A Relation between Meteor Showers and the Rainfall of November and December

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Abstract

An examination is made of the November and December rainfall of approximately 300 stations distributed over the globe. Six singularities are found, five of which occur about 30 days after prominent meteor showers. This result is similar to one which has already been reported for the month of January. The remaining singularity on November 26 could be due to a daylight meteor stream from the direction of Virgo which has just been discovered in the Southern Hemisphere.

One of the better known meteor showers during the period investigated, namely the Giacobinids is known to have an orbital period of 6.6 years. A similar recurrence tendency is found in the rainfall 30 days later.

1. Introduction

In a recent paper (BOWEN, 1956) the hypothesis was advanced that the rainfall of many parts of the world is influenced by the earth's passage through streams of dust in the solar system. It was shown that if the daily rainfall records of a sufficiently large number of stations were totalled for the month of January, they did not result in a smooth curve approximating to the mean January rainfall, but tended to show well defined maxima on certain calendar dates. The dates of these maxima showed a close correspondence for regions separated both in latitude and longitude and they occurred approximately thirty days after prominent meteor showers. It was suggested that the phenomenon was due to the nucleating effect of the dust associated with meteor streams falling into the cloud systems of the lower atmosphere.

This hypothesis was first put forward in a preliminary note (BOWEN, 1953) which was subsequently criticized in rather severe terms by SWINBANK (1954), MARTYN (1954), NEUMANN (1954) and by M. B. and V. J. OLIVER (1955). The basis of these criticisms was that the variations in rainfall were not real and could be accounted for as normal statistical fluctuations or, alternatively, any variations which did take place could be accounted for in terms of well-known climatological phenomena. It is not proposed to deal with these criticisms in detail in the present paper except to point out that each of these authors based his opinion on an extremely small amount of data. The investigation of a world-wide effect

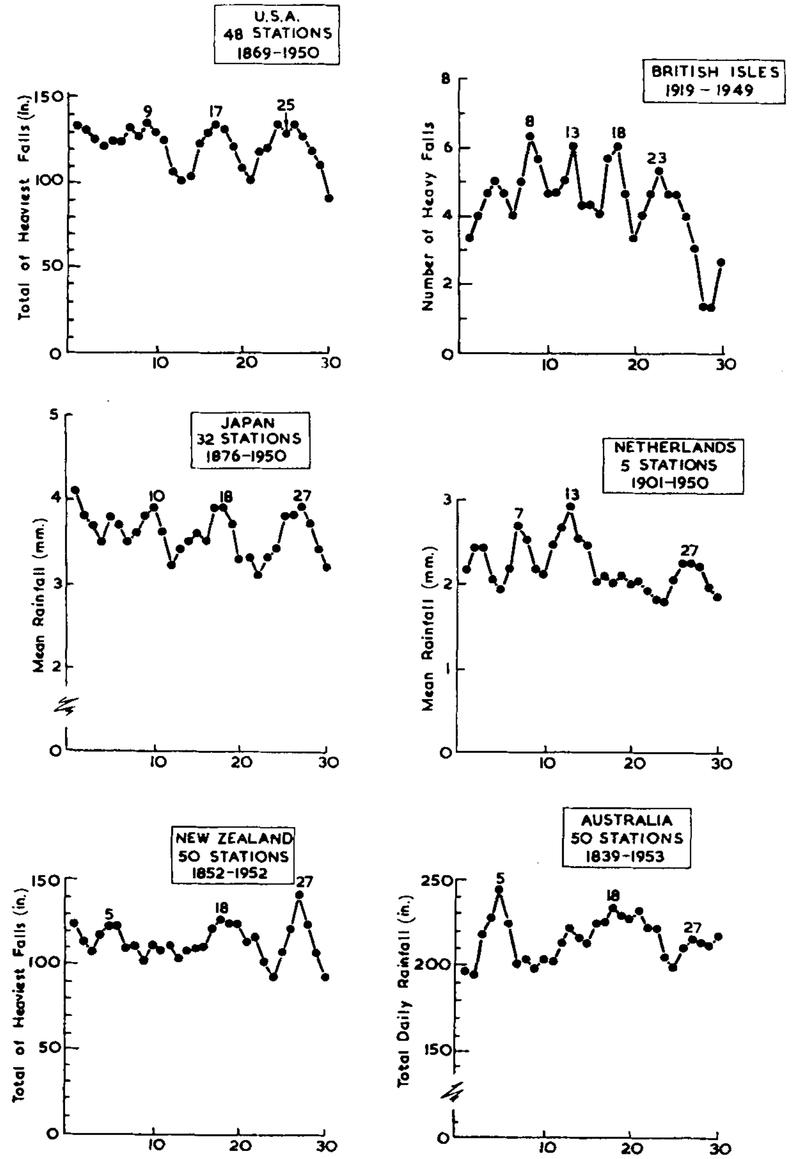

Fig. 1. Rainfall curves for the month of November for U.S.A., Great Britain, Japan, Netherlands, New Zealand and Australia.

calls for the study of a large amount of data from widely separated points. Swinbank, however, referred to the rainfall records of only three stations, Melbourne, Madras and Nagapattinan, while the Olivers used data from a small number of stations in Kenya covering a period of only 10 years. Martyn referred to 8 stations in Australia covering a period of 6 days in one year only, namely 1911. This is approximately 1/10,000th of the amount of data given in Fig. 1 or Fig. 2 of the present paper. Neumann performed a statistical test which violates one of the first rules of time series analysis, namely that under no circumstances should the data be shuffled.

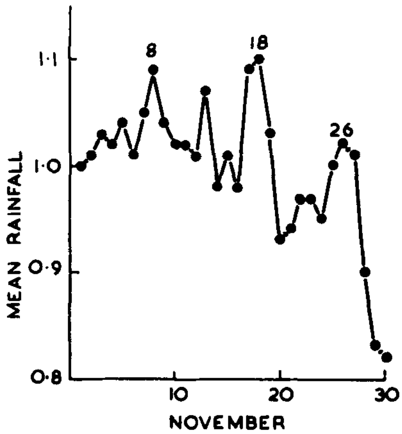

Fig. 2. The mean rainfall curve for November obtained by summing the means of all curves in Fig. 1.

It is only fair to point out that the meteor hypothesis has been commented on less critically by RIEHL (1954) and by BROWNE, PALMER and WORMELL (1954). The latter add a warning which might well have been heeded by the previous critics, namely that the "suggestion needs more than a superficial examination before a conclusion can be reached and [the] observations, if they are valid, will be hard to explain by any other theory". DHAR (1954) has published evidence that there might be a similar influence affecting the rainfall in India, while CWILONG (1955), SMITH, KASSANDER and TWOMEY (1956) and BIGG (1956) have described physical measurements of the entry of meteoritic dust into the top of the atmosphere and observations of the behaviour of freezing nuclei in the lower atmosphere which either support the hypothesis or are consistent with it.

The present paper presents an analysis of the rainfall for the months of November and December which is similar to that already published for January. The choice of these months is dictated by the fact that some of the best known meteor showers occur about this time of year and their properties have been reasonably well established. Because experience has shown that it is difficult to appreciate the details of more than one month's rainfall at any time, it is proposed to treat the months separately and to assemble the results at the end of the paper.

II. Sources of data

In analysing the rainfall records of different parts of the world it would be preferable to use the identical quantity—for example, the daily rainfall or the heaviest fall of the month—for each locality. Unfortunately, records which are in precisely the required form are not easy to obtain and the records used in the present analysis are those which could most readily be obtained by mail from the respective Weather Bureaus. They refer to six widely separated regions of the globe and in every case the stations were selected by officers of the Weather Bureaus concerned. They comprise the following:—

1. The heaviest falls of the month for 48 stations in the U.S.A.
2. The falls exceeding $2^1/_2$ inches in 24 hours recorded on any of the official raingauges in Great Britain.
3. The mean daily rainfall of 32 stations in Japan.
4. The mean daily rainfall of 5 stations in the Netherlands.
5. The heaviest falls of the month for 50 stations in New Zealand.
6. The daily rainfall of 50 stations in Australia.

These data are identical with those used in the previous paper except that, in the case of Australia, figures for 50 stations distributed throughout the continent are now available and have been used in preference to those of 23 stations in the State of New South Wales. A list of stations and periods for which records are available in the first five regions was given in the Appendix to the previous paper. The corresponding list of Australian stations is given in the Appendix to the present paper. Approximately half these records date from 1907 or 1908 and the remainder from about 1880. There are a few longer records, however, notably that of Adelaide which dates from 1839. The whole have been included in the present analysis; it will be observed that the dates assigned to each region in the curves of Fig. 1 are the earliest and latest dates for which any records are available.

III. November rainfall

In Fig. 1 are given the rainfall curves of November for the above regions of the world.

As in the previous paper, these curves and those of Fig. 6 have been smoothed by taking three day running means. During the first ten days of the month the agreement between the curves is not good, but during the latter part of the month there are peaks which are grouped about November 18 in five of the six regions, and peaks grouped about November 26 in all six. Following the procedure in the previous paper, the curves have been normalized and added together giving the curve of Fig. 2. It may be taken to represent the daily variations from the November mean for approximately 300 stations distributed over the globe. It shows distinct maxima on November 18 and 26, as might be expected from the individual curves, and a third peak on November 8. There is a smaller peak on November 13 which must be regarded as of doubtful significance since there is a minimum on three of the curves on this date.

In the previous paper it was shown that the peaks in the January rainfall tend to occur about thirty days after prominent meteor showers. On this hypothesis, the meteor streams which might be expected to affect the November rainfall are the Giacobinids of October 9 and the Orionids which commence on October 20 and continue until the 23rd. It is seen that the rainfall peak of November 8 occurs exactly 30 days after the Giacobinids, and the peak of November 18 is 29 days after the date of the first appearance of the Orionids. This is in good agreement with the January results.

If the hypothesis is correct, one might also expect a meteor shower about October 27, to

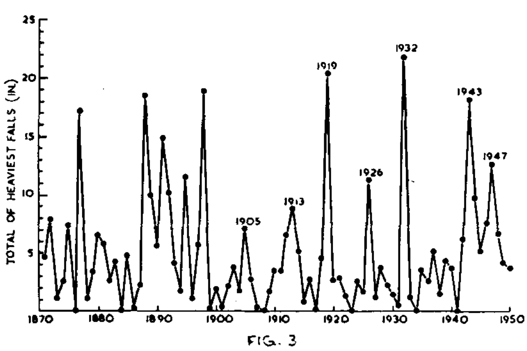

Fig. 3. The heaviest falls of the month for the three days, November 8, 9 and 10, for 48 stations in the U.S.A. from 1870 to 1950.

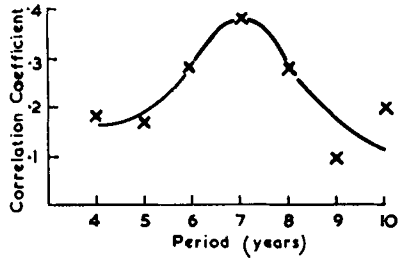

Fig. 4. Cross correlation of rainfall of U.S.A. on November 8, 9 and 10 against a saw-toothed function with period from 4 to 10 years.

account for the rainfall peak on November 26. The day and night time meteor streams of the northern hemisphere, and the night time streams of the southern hemisphere are now reasonably well known, but there is no prominent stream on this date. However, the possibility remains of a day time stream being discovered in the southern hemisphere.

It is interesting to observe that Ellyett and Roth (1955), in their radar observations of daytime meteors in the southern hemisphere, appear to have found a stream on about the expected date. They state that "A new shower from the direction of Eridanus is present in late June, and there appears to be a strong and quite enduring shower from the direction of Virgo over the period October 22—November 7 . . . No significant daylight activity has been found over the other months."

It will be interesting to see if future observations confirm the existence of this shower and indicate whether there is a maximum activity about the anticipated date of October 27.

The periodicity associated with the Giacobinids.—The Giacobinids are one of the meteor streams of recent origin which exhibit a marked variation in intensity from one year to the next (Lovell, 1954). The meteors are associated with the Giacobini-Zinner comet which has an orbital period of 6.6 years. It appeared in 1900 and the earth passed very close to the tail. It was predicted that the earth would pass through the tail on its later appearances and that a display of meteors might be expected. There are reports of such meteors in 1913 and 1914 (Davidson, 1915; Denning, 1918) which are open to some doubt, but in 1926, 1933 and 1946 there were spectacular appearances which have been extensively

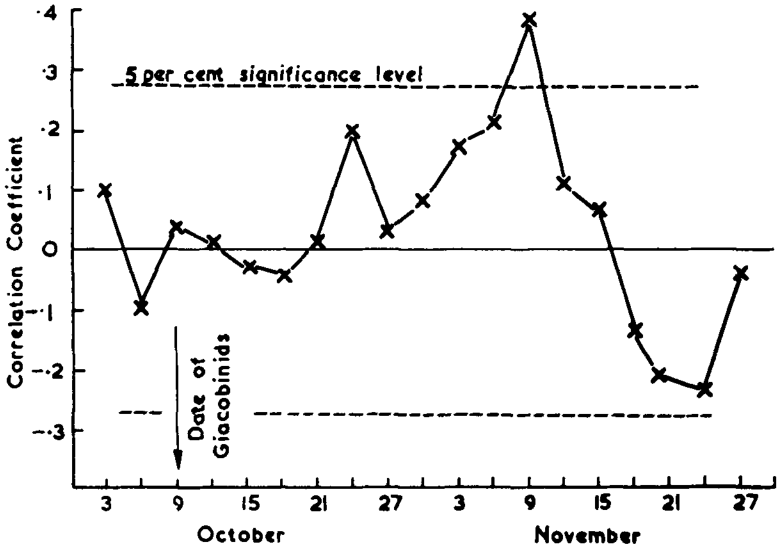

Fig. 5. Cross correlation of rainfall of U.S.A. with a sawtoothed function of period 7 years, for each successive three day period in October and November.

described. The meteors were not observed, however, in 1939.

If the rainfall thirty days after the Giacobinids were influenced by that stream it would be expected to show a similar 6 to 7-year recurrence tendency. The rainfall peak which might correspond to this shower occurs in the U.S.A. on November 9, and in Fig. 3 is given the total of the heaviest falls of the month for the 48 stations in the U.S.A. for the three days November 8, 9 and 10 for each year over the period of records. It will be seen that there is no obvious pattern prior to 1900, but commencing about 1900 the rainfall shows sharp maxima in 1905, 1913, 1919, 1926 and 1932, that is, with approximately the same period and phase as the meteor stream. There is no peak in 1939 when the meteor stream was absent, but there are other peaks in 1943 and 1947.

If there is a relation between the meteor stream and rainfall, the latter would be expected to show a significant 6 or 7-year recurrence tendency. This may be investigated quantitatively by cross correlating the rainfall against a saw-toothed function having successive values 0, 0, $^1/_2$, 1, $^1/_2$, 0, 0 etc. with gradually increasing period. The correlation coefficients between this function and the rainfall of the U.S.A. from the date of appearance of the comet, namely 1900 until 1950, are given in Fig. 4 for periods from 4 to 10 years. They fall on a smooth curve with a maximum value at 7 years. The correlation coefficients at 6 and 8 years each have a value 0.28, which is significant at the 5 per cent level. The value for a recurrence period of 7 years is 0.38, which is significant at the 1 per cent level.

The rainfall for corresponding 3-day periods before and after these three days shows no such recurrence tendency. In Fig. 5 are given the correlation coefficients against the saw-toothed function with a 7-year period, for each successive 3-day period throughout the months of October and November. They are all below the 5 per cent significance level with the exception of November 8, 9 and 10. This may be taken as supporting evidence that the rainfall of November 8, 9 and 10 is related to the Giacobinid meteor shower.

It will be interesting, when more data become available, to examine the geographical distribution of this effect over the northern and southern hemispheres. The Giacobinids are incident on the earth from declination 54° N and it is doubtful whether dust associated with this shower would reach into the southern hemisphere. It appears from the curves of Fig. 1 that the rainfall peak about November 8 is absent in the Australian and New Zeeland

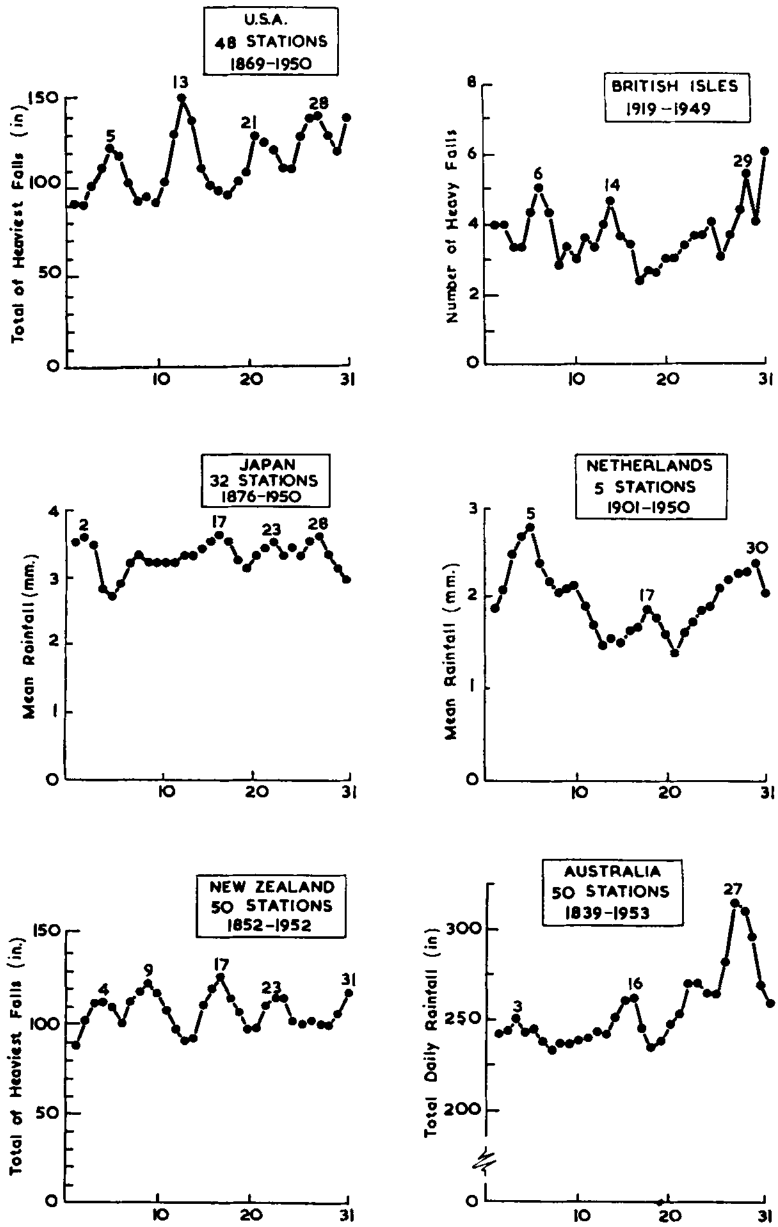

Fig. 6. Rainfall curves for the month of December for U.S.A., Great Britain, Japan, Netherlands, New Zealand and Australia.

records, but it requires data from the other two land masses in the southern hemisphere before this point can be adequately investigated.

Before proceeding, there are several features of Fig. 3 which should be remarked upon. In the first place it is interesting that the effect on rainfall appears to have started about the same time as the appearance of the comet and before visible meteors were observed. This suggests that the dust which is influencing rainfall is not in quite the same orbit as the visible meteors, a result which is similar to that already obtained with the Bielids (BOWEN, 1956). In the same way, although there is a good statistical relation between the period and phase of the visible meteors and the rainfall, there is not always exact agreement in the dates of the maxima. For example, the visible meteors made a strong appearance in 1933 but the rainfall peak appeared in 1932. This suggests that the earth passed through the dust which was capable of affecting rainfall in 1932 but did not pass through the larger particles which give visible meteors until it had returned to the same position in its orbit a year later.

Finally, it is interesting to observe in Fig. 3 the depth of the rainfall minima during periods when the meteoritic dust is presumably absent, and the exceptional magnitude of the peaks when it is present.

IV. December rainfall

In Fig. 6 are given the rainfall curves for the month of December for the same regions as in Fig. 1. The agreement between the individual curves is not as close as for November and January but peaks appear in five out of the six regions on dates distributed around December 4, and in all six regions about December 29. Combining the curves by addition of the daily means gives the curve of Fig. 7, in which it is seen that three peaks occur on December 5, 14 and 29 respectively.

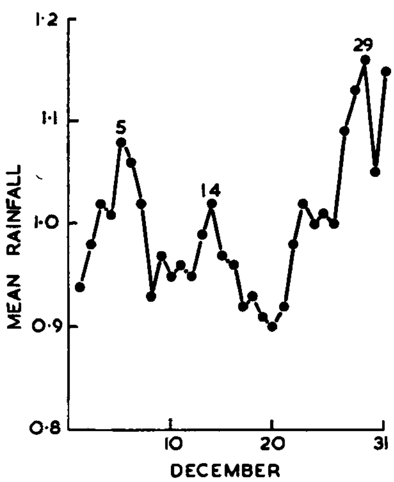

Fig. 7. The mean rainfall of December obtained by summing the means of all curves in Fig. 6.

The meteor showers which might influence the December rainfall are the Taurids, the Leonids and the Bielids. The Taurids are of relatively long duration, commencing on November 3 and continuing until November 10. If the date of commencement is arbitrarily taken as the basis of reference, the rainfall peak on December 5 occurs 32 days later, in fair agreement with the results for November and January. The Leonids have been known for hundreds of years and occur on November 16. This is 28 days before the peak on December 14, also in fair agreement with the previous results. The rainfall peak of December 29 has already been related to the Bielids I (BOWEN, 1956) and will not be discussed further.

V. Summary

It appears therefore that there are peaks in the world rainfall during November and December which occur approximately 30 days after prominent meteor showers. This is consistent with the hypothesis, which was arrived at from a study of the January rainfall, that dust associated with meteor streams is affecting world rainfall.

In Fig. 8 is given a composite curve of the rainfall for the three months November, December and January, obtained by combining Figs. 2 and 7 of the present paper with Fig. 4 of the previous one. It may be taken to represent the departure of daily rainfall from the mean for approximately 300 stations over many parts of the world. In table 1 are listed

Table 1. Comparison of dates of meteor streams and rainfall peaks

Date of rainfall peak		Meteor Stream	Date		Time Difference (days)
November	8	Giacobinids	Oct.	9	30
	18	Orionids		20—23	29
	26	Not known with certainty			—
December	5	Taurids	Nov.	3—10	32
	14	Leonids		16	28
	29	Bielids I		27→15	—
January	1	Bielids II	Dec.	2	30
	12	Geminids		13	30
	22	Ursids		22	31
February	1	Quadrantids	Jan.	3	29

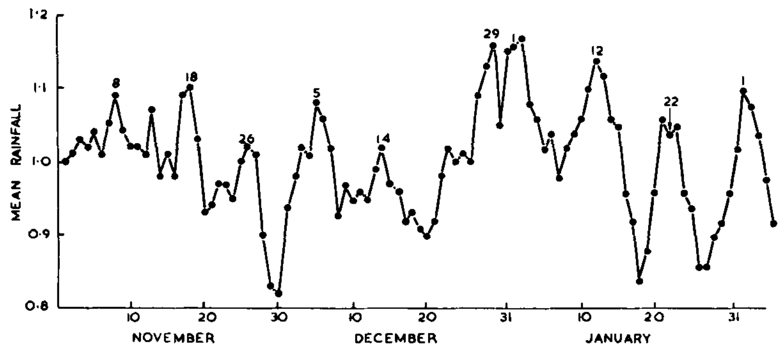

Fig. 8. Composite curve giving the daily mean rainfall of approximately 300 stations over the globe for the three months, November, December and January.

the dates on which rainfall singularities appear, together with the meteor showers which are thought to be associated with them. In the final column is given the time difference between the dates of the meteor showers and that of the rainfall peaks. They have a mean value of 30 days, the greatest departures from this value being $\pm$ 2 days.

VI. Discussion

There are many aspects of the present hypothesis which are difficult to accept and many questions arise. How does the amount of dust entering the atmosphere vary from one day to the next, why is the effect on rainfall confined to such a few days and why is the time of fall so consistent from one meteor shower to the next. These questions are without specific answers at the present time and they are all clearly in need of careful physical investigation.

Easily the most unsatisfactory part of the hypothesis is concerned with the fall of the dust through the atmosphere. The particles entering the atmosphere would be expected to have a wide range of sizes and a correspondingly wide distribution of fall times. However, the postulated effect on rainfall is a trigger effect, so that a sharp advancing front in the dust arriving at the lower atmosphere would be adequate to account for a peak in the rainfall.

The variation of only $\pm$ 2 days in the fall time given in the last column of table 1 is less difficult to understand. Each observation of the time difference between a meteor shower and a rainfall peak in this table is the mean of some 20,000 individual observations. The variation in any one place and in any one year would obviously exceed this figure.

Whipple (1954) has expressed the opinion that the flux of meteoritic dust entering the atmosphere is almost constant and increases only by a small percentage at the time of meteor showers. However, in a recent publication Bigg (1956) described a simple method of detecting the entry of meteoritic dust into the top of the atmosphere. He showed that there were variations in the amount of this dust of the order of 5 to 1 from one day to the next and that these variations were closely correlated with meteor showers.

This paper has been principally concerned with the information which can be gleaned from a study of rainfall data but there are clearly limitations to this method. For real advances to be made one must look to proper physical investigations of the behaviour of meteoritic dust in the atmosphere. The arrival of the dust at the top of the atmosphere can be detected by Bigg's "twilight" technique. Its behaviour as a nucleating agent in the lower atmosphere can be studied by measuring the freezing nucleus concentration in the manner described by Cwilong (1955) and Smith, Kassander and Twomey (1956). It would seem of greatest importance to the science of meteorology that an intensive study of the time variations of these quantities be made in different parts of the world.

Acknowledgement

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REFERENCES

BIGG, E. K., 1956: The detection of atmospheric dust and temperature inversions by twilight scattering. *Nature*, **177**, pp. 77—79.

BOWEN, E. G., 1953: The influence of meteoritic dust on rainfall. *Aust. J. Phys.*, **6**, pp. 490—497.

BOWEN, E. G., 1956: The relation between rainfall and meteor showers, *J. Meteor.* **13**, pp, 142—151.

BROWNE, I. C., PALMER, H. P., and WORMELL, T. W., 1954: The physics of rainclouds. *Quart. J. Roy. Meteor. Soc.*, **80**, pp. 291—327.

CWILONG, B. M., 1955: Abnormal freezing nuclei in the atmosphere. *Nature*, **176**, pp. 129—130.

DAVIDSON, M., 1915: Meteor radiants from debris of comets. *J. Brit. Astronom. Assoc.*, **25**, pp. 292—293.

DENNING, W. F., 1918: Giacobini's comet of 1900 and a connected meteoric shower. *J. Brit. Astronom. Assoc.*, **28**, p. 229.

DHAR, O. N., 1954: Meteoric dust and rainfall. *Indian J. Meteor. Geophys.*, **5**, pp. 356—357.

ELLYETT, C. D., and ROTH, K. W., 1955: The radar determination of meteor showers in the Southern Hemisphere. *Aust. J. Phys.*, **8**, pp. 390—401.

LOVELL, A. C. B., 1954: *Meteor Astronomy*, Oxford, Clarendon Press, 463 pp.

MARTYN, D. F., 1954: Comments on a paper by E. G. Bowen entitled "The influence of meteoritic dust on rainfall". *Aust. J. Phys.*, **7**, pp. 358—364.

NEUMANN, J., 1954: Fluctuations of long-period accumulations of daily rainfall amounts. *Aust. J. Phys.*, **7**, pp. 522—526.

OLIVER, M. B. and V. J., 1955: Rainfall and stardust. *Bull. Amer. Meteor. Soc.*, **36**, pp. 147—151.

RIEHL, H., 1954: *Tropical Meteorology*, New York, McGraw-Hill, 392 pp.

SMITH, E. J., KASSANDER, A. R., and TWOMEY, S., 1956: Measurements of natural freezing nuclei at high altitudes. *Nature*, **177**, pp. 82—83.

SWINBANK, W. C., 1954: Comments on a paper by E. G. Bowen entitled "The influence of meteoritic dust on rainfall". *Aust. J. Phys.*, **7**, pp. 354—358.

WHIPPLE, F.: Seminar Discussion at U.S. Weather Bureau, Washington, D.C., January 1954.

Appendix

List of 50 rainfall stations in Australia used in Figs. 1 and 6 and dates for which rainfall figures are available.

Station	Dates
New South Wales	
Sydney	1859—1952
Goulburn	1857—1954
Forbes	1875—1954
Armidale	1858—1954
Narrabri	1870—1954
Port Macquarie	1870—1954
Dubbo	1870—1954
Wagga	1871—1950
Bathurst	1858—1954
Cooma	1858—1954
Queensland	
Brisbane	1900—1953
Mackay	1907—1953
Gladstone	1907—1952
Charleville	1907—1953
Roma	1907—1952
Stanthorpe	1907—1952
Aramac	1887—1948
Hughenden	1907—1952
Cunnamulla	1907—1952
Palmerville	1908—1952
Townsville	1913—1952
Camooweal	1907—1952
Burketown	1908—1952
Victoria	
Melbourne	1859—1954
Orbost	1883—1954
Echuca	1881—1954
Wangaratta	1878—1954
Stawell	1865—1954
Tasmania	
Hobart	1908—1954
Lake Leake	1908—1953
Burnie	1908—1953
Cressy	1908—1953
Thule	1908—1953
Queenstown	1908—1953
South Australia	
Adelaide	1839—1954
Clare	1882—1953
Port Lincoln	1884—1954
Streaky Bay	1878—1953
Mount Gambier	1861—1953
Western Australia	
Perth	1880—1952
Albany	1907—1954
Bunbury	1907—1954
Esperance	1907—1954
Geraldton	1907—1952
Marble Bar	1901—1953
Katanning	1907—1953
Wyndham	1907—1953
Mt. Florence	1907—1954
Northern Territory	
Darwin	1869—1951
Daly Waters	1880—1949