COMMENTS ON A PAPER BY E. G. BOWEN ENTITLED " THE INFLUENCE OF METEORITIC DUST ON RAINFALL ". 2*

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In this Journal Bowen (1953) has recently put forward evidence purporting to show that " there is a marked tendency for heavy falls of rain to occur on certain days rather than on others, and for this pattern to be repeated year after year ". It is claimed that these days of heavy rain coincide (within a margin of variation of ± 2 days) in many parts of the world, and a theory is put forward explaining the supposed phenomenon in terms of world-wide concentrations of dust produced by the impact of known meteor showers on the atmosphere. He suggests that debris from these meteors, partially disintegrated by atmospheric friction at heights of about 100 km, filters down to the tropopause in about 29 days, where it activates or " seeds " rain clouds, so producing heavy rainfall.

One purpose of this note is to show that Bowen has produced no real evidence of the existence of the world-wide phenomenon he describes ; that the various rainfall peaks he selects are due to one or two *local* cyclones ; and that it is possible to " establish " peaks on *any* calendar date by following his methods.

Analysis of Rainfall Data

It is notorious that of all meteorological data available for statistical analysis rainfall measurements are the least satisfactory ; these can and do fluctuate

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wildly from day to day, and from place to (nearby) place ; one hour of torrential rain may profoundly alter the run of statistics collected over many years. Therefore, before basing conclusions upon rainfall data it is doubly essential to apply the tests of " reality " which modern statistical theory has given us : this, unfortunately, Bowen does not do.

To illustrate in a simple way the erroneous conclusions which may be drawn from inadequate treatment of rainfall data it is proposed first to examine statistics for Sydney, over the period 1902–1944, for one day, January 13. This day (Bowen 1953, Fig. 1 (*b*)) gives the greatest aggregate rainfall of any January day over the 43-year period : its total rainfall, summed over 43 years,

TABLE 1

SOME EXCEPTIONAL RAINFALLS IN QUEENSLAND, NEW SOUTH WALES, AND VICTORIA DURING JANUARY 1911

Place	District	Date	Rainfall for One Day (points)	Normal January Rainfall for One Day (points)
		January		
West Leichhardt	Q. (Upper Western)	8	798	11
Cloncurry	Q. (Lower Carpentaria)	9	845	14
Muckadilla	Q. (Maranoa)	10	407	11
Kenilworth	Q. (Moreton)	11	911	25
Hebel	Q. (Warrego)	12	450	5
Sydney	N.S.W. (Metropolitan)	13	708	12
Eden	N.S.W. (South Coast)	14	665	10
Walhalla	Vic. (Gippsland)	14	552	10

is 1140 points (11·4 in.). It is readily calculated from Bowen's diagram that the *mean* aggregate daily rainfall, averaged over all January days, is 470 points. Thus January 13 has more than double the average for January days, and is accounted a significant peak (his Table 1 and Fig. 3) derived from an excess of rain " repeated year after year " on this particular date.

Now consider the rainfall on January 13 of *one year only*, namely, 1911. On that one day, according to Hunt (1912), 708 points fell in Sydney. Deducting this one fall from the 43-year aggregate leaves only 432 points to be credited to the remaining 42 January 13ths. Thus over 42 of the 43 years this date receives *less* rain than the January daily average, though classed by Bowen as a peak rainfall day of major significance.

It seems difficult indeed to derive any worthwhile conclusion from data so variable and so limited, and impossible to attach significance to daily peaks which, contrary to the quoted statement, do *not* derive from a repeated yearly pattern, but are built of one major fall. In fact, it should be possible by such methods, and judicious choice of place and epoch, to " establish " peaks of rainfall on any chosen date. We now do this (for a limited number of days), not only as a *reductio ad absurdum*, but because in the process light is thrown upon the true origin of such peaks. Using Hunt's (loc. cit.) rainfall figures for Australia during January 1911, Table 1 has been prepared. For each selected day (between January 8 and 14), a place was located which had received more than 35 times its average daily fall. It is then virtually certain that each of these places will exhibit a prominent peak on this calendar day, when the data of 43 years are

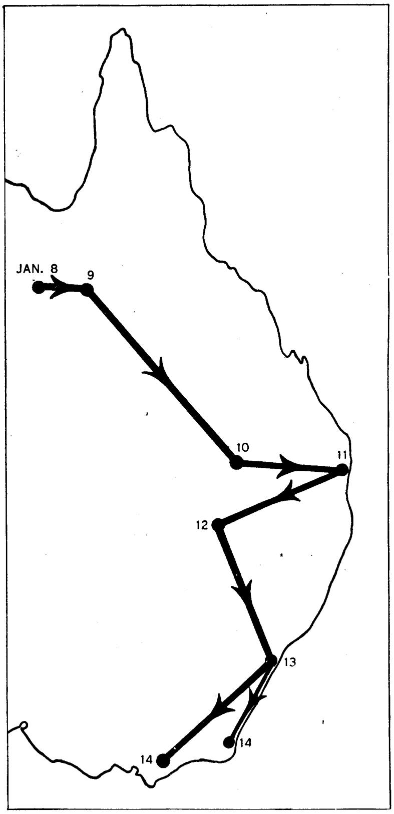

Fig. 1.—Centres in Queensland, New South Wales, and Victoria which successively have notable rainfall peaks on January 8, 9, 10, 11, 12, 13, 14 for the period 1902–1944, each the result of one heavy fall produced by the travelling cyclone of January 1911.

summed. It can be seen from the table that the rainfall figures of West Leichhardt (Upper Western Queensland), if examined by Bowen's method for 43 years, will show a peak on January 8, Cloncurry on January 9, and so on down to Eden (N.S.W.) and Walhalla (Vic.) which peak on January 14. The daily march of the sites of excessive rainfall from Carpentaria southwards is interesting (Fig. 1). As one might expect, a travelling cyclone was associated with all these heavy falls ; its track (Hunt 1912) follows closely in time and place the track of Figure 1.

Clearly, daily rainfall peaks derived from data covering only 50 years merely reveal the dates on which one or two active cyclones visited the selected region. The evidence of Table 1 shows that peaks can be obtained for *any* chosen day simply by searching the rainfall figures of stations in the vicinity of a cyclone particularly active in any of the chosen years. The period January 8–14 has been here chosen for illustrative purposes since during this week the centre of the cyclone of 1911 was over the Australian mainland and could be followed from day to day. However, this cyclone produced very heavy rainfall in Australia for at least a fortnight, as the following two quotations from Hunt (1912) show:

> " *Monsoonal Depressions* (*of January 1911*).—The first of these influences (1st to 17th) was one of the most noteworthy monsoonal rainstorms on record. Starting in the Gulf of Carpentaria, it moved very slowly southward over the district at the head of the Gulf, thence through central, eastern, and south-eastern Queensland into the central eastern parts of New South Wales. Over a wide area on either side of its central track in Queensland and New South Wales continuous and heavy rains fell, and in Northern Queensland some phenomenal falls were recorded, e.g., Port Douglas, 1954 (for forty-eight hours to 9 a.m. 2nd); Granada, late Donaldson, 2780 (for forty-eight hours to 9 a.m. 9th). The average annual rainfall at Granada, it may be noted, equals 2266. The rains also extended to the Straits and very heavy falls were recorded in Gippsland."

> " *Weather Notes—January 1911. Queensland.*—In the closing days of last year a disturbance developed off Port Darwin, and, having caused very heavy rain in the far north of Northern Territory, travelled in an eastward direction to the Gulf of Carpentaria where it lodged, with practically no change of position, until the 5th. Up to that date the influence of the approaching rainstorm co-operated with a tropical disturbance to the north-east of Cooktown, and general heavy rain fell in consequence throughout the Peninsula and Northern Coast Divisions, among the more notable registrations being 420 points at Fairview, 720 at Cairns and 1164 at Port Douglas to 9 a.m. 2nd; 1197 points at Cairns to 9 a.m. 3rd, and 700 at Ingham and 989 at Innisfail to 9 a.m. 4th. On the 5th the monsoonal storm began to move definitely on a south-easterly course till the centre reached the vicinity of Emerald whence it bore more and more southerly, finally passing into the north-eastern regions of the neighbouring state. Rain of a widespread and generally heavy nature attended the passage of this famous disturbance throughout the entire length of Queensland, and only that part of the state lying to the westward of a line joining Camooweal, Isisford, and Hungerford escaped substantial benefit. The registrations at many of the stations over which the centre of the disturbance passed were of a quite phenomenal and, in several instances, unprecedented nature."

It is clear that this one cyclone produced rainfall peaks in local parts of Australia on each day from January 1 to 14 in the statistics for the period 1902–1944. This finding is entirely inconsistent with Bowen's conclusion that meteoritic dust tends to produce heavy rainfall all over the world on January 12–13. His remarkable histogram (Fig. 3, loc. cit.), with three major groupings around certain dates, is not evidence of a natural phenomenon ; it demonstrates, as does Figure 1 above, that for statistically short periods (say 50 years) sites may be *selected*, from the wealth of world-wide data available, which will show rainfall peaks near any particular day or group of days. It should be observed, also, that, since he deals with sites and epochs yielding 2–4 peaks per month, and allows a margin of ± 2 days for coincidence, there is an even chance that a peak in any newly chosen locality will " coincide " with a peak already found.

Local Weather Singularities

Nevertheless, although no evidence appears of *world-wide* calendar days of excessive rainfall, it should not be assumed that in *local regions* there is not a tendency for certain weather singularities to recur on or about the same dates each year. The Indian monsoons provide striking examples of such regularities : the European " summer monsoon " of early June is less marked, but equally real (Brooks 1946).

Folk-lore of the older countries contains numerous suggestions that abnormal weather tends to recur at certain times of the year. In Europe there is " Blackthorn winter " at the end of March, the " Ice saints " of May 11–13, the " Old wives' summer " of late September, " St. Luke's summer " in mid October, and the " Christmas storm ". These legends were ignored by meteorologists until Buchan (1869) published a paper entitled " Interruptions in the regular rise and fall of temperature in the course of the year ". Buchan believed that he had found (for Edinburgh) six short periods of cold spells and three abnormally warm periods. Buchan's work aroused great interest, and his " hot " and " cold " spells are still frequently referred to by laymen, particularly in Scotland.

In recent years Brooks (loc. cit.) has published a statistical examination of annual weather " singularities " in Western Europe, made in the British Meteorological Office in 1941–1942, obviously with a view to possible military application. In this study Brooks examined one of the most fundamental of weather phenomena, the pressure distribution. After careful statistical investigation he concludes that at least part of European folk-lore, and a part of Buchan's conclusions, are well founded. For example, he finds, from 52 years' data, a high probability that early January will be stormy (cyclonic), mid January quiet (anticyclonic). It is intrinsically likely that weather instabilities should appear regularly at this time of the year in Western Europe. To quote Brooks : " In winter the land masses, and the air over them, cool rapidly, while the surface of the ocean stays relatively warm. A pool of cold air collects over Europe, retained in place for a time by friction with the surface. Ultimately this pool becomes unstable and breaks out towards the Atlantic as a stream of cold air, after which the process begins again. Since solar radiation varies little from one year to another, the growth of the pool of cold air to the point of instability might be expected to take about the same time in different years, so that the alternations of warm and cold periods in Britain should recur at or near the same dates."

I suggest that the " British Rainfall " data displayed in Figure 2 of Bowen's paper agree with Brooks's findings *for this region.* Bowen's data are confined to the years 1919–1949, whereas Brooks covers the period 1889–1940 ; both authors find a rough 10-day cycle, a stormy period early in January, and a fine spell in mid January. In view of the general agreement between Bowen's British rainfall cycle in January and the British storm cycle previously found by Brooks, there is no reason to doubt the physical reality of the former, in spite of the apparent inadequacy of the 30 years' rainfall data used. The explanation undoubtedly lies in the fact that Bowen's data, in this instance, are derived from *all* the rain-gauges in Britain ; the paucity of years is substantially compensated by the abundance of observers ; his " wet days " are those on which heavy rain was recorded *anywhere* in Britain.

In concluding this brief discussion of Bowen's British rainfall statistics, which, for the reason just given, appear much more soundly based than those used for the southern hemisphere, it is important to point out that these stormy periods in Britain are, as in Australia, associated with the normal travelling cyclonic disturbances which bring storms and rain to any part of the world. There can be no question of cosmic dust releasing heavy rain on any particular day or days of the year, as Bowen suggests ; during their whole lives such cyclones bring storms and rain to the regions they traverse. The fact that Bowen's " wet day " cycle agrees with Brooks's cyclone cycle shows that no novel process of rainmaking is required. Energy of at least 10^{24} ergs must be supplied to create a cyclone ; this vast amount (much greater than has been released in all nuclear explosions to date) cannot come from a sprinkling of dust ; it comes from the solar furnace.

Noctilucent Clouds and Meteoritic Dust

Bowen concludes by demonstrating pictorially a correlation between Vestine's (1934) data on the occurrence of noctilucent clouds and Lovell and Clegg's (1952) data on meteor showers, as detected by radio means. On the limited meteor data available in 1934, Vestine had concluded that these clouds, which occur at a height of about 82 km, were probably composed of cosmic (i.e. non-terrestrial) dust. This conclusion is intrinsically likely, since meteors disintegrate near this level owing to friction with the atmosphere. Moreover, 82 km is a level of temperature inversion (Martyn and Pulley 1936) at which the atmosphere becomes dynamically stable. In the lower atmosphere the concentration of smoke and haze at such inversion levels is well known. Applying Lovell and Clegg's data Bowen has considerably improved Vestine's correlation of cosmic dust showers with noctilucent clouds. It is now virtually certain that noctilucent clouds are the visible manifestation (by reflected sunlight) of the deposition of a tenuous layer of cosmic dust at great heights. As it settles slowly through the turbulent atmosphere below 82 km this dust layer will be rapidly dissipated and spread out over great depths. Its gradual arrival in the weather region of the troposphere must be spread over weeks or months, and could have no world-wide effect on the rainfall of any particular calendar day. But this point needs no belabouring in the absence of real evidence that world-wide rainfall singularities exist.

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