JANUARY FREEZING NUCLEUS MEASUREMENTS

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Summary

Measurements of the concentration of freezing nuclei in the atmosphere have been made in widely separated parts of the globe during January in one or more of the three successive years 1954, 1955, and 1956. The results of all three sets of observations are summarized and it is shown that high freezing nucleus counts tend to occur on dates which are identical or nearly identical with those on which unusually heavy falls of rain have previously been shown to occur. The results are discussed in relation to the possible connexion between meteoritic dust and world rainfall.

I. Introduction

The suggestion has been made that dust from meteor streams when it falls into the cloud systems of the lower atmosphere acts as a nucleating agent and induces unusually heavy amounts of rain to fall. Examination of the world rainfall records for the first 5 weeks of the year suggests that the dates on which heavy rainfall occurs are approximately January 12 and 22 and February 1. If the hypothesis is correct, it would be expected that the freezing nucleus concentration in the atmosphere would also be high on or about these dates.

Measurements of freezing nucleus concentration were made in Sydney in January 1954 and again in Sydney and in other parts of the world in January 1955. The results have been reported by Cwilong (1955) and by Smith, Kassander, and Twomey (1956) and they gave sufficient support to the hypothesis to encourage further measurements during January 1956. These were carried out in South Africa, on the west and east coasts of Australia, and on the west coast of the U.S.A. The results are reported in the present group of four papers.

The South African measurements were undertaken at Pretoria by Dr. S. C. Mossop of the South African National Physical Laboratory and those in the United States of America by Dr. R. N. Bracewell of Stanford University. The Australian measurements were carried out by members of the staff of the Radiophysics Laboratory at Carnarvon on the north-west coast and at Sydney on the east coast. The detailed results of the 1956 measurements are given in the three papers which follow. The purpose of the present paper is to summarize the results obtained in the whole series of observations made during 1954, 1955, and 1956 and to comment on the method of measurement.

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II. Scope of the Measurements

Freezing nuclei may be defined as particles in the atmosphere on which ice crystals can grow from the vapour phase or, alternatively, as materials which, in solution in a water droplet or in contact with it, will induce it to freeze. They become effective at some temperature below 0 °C, the actual value of which depends on their chemical composition and the immediate past history of the surface exposed to the atmosphere. Schaefer (1950) has shown that a number of the materials commonly found on the Earth's surface are active at temperatures about −15 to −20 °C, while certain other materials, of which silver iodide is an example, are effective at comparatively warm temperatures of about −4 °C.

The method of measuring the number of freezing nuclei in the atmosphere and the temperature at which they become effective is to reproduce in a cold chamber the process which usually occurs in a supercooled cloud. A sample of air is taken, it is saturated with water vapour, and the temperature is reduced. A cloud of water droplets forms and, after a short interval, a comparatively small number of ice crystals appears. An estimate is then made of the number of freezing nuclei per litre and the temperature at which they become active.

It is likely that freezing nucleus measurements may be adversely affected by terrestrial dust and contamination from industrial sources. In order to be representative of what happens in clouds, measurements are preferably made in aircraft above the haze layer. When aircraft are not available, a reasonable alternative is to make measurements at ground level in air of recent maritime origin. The 1956 measurements in Pretoria and Sydney were made in aircraft at heights up to 20,000 ft; those in Western Australia were made on the ground in air which had had a long travel over the Indian Ocean; and those at Palo Alto were also made on the ground in air which was predominantly from the Pacific Ocean.

The South African and Sydney measurements were made in aircraft of the South African Air Force and the Royal Australian Air Force respectively, in a cold chamber specially designed for aircraft operation by Smith and Heffernan (1954). The measurements in Western Australia and on the west coast of the United States of America were made by a new method devised by Bigg and described in one of the accompanying papers. This method had the advantage of being an objective one, it was more sensitive than the methods which had previously been employed, and was particularly valuable in that it was capable of measuring small concentrations of very active particles.

There were systematic differences between the mean readings taken in aircraft and on the ground. These appear to have been due partly to the different geographical locations but more particularly to the different methods of measurement employed. In the aircraft equipment the temperature of the cold chamber fell continuously at a rate of 4 deg/min, so that a crystal which formed at any given temperature would not be seen and counted until a colder temperature had been reached. In Bigg's cold chamber, however, the temperature was maintained at one value during the whole period an ice crystal was growing. These differences bring out the importance of using a standardized method of measurement in any future series of observations, in order to determine whether there are any systematic differences in the freezing nucleus concentration in one part of the world as compared with another.

III. Summary of Results

An outstanding characteristic of measured values of freezing nucleus concentration is that they remain at comparatively low values for up to a week or ten days at a time and then suddenly increase by orders of magnitude for one or two days. The interesting periods are those in which the freezing nucleus counts were high, and the dates on which this occurred in the present series of measurements are summarized in Table 1. In the first part of the table are the results for 1954 and 1955 which have already been given by Cwilong and Smith, Kassander, and Twomey. In the latter part of the table are the results for 1956 described in the accompanying papers. In the latter series of measurements, peaks in the freezing nucleus counts were obtained on the dates indicated in South Africa, Western Australia, and the west coast of the United States of America. At Sydney no peaks were obtained comparable in magnitude with those in 1954 and 1955. This is thought to have been due to one of two causes : either the particles responsible for high nucleus counts were absent in this area in 1956, or they may have precipitated out during the heavy rain which fell in Sydney on the few days immediately preceding the dates on which high freezing counts were observed elsewhere.

Table 1

Dates of high freezing nucleus counts in January 1954–1956

Year	Place	Date (January)		
1954	Sydney	12, 14	22	31
1955	Sydney	13	23	29
	Hawaii	10	23	29
	Arizona	—	—	—
	Panama	13	18	31
1956	South Africa	13	—	29
	Western Australia	13	22	Feb. 1
	Sydney	—	—	—
	Palo Alto, U.S.A.	13	21	—

It is apparent from Table 1 that the peaks do not always appear in all localities, but when they do occur they are on nearly the same dates in widely separated parts of the globe. A histogram giving the 3-day totals of the dates on which the freezing nucleus peaks were observed is given in Figure 1, showing peaks on January 13, 22, and 30.*

* It should be observed that the majority of the measurements in this series did not commence until January 2 or 3, so that this diagram contains no information about the first three days in January.

This behaviour is that to be expected from the pattern of rainfall for the month of January for many parts of the world (Bowen 1956). In that paper it was shown that singularities in rainfall tend to occur on approximately the same dates in Australia, New Zealand, South Africa, United States of America, Great Britain, Japan, and the Netherlands. Totalling the available rainfall data from all these regions gives the curve of Figure 2, which shows peaks on January 12 and 22 and February 1, in close agreement with the freezing nucleus curve of Figure 1.

The fact that high freezing nucleus counts are obtained on identical or nearly identical dates in places separated up to 180° in longitude points to an

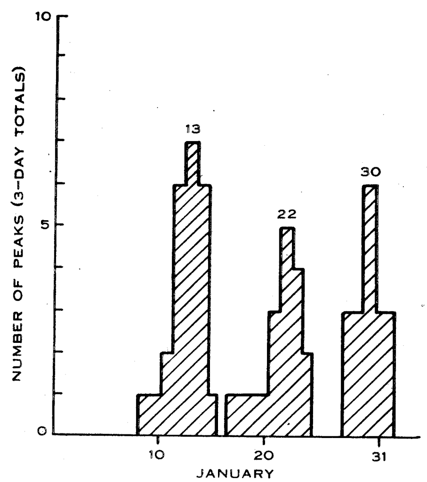

Fig. 1

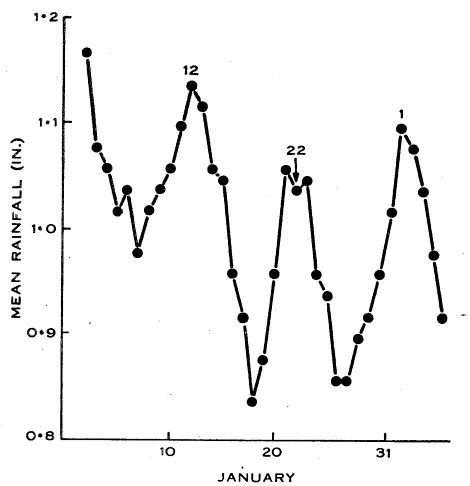

Fig. 2

Fig. 1.—Histogram of the dates in January on which high freezing nucleus counts were obtained during 1954, 1955, and 1956.

Fig. 2.—The mean daily rainfall of January for approximately 300 stations distributed over the globe.

extraterrestrial origin of the particles. The fact that the phenomenon has tended to repeat on each of the three years of observation is consistent with the meteor hypothesis.

It is thought that the present results make some contribution to the understanding of the processes in the atmosphere leading to the formation of rain, and provide encouragement to obtain further measurements of freezing nucleus concentration in many different parts of the world.

IV. References

Bowen, E. G. (1956).—*J. Met.* **13**: 142–51.

Cwilong, B. M. (1955).—*Nature* **176**: 129–30.

Smith, E. J., and Heffernan, K. J. (1954).—*Quart. J. R. Met. Soc.* **80**: 182–97.

Smith, E. J., Kassander, A. R., and Twomey, S. (1956).—*Nature* **177**: 82–3.

Schaefer, V. J. (1950).—*Z. angew. Math. Phys.* **1**: 153–84, 217–36.