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ORGANIZATION OF METEOROLOGICAL SERVICES

The meteorological services of the different countries have been developed to meet their own national needs, and their organizations vary in accordance with the major economic features of the country concerned. In maritime countries like our own it was the desire for forecasts to meet the needs of shipping which first led to the formation of a state service, and the British Meteorological Office originated as a Department of the Board of Trade. Similarly, in the United States, the Weather Bureau was founded for the benefit of navigation both on the sea coast and on the Great Lakes ; in many other countries it was chiefly to meet the needs of agriculture that a knowledge of weather was first required, and in not a few the State Meteorological Service is still administered by the Department of Agriculture.

The first world war brought the importance of weather still more into the forefront particularly for flying operations, and after the war many countries found themselves with two or more services, which had grown up to meet the needs of the Army, the Navy, or the Air Force, in addition to the Civilian Service already providing for the peace-time needs of the people. The vital importance of weather in the development of civil aviation led in many countries to unification of the meteorological services under the Department of Aeronautics or of Transport. During the second world war history was to some extent repeated and there has been a further tendency towards the formation of a single state service which in some countries includes the colonial services also.

In Europe, in both France and Portugal the meteorological services at home and overseas have been unified. In France the new service, known as the Direction de la Météorologie Nationale, forms part of the Ministère des Travaux Publiques et de Transport. The meteorological services of the French colonies remain autonomous under the Colonial Governors but their work is co-ordinated under the Direction de la Météorologie Nationale by the Service Central de la Météorologie Coloniale. In Portgual the various meteorological services of Portugal, the Azores and the Colonies were combined in August 1946 into a National Meteorological Service under the President of the Council. There is also a Naval Service which is independent of the National Service.

Unification is not confined to Europe. In Egypt, in April of this year, the Meteorological Services of the Physical Department and of the Civil Aviation Department have been amalgamated into a single Meteorological Department under the Minister of Defence. A Meteorological Service has been formed in Anglo-Egyptian Sudan under the Sudan Posts and Telegraphs Department. Reorganization has taken place also in several of the South American Services, in Brazil in 1944, in the Argentine in 1945 and more recently in Peru ; in all cases it is intended that the reorganization should lead to increased activity. A state weather service known as the Chinese Weather Bureau has been established in China where it forms part of the Ministry of Education. The National Research Institute which was formerly responsible for the meteorological service of China devotes itself now purely to research and is entirely independent of the Weather Bureau though it is located only 100 yards from it and uses the same address.

The Meteorological Service of the U.S.S.R. has also developed very rapidly. The nucleus of the Service was formed as long ago as 1844 when the Central Geophysical Observatory was established in what was then St. Petersburg. After the revolution in 1917, there was at first a tendency for the separate departments to develop their own networks of observing stations and a stage was reached when the Ministries of Agriculture, Medicine, Forestry, Railways, etc., each had its own meteorological organization in addition to the independent institutes dealing with meteorology, hydrography, terrestrial magnetism, etc. In 1932 the various civilian meteorological organizations and institutes were united under the control of a State Hydrometeorological Service. Originally this was under the Department of Agriculture but later it became an interdepartmental service and finally it came directly under the Council of Peoples' Commissars. The Army and Navy continued to develop specialist services of their own. When war began in the U.S.S.R. the Hydrometeorological Service was largely militarised and combined with the other two services to form a single Hydrometeorological Service for the whole country.

The United States is exceptional in having three Government Meteorological Services, the Weather Bureau, the Weather Service of the U.S. Army Air Force and the Aerology Section of the U.S. Navy. The first provides meteorological information for the general public and the other two cater for the needs of the armed forces to which they are attached. Co-ordination between the three services is in the hands of a Committee of their chiefs. The Weather Bureau, by far the oldest of the three, was founded in 1870 as part of the Signal Service of the U.S. Army (later known as the Signal Corps), in 1891 it was transferred to the Department of Agriculture where it remained until 1940, when it was transferred to the Department of Commerce. In addition to the three State Services several of the private airlines in the United States have meteorological services to meet their own requirements both within and outside the United States.

In Europe in ex-enemy countries and in countries where the meteorological services were disorganised during the war new services are gradually being built up again. In Czechoslovakia the Service is under the Ministry of Transport ; there are two Meteorological Offices, the State Meteorological Office in Prague and the State Hydrological and Meteorological Office for Slovakia at Bratislava. In Greece the complete reorganization of the Meteorological Service and of the National Réseau of meteorological stations is under consideration by the Government.

In both Germany and Austria as a result of quadripartite agreement after the war ended meteorological organizations were set up in each of the four zones to meet the needs of the Allied Powers. The services were under the direct control of the Military Government of the occupying power, co-ordination being maintained through a Committee of Meteorology. In Austria the Allied Council approved the establishment of a united Austrian Meteorological Service from August 1, 1946. The Service is administered by the Ministry of Education of the Austrian Government through the Central Institute for Meteorology in Vienna but is still supervised by the Quadripartite Meteorological Sub-Committee of the Air Directorate, Allied Commission for Austria. In Germany the four zonal meteorological organizations came into being in 1946, their structure being based on a plan of British origin. At present the policy is determined by the Quadripartite Committee on Meteorology of the Allied Control Authority in Berlin. In the British Zone a Central Office, the "Meteorologische Amt für Nordwest Deutschland" (M.A.N.W.D.) has been established in Hamburg under the direction of the Chief Meteorological Officer of the zone. At some time in the future it is expected that the four German zonal organizations will be merged into one service, directed by Germans but controlled by an agency appointed by the Allied Control Authority.

In conclusion a brief list of some of the Meteorological Services, classified according to the Departments by which they are administered, may be of some interest. The classification cannot of course be very rigid, owing to differences in the names and functions of the Departments in the different countries. The information is taken chiefly from Publications Nos. 2 and 52 of the International Meteorological Organization.

Agriculture.—Burma, Bolivia, Brazil, Bulgaria, Costa Rica, Finland, Guatemala, Haiti, Hungary, Mexico, Philippines.

Aeronautics or Air.—Algeria, Argentina, Australia, Cameroons, Great Britain, Greece, Italy, Palestine, Peru, Rhodesia, Spain, Syria, Tunis.

Communications, Transport, Works, Interior, Posts and Telegraphs.—Anglo-Egyptian Sudan, Canada, Czechoslovakia, France, India, Iraq, Lebanon, Netherlands and Netherlands East Indies, Poland, Switzerland, Sweden, and South Africa.

National Defence, Navy, Marine, War.—Chile, Cuba, Denmark, Egypt, Portuguese East Africa, Roumania, Thailand, Uruguay, Venezuela.

Commerce or National Economy.—Colombia, Ecuador, Eire, United States.

Education or Research.—Belgium, China, Salvador, Norway, New Zealand and Samoa, Yugoslavia.

UNSOLVED PROBLEM OF CLIMATIC CHANGE

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

Part II. Theories

At one time or another more than fifty different theories have been put forward to account for geological changes of climate. If we leave aside a few freaks, these fall into five broad classes : variations of solar radiation ; changes in the elements of the earth's orbit ; movements of the continents relative to the poles and to each other ; changes in the constitution of the earth's atmosphere ; and changes in the configuration of the earth's surface.

Quite early after the discovery of ice ages, theorists naturally turned to the sun, and evolved ingenious mechanisms for decreasing solar radiation, either the amount emitted by the sun, or the amount reaching the earth. In 1929 however Sir George Simpson [1,2*] pointed out that glaciation implies increased snowfall and therefore stronger solar radiation to give the necessary evaporation. His argument was that the sun is a variable star, at present near its mean phase. As radiation increases, so does evaporation, cloud and precipitation. The proportion of precipitation falling as snow decreases, but for a time the actual snowfall increases ; this causes glaciation. But as the sun grows still hotter, snow turns more and more to rain and finally vanishes ; this is an interglacial and also a pluvial period in the tropics (see page 129). Radiation reaches its maximum and begins to decrease, bringing a second glaciation, but as it falls to its minimum, although the ratio of snow to rain becomes very high, the total amount is insufficient to maintain the glaciers and there follows a long dry cold interglacial.

This theory accounts well enough for the series of individual glaciations (though there are difficulties about the cold interglacial), but it does not consider the cause of the ice age as a whole. If as is assumed, the sun is a periodically variable star, glaciations should have recurred at short intervals throughout geological time ; the theory cannot account for the long genial periods. This difficulty was to some extent overcome by F. Hoyle and R. A. Lyttleton[3], who supposed that at intervals of time of the order of 100 million years the sun passes through clouds of interstellar matter. The particles on and near the track fall into the sun, their kinetic energy being converted into heat and giving rise to increased solar radiation. Since the cloud would in general be densest near the centre, radiation would rise to a maximum and then decrease again, the time of passage being of the order of 100,000 years. Further, since many such clouds are irregular, the one causing the Quaternary ice age may have had two centres, so giving two maxima of radiation and four glaciations. The combined theory appears to be possible and does not conflict wildly with the data, though it fails to account for the long mild periods and there remain also a number of minor difficulties.

The second group of theories, which relate climatic changes to the elements of the earth's orbit, goes back to Croll's famous argument in 1875 that glaciation occurred in periods of great eccentricity of the earth's orbit in the hemisphere with winter in aphelion. This supposes that glaciations alternated in the two hemispheres, which we now know to be untrue. Further, it is unlikely that a very cold winter and a very hot summer would cause glaciation ; in fact as early as 1876 J. J. Murphy pointed out that glaciation was more probable in the hemisphere with summer in aphelion, and the view that low summer radiation is more important than low winter radiation for glaciation is now generally accepted. Eccentricity is not the only factor however ; the obliquity of the ecliptic, which governs the latitude of the Arctic and Antarctic circles, is equally important, and the variations of this factor coincide in both hemispheres. Detailed calculations of radiation in the summer half-year, taking all astronomical factors into account, were published by M. Milankovitch in 1921, and

* The list of references is on page 151.

have recently been made the basis of an elaborate reconstruction of the Quaternary ice age by F. E. Zeuner[4]. Zeuner shows that the variation of the present snow-line with latitude closely follows the variation of radiation in the summer half-year, and argues that with changing astronomical conditions a rise of the winter temperature increases the snowfall and the corresponding fall of summer temperature enables the snow to persist through the summer (the sun remaining unchanged, a decrease of summer radiation is accompanied by an approximately equal increase of winter radiation). Zeuner also follows up various secondary effects such as reflecting power of snow, change of tracks of depressions, lowering of sea level due to locking up of water in the form of ice, and the delayed isostatic effect of ice in depressing the land. The result is a detailed scheme of changes of climate and sea level which fits in very well with the most recent geological interpretations. The chief difficulties are that here again we have a theory of glaciations, but not of the succession of ice ages and genial periods, and that the changes of radiation associated with these astronomical factors seem very small in relation to the mighty consequences they are supposed to have brought about. In particular, the minute changes of radiation near the equator bear no relation at all to the great sequence of pluvial and interpluvial periods, and the latter are more adequately accounted for either on Sir George Simpson's theory or as secondary effects of the glaciation of higher latitudes on the atmospheric circulation.

Movements of the continents relative to the poles, or *vice versa,* account for the appearance of climatic change by denying its reality. The idea dates back to 1886 but is now generally associated with the name of A. Wegener, who constructed a detailed hypothesis of the drift of continents relative to each other and to the poles, which appeared to explain away all the evidence for long-term climatic changes, though he had to turn aside to astronomical causes for the details of the Quaternary Ice Age. Even at the time of publication the theory met with a very mixed reception, and since then difficulties have accumulated. The theory of continental drift now finds little support ; practically its only remaining claim to favour is that no other theory seems able to deal so easily with the low-latitude glaciation of the Permo-Carboniferous.

The suggestion that long-period variations of climate might be due to changes in the amount of carbon dioxide in the atmosphere was first made by S. Arrhenius in 1896, and has had a chequered career depending on the state of knowledge of the absorption of radiation in the atmosphere. Favourably received at first, it was almost abandoned in the 1920's, but was revived by G. S. Callendar[5], who attributed the Permo-Carboniferous and Quaternary ice ages to the exhaustion of carbon dioxide by the great forests of Carboniferous and Tertiary times and the resulting formations of coal and lignite respectively. Callendar clinched his argument by pointing to the great liberation of the gas in recent decades by human agencies, and the general rise of temperature since about 1885. The latter rise covered too short a period to form the basis of a satisfactory argument (as subsequent events have shown). The geological changes in the composition of the atmosphere may have had a long-term effect on climate and may have been a contributory factor in the occurrence of ice ages, but they cannot have caused the rapid changes from one glaciation to another within an ice age.

Finally we come to a large and diverse group of theories which depend only on the effect of the ordinary geological processes of elevation, erosion and depression of continents on the configuration of the earth, the height of mountain ranges and the course of ocean currents. The importance of land and sea distribution is obvious on any world map of temperature or precipitation, and its geological significance was pointed out by Charles Lyell ; elevation as a cause of climatic change was emphasised by W. Upham in 1890, while the possible effect of a deflection of the Gulf Stream has been toyed with since early days. At first sight the calculated effects are insufficient to explain the great geological changes of climate but this difficulty was overcome by the discovery of a critical dividing line between glacial and non-glacial climates . On the other hand the geographical theory fails to account for the sequence of glaciations within an ice age and is in some trouble over the peculiar climates of the Permo-Carboniferous. The latter difficulty has to some extent been removed by recent work, such as that of B. Haurwitz on the power of dense cloud to reflect solar radiation, and by the experiments of P. Lasareff on oceanic circulation. The climate of the Permo-Carboniferous was unique, but so also was the distribution of land and sea, and the geographical explanation may not be entirely ruled out.

Another difficulty is that the major ice ages were not synchronous with the major periods of mountain building, but lagged some millions of years behind them. This was met by A. Wagner by the suggestion that mountain building releases great quantities of earth heat which for some time keep the nascent glaciers mobile and easily destroyed, so that it is not until this earth heat is largely dissipated that great ice sheets can develop.

From this rapid survey we see that the possible factors of climatic change are manifold and diverse. Some, like variations of solar radiation and continental drift, are possible and could undoubtedly have effected some of the changes observed, but there is little or no evidence that they actually occurred ; in the case of shifting continents the evidence is on the whole adverse. The changes in the earth's orbit presumably occurred very much as calculated by Milankovitch, and must have produced some effect on climate. There are sequences of deposits in earlier geological ages which point to rhythmic changes of the annual variation of temperature over periods of 20,000 years or so, and these are reasonably attributed to the precession of the equinoxes. But these effects are small, and it seems unlikely that any such changes, which leave the total solar radiation unaltered, could possibly have resulted in climatic changes so vast as the alternation of glacial and interglacial periods. Moreover, none of these theories account for the genial periods which make up by far the greater part of geological time. Changes in the amount of carbon dioxide in the atmosphere have most probably occurred, and by their selective absorption of radiation may have modified temperature somewhat, but probably not to a sufficiently large extent ; moreover they are necessarily slow and could not explain the rapid fluctuations during an ice age. Finally changes in land and sea distribution are probably able to account for genial climates and ice ages, but not for the alternation of glacial and interglacial periods. The conclusion forced upon us is that no single cause can explain all the phenomena of geological changes of climate, and we must look to a combination of causes.

If we look at the problem from another angle, we reach the same conclusion. We cannot know for certain that solar radiation has varied widely from one geological period to another, but when we consider the known changes of the sunspot cycle, such variations appear inherently probable, and if they occurred, their consequences must have resembled those described by Sir George Simpson.

The known changes of the elements of the earth's orbit appear to fit the details of the Quaternary ice age very well. We know that the composition of the earth's atmosphere must have changed, and the changes fit the positions of the great ice ages in the geological sequence. Finally, we know that the configuration and elevation of the land masses have undergone great changes, and the changes of climate inferred from palaeogeography fit in well with the known facts of palaeoclimatology.

In physical experiments, the correct procedure is to keep all the factors constant save one, and to observe the effects of varying that one. It happens that during the past 3,000 years or so there have been no appreciable changes in the elements of the earth's orbit, the configuration of the land or (until man took a hand in the nineteenth century) the composition of the atmosphere. The only remaining factor, solar radiation, may or may not have been constant, but at least there is evidence that the aspect of solar activity represented by sunspots has varied greatly. The data are somewhat scanty but both sunspots and aurorae appear to have been unusually numerous between about 1070 and 1375. This was a period of increased rainfall generally and of great storminess in the North Sea, but not of an extension of glaciers, which so far as can be determined remained quiescent. There was a period of reduced solar activity from 1380 to 1510, during which the climate of Europe seems to have been on the whole rather mild and dry. On the other hand the "Little Ice Age" which began about 1600 does not appear to show any connexion with solar activity and is at present unexplained. The solar theory, like all other theories of climatic change, remains unproved.

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DIURNAL VARIATION OF EVAPORATION FROM NATURAL SURFACES

BY E. J. SUMNER, B.A.

Part I

In the past, evaporation studies have been determined by the needs of water engineers and agriculturalists, who are principally interested in the total evaporation over a long period of time rather than changes in the evaporation rate over short periods. The present article is concerned with the diurnal variation of evaporation and indicates a way of finding it based on energy considerations. A similar method has been applied to the diurnal variation of evaporation from oceans by Sverdrup[1*] but, to the author's knowledge, it has not been applied to the earth before.

By far the larger part of the evaporation from a surface covered with living vegetation is due, not to direct evaporation from the underlying soil, but to transpiration from the plants themselves, and the two words are used synonymously in this context.

Energy Method.—Briefly, it is proposed to find the amount of heat available at a given time for the evaporation of water from the earth.

Let I be the surplus radiant energy absorbed by unit area of the ground per unit time, that is, the radiation from sun and sky minus the effective back radiation from the surface. If H_E is the heat used in evaporation and H_C is the rate at which heat is dissipated to the atmosphere, then by the Conservation of Energy

$$H_E + H_C = I - \int_0^\infty \frac{\partial(cT)}{\partial t}\, dz \qquad \text{.. (1)}$$

where the integral is equivalent to the heat stored in the ground per unit time, T being the temperature, z the depth below the surface, t the time, and c the thermal capacity of the soil per unit volume.

The surface temperature, T_G say, may be analysed into its various harmonics and expressed mathematically by a Fourier series of the form

$$T_G = A_0 + \sum A \sin (\alpha t + \beta) \qquad \text{.. (2)}$$

In practice only two or, at the most, three harmonics are necessary.

Assuming that the earth is an isotropic substance and that the isothermal surfaces are planes parallel to the surface so that there is no inflow of heat from the sides, then T satisfies the following differential equation :—

$$\frac{\partial T}{\partial t} = \mu \frac{\partial^2 T}{\partial z^2}$$

where μ is the thermal diffusivity of soil, here assumed to be constant. The solution of this equation with the appropriate boundary condition (2) is

$$T = A_0 + Bz + \sum A e^{-\sqrt{(\alpha/2\mu)}.z} \sin \left(\alpha t - \sqrt{\frac{\alpha}{2\mu}} \cdot z + \beta\right)$$

from which we get

$$H = \int_0^\infty \frac{\partial(cT)}{\partial t}\, dz = \int_0^\infty c \left\{ \sum A \alpha e^{-\sqrt{(\alpha/2\mu)}.z} \cos \left(\alpha t - \sqrt{\frac{\alpha}{2\mu}} \cdot z + \beta\right) \right\} dz$$

$$= c \sum \sqrt{(\alpha \mu)} \cos \left(\alpha t + \beta - \frac{\pi}{4}\right) \qquad \text{.. (3)}$$

If we write the ratio H_C/H_E as R, the so-called Bowen's ratio, and put H_E equal to LE, where E is the rate of evaporation at the time considered and L is the latent heat of evaporation of water (585 cal./gm.), equation (1) becomes

$$EL\,(I + R) = I - c \sum A \sqrt{(\alpha \mu)} \cos \left(\alpha t + \beta - \frac{\pi}{4}\right) \qquad \text{.. (4)}$$

* The list of references is on page 157.

In order to evaluate E, the rate of evaporation, it merely remains to find R since all the factors on the right of equation (4) are calculable provided the necessary climatological observations exist.

Derivation of Bowen's ratio. The following analysis is fundamentally the same as that given by Bowen[2] himself with a few modern refinements.

In the earth's atmosphere the equations for the transfer of heat and moisture (or its heat equivalent) take the form

$$\left.\begin{aligned} H_C &= -\ \mu_1 \rho c_p \left(\frac{\delta T}{\delta z} + \gamma\right) \\ H_E &= -\ \mu_2 \rho \frac{0{\cdot}621\ L}{p} \cdot \frac{\delta e}{\delta z} \end{aligned}\right\} \quad \ldots (5)$$

where, in the steady state, H_C and H_E are constants independent of the height. In these equations μ_1 and μ_2 are the coefficients of eddy diffusivity of heat and moisture respectively, T is the air temperature, e the vapour pressure, c_p the specific heat of air at constant pressure (0.241), p the atmospheric pressure, ρ the density of air, and γ the dry adiabatic lapse rate (1.0°C./100m.)

Integrating equations (5) we get

$$H_C \int_0^h \frac{dz}{\mu_1} = \rho c_p \left(T_G - T_A - \gamma h\right)$$

$$H_E \int_0^h \frac{dz}{\mu_2} = \rho\ \frac{0{\cdot}621\ L}{p}\ (e_G - e_A)$$

where the suffixes G and A refer to the value of the appropriate element at the ground and at a low height h, respectively.

Now, since the agency involved in the vertical transport of moisture and of heat is the same, viz. eddy diffusion and convection, we can equate μ_1 and μ_2, making the two integrals the same, so that

$$R = \frac{H_C}{H_E} = \frac{p c_p}{0{\cdot}621\ L} \cdot \frac{T_G - T_A - \gamma h}{e_G - e_A}$$

Putting in numerical values for c_p and L, and ignoring the small quantity γh, which is only .03, when h is equal to 3m. (screen height at Kew), then

$$R = \frac{0{\cdot}66 p}{1{,}000} \cdot \frac{T_G - T_A}{e_G - e_A} \quad \ldots (6)$$

It should be noted that this ratio is exact under the conditions specified and is in no way affected by the variation of μ_1 and μ_2 with height. The validity of applying it to the present problem and the degree of inaccuracy entailed will be discussed later.

We are now in a position to determine E, the rate of evaporation.

Diurnal evaporation from a grass surface.—The results of the calculations for Kew for all seasons of the year 1927 (except winter) are shown in Fig. 1. The curve for winter was excluded because R was found to approach 1 on many occasions, so that a small percentage error in Bowen's ratio would produce a manifold error in the computed evaporation or deposition. Values for the thermal diffusivity of soil (ranging from 4 to 5 × 10^{-3} sq. cm./sec.) and the Fourier coefficients for the diurnal variation of ground and air temperatures were given

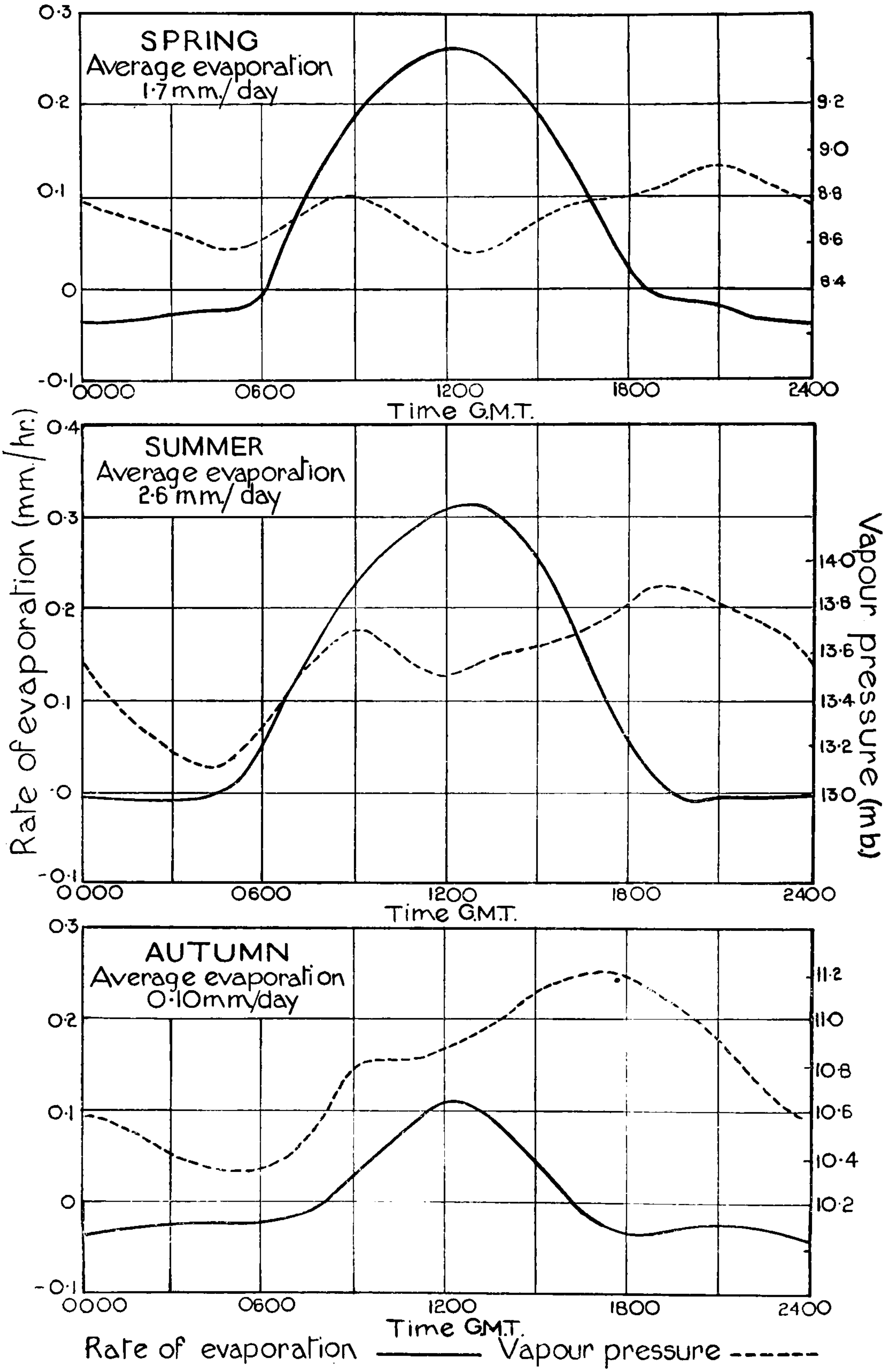

FIG. 1—DIURNAL EVAPORATION AT KEW, 1927

in a paper by H. L. Wright[3], while such information as the mean sunshine, the mean vapour-pressure, etc., was taken from the *Observatories' Year Book* for 1927.

The year in question was an abnormal one in some respects, having a warm sunny spring and a cloudy summer and autumn with plenty of rain. The relatively high sunshine in spring partly accounts for the high evaporation found for this season.

Since diurnal readings of evaporation are practically non-existent it is impossible to check the shape of these curves satisfactorily. However one can compare the average values of the total evaporation with existing values.

Dr. H. L. Penman[1] of the Rothamsted Experimental Station, found by actual measurement of the evaporation from experimental tanks with a covering of turf, the following average values for 1945 : about 2·5 mm./day during the summer months, and roughly 1·9 mm./day in spring. These figures are in good agreement with those for Kew.

The following readings, due to Wallén, and taken from a paper by Ångström[5] are tabulated with those obtained for Kew.

		Average total insolation reaching the ground	Mean air temperature	Evaporation
		cal./sq. cm./day	°C.	mm./day
Spring	Stockholm	277	4.0	1.0
	Kew	270	9.9	1.7
Summer	Stockholm	355	15.3	2.2
	Kew	310	15.5	2.6

Wallén's figures were found from the difference between rainfall and run-off over a long period of time. The summer values are in good agreement, whereas those in spring are very much smaller for Stockholm owing to the lower temperature.

Commentary.—For evaporation to proceed two things are necessary : a continuous supply of energy and a mechanism for transporting vapour away from the evaporating surface so as to maintain a moisture deficit in the air immediately in contact with it ; if either is absent evaporation soon ceases. Near to the earth's surface the flux of moisture is effected mainly by molecular diffusion, and the moisture gradient within the semi-boundary layer controls the rate of flow and hence the rate of evaporation. Conditions at the ground are generally very different from those at a few metres above it, and it is quite possible for evaporation to stop even when humidities at screen height are well below saturation. Another consideration is the fact that plants, unlike free water surfaces, can exercise a limited amount of control over transpiration losses by means of stomatal movements. The stomata (pores) of most plants are markedly sensitive to light intensity, closing up at night and opening promptly at sunrise.

With these ideas in mind it is easier to interpret the diurnal curves. They all show the controlling influence of solar radiation (see Fig. 2), so that the maximum rate of evaporation is reached around midday and not in the middle of the afternoon when the evaporativity of the air at screen height is greatest. Another feature they have in common is the absence of evaporation at night and its early start immediately after dawn when stomatal control is relaxed.

In spring and autumn there is a quite noticeable increase in the rate of dew deposition soon after 2100 as the initial rapid release of heat stored in the ground begins to diminish. Although this effect is not visible in the other mean curves it is probable that individual days at all seasons would show a similar tendency.

Of the available heat energy, on an average about 60 per cent. goes in evaporation, about 20 per cent. is stored in the ground during the day, and the rest is given off to the atmosphere. These proportions, of course, vary from place to place.

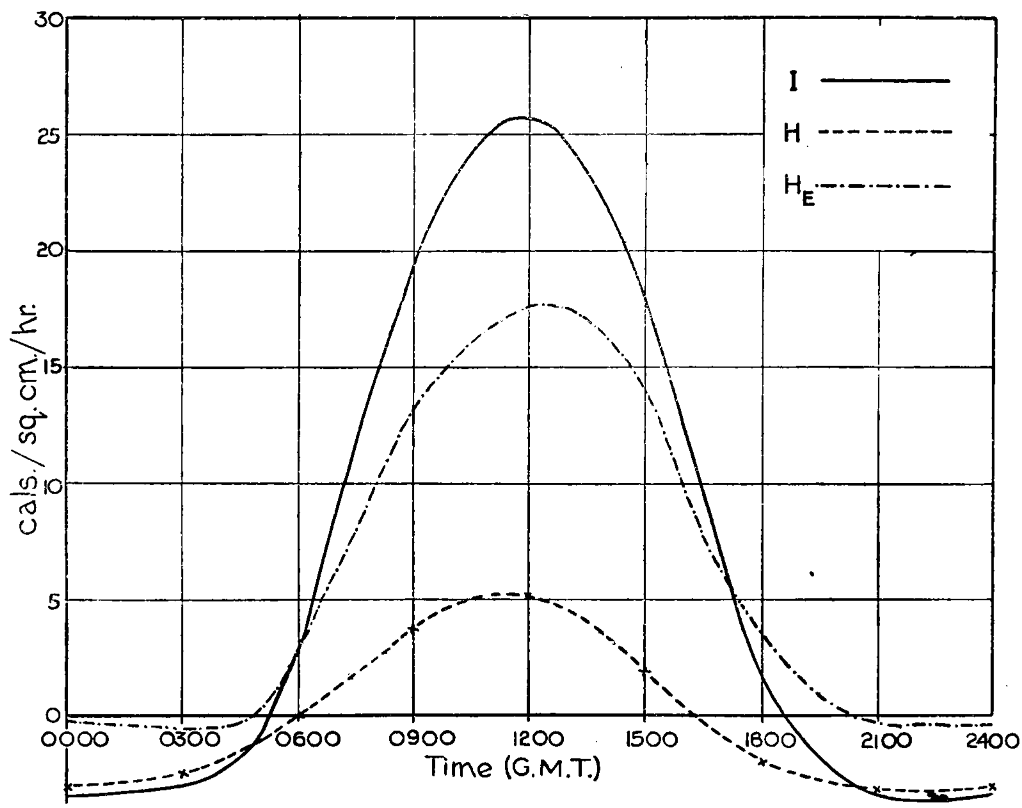

FIG. 2—DIURNAL VARIATION OF AVAILABLE SOLAR RADIATION, BODY HEAT AND HEAT OF EVAPORATION AT KEW DURING SUMMER, 1927

It is well known that grass-covered soil is subject to less extremes of temperature than bare earth. This is partly due to the insulating effect and the thermal capacity of the grass itself, but mainly to the heat absorbed in evaporation. The surface layers of bare soil soon dry up under evaporation and remain dry until rain falls again, whereas plants are enabled to collect much sub-soil moisture and maintain their transpiration rate for very much longer periods.

Variation of Vapour Pressure.—The variation of vapour pressure at any point above the earth depends both on the rate of evaporation from the surface below and the vertical transport of moisture away from it due to eddies together with advection effects resulting from lack of horizontal homogeneity. No attempt

[To face p. 156.

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ALTOCUMULUS CASTELLATUS AT BRISTOL, APRIL 16, 1947

(see p. 161)

LOW STRATUS CLOUD AT GIBRALTAR

September 18, 1946—Light easterly situation.

Photographs by E. L. Hawke

WRECKAGE OF OUSELEY KIOSK IN WHIPSNADE ZOOLOGICAL PARK, JANUARY 18, 1945

The right-hand photograph shows a 12-ft. strip of corrugated-iron roofing caught 30 ft. above ground by a neighbouring tree.

(see p. 162)

has been made to treat the subject quantitatively here, but the broader qualitative effects are very conspicuous in the curves which are included in Fig. 1, of the mean diurnal variation of vapour pressure at screen height (3 m.).

They all show the same characteristics : an initial fairly rapid increase in the vapour pressure, due to evaporation at a time when the atmosphere is stable so that the available moisture is confined to a thin layer of air, followed by a temporary drop, or a steadying up in autumn, when turbulence and convection make their presence felt. The moisture content of the air almost invariably decreases with height at this time of the day, so that increased turbulence transports drier air downwards. Ultimately evaporation gains control again and the rise is resumed. A considerable lag is evident in the upward diffusion of vapour in spring and autumn.

It is interesting to note that the biggest variation in vapour pressure is in autumn in spite of the small amount of evaporation. This reflects the stabler atmospheric conditions experienced at this time of the year, when evaporated moisture is spread over a shallow layer of air and, what is more important, deposited moisture is abstracted from a still shallower layer.

(To be continued)

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METEOROLOGICAL RESEARCH COMMITTEE

The 49th meeting of the Meteorological Research Committee was held on June 19 with Prof. G. M. B. Dobson as Chairman in succession to Prof. S. Chapman.

Some time was spent in considering the machinery for promoting international co-operation in meteorological research. The papers considered by the Committee included a note on the shape of falling raindrops, a paper dealing with the estimation of the pressure-pattern flight path for time of minimum flight and a report on some measurements of turbulence in clear air by means of smoke puffs.

ROYAL METEOROLOGICAL SOCIETY

At the meeting of the Society held at 49, Cromwell Road, on May 21, Prof. G. M. B. Dobson, President, in the Chair, the following papers were read :—

Professor O. G. Sutton—The problem of diffusion in the lower atmosphere.

Prof. Sutton introduced the paper by remarking that, for the first time, it had been possible to publish some of the large amount of experimental data on the diffusion of gas which had been accumulated at the Chemical Defence Experimental Station Porton in the last 25 years. This experimental ground work, of good accuracy, was of fundamental value for the study of diffusion.

The paper gives an account of the theory of diffusion, developed by the author between 1932 and 1938, based on a concept which permits turbulent mixing to be treated as a continuous process. Using results from aerodynamic theory, the eddy diffusivity is related to the correlation coefficient R_ξ between an eddy velocity at any given instant and its value ξ seconds later. As the measurement of R_ξ directly is generally impracticable, it is necessary to find a suitable expression for it in terms of readily measurable quantities. The expression chosen is, in the case of vertical diffusion

$$R_\xi = \left(\frac{\lambda}{\lambda + \overline{w'^2}\,\xi}\right)^n \qquad , n \geqslant 0$$

in which λ is the kinematical viscosity of the fluid and n is obtained from wind-velocity measurements, it being shown that the index in the power-law representation of the wind velocity profile is $n/(2-n)$. The final expressions for diffusion from point and line sources at ground level give excellent agreement with observation when the value of $\overline{w'^2}$ (the mean-square vertical eddy velocity) is obtained from the records of a Taylor bi-directional vane by drawing an oval round the trace in the manner described by Best.*

Difficulties in the treatment are discussed, the chief being that when true values of mean square eddy velocity are employed instead of the " extreme " values given by the vane technique, then the theoretical rate of diffusion is considerably smaller than that found experimentally. This may be due to one of two causes :—

(i) The value of Kàrmàn's constant may be greater for the atmosphere than 0·4, the value found in laboratory work on fluid flow.

(ii) The surface of the earth may not be aerodynamically smooth.

These possibilities are discussed and it is finally suggested that both may be important.

Prof. D. Brunt welcomed the publication of this work and hoped that further papers in this field would follow. In the ensuing discussion several speakers paid tribute to the inspiration Prof. Sutton's work had afforded in the study of atmospheric diffusion. On the question of the source of the discrepancy referred to by Prof. Sutton, Prof. P. A. Sheppard considered there was little justification for an " atmospheric " value of Kàrmàn's constant. He felt the discrepancy resulted from the fact, now becoming well established, that flow over the earth's surface was, in general, aerodynamically rough, in which case the kinematical viscosity would not be expected to appear in the formulation.

W. G. V. Balchin and N. Pye—A microclimatological investigation of Bath and the surrounding district.

In this investigation the authors use the term " microclimatology " to mean the comparison of standard surface observations within a region of a few square miles ; they are not concerned with microclimatology in the sense in which it is sometimes used by agriculturists, viz., the comparison of observations made for special purposes in the lowest few feet of the atmosphere.

The authors showed a great deal of ingenuity in overcoming the difficulties of starting this investigation and they were finally able to obtain daily observa-

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* BEST, A. C. ; Transfer of heat and momentum in the lowest layers of the atmosphere. *Geophys. Mem., London*, 7, No. 65, 1935.

tions from 28 stations for 15 months. These records are not yet completely analysed, but the authors are already able to publish some interesting results. For example, maximum temperatures show that the valley stations are 3 to 4°F. warmer than the hill-top stations in winter, and 5 to 7°F. warmer in summer; on nights with " valley inversion " however, stations in the valley are 4°F. colder than those on the plateau ; these inversions occurred on more than one third of the nights and would have been still more frequent but for the " urban effect " of the city.

Many interesting slides were shown and those which dealt with the distribution of rainfall were particularly useful. It was clear that in 1945 the hill tops received 4 to 5 in. more rain than the valley bottoms, and that the windward slopes were wetter than leeward slopes.

There was a stimulating discussion at the end of the paper ; although not all the speakers agreed with some of the terms used by the authors, they were all convinced of the value of this type of work.

At the meeting of the Society held at 49, Cromwell Road, on June 18, Professor G. M. B. Dobson, President, in the chair, the following papers were read :—

Sir Gilbert Walker—Arctic conditions and world weather.

It is widely recognised that there have been large changes in recent years in northern regions, including a widespread temperature rise and an increase in the pace of the circulation. One of the most promising suggestions for the explanation of European weather changes is the disturbance of conditions by ice increases in the northern seas, and a considerable amount of work has been devoted to this relationship. During the past 30 or 40 years the mechanism of control seems to have changed fundamentally and the present paper represents a preliminary attempt to find out the relations of recent years. Conditions so closely associated 20 or 30 years ago that their connexion inevitably seemed to be a physical reality have in some cases changed materially, their relationships being diminished or even reversed.

The correlation derived between arctic pack-ice and Thorshavn temperatures suggests that the weather changes may be regarded as being made up of three component variations (*a*) relatively rapid, covering a few days (*b*) of medium length, three to nine months·(*c*) of slow change, covering four to twelve years or more. The effect of the slow changes are largely got rid of by taking departures from smoothed curves.

The annual values of the pack-ice of the Greenland and Barents Seas are correlated with meteorological conditions. It is found that the closest relationship occurs between the ice of one spring and summer season and pressure conditions of the previous winter. Wind thus appears to be the deciding factor, according with Speerschneider's dictum that the effect of wind on the amount of ice is so great that a severe ice year ought to be called a year of pronounced or abnormal wind conditions. Heavy ice years are found to be associated with high pressure in the previous winter in east Canada, Greenland, Iceland, Spitsbergen, Norway and the Faroes and with low pressure in the more southern regions such as the Azores, Austria and Siberia. At some stations there is evidence of a marked change of relationship between 1900 and 1910.

The correlation of the pack-ice with pressure and temperature at Stykkisholm and Thorshavn suggests the possibility of forecasting the general ice conditions at the beginning of March. The value of the joint coefficient, ·66, is however not large enough to justify an annual prediction.

For the ice off the Newfoundland Bank the data are more complete, but more baffling. The coefficients of −·76 and −·80 of this ice with pressures in Iceland and Greenland, based on over 20 years before 1906, have since become small. Many other striking changes are also shown for the period since 1905. The series of data must however be extended and the relationships corroborated before actual use of them for forecasting can be made.

The fundamental change in the relationships which occurred about 1905 must be physical in origin, but the nature of the change is still very obscure. It is suggested that there has been a large increase in the amount of ice carried into Baffin Bay by the easterly ocean current through the Canadian Archipelago. This would imply stronger westerly wind impelling the current, and consideration of pressure data from Barrow for 1922–40 appears to substantiate this. It seems however to have been overlooked that while the Newfoundland ice data used were derived from the numbers of bergs reaching the Bank, few or no bergs come through the Canadian Archipelago or Smith Sound. The places of origin of the great majority are all well known and are situated on the west coast of Greenland. The quantity of Newfoundland bergs must therefore primarily depend on previous conditions in west Greenland.

S. Duvdevani—An optical method of dew estimation.

All previous methods of observing dew depended on weighing, both before and after exposing to nocturnal radiation, a number of, usually hygroscopic, substances, ranging from gypsum plates to blotting paper and woollen cloth. These methods therefore suffer from the defect that, since they involved the careful use of the balance, they can only be used at research stations and not at many stations over a wide area.

Mr. Duvdevani's dew gauge depends on a simple eye observation of the appearance of the dew on a standard surface and comparing it with a number of photographs, each of which corresponds to a known amount of dew deposition as measured at a research station with Leick plates. The standard gauge finally adopted by Mr. Duvdevani in Palestine consists of a rectangular wooden block, 32 cm. × 5 cm. × 2·5 cm., coated with red oil paint.

A dew scale has been worked out, each number of the scale corresponding to a photograph in the dew atlas used with each observation, and it has been found that the personal effect in estimation leads to insignificant errors since discrepancies never amount to as much as a whole dew number.

As was pointed out in the meeting, the dew gauge suffers from similar defects to those of the evaporimeter in that it measures the amount of dew that would be deposited on standard substances and not the amount actually deposited on the ground or on plants.

As distinct from previous methods of measuring dew, the dew gauge measures the maximum dew deposited during the night not the net deposit of dew and it is not necessary to observe the gauge exactly at sunrise. Light rain has a different optical appearance on the gauge from dew and there is therefore no possible confusion between the two sources of moisture.

In Palestine, the gauge measures amounts of dew within the range 0·01 to 0·35 mm. but this range can be modified to suit other climates by applying a different coat of paint or by placing the gauge at a different height from the ground. Mr. Duvdevani emphasised that though the gauge gives valid data for monthly and annual totals, it does not yield accurately the amount of dew on any particular night.

LETTERS TO THE EDITOR

Instability in the uplifted warm air of occlusions

During a year's practical investigations on the North Atlantic Ocean which I conducted on board the S.S. *Manchester Port* in 1936–7, three examples of marked instability in the uplifted warm air of occlusions were experienced.*

In the first case there was lightning accompanied by rain and hail squalls. In the second case thunder and lightning were observed and there was a heavy shower (this was the only occasion on which thunder was heard at sea during the whole year's investigations). In the third case there was a period of heavy rain which corresponded to a rain belt of about 100 miles. In the last case one of the flying boats, *Caledonia,* then conducting a series of experimental transatlantic flights passed through the occlusion at about the same place and time and the pilot reported cumulonimbus cloud to 16,000 ft.

It was placed on record that it was " perhaps significant that in all three cases the warm air had only recently been occluded", that is, the marked instability was experienced near the apex of the warm sector of each of the respective depressions. It is of interest to note that the tentative suggestion implied in the above statement has since been confirmed by one of the more recent meteorological observational devices to which reference was made by Sir Nelson Johnson in his paper " Recent Advances in Meteorological Methods."† In that paper he points out that the development of the cathode-ray tube as a means of locating the position of electric atmospheric disturbances has enabled the distribution of such disturbances within cyclones to be investigated. It has been found that with occluded depressions " there is a maximum of atmospherics at the very apex of the warm sector suggesting that the velocity of ascent of the warm air is also greatest at this point."

This, theoretically interesting, result is of obvious practical importance to all forecasters, especially those engaged on aviation forecasting.

D. A. DAVIES

June 9, 1947.

Unusual cloud formation over Bristol

The following sequence of cloud formation occurred over Bristol during the afternoon of April 16, 1947 :—

From noon, excellent cirrocumulus developed to the south-west and was moving from 200° with a relative speed of 60 m.p.h. At 1300, small patches of altocumulus castellatus developed, at some 18,000–20,000 ft., and enlarged to a well-formed mushroom type of cloud. From about 1430, the medium cloud

* London, Meteorological Office ; Report on a year's meteorological investigations on the North Atlantic Ocean. *Atlantic met. Rep., London,* No. 7, 1939.

† *Nature, London,* **157,** 1946, p. 24.

precipitated to a great length, retaining its mushroom-like top and producing the rare phenomena of a " parachute " appearance.

The photograph facing page 156 was taken between 1500 and 1700 G.M.T. looking north-east.

R. G. HOSKINS

April, 1947.

[The photograph shows an exceptionally good example of virga. The tops of the clouds probably consisted of supercooled water drops.

The Larkhill soundings do not show any outstanding feature, but at 1800 the lapse rate was slightly above the saturated adiabatic between 400 and 350 mb. (roughly 23,000 and 27,000 ft.). Relative humidity differed little from 70 per cent. between 550 and 350 mb., but there was very dry air lower down, the relative humidity being 7 per cent. at 850 mb. The upper winds over Larkhill showed no shear at any height which can explain the distortion of the precipitation trails towards the south-east, so that this effect must have been a local one. At 1800 over Larkhill, the wind at 500 mb. was 260° 25 kt. and above that it veered and increased slowly with height.

The general synoptic situation was one in which unstable medium and high clouds are frequent. There was a declining anticyclone over Germany and a new anticyclone coming in from the Atlantic. A slow-moving cold front over Ireland was still giving slight rain, but when it reached southern England next morning it gave no rain. A belt of falling pressure moved on ahead of the front and produced a flat pressure distribution over England, France and the Bay of Biscay by 1800. There was " sferic " activity over north Spain and the southern part of the Bay of Biscay during the afternoon and evening.

C. K. M. DOUGLAS]

NOTES AND NEWS

Small tornadoes or whirlwinds in the British Isles

In the March 1947 issue of the *Meteorological Magazine*, accounts were given of several small tornadoes or whirlwinds in the British Isles and mention was made of damage suffered at Whipsnade Zoological Gardens on January 18, 1945. Below we give a more detailed account of this and also of a small tornado which occurred in Birmingham on February 4, 1946.

Tornado-like characteristics appear to have developed during the passage over Dunstable Downs of the line-squall which crossed central and southern England on January 18, 1945, to the accompaniment of thunder, lightning and widespread heavy rain and hail. Within five minutes, between 1350 and 1355 G.M.T., very severe damage was done along a track not more than about 150 yds. wide in the northernmost area of Whipsnade Zoological Park, Bedfordshire, at a height of about 750 ft. above sea level. The Ouseley kiosk was demolished, the corrugated iron roof being smashed to pieces and large portions being whirled into adjacent trees, one section to a height of 30 ft. above ground (see photographs facing p.157). Some 120 yds. to the north-west of the kiosk, the Bison shed had its upper part carried away ; this consisted of heavy-gauge corrugated iron with timber supports, including five lengths 13 ft. × 4 in. × 3 in., weighing approximately 15 cwt., and was blown *en masse* for a distance of about 300 yds. to north-eastward, where four lengths of 3 in. by 2 in. quartering were each driven end-on into the turf to a depth of 2 ft. After first striking the ground the corrugated iron roofing again became airborne and finally came to earth a further 100 yds. or so to the north-east, where it disintegrated. Numerous trees, among them sound and sturdy young oaks, were split and broken in the track of the storm.

During the tornado-like squall, which was accompanied by heavy rain, thunder and lightning, the thermograph in the Superintendant's garden—well away from the zone of destruction—showed an almost instantaneous fall of temperature of 5°F. followed by a rapid rise of 2 °F. It was reported at Dunstable that the barometer rose suddenly 2 mb. just before 1400 in the midst of a rapid fall, the temperature fell from 46°F. to 3 °F., the wind gusted to 62 m.p.h. with a veer from SW. to W. and there was heavy precipitation from 1325 to 1350.

The noise occasioned by the squall and by the demolition of the Ousely kiosk and the Bison shed were such that numbers of the staff were led to believe that a rocket-bomb had fallen in the park. Masses of chalk were blown for some hundreds of feet out of the flint pit to the south-east of the Ouseley kiosk.

E. L. HAWKE

The Birmingham City area experienced two brief but very intense thunder squalls within 24 hours in February 1946. The first occurred in the evening of the 3rd and the second about midday on the 4th.

I give my own private record of the weather of the 3rd, this was as follows :—

" A dull day with moderate to fresh, squally winds, varying in direction from SSW. to WSW. Slight intermittent to continuous rain fell between 0445 and 0940. Moderate intermittent to continuous slight rain fell most of the afternoon, but at 1900 there was an almost complete clearance of the sky. At 2040 cloud began to spread rapidly from the west and a faint rumble of thunder was heard ; at 2043 a much louder peal of thunder ; at 2045 a vivid flash of lightning and five seconds later a clap of thunder which shook doors and windows like a near by bomb explosion (reverberations prolonged over ten seconds) ; at 2050 commenced to rain moderate to heavy, no more lightning until 2055 ; thunder not quite so heavy as previous clap ; at 2058 the wind which had been fairly steady at 16 to 18 m.p.h. over the previous two hours shot up to a gust of 64 m.p.h. with a vivid flash of lightning and a rather terrifying clap of thunder and a torrential downpour of hail and rain which was driven almost horizontally by the squall. By 2105 the precipitation had practically ceased and by 2115 the wind had died down to an average of 20 m.p.h. The sky cleared and continued so until midnight, the wind remaining fresh WSW. The whole storm or at least the major portion of it only lasted 20 minutes. Strangely enough there was no sudden change of wind direction during the squall, only a slow movement from SW. to W."

Now to carry on to the weather of the 4th ; I will quote again my record of the conditions as seen from the observatory.

" Fine from midnight to 0600 except for a very slight shower at 0200 ; sky becoming cloudy by 0900 with slight showers at 1050 and 1140 ; at 1240 a sudden squall, (gust 46 m.p.h. sudden wind change SW. to W.), accompanied by rather intense thunder and lightning (but not so bad as the previous evening), broke over the area ; a heavy shower of rain and hail occurred, (hailstones

$\frac{3}{8}$ in. diameter), ending with sleet at 1255. The weather cleared soon after and remained mainly fair for the rest of the day."

The main items of damage as reported in the newspapers were as follows :—

Houses were struck by lightning at Woodlands Farm Road, Pype Hayes, and also a factory in Cliveland Street which is nearer to the City centre. In the same area as the factory and about half a mile to the eastward a large hoarding was blown across what is normally a busy main road, (Aston Road in the vicinity of Love Lane) ; fortunately no one was injured. Further to the north in the Witton area some damage was done to house property by wind and in the same district it was reported that two men (one of them about 15 stones in weight) were blown violently to the ground and injured.

Further details of the storm on the 4th are given by the following letters.

The first is from H. M. Myers of the I.C.I. (Metals) Ltd., Witton, who writes :—

" I was holding a meeting in my office and at 12.45 p.m., approximately, the sky went as dark as night with violent thunder and lightning striking a few yards away. A terrific wind developed suddenly, to such an extent that we all feared that the building (very strongly constructed) was coming down. The noise of the wind, which only lasted a few seconds, rose to a shriek and the roof was lifted off a nearby building and carried about 20 yards away. At the same time the gable wall of another brick-built building was taken out completely without disturbing the roof. Slates were blown off roofs and glass was shattered in windows a considerable distance away, and telephone wires were down everywhere.

" I was in the track of the tornado, or whatever it was and judging from the damage it would appear to cover a width of only about 10 to 15 yards. Lightning was observed to strike during the short duration of the storm.

" I should add that I have had experience of 14 days' gales on the Atlantic, including one night of ' whole gale ' when shipping disappeared without trace, but I have never before experienced wind velocity such as occurred on Monday, but being indoors at the time I could not guess at the speed."

The second is from L. Hancox who writes :—

" We were in a building at Witton which was struck by the lightning, thunderbolt, or whirlwind, at exactly 1245 ; to me it seemed a combination of all three.

" It went very dark and then started to hail very hard. Then for a few seconds the hailstones were terrific and everything seemed to go to pieces. There was a sort of ripping tearing noise and everything seemed to vibrate, glass, slates and bricks started to fly about and then came an explosion, the roof fell in and the air was filled with a definite sulphurous taste ; everybody had it in their throats for some little while.

" In my opinion there was definitely a whirlwind or tornado with the storm, it could be heard coming and in those few seconds everybody sought cover. Luckily only one or two people were slightly hurt. An entire wall of one building appeared to be ' sucked out '."

The third letter is from H. T. Patchett, the Works Manager of Messrs. Higgs Motors Ltd., also of Witton and in the very near vicinity of the I.C.I.

" Whilst the thunderstorm was at its height, sudden gusts of wind, apparently, swept across our buildings and actually sucked out of a ' North-light ' building, in various places, sheets of glass measuring 7 ft. by 2 ft. to the extent of 450 to 500 sq. ft. in area.

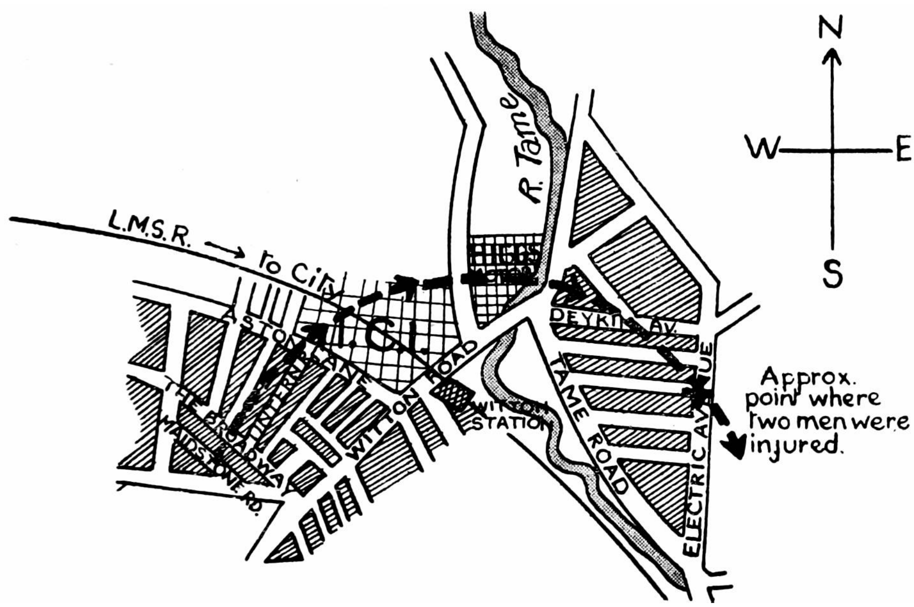
" In addition it ripped from the roofs some scores of feet of lead flashing. In front of the works, five trees that were planted between fifteen and twenty years ago, were torn out of the ground.

" The approximate time that this damage occurred was 12.45 p.m. and it was fortunate that the workers were not in the buildings and that the glass was sucked out instead of being blown in. This area seems to have been in the centre of a severe storm."

I do not think that there can be the slightest doubt from these three descriptions, that a small but rather intense tornado struck this particular portion of the Witton area during this storm.

The map below shows the route followed by the tornado.

A. L. KELLEY



[On February 3, 1946, a very deep depression was centred to the south of Iceland. A well marked cold front passed over the Birmingham area at 1900 G.M.T. The geostrophic wind across the front was about 60 m.p.h.

On the 4th the depression was still centred in the same position and a very unstable westerly air current giving heavy showers was blowing across the British Isles. No front could be traced in the Birmingham area near the times specified.—Ed. *M.M.*]

WEATHER OF MAY, 1947

The month opened with three days of cold NE. winds associated with high pressure to the north-west of the British Isles, but after about the 3rd, low pressure over the Atlantic west of Ireland caused light south-easterly winds with mild damp weather but little rainfall. A brief anticyclonic spell on the 12th–13th was followed by rather indefinite pressure distributions but moderately fine sunny weather until the 24th. On the 25th a deep depression developed over the Atlantic some distance west of Ireland while an anticyclone lay over Germany. This distribution persisted with little change until the end of the month. The resulting air stream from the continent gave a spell of fine very hot weather over much of England, but thundery conditions developed in parts of western England, Wales, Scotland and Northern Ireland.

The average pressure chart for the month shows anticyclones (above 1020 mb.) extending from north-east Greenland to include the Baltic, and from Bermuda eastwards across the Atlantic and a depression below 1009 mb. centred about 55° N. 35° W. The highest pressures of 1022 mb. in Sweden were 8 mb. above normal, and the lowest, about 1009 mb. south-west of Ireland, 5 mb. below normal. Elsewhere pressures differed little from the average for the month. Over the British Isles mean pressure exceeded the average in the northern half and was somewhat below the average in the south-west, the deviation at 0900 ranging from +5·9 mb. at Lerwick to —1·9 mb. at the Scilly Isles. As a result winds from some easterly points were more frequent than usual and the total run of the wind was considerably below the average. The weather was warm and quiet, with frequent thunderstorms. Mean temperature exceeded the average ; over England and Wales as a whole it is estimated that it was the warmest May since before 1901. At Southport and Sheffield the mean temperature was the highest for May since records were started in 1871 and 1883 respectively. The period 28th–31st was exceptionally warm ; the temperature rose to 85°F. or somewhat above at numerous stations in England on the last three days. With regard to rainfall, broadly speaking, less than the average occurred in the north of Scotland and the eastern half of England and more than the average elsewhere. More than twice the average was received in parts of Angus and Fife, the extreme south-west of Scotland, locally on the west coast of Lancashire, in the neighbourhood of Bradford and Huddersfield and at Seaforde, County Down. On the other hand less than 25 per cent. was registered in an area extending south-south-east from the Humber across the Fens and the neighbouring part of Norfolk. In Shetland and Orkney, where it was the driest May since 1919, the rainfall amounted to little more than 25 per cent. of the average. Thunderstorms were reported on 9 days at Dumfries, Bellingham and Wakefield. Sunshine exceeded the average in east and north-east England and in Orkney and Shetland and was, on the whole, below the average elsewhere. In Orkney and Shetland it was the sunniest May for at least 25 years. The last week was very sunny over most of England, particularly in the eastern districts and the Midlands.

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

	Air Temperature			Rainfall		Sunshine	
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days diff. from average	Percentage of average	Percentage of possible duration
	°F.	°F.	°F	%		%	%
England and Wales	90	28	+3.1	103	+1	94	39
Scotland	81	27	+ 2.3	124	+ 1	93	31
Northern Ireland ..	74	33	+ 2.2	156	+ 3	93	35

RAINFALL OF MAY, 1947

Great Britain and Northern Ireland

County	Station	In.	Per cent of Av.	County	Station	In.	Per cent of Av.
London	Camden Square ..	.97	55	*Glam.*	Cardiff, Penylan ..	2.48	101
Kent	Folkestone, Cherry Gdns.	1.12	67	*Pemb.*	St. Ann's Head ..	3.36	167
,,	Edenb'dg, Falconhurst	1.73	94	*Card.*	Aberystwyth	2.97	143
Sussex	Compton, Compton Ho.	1.51	68	*Radnor*	Bir. W. W. ,Tyrmynydd	3.93	115
,,	Worthing, Beach Ho. Pk.	1.35	82	*Mont.*	Lake Vyrnwy	3.70	109
Hants.	Ventnor, Roy. Nat. Hos.	1.59	94	*Mer.*	Blaenau Festiniog ..	3.78	67
,,	Fordingb'dg, Oaklands	1.80	87	*Carn.*	Llandudno	3.47	195
,,	Sherborne St. John ..	1.50	77	*Angl.*	Llanerchymedd ..	3.98	169
Herts.	Royston, Therfield Rec.	.90	46	*I. Man.*	Douglas, Boro' Cem. ..	4.02	161
Bucks.	Slough, Upton ..	1.89	113	*Wigtown*	Pt. William, Monreith..	4.97	211
Oxford	Oxford, Radcliffe ..	1.88	100	*Dumf.*	Dumfries, Crichton R.I.	4.45	162
N'hant	Wellingboro', Swanspool	1.15	59	,,	Eskdalemuir Obsy. ..	3.49	106
Essex	Shoeburyness	1.15	88	*Roxb.*	Kelso, Floors	2.91	151
Suffolk	Campsea Ashe, High Ho.	.38	25	*Peebles.*	Stobo Castle	3.14	138
,,	Lowestoft Sec. School ..	.57	35	*Berwick*	Marchmont House ..	3.27	132
,,	Bury St. Ed., Westley H.	.54	30	*E. Loth.*	North Berwick Res. ..	3.87	194
Norfolk	Sandringham Ho. Gdns.	.31	17	*Midl'n.*	Edinburgh, Blackfd. H.	2.93	143
Wilts.	Bishops Cannings ..	2.05	105	*Lanark*	Hamilton W. W., T'nhill	3.29	138
Dorset	Creech Grange.. ..	2.35	115	*Ayr*	Colmonell, Knockdolian	3.53	138
,,	Beaminster, East St. ..	2.64	128	,,	Glen Afton, Ayr San. ..	5.58	186
Devon	Teignmouth, Den Gdns.	2.64	144	*Bute*	Rothesay, Ardencraig ..	5.09	168
,,	Cullompton	3.19	148	*Argyll*	Loch Sunart, G'dale ..	4.27	120
,,	Barnstaple, N. Dev. Ath.	1.73	84	,,	Poltalloch	4.02	139
,,	Okehampton, Uplands	3.62	135	,,	Inveraray Castle ..	4.45	113
Cornwall	Bude School House ..	3.45	187	,,	Islay, Eallabus ..	4.54	171
,,	Penzance, Morrab Gdns.	2.71	123	,,	Tiree	3.61	144
,,	St. Austell, Trevarna ..	4.27	176	*Kinross*	Loch Leven Sluice ..	3.88	159
,,	Scilly, Tresco Abbey ..	3.38	200	*Fife*	Leuchars Airfield ..	4.26	218
Glos.	Cirencester	1.55	75	*Perth*	Loch Dhu	6.10	136
Salop	Church Stretton ..	2.94	116	,,	Crieff, Strathearn Hyd.	4.11	165
,,	Cheswardine Hall ..	2.85	129	,,	Blair Castle Gardens ..	3.74	184
Staffs.	Leek, Wall Grange, P.S.	2.89	121	*Angus*	Montrose, Sunnyside ..	4.60	225
Worcs.	Malvern, Free Library	1.96	91	*Aberd.*	Balmoral Castle Gdns...	3.06	132
Warwick	Birmingham, Edgbaston	2.44	114	,,	Aberdeen Observatory	2.89	124
Leics.	Thornton Reservoir	1.26	63	,,	Fyvie Castle	2.61	101
Lincs.	Boston, Skirbeck ..	.43	24	*Moray*	Gordon Castle	1.67	79
,,	Skegness, Marine Gdns.	.13	8	*Nairn*	Nairn, Achareidh ..	1.52	85
Notts.	Mansfield, Carr Bank	2.04	96	*Inv's*	Loch Ness, Foyers ..	2.05	84
Ches.	Bidston Observatory ..	3.92	206	,,	Glenquoich	2.97	54
Lancs.	Manchester, Whit. Park	2.15	101	,,	F . William,Teviot ..	3.52	89
,,	Stonyhurst College ..	2.49	87	,,	Skye, Duntuilm ..	2.43	85
,,	Blackpool	4.40	202	*R. & C.*	Ullapool	1.04	42
Yorks.	Wakefield, Clarence Pk.	3.19	162	,,	Applecross Gardens ..	1.95	60
,,	Hull, Pearson Park ..	.55	28	,,	Achnashellach	1.94	46
,,	Felixkirk, Mt. St. John	2.22	118	,,	Stornoway Airfield ..	2.05	84
,,	York Museum	1.55	78	*Suth.*	Lairg	2.58	102
,,	Scarborough	.89	47	,,	Loch More, Achfary ..	1.52	35
,,	Middlesbrough.. ..	1.48	77	*Caith.*	Wick Airfield	1.24	60
,,	Baldersdale, Hury Res.	1.83	71	*Shet.*	Lerwick Observatory ..	.60	29
Norl'd	Newcastle, Leazes Pk.	1.80	91	*Ferm.*	Crom Castle	3.84	138
,,	Bellingham, High Green	3.17	132	*Armagh*	Armagh Observatory ..	3.54	149
,,	Lilburn, Tower Gdns..	2.45	106	*Down*	Seaforde	5.38	205
Cumb.	Geltsdale	2.27	88	*Antrim*	Aldergrove Airfield ..	3.17	140
,,	Keswick, High Hill ..	3.34	105	,,	Ballymena, Harryville..	3.34	117
,,	Ravenglass, The Grove	4.97	178	*Lon.*	Garvagh, Moneydig ..	4.52	177
Mon.	Abergavenny, Larchfield	3.22	121	,,	Londonderry, Creggan	4.08	156
Glam.	Ystaeyfera, Wern Ho. ..	4.17	119	*Tyrone*	Omagh, Edenfel ..	4.36	168

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, JANUARY, 1947

Stations	Pressure: Mean of Day M.S.L.	Pressure: Diff. from normal	Temperatures: Absolute Max.	Temperatures: Absolute Min.	Temperatures: Mean values Max.	Temperatures: Mean values Min.	Temperatures: Mean values ½ (Max. and Min.)	Temperatures: Mean values Diff. from normal	Temperatures: Mean values Wet bulb	Relative humidity	Mean cloud amount	Precipitation: Total	Precipitation: Diff. from normal	Precipitation: Days	Bright Sunshine: Mean	Bright Sunshine: Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	tenths	in.	in.		hrs.	%
London, Kew Observatory	1016·3	−0·6	52	15	40·5	31·1	35·8	−4·7	33·6	86	6·5	1·35	−0·41	15	1·6	19
Gibraltar	1018·3	−3·2	69	40	59·6	50·0	54·8	-0·1 —	51·8	91	7·2	5·27	—	14	—	—
Malta	1014·1	−2·9	66	44	58·0	49·1	53·5	—	52·2	81	5·4	3·06	—	14	5·1	51
St. Helena	1014·2	−1·8	72	57	68·4	59·3	63·9	+0·5	59·8	97	9·7	3·37	+1·33	24	—	—
Freetown, Sierra Leone	1010·3	+1·0	90	69	84·3	75·1	79·7	+0·9	72·9	81	4·7	0·00	−0·41	0	8·2	70
Lagos, Nigeria ..	1010·2	+0·6	96	61	93·0	70·0	81·5	+0·6	74·6	83	6·5	0·00	—	0	6·8	58
Kaduna, Nigeria ..	1010·9	—	97	52	88·9	57·4	73·1	−0·5	52·2	14	1·6	0·00	0·00	0	9·7	84
Zomba, Nyasaland ..																
Salisbury, Rhodesia ..																
Cape Town ..	1014·4	+1·0	86	54	78·4	61·5	69·9	0·0	60·9	64	2·8	0·52	−0·16	6	—	—
Germiston, South Africa	1010·8	—	88	53	80·1	59·2	69·7	—	60·2	65	4·2	4·43	—	15	8·9	65
Mauritius	1008·9	−2·8	94	71	87·3	74·7	81·0	+1·7	75·6	80	6·4	6·11	−2·05	21	7·3	55
Calcutta, Alipore Obsy.	1014·8	−1·0	83	50	78·8	57·2	68·0	+1·4	57·3	84	2·0	0·24	−0·18	1	8·2	75
Bombay	1011·5	−2·1	90	62	84·8	67·1	75·9	+0·4	65·9	78	1·5	0·00	−0·10	0	9·9	89
Madras	1012·4	−1·7	87	68	83·0	71·9	77·5	+1·3	72·6	92	5·6	5·34	+4·20	8	8·2	72
Colombo, Ceylon ..	1010·5	−0·3	89	69	85·4	72·9	79·1	−0·4	73·6	95	6·3	3·13	−0·12	13	6·6	56
Singapore	1009·2	−1·2	91	71	87·0	73·5	80·3	+0·6	76·7	83	—	11·51	+1·62	19	—	—
Hong Kong	1018·3	−1·4	75	49	66·1	58·3	62·2	+2·0	59·3	87	—	2·60	+1·28	9	2·1	19
Sydney, N.S.W. ..	1013·4	+1·0	86	59	77·2	64·4	70·8	−0·8	64·9	66	5·3	1·67	−2·00	10	8·6	61
Melbourne	1012·6	−0·3	103	46	80·4	55·6	68·0	+0·6	57·9	48	5·5	0·65	−1·24	4	8·5	59
Adelaide	1013·9	+0·9	103	52	85·4	60·3	72·9	−0·8	60·8	40	5·5	0·21	−0·51	6	9·7	69
Perth, W. Australia ..	1013·0	+0·5	99	51	83·3	62·2	72·7	−1·1	62·8	50	3·8	0·01	−0·33	1	10·5	86
Coolgardie	1011·6	+0·2	105	55	93·4	64·6	79·0	+1·6	60·7	37	2·4	0·25	−0·21	2	—	—
Brisbane	1011·6	+0·3	92	66	84·8	70·8	77·8	+0·6	72·1	64	7·7	11·91	+5·46	14	7·6	56
Hobart, Tasmania ..	1011·2	+0·9	93	43	71·7	51·0	61·3	−0·7	54·0	56	6·3	0·79	−1·04	12	8·9	60
Wellington, N.Z. ..	1013·8	+0·5	74	43	66·8	52·2	59·5	−1·7	55·7	75	8·2	1·93	−1·40	7	6·8	46
Suva, Fiji	1008·0	+0·5	92	72	86·3	75·2	80·7	+0·8	76·8	83	6·7	11·73	+0·30	22	7·3	56
Apia, Samoa ..	1007·6	−0·3	89	72	87·4	75·2	81·3	+2·3	78·7	80	7·4	16·55	−0·50	23	6·8	53
Kingston, Jamaica ..	1015·2	+0·1	91	66	80·4	70·2	75·3	−1·5	71·2	70	2·3	0·41	−0·55	2	9·3	83
Grenada, W. Indies ..	—	—	85	69	83·2	74·0	78·6	+1·5	74·1	76	6·7	4·88	+0·50	20	—	—
Toronto	1016·1	−1·8	48	0	34·2	19·9	27·1	+4·9	23·4	—	8·2	1·57	−1·22	8	2·2	24
Winnipeg	1013·4	−7·5	38	−25	16·9	−3·2	6·9	+10·8	3·6	—	5·6	1·46	+0·55	11	2·2	26
St. John, N.B. ..	1014·8	−0·7	50	−10	31·8	11·5	21·7	+2·5	18·8	—	5·7	4·90	+0·10	15	3·9	42
Victoria, B.C. ..	1018·9	+2·9	53	5	41·1	26·8	33·9	−5·1	32·4	90	6·9	7·12	+2·58	19	2·3	26