SHORT COMMUNICATIONS

THE INFLUENCE OF METEORITIC DUST ON RAINFALL*

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A great deal of attention has been given in the meteorological literature to periodicities in the weather and to singularities in temperature or pressure, that is, occasions on which these quantities tend to have an abnormally high or an abnormally low value. The analysis of daily rainfall figures has not received as much attention, however, and it is the purpose of this note to point out some unexpected features in the rainfall occurring in different parts of the world and to advance a possible explanation for the phenomenon.

The weekly or monthly mean rainfall figures for any one station over a number of years seldom show departures from the mean which are greater than would be expected from statistical fluctuations. If the daily rainfall figures are examined, however, it is apparent that in some localities 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.

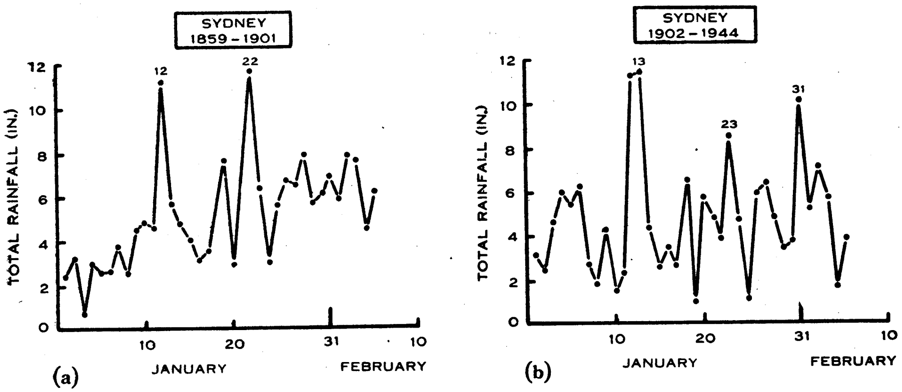

Fig. 1.—Daily rainfall of Sydney for January. (*a*) 1859–1901 and (*b*) 1902–1944.

For purposes of illustration the total daily rainfall of Sydney for January and the first five days of February for the period from 1859 to 1901 is given in Figure 1 (*a*). It shows a general increase throughout the month, conforming to the seasonal pattern, and two exceptional peaks occurring respectively on January 12 and January 22. The magnitude of each peak is approximately twice the mean and their departure from the mean about four times the standard

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deviation of the remainder. The corresponding curve for the period from 1902 to 1944 is given in Figure 1 (*b*) and it is seen that two similar peaks occur on January 12–13 and January 23, while another appears on January 31. It will be shown later than this third peak is a significant one.

The near coincidence in time of the first two peaks was unexpected enough to stimulate an examination of the rainfall figures of other stations in corresponding latitudes to see whether they too showed any unusual characteristics. The surprising discovery was made that many stations over a wide area tended to show peaks of similar magnitude on nearly the same days. Figures for periods of approximately 50 years are available for seven stations in the southern hemisphere extending over 180° in longitude from South Africa to New Zealand. These are listed in Table 1, together with the dates on which the rainfall exceeds the mean by 50 per cent.

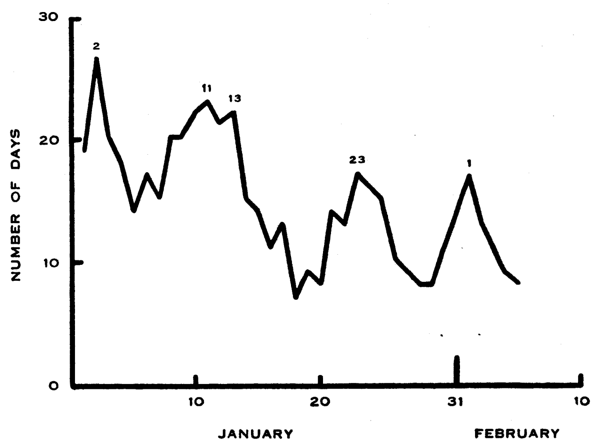

Fig. 2.—Number of occasions in January on which heavy falls of rain were recorded in the British Isles from 1919 to 1949.

Figures for a comparable area in the northern hemisphere are, unfortunately, not available at the time of writing, but records are available for a few individual stations in the British Isles. They show that the rainfall there has a smaller variability than in the stations just discussed and they do not show peaks which depart significantly from the normal fluctuations. Examination of the daily records in localities which do show the peaks of rainfall indicates that they are due to a comparatively few days of exceptionally heavy rain and are not due to a greater frequency of rain on those days. The British records have therefore been re-examined, taking into account only exceptionally heavy falls. These are recorded in the publication "British Rainfall" and Figure 2 gives the number of days on which heavy* rain fell anywhere in the British Isles during the period from 1919 to 1949. This curve shows a maximum on January 2 which does not correspond to those already discussed and three other maxima

* Heavy rain is defined in the records as more than $2\frac{1}{2}$ in. in a day, or more than $7\frac{1}{2}$ per cent. of the annual rainfall in areas where this is less than $33 \cdot 3$ in.

respectively on January 11, January 23, and February 1, corresponding closely to those in the Sydney rainfall.

These peaks have been included with those of southern hemisphere stations in Table 1. It is seen that in all stations there is a remarkable grouping of the peaks, the actual distribution over the month being given in Figure 3. With the single exception of January 2 already noted, the peaks are grouped around January 13, 23, and 31 with a spread of ± 2 days about these dates. Although these examples are confined to January, similar results are obtained in other months of the year.

TABLE 1

DATES OF RAINFALL PEAKS

Place	Period	Dates on which Peaks of Rain Occur			
Durban	1900–53		Jan. 12 & 16	Jan. 22	Jan. 30
Perth	1907–52		15	20 & 24	31
Alice Springs ..	1900–52		14	21	28 & 31
Sydney	1900–49		12 & 13	23	31
Brisbane	1900–49		13	24	Feb. 1
Auckland	1900–53		13	21	Jan. 29 & Feb. 1
Christchurch ..	1905–53		14	24	—
Great Britain ..	1919–49	Jan. 2	11 & 13	23	Feb. 1

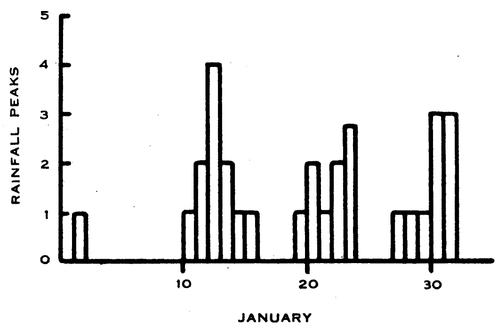

Fig. 3.—Distribution of rainfall peaks in January for Durban, Perth, Alice Springs, Brisbane, Sydney, Auckland, Christchurch, and the British Isles.

The question arises whether this phenomenon can be accounted for by climatological factors alone or whether some other influence is at work. If it were due to climatological effects one would expect it to be propagated with a velocity similar to those of weather systems. No such tendency is found and there is no evidence for progressive displacement in the timing of the peaks with geographical location. Furthermore; the particular years on which heavy falls of rain contributed to the peak on January 14, at Alice Springs for example, are quite different from those which gave a peak on the same date at Christchurch. Finally, it is difficult to conceive of any climatological effect which would give heavy rainfall in the southern hemisphere on approximately the same dates as in the northern hemisphere. Clearly, the explanation of the effect is likely to be found in a phenomenon which can operate simultaneously over a large part of the world; this suggests that it is of extraterrestrial origin. Of the great number of extraterrestrial phenomena which could be responsible, the only one which meets the requirement of repeating year after year on the same dates is that of meteor showers.

The average number of meteors which can be seen by eye in any part of the sky is 10 or 12 per hour. These are due to meteor particles which are distributed more or less at random in the solar system. Occasionally, however, the Earth passes through vast meteor streams which follow elliptical orbits about the Sun and the number of visible meteors can then increase to upwards of 50 or 60 an hour. Ten night-time streams of this kind are known to observers in the northern hemisphere and they occur regularly year after year at fixed dates and times. Other, daylight streams have recently been discovered by radar methods and a complete description can be found in the literature (see Lovell and Clegg 1952; Porter 1952).

The dates of meteor streams nearest in time to the rainfall peaks already discussed are:

Geminids	December 13–14
Ursids	December 22
Quadrantids	January 3

That is, the rainfall peaks tend to follow the meteor showers after an interval of about 30 days.

Meteor streams occur predominantly at two periods of the year, during May, June, and July and again during October, November, and December. Those in May, June, and July are closely grouped in time and are difficult to distinguish from one another. Those in October, November, and December, however, are separated by longer intervals. If the Sydney rainfall for this period is examined it is found that distinct peaks of rainfall follow each meteor shower with an average delay of about 29 days. In Figure 4 is given the curve of the daily rainfall during November, December, and January from 1900 to 1949. Immediately above are the dates of each meteor shower displaced 29 days in time. The correspondence with the rainfall peaks is obviously a close one.

It can be concluded therefore that at certain stations and at certain times of the year there is a high probability of a peak of rainfall appearing some 29 or 30 days after the Earth enters a major meteor stream.

It remains to explore the physical process by which meteor showers might influence world rainfall in this way. One possibility is that the meteoritic dust accompanying meteors provides rain-forming nuclei when it falls into cloud systems in the lower atmosphere. It is well known that the formation of rain in clouds is dependent on the existence of certain types of nuclei. On occasion, these are not available from terrestrial sources and clouds build up to great heights without giving rain.

The dust in interplanetary space is known to consist of particles with a wide range of sizes. These are swept up by the Earth in its orbit, and Whipple (1950) has shown that those greater than 4 μ in diameter have sufficient energy to burn up on entering the atmosphere and become visible as meteors. Those smaller than 4 μ are not consumed and fall slowly to the ground. The total mass of material falling on the Earth in sizes large enough to give visible meteors is estimated to be about a ton a day. The amount of accompanying material in smaller sizes appears to be very much greater and van de Hulst (1947) has shown, from considerations of the way in which they scatter light from the

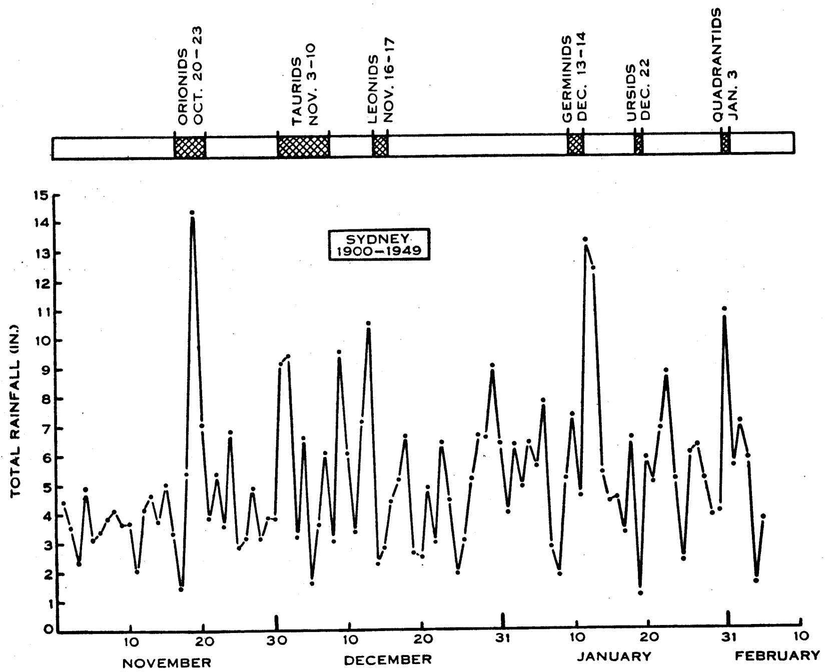

Fig. 4.—Daily rainfall of Sydney for November, December, and January for the period 1900–1949, together with dates of the main meteor streams displaced 29 days in time.

Sun, that the concentration of these particles in free space is approximately $10^{-6}/m^3$, and the total mass swept up by the Earth is on the average about 10,000 tons a day.

The particles have velocities ranging from 10 to 30 km/sec in relation to the Earth and on entering the atmosphere they are decelerated suddenly at about 100 km, a height which is relatively independent both of their initial velocity and direction of arrival. Their velocity falls abruptly from tens of kilometres a second to less than one centimetre a second. A sudden increase of particle density of about a million times therefore takes place at this level; that is, their concentration within the atmosphere will approach $1/m^3$.

A calculation of the time of fall of particles of 1–4 μ diameter from the 100 km level shows that they would take from 30 to 50 days to descend to the

40,000 or 50,000 ft level. At this height they could meet some of the larger cloud structures of the lower atmosphere and might thus influence the incidence of rainfall.

It is seen therefore that meteoritic dust exists in adequate quantities to affect the rainfall of the lower atmosphere and its time of fall is of the right order to account for the observed interval between meteor showers and peaks of rainfall.

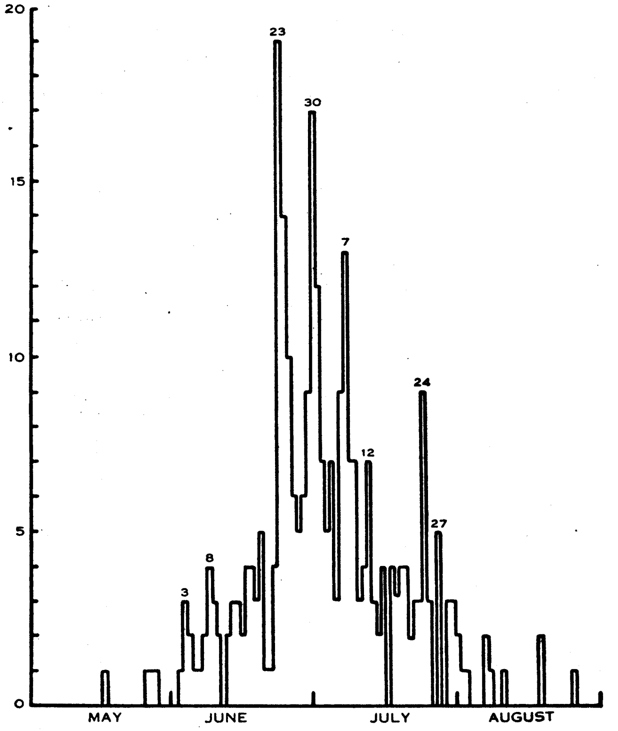

Fig. 5.—Number of occasions on which noctilucent clouds have been observed for the period 1885–1933 (Vestine 1934).

The Relation between Meteoritic Dust and Noctilucent Clouds

If, in fact, meteoritic dust can influence rainfall in this way it might produce other effects in the atmosphere which can be recognized. Among the effects already reported is a reduction in atmospheric transparency about the time of the Perseids described by Zacharov (1952). The ionization produced by the heavier particles in the ionosphere is, of course, well known and will not be enlarged upon.

The sudden stoppage of the smaller particles and the corresponding increase in their concentration in the 80–100 km region leads one to connect them with noctilucent clouds, which are occasionally seen at these heights. The origin of these clouds has never been completely determined but Vestine (1934) examined the possibility of their being due to dust from volcanoes, the debris of comets, or meteoritic dust. He concluded that there was no evidence in favour of the first two and that they were probably due to the third.

This probability becomes almost a certainty if a comparison is made between the incidence of noctilucent clouds and the time of occurrence of meteor streams. Vestine gives a curve, which is reproduced in Figure 5, of the total number of occasions on which noctilucent clouds have been seen in the period from 1885 to 1933. These are concentrated around the summer solstice, when seeing conditions are good in the northern hemisphere. This curve has a number of well-defined peaks which occur on the dates given in the first column of Table 2. In the second column are given the dates of the principal meteor streams which occur during the same period. It is seen at once that the noctilucent clouds

TABLE 2

COMPARISON BETWEEN DATES OF APPEARANCE OF NOCTILUCENT CLOUDS AND METEOR SHOWERS

Dates on which Noctilucent Clouds Observed (Vestine)	Date of Meteor Shower (Lovell)	Name of Meteor Shower
June 3	June 3	ζ-Perseids
8	8	Arietids
23	25	54-Perseids
30	July 2	β-Taurids
July 7	—	—
12	12	ν-Geminids
24	25	θ-Aurigids
27	28	δ-Aquarids

tend to appear either at precisely the same date or within a few days of the meteor streams. It is noteworthy that, with the exception of the δ-Aquarids on July 28, the whole of these are daylight streams which were not discovered until 1948 and were unknown when Vestine examined the data.

It can be concluded with a fair degree of certainty, therefore, that noctilucent clouds have their origin in meteoritic dust. Whether the material which becomes visible is the dust itself or whether it acts as a nucleus for the formation of ice crystals or the condensation of water vapour remains to be decided. Noctilucent clouds have been seen at line-of-sight distances up to 600 km and the same cloud has been seen simultaneously from Canada and Siberia. Clearly a great number of particles are involved and when they fall to the lower atmosphere they might well influence the rainfall in the manner which has been discussed.

Meteorological Implications of the Phenomenon

In conclusion, some brief remarks are made about the meteorological implications of the phenomenon discussed in this paper.

In the first place, the art of forecasting might be influenced in one important respect. As pointed out earlier, while the amount of rain on a certain date might be considerably in excess of normal, the probability of rain occurring on that day is no higher than on the days immediately preceding or following it. In other words, the probability that clouds suitable for the formation of rain will build up is determined by climatological factors and, averaged over a long period of years, would not show great variations from one day to the next. The amount of rain, however, is influenced by the supply of rain-forming nuclei in the atmosphere. In the absence of nuclei from terrestrial sources, knowledge of an impending fall of meteoritic dust might be important in estimating whether extremes of rain are likely to be obtained in any given climatological situation.

Finally, the results might have an important bearing on the problem of artificial rainmaking. If the present results are substantiated it means that the presence of relatively small concentrations of particles falling from the upper atmosphere can result in the rainfall of particular days being about double that of days preceding them. It suggests that, at least in certain parts of the globe, the potential increase in rainfall which could be obtained by artificial methods might exceed the figure of 10 or 15 per cent. which has previously been estimated.

Acknowledgments

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