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REORGANIZATION OF THE METEOROLOGICAL OFFICE

By the Director-General

In 1955 the Secretary of State for Air appointed a Committee under Lord Brabazon to review the organization of the Meteorological Office in relation to current and future requirements. The Committee took voluminous evidence, written and oral, from user interests, both within and outside the Government service, and also from senior members of the directorate and from the Meteorological Office Staff Side. In addition, the Committee visited a number of headquarters units and outstations of the Office. The report of the Committee, which was produced in 1956, is intended for departmental and interdepartmental use and will not be published. Its main conclusions were recently announced to the House of Commons in a written reply by the Secretary of State for Air.

It is obviously impossible here to give more than a brief summary of the salient points in the Committee's report. First, the Committee considered that the decision, taken in 1919 and re-affirmed in 1945, to entrust responsibility for the State Meteorological Service to the Air Ministry, is sound and should continue. It also came to the gratifying conclusion that the present standing of the Office as a scientific institution is high, that user interests appreciated the advances in recent years and that, all told, there is considerable confidence in the services provided. Second, in looking at probable lines of advance, the Committee singled out the development of numerical methods of forecasting as one of the more important, and it welcomed the decision to install an electronic computer in the Office. It was considered, also, that there was a possibility of achieving greater precision in local forecasting by a more detailed study of weather characteristics, coupled with the use of radar scanners. The Committee also welcomed the decision to develop a unified Headquarters at Bracknell.

Reorganization of the Directorate.—The main result of the Committee's more detailed recommendations has been that the Office is reorganized in three 'prongs', dealing with forecasting and services, research, and administration, respectively, with a regrading of the senior posts. The post of Director has been raised to that of Director-General (D.G.M.O.). The forecasting and services side of the Office is placed under the Director of Services (D.S.M.O.) and the research side under the Director of Research (D.R.M.O.), each

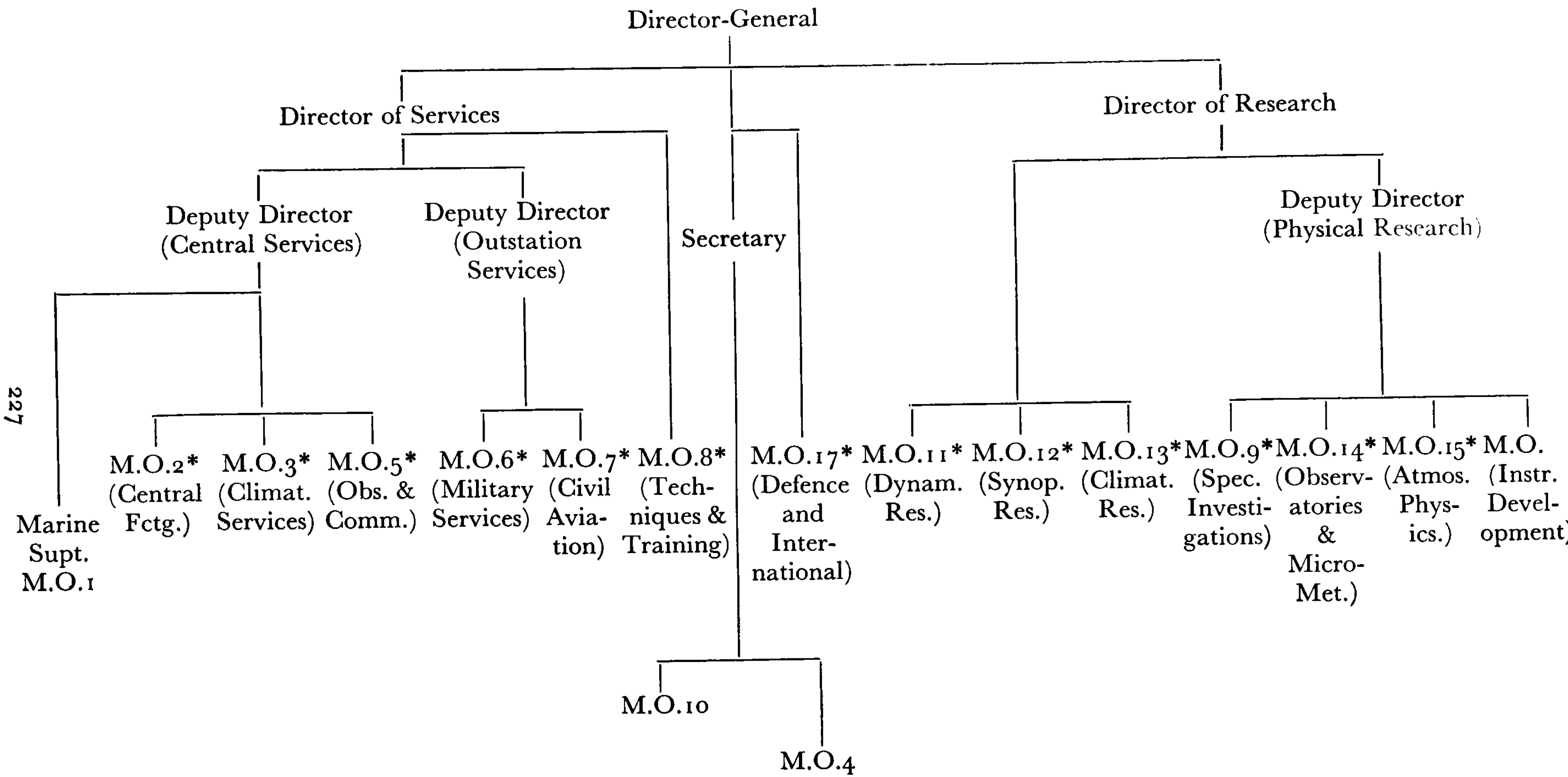
Director being in the grade of Chief Scientific Officer. The administrative prong has been placed under an Assistant Secretary with the title of 'Secretary of the Meteorological Office'. The effect of these changes is to make the Meteorological Office a much more self-contained unit than hitherto, especially on the administrative side.

In addition, new posts have been created in the grades of Deputy Chief Scientific Officer and Senior Principal Scientific Officer. The Brabazon Committee expressed concern regarding career prospects for members of the Scientific Civil Service in the Meteorological Office. The need for improvement was especially evident in the Scientific Officer class, and poor prospects may have contributed in part to the difficulty experienced in the past of keeping up the rate of entry of men and women of high ability into meteorology as a career. The precise weight of this factor in slowing down recruitment probably can never be decided with certainty, for the Meteorological Office has had to compete with other branches of the Scientific Civil Service in attracting recruits at a time when the country's output of scientists and technologists has been insufficient to meet the demands of industry, the universities and the technical colleges, but it is certain that improvements in career prospects must have a beneficial effect.

The new headquarters organization is shown in detail in the diagram on p. 227. All told, the total number of posts above Principal Scientific Officer has been increased to 23 (20 at headquarters and 3 at outstations). Concurrently, it is proposed, by stages, to reduce the overall establishment in the Scientific Officer class by a relatively small amount, again with the primary object of improving the chances of all entrants to this class of reaching the higher levels. At the same time it is proposed to increase the number of senior appointments in the Experimental Officer class, so that the net result will be an overall improvement in the careers available to entrants in all classes.

Services.—Some of the new posts are novel in scope. It will be seen that an Assistant Director is to be appointed with the title of 'Techniques and Training'. This post is designed to meet a need which has been felt in the Office for some time, a need which was emphasized in the evidence submitted by the Staff Side to the Brabazon Committee. Meteorology is rapidly becoming a more exact science, with a considerable volume of research effort now available, in this country and abroad. There is a real need for operational forecasters, especially those in the more remote outstations, to be brought into closer contact with the results of research. Equally, it is of prime importance that research should not lose contact with operations. In the past the Meteorological Office has attempted to meet this need by the institution of what have come to be known as the 'Monday Evening Discussions' and by the circulation of specially prepared abstracts of selected papers, but today this is not enough. The prime duty of the occupant of this new post will be to ensure that the flow of information from the research side to the operational side, and the equally valuable return flow of operational experience to the research side, is maintained at a high level. In addition, this post carries with it the cognate responsibilities of directing the training of new entrants and of providing refresher courses at the Training School, as well as the supervision of the preparation of manuals and handbooks intended for use by professional meteorologists in the field.

HEADQUARTERS ORGANIZATION 1957



*Assistant Directorates

Another new Assistant Director post, reporting directly to the Director-General, carries responsibility for certain defence and international aspects of meteorology. The volume of work connected with the World Meteorological Organization, its Technical Commissions, Regional Associations and Working Groups, has grown enormously in recent years, and may be expected to increase still further. Until now, the coordination of this work has been carried out by the Director and his personal staff, but the need has now been recognised for a senior officer to coordinate the very large efforts made by the Meteorological Office, in common with the other meteorological services of the world, to maintain this highly important international work.

The post of Assistant Director (Public Services) no longer exists. This in no way indicates any decrease of interest in the non-aviation aspects of the work of the State Meteorological Service. On the contrary, the Brabazon Committee emphasized the necessity of expanding this side of the work of the Office, particularly by means of the automatic telephone weather service and other aids. The abolition of this particular post reflects the intention to integrate the public services work with existing services much more closely than in the past. The groundwork of such integration has been well laid, as is evidenced by the growing popularity of the sound and visual broadcasts, and the country-wide extension of WEA. The Brabazon Committee were of the opinion that a requirement undoubtedly exists for local forecasting units for non-aviation users, particularly in agricultural districts, but it was recognized that man-power considerations and other factors must be taken into account, and it will be much easier to estimate the value of such schemes when more experience has been gained with the present improved systems of dissemination.

Research.—It is, perhaps, in the improved facilities for research that the reorganization is most striking. For the first time in its history the Office may now say truly that it has a fully developed research side. In its review of the purely scientific activities of the Office the Brabazon Committee paid tribute to the work of the Meteorological Research Committee, and they saw no reason to suggest any changes in its constitution or terms of reference. The M.R.C., which was formed in 1942, has been an outstanding success and the Office has every reason to be grateful to the many outside scientists who have devoted so much of their time to its activities. In one important matter, however, the Committee felt that a change was needed. For some years now the Gassiot Committee of the Royal Society has received from the Air Ministry a separate grant for fundamental research. The present grant, which is for £7,000 a year, lasts until 1961. The Committee, while recognizing the value of the work done by the Gassiot Committee since the end of the war, felt that in future grants for meteorological research emanating from the Air Ministry should normally be channelled through the Meteorological Research Committee. This recommendation is now being discussed with the Royal Society.

Some new subdivisions of research have been recognized. The Director of Research will have under him a Deputy Director whose interests will be specifically in physical meteorology. All the existing Assistant Directorates in research are retained, and two new headquarters posts have been added. These are: an Assistant Director to coordinate and supervise research in micro-meteorology (which at the present time is going on chiefly at Kew, Cambridge and Porton), with special responsibilities also for the Observatories; and an

Assistant Director for research in dynamical meteorology, who will be primarily responsible for the development of numerical methods in the synoptic field. The Assistant Director (Synoptic Research) will be mainly concerned with long-range forecasting and general synoptic problems, and the existing Assistant Directorates of Special Investigations, Climatological Research and Physical Research (renamed Atmospheric Physics) will cover much the same fields as at present. Instrument Development becomes purely investigational, with the provisioning and accounting side transferred to the Secretary. The post of Head of the Meteorological Research Flight, which has now attained world-wide recognition as one of the primary units of upper-air research, has been raised to Senior Principal Scientific Officer.

Finally, the reorganization has allowed certain anomalies in the historic system of numbering divisions of work to be rectified, and in future the letters 'M.O.' followed by a number will be used as a short title for an Assistant Directorate. The only exceptions to this rule are M.O.1, which remains under the Marine Superintendent and the personnel administration and provisioning branches, M.O.10 and M.O.4, which come under the Secretary.

The Meteorological Committee.—The system of general supervision of the work of the Office by the Meteorological Committee has been overhauled. Hitherto the Meteorological Committee has included representatives of the various Government Departments which have a user interest in meteorology, the universities, the Royal Society and the Royal Society of Edinburgh. Such a body is unavoidably large and, in the view of the Brabazon Committee, its structure was such that it had ceased to perform any very useful function. Instead, the Brabazon Committee suggested that it should be replaced by an advisory committee of not more than five members, all from outside the government service, and this advice has been accepted by the Secretary of State. The new Committee is not a 'representative' committee in the usual sense of the word. It consists of an independent chairman and four members, two of whom will be scientists and two normally laymen. One of the scientists will be the chairman of the Meteorological Research Committee and the other scientist member will be appointed after consultation with the President of the Royal Society. The Meteorological Office may count itself exceptionally fortunate in that Lord Hurcomb has accepted the invitation of the Secretary of State to become the first Chairman of the reconstituted committee.

The Committee will be required to keep under review the progress and efficiency of the Meteorological Office and the broad lines of its current and future policy, as well as the general scale of effort and expenditure devoted to the Meteorological Office, and also to study contact between the Office and the users. The Meteorological Office Advisory Committee for Scotland remains in its present form.

It would be unwise to attempt to forecast here the ultimate result of these changes on the Meteorological Office and on meteorology in the United Kingdom generally. The full benefit of the reorganization will not be felt until the headquarters units have settled into the new buildings at Bracknell, for which design work is now well advanced. The recognition of the Meteorological Office as a major national scientific institution with two functions of equal importance, of providing a public service and of leading research in meteorology in this country, cannot but help to promote the growth and well-being, not only of the Office itself, but also of the science to which it is dedicated, and we are grateful to Lord Brabazon and his colleagues for their help in bringing about these changes. At the opening of its second century, the Meteorological Office may look forward to an even brighter future.

METEOROLOGICAL OFFICE DISCUSSION

Stratocumulus Clouds

The Meteorological Office Discussion held at the Royal Society of Arts on Monday, March 18, 1957 was opened by Dr. D. G. James. His statement dealt with the behaviour of a sheet of stratocumulus cloud situated under a dry type inversion, and the physical processes leading up to the dissipation of the cloud.

Forecasting experience shows that winter anticyclones near the British Isles frequently produce extensive areas of stratocumulus cloud over the country. Radio-sonde soundings through such a sheet of stratocumulus invariably show a well-marked temperature inversion accompanied by a steep hydrolapse in the layer directly above cloud top. It is generally agreed that some degree of subsidence is necessary to give the very low dew-points above cloud top, but various authors have shown that subsidence is rarely responsible for the full magnitude of the temperature inversion. In 1933 Mal, Basu and Desai carried out investigations by aircraft of several of these dry-type inversions when no cloud was present[1]. They concluded that the temperature inversions were intensified by radiative cooling from the tops of the haze layers always found in association with these conditions. They noted that the haze layers were composed largely of hygroscopic nuclei which, though not forming cloud, were sufficiently moist to produce a large increase of long-wave radiative cooling over that expected from dry air.

The formation of the cloud has been described by Douglas[2] and Wood[3] who deduce that turbulent convection is mainly responsible. Douglas, in an analysis of air which had arrived in this country after crossing the North Sea, showed that a considerable amount of water was evaporated at the sea surface, and that on average, the flux of water vapour upwards by turbulent diffusion was sufficient to increase the humidity mixing ratio of the first 3,000 ft. of an air mass by about 1 gm./Kg. This is frequently sufficient to cause a layer of stratocumulus to be formed by the time the air mass reaches the land. The rate at which this water vapour is carried upwards is determined by the lapse rate of temperature upwards from the surface and also by the wind shear. Wind shear is also important in determining the pattern which the cloud will take when it begins to break up. Wind tunnel experiments carried out by Phillips and Walker in 1932 showed that, in the absence of any vertical shear across a stratified cloud sheet, the breaking up of the cloud caused polygonal patterns to be formed. For large values of shear alternate vortices were produced with axes parallel to the shear, whilst for small shear rectangular patterns were formed. Although for the clouds which will be considered later the wind shear was thought to be negligible—the clouds were very thin—clearly accurate surface observations of the cellular pattern of the cloud can give a good indication of the wind shear, and hence of the degree of turbulence to be expected at cloud level.

Recent work in the Forecast Research Division at Dunstable has been concerned with the dissipation of a sheet of stratocumulus under a dry-type inversion. The work falls naturally into two classes: firstly a statistical analysis of radio-sonde soundings and surface observations on occasions of extensive stratocumulus sheets, and secondly an analysis of observations made near stratocumulus clouds from an aircraft. The first part of this work has been published in the *Meteorological Magazine* as "Nocturnal dissipation of stratocumulus cloud", and it is proposed merely to review some of the conclusions of that paper[4].

Hourly charts for the four years 1944 to 1947 were examined for occasions of extensive stratocumulus sheets present at midday, it being the intention to consider only the clouds which were present during a given day and which persisted through or dissipated during the night. The appropriate radio-sonde soundings were examined to ensure that the clouds were bounded at their tops by dry-type inversions. The first significant fact which emerged from this selection was that of the 53 occasions considered suitable, 52 occurred in the winter months.

The occasions were divided into two groups according to whether the cloud sheet had or had not dissipated within 12 hours of the afternoon radio-sonde soundings. In fact, of the 53 cloud sheets selected, 26 dissipated within the stipulated time. For the purposes of the investigation, the cloud was considered to have dissipated if the surface observations reported that the sheet had reduced to 2 oktas or less for at least two consecutive hours. This is not to say that the cloud only partially disperses: on the contrary, synoptic experience shows that if a stratocumulus sheet does dissipate then it goes quickly and it goes completely.

Examination of the appropriate radio-sonde soundings showed that, for the two groups considered—namely cloud sheets which do or do not dissipate within 12 hours—the means of several synoptic variables were significantly different at about the 10 per cent. level.

Although the means of these variables are statistically significant, individually they are of little use for forecasting purposes. However, using a linear combination of the variables it is possible by maximizing "Student's" t value[5] to obtain an expression which may be of some assistance in forecasting the future behaviour of the cloud sheet up to 12 hours from the time of the afternoon radio-sonde sounding. Using such a linear combination we can obtain a parameter defined as:—

$$\xi = x - 9\cdot15y - 0\cdot77z$$

where x is the maximum depression in °F. of dew-point below temperature at any level up to 50 mb. above cloud top, y is the average hydrolapse in 10^{-2} gm./Kg./mb. over 50 mb. below cloud base and z is the cloud thickness in mb. The difference in the means of the ξ's for the two groups of dissipating and persisting clouds is now statistically significant at the $0\cdot2$ per cent. level, which suggests that this variable may well be of some use to the forecaster. The errors which arise, however, are large and can be directly attributed to inaccurate assessment of the three variables x, y and z. The lags of the radio-sonde elements are too great to reproduce faithfully the steepness of the temperature inversion and hydrolapse directly above cloud top. Furthermore, surface observations from neighbouring stations of the base of the stratocumulus sheet were not mutually consistent, and on occasions could not be fitted to the temperature and dew-point profiles as indicated by the radio-sonde soundings. Consequently, considerable errors sometimes arose in estimates of the cloud thickness. It was thought therefore that a better appreciation of the problem could be obtained only by accurate measurement of all the synoptic variables by an aircraft flying through and in the neighbourhood of a stratocumulus cloud sheet.

The second part of the work was therefore concerned with flights carried out by an aircraft of the Meteorological Research Flight during the latter half of November 1955. The pre-arranged flight plan was such that following an ascent to about 10,000 ft. the aircraft performed level runs of 3 to 5 minutes at 250-ft. intervals from 1,000 ft. below cloud base to cloud top, then at 100-ft. intervals up to 500 ft. above cloud top. Finally two level runs of 8 minutes duration were carried out at 200 ft. above cloud top and 200 ft. below cloud base. Height, airspeed, temperature and frost-point were observed every 250 ft. on the ascent to 10,000 ft., and every 30 secs. on the level runs, along which an accelerometer was used to record the bumpiness experienced by the aircraft. In cloud an attempt was made to measure the liquid water content.

The second half of November 1955 was particularly favourable for the formation of extensive sheets of stratocumulus cloud over the southern half of the British Isles. An anticyclone centred over Scotland during the early part of the month moved slowly westwards, later returning and moving gradually south-east into the continent. Generally, during this period, south-east England was in an anticyclonic weak north-easterly flow which was shown by radio-sonde soundings to exhibit a well marked dry-type inversion. Strato-cumulus frequently formed under this inversion and sometimes it dissipated during the night.

Eight flights were carried out in the period November 14–28, 1955, but on only four of these were full sets of data obtained.

The temperature measurements were made by a standard Meteorological Office flat plate thermometer the lag of which is about 8 sec. A level run of 3 to 5 minutes thus allows ample time for the thermometer to settle down, but the standard deviations of any fluctuations of temperature recorded will be reduced. Furthermore, on a level run the height of the aircraft was noted to the nearest 10 ft. and varied as much as ± 50 ft. so that, particularly in the inversion layer the temperature fluctuations which are observed will be considerably greater than those which actually occur at any particular level. Even so the recorded standard deviations have been used to provide a linear increase of temperature with height in the profile which we must assume later.

The temperature profiles near the cloud sheets as shown by the aircraft observations indicate that

(i) below cloud base the lapse rate is dry adiabatic almost down to ground level,

(ii) the cloud top is bounded by a sharp temperature inversion which is considerably steeper than that shown by the corresponding radio-sonde sounding in the same place and at the same time,

(iii) the slope of the inversion is about 2 to 3 °C. per 100ft., the whole of the inversion occuring within the first 500 ft. of cloud top.

The frost-points were measured by a Dobson-Brewer manual hygrometer. In the range in which observations of frost- and dew-points were taken, i.e. −20°C. to +10°C. this instrument is accurate to about 0·5°C. As the hygrometer is manually operated, the frost-points obtained are not, in general, synchronous with the temperature observations. In the inversion layer where the hydrolapse is very great, small variations in aircraft height can lead to large variations of frost-point, so that the standard deviations of the measurements are unreally large and cannot be used as an estimate of turbulent mixing at any particular level. However, as will be seen later, the standard deviation as well as the means of the frost-points on level runs are used to obtain a linear variation of dew-point with height above cloud top. The hydrolapse in the inversion layer is of the order of 1 to 2 gm./Kg./100 ft., the "fall of humidity" taking place entirely within the first 500 ft. or so above cloud top. This is again considerably greater than the hydrolapse indicated by the appropriate radio-sonde sounding.

Dr. James then showed accelerometer records obtained by a Hastings aircraft of the Meteorological Research Flight in and near a stratocumulus sheet on November 14, 1955. The considerable turbulence recorded in and below the cloud decreased sharply above cloud top until at some 500 ft. above cloud the turbulence was negligible. Evaluation of the turbulence index confirms this impression, the index having maximum values in the cloud and at cloud top. This suggests that the turbulence is instigated near cloud top and is effective below cloud base and also, to a lesser extent, above cloud top.

Accurate assessment of vertical velocities from the accelerometer traces, as was made by Jones using traces obtained in CuNb clouds[6], proved impossible since a recording altimeter was not used, and therefore the zero errors could not be applied to the integrated traces.

A slide presenting the assumed temperature and humidity profiles near a stratocumulus cloud sheet was then shown. The temperature measurements indicated a dry adiabatic layer extending for some considerable depth below cloud base, and it was assumed that this lapse rate is effective down to ground. In the cloud, although no accurate observations are available, the lapse rate is probably wet adiabatic up to the cloud top with an apparent discontinuity at the base of the inversion layer in which the temperature increase has been assumed linear with height.

Complete saturation was not indicated by the hygrometer on any flight, but the observations below cloud suggest that the humidity mixing ratio is constant from cloud base to near the ground, and this constant value has been obtained by assuming saturation at cloud base. This assumption is supported by the accelerometer records, the turbulence shown in and below cloud probably being sufficient to distribute evenly the available water vapour below cloud top. In the inversion layer the decrease in dew-point has been assumed to be linear with increasing height.

All flights support the existence of such profiles and furthermore show that there is little variation in the magnitudes of the temperature inversions and hydrolapses from flight to flight. On all occasions the clouds had been in existence for some 10 hours prior to the times of the flights and had persisted for several hours afterwards. Also, no systematic change was noted in the heights of the base or top of a given cloud sheet during a flight. It is unlikely therefore, that at the times of observation the temperature and humidity profiles were changing rapidly. The second assumption made is that during the day the *status quo* of the cloud and inversion layer is preserved.

However, the accelerometer records show considerable turbulence immediately above cloud top. This turbulence will transfer heat downwards into the cloud and water vapour upwards from the cloud top. The indicated turbulence decreases with height through the inversion layer and is negligible some 500 ft. above cloud top, so it seems that the heat added to and water vapour taken from the cloud at cloud top are respectively taken from and added to the inversion layer. The turbulence would thus quickly change the magnitude of the temperature inversion and hydrolapse directly above cloud, and the cloud would build upwards into the inversion layer. However, no such tendency was observed on any flight—though the flights were necessarily of limited duration. It is therefore concluded that the air immediately above the cloud top is continually being replaced by subsidence which operates against the turbulence to give an approximately steady state at and immediately above the cloud top.

Before evaluating the rate of subsidence it was first necessary to consider the heat and water vapour budgets of the cloud and air below, so that an estimate could be made of K, the coefficient of eddy diffusion appropriate to the inversion layer. An initial guess of 3×10^3cm.^{2}/sec. was made for K in respect of the diffusion of both heat and water vapour. This is the value given by Taylor for stable conditions at lower levels over the sea.

The heat budget of the cloud and air below was then considered. Radiation measurements made from aircraft above sheets of stratocumulus indicate that the albedos of the clouds vary considerably with cloud thickness. Values between 0·3 and 0·8 have been obtained for clouds whose thicknesses range from "very thin" to 4,500 ft. For the cloud investigated by Meteorological Research Flight aircraft on November 14, 1955 which was about 300 ft. thick an albedo of about 0·5 is probably close enough for our calculations.

Measurements at Kew show that on a clear day in November, about 180 cal./cm.^{2} are available at the surface from solar radiation, or an average of about 20 cal./cm.^{2}/hr. between sunrise and sunset. This figure is supported by data given by Charney and also Houghton for solar radiation received at the surface at latitude 50°N. during November[7, 8]. It will therefore be assumed that about 25 cal./cm.^{2}/hr. were available at cloud top i.e. 5,000 ft., on November 14, 1955 from solar radiation. An albedo of 0·5 allows some 13 cal./cm.^{2}/hr. to pass into cloud top.

The loss of heat at cloud top by long wave radiation may be obtained by use of the Elsasser radiation chart, and was about 10 cal./cm.^{2}/hr. for the case considered. Measurements at Kew show that, during November, about 1 cal./cm.^{2}/hr. is conducted into the earth during the day, the heat being restored by the earth at the same rate during the night.

Some heat is used in the evaporation of water at the earth's surface. On the dates of the flights the evaporation from tanks of water at Kew was about 7×10^{-2} gm./cm.^{2}/24 hours. It is known that the average rate of evaporation during the day is some 3 or 4 times that at night, so that the average rates of evaporation during the day and night on the dates of the flights were $6 \cdot 0 \times 10^{-3}$ and $1 \cdot 5 \times 10^{-3}$ gm./cm.^{2}/hr. respectively. The heat required for these rates of evaporation is about 4 and 1 cal./cm.^{2}/hr.

The flux of heat downwards into cloud top by turbulence is given by

$$F_H = \rho c_p K_H \frac{T}{\theta} \frac{\partial \theta}{\partial z},$$

where ρ is the air density at the heights considered,
c_p is the specific heat at constant pressure of the air,
K_H is the appropriate coefficient of eddy turbulence,
T is the absolute temperature,
θ is the potential temperature
and z is the height.

For November 14, 1955, assuming a linear variation of temperature with pressure from cloud top at 851 mb. to the top of the inversion layer at 838 mb., then $\frac{\Delta \theta}{\Delta p}$ through this layer is $0 \cdot 44$°C./mb. Assuming $K = 3 \times 10^3$cm.^{2}/sec. the flux of heat into cloud top by turbulence is about 1 cal./cm.^{2}/hr.

A further slide showed a summary of the figures presented for the heat balance of the cloud and air below. These suggest that during the day the cloud and air below lose about 1 cal./cm.^{2}/hr., which causes a cooling of about $0 \cdot 2$°C. during the daylight hours. (It was pointed out that to facilitate simple analysis a day in mid-November was considered to consist of 8 hours of daylight and 16 hours of darkness.)

At night there is a net loss of about 9 cal./cm.^{2}/hr. which gives a cooling of the cloud and air below of about $3 \cdot 3$°C. during the night. This is about twice as great as is actually observed from radio-sonde soundings at 12-hour intervals through the same air mass, and must therefore be considered further.

The main factor responsible for this excessive rate of cooling is the long wave radiation loss from cloud top computed from the Elsasser radiation chart. However, measurements from aircraft of the flux of long-wave radiation near stratocumulus cloud by Houghton and Brewer in 1955 confirm the Elsasser value to within ± 1 cal./cm.^{2}/hr.[9]. To obtain a rate of cooling comparable with that observed the cloud and air below should lose heat at about 5 cal./cm.^{2}/hr. instead of the 9 calculated above. This could be obtained by increasing the value of K in the inversion layer to 10^4/cm.^{2}/sec. or perhaps a little more. This value of K would, through more rapid transport of heat downwards into cloud top, 4 cal./cm.^{2}/hr., restrict the cooling of the cloud and air below to about $2 \cdot 2$°C. during the night, which is much closer to the actual cooling observed. There is thus some indication that we need to consider values of K considerably greater than 3×10^3 and possibly greater than 10^4 cm.^{2}/sec. For a value of K equal to 10^4 the cloud and air below warms by $0 \cdot 4$°C. during the day and cools by $2 \cdot 2$°C. at night.

The water vapour budget of the cloud and air below were next considered. The water vapour available by evaporation at the surface is about $6 \cdot 0$ and $1 \cdot 5 \times 10^{-3}$ gm./cm.²/hr. by day and night respectively. Since all flights indicate a constant humidity mixing ratio from cloud base to ground it is likely that the turbulence below cloud as shown by the accelerometer records is sufficient to distribute the evaporated water evenly through the cloud and air below.

The cloud loses water vapour by turbulent diffusion upwards in the cloud top. The measurements of liquid water content in the cloud are not reliable, but it is reasonable to assume that the humidity mixing ratio in the cloud (including liquid water) is determined by the dry adiabatic immediately below cloud and the observed level of the cloud base. Thus for the data of November 14, 1955 the average hydrolapse $\frac{\Delta x}{\Delta p}$ through the inversion layer immediately above cloud top is $0 \cdot 20 \times 10^{-3}$ gm./gm./mb. The flux of water vapour upwards from cloud top is given by

$$F_w = \rho K_w \frac{\partial x}{\partial z},$$

where ρ is the air density at the heights considered,
K_w is the appropriate coefficient of eddy turbulence,
x is the humidity mixing ratio
and z is the height,

which for K 10^3 cm.²/sec. gives the flux as $2 \cdot 2 \times 10^{-3}$ gm./cm.²/hr.

Thus for K 10^3 cm.²/sec., there is a net gain of water vapour of $3 \cdot 8 \times 10^{-3}$ gm./cm.²/hr. by day and a net loss of $0 \cdot 7 \times 10^{-3}$ gm./cm.²/hr. by night. The changes in humidity mixing ratio would thus be about $0 \cdot 2$ gm./Kg. during the day and $-0 \cdot 07$ gm./Kg. during the night. For K 10^4 cm.²/sec. the changes would be $-0 \cdot 06$ and $-0 \cdot 5$ gm./Kg. by day and night respectively.

We now consider the effect of various values of K on the balance of the inversion layer. The accelerometer records show considerable turbulence in and below the layer from cloud top up to some 10 mb. above cloud top, but none whatsoever in the dry air above this level. It must therefore be assumed that the heat gained by the cloud and air below by turbulent diffusion is taken entirely from this layer: also this water vapour lost by the cloud is accumulated in this layer. Now for K 3×10^3 cm.²/sec., the heat gained and water vapour lost by the cloud is about 1 cal./cm.²/hr. and $2 \cdot 2 \times 10^{-3}$ gm./cm.²/hr. respectively, so that the inversion layer would cool at about $0 \cdot 6$°C./hr. and its humidity mixing ratio would increase by $0 \cdot 22$ gm./Kg./hr. Furthermore, these changes would be immediately effective just above cloud top where the turbulence is at a maximum, and the cloud would grow upwards into the inversion. For K 10^4cm.²/sec., these changes would be $1 \cdot 3$°C./hr. and $0 \cdot 73$ gm./Kg./hr. respectively. However, no systematic variation in the height of cloud top was observed on any flight—albeit of limited duration—and so the upward growth of the cloud must be prevented by subsidence, by which the air in the inversion layer is continually being replaced by warm dry air from above.

If air is subsiding through a given layer, then the heat added to that layer is proportional to the rate of subsidence and to the difference between the potential temperatures at the limits of the layer. For the data of November 14, 1955 the change in potential temperature through the inversion layer was 6°C., so that for K 10^3/cm.^{2}/sec., a subsidence rate of rather less than 1 mb./hr. is sufficient to counteract the cooling produced by turbulence.

Similarly, if the transport of water vapour downwards by subsidence is equal to that upwards by turbulence in the inversion layer then a subsidence rate of rather less than 1 mb./hr. will maintain the hydrolapse above cloud top. Thus for K 3×10^3 cm.^{2}/sec., a subsidence rate of 1 mb./hr. is sufficient to counteract the turbulent mixing at cloud top and to maintain the cloud top at the same level. For K 10^4 cm.^{2}/sec., a subsidence rate of about 3 mb./hr. is required.

The next slide showed a table presenting the corresponding data and deductions for the four flights on which full sets of measurements were obtained. Changes of temperature and humidity mixing ratio of the cloud and air below were given for the 8 hours of daylight and 16 hours of darkness for values of K of 3×10^3 and 10^4 cm.^{2}/sec. The final columns of the table presented the calculated and actual behaviour of the cloud sheet. It was seen that for K 3×10^3 cm.^{2}/sec. and a subsidence rate of 1 mb./hr. the cloud would thicken by day and by night, predominently during the latter. Conversely for K 10^4 cm.^{2}/sec. and a subsidence rate of 3 mb./hr. the cloud would thin by day and by night but rather more by day.

Before considering the dissipation of the cloud Dr. James reconstructed the argument up to that point. In the absence of any turbulent mixing at cloud top, the cloud and air below would at all times be cooling and moistening, with an excess of cooling during the night and an excess of moistening by day. The cloud would thus be always thickening by downward growth from cloud base.

Now we know from successive radio-sonde soundings that the cloud and air below warm slightly during the day and cool some 1·5°C. to 2°C. by night. Furthermore the turbulence above cloud as shown by the accelerometer records causes warmer, drier, air to mix with the cloud partly offsetting the tendency to cool by day and night, and also removing water vapour from the cloud. The cloud now grows downwards less quickly, but extends upwards from its top into the inversion layer. This upward growth is not observed by day and so subsidence must be introduced to maintain the level of cloud top, the rate of subsidence varying directly with the rate of mixing of the cloudy air with the warmer drier air above. A value of K of 10^4 cm.^{2}/sec. with a subsidence rate of about 3 mb./hr. is sufficient to cause the cloud to thin and perhaps dissipate at day and at night, the cloud warming by day and drying out by night.

However, for the first two flights considered, the cloud sheet persisted through the day and dissipated during the night which means that either the rate of subsidence increased from about 1 mb./hr. during the day to 3 mb./hr. at night, or the value of K at cloud top increased rapidly with the setting of the sun from about 3×10^3 to greater than 10^4 cm.^{2}/sec.

The first alternative may occur on a few occasions, but there is no direct evidence which supports a regular threefold increase in subsidence at night in winter anticyclones.

The second alternative is not altogether unreasonable. It is known that the cooling caused by long-wave radiation from cloud is immediately effective in the uppermost 50 ft. or so of the cloud. In the absence of solar radiation, the absorption of which by the cloud would partly affect this loss, the top of the cloud cools very rapidly and produces vigorous convective turbulence inside the cloud. The presence of a dry adiabatic lapse rate below cloud base ensures that this turbulence is effective down to near ground level, but at cloud top the rate of cooling is so great that the convection inside the cloud may well cause overshooting of the cloudy air into the drier air above, thereby increasing the rate of mixing and the value of K. This larger K partly affects the excessive cooling of the cloud and air below, and also increases the upward flux of water vapour. With a value of K 3×10^3 cm.^{2}/sec. by day, a rate of subsidence of about 1 mb./hr. is necessary to maintain the level of cloud top. With the increase in K at night this rate of subsidence cannot counteract the upward growing tendency of the cloud, and the cloud top rises causing an increase in height of the inversion base.

This variation during the night has been noticed by Neiburger during an investigation of the formation and dissipation of stratus cloud on the west coast of the United States. On several occasions when stratus cloud was present radio-sonde soundings were made every 3 hours over a period of 48 hours or more. One of the conclusions reached was that the height of the inversion base showed a marked diurnal variation, being a maximum at early morning and a minimum in the evening.

This agrees well with the above assumptions, for if the subsidence rate during the day and night is rather more than 1 mb./hr. then clearly the base of the inversion will lower during the day without necessarily causing the cloud to dissipate. At night the base of the inversion will rise by the upward growth of the cloud, until, at sunrise the longwave cooling begins to be offset by solar radiation.

As the cloud grows upwards the slope of the humidity mixing ratio above the cloud top decreases causing a lessening in the upward flux of water vapour from the cloud. But the slope of the inversion increases so that more heat enters the cloud top from the air above.

For the two cases when the cloud dissipated before dawn it is possible to calculate a value of K which will cause the cloud to thin sufficiently during the night. For values of K less than 3×10^3 cm.^{2}/sec. and a subsidence rate of about 1 mb./hr. both cloud base and top lower, the former at a greater rate than the latter so that the cloud thickness increases downwards. For values of K rather greater than 3×10^3 cm.^{2}/sec. and the same rate of subsidence, the cloud top rises into the inversion and the cloud base lowers so that the cloud thickness increases upwards and downwards. For K rather greater than 10^4 cm.^{2}/sec. and again a subsidence rate of 1 mb./hr., cloud base and cloud top rise, but the former more rapidly than the latter, causing a thinning of the cloud. A value of K of $2 \cdot 0 \times 10^4$ cm.^{2}/sec. is sufficient in both cases to cause the clouds to dissipate before dawn.

However such a large value of K is not required, for if the sheet becomes thinner than 50 ft. or so then its radiative properties change very rapidly and the cloud can no longer be regarded as a black body for calculations of long-wave radiative losses. In fact the outward flux falls from 10 to less than 1 cal./cm.^{2}/hr. The value of K also falls from 2×10^4 cm.^{2}/sec. but is probably still sufficient to cause a net warming of the cloud sheet. In its final stages, therefore, the cloud dissipates by warming produced by turbulent mixing with the air above, the increase in stability at cloud level preventing a rapid downward transfer of heat to the air below. This warming is clearly shown by radiosonde soundings made soon after the cloud has dissipated. The simple temperature profile of dry adiabatic–steep inversion found when cloud is present is completely modified by several more stable layers found below the inversion top.

Dr. James concluded with a few hints to forecasters, though he admitted that the problem was perhaps only formally solved.

(i) The cloud thins initially by drying caused by mixing with the drier air above, and finally dissipates by warming. Thus the hydrolapse and the steepness of the inversion directly above cloud top are important. Also, since in the early stages the drying is all important, thin cold clouds are more likely to dissipate than thin warm clouds.

(ii) The mixing at cloud top which causes the thinning of the cloud is intensified by the long-wave radiation loss from cloud top. The presence of an upper cloud sheet could thus restrict the cooling at cloud top, preventing the increase in K necessary to produce the required mixing. Also, since the cloud thins gradually then the longer the night the more likely the cloud is to dissipate, i.e. stratocumulus clouds formed in late December stand a better chance of dissipating than those formed in October or March.

(iii) Finally, the amount of subsidence is critical in determining the behaviour of the cloud. With too little subsidence the cloud builds upwards by day and night and will always persist. With too much subsidence the cloud top will lower during the day and possibly at night also and the cloud will always dissipate.

Dr. James hoped that with the arrival of the electronic computer some assistance would be given to the forecaster in estimations and forecasts of vertical motion.

The Chairman, *Dr. Sutcliffe*, opened the subsequent discussion by recalling some of his forecasting experiences on occasions of anticyclonic stratocumulus clouds. He hoped that outstation forecasters present at the meeting would participate in the discussion, in particular stating what method they employed for forecasting the dissipation or persistence of stratocumulus cloud.

Dr. Pasquill presented records made by a wind vane attached to the cable of a captive balloon. The instrument was sensitive only to vertical gusts and had a lag of about 0·1 sec. The records obtained near stratocumulus clouds resembled closely the accelerometer records shown earlier, the vertical motion being a maximum near cloud. Above cloud the records were quite smooth showing little vertical motion, whilst below cloud the traces indicated convective type turbulence.

Mr. Oddie suggested that cloud physicists did not devote sufficient attention to studies of layer clouds, being concerned mainly with the physical properties of cumulus. He wondered whether the argument was correct in assuming that the upper part of the hydrolapse in the inversion layer remained unchanged. He suggested that the effect of turbulence would be to round off the corner in the dew-point profile at this level. Dr. James agreed that this should be so, but pointed out that although the clouds had been in existence for 10 hours or more the sharp corner in the hydrolapse was still present. Also, the turbulence as indicated by the accelerometer records was a minimum at this height.

Dr. Robinson wondered whether the Kew radiation measurements were sufficiently accurate for such an analysis. He pointed out that a small change in K and in the radiation values can cause great changes in the budgets of the cloud.

Mr. Murgatroyd said that there were hopes of improved accuracy of measurements from aircraft with the new albedometer and Houghton's infra-red radiometer. He asked whether a shallow stable layer had been found below cloud base which corresponded with that present during the formation of cumulus cloud. Dr. James agreed that there might be such a layer during the day when the cloud was warming slightly, but it was necessary to assume a dry adiabatic below cloud base to simplify the arguments.

Mr. Sawyer said that the persistence of the cloud sheets suggest that they possess some self-balancing mechanism. He suggested that the value of K might well be connected with the depth of the cloud. It seemed curious that the argument presented required slow descent of air to maintain the cloud sheet.

Dr. Sutcliffe doubted if the present physical analysis was sufficient in itself to enable rules to be provided to a forecaster concerning the subsequent behaviour of the cloud. However, more accurate observations and a further clarification of the physical processes operating could lead to helpful results. He wondered if the terrain over which stratocumulus sheets form had any bearing on the subsequent behaviour of the cloud.

Mr. Zobel and *Dr. Tucker* described a test carried out at Bomber Command on the forecasting of the dissipation of stratocumulus sheets using the formula given by Dr. James in his Meteorological Research Paper. They obtained quite satisfactory results.

Mr. Dight described a flight to Holland when, with no cloud over England, layers of stratocumulus were found over the North Sea. He wondered what effect a change of sea temperature might have on the formation of the cloud. He also pointed out that icing risks were considerable in stratocumulus cloud.

Another speaker wondered if any precipitation was noticed below cloud on any of the flights analysed by Dr. James. He doubted whether subsidence could lower cloud base when it seemed that the base was determined by surface conditions. His advice to forecasters was to assume that the cloud would persist unless there is any change in synoptic features.

Mr. Taylor said that the profiles of dew-points above stratocumulus cloud as shown by radio-sonde soundings differed from those shown by Dr. James. The soundings usually show an increase in dew-point just above cloud and then a rapid fall off. A forecasting rule used by him was that if the ground turbulence was not sufficient to reach the cloud base then the cloud dispersed.

Mr. Murgatroyd suggested that the discrepancy in dew-point profiles was due to the lag in the humidity element of the radio-sonde.

Dr. Scrase did not agree but argued that the wetting of the gold-beaters' skin combined with the rise in temperature above cloud top could account for the discrepancy.

CUMULONIMBUS TOPS

Left: Near Shetland Islands, January 9, 1957.

Right: West of Biscay, January 23, 1957.

(see p. 243)

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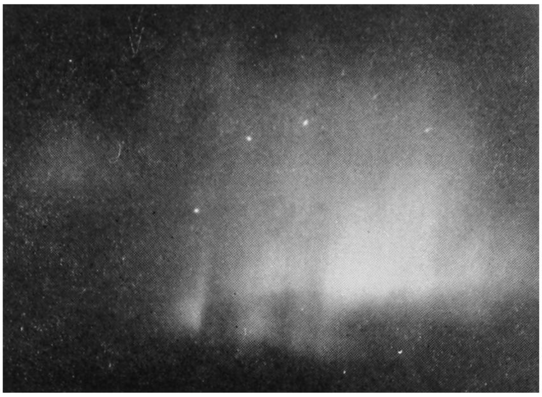
Crown Copyright

PILEUS BEFORE CUMULUS

Photographs taken at Stanmore, Middlesex, at about 0955 G.M.T. on May 27, 1957.

(see p. 245)



Photograph by J. Paton

Curtains

Photograph by J. Paton

Long rays with tops coloured a deep red

UNUSUAL DISPLAY OF AURORA, OCTOBER 26–27, 1956

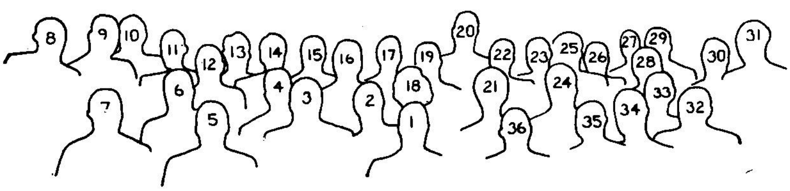
This display was characterized by very long red rays extending up to over 600 Km. The photographs were taken near the time of maximum at 2312 G.M.T. October 26. The features were quick moving so the photographs had to be somewhat underexposed. Prof. Størmer has informed Mr. Paton that he had not seen a display of this type since January 3–4, 1940.

[*To face p. 241*

Photograph by W. F. de Wildt

THE WORKING GROUP ON METEOROLOGICAL TRANSMISSIONS OF THE EUROPEAN REGIONAL ASSOCIATION OF THE WORLD METEOROLOGICAL ORGANIZATION. PHOTOGRAPH TAKEN AT UTRECHT IN APRIL 1957.

(see p. 241)



1.	Ockenden	(United Kingdom) *Chairman*
2.	Crone-Levin	(Denmark)
3.	Postma	(Netherlands)
4.	Mastrangeli	(Italy)
5.	Sundaram	(World Meteorological Organization)
6.	Popov	(U.S.S.R.)
7.	Cudny	(Poland)
8.	Ortmeyer	(Germany)
9.	Weber	(Switzerland)
10.	Venho	(Finland)
11.	Piper	(Germany)
12.	Saltin	(Finland)
13.	Rohan	(Ireland)
14.	Novotn´	(Czechoslovakia)
15.	Drevikovsky	(Czechoslovakia)
16.	Dési	(Hungary)
17.	Rafalowsky	(Poland)
18.	Denisova	(U.S.S.R.)
19.	Dené	(Netherlands)
20.	Bleeker	(Netherlands)
21.	Spanjer	*Interpreter*
22.	Methorst	*Interpreter*
23.	Magnusson	(Sweden)
24.	Dufour	(Belgium)
25.	Grandy	(United Kingdom)
26.	Van Der Ham	*Administrative Officer*
27.	Fokkens	(Netherlands)
28.	Silva de Sousa	(Portugal)
29.	Duner	(Sweden)
30.	Ribault	(France)
31.	Jakobsen	(Denmark)
32.	Lytskjold	(Norway)
33.	Leclercq	(France)
34.	Schutte	(Netherlands)
35.	Wusthoff	(Germany)
36.	Bell	(United Kingdom)

Dr. Robinson wondered if much importance could be attached to the term concerned with conditions below cloud in the statistical forecasting parameter. The absorption of solar radiation by the cloud is spread through a considerable depth below cloud, but the long-wave radiation from cloud top tends to cool only a shallow layer near the top. Dr. James agreed that perhaps this term was not very important, but pointed out that the net increase in the cooling at cloud top at night was the agency by which the mixing with the inversion layer was intensified. This could lead to the dissipation of the cloud.

Mr. Gold asked if any measurements of drop sizes had been made in cloud, particularly near cloud top. He also suggested that condensation high up in the troposphere could affect the radiation falling on the cloud top. Dr. James agreed that the presence of a high saturated layer and particularly an upper cloud sheet could modify the heat budget of the stratocumulus sheet, but on the occasions described no upper cloud was present.

Mr. Illsley wondered why a term involving the surface wind did not appear in the statistical forecasting parameter, since ground turbulence was largely dependent on the wind. The dry adiabatic lapse rate and constant humidity mixing ratio below cloud have indicated that turbulence was effective at least as far up as cloud base.

Mr. Sawyer pointed out that the origin of the turbulence was in the cloud and not at the ground, the mixing spreading downwards from the cloud to near the earth's surface.

Dr. Sutcliffe summed up and thanked Dr. James for opening the discussion.

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WORLD METEOROLOGICAL ORGANIZATION

Third Session of the European Working Group on Meteorological Transmissions

The Working Group on Meteorological Transmissions of the European Regional Association of the World Meteorological Organization met, under the Chairmanship of Mr. C. V. Ockenden (United Kingdom), in Utrecht from April 12 to 18, 1957. Some 30 representatives and advisers attended the meetings and 18 European countries were represented. In opening the Session, Dr. Warners, the Director-in-Chief of the Netherlands Meteorological Institute, recalled that it was also at Utrecht exactly ten years previously that the idea had been conceived of an international meteorological teleprinter network for Western Europe. He was glad to observe that several of those present were included in the list of representatives who attended the earlier meeting in 1947.

A very full agenda had been prepared for the session and to expedite the work, two main committees were formed under the Chairmanship respectively of Dr. Postma (Netherlands) and Mr. Bell (United Kingdom). The most important items discussed concerned the method of connecting the Western European Meteorological Teleprinter Network and a similar network in eastern and central Europe, and the possibilities for reorganizing the overall methods of exchange of basic data by land-line, radio, radio-teleprinter and facsimile within the European Region. These problems formed the subject of Resolutions at the last Regional conference, an account of which appeared in the *Meteorological Magazine* for June 1956. Regarding the first item, statistics relating to the quantity of information of various categories had to be examined to determine how the material could best be disseminated to schedules which involved the minimum of delay. It was finally agreed that, pending the implementation of any major reorganizations in communications which might arise as a result of a joint World Meteorological and International Civil Aviation Organizations meeting to be held next year, the East and West exchange should be carried out over duplex circuits between Frankfurt on Main and Prague and Frankfurt on Main and Potsdam. Lists were produced of the selected stations to be included for various countries both for surface and upper air observations for different synoptic hours for guidance.

Regarding the possibilities of reorganising the general framework for the exchange of basic data, some far-reaching proposals for an extensive use of radio-facsimile broadcasts were put forward by the representative of Western Germany but otherwise there were no firm proposals for a radical change in the system of Continental, sub-Continental and Territorial radio broadcasts or in the existing trunk circuits used in the teleprinter network. It was, however, recommended that countries concerned should forward to the World Meteorological Organization Secretariat by August 1, details of the extent to which they could implement proposals for facsimile and radio-teleprinter broadcasts. Several representatives were of the opinion that more data were circulating between the three main centres Dunstable, Paris and Frankfurt, than were actually required or used by countries connected to the network. It was considered therefore, that before a realistic approach could be made to the general problem of routine and scheduling, a first step should be to circulate a questionnaire to all countries in the Region asking for precise details of their minimum requirements. Replies to the questionnaire will be consolidated by the chairman and the comments of members obtained by correspondence so that further consideration can be given to modifying schedules and circuits and, if necessary, "areas of responsibility" of various centres, by a small *ad hoc* group to be convened at an appropriate time well before the joint World Meteorological and International Civil Aviation Organizations meeting.

A large number of other outstanding matters were discussed and recommendations adopted. These included a technical examination of reports on the 6-month trial reception in Europe of the radio-teleprinter broadcasts from New York, a review of the data which are exchanged between Europe and

North America, the block-grouping on a time-sharing basis of wireless telegraphy Territorial broadcasts from Denmark, Sweden, Norway and Finland, changes in schedules resulting from the change of standard hours for upper air observations from 03, 09, 15, 2100 to 00, 06, 12, 1800, the means of notification of changes to the contents, schedules, frequencies and call signs of radio broadcasts and the results of experience gained in the operation of the plan for broadcasts by the Ocean Weather Ships. In addition, the opportunity was taken to review old resolutions and recommendations and frame amendments where necessary.

During the Session delegates were shown the work of the Royal Netherlands Meteorological Institute at De Bilt where they were also afforded the opportunity of attending a demonstration of the latest fully automatic MUFAX Weather Chart Equipment. The Director-in-Chief of the Meteorological Institute kindly invited representatives to a cocktail party towards the end of the Session. Much of the more detailed work had to be passed to *ad hoc* sub-committees and on some days it was necessary for these to carry on until well after the time that most of the residents of Utrecht had retired for the night. Sunday provided a welcome break and many delegates had an opportunity of visiting Keukenhof Park near Lisse, the showpiece of the Dutch bulb industry.

NOTES AND NEWS

Photographs of cumulonimbus tops

The photographs of cumulonimbus tops (facing p. 240) were taken from aircraft of the Royal Air Force. In each case the pilot rightly considered that the cloud structure would be of interest to meteorologists.

On January 9, 1957, Flying Officer B. W. Crocker was flying northwards over the Shetland Islands at an altitude of 40,300 ft. He had been flying over two to three oktas of cumulonimbus cloud, tops estimated at 20,000 to 25,000 ft. and four to five oktas of cumulus cloud, tops estimated at 10,000 ft. At 1200 G.M.T., just north of the islands, a line of cumulonimbus tops appeared to starboard, each top being surrounded by a ring of cloud. The aircraft carried a camera mounted horizontally, and the pilot banked his aircraft before making several exposures.

A vigorous depression was centred over north Scandinavia at 1200 G.M.T., and the associated cold front was moving south-eastwards across Denmark and south-east England. A trough in the polar air extended south-westwards off the Norwegian coast to just north of the Shetlands. There was very little wind shear in the vertical in the deepening westerly flow of polar air over the Shetlands during the morning. The surface wind at Lerwick veered between 1300 and 1400 G.M.T., and the afternoon ascent there showed that a veer to north of west had occurred at all heights up to the cold air tropopause at 22,300 ft. There is little doubt that the line of cumulonimbus clouds illustrated in the photograph occurred along and just ahead of the trough line, with cloud tops near the tropopause. The high degree of symmetry, particularly noticeable in the cumulonimbus in the foreground, was made possible by the absence of any appreciable shear in the westerly flow of deep cold air just south of the trough line.

The cumulonimbus cloud in the foreground is in an active state of growth. Vigorous convection at lower levels on the upwind side of the cloud is well illustrated. The tropopause temperature was −48°C. Despite the ice crystal nature of the cloud top, well illustrated by the predominance of fibrous structure, it will be noticed that several bubbles there have a fairly well defined outline, indicative of continued ascent. The sun is catching the sides of protruding towers on the south-west side of the cloud top, and the tendency for the tops of these towers to spread outwards and away from the centre of the convection cloud is quite well marked. The ring of cloud round the top of the cumulonimbus is the anvil cloud which is spreading outwards in all directions as the glaciated towers accumulate at the top of the convection cloud. This spreading outwards is assumed to occur just at or below the tropopause. New bubbles penetrating the top of the convection cloud are reaching a somewhat higher level than that of the surrounding anvil cloud. The large bubble near the centre is casting a well defined shadow towards the north. Shadows on the north side of the cloud obscure detail there, but there is evidence of thin cloud overlying the spreading anvil cloud, and this may be the remnants of pileus cloud.

The pilot had to bank his aircraft in order to photograph this cloud, therefore it has not been possible to calculate the dimensions of the cloud top in the usual way, which requires a series of photographs taken in straight and level flight and with a camera at fixed and known declination. However, an estimation of the dimensions of the top of the cloud in the foreground can be made by assuming that the general cloud field of convection cloud tops and associated cirrus occurs at the tropopause. From the dip below the horizontal of the horizon line of this cloud field an estimation of the declination of the camera can be made. An estimation of the dimensions of the top of the convection cloud can then be made.

The north–south diameter of the inner core of active convection probably lies between 4 and 4½ miles, whilst the complete north–south diameter including the anvil cloud is about 6 miles. The complete east–west diameter is probably of the order of 7 to 8 miles. A diameter of the inner core of active convection of the order of 4 to 4½ miles agrees well with the depth of the cloud, which must have been about 4 miles.

The cumulonimbus clouds on the horizon to the right are considerably higher than those nearer the camera. These distant clouds are probably over Norway.

The photograph of January 23, 1957 was taken by Squadron Leader D. A. Hammatt, A.F.C., D.F.M. in a flight over the Atlantic to the west of Biscay. The aircraft was flying north-north-westwards in the early afternoon at a height of 8 miles, the horizontally mounted camera was pointing west-south-westwards, and the aircraft was banked during the exposure.

The photograph shows a field of convection cloud in maritime polar air about 200 to 300 miles behind a cold occlusion. It consists largely of relatively small cumulus clouds with larger convection cloud here and there, and some extensive patches of cirrus. The photograph is dominated by the extensive top of a cumulonimbus cloud. Wind shear in the cloud-laden air is small, with the wind blowing towards the bottom left-hand corner of the photograph.

There is a good break in the clouds just downwind of the extensive cumulonimbus cloud, but details of the side of this cloud are obscured by cirrus cloud. The top of the cumulonimbus cloud is still being fed by many bubbles rising into it, and the spreading outwards from the top of the convective column of the ice-crystal anvil cloud is well illustrated. The height of the cloud top is estimated to be about 20,000 ft., and it is about 7 miles across.

J. HARDING

Pileus before Cumulus

Up to about 0930 G.M.T. on May 27, 1957, the sky was practically cloudless at Bentley Priory, Stanmore, with good visibility and a moderate north-east wind. About 0930 numerous lenticular clouds began to form quickly to the north-east, some with fantastic shapes like a Loch Ness monster, and then in five to ten minutes small cumulus began to form under each cloud so that the sky was about five oktas covered with a double layer. In places the cumulus cloud seemed to touch the pileus and both seemed to move together with the wind.

The temperature was 61°F., and the dew-point about 39°F.; thus the bases of the cumulus cloud were about 5,000 feet and the tops mostly around 6,000 feet. Judging from the Hemsby temperatures at 0001 G.M.T. on the 27th, there was an inversion of 3°F. at about 8,000 feet with a rather moist layer just below which might determine the height of the pileus clouds.

The photographs between pp. 240 and 241 were taken looking south-east within a couple of minutes of 0955 G.M.T.

R. M. POULTER

Standard deviation of the height of the 500-mb. surface over the North Atlantic

The working charts of the Central Forecasting Office of the Meteorological Office provided the basic data for this investigation. The 1500 G.M.T. charts for each day of January, April, July and October for the period 1949–53 were used; from them values of contour height were read off, correct to the nearest 100 ft., at the points of the network 35°N. 65°N., 80°W. 30°E. Values of the standard deviation, σ_{500}, were then computed for each point of the network. These values of σ_{500} were used in connexion with other work*; but since it was considered that they might be of interest in themselves they were plotted on four charts, and isopleths were drawn. They are shown in Figs. 1–4 on pages 246–9.

A. F. JENKINSON

Altocumulus in a standing wave

In a note accompanying photographs of altocumulus published in the *Meteorological Magazine* for ~~July~~ June 1957 (between pp. 176 and 177) a superscript minus sign was omitted from the dimensions of Scorer's parameter.

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* JENKINSON, A. F.; The relationship between standard deviation of contour height and standard vector deviation of wind, with practical applications. *Met. Res. Pap., London*, No. 869, 1954.

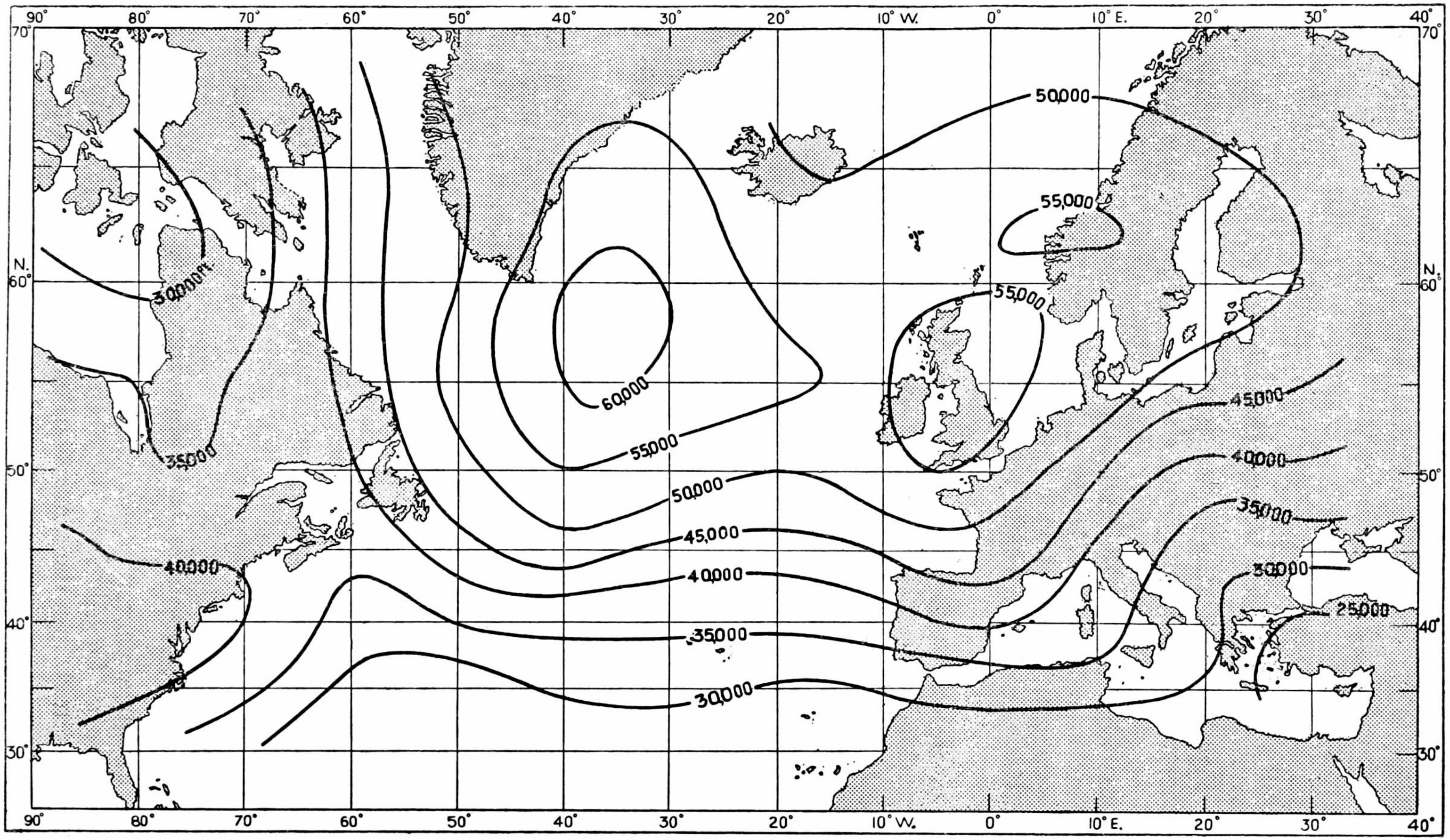

FIG. 1—STANDARD DEVIATION OF HEIGHT OF 500-MB. SURFACE, 1500 G.M.T. FOR JANUARY

(see p. 245)

N.B.—The plotted values of the isopleths must be divided by 100, thus 60,000 should be 600 ft.

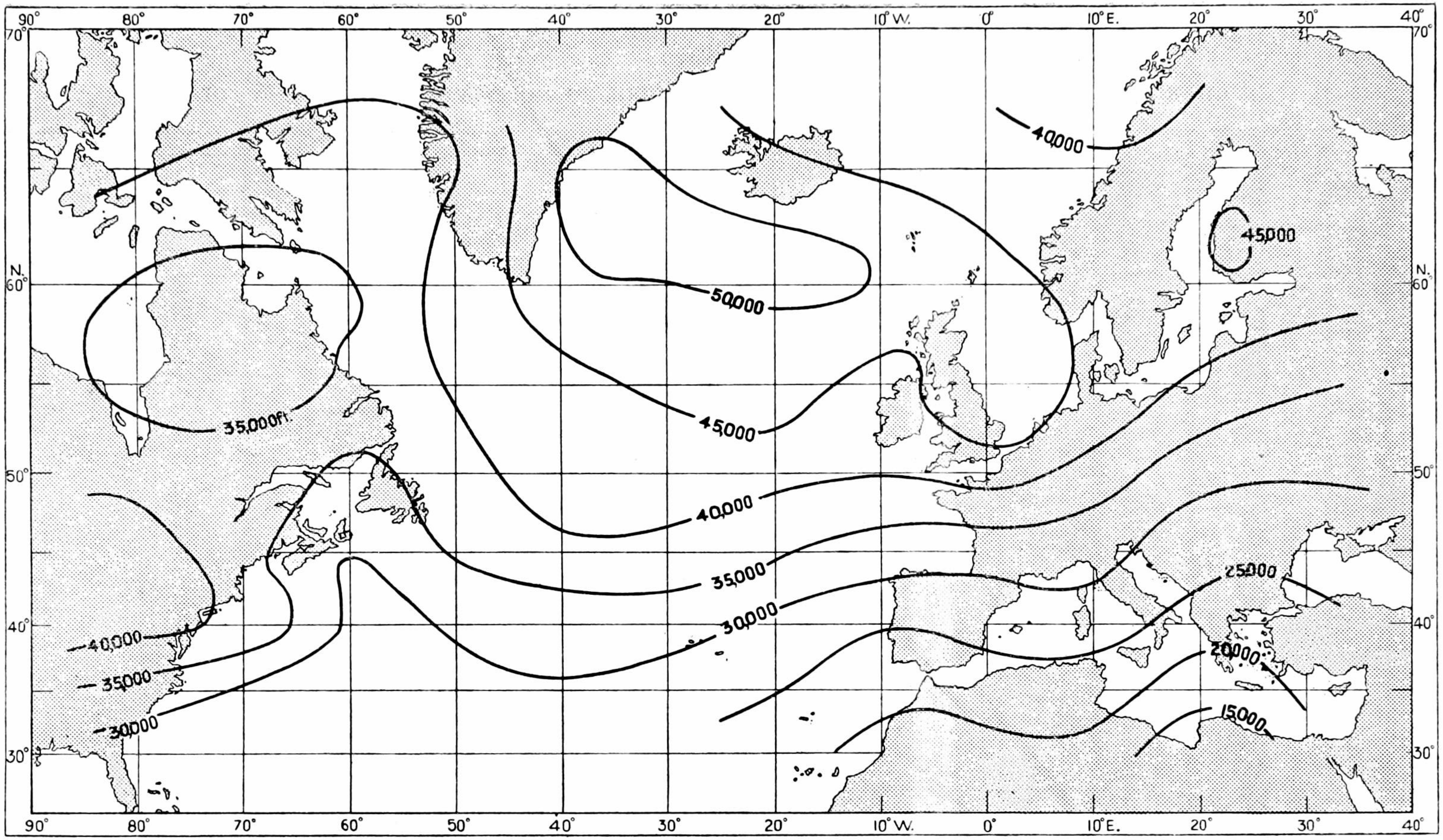

FIG. 2—STANDARD DEVIATION OF HEIGHT OF 500-MB. SURFACE, 1500 G.M.T. FOR APRIL

(see p. 245)

N.B.—The plotted values of the isopleths must be divided by 100, thus 50,000 should be 500 ft.

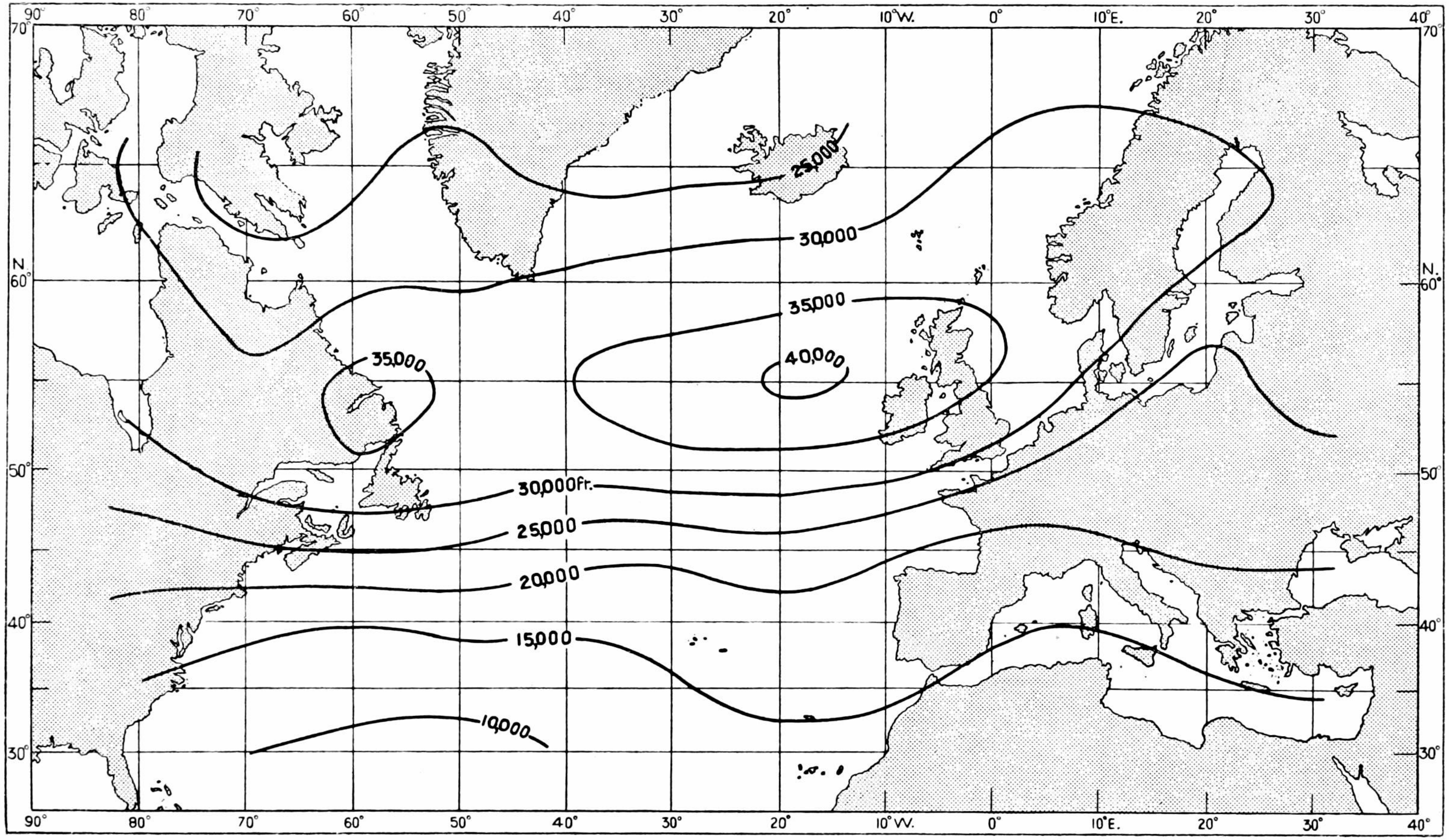

FIG. 3—STANDARD DEVIATION OF HEIGHT OF 500-MB. SURFACE, 1500 G.M.T. FOR JULY
(see p. 245)

N.B.—The plotted values of the isopleths must be divided by 100, thus 40,000 should be 400 ft.

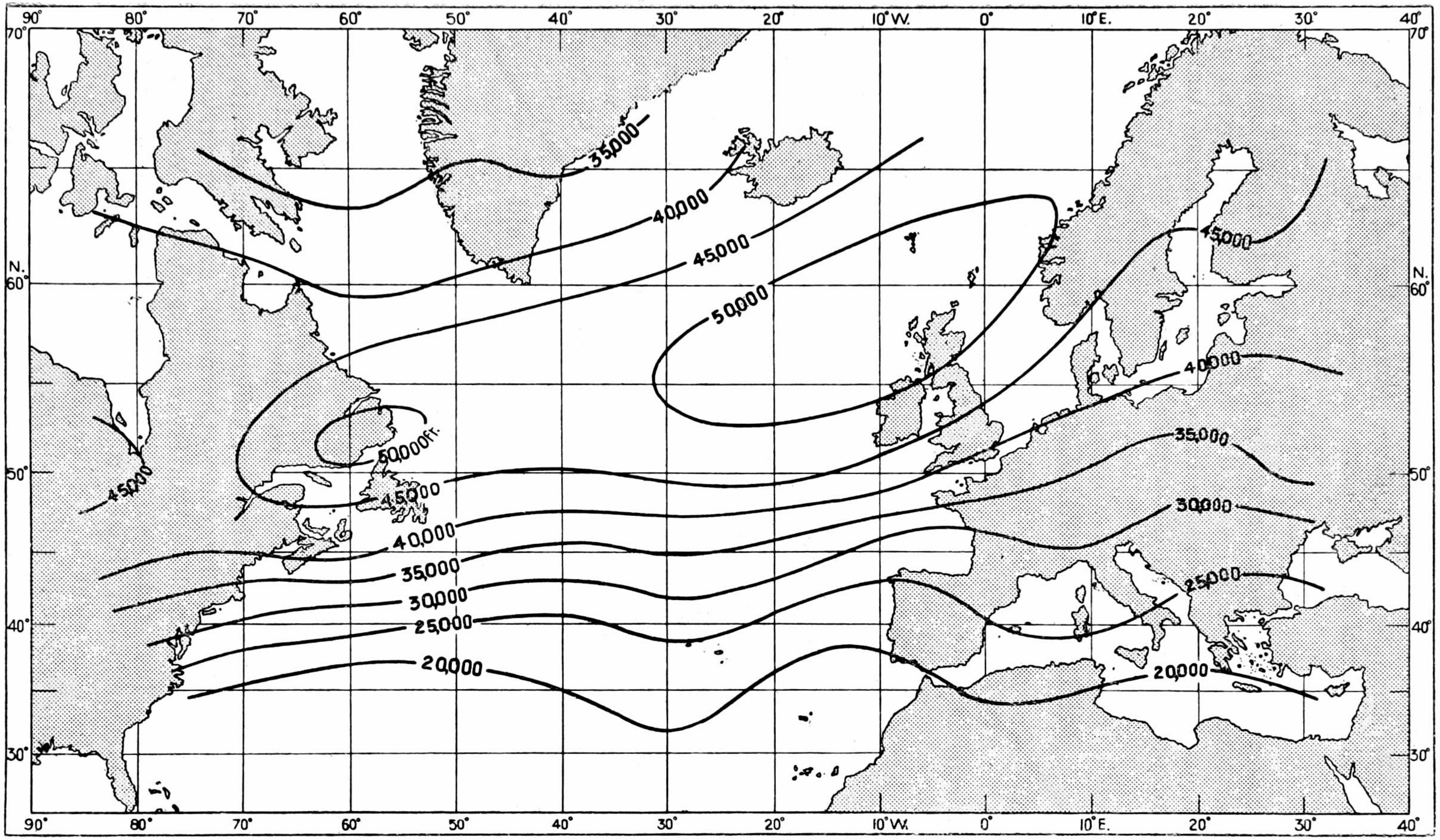

FIG. 4—STANDARD DEVIATION OF HEIGHT OF 500-MB. SURFACE, 1500 G.M.T. FOR OCTOBER

(see p. 245)

N.B.—The plotted values of the isopleths must be divided by 100, thus 50,000 should be 500 ft.

HONOURS

I.S.O.

The Birthday Honours List, June 1957, announced the appointment of Dr. J. Glasspoole, Principal Scientific Officer, Meteorological Office, to be a Companion of the Imperial Service Order.

POLAR MEDAL

In the Supplement to the *London Gazette* for June 28, 1957, it was announced that the Polar Medal has been awarded to Mr. D. W. S. Limbert for good services as a member of the Advance Party of the Royal Society Antarctic Expedition for the International Geophysical Year.

METEOROLOGICAL OFFICE NEWS

Retirements.—*Miss E. E. Austin* relinquished her temporary appointment as Senior Scientific Officer on June 30, 1957, in which capacity she had served after her retirement on August 9, 1955. Miss Austin joined the Office in July 1918 as secretary to Sir Napier Shaw. In November 1920 she was seconded for duty with Sir Napier who was then Professor of Meteorology at the Imperial College of Science and Technology. She remained with Sir Napier until 1935 and during these years she assisted in the preparation and publication of the four volumes of Shaw's *Manual of Meteorology.* In 1935 she was posted to the Climatology Branch and became responsible for the preparation of the various handbooks on Weather over the Oceans and Coastal Regions. In 1948 she was appointed Head of the newly formed World Climatology Branch and in 1951 became Head of the new Upper Air Climatology Branch. She retired in 1955 from the latter post but continued to serve in the same Branch in a temporary capacity. Miss Austin was well known in international meteorological affairs. She accompanied Sir Napier Shaw to several International Union of Geodesy and Geophysics meetings and was later one of the British representatives on the World Meteorological Organization Commission for Aerology.

Mr. E. V. Newnham, Senior Scientific Officer, retired on June 30, 1957. He joined the Office in September 1914 as a Graduate Assistant in the Forecast Division. Apart from a period of twelve months in 1915–16 at Benson the whole of his 42 years' service has been spent at Headquarters in the Forecast, Climatological, Instruments and World Climatology Divisions. At the time of his retirement he was serving in the World Climatology Branch at Harrow.

Mr. A. W. Berry, Senior Experimental Officer, retired on June 16, 1957. He first worked at the Royal Observatory, Greenwich, and after service in the London Rifle Brigade and the Royal Air Force during the First World War he joined the Office in June 1921 as a Technical Assistant. The whole of his service in the Meteorological Office has been spent at aviation outstations. Since 1949 until his retirement he has been officer-in-charge of the Meteorological Office at Birmingham (Elmdon) Airport.

Mr. C. C. Newman, Senior Experimental Officer, retired on June 29, 1957. He joined the Office in August 1914 as a Boy Clerk in the Forecast Division. During the first World War he served in the Royal Naval Air Service from

January 1917 until October 1918 when he was gazetted a Second Lieutenant in the Royal Air Force. He returned to the Forecast Division in September 1920 and since 1923 he has been mainly concerned with forecasting for the Royal Air Force. Mr. Newman served over twenty years at various stations in the Middle East including some ten years at Aden where he was serving at the time of his retirement.

Sports activities.—Mr. J. H. Keers, London Airport, was runner-up in the Civil Service Lightweight Boxing Championship, at King Edward Buildings, London, on April 11.

The Air Ministry Annual Sports were held at the White City Stadium on June 19, and marked the end of the year for the competition for the Bishop Shield which is presented to the department gaining the highest number of points in all the Air Ministry sports competitions held during the year.

This year the Office was runner up in the competition having failed to retain the Shield they had held for eight consecutive years. Miss E. Forster won the Ladies' 100 yards Championship, Mrs. A. Brown was second in the Ladies' High Jump, Miss B. Abbott was second in the Ladies' Long Jump and Mr. D. G. Maunder was second in the 440 yards Championship. The Office was second in the Men's Inter-Divisional Relay Championship and lost the Tug-of-War by two pulls to one after a long and close struggle.

The Harrow Social and Sports Committee held its Annual Sports Meeting on the evening of Wednesday, June 26 at the Headstone Manor Ground. The events were open to all members of the Meteorological Office and there were many entries for the track events, there being 11 starters for the half-mile and 14 for the one mile. Results of the four Meteorological Office Championship events were as follows:

Men's Hundred Yards ...	Mr. P. H. Anderson (Kew)
Half Mile	Mr. G. F. Burton (Kew)
One Mile	Mr. G. F. Burton (Kew)
Ladies' Hundred Yards ...	Miss E. Forster (London Airport)

Miss M. Boucher won the Ladies' High Jump with 4 ft. 5¾ in., a new record for Harrow Sports.

The weather was excellent and many visitors, including Sir Graham and Lady Sutton, came from Victory House, Dunstable, London Airport, Kew Observatory and Stanmore. Several novelty competitions and races proved popular. Mrs. S. P. Peters presented the prizes.

REVIEW

Weather analysis and forecasting, Vol. II. By S. Petterssen. 9 in. × 6 in., pp. xii + 266, *Illus.* McGraw-Hill Publishing Co. Ltd., London, 1956. Price: 45*s*. Volume I of this publication, under the sub-title "Motion and motion systems", was published early last year, and is now followed by the second and concluding volume, on "Weather and weather systems". Broadly, the first volume was directed towards the evolution of forecast charts and the understanding of the larger-scale mechanism of the atmosphere. Volume II deals primarily with the visible elements of weather such as cloud, fog and precipitation, and with their forecasting on every scale of development.

Chapter 20, the first in the new volume, is on the production and transformation of air masses. It deals with the ways in which the atmosphere gains or loses heat and moisture by direct exchange, and then with adiabatic changes in the vertical temperature structure consequent on changes in the vorticity of the moving air stream. Temperature and humidity relationships are the subject of the next chapter, including the essential features of thermodynamic diagrams. This is followed by an elementary description of clouds and precipitation and their formation; much of the text and a number of the illustrations here are taken from the first edition.

Up to this point the material of this volume is fundamental and a necessary part of a textbook, but much of it is such as to provide little scope for attractive presentation: it includes a good deal about some of the basic tools of the meteorologist, and there are few alternative ways of describing a tool. However, the subject which follows is largely a post-war development. J. C. Thompson contributes a chapter on quantitative precipitation forecasting, a branch of research for which the meteorologist in America is perhaps the best equipped by reason of the shape and extent of his observational network. Two distinct methods are outlined. One is the wholly physical approach in which the precipitable water, with the assumptions that term involves, is estimated from the temperature structure and calculated ascent of the atmosphere. This provides a broad pattern of the expected rainfall distribution over a large area. The other method is the statistical one, described more fully in a later chapter, which is based on observed relationships between the rainfall at a place and miscellaneous parameters which are more or less independent of each other. This wholly empirical method is of course widely used in local forecasting of various elements, fog-prediction diagrams being a familiar example.

Mist, fog and stratus are the contents of the next chapter, a subject which makes interesting reading in any textbook because the main principles are clear-cut, yet in detail these are major hazards to the aviation forecaster. The author gives a certain amount of information on methods of predicting the formation of fog, but little on either the process or the forecasting of its dispersal. The term "stratus" is not used in its generic sense, for one finds that when stratocumulus and nimbostratus were defined a few pages earlier they were in fact making both their entrance and their exit. The next chapter, a long one, is shared between convective clouds and "weather", the latter covering thunderstorms, squalls, tornadoes and other violent phenomena which are so well suited to mesoanalysis, a technique to which some prominence is given in the concluding pages.

Following a discussion of some actual synoptic developments, introduced by way of recapitulation of the physical processes previously discussed, the author includes a short chapter on local forecast studies, which deals with forecasting by means of prediction diagrams and regression equations. In effect the aim is to express in usable form the kind of knowledge an experienced forecaster accumulates from familiarity with developments on synoptic charts. The method of handling the information, although quite simple, is a reminder that, although the meteorologist may be able to give a fairly adequate explanation of the mechanism of weather, when the question to be answered is "Will it happen here and, if so, when?" the problem is sometimes best put to the statistician who knows a little meteorology.

A further step towards objectivity is illustrated by the last chapter in the book, in which Dr. T. F. Malone contributes an interesting account of the application of synoptic climatology to forecasting. The problem he describes is that of using climatological data in conjunction with past and predicted charts in order to produce objective forecasts of various meteorological elements. The method applied so far has been to relate the value of an element, such as temperature, to a sequence of sea-level circulation patterns, and thus to forecast its future change as a function of the change expected in the circulation. To make the circulation pattern mathematically tractable, the isobaric surface is approximated to the sum of a number of orthogonal surfaces. Examples are given of what is in principle a wholly objective forecast of mean daily temperature at one place, but it is perhaps too early to form an opinion as to whether other elements will show an equally consistent relationship with the surface circulation patterns. Moreover, the greater promise is doubtless in medium-range forecasting, which necessarily smooths out the small-scale features.

Much of Volume I of "Weather analysis and forecasting" brings home to the reader the rapid progress of meteorology, and indeed the book can be dated by its contents. This is not true to the same degree of the second volume, which in the main deals with subjects in which advances have been made on narrower fronts. The book as a whole is an admirable and timely production. It is a common grievance of the meteorologist that he gets too little opportunity for consolidating his knowledge. He will be grateful to Dr. Petterssen for a book that is unusually concise, lucid and coherent.

C. J. BOYDEN

OFFICIAL PUBLICATION

The following publication has recently been issued:—

PROFESSIONAL NOTES

No. 121—*A statistical study of the variation of wind with height.* By C. S. Durst, B.A.

The variation of wind with height is examined by means of vector correlation coefficients in a similar manner to the variation of wind with distance and time published in *Geophysical Memoirs* No. 93.

The correlation coefficients are given for the British Isles up to 100,000 ft., for Habbaniya up to 40,000 ft. as indicating the conditions in middle latitudes, for Nairobi indicating conditions in the tropics and for Barrow, Alaska, indicating conditions in the far north.

RAINFALL AT TENBY. In the Rainfall Table for April 1957 published in June the percentage of average for Tenby should read 14.

WEATHER OF JUNE 1957

The low pressure area on the western Atlantic was displaced south and east of its normal June position towards mid ocean (lowest mean pressure 1010 mb. near 52°N., 37°W.): the intensity indicated by the central pressure was about normal, but implied considerably above normal south-westerly wind between 50°N. and the Azores. The Atlantic low pressure system presented the strongest circulation in northern latitudes on the mean pressure map for the month, and must have been associated with the reported distribution of excessive amounts of ice on the north-western part of the ocean. The highest pressure in the subtropical Atlantic (1020 mb., near the Azores) was 6 mb. below normal.

The polar anticyclone was intensified and displaced towards the Atlantic sector, giving a highest mean pressure of 1020 mb. in east Greenland (the pressure anomaly was +6 mb. in this area). There was a very wide region of rather above normal pressure over Europe and the eastern Atlantic between 10 to 20°W. and 20°E. and 35 to 65°N.

Pressure was below normal over most of North America, the anomaly reaching −4 mb. over a wide area about Hudson's Bay. Pressure was below normal by a similar amount over north Russia. The lowest mean pressures in the northern hemisphere were believed to be 1008 mb. over the White Sea and 997 mb. over north-west India, the latter being a normal value for the monsoon system.

There was a marked northerly and north-westerly stream of Arctic air between the Greenland high and the White Sea depression, giving rather low mean temperatures for June in Greenland, Scandinavia and eastern Europe in spite of abnormally little ice and high water temperatures in the East Greenland Sea (a legacy of the very mild winter in this sector). Western and central Europe came more often under the influence of warm air from the south and mean temperatures were up to 3°C. high for June, with noteworthy heat waves reported in many places towards the end of the month: on the 30th temperature reached 34°C. in Paris and similar values were general over the region between Madrid, London, Hanover and Rome.

Mean temperatures for the month were 2 to 3°C. above normal on the American Atlantic seaboard near New York and Washington, also over the Rockies in California and the desert states and in Alaska; most of the rest of North America was cool, the anomaly reaching −3°C. in central Canada.

June was dry in Iceland, over much of Europe between 45 and 55°N. and in the Baltic, but rainfall excesses were reported over the greatest parts of North America, northern and southern Europe and the Mediterranean.

In the British Isles June was warm and unusually sunny; the pressure features were somewhat indefinite, but the weather was broadly, though weakly, cyclonic during the first ten days and anticyclonic during most of the remainder of the month.

Although there was some rain in Scotland, the first two days of the month in England and Wales were generally sunny and dry with afternoon temperatures reaching the seventies, but on the 3rd thunderstorms developed over a wide area in south-east England giving many places their first rain for ten days. Weather was cooler with occasional rain or showers alternating with good sunny periods during the next few days, but there were outbreaks of thundery rain and thunderstorms with unusually heavy rain in places from the 8th to the 10th as a depression moved slowly from our South-west Approaches to the North Sea. On the 8th 3·05 in. of rain fell in 2 hr. during a thunderstorm at Nantwnalle, Cardiganshire, while Camelford had the worst thunderstorm ever experienced in Cornwall; 7·06 in. of rain was recorded there in 12 hr., 5·48 in. of which fell between 13 h. and 16 h. Pressure rose rapidly in the cool northerly air stream behind the depression and by the 12th an anticyclone was situated over southern England, which later moved slowly north, giving about 10 days of brilliantly fine, warm weather. Rhayader, in Wales, reported a pressure of 1037·4 mb. on the 13th, nearly 1 mb. more than the highest June pressure previously recorded in the British Isles (in 1870). During this fine period Stonyhurst reported nine successive days, from 12th to 20th, with 15 hr. or more sunshine and Oban had four consecutive days with at least 16 hr. sun. By the 14th afternoon temperatures exceeded 80°F. at many places in southern England and at both London Airport and Hurn temperatures rose into the eighties on five successive days from that date and reached 87°F. at both places on the 17th and 18th. On the 18th thunderstorms again broke out at many places in Wales and southern England—Andover had a "noteworthy" fall of 1·68 in. of rain in 2 hr. during a storm—but although temperatures were about 10°F. lower the following day there was no general break in the fine weather until the 22nd. On that date a cool northerly air stream spread southwards over the country bringing outbreaks of thundery rain to many areas and maximum day temperatures down into the sixties generally. Fairly widespread ground frost occurred, particularly in the north; at Ross-on-Wye the grass minimum temperature was 29°F. on the 23rd, the latest date with ground frost in nearly a hundred years of records at that station, while further north screen temperature fell as low as 26°F. at Eskdalemuir. On the 26th an anticyclone over the Bay of Biscay moved north-eastwards over France and intensified, and associated with this development very warm tropical air spread over the British Isles. The last three days were the warmest of the month with temperatures reaching 90°F. in many southern and midland districts. Temperature did not fall below 70°F. on the Air Ministry roof, Kingsway, on the night of the 28th–29th—the warmest night in London since September 1949—and the following day reached 95°F. at Northolt and 96°F. at Camden Square, London, the latter being the highest temperature recorded in the British Isles during June since 1858.

It was the sunniest June on record at many stations; at Worthing since 1899 and at Stonyhurst since 1881. Rainfall over England and Wales was about 80 per cent. of the averages, the third successive month with below average fall; the total for the period April–June was the lowest for these three months since 1921. Although the weather has been almost perfect for harvesting the rather light hay crop, farmers have been severely handicapped in other directions by the very warm dry weather. Second growth grass has been negligible, milk yields have declined rapidly and great difficulty has been experienced in planting out and establishing autumn and winter vegetables.

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 ...	96	26	+1·6	79	−3	143
Scotland	87	26	+1·0	100	−2	134
Northern Ireland ...	82	32	+0·9	73	−6	155

RAINFALL OF JUNE 1957

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ...	·61	30	*Glam.*	Cardiff, Penylan ...	·96	38
Kent	Dover	·21	11	*Pemb.*	Tenby	3·31	138
„	Edenbridge, Falconhurst	1·54	70	*Radnor*	Tyrmynydd	2·60	80
Sussex	Compton, Compton Ho.	1·81	73	*Mont.*	Lake Vyrnwy	1·74	54
„	Worthing, Beach Ho. Pk.	1·59	91	*Mer.*	Blaenau Festiniog ...	3·90	60
Hants.	St. Catherine's L'thouse	1·06	60	„	Aberdovey	2·69	99
„	Southampton (East Pk.)	1·69	84	*Carn.*	Llandudno	2·26	119
„	South Farnborough ...	1·13	59	*Angl.*	Llanerchymedd ...	2·15	91
Herts.	Harpenden, Rothamsted	2·29	102	*I. Man*	Douglas, Borough Cem.	1·79	70
Bucks.	Slough, Upton	0·69	34	*Wigtown*	Newton Stewart ...	1·75	66
Oxford	Oxford, Radcliffe ...	2·19	98	*Dumf.*	Dumfries, Crichton R.I.	1·07	42
N'hants.	Wellingboro' Swanspool	2·39	114	„	Eskdalemuir Obsy. ...	1·67	53
Essex	Southend, W. W. ...	1·11	59	*Roxb.*	Crailing...	0·80	36
Suffolk	Felixstowe	·98	57	*Peebles*	Stobo Castle	2·57	110
„	Lowestoft Sec. School...	1·95	108	*Berwick*	Marchmont House ...	1·15	50
„	Bury St. Ed., Westley H.	1·65	79	*E. Loth.*	North Berwick Gas Wks.	·87	53
Norfolk	Sandringham Ho. Gdns.	1·93	89	*Midl'n.*	Edinburgh, Blackf'd. H.	1·17	59
Wilts.	Aldbourne	1·56	63	*Lanark*	Hamilton W. W., T'nhill	2·01	91
Dorset	Creech Grange... ...	1·19	52	*Ayr*	Prestwick	2·13	111
„	Beaminster, East St. ...	2·32	103	„	Glen Afton, Ayr San. ...	1·78	59
Devon	Teignmouth, Den Gdns.	1·15	60	*Renfrew*	Greenock, Prospect Hill	2·41	77
„	Ilfracombe	1·33	61	*Bute*	Rothesay, Ardencraig ...	...	...
„	Princetown	2·62	65	*Argyll*	Morven, Drimnin ...	3·96	128
Cornwall	Bude, School House ...	2·72	135	„	Poltalloch	3·79	124
„	Penzance	1·96	88	„	Inveraray Castle ...	4·65	117
„	St. Austell	4·16	160	„	Islay, Eallabus	2·52	96
„	Scilly, Tresco Abbey ...	·75	43	„	Tiree	2·37	93
Somerset	Taunton	3·81	216	*Kinross*	Loch Leven Sluice ...	1·56	71
Glos.	Cirencester	1·34	54	*Fife*	Leuchars Airfield ...	0·73	44
Salop	Church Stretton ...	1·75	69	*Perth*	Loch Dhu	2·71	65
„	Shrewsbury, Monkmore	1·58	76	„	Crieff, Strathearn Hyd.	2·06	78
Worcs.	Malvern, Free Library...	1·69	73	„	Pitlochry, Fincastle ...	1·37	66
Warwick	Birmingham, Edgbaston	1·77	69	*Angus*	Montrose Hospital ...	1·20	72
Leics.	Thornton Reservoir ...	1·42	66	*Aberd.*	Braemar	1·60	82
Lincs.	Boston, Skirbeck ...	1·98	109	„	Dyce, Craibstone ...	3·27	175
„	Skegness, Marine Gdns.	1·43	79	„	New Deer School House	2·46	124
Notts.	Mansfield, Carr Bank ...	1·44	64	*Moray*	Gordon Castle	3·04	149
Derby	Buxton, Terrace Slopes	2·12	66	*Nairn*	Nairn, Achareidh ...	1·99	112
Ches.	Bidston Observatory ...	1·11	50	*Inverness*	Loch Ness, Garthbeg ...	1·99	87
„	Manchester, Ringway...	1·48	61	„	Loch Hourn, Kinl'hourn	6·21	126
Lancs.	Stonyhurst College ...	1·99	65	„	Fort William, Teviot ...	2·98	84
„	Squires Gate	1·47	71	„	Skye, Glenbrittle ...	4·22	99
Yorks.	Wakefield, Clarence Pk.	2·07	96	„	Skye, Duntulm... ...	3·26	125
„	Hull, Pearson Park ...	2·57	125	*R. & C.*	Tain, Mayfield... ...	2·44	132
„	Felixkirk, Mt. St. John...	2·08	95	„	Inverbroom, Glackour...	3·20	113
„	York Museum	2·26	109	„	Achnashellach	5·02	134
„	Scarborough	1·29	70	*Suth.*	Lochinver, Bank Ho. ...	3·93	184
„	Middlesbrough... ...	2·17	115	*Caith.*	Wick Airfield	3·03	168
„	Baldersdale, Hury Res.	1·31	60	*Shetland*	Lerwick Observatory ...	2·53	141
Norl'd.	Newcastle, Leazes Pk....	2·08	99	*Ferm.*	Crom Castle	1·78	66
„	Bellingham, High Green	1·80	78	*Armagh*	Armagh Observatory ...	1·40	56
„	Lilburn Tower Gdns. ...	1·13	55	*Down*	Seaforde	1·16	42
Cumb.	Geltsdale	1·72	64	*Antrim*	Aldergrove Airfield ...	1·64	68
„	Keswick, High Hill ...	1·48	51	„	Ballymena, Harryville...	3·43	118
„	Ravenglass, The Grove	2·55	98	*L'derry*	Garvagh, Moneydig ...	2·05	81
Mon.	A'gavenny, Plâs Derwen	·84	31	„	Londonderry, Creggan	2·24	80
Glam.	Ystalyfera, Wern House	1·60	42	*Tyrone*	Omagh, Edenfel ...	2·08	74

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