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Hailstorms at Gauhati on 18 March 1961

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ABSTRACT. Several hailstorms occurred at Gauhati airport on 18-19 March 1961. The hailstones of one of the storms had opaque cores and density of 0·8 grams per c.c. On immersion in kerosene oil, stones were found to be ejecting air bubbles. Approximately 2210 hailstones fell in one square meter area.

1. Introduction

A number of hailstorms occurred over Assam on 18 and 19 March 1961, causing considerable damage to tea plantation and properties. At Gauhati airport the fabrics (which can withstand a pressure of 25 lbs per sq. inch) of an aircraft were torn by the hailstones. At the airport there had been four occasions of hailstorms on the 18th—one each at 0025, 0155, 1210 and 1625 IST. In fact there had been a series of thunderstorms on this day. On the 18th, Gauhati town, which is about 25 km from the airport, had also some hailstorms. On the 19th, Gauhati airport got a mild hailstorm at night. Gauhati town received a severe one on this day. Hailstorms are not uncommon in Assam but are rare in comparison to other similar phenomena like rainstorms and thunderstorms. Such a widespread activity is also not uncommon. But such repeated occurrence of hailstorms at a station on one and the same day is rare.

Detailed information about hailstorms are not numerous in literature. For understanding the machanism of formation of hailstones, information about size, shape, density and structure of hailstones should be known. Such a study has been made in this case and the results reported in the paper.

2. Meteorological condition

The synoptic charts revealed that vigorous incursion of moisture was taking place over Assam. Tephigrams of Gauhati showed the presence of a high degree of latent instability. Besides these, there was nothing else to indicate the possibility of such severe and repeated hailstorms.

It has been recognised by many workers (Rao and Mukherjee 1958, Browning and Ludlam 1960) that hailstorm is associated with pronounced wind shear in the vertical. In the present study also pronounced wind shear in the vertical was observed.

Several cumulonimbus clouds passed over and near the Gauhati airport observatory. The clouds which were moving north of the station were found to be inclined in accordance with the direction of the wind shear in the vertical. Those clouds which passed overhead were also inclined. First their top portions appeared followed by the lower portions. The evening thunderstorm approached in the same way. Nearly half an hour before the hailstorm it became quite dark. At 1620 IST the northwest sky was showing very low dark cloud mass approaching the station. At 1622 IST it appeared that a very dark rolling cloud mass was descending towards the ground. This threatening cloud mass took about three minutes to descend and just as it

TABLE 1

Size, shape and structure of hailstones*

S. No.	Shape	Diameter (cm)	Mass (gm)	Core and its diameter	Thickness of layers (cm)	Outer layer
1	Spherical	5·2	50	Opaque	Layers of unequal thickness	Jagged Opaque
2	Spherical	4·2	28	Opaque 1·8 cm	T — 0·7	Opaque Jagged
3	Spherical	3·2	11	Opaque 1·0 cm	T — 0·2 O — 0·1 T — 0·2 O — 0·2	Transparent Jagged
4	Spherical	2·8	—	Opaque 1·0 cm	T — 0·5	Transparent Smooth
5	Elliptical	2·0 × 1·7	2·9	Opaque 0·7 cm	T — 0·1 O — 0·1 T — 0·2	Opaque Smooth

*Average of 20 stones   T means transparent   O means opaque

came over the observatory the squall struck. From E'ly, 10 kts, the surface wind changed to WNW'ly, 45 kts.

Asnani (1961) states that in case of severe hailstorms, there is a possibility of dip in barograph traces. In the present study barograph traces showed sharp increase in pressure with the incidence of hailstorm. Dip in barograph trace took place before the occurrence of hailstorms. The relevant portions of the barograph traces are shown in Fig. 1.

3. Hailstones

The hailstones of the evening hailstorm were collected and measurements of size and thicknesses of the layers inside the hailstones were made; determinations of mass and densities were also done. For measuring thicknesses of layers these were cut into sections through the centre. While cutting, it was noticed that the opaque outer layers of the stones were softer than the transparent outer layers. The relevant data are given in Table 1. It should be mentioned here that in the beginning of the storm mostly big hailstones were falling. During the measurements also a bias towards the bigger stones was maintained. However, as the storm continued, stones of smaller sizes became numerous, and hence stones were collected at random and measurements were made.

Density of these hailstones could be found out by dividing the mass by the volume of the hailstones as calculated from the diameter. The density values so found would not be accurate as the outer surface of many of the stones is not quite smooth. Moreover, the measurements of sizes were made with the help of a scale only, and the degree of accuracy of such measurements was not high. The authors were aware that the density determinations should be very accurate, these measurements being necessary in quantitative computations of growth of

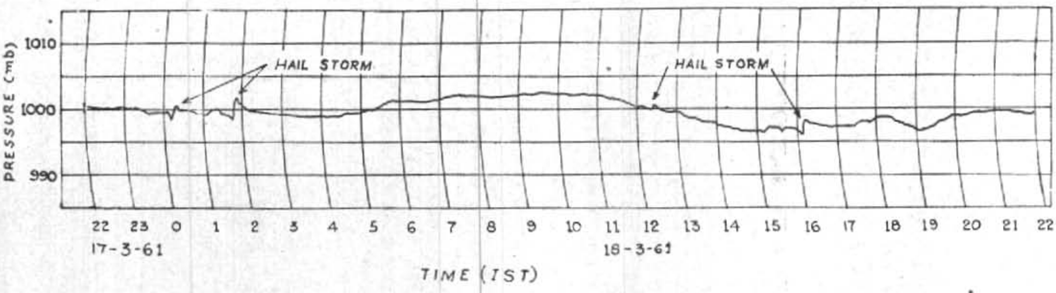

Fig. 1. Trace of Gauhati barogram of 17-18 March 1961

hailstones (Ludlam 1958). Formerly it was believed that the specific gravity of hailstones may be anything between 0·1 and 0·9 (Mason 1957). Recently, some very accurate determinations of density have been reported in the literature. Vittori and Di Caporiacco (1959) have reported their measurements according to which the stones have densities ranging between 0·873 and 0·915 gm per c.c. excepting three stones which gave value of 0·8 gm per c.c. Macklin, Strauch and Ludlam (1960) also reported some very accurate determinations. Their values ranged from 0·873 to 0·915+0·003 gm per c.c. The latter authors measured the densities by immersing the stones in series of chilled liquids (mixtures of paraffin oil and carbon tetrachloride) of varying densities. In the present study, the hailstones were collected and put in kerosene oil of density 0·80 gm/c.c. While many of the stones sank in kerosene, some of them did not do so readily. Those which sank did so only slowly. Their densities were therefore, slightly higher than the liquid. Those which did not sink had to be pressed to make them do so. On immersing the hailstones inside kerosene, air-bubbles were found to be coming out. Some hailstones were allowed to melt inside the kerosene oil. They were also found to be ejecting air-bubbles. From this observation it appears that hailstones keep some entrapped air, and probably the amount of entrapped air is more near the surface than in the interior. This view is supported by the fact that those stones which did not sink in kerosene did so after they were kept floating over the liquid for some time. The densities of the hailstones, therefore, increased as the latter melted. Macklin *et al.* (1960) found that hailstones showed a tendency to increase in density as they melt. The same trend was observed during the present study also. The authors also noticed that the increase in density was accompanied by increase in transparency.

List (1958) suggests that the centres of all hailstones are modified soft hails or graupels which have grown by accretion upon small frozen droplets or ice crystals. In this case it is expected that hailstone cores should be opaque. The other possibility is that the cores are frozen raindrops which have grown by coalescence. In this case the core should be transparent. Macklin *et al.* (1960) found that most of the hailstones collected by them had transparent cores. In the present study, however, not a single stone was found to have transparent core which shows that List's idea holds good in the present case. Following Macklin *et al.*, thin sections of some stones were prepared by melting them between metal plates, care being taken to ensure that sections were made through the centres of the stones. The stones were examined from time to time during this process but no visual change could be noticed. In this process also no transparent core could be found in any of the sections.

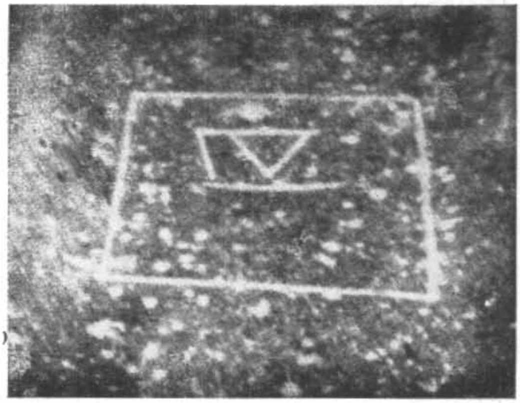

Fig. 2

The numbe of oute r layers varied greatly as can be seen from the table. In a few cases it was noticed that the layers were not of uniform thickness. It was also noticed that in all the cases the thicknesses of opaque and transparent layers were not equal. Ludlam (1958) speculated that opaque layers in the outer parts of the hailstones might represent revisions to 'dry' growth and be composed of ice having low density. He himself (*see* Macklin, Strauch and Ludlam 1960) has contradicted the idea on the basis of density measurements in one hailstorm. The present study on the other hand, suggests, though not strongly, that there is probably some truth in his original idea.

From a study of hailstorm in northwest India, Rao and Mukherjee (1958) concluded that hailstones other than graupel are of two types, *viz*., elementary and compound. Elementary stones possess a single central core surrounded by varying number of symmetrical layers of glazed ice and rime. Compound stones are formed by cementing together just above the freezing level of varying number of elementary stones. A few compound stones were obtained but they did not look like fused elementary stones. They were having many opaque spots embedded in a glazed ice mass. A search for binary stones as described by Rao and Mukherjee was made but no such stone was available.

Venkiteswaran and Ramakrishnan (1954) measured number of hailstones that fell on a unit area by observing the dents on aluminium sheets. In the present study, the counting of number of marks left by falling hailstones on a blackened roof was done for determining the number of stones that fell per unit area. Ten squares, each of 20 cm$\times$20 cm (Fig. 2) were drawn on the roof. The average of the number of stones in those squares came out to be 88$\cdot$4. Thus on one square meter area 2210 stones fell. This number may not be representative of the actual figure for the evening hailstorm due to the following limitations of the method:

(1) Two stones might have fallen on the same spot, (2) All stones might not have left marks on the roof, and (3) At 0155 IST one hailstorm lasting for two minutes occurred which produced equally big stones. Some of the marks might have been left by this storm.

4. Conclusions

From the study of the hailstorms at Gauhati airport on 18 March 1961 we come to the following conclusions—

(*i*) The development of hailstorms was not associated with any special synoptic situation. Sufficient amount of moisture, local orographic features and latent instability in the atmosphere seem to have given rise to the hailstorms.

(*ii*) The hailstorms were in association with strong vertical wind shear.

(*iii*) Sharp rise in pressure was associated with the incidence of hailstones.

(*iv*) Almost all stones were elementary with opaque cores.

(*v*) Density of hailstones was 0·8 gm per c.c. approximately.

(*vi*) Hailstones contained air bubbles. (During a subsequent hailstorm on 6 April 1961, stones were found to contain air bubbles).

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