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# Thunderstorm studies in India

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The symposium on thunderstorms held at the Meteorological Office, New Delhi, on 9–11 March 1960 helped to focus the attention of meteorologists in India on the subject and to take stock of the present knowledge and plan future studies. The papers presented at the symposium and published in this issue of the Indian Journal of Meteorology and Geophysics deal with the formation and structure, radar studies and climatological statistics, of thunderstorms.

In India, interest in the thunderstorm has been evinced for a long time. In many parts of the country, it is on the seasonal, though somewhat uncertain, thundershowers that the farmer depends for his agricultural operations. While the farmer looks at the majestic and towering thundercloud with hope because of the oncoming showers and consequent benefits, the aviator dreads it and tries to keep away from it. As is well known, the thunderstorm is a serious weather hazard to aviation and a large percentage of aircraft accidents due to weather have been due to thunderstorms. It, therefore, formed the subject of a special and elaborate study in the U.S.A. in 1946-48 by the Thunderstorm Project, which resulted in *The Thunderstorm*, a report which is a store-house of very valuable information on the subject.

Thunderstorms are known to be generally more severe in the tropics and subtropics than elsewhere. In India, the thunderstorms of Bengal and Assam of the pre-monsoon period, *viz.*, March to May and early part of June, which are sometimes associated with severe destructive northwesterly squalls of tornadic violence, called "Nor'wester" or "Kal Baisakhi" (calamities of the month of Baisak, April-May), are well known. The "Andhi" or convective duststorm of north and northwest India which occurs during March—June and is really a thundersquall raising dust and associated with little or no rain, is also well known and can sometimes be very severe. The "Andhi" which occurred at Delhi at 1745 IST on 7 March 1960 with the maximum squall speed of 98 miles per hour from NW is a typical example and is one of the severest on record in north India. The radar echo of the cumulonimbus cloud with which the squall was associated extended to a height of about 31,000 feet as seen on the RHI scope. A detailed study is being made of this squall and the results will be published separately.

Thunderstorms occur in all parts of the country and there is no month in which they do not occur in some part of the country or the other. The period during which most thunderstorms occur, considering India as a whole, is March—September, specially March—May. The period of least thunderstorm activity is December—February, although even in this period thunderstorms occur in the northeastern parts of India and the adjoining areas and in the extreme south of India. The periods of maximum thunderstorm activity in south India (south of Lat. 15°N) are March—May and October—December. The areas with marked thunderstorm activity are Assam, Bengal, Orissa, Chota Nagpur and the adjoining regions of Central India and extreme south India. It is interesting to note that the areas of most thunderstorm activity, taking

the year as a whole, are the extreme northeastern and extreme southwestern parts of the country. While in the extreme northeastern parts, the period of activity is March to September, it is September to December in the extreme southwestern parts. In the monsoon season, June to September, the maximum thunderstorm activity is in Bengal, Bihar, Orissa and the adjoining areas. The areas with very little thunderstorm activity, even during the period March–September when many parts of India have good thunderstorm activity are Kutch, Saurashtra and the adjoining areas. It would be interesting to examine why this is so.

While the severest thunderstorms occur in the pre-monsoon period (March—May) in Bengal and Assam, those which occur in May and June before the onset of the monsoon on the West Coast and in the Deccan and south India can be quite severe. Although severe thunderstorms generally occur late in the afternoon, they can occur in the night and early morning hours also; for example many of the thunderstorms in Assam and in the coastal areas of south India, specially in the northeast monsoon season, occur in the night and early morning. Thunderstorms are sometimes accompanied with hail, specially in March—May in north India mainly in and near submontane regions. These hailstorms, sometimes occurring over extensive areas, cause considerable damage to crops and are also a serious hazard to aviation. A hailstorm which occurred about 100 miles WSW of Delhi at 1700 IST on 27 May 1959 badly damaged Indian Airlines Corporations' Viscount aircraft which was flying from Karachi to Delhi. From the damage which the aircraft suffered, it is estimated that hailstones may have been at least 5 inches in diameter. There have been reports of hailstones of the size of a tennis ball, in north India, which indicates the existence of very strong upward and downward currents in thunderstorms which can give rise to hailstones of that size. Hailstorms also occur in December—February in some parts of northern India in association with western disturbances but the southwest monsoon season is remarkably free from hailstorms. It is interesting to examine why it should be so when severe thunderstorms do occur in that season. The earliest study of hailstorms in India (in 1883–1897) was by Eliot in Vol. VI, Part IV of the *Indian Meteorological Memoirs*. A later study of frequency of hailstorms in India was made by Ramdas in 1938. There is need now for a comprehensive study of hailstorms in India from all aspects including radar studies of hail-producing thunderstorms.

The India Meteorological Department has studied the thunderstorm since the last 70 years. There is record of a circular issued by the Department in March 1896 to observers of ten selected stations in India "to collect data of thunderstorms to enable the department to investigate some of the more important features of this class of storms". The circular was a model of thoroughness and wanted, among other items, information of the time interval between the seeing of lightning and hearing of thunder and also regarding types of lightning flashes and their colour. The data collected in 1897 was discussed by Dallas in 1900 in Volume VI, Part VII of the *Indian Meteorological Memoirs*. Fundamental work on the electricity of rain and its origin in thunderstorms was done by G. C. Simpson in Simla in 1907—1909 and his classical paper on the subject in Volume XX, Part VIII of the Memoirs of the Department is well known. In later years, S. K. Banerji studied the electric field of overhead thunderclouds at Bombay and the results of his studies were published in the *Philosophical Transactions of the Royal Society of London* (Series A, Volume 231). The earliest studies of thunderstorms after Dallas were of thunderstorms of Trivandrum by K. R. Ramanathan in 1920 and of thunderstorms of Calcutta by V. V. Sohoni in 1931. C. W. B. Normand introduced in 1931 the concept of real

latent instability as a condition favourable for thunderstorm development and many studies based on this concept were made by others in later years. Numerous studies have also been made in later years by the members of the India Meteorological Department on the statistics and climatology of thunderstorms; formation and development of Nor'westers; dynamics and thermodynamics of thunderstorms and duststorms; synoptic studies and forecasting of thunderstorms and duststorms; squalls associated with thunderstorms and radar study of thunderstorms. Reference to the papers in which these studies are published will be found in standard bibliographies on the subject. Special reference should however be made to the investigation conducted by the India Meteorological Department on Nor'westers of Bengal in April—May 1941 (*India met. Dep. Tech. Note*, No. 10) in which numerous upper air soundings with Dines meteorographs were made from seven stations within a limited area. This study led to the recognition of four types of Nor'wester thunderstorms according to their origin and movement and indicated the existence of time sequence in thunderstorm activity in Bengal and the neighbouring areas.

The highest wind speed recorded in a Nor'wester type of thunder-squall in Calcutta has been 92 mph and a Nor'wester cumulus cloud may extend vertically upto about 65,000 feet (about 20 km). The installation of a powerful weather radar at Calcutta and a radar at Gauhati has provided additional tools for the study of Nor'westers, which will have to be fully utilised in the future. The installation of a weather radar at Gaya and two or three more at Assam stations in the near future will be an added facility for the study of Nor'westers. The Nor'wester is a phenomenon of such serious consequence that it will long remain a subject of study.

Some years ago it was thought that the maximum height to which a thunderstorm cloud could extend in the tropics and subtropics was 35,000 to 40,000 feet and that the tropopause which occurs at a height of 50,000 to 55,000 feet sets the limit to the vertical extent of such clouds. It is now known from observations from high flying jet aircraft and from radar studies that cumulonimbus clouds can sometimes extend to 60 to 65 thousand feet in the tropics and sub-tropics, much above the normal tropopause level. The maximum height to which radar echoes of cumulonimbus cloud was found to extend in the U.S.A. Thunderstorm Project studies was 56,000 feet, the average height being about 37,000 feet. Radar studies so far made of thunderstorm clouds in India have shown that their echoes extend above 50,000 feet on many occasions. The maximum height of radar echo of cumulonimbus cloud observed on the radar at New Delhi was about 61,000 feet (18·5 km). The cumulonimbus associated with Nor'wester squalls appears to extend sometimes to much greater heights. The maximum height of radar echoes of cumulonimbus clouds at Calcutta has been about 65,000 feet (20 km). These heights show that even the modern jet aircraft flying at 40 to 50 thousand feet can meet with thunderclouds over India at those heights. Even when, in the next decade or so, supersonic aircraft services begin to fly at heights of 60 to 80 thousand feet at speeds of over 2000 mph, as anticipated, the thunderstorm over the tropics and sub-tropics will remain a hazard to aviation.

The India Meteorological Department has installed weather radars at six aerodromes (Calcutta, Delhi, Bombay, Nagpur, Madras and Gauhati) in the last few years and the Cloud and Rain Physics Unit at the National Physical Laboratory, Delhi, has a radar exclusively for their studies. The radars at Calcutta and Delhi are powerful ones and have RHI scope also. It is proposed to instal two or three more weather radars in Assam soon. A few more weather radars will be installed within the next five years by the end of which period it is expected that

there may be over 15 weather radars spread all over the country. These radars will provide a valuable tool for the study of thunderstorms over different parts of the country. Results of a few such studies have been published in earlier issues and also in this issue of the journal.

Thunderstorms in different parts of India have different characteristics. It is very essential not only from the purely scientific point of view but also from the point of view of aviation weather forecasting and warning that the characteristics of thunderstorms in different parts of the country—their breeding areas, seasonal and diurnal frequency and variation, intensity, horizontal and vertical extent, rate of growth and decay, the upward and downward currents and turbulence within them, their cellular structure etc—should be studied with the use of radar and in collaboration with the Air Forces, the Civil Aviation Department and other interested scientific organisations. Such meso-scale study of thunderstorms should be organized at a number of centres spread over the country where weather forecast centres have (or will have) radar equipment; for example at Calcutta-Gauhati for thunderstorms of northeast India; at Bombay-Poona-Ahmedabad for thunderstorms of western India; at Bangalore-Madras-Trivandrum for thunderstorms of southern India; at Hyderabad-Nagpur for thunderstorms of the central parts of India, at Delhi—Jodhpur—Lucknow for thunderstorms of north India; at Visakhapatnam for thunderstorms of eastern India.

Forecasting of the development and occurrence of thunderstorms is a problem of considerable practical importance, specially for aviation. In a hilly region like Assam where severe thunderstorms occur at all times of the day and where flying weather conditions can sometimes be quite bad during March to September with extensive low cloud, severe thunderstorms and widespread or local heavy rain, all occurring together or separately, forecasting of thunderstorms is of vital importance. It is hoped that with the installation of weather radars at three or four important stations in Assam, we will be in a better position to detect cumulonimbus clouds and watch their development and movement to be able to issue timely forecasts of thunderstorms in the area for aviation and other purposes. The synoptic weather situations at the lower tropospheric levels and the associated upper air circulations at the upper tropospheric levels which precede and favour scattered or widespread thunderstorm activity over different parts of the country in different seasons require careful study so that the knowledge can be utilised for prognostic purposes. The relation between thunderstorm activity and the variations in the strength and position of the westerly and easterly jet streams also requires study. Some studies on these lines have been made but further studies are required.