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Forecasting hailstorms over India

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ABSTRACT. It is generally believed by forecasters that hail may occur whenever severe thunderstorms are expected. However, it is seen that most severe thunderstorms in India are not normally accompanied by hail. Hence, synoptic-thermodynamic investigations of the conditions that produce hailstorms have been undertaken. After discussing the geographic and seasonal distribution of hail frequency over India, the authors investigated the role of the height of freezing level on incidences of hailstorms. The general belief that hailstorms are invariably associated with thunderstorm clouds which tend to develop to great heights, has not been found to have been substantiated from the available data. The relationship between the magnitude of updrafts and hailstorm formation in cumulonimbus clouds have also been investigated. The correlation between the southernmost extension of sub-tropical front and southernmost boundary of the region predominantly affected by hailstorms has been pointed out. The role of strong wind field and large vertical shear in hailstorm formation has also been studied. Synoptic situations characteristic of hailstorm situations in India, to be of great use to the forecasters, have been evolved.

1. Introduction

Hailstorms always develop in association with cumulonimbus, either of line squall or of the individual type. Consequently there is a tendency amongst the forecasters to mention hail whenever severe thunderstorms are expected, especially over hailstorm-prone areas. However, most of the severe thunderstorms which occur in India are normally not accompanied by hailstorms. The Norwesters of Bengal during later parts of pre-monsoon months which are manifestations of severe line squall type thunderstorms are rarely accompanied by hailstorms. The present paper is not intended to deal with the cloud physics problem of the growth of hailstorms but is primarily concerned with the synoptic-thermodynamic investigation of the conditions that produce hailstorms. Here the authors present forecasting procedures which have proved valuable in predicting hailstorms.

2. Geographic and seasonal distribution of hail frequency

Philip and Daniel (1976) had published monthly and annual charts showing average number of hailstorms over India during different seasons. In the present paper the authors have described the geographical and seasonal distribution of hailstorms over India in a slightly modified form.

A new parameter named as "hailstorm probability per thunderstorm" has been introduced in this paper with the object of expressing geographical as well as seasonal susceptibility of different regions towards hail formation. The hailstorm probability per thunderstorm (expressed in per cent) N of a region during a particular month is given by

$$N = \frac{\text{No. of days of hailstorm during the month}}{\text{No. of days of thunderstorm during the month}} \times 100$$

For calculating the value of the parameter over a region the Indian sub-continent had been divided into 14 sections, generally a five degree square section as given in Fig. 1. Mean number of days of hailstorm and thunderstorm over each section had been depicted in the form of histogram boxes in Fig. 2. The mean values plotted in the histogram are based on values of all Indian stations in each section as given in *Climatological Tables of Observatories in India* (1931-1960). Undoubtedly more hailstorms as

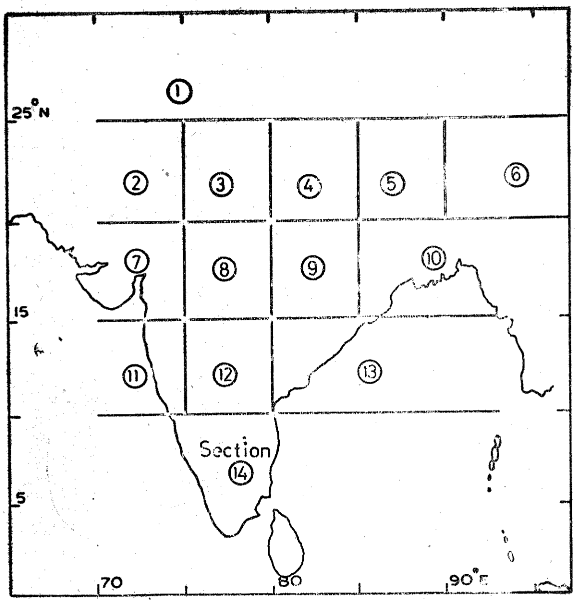

Fig. 1. Description of sections into which Indian stations had been grouped together

well as thunderstorms than those recorded, had occurred and hence it is admitted that there could be some inaccuracies when a finer estimate of the values are made.

It is seen that during the winter months of December, January and February over north India to the north of Lat. 30 deg. N, on 25 to 40 per cent occasions thunderstorms may be expected to be associated with hailstorms. Over the sections 3, 8 and 9, thunderstorms may be associated with hailstorms on 8 to 13 per cent occasions. Fig. 2 also indicates that though during the months of March and April hailstorm frequency over the country reaches highest values, hailstorm probability per thunderstorm decreases considerably and does not exceed 10 per cent except over sections 1 and 2. This will imply that though the thermodynamic conditions such as atmospheric instability etc. become more and more favourable for occurrence of greater number of thunderstorms with the advancement of the pre-monsoon season, intrinsic criteria associated with the growth of hailstones become less and less predominant.

Latitudinal variation of hailstorm frequency over India is clearly revealed in Fig. 2. It shows that hailstorm frequency decreases as one moves from north to south. As regards longitudinal variation, Fig. 2 reveals that hailstorm activity shows an increasing tendency as one moves from west to east. This is perhaps due to greater moisture content in the lower troposphere over eastern parts of India compared to western parts. Fig. 2 also brings out another significant characteristic of hailstorm frequency over India. It shows that hailstorms over India are mostly confined to the region to the north of Lat. 20 deg. N.

3. Role of the height of freezing level on incidence of hailstorms

A hailstone appears to be formed by collision and coalescence of super-cooled water drops with some kind of ice pellets. It is quite reasonable to believe that the height above freezing level of the place of origin of the core snow pellets is an important factor in hail formation. However snow pellets are commonly observed inside cumulus congestus clouds in the precipitation initiation and later stages at or somewhat above the freezing level. It does not stand to reason that on occasions of significant hail formation the snow pellets should originate at much greater heights than are commonly observed. On the contrary, consequent of favourable synoptic situations on days of hailstorms, the freezing level appreciably comes down so that the place of origin of the core pellets automatically becomes much above the freezing level. Such lowering of freezing level will also minimise appreciable melting of hailstones before they reach ground.

It is well known that the thunderstorm and hailstorms activities over central and northern India during winter and pre-monsoon months are always associated with the passage of active western disturbances. The passage of these disturbances causes advection of cold air aloft and thereby considerably lowers the freezing levels by as much as 1500 metres on the day of occurrence of severe hailstorm (Chowdhury *et al.* 1973). This lowering takes place before the

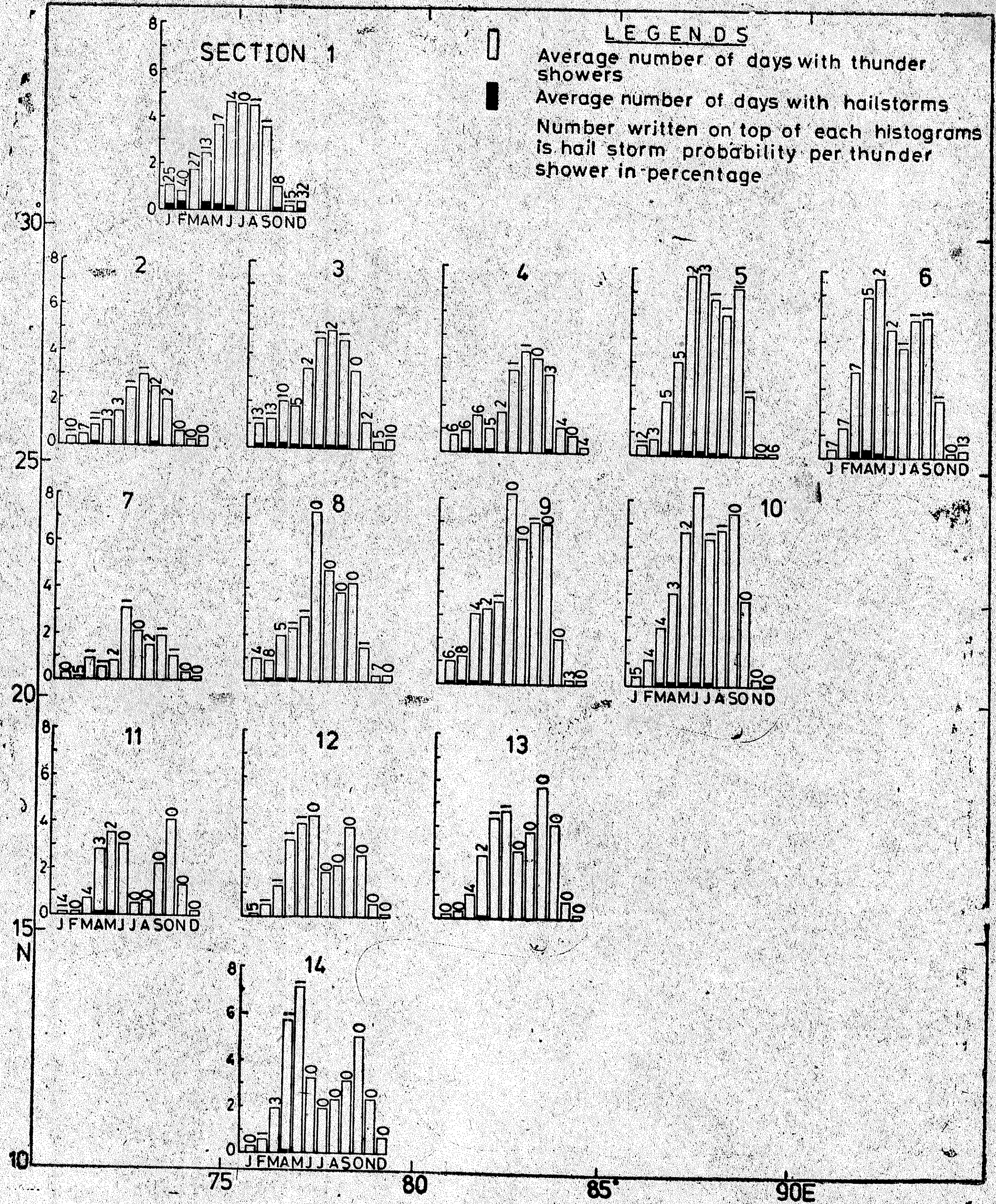

Fig. 2.

occurrence of hailstorms. In Figs. 3(a) and 3(b) average heights of freezing level during each calendar month over Srinagar, Delhi, Jodhpur, Bombay (roughly along Long. 70 deg. E), Lucknow, Nagpur and Madras (roughly along Long. 80 deg. E) had been plotted (Poornachandra Rao 1970).

As per study made by Chowdhury *et al.* (1973) the actual height of freezing level over Nagpur on days of severe hailstorms before actual occurrence of hailstorm veries between 3500 gpm and 4000 gpm whereas average height of freezing level over Nagpur in the month of March is 4500 gpm. Provided other criteria for occurrence of hailstorm over a certain region are satisfied, actual or anticipated lowering of freezing level by 1000 gpm or more below the normal freezing level of the region corresponding to the month of March is expected to provide an important parameter towards hailstorm forecasting.

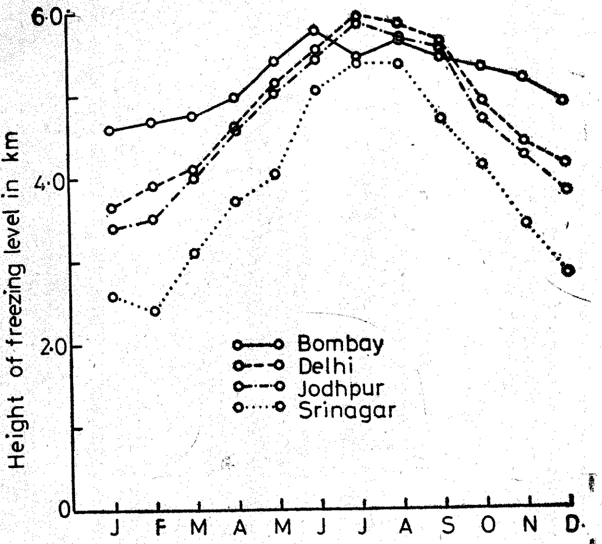

Fig. 3(a). Height of freezing level of stations along longitude 75° E

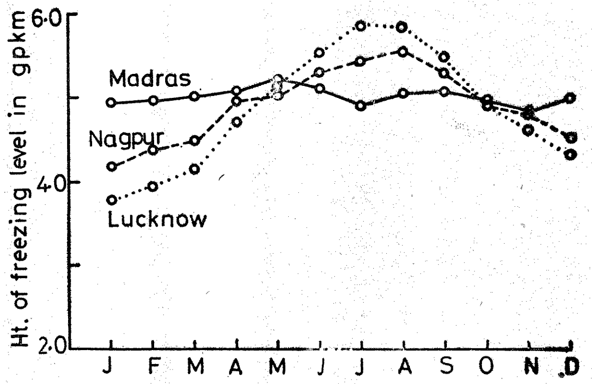

Fig. 3(b). Height of freezing level (km) of stations along longitude 80° E

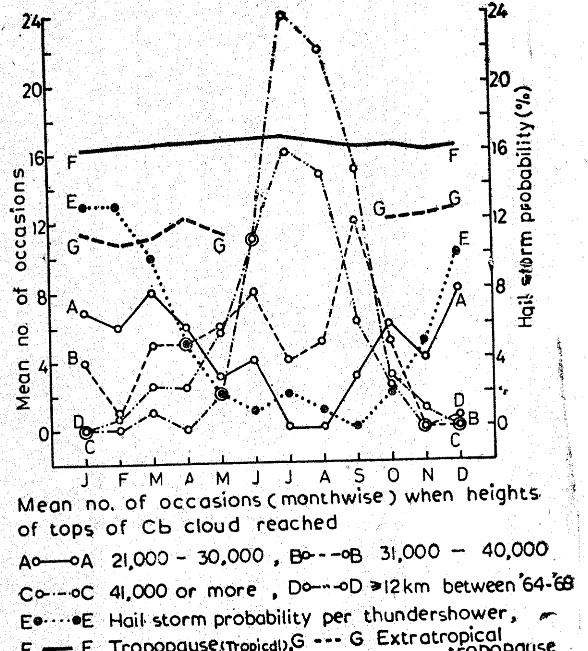

Fig. 4. Frequency distribution of *Cb* tops over New Delhi during all months

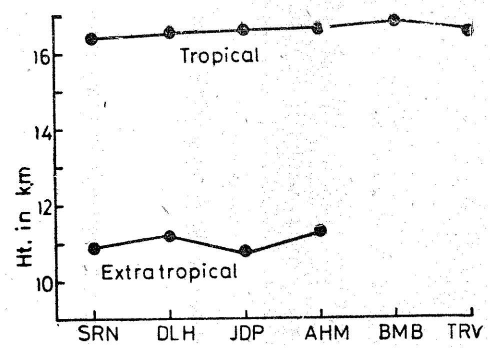

Fig. 5. Height of tropopause along longitude 75°E during March

4. Relationship between height of cumulonimbus cloud and incidence of hailstorm

It is generally believed that hailstones are invariably associated with thunderstorm clouds which tend to develop to great heights. Kulshrestha (1962) had studied frequency distribution of heights of cumulonimbus cloud tops over New Delhi based on radar observations during the period from December 1957 to June 1960. His results had been plotted in a modified form in Fig. 4. The curve marked AA denotes mean number of occasions (monthwise) when heights of tops of cumulonimbus clouds reached the ranges between 21,000 ft and 30,000 ft. The curve BB similarly denotes mean number of occasions when heights of tops of *Cb* clouds reached the ranges between 31,000 ft and 40,000 ft. The curve CC represents mean number of occasions when heights of *Cb tops* reached

41,000 ft or more. Natarajan and Rama Sastry (1970) had made a similar study of tops of *Cb* clouds extending beyond 12 km over Northern India. Their observations had been denoted in the same figure by the curve DD which is very much similar to the curve CC. The values represented by the curve DD can be expected to be more representative as it is based on data covering a longer period of 5 years (1964-1968). The curve marked EE represents hailstorm probability per thunderstorm corresponding to the section 3 (Fig. 1) in which New Delhi is located. Tropical as well as extratropical tropopauses over Delhi during the year have also been drawn in the diagram (Sivaramakrishnan *et al.* 1970).

The figure clearly shows that during the winter and beginning of pre-monsoon months (March and April) when incidence of hailstorm over the country is maximum, height of tops of *Cb* clouds exceeds 9 km (30,000 ft) only on rare occasions. During these months except on two or three occasions, *Cb* tops do not exceed 41,000 ft. During late pre-monsoon (May) and monsoon months (June to September) incidence of high *Cb* tops exceeding 41,000 ft (or 12 km) are very numerous in marked contrast to the rare incidences of low *Cb* tops not exceeding 30,000 ft (9 km) during the same period. Notwithstanding the existence of *Cb* clouds of very large vertical extent, incidence of hailstorms during these months are almost negligible. During winter and pre-monsoon months with the passage of active western disturbances, the height of extra-tropical tropopause further lowers down from the normal heights indicated in the figure. It is well known that tropopause generally limits the tops of *Cb* clouds. From the point of view of theoretical considerations as well as on the basis of these actual observations it can be concluded that majority of hailstones develop in *Cb* clouds which do not grow to great heights as it is customary to postulate. At present it is an accepted fact that severe hailstorms are mainly confined to the continental interiors of middle latitudes where top of cumulonimbus cloud does not grow to very great heights. To enable development of cumulonimbus clouds, the temperature distribution of the air column as a whole must be such as to indicate conditional instability. For development of hailstones it will suffice if the upper limit of this conditional instability extends upto or a little beyond the level of extra-tropical tropopause.

During the passage of western disturbances, the height of extra-tropical tropopause also comes down below its normal height around 11 km over north India (Figs. 4 and 5). Hence it can be inferred that a cumulonimbus cloud with hight of its top around 8 to 9 km can have sufficient potentiality for development of hailstones. This inference, however, does not preclude hailstone formation in a cumulonimbus cloud which extends to very great heights but such great vertical extension is not, at least, a necessary condition for development of hailstones. On the contrary, the inverse relationship as revealed between the hailstorm probability curve EE and frequency distribution curve DD (or CC) with very high *Cb* tops in Fig. 4 suggests that cumulonimbus clouds with great vertical extent in effect may not be conducive to hailstone development.

5. Relationship between magnitude of updrafts and hailstone formation in cumulonimbus clouds

It s generally believed that in order to form hailstones, the ice pellets which are required to be supported at the subfreezing level must encounter unusually strong updrafts. However, from flight experience there is reason to believe that the updrafts in most hailstorms are no more severe than in more intense thunderstorms that do not produce hail (Byers 1959).

A 'COMET' aircraft during its flight along Colombo-Bombay route on 10 October 1953 had encountered occasional hail and lightning accompanied by only light turbulence while flying through extensive cumulonimbus clouds (Ramamurthy 1955). On the contrary, another 'COMET' aircraft on 1 October 1952 along the same route experienced severe turbulence but no hail while passing through cumulonimbus clouds, tops of which were reaching 51,000 ft. Also the fact discussed in the previous section that cumulonimbus clouds need not grow to very great heights for the formation of hailstones also corroborates the postulation that severe updraft conditions at subfreezing heights are not a prerequisite condition for formation of hailstones.

Saha (1961) had given the following equation for the ultimate diameter of a hailstone whose initial diameter at a height of 9 km was assumed to be 3.0 cm:

$$L = \frac{\sigma}{m}(2D-6)\frac{-4u}{m}(3\,K\rho\,\sigma/\pi g)^{\frac{1}{2}} \times \left[(2\,D)^{\frac{1}{2}} - 2{\cdot}45 \right]$$

where L is the depth of fall of the hailstone above freezing level, m the concentration of condensed water, u the updraft velocity, σ the average hailstone density, ρ the air density and D the ultimate diameter of the hailstone.. Table 1 gives the ultimate diameter of a hailstone that falls from a height of 9 km to the freezing level at 4.5 km for different values of updrafts and concentration of condensed water.

The values of other parameters involved in the growth equation are:

$L = 4.5 \times 10^5$ cm
$K = 0.1$ (for the Reynold's number involved)
$g = 981$ cm/sec^2
$\rho = 5 \times 10^{-4}$ gm/c.c.
$\sigma = 0.7$ gm/c.c.

TABLE 1

Ultimate diameter (in cm) of hailstones

Concentration of condensed water (gm/c.c.)	Updraft velocity (m/sec)			
	(a)	(10a)	(20a)	(30a)
1×10^{-6}	3.3	3.4	3.5	3.8
10×10^{-6}	6.3	6.9	7.8	9.1
20×10^{-6}	9.5	10.5	12.0	13.9
30×10^{-6}	12.8	14.2	16.0	18.3

The U.S. Thunderstorm project had measured updraft of the order of 30 m/sec in some of the severe thunder clouds. Schumann (1938) quoted a value of 38 x 10^{-6} gm/c.c. for *m* deduced from a case of heavy rainfall in Panama. A perusal of Table 1 will clearly bring out the fact that the growth of hailstones does not depend so much upon the magnitude of updraft velocity as it depends upon the concentration of condensed water. Keeping the value of concentration of condensed water constant at 1×10^{-6} gm/c. c., if the updraft velocity is increased ten times from an initial value of 1 m/sec to 10 m/sec, difference in ultimate diameters of the hailstones comes out to be only 0.1 cm. On the other hand if the updraft velocity is kept constant at 1 m/sec and condensed water concentration is increased ten times from 1×10^{-6}gm/c.c. to 10×10^{-6}gm/c. c., the difference in ultimate diameters comes out to be 3.0 cm, *i.e.,* thirty times greater than the previous value. Hence it can be concluded that very high values of updrafts are not a necessary condition for formation of hailstones in thunderclouds. The reason as to why the updraft values in cumulonimbus clouds which breed hailstones do not attain very high values will be discussed in section 7.

6. Relationship between the southernmost extension of extra-tropical tropopause and southernmost boundary of the region predominantly affected by hailstorms

The geographical and seasonal variation in the distribution of hailstorms over India had been clearly revealed in Fig. 2, wherein it can be clearly seen that hailstorm activity over India is mostly confined over the region to the north of Lat. 20 deg. N. At present is is generally accepted that giant hailstone formation is mainly confined to the continental interiors of middle latitudes and it is a rarity over the tropics. So far no explanation had been postulated for such selective nature in hailstone distribution. In this paper the authors offer an explanation as to why hailstone formation is mainly confined over the middle latitudes and does not generally penetrate far into the tropics.

In Fig. 5, normal heights of tropical as well as extra-tropical tropopauses during the month of March over India roughly along Long. 75 deg. E had been plotted with the help of data furnished by Sivaramakrishnan *et al.* (1970). The extra-tropical tropopause on the normal chart does not extend southwards beyond Ahmedabad although simultaneously with the passage of well marked western disturbances it extends further southwards. In accordance with the terminology of Defant and Taba the lower tropopause mentioned as extra-tropical tropopause by Sivaramakrishnan *et al.* is the so-called middle tropopause. This is the tropopause which is the northward extension of the lower boundary of the sub-tropical front which can be located over India simultaneously with the passage of a well marked western disturbance. The middle and tropical tropopauses are reported almost regularly by all north Indian stations during winter and pre-monsoon months. The core of the westerly jet stream is located in the tropopause break between the tropical tropopause and the middle tropopause. The level of maximum wind which lies between the tropical tropopause and the middle tropopause slopes downwards towards south (Fig. 10). Many authors had observed the presence of strong upper winds with marked wind shear over regions where hailstorms occur. But the pertinent requirement is that strong wind field with marked wind shear must occur in the layer where cumulonimbus cloud is extended. To be more precise, the level of maximum wind should more or less coincide with the top of cumulonimbus cloud. An estimate of the height of cumulonimbus cloud top can be made from the study of the thermodynamical diagrams. Actual radar observations can also help in the estimation of *Cb* cloud tops. Hailstone formation may be expected over the region where the height of the level of maximum wind is a little higher than the estimated height of the top of *Cb* clouds. It had already been mentioned that cumuliform clouds in which hailstones form, do not grow far beyond the middle tropopause level. During the passage of strong western disturbances the height of middle tropopause lowers down close to 300 mb level. Hence hailstorm can be normally expected over regions where the level of maximum wind lies very close to 300 mb level. The level of maximum wind which slopes southwards will be located close to the 300 mb level over the latitude belt where the sub-tropical front is generally located between 400 mb and 300 mb levels. In the following section it will be explained as to how this strong westerly wind field with pronounced wind shear is an essential requirement for hail formation. The sloping level of maximum wind is an integral part of sub-tropical front. Thus the southernmost protrusion of the sub-tropical front limits the boundary of the region which are predominantly affected by hailstorms.

7. Role of strong wind field and large vertical shear in hailstone formation

While deriving the expression for ultimate diameter of the hailstone as given in section 4, it is assumed that all supercooled water collected by the hailstone during its fall from the top of cloud to the freezing level would freeze on the surface of the hailstone. Schumann and later Ludlam had pointed out that there is a limit beyond which super cooled water deposited on an ice particle can no longer freeze completely because the latent heat of fusion cannot be dissipated sufficiently rapidly to the environment by forced convection and evaporation. When this critical limit is reached the droplets will spread over the surface in just a wet condition at 0 deg. C. Under such conditions freezing can proceed only slowly. Strong wind and large vertical wind shear will produce greater ventilation of heat away from the developing cumulonimbus cloud. The heat of fusion released on the hailstone is taken away by the strong winds at a much faster rate, thereby aiding in the process of rapid cooling of the hailstones.

The large ventilation of heat away from the developing cumulonimbus cloud consequent of strong winds, reduce the concentration of heat throughout the entire cloud mass and thereby reduces the buoyancy of the cumulonimbus cloud. Hence it will be reasonable to presume that updrafts in a thunder-cloud that breeds hailstones will be much less than the updrafts commonly observed in most severe thunderstorms.

It is now generally accepted that hailstones do not grow to large diameters consequent of a single descent through the cloud layer but such mammoth growth are accomplished consequent of a recycling process in which the particles falling from the high level outflow re-enter the updraft at a lower level and make a further ascent. Such descent and ascent through the updraft may take place even on a number of occasions before the hailstones finally fall to the ground. Recent analysis by Macklin, Merlivat and Stevenson had confirmed this recycling process envisaged by Browning and Ludlam (Mason 1975). According to Browning and Ludlam the cumulonimbus clouds in which severe hailstones grow are slightly inclined to the vertical so that the particles falling from the high level outflow outside the main body of the updraft re-enter the updraft at a lower level and are recycled again and again. Only a large vertical wind shear in that layer of the troposphere in which the cumulonimbus cloud is embedded can cause such vertical tilt in the thunder-cloud. From the study of a number of hailstorm situations in India, Rao and Mukherjee (1958) had also concluded that a strong upper wind field and a large vertical wind shear are invariably associated with hailstorm development.

8 Evaluation of synoptic situations characteristic of hailstorm situations in India

Evaluation of the synoptic situations favourable for occurrence of hailstorms over India had been attempted to in this section with particular reference to the synoptic situation which existed at 0000 GMT on 11 March 1978. A combination of synoptic situations favourable for occurrence of hailstorms had occurred on this day over extreme north Maharashtra State. On 11 and 12 March moderate to rather heavy rain or snow had been widespread over the hills of west Uttar Pradesh, Himachal Pradesh and Jammu & Kashmir. Moderate to rather heavy rain or thundershowers had also been widespread over Punjab. Another belt in extreme north Maharashtra State covering Vidarbha, Marathwada and some parts of north Madhya Maharashtra and east Madhya Pradesh also received widespread rain or thundershowers though the rainfall intensity was only light to moderate. However, a number of stations over north Maharashtra State reported hailstorms which according to newspaper reports caused considerable damage to standing crops and fruit vegetations. Chindwad and Pimpri in Pune district experienced hailstorms during 10-11 March night whereas Pathardi, Shergaon, Paithon, Patoda and Ashti in Ahmednagar district and a few places in Akola district reported hailstorms on the afternoon of 11 March. Size of hails reported from Akola city was reported to be 3-4 cm in diameter.

Western disturbances creating conditions favourable for occurrence of hailstorms appear in majority of cases on the surface chart as closed lows with frontal characteristics associated with them. Notwithstanding the fact that the delineation as well as the evolution of cold and warm fronts with respect to successive surface charts over India are to some extent subjective, these fronts can always be located at least as the boundary zones of two airmasses. Generally the advancing boundary zones reminiscent of the cold fronts give rise to hailstone formation over areas where other criteria are satisfied. The advancing cold front at the surface followed by deep cold airmass lifts the air column characterised by conditional instability. Chowdhury *et al.* (1973) had also observed that most of the hailstorms over Madhya Pradesh and Vidarbha occurred in or near such boundary zones.

The sea-level chart corresponding to 0000 GMT on 11 March 1978 is given in Fig. 6, wherein the locations of cold and warm fronts pertaining to the hours of chart had been delineated. Also the centre of the low as well as the

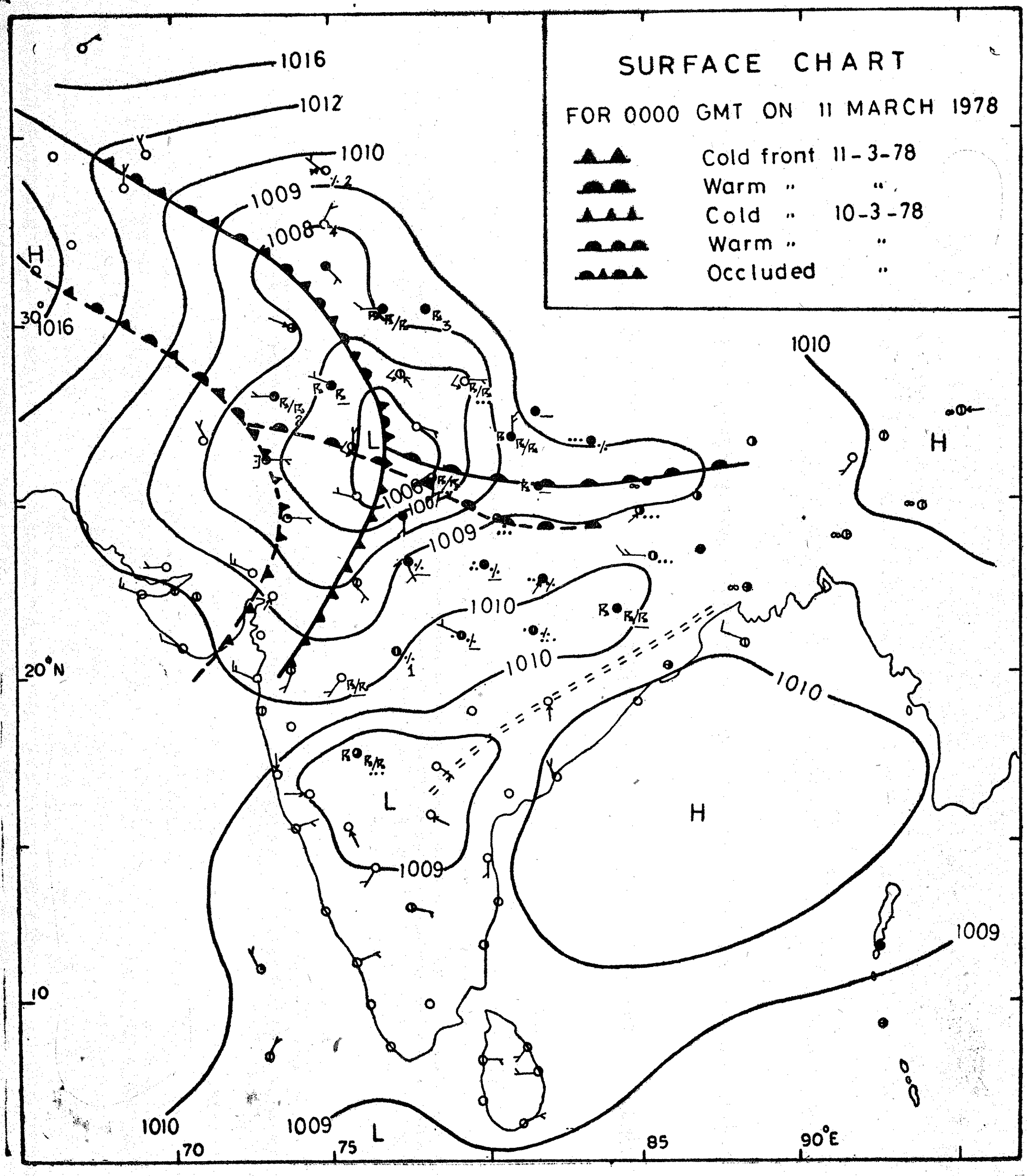

Fig. 6. Centre of low with locations of cold and warm fronts

locations of cold and warm fronts at 0000 GMT of 10 March had also been marked on this chart. The locations of the fronts on sea-level chart had been made with the help of upper air charts.

In association with the surface low located over east Rajasthan and adjoining west U.P., the associated upper air cyclonic circulation extended upto 300 mb tilting northwestwards with height. Under its influence, the anticyclone in the lower troposphere which lay over central parts of India and the adjoining Peninsula shifted to Bay of Bangal and caused favourable wind circulation in the lower troposphere which resulted in considerable moisture influx over most parts

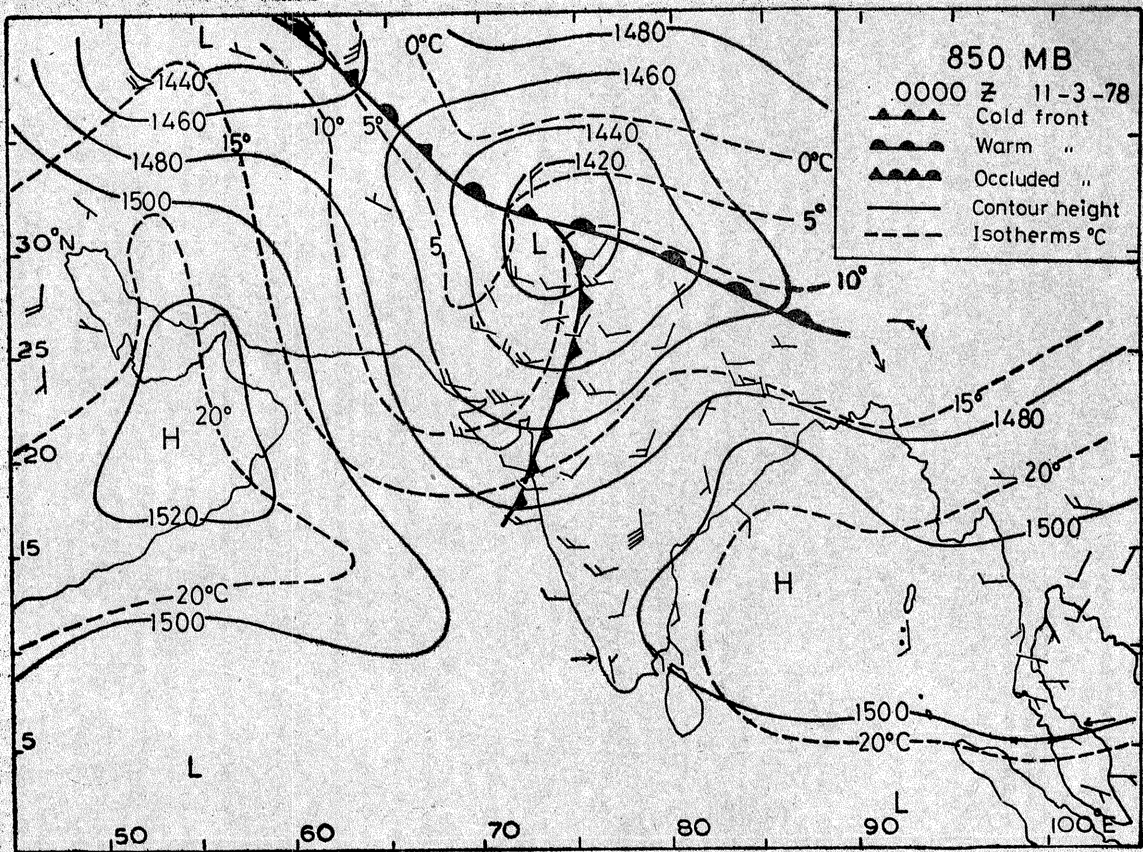

Fig. 7. Constant pressure chart at 0000 GMT on 11 March 1978

of the country (*see* Fig. 7). At this level the strong thermal gradient and orientation of isotherms in relation to the cold and warm fronts marked on this chart can also be noticed. Fig. 8 gives the analysis corresponding to the 300 mb level on which the location of the trough in westerlies, jetstream, isotach analysis and isotherm analysis had been indicated.

The importance of upper air divergence assocaied with such troughs, jetstreams and other upper air patterns towards development of weather of severe character are well recognised by all forecasters. But the problem in hailstrom forecasting is to delineate precisely the preferential area favourable for hailstone formation. Fig. 9 represents the vertical cross-section of temperature at 0000 GMT of 11 March 1978 along Long. 75 deg. E. This figure shows the presence of an inclined front, the so-called 'subtropical front' extending from New Delhi to further southwards beyond Bombay. The lower end of this sub-tropical front is the extension of the middle tropopause reported at heights of 207 mb over Srinagar, 258 mb over New Delhi, 258 mb over Jodhpur and 337 mb over Ahmedabad.

Fig. 10 gives the vertical crose-section of wind corresponding to Fig. 9. The tropopauses, fronts etc are also marked in this diagram. The isotach analysis shows the presence of two jetstream cores, one occurring at a latitude a little north of Delhi and the other lying between Ahmedabad and Bombay. The jet core lying between Ahmedabad and Bombay appears to be more stronger. The height of the jet core north of Delhi is located at a height of about 13.5 km whereas the other jet core is located at a height of about 10.5 km near Lat. 21 deg. N. The level of maximum wind lies in the space between the tropical tropopause and the upper boundary of the sub-tropical front. The level of the maximum wind slopes downwards towards south and reaches a height of about 9.8 km over Bombay. Along an advancing cold front (boundary zone between cold and dry air and warm and moist air) the latitudinal belt having strong winds and large vertical shear will be the preferential region where hailstone formation will take place.

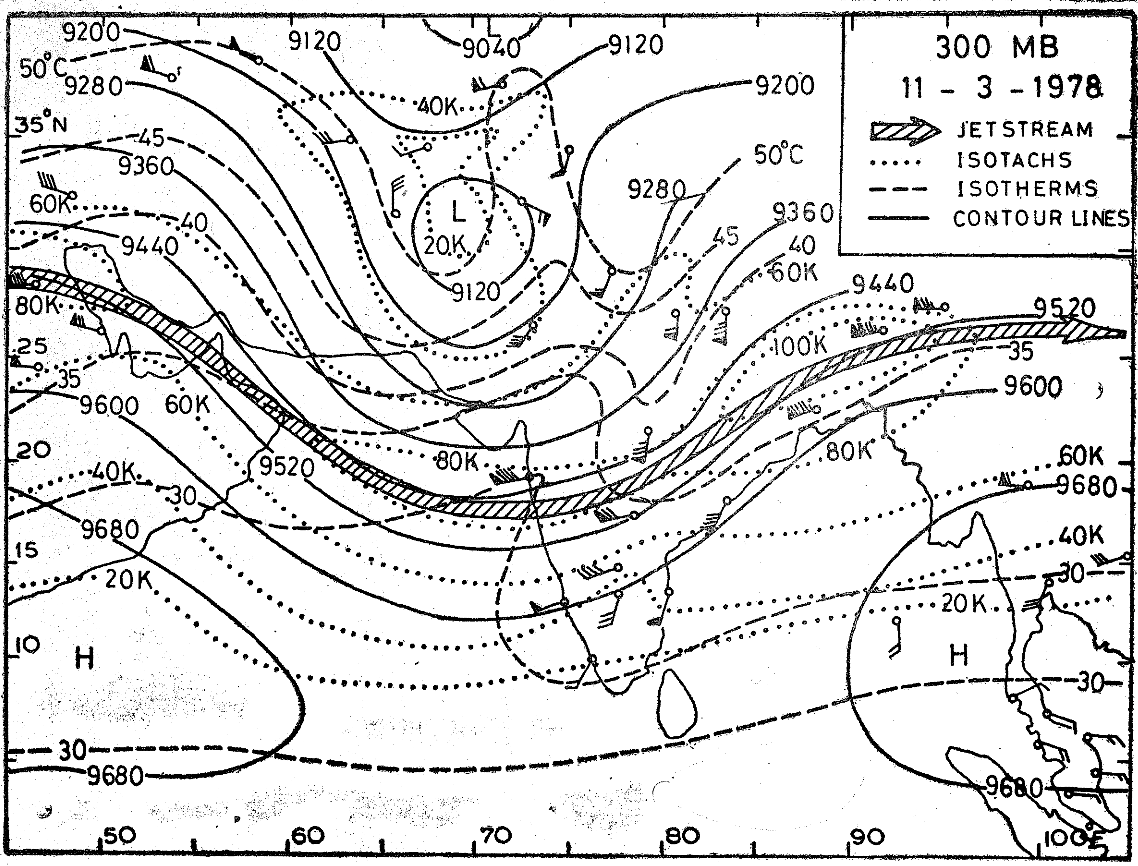

Fig. 8. Constant pressure chart at 0000 GMT on 11 March 1978

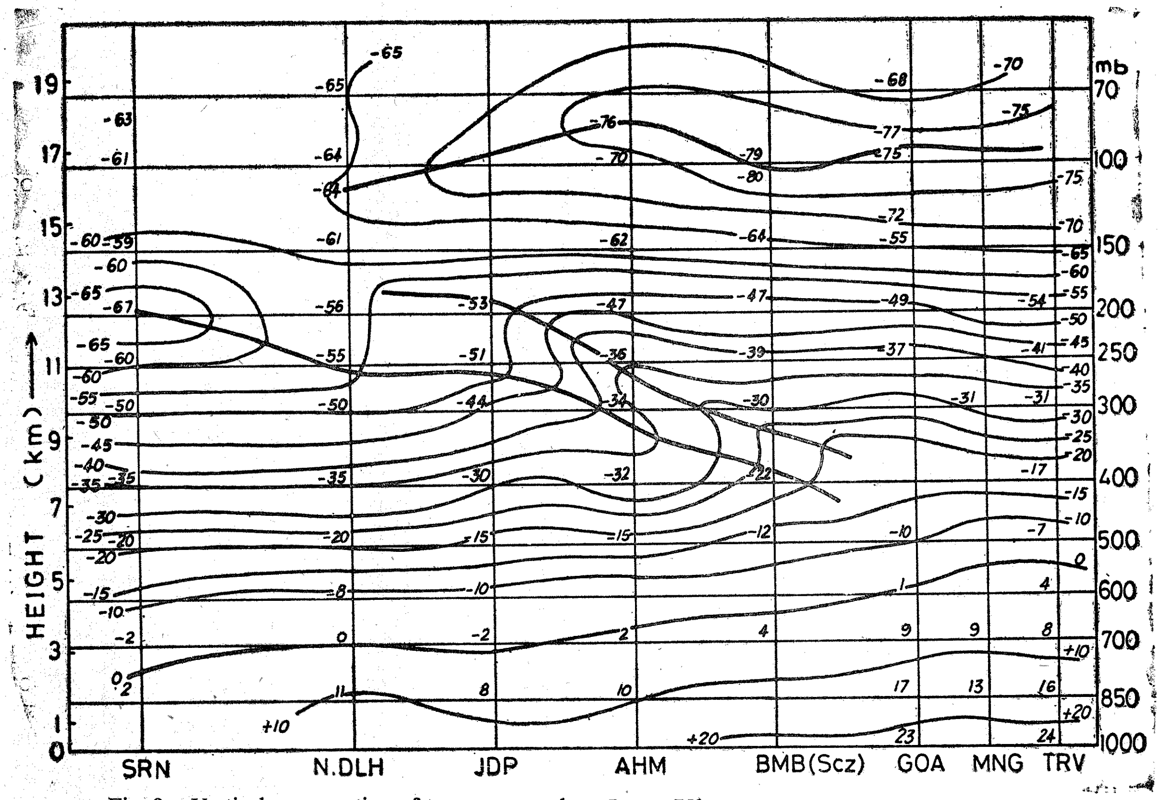

Fig. 9. Vertical cross-section of temperature along Long. 75° E at 0000 GMT on 11 March 1978

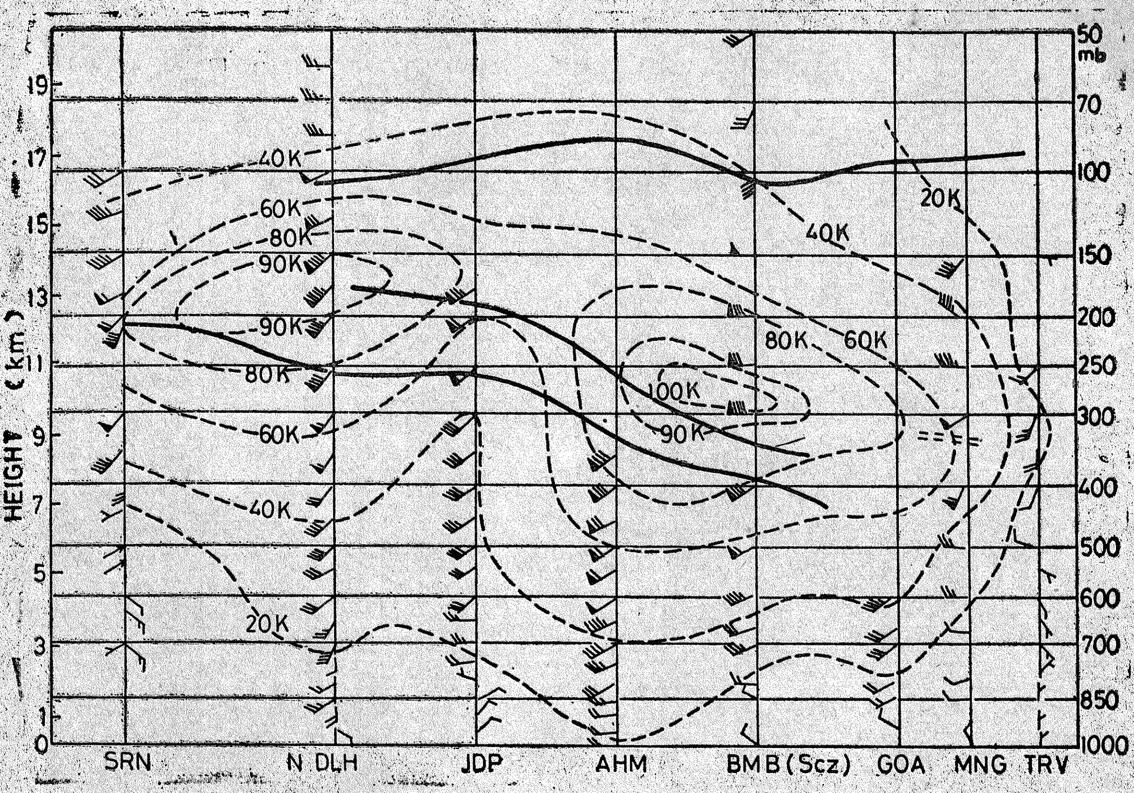

Fig. 10. Vertical cross-section of wind along Long. 75° E at 0000 GMT on 11 March 1978

In order to facilitate quick ventilation of heat of fusion of ice, winds of about 40 kt or more at and above the freezing level are considered very favourable for hail formation. Over and above this, in order to facilitate proper vertical tilting of the cumulonimbus cloud a wind shear of about 40-50 kt between the freezing level and 9.0 km is considered the second favourable upper air condition for hailstone formation. A combination of such two favourable upper wind patterns is created in association with the sloping level of maximum wind overlying the upper boundary of sub-tropical front. The region where the level of maximum wind reaches a height of about 9-10 km with wind speed of the order of 90-100 kt may be considered to have an upper air wind distribution favourable for hailstone formation.

For forecasting hailstorms we can delineate the areas where a combination of all the above mentioned surface and upper air conditions are satisfied. Based on the favourable synoptic situations which had been discussed above, Weather Office located at the Regional Meteorological Centre, Colaba, Bombay had issued hailstorm warning for areas in extreme north Maharashtra State which had subsequently reported hail. It may be mentioned that the height of top of cumulonimbus clouds over the region wherefrom hailstorms were reported was only 9 km as recorded by Cyclone Warning Radar, Colaba on the day of hailstorm report.

As per newspapers reports, rains accompanied by hailstorms on 2 December 1978 caused considerable damage to crops in the districts of Amaravati, Wardha and Nagpur in Vidarbha of extreme north Maharashtra State. At Hinganghat hailstones were reported to be of the size of lemons. It may be mentioned that based on favourable synoptic situations mentioned above Weather Office located at Colaba had issued the first hailstorm warning after the monsoon season of 1978 on the morning of 2 December for the area under its jurisdiction in extreme north Maharashtra State, Vidarbha, though a part of extreme north Maharashtra State falls just outside the area of jurisdiction of Weather Office, Colaba.

On some rare occasions, instances of hailstorms occurring in the same airmass had also been observed. However, on such occasions of hailstorms which are associated with the so called "airmass type" thunderstorms, the characteristic upper air wind features are considered essential for hailstone formation.

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