchar ...	31°40'N.	2°10'W.	1,524	3,134	5,691	9,317	11,935
Aoulef	27°04'N.	1°06'E.	1,517	3,108	5,734	9,391	12,051
Dakar	14°40'N.	17°26'W.	1,512	3,126	5,797	9,526	12,220

Fig. 1 shows the 850-mb. heights plotted against the cosine of the latitude. It will be seen that a reasonably smooth curve results, and that the change in slope at about latitude 32·5°N. indicates that this latitude marks the division between the westerly flow of middle latitudes and the tropical easterlies in the 850-mb. surface. The slope of the curve is almost constant between latitudes 35°N. and 47°N., and is greater here than elsewhere. This indicates that the mean zonal wind speed at the 850-mb. level is almost uniform over a very broad band of latitude, that is, the wind maximum is very flat or the mean jet stream is very diffuse. Around latitude 50°N. there is a considerable reduction in the slope of the curve, and hence of the corresponding geostrophic wind speed. One might feel tempted to attribute this abrupt change to the transition from French to

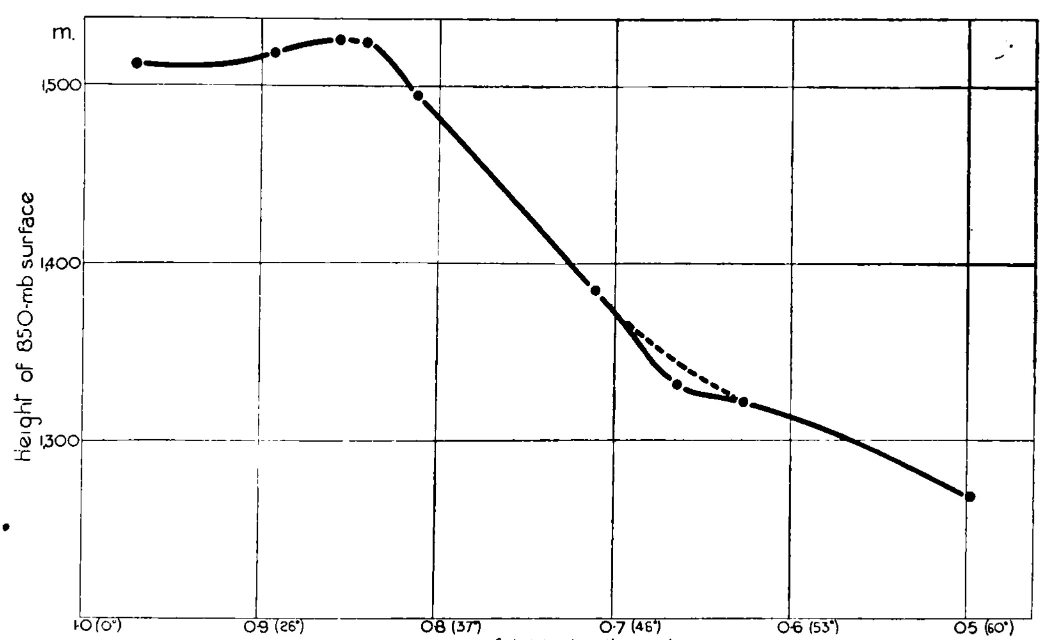

FIG. 1—RELATION BETWEEN HEIGHT OF 850-MB. SURFACE AND COSINE OF LATITUDE ALONG THE GREENWICH MERIDIAN

British ascents. This slope minimum could be eliminated by smoothing, as indicated by the broken line.

Fig. 2 shows the corresponding curve for 300 mb. The easterlies are absent at this level. One distinguishes a maximum of slope between Gibraltar (36°N.) and Bordeaux (44°50′N.); the "jet-stream latitude" at 300 mb. may be taken as approximately 37°N. The speed maximum is again very broad, and there is again a suggestion of minimum slope between Brest and Larkhill, which may be spurious.

The general impression gained by a study of the curves is that a consistent smooth curve can be drawn through the data, and that the slope of this curve can readily and rapidly be evaluated to give the mean geostrophic westerly component.

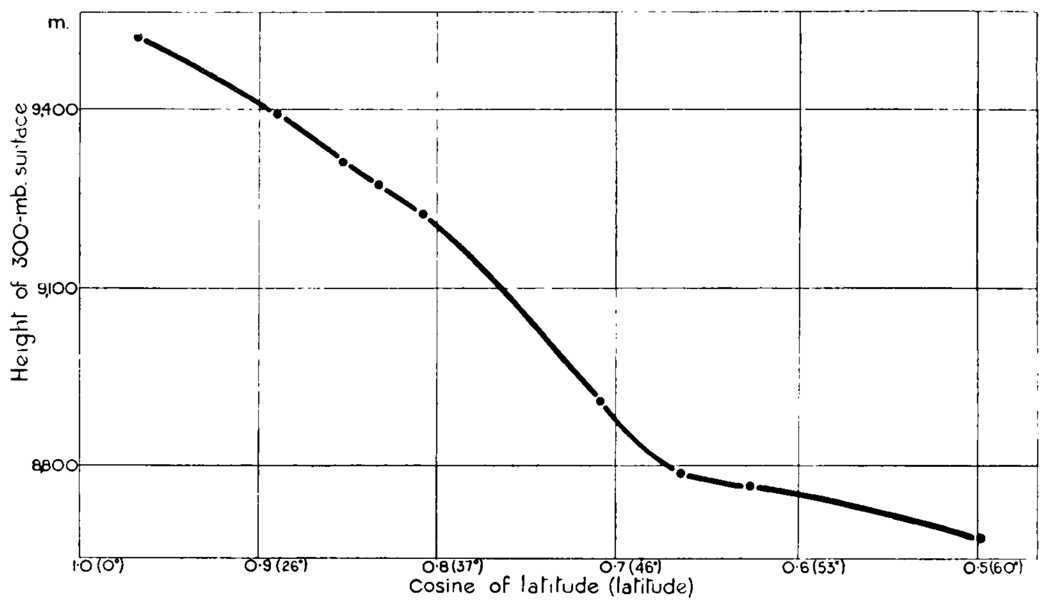

FIG. 2—RELATION BETWEEN HEIGHT OF 300-MB. SURFACE AND COSINE OF LATITUDE ALONG THE GREENWICH MERIDIAN

Geostrophic-wind profile.—Curves of height against cos φ were drawn for the 850-, 700-, 500-, 300- and 200-mb. levels, and the slopes read off for selected values of φ. The corresponding wind speeds were obtained from the expression (3), and from these figures the geostrophic-wind profile cross-section shown in Fig. 3 was drawn.

Normally the height is taken as the vertical axis in such a cross-section. This is appropriate when the analysis is in terms of pressure at a fixed height, but in contour analysis it is more natural to use pressure as the ordinate. To make this co-ordinate correspond as closely as possible with the actual height we have used the logarithm of pressure. It is not difficult to display the wind speed as a function of the actual height, if this is desired, but slightly more computation is involved, and the distortion involved is so slight as to be inappreciable on inspection. In any event, since wind speeds are normally quoted at fixed levels, the presentation used here is the more appropriate. The latitude is taken as the spatial co-ordinate. We could equally well have employed cos φ when the low-latitude end of the scale would have been compressed relative to the high-latitude end.

A glance at Fig. 3 reveals that the W.-wind profile along the Greenwich meridian in winter resembles the winter profiles found in other parts of the world. There is a flat maximum (mean jet) in about latitude 40°N. Over the North American continent the winter maximum occurs in about latitude 37°N., with a subsidiary jet stream in latitude 55°N. There is no evidence of this subsidiary in the Greenwich cross-section, unless the flat maximum may be regarded as a coalition of the two jet streams.

There are other differences between the two cross-sections. Over North America the wind maximum occurs near the 200-mb. level, whereas on the European seaboard the maximum is closer to 300 mb.

Unfortunately the surface geostrophic-wind profile for west Europe is not available, but the evidence points to an approximate four-fold increase in geostrophic wind speed between the surface and the jet-stream level. This corresponds to the structure found by Loewe and Radok[2], and by Hutchings[3], for maritime areas of the southern hemisphere. On the other hand, over North America there is something like an eight-fold increase in speed between the surface and the jet-stream level, and this ratio holds also for the Chinese cross-section[4]. In addition, the jet-stream speed is less over Europe than over North America, 35m./sec., as against 45m./sec.

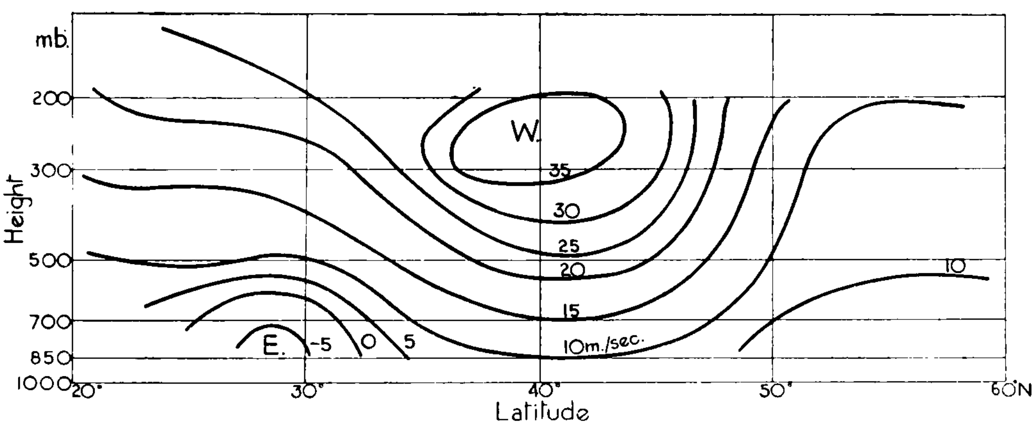

FIG. 3—ISOPLETHS OF MEAN ZONAL WIND VELOCITY

In a paper accepted for publication shortly in *Tellus*, the author presents evidence that these differences in the mean westerly flow are characteristic of land and oceanic regions respectively. The stronger westerlies aloft and the stronger gradient of mean westerly wind with height over the land may be taken as evidence of the greater dissipation of westerly momentum by skin friction. Since a land area represents a stronger sink of westerly angular momentum, the transport downwards of momentum must be strongest over the land. This is facilitated by stronger westerlies aloft and a greater gradient of momentum with height.

The wind profile for February 1951 is not necessarily typical of the mean winter structure over the east Atlantic, and it is highly desirable to have seasonal mean profiles. The present profile is offered simply as an illustration of the ease with which such diagrams can be constructed when the upper air climatological data are available.

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UNEXPECTED FAIR WEATHER OVER SOUTHERN SCOTLAND, MARCH 10, 1951

By W. D. S. McCAFFERY, B.Sc.

Summary.—The afternoon and evening of Saturday, March 10, 1951, was unexpectedly fine over much of southern Scotland and northern England. The fine weather can be attributed to the movement of a "bubble" of dry air. The detachment of this bubble from a reservoir in the Iceland area and its subsequent history are described.

Synoptic situation.—The 0900 G.M.T. chart for March 10, 1951 (Fig. 1), showed practically clear skies at Renfrew, Prestwick, West Freugh, Isle of Man and over much of Ireland. Over the remainder of the British Isles, weather was mainly cloudy with some fog patches, drizzle, sleet and snow showers over England and Wales, and snow or snow showers over Scotland.

The precipitation over England fell from a fairly thick layer of stratus and stratocumulus cloud which had moved westwards in the easterly air stream between an anticyclone over Norway and a complex depression over the Bay of Biscay and France (Fig. 2). There was probably little or no medium cloud. The Larkhill and Downham Market upper air ascents were dry above 700 mb., and there was a pronounced inversion at 850 mb., which would limit the depth of the cloud layer. The snow which fell over most of Scotland was associated with a polar depression centred approximately over the Isle of Skye. Both the Lerwick and Stornoway upper air ascents for 0900 G.M.T. were conditionally unstable and fairly moist up to at least 500 mb., and solid cloud of cumulonimbus or nimbostratus type could be expected. The Leuchars ascent was unstable up to about 650 mb. The problem for the forecaster was to find a satisfactory explanation for the area of clear skies and to forecast future developments.

Before 0900 it had been expected that the polar low would move south-south-west from the Moray Firth and that an easterly or south-easterly gradient wind would re-establish itself over the whole of Scotland except the extreme south-west, bringing to all east Scotland cloudy conditions, with occasional snow flurries in coastal areas, and more prolonged snowfall over the windward slopes of the hills. By the time the 0900 chart was ready for analysis, the cloud sheet over south-east Scotland had begun to break up from the west and snow had ceased at Silloth and Eskdalemuir, and by 1200 had also ceased at St. Abb's Head. Analysis of the 0900 chart showed that the polar low was now moving

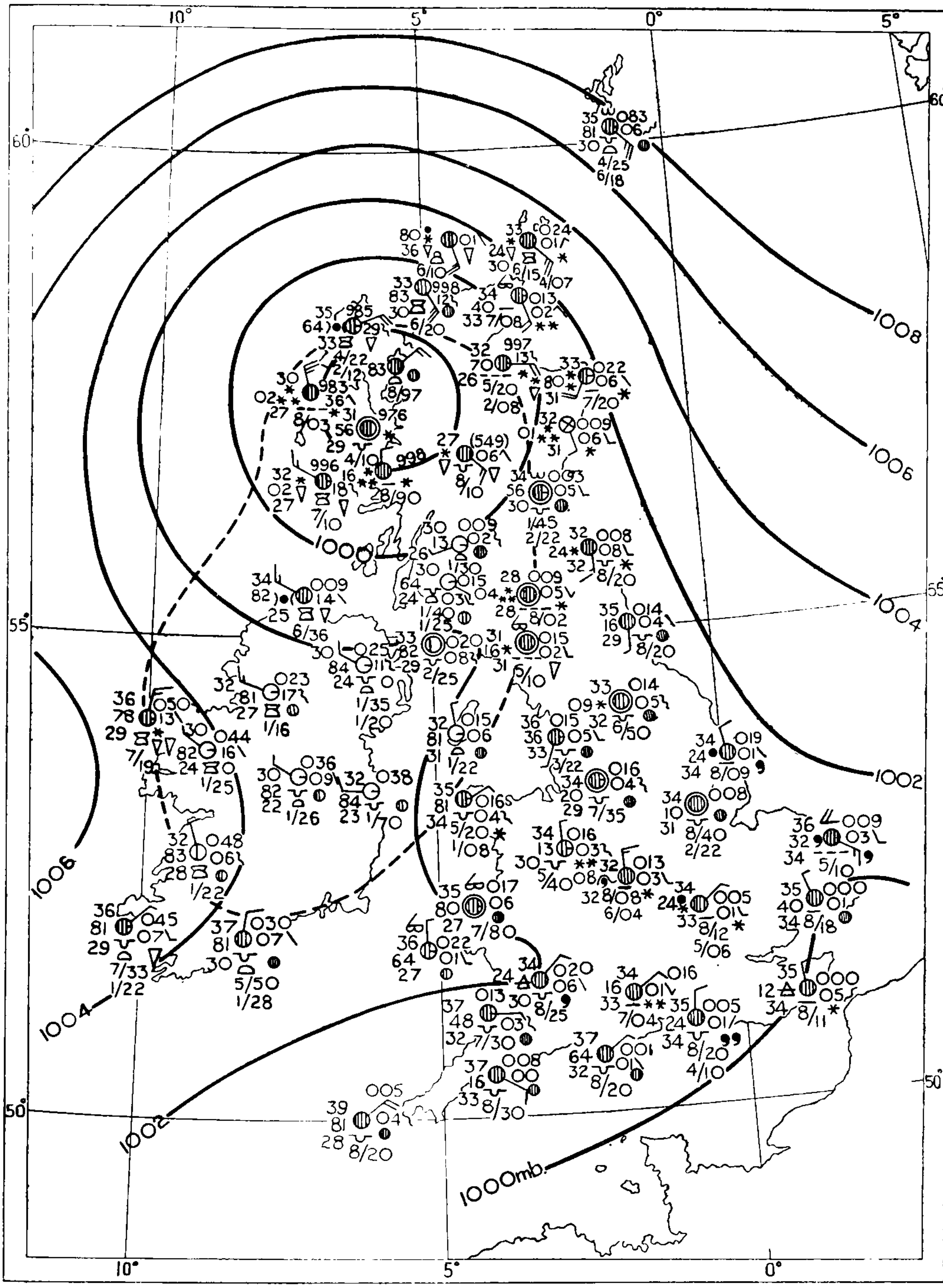

FIG. 1—SYNOPTIC CHART, 0900 G.M.T., MARCH 10, 1951
The boundary of the drier air is shown by the broken line.

only just slightly south of west (Fig. 2) with a fairly definite circulation, consequently the westerlies to the south of the centre could be expected to continue to affect south Scotland for at least several hours. In fact, the clear skies observed in the south-west at 0900 spread eastwards to a line from Aberdeen to St. Abb's Head, before retreating westwards as a south-easterly gradient wind became established during the following night.

Dew points within this area of clear skies fell very low (14°F. at Turnhouse at 1500 for example), while the 1500 upper air ascent at Leuchars showed a dew point of 3°F. at 900 mb. with an air temperature of 33°F. At 800 mb. on the same ascent, the corresponding temperatures were 9°F. and 12°F. respectively. The clear skies were apparently associated with a shallow surface layer of very dry air.

On the 0900 chart a line of demarcation can be drawn between dew points of about 30°F. or above and those below 30°F. and mainly around 25°F. (Fig. 1). This line runs from Benbecula to Kinloss, Leuchars, Silloth, Isle of Man, Shannon and Blacksod Point. From Kinloss to south of Silloth the line has the characteristics of a front, and indeed, the cessation of snowfall and clearance of cloud from the west, and its subsequent return from the east during the night and next day, can be explained on that basis. Mr. C. K. M. Douglas comments:

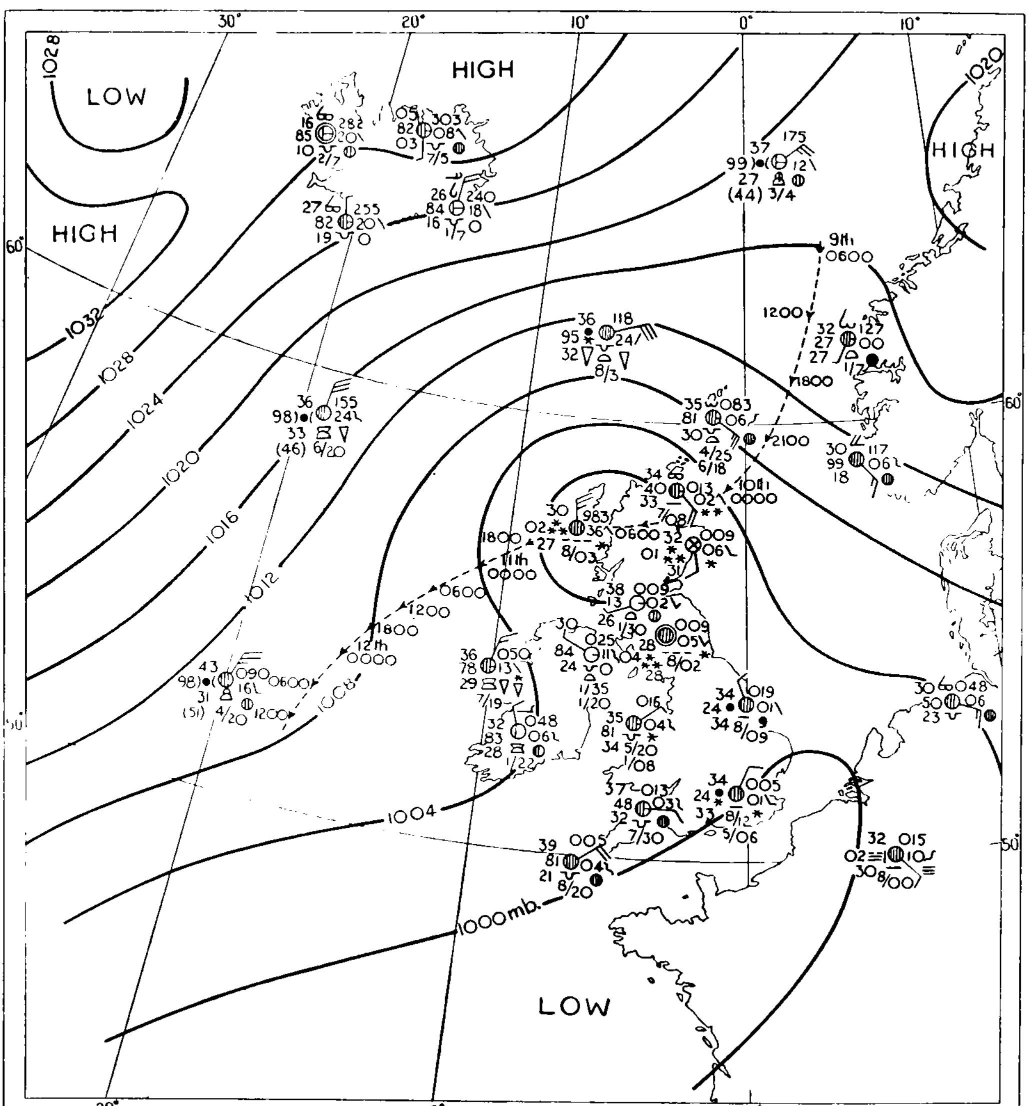

FIG. 2—SYNOPTIC CHART, 0900 G.M.T., MARCH 10, 1951

The movement of the polar low between 0600, March 9, and 1200, March 12, is shown by the broken line.

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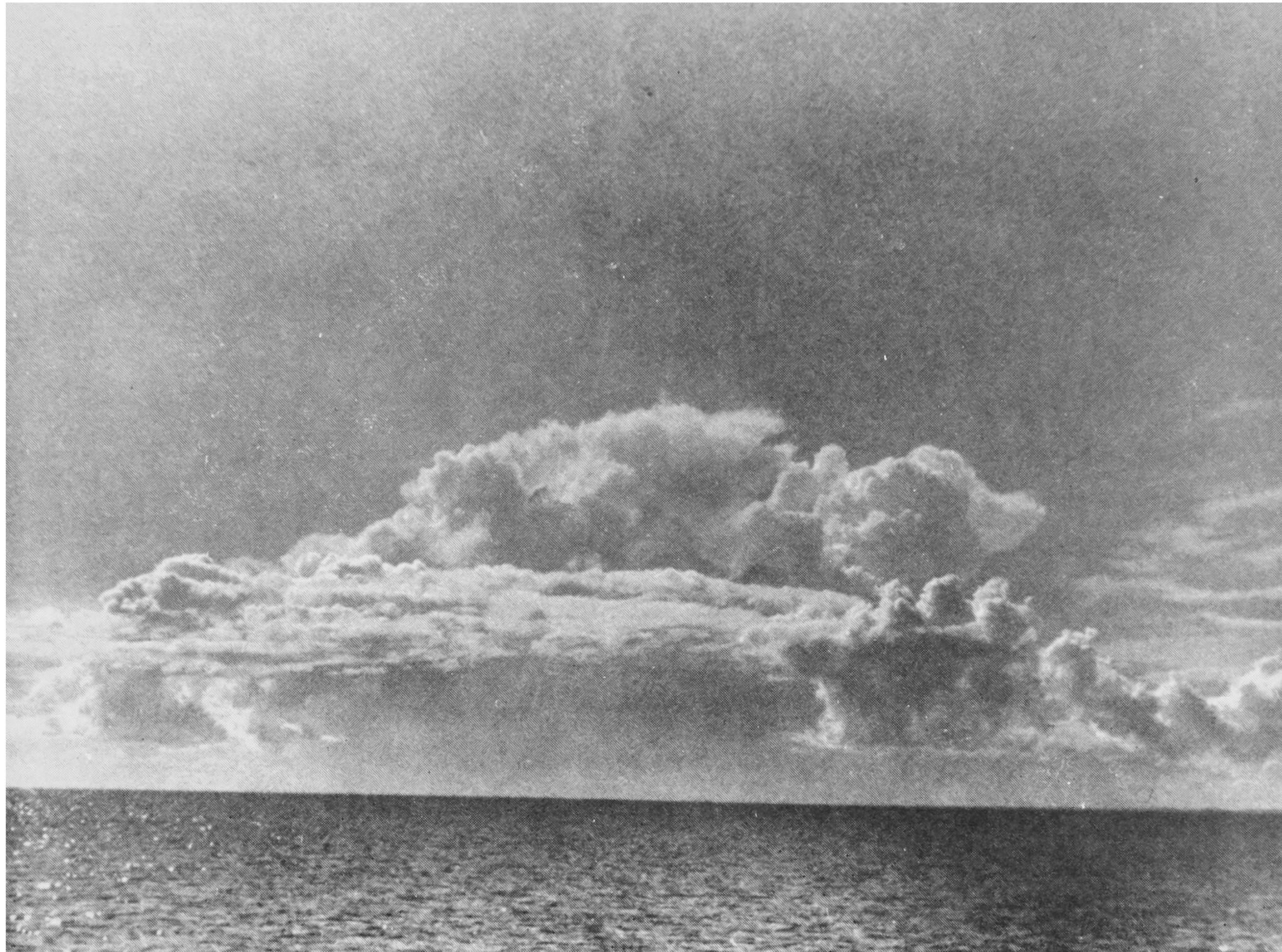
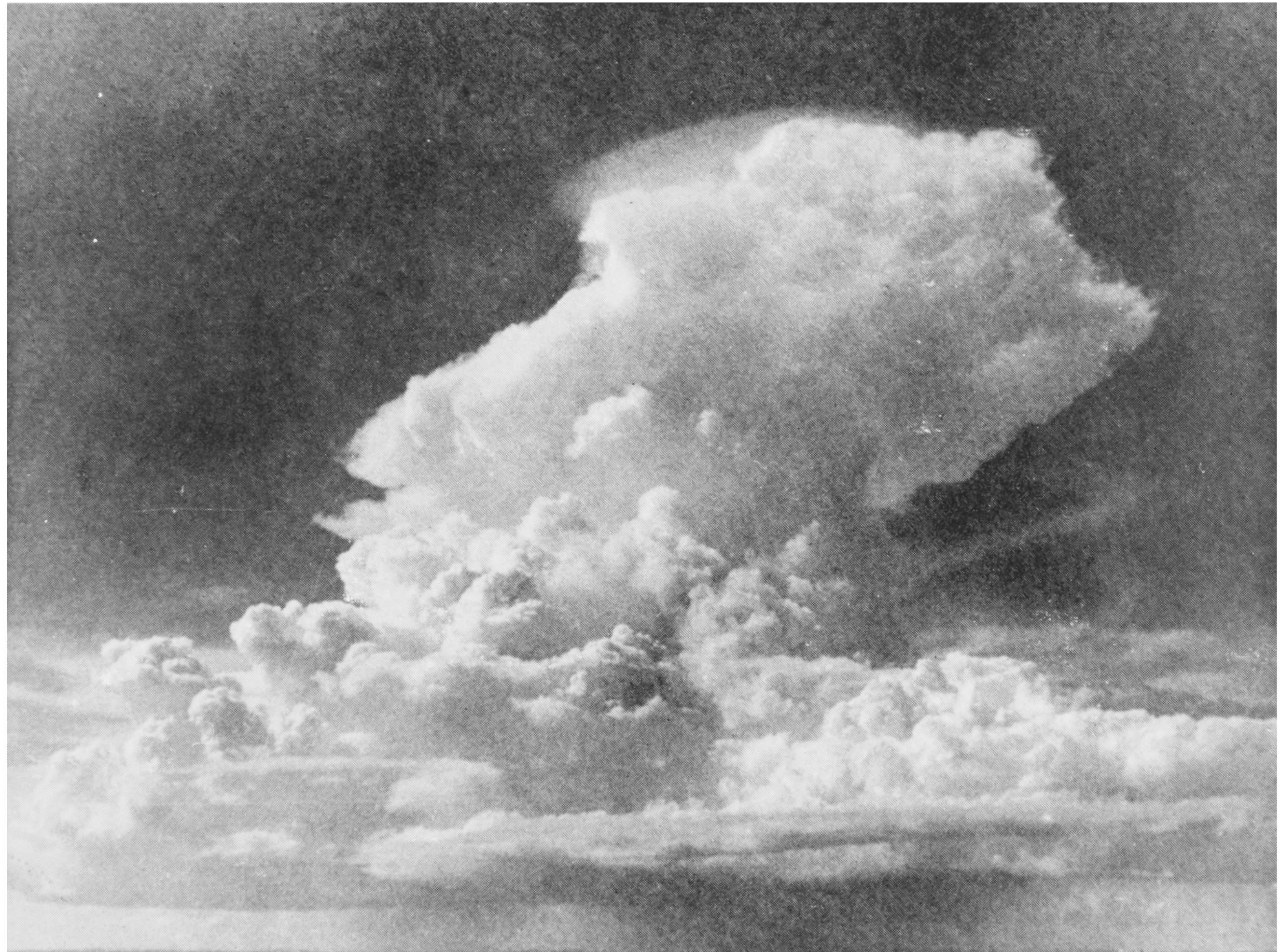


Photograph by the late Mr. M. C. Gillman

CUMULONIMBUS CLOUDS OVER LAKE VICTORIA
(see p. 367)



Photograph by the late Mr. M. C. Gillman

CUMULONIMBUS CLOUDS OVER LAKE VICTORIA
(see p. 367)

"The sequence of temperature and humidity observations at Leuchars and the wind structure showed that there was undercutting by the cold air, i. e. the slight rain was of a cold-front type although there was no historical cold front. Subsidence behind a cold front is frequent even in a depression in a region of cyclonically curved isobars. In this case the col was not too far to southward and the dryness extended to Liverpool in the col area at 2100." It should be noted that subsidence was occurring in the lower levels of the atmosphere over an area of steadily falling surface pressure.

Although the cessation of snowfall and the clearing skies over south Scotland and parts of Ireland and north-west England can be explained by the introduction of a cold front, the subsequent development of the area of low surface dew points and, on careful examination, the events leading up to the situation on March 10, described above, indicate that this is not the whole explanation. The history of events appears to be as follows.

Previous synoptic history.—At 0000 G.M.T. March 8, 1951 (Fig. 3), cold air with dew points 25–27°F. was flowing west-south-westwards over the O.W.S. *Polar Front* (66°N., 2°E.) and Iceland. This stream of air lay to the north

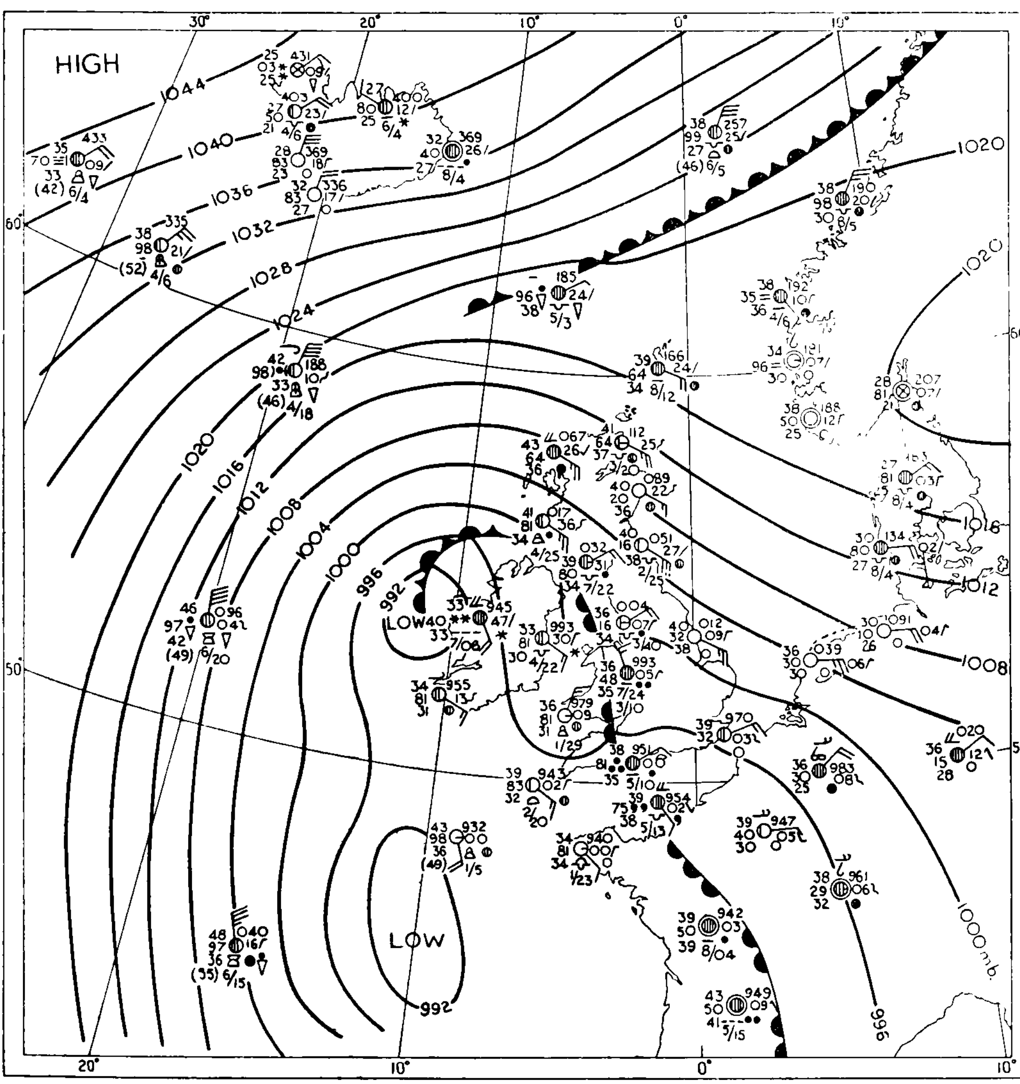


FIG. 3—SYNOPTIC CHART, 0000 G.M.T., MARCH 8, 1951

of the Faeroes and the ocean weather ship at 59°N., 19°W.; both these stations had dew points above 32°F. The immediate origin of the cold air lay in the Jan-Mayen–Bear-Island area. An old occlusion ran north-eastwards from just north of the Faeroes, but this was subsequently dropped from the official analysis of the Central Forecasting Office, Dunstable. Twenty-four hours later the drier air had moved south of the Faeroes, but was still to the north-west of southern Norway and north of the ship at 59°N., 19°W. This cold tongue, bulging southward, was due primarily to the very pronounced anticyclone over Greenland (central pressure over 1050 mb.), and was responsible for the formation of a marked trough off south-west Norway in which a polar low formed on March 9. The dew point at the Faeroes, after falling as low as 19°F. at 0900 on the 9th, rose to 32°F. at 1200 and to 36°F. at 1800; dew points in Iceland by this time were down to 16°F., and it was clear that the tongue of cold air, having first protruded southwards over the Faeroes, later moved slightly westwards, causing the observed fall and subsequent rise in dew points at that station. The westward boundary of the tongue at this time lay somewhere to the east of the ship at 59°N., 19°W.

Further southward movement of the cold air was indicated by falling dew points in north-west Scotland behind a belt of snow which moved south-east. By 1800 on the 9th, the dew points at Cape Wrath, Stornoway and Benbecula were down to about 25°F. and snow was falling along a line from Shetland to Kinloss, Dalwhinnie and Tiree. At 0000 on the 10th the boundary lay just north of Blacksod Point, south of Ballykelly, through Kinloss, Wick and Orkney and west of Shetland. Throughout all this time, the dew point at the ocean weather ship at 59°N., 19°W. had remained at 32°F. or above and no movement of drier air over the ship from east to west had occurred, nor in fact ever did occur despite the north-easterly air flow in that area during the entire period. It must therefore be concluded, and the conclusion is verified by subsequent events, that at 0000 on the 10th, the boundary of the colder air, partially indicated above, was completed by a line curving from west of Shetland to south of the Faeroes and thence south and south-eastwards to Blacksod Point. Early in its history, therefore, the tongue of cold air had been converted into a "bubble", cut off from the main reservoir in the Iceland area by the westward movement of air which had spent some little time over the sea between Scotland and Norway.

The subsequent movement of this bubble of relatively colder and drier air, and the subsidence which occurred within it more especially to the south and south-east of the centre of the polar low with which it was associated, explains the fine weather which spread eastwards over south Scotland on March 10. The southern and eastern boundary of the bubble had the characteristics of a cold front, and could be related to the old occlusion lying to the north of the Faeroes on the 8th (Fig. 3).

Subsequent synoptic history.—It may be of interest to record that the bubble, considerably shrunken, was still in evidence on March 12, with fine weather over Northern Ireland and the Western Isles south of Benbecula. It subsequently moved north-eastwards after splitting in two, and then north or north-westwards, and was last in evidence as a solitary observation from Cape Wrath at 1800, March 13, with a dew point of 25°F.

The movement of the polar low (Fig. 2) is also of interest. It was formed on the 9th in the trough off south-west Norway, with the cold tongue lying to the west. It first moved south-south-west as was to be expected from the pressure-tendency field and the thermal pattern. At this time the bubble lay mainly to the west of the low. Later the bubble moved south more quickly than the low, and the two appeared to act as a dumb-bell, the low being swung very sharply west round the northern boundary of the bubble before resuming its mainly south-westward movement. It is quite likely that there is more than coincidence here, although it is impossible to prove which was cause and which effect. It should be noted, however, that once the colder air of the bubble had moved to the south or south-west of the polar low, some slight distortion of the thermal pattern would take place, a westward component being added in the neighbourhood of north Scotland, which would be the stronger, the deeper the bubble. In this case the bubble was limited in depth to below about the 800-mb. level, but may have been deep enough to steer the surface low to the west.

Mr. C. K. M. Douglas writes: "The subsequent motion of the low can be looked at in at least two ways. One could regard it as dominated by the movement of the upper depression steered by the Greenland anticyclone which was pronounced at 500 mb. Alternatively one could lay the emphasis on the lower current which was advecting cold air to the south-west and producing a moving area of 'relative divergence' on the thickness pattern with falling sea-level pressure under it. These aspects are not incompatible but the complete problem is not yet understood."

Conclusion.—The unexpectedly fine weather which spread east over south Scotland on March 10, 1951, can be ascribed to the formation and subsequent life history of a bubble of colder and drier air which became detached from a reservoir in the Iceland region. Unlike a cold pool, which involves considerable thickness and may not be directly in evidence on the surface at all, the bubble may be thought of as a shallow dome.

Isolated patches of drier air are fairly frequent, but are very rarely so pronounced as on this occasion. Even the most homogeneous air mass contains minor irregularities due, for example, to variations of the sea track or of the surface topography over which the air mass has passed, but the "seclusion" of such a large bubble in the manner here described must be very unusual. So far as is known a description of the phenomenon has not previously been published.

Acknowledgement.—The author is indebted to Mr. C. K. M. Douglas for helpful comments on the situation and to Mr. S. E. Virgo for discussions.

METEOROLOGICAL OFFICE DISCUSSION

Evaporation as a factor in hydrology

The first discussion of the 1951–52 series, held at 11 Carlton House Terrace, on October 8, 1951, dealt with evaporation as a factor in hydrology. It was opened by Mr. A. Bleasdale with a statement based on the following papers.

BENTON, G. S., BLACKBURN, R. T., and SNEAD, V. O.; The role of the atmosphere in the hydrologic cycle. *Trans. Amer. geophys. Un., Washington D.C.*, **31**, 1950, p. 61.

GLASSPOOLE, J.; Rainfall, run-off and evaporation. *Wat. & Wat. Engrs, London*, **55**, 1951, p. 16.

PENMAN, H. L.; Evaporation over the British Isles. *Quart. J. R. met. Soc., London*, **76**, 1950, p. 372.

Whilst dissimilar in their approaches, the three papers have the common feature of dealing with broad general effects in which evaporation plays a part, and not with the details of the physical process. They therefore lend themselves to discussion of various aspects of the hydrological cycle through which the material of the different authors may be brought together.

The first paper sets out to disprove a theory which gained some acceptance in the past, and even in recent years, that a great part of the water precipitated over a continent is derived from moisture evaporated over that continent. A consequence of this theory is that modification of land use in such a way as to alter the evapo-transpiration over an area could affect precipitation over that area or nearby areas. Hence it has been seriously suggested that a chain reaction—precipitation–evaporation–precipitation—can be encouraged, and that this will then persist until the loss due to run-off, which may be relatively small, depletes the area of its moisture.

Quantitative evidence for or against this theory was lacking until recent times, and the present paper includes an analysis of upper air data, bringing out the separate roles of maritime and continental air masses, which has been made possible only by the developments of the last 10–15 years.

The method employed is to set up simple water-balance equations for the Mississippi basin, taken as a convenient example of a continental area, and to estimate the relative magnitudes of the component terms. The treatment given to the different components is not at all uniform, and the analysis is open to criticism on these grounds, and also because there is no final check on the balance of the equations. The basis of the estimates, starting from mean annual values of (*a*) general rainfall over the basin, (*b*) distribution of evapo-transpiration, and (*c*) total run-off, may be summarized as follows:—

	Based on data from:-
(i) Separation of rainfall amounts from maritime and continental air masses respectively	1 station for 1 year (1946)
(ii) Separation of evapo-transpiration amounts into maritime and continental air masses respectively	5 stations for 5 years (1942–46)
(iii) Transport of water vapour into the basin by maritime and continental air masses respectively	14 radio-sonde stations for 3 years (1946–48)
(iv) Transfer of water vapour from maritime to continental air masses	estimated
(v) Transport of water vapour from the basin by maritime and continental air masses respectively	derived from (i), (ii), (iii) and (iv)

It is argued that it is not feasible to make independent estimates under item (v), and the absence of such estimates means that there is no check on items (i)–(iv). This is unfortunate, particularly in view of the rather mixed sets of years which are used to estimate supposedly comparable averages for the different items.

Nevertheless the general conclusion is probably beyond doubt: that the quantities of water vapour transported over the basin (items (iii) and (v)) are overwhelmingly larger than any of the other items. Only about 20 per cent. of this water is ever precipitated over the basin, and therefore it may be calculated that not more than 12–14 per cent. of the precipitation can be land-derived, the remainder being oceanic in origin. An increase in evapo-transpiration due to changes in land use can thus have very little effect on precipitation in surrounding areas, since the amount of precipitation must depend primarily on such factors as the intensity of the hemispheric circulation.

Generally speaking, precipitation is not and cannot be a chain reaction, but the authors conclude on a note of caution: the amount of 12–14 per cent. which represents land-derived precipitation applies to the Mississippi basin as a whole. Locally (and presumably in some other parts of the world) it could be as high as 20–30 per cent. So that the effect may be important for some areas. The authors still feel that "owing to the exteme mobility of the atmosphere the land sources for precipitation in one region are bound to be hundreds or even thousands of miles away from that region. Increasing or decreasing precipitation even slightly by local regulation of land use is therefore out of the question."

The opener thought, however, that just as the general figure of 12–14 per cent. must be looked at with the possibility of local variations in mind so also the possibility of variations in individual years, and more especially in individual seasons, must be considered. In place of the attempt to estimate average conditions from small and mixed sets of years, it might have been possible to take the summer and winter half-years separately in, say, three individual years, in order to estimate seasonal and yearly fluctuations in the quantities involved in the water-balance equations. It is not inconceivable that the percentage of precipitation which is land-derived will be highest when it is most important (economically) that it should be so, i.e. in individual years or seasons when the hemispheric circulation is relatively weak and precipitation generally is deficient.

Glasspoole considers the various components of the hydrological cycle and stresses the need to consider them in conjunction. The state of affairs in this country has not hitherto been very satisfactory in that various bodies (which are enumerated) have specialized in different branches of hydrology, but central co-ordination has been lacking.

In the section dealing with evaporation the factors affecting its variation are discussed to show that in this country the most important variation is the seasonal difference between summer and winter months. Variations from year to year, and even from one part of the country to another, are relatively small. In so far as this may also be true for the Mississippi basin (and most areas having well marked seasonal cycles of temperature, duration of sunshine, vegetable growth, etc.), the suggestion made with regard to the American paper is supported.

Sources of quantitative information are discussed with a review of their limitations, and with indications of the degrees of agreement obtained by the use of different techniques of measurement and estimation. Some of the important quantitative results may be summarized as follows:—

Seasonal variation in the British Isles.—About 85 per cent. of the annual evaporation occurs in the summer half-year from April to September, and nearly 95 per cent. in the eight months March to October.

Variation over the British Isles.—Annual evaporation amounts to about 13 to 14 in. in the north of Scotland and is about 50 per cent. more in southern England. There is a similar but smaller increase, probably from north-east to south-west, over Ireland.

Example of relative loss due to evaporation.—For the catchment area of the Thames above Teddington weir, the loss is about two-thirds of the annual rainfall over the area. This compares with just over three-quarters for the Mississippi basin as given in the first paper.

The general trend of Glasspoole's treatment is that, from the point of view of the practical hydrologist, evaporation represents a very important loss from the water resources of this country. The reduction of this loss by the use of covered reservoirs is impracticable on any large scale; therefore, since the loss is mainly confined to the summer half-year, it may be more profitable to approach the problem by considering the timing of the use of surface water and underground supplies. If greater use could be made of the abundant surface supplies in winter, there would be conservation of naturally stored underground water which could be drawn on more extensively in summer when the surface supplies become depleted.

Penman's paper is an application of an equation previously derived[1] to estimate mean annual evaporation over the whole of the British Isles. The method adopted is a combination of the two classical approaches to evaporation studies, the energy-balance approach and the hydrodynamic approach. The latter involves consideration of the theories of turbulent transport developed by Sutton, Pasquill and others, and Pasquill[2] has made a fundamental criticism of the method, which is undoubtedly important. The basis of the criticism is twofold: first, that the method assumes the identity of the eddy diffusivities of heat and momentum, an assumption which Pasquill shows to be invalid in unstable conditions*; secondly, that the hydrodynamic relation used by Penman is empirical and valid only in very limited circumstances which do not occur very often in nature.

In the present paper, Penman recognizes the criticism and suggests that, if it is accepted, his estimates of annual evaporation may be reckoned as about 5 per cent. too high. It seems reasonable to adopt the attitude that, whilst Pasquill's criticism should be followed up in the interests of clearer theoretical understanding, Penman's estimates may be accepted as substantially correct, at least until the appearance of similar estimates which are demonstrably better. Their value has already been established in practical applications.

The meteorological data required are mean values, for the period under consideration, of duration of bright sunshine, air temperature, vapour pressure and wind speed. The period may be a month or a year to obtain reasonably accurate results. An intermediate step in obtaining natural evaporation, or evapo-transpiration, is to calculate the hypothetical evaporation that would take place from an extended sheet of open water exposed to the given conditions. A direct check has been possible in one case (Abberton reservoir near Colchester)

*Pasquill's conclusion has again been questioned and the matter is still controversial.

and mean monthly values over 8 years for July, August and September showed the estimates to agree with the actual observations within about 6 per cent.

Penman's final map gives mean annual values for 102 stations distributed over the British Isles. There is good general agreement with the values of mean rainfall minus mean run-off for 41 catchment areas covering a great part of the country, though the precise isopleths for the distribution of mean annual evaporation cannot be drawn with confidence.

Penman's claim regarding the accuracy of the estimates (5–10 per cent. for individual years and 15–20 per cent. for individual months, quoted from a later paper[3]) is probably well founded, and in this connexion it is relevant to consider the accuracy which may be attained in other hydrological measurements. In the most favourable cases the general rainfall over an area and also run-off may be assessed with much greater precision (e.g. probably to within 3 per cent. for general rainfall over the Thames Valley), but there are unfavourable cases (e.g. the general rainfall of mountainous areas with a sparse network of stations) for which great accuracy is not yet attainable. It is probable that the estimation of evaporation is at present more or less on a level, with regard to accuracy, with the measurement of other hydrological quantities, though the factors which affect accuracy will operate very irregularly, so that the quantity which is most accurately assessed will not always be the same. With the improvements that can be expected within the next few years in the hydrological field (arising largely from the River Boards Act of 1948 and allied developments), it is likely that Penman's method will require some refinement, and it is in this respect that the stimulus of Pasquill's theoretical criticism should prove its value.

The paper concludes with reference to practical applications which illustrate an earlier statement in the introduction, that natural evaporation "can be the dominant factor in successful agriculture and in practical hydrology". Subsequent work, in particular controlled irrigation experiments continuing the early ones referred to, has amply demonstrated the significance of this view.

When the attempt is made to bring out the relationship between the present (or similar) papers by reference to the hydrological cycle, the form of diagram currently in favour with such authorities as Linsley, Kohler and Paulhus[4] does not lend itself readily to the purpose. Whilst having the virtue of being more or less complete, this form does not bring out very clearly the outstanding features of some important sectors of the cycle. A form of the diagram may be prepared (Fig. 1) which, whilst not intended to be absolutely complete, is based on a logical scheme giving prominence to the basic components in their relationships both to each other and to the relevant fields of study.

In this diagram the upper half represents the vapour phase and the lower half the liquid or solid phase; the left-hand half covers sea areas and the right-hand half the land. The diagram in this form could be elaborated for any specific purpose, and, as an example and as a concession to completeness though not of special interest at present, the tidal ebb and flow in river estuaries has been represented. This sub-cycle C shows the normal rhythmic interference with the continuous process of run-off; but there is also a separate branch g to indicate that, when there is a tidal contribution to flooding, a part of the tidal water becomes involved with surface water and soil moisture.

Considering the diagram in quadrants, the processes making up the lower left-hand quadrant received a bare mention in the first paper, but were otherwise not dealt with; they are in the field of marine meteorology. The American authors cover the remainder of the cycle, but their quantitative work is concentrated mainly in the field represented by the upper right-hand quadrant. It is their contention that the sub-cycle A, which takes place wholly within the atmosphere and consists solely of the vapour phase, involves such enormous quantities of water vapour and is so vigorous that the branch e, representing

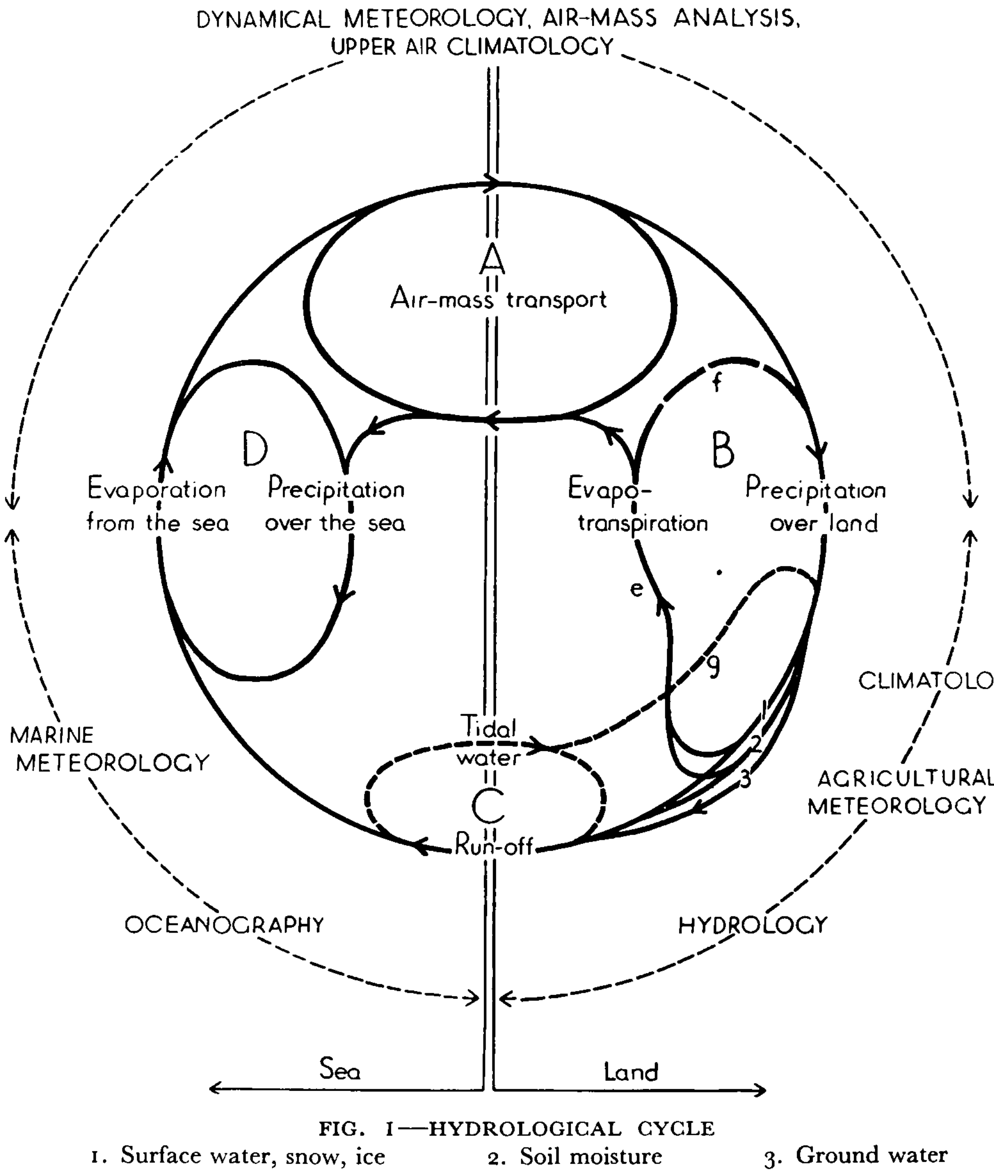


FIG. 1—HYDROLOGICAL CYCLE

1. Surface water, snow, ice 2. Soil moisture 3. Ground water

evapo-transpiration over land, is very largely drawn into it. This branch, therefore, can make but a small contribution to precipitation over land, and the uppermost arc f of the sub-cycle B over land can be virtually eliminated. The latter sub-cycle cannot have a completely independent existence (described as a chain reaction), but in the main exists merely as a loop from the atmospheric sub-cycle A which derives its dominant independent existence from the vigour of the general circulation and the quantities of water vapour involved therein.

Though some doubts have been suggested above about the universal validity of this argument, it must for obvious reasons hold good for the British Isles. The fact of its implicit acceptance appears in the papers by Glasspoole and Penman who deal only with processes represented in the lower right-hand quadrant of the diagram. The out-going evapo-transpiration branch has no direct connexion, outside the quadrant, with the incoming precipitation branch; it represents an inevitable loss which can be modified in various ways in its incidence but only in a small degree in its total quantitative effect. This quadrant (with sufficient elaboration) covers the field of study of hydrology proper, at least in the practical sense, with the first paper contributing a border-line subject, of only theoretical interest in this country, from other fields.

Dr. Stagg, in introducing the opener, had pointed out that, though the physics of evaporation had been dealt with in Meteorological Office Discussions on two occasions, the treatment of evaporation in the hydrological setting was a new departure. This was a reflection of the increasing interest being taken in hydrology within the Office. Inviting contributions to the discussion, he suggested that the question of the relative accuracy of hydrological measurements should not be permitted to lead too far towards detailed consideration of physical principles, but should be kept in the wide general field already indicated. He thought that there was a need to discuss also the importance of the role of underground water in the hydrological cycle.

Cdr. Frankcom dealt with the importance of the oceans to hydrologists and with the relative neglect of the processes represented by the lower left-hand quadrant of the diagram of the hydrological cycle. This neglect could be explained by the great difficulty of making reliable measurements of rainfall and evaporation from ships. Attempts were being made to overcome this, but it had also been found difficult in the past to relate data from moving ships with data from adjacent land stations.

Mr. Gordon referred to the recent Maritime Conference at Genoa at which the hydrological balance of the Mediterranean and the Baltic Seas had been discussed. It had been deduced that for the former evaporation was of the order of four times the rainfall, and for the latter the two approximately balanced.

Mr. Houghton discussed the measurement from ocean weather ships of the temperature gradient of the upper layers of the sea on quiet afternoons. He showed graphs of the two forms of curve obtained with air temperature less than sea temperature (unstable lapse rate in the lower layers of the air) or greater (stable lapse rate). The diurnal variation of temperature was closely linked with the heat loss due to evaporation, and the data showed promise of yielding an estimate of evaporation from the sea.

Mr. Veryard asked for information about run-off and its measurement, and about the accuracy of measurements of run-off and of rainfall.

Dr. Glasspoole pointed out that attention had been paid to the accuracy of run-off data for a long time, details of published papers being given in the Report for 1950 of the Inland Water Survey Committee[5]. Similarly much thought had been given to maintaining the accuracy of rainfall records by inspecting rainfall stations, estimating any errors quantitatively and putting them right, and by examining the fit of the records on maps. The accuracy of rainfall and run-off values could best be judged by detailed comparison of the data for the same area, and with evaporation values as determined by Penman's method.

Dr. Penman, Rothamsted Experimental Station, replying to Dr. Stagg, said that the variations in underground water storage could be virtually eliminated by taking very long-term averages, but that over a period of a few months or only one year it could be shown that the variation in storage was important. Thus the basis of his method of dealing with the water balance of the Stour[6] and the Thames[3] was to treat storage as the unknown quantity dependent on other terms in the water-balance equation, which could be measured or estimated. He stressed the need for more well records, to correlate with calculated variations in storage. In commenting on the accuracy of data he said that this could be very varied, particularly for run-off.

Dr. Stagg asked whether there is any check on the accuracy of run-off records comparable with the systematic inspection and checking of rain-gauges and rainfall data carried out by the British Rainfall Organization of the Meteorological Office.

Mr. Allard, Inland Water Survey, Ministry of Local Government and Planning, explained that the Inland Water Survey collects and examines run-off data and visits the sites of river-gauging stations whenever possible, but that the final check is given by the degree of agreement with rainfall and evaporation data. Whilst there were bad cases he was of the opinion that published data[7] were accurate within 5–10 per cent.

Dr. Buchan, Geological Survey, Department of Scientific and Industrial Research, described the task of the Geological Survey as the estimation of undeveloped ground water resources, and mentioned the role of observation wells in this work. He felt that we could expect progress in several branches of hydrological work within a few years. Taking the Lea Valley as an example he explained how underground storage in one place (in this case under impermeable clay) could depend on percolation elsewhere. From data of the abstraction of water from below London, evaporation in the chalk area of the Lea Valley could be deduced.

Capt. McClean discussed the high degrees of accuracy which could be obtained in run-off measurements where the river-gauging station had been thoroughly investigated with flow-meter measurements, or where properly constructed weirs or flumes were in use. Where volumetric estimates depended only on observations of river stage, accuracy over the whole range was rarely to be expected. Similarly there was a need for greater accuracy in rainfall assessment in some areas, particularly mountainous areas.

Mr. Gold suggested the need for a new word to replace "evapo-transpiration" and to mean "the quantity of water removed by the atmosphere"; this was the quantity of interest to hydrologists, and in the processes of evaporation, transpiration, dew formation, etc., it would be less than the total quantity of water evaporated and transpired. He considered long-term storage effects to be small in comparison with rainfall and run-off, and spoke of recent work[8] on the lag in run-off as compared with rainfall in which he had shown that for the Thames Valley the rainfall of the preceding three quarters had a perceptible effect on current run-off, whilst the effect of the rainfall in earlier quarters was negligible. He had also shown that when monthly amounts of rainfall minus run-off are plotted against rainfall, the points lie very close to a straight line, showing that the loss due to evaporation increases regularly with rainfall, at least over a large range, not only in summer but even in winter, though the regularity is somewhat reduced.

Mr. Ward, Building Research Station, Department of Scientific and Industrial Research, spoke of the difficulty of allowing for the changes in percolation and underground storage due to progressive urbanization during a period taken to assess averages. (Dr. Buchan thought that the effect would not necessarily be great.) He thought that town run-off might often be passed for storage into the chalk instead of being run wastefully into the rivers.

Dr. Stagg closed the discussion, after a few small outstanding points had been cleared up, with a reference to the appreciation by the Meteorological Office of the interesting contributions from outside visitors.

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HONOURS AND AWARDS

The Council of the Institute of Navigation have awarded the Bronze Medal for the best paper to be published in any year in the Institute's Journal to Mr. C. S. Durst and Mr. N. E. Davis for their paper "Jet streams and their importance to air navigation" which was published in Volume 2*. The Council have awarded a Fellowship of the Institute to Cdr. C. E. N. Frankcom, R.N.R.

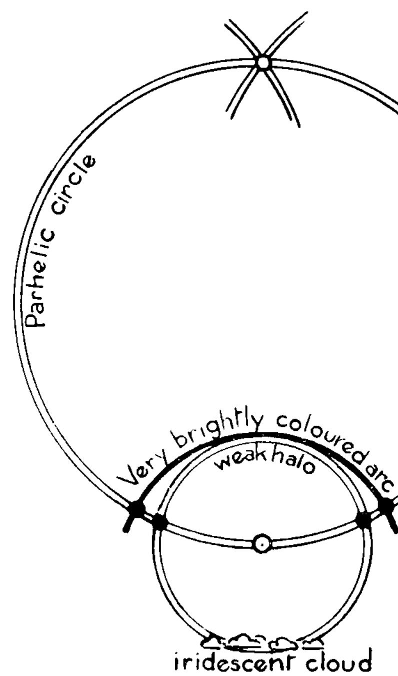
LETTER TO THE EDITOR

Halo phenomena at Prestwick, August 31, 1951

The phenomena were first observed at approximately 1115 G.M.T. by the duty observer, who drew attention to a patch of what seemed to be at first iridescent cloud above the sun, but on closer inspection was seen to be a very marked upper tangent arc associated with a weak 22° halo. The arc of contact was brightly coloured with orange, yellow and green clearly defined. While the phenomena lasted the total amount of cloud was never more than 6 oktas and was mainly thin cirrostratus with patches of altocumulus.

* *J. Inst. Nav., London*, **2**, 1949, p. 210.

A few minutes after first noticing the halo a well formed parhelic circle was seen, and, with the arc of contact, remained the salient feature of the phenomena. Four well defined mock suns were observed at the points of intersection of the halo, arc of contact and parhelic circle (see diagram).



The most interesting occurrence, however, was observed approximately 45 min. after the phenomena were first noticed when two very weak partial curves were seen to be producing a weak mock sun at their point of intersection on the parhelic circle immediately opposite the sun.

The phenomena gradually disappeared with the dispersal of the upper cloud, having lasted for approximately 1hr. 50min.

The elevation of the sun at noon was 42°.

R. A. HAMILTON
J. T. RONXIN
A. P. PARRY

September 6, 1951

[The interesting features are:—

(i) It is unusual for the tangent arc to the 22° halo to be brightly coloured.

(ii) The parhelia observed at the points of cutting of the tangent arc and parhelic circle appear to be the true parhelia which, for a solar elevation of 42°, would be situated very near the points given.

(iii) The parhelia described as situated where the halo met the parhelic circle appear to be due to an additive illumination effect sometimes noticed where two arcs of illumination cut.

(iv) The anthelic arcs are rather rare. Humphreys* states that the anthelion itself is rare. — Ed. *M.M.*]

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*HUMPHREYS, W. J.; Physics of the air. New York and London, 3rd edn, 1940, p. 538.

NOTES AND NEWS

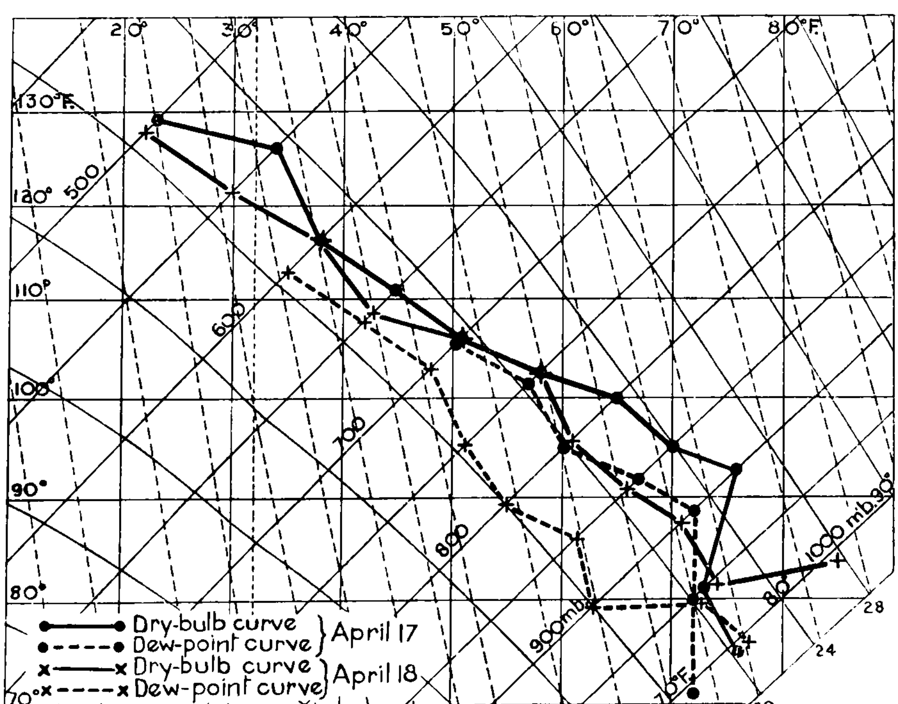
Clear-air turbulence

On April 17, 1951 at 2050 G.M.T. a Dakota, which had just left Changi (Singapore) for Saigon, was climbing slowly and smoothly 18 miles north of Changi when it suddenly encountered violent turbulence in clear air over south Malaya.

The aircraft fell from 4,800 ft. to 3,000 ft. (according to altimeter) in five seconds, while indicated airspeed of 110 kt. changed to between 160 and 180 kt. The crew of three were pinned to the roof for a short time but not "blacked out". A sextant inside its case was badly dented and the case smashed. Stoppers on all the large vacuum flasks were ejected and loose equipment scattered.

The incident took place over flat mangrove swamp and jungle nine miles from the South China Sea but only four miles from the tidal waters of the Johore river estuary. There was no moon and it was about two hours before dawn twilight (0420 April 18, Malayan Time).

The intertropical front was 300 miles to the north and the air up to 10,000 ft. had its origin in a southern subtropical anticyclone near Australia. This air had dried out and cooled considerably during the previous day as the tephigram shows, but cumulus formation over and near a sea surface of temperature 81 °F. was possible. Records for nearby stations show that showers died out in the area the previous evening and did not reappear the following day, cumulus amounts remaining below 3 oktas throughout the night and the following day. Distant lightning was observed, however, to the north, west and south near the time of the occurrence by the crew of the aircraft and by meteorological



TEPHIGRAM OF SPITFIRE ASCENTS AT SINGAPORE, 0130 G.M.T., APRIL 17, 1951 AND 0200 G.M.T., APRIL 18, 1951 observers on Singapore Island, but no one observed low cloud near to their own position. Barographs at nearby stations revealed no unusual changes of pressure at the time. The winds over the area as observed by pilot balloon at Changi at 2030 G.M.T. were less than 10 kt. between south and west up to 7,000 ft.

If the crew's observations were correct, there must have been an acceleration of at least 9*g* at some stage. For, assuming no vertical velocity at the beginning and end of the five seconds during which the aircraft fell 1,800 ft., and a steady downward acceleration *f* followed by a steady upward acceleration *f*, we have:—

$$900 = \tfrac{1}{2} f \left(\tfrac{5}{2}\right)^2$$

$$\text{or} \quad f = 9 \times 32 = 9g$$

and for any other type of motion under these conditions, a greater acceleration is involved. Thus it is quite clear that the observations are not accurate in spite of the fact that both pilot and navigator are agreed, since a crew normally "black out" under about 5*g*. The erroneous readings may have been height, as recorded by altimeter, or time. With regard to time it would be unusual for a crew to underestimate the time of a nerve-shattering experience, the tendency being to overestimate. The altimeter readings, based as they are on pressure, are suspect, particularly as the expulsion of stoppers from the vacuum flasks indicates large fluctuations of pressure.

However, it is certain than an acceleration of more than 1*g* downwards was experienced since we have the evidence of the crew pinned to the roof and the smashed sextant case. This in itself is sufficiently remarkable if the incident was actually in clear air. On this latter point the crew were quite definite that they were not in cloud, while observers at Changi, 18 miles away, confirm that although there was no moon it was light enough to see cloud.

The most likely explanation would appear to be an eddy with a horizontal axis, but while this has been observed in cumulonimbus, it seems far less likely in clear air, especially with such light winds in the area.

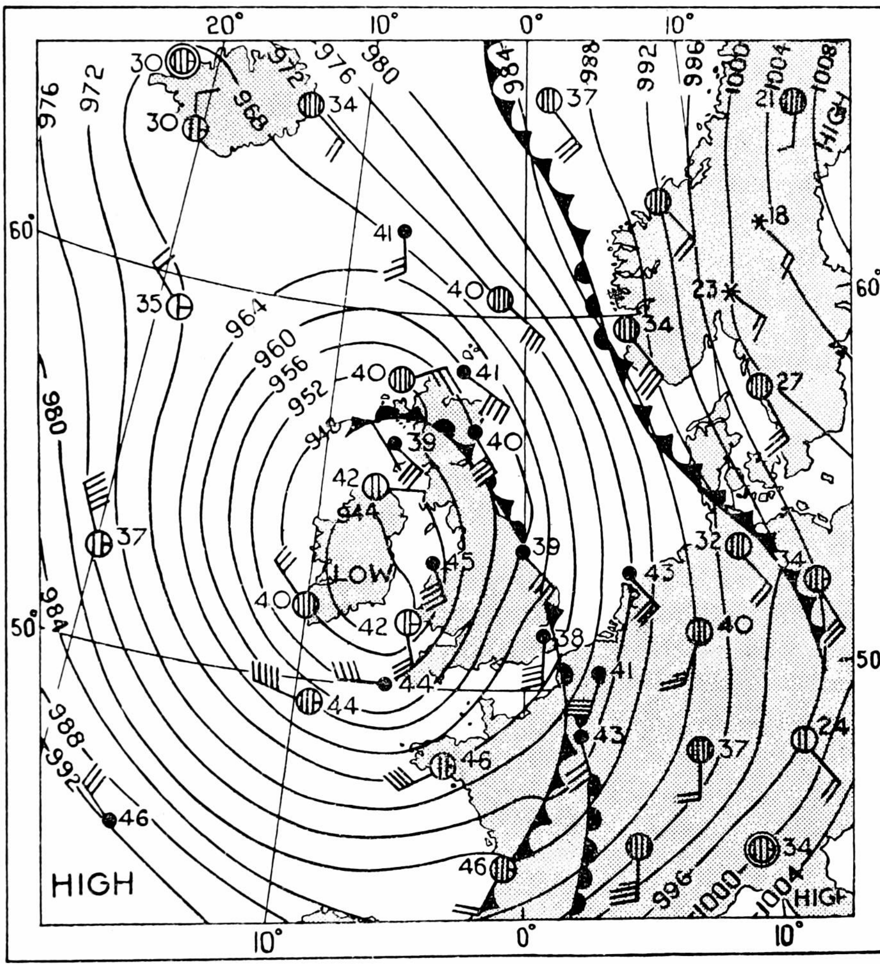
P. E. PHILLIPS

Low pressure recorded on February 4, 1951

On January 31, 1951, a depression developed on a very pronounced front near the southern coast of the United States, in the Gulf of Mexico. At 0600 G.M.T. on February 2 it was centred near the north-east corner of the United States, at 46°N., 71°W., with central pressure 996 mb., and 24 hours later at 53°N., 43°W. with pressure about 985 mb. After another 24 hours, at 0600 on the 4th, it was close to west Ireland with a central pressure about 944 mb. It was then occluded up to 300 miles from its centre and its speed and rate of deepening were rapidly decreasing. Throughout its movement from the Gulf of Mexico to Ireland it was in a very strong thermal field which enabled it to combine rapid movement with sustained deepening which became rapid on the 3rd. The presence of a large warm anticyclone to the west-south-west of the Azores, with central pressure over 1040 mb. on the 3rd, favoured the maintenance of a large warm sector. During the period of rapid deepening on the 3rd–4th this anticyclone decreased slightly in intensity, as also did the Russian anticyclone.

By 1200 on the 4th the depression appears to have temporarily developed two centres, one near Malin Head in Northern Ireland and the other near Cork, with pressure of about 944 and 942 mb. respectively. Subsequently it filled up slowly whilst drifting north-eastwards, turning north-north-west later.

The depression was remarkable for the low pressure to which it gave rise over the whole of the British Isles. It was not exceptional in other respects although there were fresh to strong gales around our coasts. Rainfall amounts were not large. Letters were received in the Meteorological Office from members of the general public in all parts of England and Wales, and also in Eire, reporting the exceptionally low pressure and asking for details as to its cause.



SYNOPTIC CHART FOR 1800 G.M.T., FEBRUARY 4, 1951

The lowest pressure seems to have occurred at Midleton, Co. Cork, where the mean-sea-level value was 942·3 mb. at 1500 on the 4th, a record for February for the British Isles. Other stations reporting record low pressure for the month were Oxford (956·2 mb. at 0000 on the 5th), Southport (950·4 mb. at 2100 on the 4th) and Kew Observatory (961·2 mb. at 2200 on the 4th).

For comparison the lowest pressure ever recorded at Kew, where records began in 1869, was 959·3 mb., reduced to mean sea level, on December 9, 1886. The record for the British Isles is 925·5 mb., recorded at Ochtertyre, near Crieff, Perthshire, on January 26, 1884, and the world record 887 mb. in the Pacific Ocean on August 18, 1927.

Some depressions which attain exceptional depth have a more complex structure than this one, with more deepening after the first occlusion. The fall of pressure at Cork of 70 mb. in 54 hours and of 62 mb. in 30 hours was probably as unusual as the low minimum itself. Very low pressures over or near the British Isles more often follow a low general pressure level in the area.

H. C. SHELLARD
C. K. M. DOUGLAS

Radar and bright-band cloud echoes in Southern Rhodesia

The Rhodesia Meteorological Service has a Naval Type 277 radar in use at Salisbury, Southern Rhodesia. The aerial unit is mounted on a 40-ft. steel tower, and transmitter, receiver, displays and associated equipment are housed in a building constructed around the legs of the tower.

Installation began in September 1950 and, after a number of difficulties had been overcome, the set was in proper working order by the middle of February 1951.

The radar is being used for experimental and research purposes in the directions of storm detection and cloud study. Experiments are also being carried out with a view to using the set for upper wind measurement.

During the 2½ months of rainy season in which the set has been in use, very interesting results have been obtained. The most striking observations are those of bright-band echoes. This type of echo, obtained by directing the radar beam vertically upwards at a precipitating cloud, has so far been observed on two occasions.

On the first occasion a thundery shower occurred at the station, giving a steady rate of rainfall for 15 min. and thereafter a steady fall for 75 min. at a rate of about one-tenth the initial rate. During the first period, the vertical radar beam showed cloud and rain echo extending to more than 20,000 ft. above ground, i.e. 25,000 ft. above sea level; this echo was unchanging and had no special characteristics. During the second period of lower rate of rainfall, a bright band of echo was observed between 9,000 and 10,000 ft. above ground. This band of echo was 3–5 times as intense as the remainder of the echo above and below; it was observed for about 45 min. while no noticeable change took place in height, intensity or thickness of the band.

On another occasion when a line-squall was known to be approaching Salisbury, the movement of the instability volume was recorded by photographing the associated cloud echoes at suitable intervals. A few minutes after the squall had passed through Salisbury, light rain began and the vertical radar beam gave extremely interesting bright-band echoes. There were frequent intervals of several minutes together when no cloud echo was apparent. Quite suddenly a band of echo appeared and rapidly intensified; sometimes the band remained in position for perhaps a minute then faded out, sometimes it descended fairly rapidly. Several times a band formed at 9,000 ft. and about half a minute later a second band formed at 15,000 ft.; the latter, after remaining in position for about half a minute, descended to merge with the lower band. At one time a band appeared at 12,000 ft., paused for a few moments then descended; a second band formed at 12,000 ft. and both lowered, while a third band appeared at 12,000 ft. The 3 bands merged to form a single band between

[*To face p. 364*

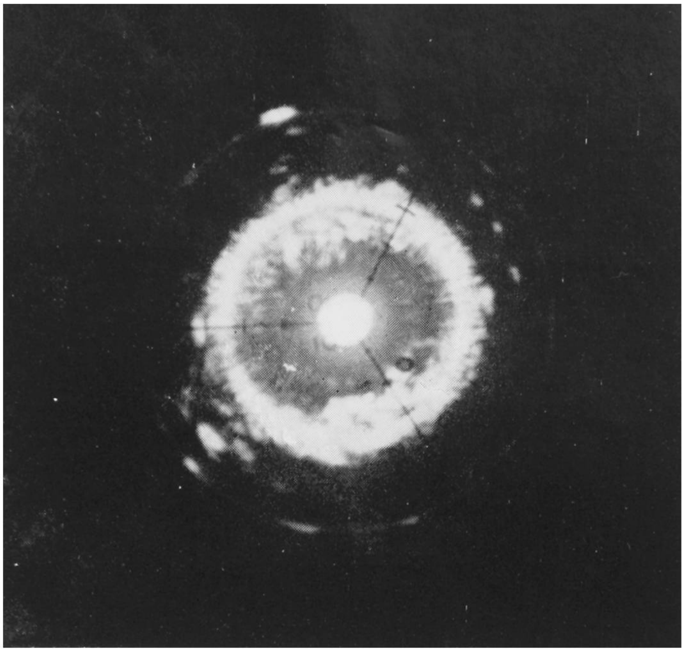


FIG. 1—STRONG BAND ECHO AT 9,000 FT.
Time: 2236

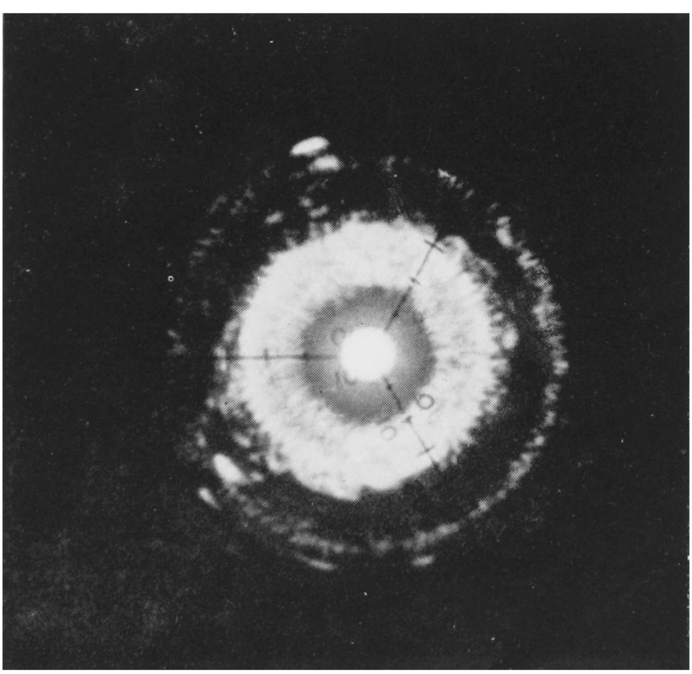


FIG. 2—VERY BRIGHT BAND ECHO AT 9,000 FT. WITH ECHO EXTENDING DOWN TO ABOUT 4,500 FT.
Time: 2238

BRIGHT-BAND CLOUD ECHOES OBSERVED BY RADAR AT SALISBURY, SOUTHERN RHODESIA

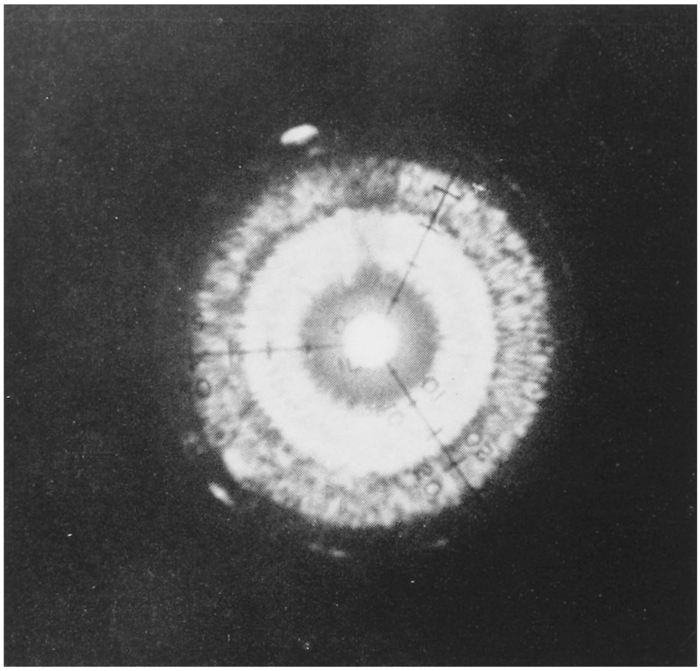


FIG. 3—TWO LOWER BANDS, ONE AT 8,500 FT., ANOTHER AT 6,000 FT., Time: 2239

BRIGHT-BAND CLOUD ECHOES OBSERVED BY RADAR AT SALISBURY, SOUTHERN RHODESIA

Photograph by R.A.F.

CIRRUS AND CIRROSTRATUS IN ADVANCE OF A WARM FRONT

This photograph was taken at a height of 10,000 ft. in 51°N. 16°W. at 1400 G.M.T., January 4, 1949.

7,500 and 12,000 ft. This complete band lowered, narrowed and finally disappeared at about 3,500 ft. Later a single band appeared between 6,000 and 15,000 ft., persisted for about half a minute, then rapidly split up into one band at 15,000 ft. and two merging together at 7,000–8,000 ft.; all the bands descended and faded out.

The photographs facing pp. 364 and 365 illustrate the general appearance of the echo bands as seen on the P.P.I. The bands appear as bright rings whose radius gives the height of the cloud layer from which the echo is obtained. Fig. 1 shows a strong band echo at 9,000 ft. Fig. 2, taken 2 min. later, has a very bright echo band at 9,000 ft. with echo extending down to about 4,500 ft. and an upper descending band at 14,000 ft. Fig. 3, taken 1 min. later, shows two lower bands—one at 8,500 ft. and one at 6,000 ft.; these bands were beginning to separate out in the previous picture; the upper band has descended and widened so that echo extends all the way from 4,500 to 13,000 ft.

V. G. MILES

Very high cloud layer, August 10, 1951

A pilot who flew at about 45,000 ft. from the London area to Lancashire and back between 1230 and 1330 on August 10 telephoned to the Meteorological Office to state that he had observed a thin cloud layer situated at 47,000 ft. The information was considered of such interest that he was asked to send a written report. This he very kindly did and his report is published below with a note on the synoptic situation.

Pilot's report.—On August 10, between 1230 and 1330, I flew from the London area to Lancashire and back at an altitude of 45,000 ft.

At about 30,000 ft., during the climb, it first became apparent that a layer of thin tenuous high cloud existed. At the cruising height of 45,000 ft. this layer was still above the aircraft, giving 8 oktas cover over the area flown but apparently diminishing towards the east.

When approximately over Preston, altitude was increased to check the vertical extent of the cloud and the bottom and top were found to be 46,500 ft. and 47,500 ft. respectively. These figures are only approximate due to the difficulty in identifying the points of entering and leaving such tenuous cloud.

Throughout the flight conditions were smooth and stable, there being about 1 okta medium cloud and 8 oktas low cloud south of a line Birmingham–Swansea. The corrected air temperature at 45,000 ft. was −56°C. throughout the flight.

I have never before seen cloud above 42,000 ft. in this country while flight-testing to altitudes of 50,000 ft. over the last three years.

Synoptic situation.—The synoptic situation was such that a depression in mid Atlantic at 1200 G.M.T. on August 10 was expected to move rapidly eastwards. There was a very large mass of warm air to the south of it and the occlusion of this air was expected to lead to prolonged rainfall over much of the British Isles, heavy in places. This in fact happened.

Upper air charts on the 10th at the relevant time showed a warm ridge on the Atlantic and a cold trough over the North Sea extending southwards to France, with a north-north-westerly air stream over the British Isles. In this stream the maximum wind was 340° 90 kt. at about 250 mb. (34,000 ft.) from

Aldergrove to Lyme Bay. The tropopause was at 37,000–40,000 ft. with an inversion to 40,000–44,000 ft., decreasing above these levels to an almost isothermal lapse rate. The wind at 45,000 ft. was 340° 30 kt., and at 50,000 ft. 340° 15–20 kt.

Stations in England were asked to keep watch for very high cloud on the evening of the 10th, and at 1910 G.M.T. Hullavington reported 6 or 8 streaks of cloud which appeared very high and like condensation trails. This cloud appeared south-east of the station behind some altocumulus by which it was finally occluded. This cloud was described as "not feathery like cirrus, but quite dense, an unusual type of cloud not previously observed". It was also observed at Benson.

Centenary of the Austrian Zentralanstalt für Meteorologie und Geodynamik

The Austrian Zentralanstalt für Meteorologie und Geodynamik celebrated its centenary from September 20 to 26, 1951.

The Anstalt was founded by Imperial Decree on July 23, 1851, and placed under the Directorship of Carl Kreil, a meteorologist and astronomer of Prague, who had, in 1848, put forward to the Austrian Academy of Sciences a plan for the foundation of a meteorological and magnetic service.

The roll of Directors of the Zentralanstalt runs:—

Carl Kreil, 1851–1862
Carl Jelinek, 1863–1876
Julius von Hann, 1877–1897
Josef Maria Pernter, 1897–1908
Wilhelm Trabert, 1909–1915
Felix Exner, 1916–1930
Wilhelm Schmidt, 1930–36
Heinrich Ficker, 1937–

The Director has always also held the Chair for Geophysics at the University of Vienna.

Jelinek is well remembered for his psychrometric tables. During his period of office the first International Congress of Meteorologists was held in Vienna.

Hann founded the Sonnblick Observatory and wrote the very well known textbooks "Handbuch der Klimatologie" and "Lehrbuch der Meteorologie".

Pernter re-organized the Zentralanstalt and particularly developed its work in synoptic meteorology. He published in 1901 a work on atmospheric optics which, as later enlarged and revised by his successor Exner, is now the standard work on the subject.

Trabert was particularly eminent as an inspiring Professor of Meteorology. He recognized early the importance of Margules's work on the "Energy of storms".

Exner is best known to British meteorologists as the author of a textbook, "Dynamische Meteorologie", for long unique in its field. He had a particularly heavy task of re-organization in very difficult economic circumstances after the first world war.

Schmidt was one of the founders of the study of turbulence in meteorology. His term "Austausch" for the turbulent process is widely used.

No historical note on the Zentralanstalt can omit the name of Max Margules, pioneer in the study of the transformation of potential and thermal energy into kinetic energy in the atmosphere. He was a member of the staff from 1882 to 1906.

Cumulonimbus clouds over Lake Victoria

The area around the north-western shores of Lake Victoria has a greater rainfall than the rest of British East Africa, and no month is a dry one although the maximum rainfall occurs in the period March to May. Consequently the vegetation in the area is always green and the land is capable of supporting a large native population. A considerable portion of the rainfall is associated with cumulonimbus clouds and thunderstorms which form over the lake during the late afternoon or evening and which persist well into the night, especially over the north-west corner of the lake and its associated islands. The photographs facing pp. 348 and 349 show typical cumulonimbus clouds over the the north-western shores of the lake on November 18, 1941, at 1530, taken looking north from a steamer sailing from Bukoba to Entebbe. The photographs overlap slightly, the photograph facing p. 348 being to the left of that facing p. 349.

REVIEW

Hugh Robert Mill. An Autobiography. By Hugh Robert Mill. 8¾ in. × 5¾ in., *Illus.* pp. xii+224. Longmans, Green and Co. London, New York, Toronto, 1951. Price: 18*s*.

This book is the outcome of a suggestion made in 1941 by the President of the Royal Meteorological Society that Dr. Mill should write some reminiscences of his connexion with the Society. These reminiscences have been extended, and in the book separate chapters are devoted to the various facets of Dr. Mill's extensive and varied experiences as a geographer, meteorologist, author and traveller. The chapters are headed (1) Forebears (2) The lure of chemistry (3) The call of the sea (4) The use of words (5) The revival of geography (6) The distribution of rain (7) The attraction of the Poles and (8) Holiday travel. "My intention was to conclude with a synthesis of these eight into one personality—myself as a whole. I had thought of calling the book *My nine lives*, but they would not have been in reality nine lives, but one life composed of a number of closely woven strands, like the log-line used for a patent log to measure the speed of a ship, not merely twisted together loosely like a piece of string." Publication was arranged by Prof. Dudley Stamp, who contributes both the Introduction and Postscript.

One of the attractions of the book is the short, vivid sketches of the great personalities Mill met during his long life, 1861–1950. His encyclopaedic knowledge of polar exploration caused him to be sought out by polar explorers; he met the leading geographers and meteorologists both in this country and abroad, and as the rainfall expert of this country he had personal contacts with many rainfall observers and the leading water-engineers.

The book should have a wide appeal. The geographer will be interested in the historical account of the attempts to secure for geography its true place as a science, the rainfall observer in the account of the development of our knowledge of the rainfall of the British Isles, and the more adventurous in the fascinating details, and troubles, of polar exploration. An autobiography by the author of "The realm of nature", "The siege of the South Pole" and "Life of Sir Ernest Shackleton", amongst other works, should also be read as a literary effort. "His words, like so many nimble and airy servitors, trip about him at command." The philosopher, too, might well find much to reflect upon. "In one respect I occupy a position of exceptional advantage. The detailed and unbroken record of my daily doings gives me a vantage point for retrospect. On looking backward, I can answer the question: 'a good thing or a bad thing, Life is which?' My answer to this, taking account of the ups and downs, rights secured and wrong endured, joys and sorrows, is that it is in the main *Good.*"

When the volume comes to be reprinted it would be useful to add the page reference (p. 124) in the index under Sir Napier Shaw and to correct the date given in Appendix I (p. 216) of the Bruton rain of 9·56 in., which should be June 28, 1917, as on p. 129.

J. GLASSPOOLE

ERRATA

October, 1951, PAGE 304, lines 10–12; *for* "This is in itself . . . . .realm of macroclimate." *read* "This in itself is the essential first step to obtain knowledge of the macroclimate. The present book is an unsurpassed attempt to make further steps towards a complete knowledge of the more real and vital realm of microclimate."

November, 1951, PAGE 337, line 3; *for* "facing p. 316" *read* "facing p. 317"; line 9; *for* "facing p. 317" *read* "facing p. 316".

METEOROLOGICAL OFFICE NEWS

Ocean weather ships.—For the flight of T.R.H. The Princess Elizabeth and The Duke of Edinburgh to Canada on Monday, October 8, 1951, ocean weather ships stationed in the North Atlantic Ocean stood by at immediate readiness. The Master of the *Weather Observer* in reporting on the voyage which covered this flight stated that, after more than a fortnight's good weather, continuous gale, which set in on October 11, was experienced during the last eight days of the voyage. The wind was force 12 and a sudden veer gave the worst sea for confusion which he had seen in four years on the station. The ship's motion was extremely violent.

Amusement—and consternation—was caused by an incident in the *Weather Observer* during the 1400 G.M.T. ascent on September 29, 1951. Immediately after the launch, the radio-sonde operator, retuning the receiver to pick up the transmitter's signal, was astonished to find the transmitter apparently emitting the strains of a cinema organ. A hurried conference with the W/T staff revealed that the music was part of the B.B.C. Home Service, on a new wave-length near the radio-sonde band, and that the transmitter was silent. The ascent was repeated—without incidental music.

Long-distance balloon competition.—One of the attractions at Gibraltar on Battle of Britain Day was a long-distance balloon competition organized by the staff of the Meteorological Office there. Competitors paid sixpence for a hydrogen-filled balloon to which was attached a stamped postcard addressed to the Office with instructions in Spanish to the finder. A first prize of £3 was offered to the sender of the balloon which travelled farthest on the evidence of the postcards returned by September 30, and small prizes for all balloons found outside a 100-Km. circle centred on Gibraltar. A prize of 17*s.* went to the finder of the postcard attached to the winning balloon. A gaily coloured stall displayed large notices giving the rules of the competition and a map showing the 100-Km. circle. After a slow start, the appearance of a few balloons drifting slowly away attracted crowds to the stall, and so busy were the balloon sellers that they had little opportunity to watch the spectacular flying display which was in progress most of the afternoon. Eventually all the balloons were sold and the sum taken covered all expenses and left a handsome profit to be handed to the Royal Air Force Benevolent Fund.

The wind varied from 080° 8 kt. at the surface to 040° 12 kt. at 10,000 ft. and 320° 12 kt. at 18,000 ft. The rate of ascent of the balloons was anything between 50 and 500 ft./min. as no attempt had been made to fill them uniformly. By the closing date 30 postcards had been returned, nine from North Africa, two from the southernmost point of Spain and the remainder from Algeciras and Los Barrios across the Bay of Gibraltar. The winning postcard was found near Tangier Airport. A few days after the closing date a batch of 5 postcards was received from a village 24 miles south-west from Tetuan, the capital of Spanish Morocco; some enterprising competitor had apparently tied several balloons together.

There were two rather remarkable coincidences in the results: two balloons released by a Gibraltar policeman were found in different parts of Algeciras by different people living at the same address; and three of the balloons returned from Africa had been released by the Senior Meteorological Officer and members of his family.

The event, the first of its kind in Gibraltar, roused considerable interest in the local press and amongst the general public.

Transfer of staff to Colonial Meteorological and other Services.—One officer and seven more Assistants have left for service in the Falkland Islands, namely Mr. S. D. Glassey, and Messrs. R. A. Berry, F. Burns, B. J. Ellis, D. S. Hosie, F. L. Johnson, B. Kemp and D. McCallum.

Mr. J. F. Fisher has been appointed Meteorological Officer in the new service in Nyasaland, and Mr. K. R. Chaplin has joined the other Assistants who have gone to serve under Mr. J. E. Stevens in Northern Rhodesia.

Mr. D. V. Field and Messrs. D. F. J. Brebner and A. J. Bunting were selected for some special work with the Institute of Aviation Medicine.

Retirement.—Miss D. R. M. Figgins retired from the Meteorological Office on October 31, 1951, because of ill health.

Since she joined the Office on November 19, 1917, Miss Figgins has worked in the British Climatological Branch. Her main responsibility has been to ensure that voluntary climatological observers had everything necessary to maintain their records whether the need was for forms, instruments or guidance. She took a keen interest in this work and acquired a vast store of knowledge about climatological stations past and present and of the data they had provided. This knowledge she used to great advantage in answering inquiries. Her job has demanded minute attention to a multiplicity of detail and might have proved a burden to some but not to Miss Figgins, with her unusually good memory and capacity for rapid working. Among her other duties Miss Figgins has on several occasions included the sub-editing of this Magazine.

We know that Miss Figgins leaves her post with regret and her colleagues share that regret while wishing her a renewal of health in retirement.

Sports.—*Swimming.*—We offer congratulations to Mr. S. W. Lewis who won the free-style and breast-stroke Air Ministry championships, and to Mr. G. Goodger and Mr. R. Nuttall who were second and third respectively in the free-style; also to Miss Barbara Davies who won the Air Ministry Ladies Swimming Championship for the third successive year.

The Meteorological Office Relay Teams gained the first two places in the Air Ministry Relay Championship, an excellent performance. This is the third year running that the Office has won the Allen Fiddes Trophy which, alas, is missing and cannot be traced.

Christmas Party.—The Social and Sports Committee announce that a Christmas Party (tickets 1*s.* 6*d.* each) will be held on December 18 in the Air Ministry Refreshment Club, "B" Block, Adastral House, from 6.30 to 10.30 p.m. Like last year's party which was so successful it will be an informal occasion with music, dancing and games.

[The balloons referred to in the paragraph on the Gibraltar competition were not from Meteorological Office stocks.—Ed. *M.M.*]

NOTICE

Price of the Meteorological Magazine

It is regretted that because of increases in the cost of paper and printing it has become necessary to increase the price of the *Meteorological Magazine* to 2*s.* with effect from the January 1952 number.

The net annual subscription will become £1. 5*s.* 0*d.*, including postage.

Present subscribers will remain on the existing rate until renewal of their subscription falls due.

WEATHER OF OCTOBER 1951

Mean pressure exceeded 1020 mb. over central Europe and Scandinavia and reached 1028 mb. in places in eastern Europe. Mean pressure lying between 1015 and 1020 mb. extended over large areas including west Europe, the British Isles, the North Atlantic south of latitude 45°N. and the greater part of North America. Mean pressure was below 1015 mb. over the central Mediterranean and fell to 1005 mb. westwards and northwards of the British Isles. The lowest mean pressure, 997 mb., was in the region south-west of Iceland, about latitude 60°N.

Mean pressure was above normal over Europe, the excess generally amounting to 10–13 mb. over southern Scandinavia. The greatest deficit of mean pressure of 5–8 mb. below normal occurred south-west of Iceland.

Mean temperature was between 40° and 50°F. over Scandinavia and east Europe, 50–60°F. over west Europe, 60–70°F. over the Mediterranean and 70–85°F. over west Africa. Mean temperature was generally 5°F. above normal over Scandinavia but about 2–4°F. below normal over the rest of Europe.

In the British Isles the weather was, on the whole, dry, sunny and quiet, with rather frequent fog at night and in the early morning, particularly in England. Mean temperature exceeded the average in the west and north.

In the opening days of the month an anticyclone was situated over Scandinavia, and subsequently it moved to the southern Baltic. This system maintained dry weather over much of the country until the 12th, though troughs of low pressure associated with depressions in the Atlantic caused rain at times in the west, for example on the 3rd, 4th, 8th and 9th (on the 9th 1·73 in. of rain was registered at Duntuilm and 1·42 in. at Tiree). Fog, mostly at night and in the early morning, was fairly widespread in England from the 4th to the 16th, while ground frost was recorded locally in Great Britain from the 8th to the 12th and was widely registered in England on the 12th. Less settled conditions set in on the 12th, when a trough of low pressure moved across England from south-west of Ireland; rather heavy rain fell in south-west Ireland and the Scilly Isles on the 12th and slight rain in England on the 13th. On the 14th and 15th another trough caused rain in the west and north; meanwhile widespread fog developed over England at night and in the early morning. On the 16th a trough, associated with a small secondary south of Iceland, moved across the British Isles; gales occurred in the north of Scotland and rain was recorded in many places but it was slight except locally in west and north Scotland. From the 19th to the 21st a deep depression over Iceland moved slowly south and turned east to a position near the Shetlands; rain or showers occurred and local thunderstorms, but there were also long bright periods. The depression subsequently moved away north-north-east. Temperature fell considerably with the influx of cold air behind the depression, and showers of rain, sleet, hail or snow and local thunderstorms occurred. The 22nd was the coldest day of the month in most places, the maximum temperature failing to reach 45°F. at numerous stations. From the 23rd to the 26th an anticyclone moved from south-west of Ireland across the southern districts of the British Isles to Germany; dry, frosty, mainly sunny weather, apart from morning fog, returned to England but some rain occurred in west and north Scotland on the 23rd and 24th. Low minimum temperatures in the screen included 20°F. at Eskdalemuir and 24°F. at Silloth on the 23rd, 23°F. at Bristol on the 24th and 25°F. at Elmdon and Shawbury on the 25th. On the 27th a depression moved quickly from south-westward of Iceland to the south-west of Ireland and later across England and Wales to the North Sea. Appreciable rain fell in parts of Ireland and south-west England on the 27th and more general rain on the 28th and 29th. On the 30th and 31st a shallow depression moving south-east from Iceland to the North Sea gave renewed rain and local thunderstorms.

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 ...	72	19	−0·2	31	−10	111
Scotland	69	19	+2·1	42	−9	104
Northern Ireland ...	68	31	+2·1	37	−8	100

RAINFALL OF OCTOBER 1951

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	·91	35	*Glam.*	Cardiff, Penylan ...	1·91	4[illegible]
Kent	Folkestone, Cherry Gdn.	3·21	80	*Pemb.*	Tenby	1·67	3[illegible]
,,	Edenbridge, Falconhurst	1·25	35	*Card.*	Aberdovey (Plas Penhelig)	1·20	2[illegible]
Sussex	Compton, Compton Ho.	1·54	34	*Radnor*	Tyrmynydd	1·53	2[illegible]
,,	Worthing, Beach Ho. Pk.	1·37	38	*Mont.*	Lake Vyrnwy	1·89	3[illegible]
Hants.	Ventnor, Cemetery ...	1·61	40	*Mer.*	Blaenau Festiniog ...	2·23	2[illegible]
,,	Bournemouth	1·66	39	*Carn.*	Llandudno	·92	2[illegible]
,,	Sherborne St. John ...	·92	26	*Angl.*	Llanerchymedd ...	·70	1[illegible]
Herts.	Royston, Therfield Rec.	·75	28	*I. Man*	Douglas, Borough Cem.	·88	1[illegible]
Bucks.	Slough, Upton	·95	34	*Wigtown*	Port William, Monreith	...	...
Oxford	Oxford, Radcliffe ...	·89	31	*Dumf.*	Dumfries, Crichton R.I.	·25	[illegible]
N'hants.	Wellingboro', Swanspool	·68	27	,,	Eskdalemuir Obsy. ...	·46	[illegible]
Essex	Shoeburyness	1·24	53	*Roxb.*	Kelso, Floors	·32	1[illegible]
,,	Dovercourt	·78	33	*Peebles*	Stobo Castle	·58	1[illegible]
Suffolk	Lowestoft Sec. School ...	·56	20	*Berwick*	Marchmont House ...	·46	1[illegible]
,,	Bury St. Ed., Westley H.	·89	33	*E. Loth.*	North Berwick Res. ...	·24	[illegible]
Norfolk	Sandringham Ho. Gdns.	1·06	35	*Midl'n.*	Edinburgh, Blackf'd. H.	·52	1[illegible]
Wilts.	Aldbourne	·67	20	*Lanark*	Hamilton W. W., T'nhill	·86	26
Dorset	Creech Grange... ...	1·63	32	*Ayr*	Colmonell, Knockdolian	1·04	2[illegible]
,,	Beaminster, East St. ...	·82	18	,,	Glen Afton, Ayr San. ...	...	...
Devon	Teignmouth, Den Gdns.	·71	18	*Bute*	Rothesay, Ardencraig ...	2·28	52
,,	Cullompton	1·32	32	*Argyll*	Morvern, Drimnin ...	3·28	55
,,	Ilfracombe	1·49	33	,,	Poltalloch	3·42	69
,,	Okehampton, Uplands	1·53	25	,,	Inveraray Castle ...	3·52	50
Cornwall	Bude, School House ...	1·76	43	,,	Islay, Eallabus	2·27	48
,,	Penzance, Morrab Gdns.	2·39	51	,,	Tiree	3·87	85
,,	St. Austell	2·01	38	*Kinross*	Loch Leven Sluice ...	·59	17
,,	Scilly, Tresco Abbey ...	1·42	37	*Fife*	Leuchars Airfield ...	·19	7
Glos.	Cirencester	1·02	31	*Perth*	Loch Dhu	2·29	32
Salop	Church Stretton ...	1·25	34	,,	Crieff, Strathearn Hyd.	·86	22
,,	Shrewsbury, Monkmore	·81	29	,,	Pitlochry, Fincastle ...	1·35	41
Worcs.	Malvern, Free Library	1·04	35	*Angus*	Montrose, Sunnyside ...	·73	26
Warwick	Birmingham, Edgbaston	·72	26	*Aberd.*	Braemar	1·10	29
Leics.	Thornton Reservoir ...	·70	25	,,	Dyce, Craibstone ...	·91	27
Lincs.	Boston, Skirbeck ...	·87	32	,,	Fyvie Castle	1·53	40
,,	Skegness, Marine Gdns.	...	...	*Moray*	Gordon Castle	1·34	42
Notts.	Mansfield, Carr Bank ...	·76	25	*Nairn*	Nairn, Achareidh ...	1·34	[illegible]
Derby	Buxton, Terrace Slopes	1·20	24	*Inverness*	Loch Ness, Garthbeg ...	1·59	[illegible]
Ches.	Bidston Observatory ...	·75	23	,,	Glenquoich	4·60	[illegible]
Lancs.	Manchester, Whit. Park	1·27	39	,,	Fort William, Teviot ...	3·63	5[illegible]
,,	Stonyhurst College ...	1·27	28	,,	Skye, Duntuilm ...	6·68	12[illegible]
,,	Squires Gate	1·65	47	*R. & C.*	Tain, Tarlogie House ...	1·13	[illegible]
Yorks.	Wakefield, Clarence Pk.	·80	28	,,	Inverbroom, Glackour ...	3·27	[illegible]
,,	Hull, Pearson Park ...	·95	32	,,	Applecross Gardens ...	5·03	84
,,	Felixkirk, Mt. St. John	1·59	55	,,	Achnashellach	4·70	[illegible]
,,	York Museum	1·70	63	,,	Stornoway Airfield ...	3·39	69
,,	Scarborough	·86	27	*Suth.*	Loch More, Achfary ...	...	...
,,	Middlesbrough... ...	1·34	45	*Caith.*	Wick Airfield	1·91	65
,,	Baldersdale, Hury Res.	·89	22	*Shetland*	Lerwick Observatory ...	2·48	63
Norl'd.	Newcastle, Leazes Pk....	·77	25	*Ferm.*	Crom Castle	1·14	35
,,	Bellingham, High Green	1·03	26	*Armagh*	Armagh Observatory ...	·85	31
,,	Lilburn Tower Gdns. ...	·76	21	*Down*	Seaforde	·51	14
Cumb.	Geltsdale	1·40	38	*Antrim*	Aldergrove Airfield ...	·75	25
,,	Keswick, High Hill ...	1·14	20	,,	Ballymena, Harryville...	1·34	36
,,	Ravenglass, The Grove	·84	19	*L'derry*	Garvagh, Moneydig ...	1·61	46
Mon.	Abergavenny, Larchfield	·99	24	,,	Londonderry, Creggan	2·08	57
Glam.	Ystalyfera, Wern House	1·71	25	*Tyrone*	Omagh, Edenfel ...	1·89	51