A Satellite Study of Tornadoes over North Delhi & Keonjhar District of Orissa

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The synoptic-scale situations leading to the occurrence of tornadoes over north Delhi on 17 Mar. 1978 and over six villages of Keonjhar district of Orissa on 16 Apr. 1978 have been investigated using scanning radiometer cloud pictures of US Defense meteorological satellite in the visible as well as thermal infrared channel with two nautical-mile resolution. The severe weather outbreak in both the tornadoes occurred in the northwest/north-northwest of the area beneath the intersection of the subtropical jet stream with the squall line. The environmental conditions in the tornado outbreak were characterized by deep surface moisture, large vertical wind shear and strong veering of winds between lower and upper troposphere.

1. Introduction

Occurrence of tornadoes in Indian subcontinent is very rare. Documented cases of tornadoes from 1886 to the present day extracted from available records show that 35 tornadoes occurred in India during a period of over hundred years. Kumar and Singh studied a case of tornado which occurred in the evening of 10 Mar. 1975 near Ludhiana in Punjab, using visible cloud imagery of ESSA-8 weather satellite. They observed unstable squall line clouds emanating from mid Arabian Sea and extending up to Punjab indicating strong instability over the cloudy area. They noted that the area of the intersection of the squall line with the subtropical jet stream is favourable for severe weather development. Mandal and Basandra also studied the Ludhiana tornado and discussed the synoptic situations and meteorological conditions in relation to stability of the air column and the horizontal and vertical distribution of moisture and the wind flow.

Certain specific environmental conditions are responsible for the occurrence of tornado. The combined use of visible and infrared imagery from weather satellites and conventional meteorological data yields a better assessment of the behaviour of the severe weather systems than is possible with the use of conventional data alone. Synoptic and meso-scale features which are associated with severe weather development are readily detectable in satellite photographs. The visible and infrared pictures have been a valuable source of information for locating active squall lines and subtropical jet-streams which play significant role in locating the area of maximum weather threat. In this paper, a study is made of two tornadoes, viz. one which occurred on 17 Mar. 1978 over North Delhi, and the other which occurred on 16 Apr. 1978 over six villages of Keonjhar district, and it is shown that the association of squall lines with subtropical jet stream leads to potentially hazardous weather over certain specified area.

2. North Delhi Tornado

A tornado originated in North Delhi over the University area at about 1805 hrs IST on 17 Mar. 1978. The track of the tornado is shown in Fig. 1. Severe damage took place over a stretch of about 5 km in length and 50 m in width. It moved almost parallel to the Najafgarh drain. The time taken by the tornado to cover its entire track was about 3 min. Almost the entire damage was confined to the east of the drain. Twentyeight persons were reported to have lost their lives and about seven hundred sustained injuries. Property worth more than ten million rupees was reported to have been destroyed. This was probably the first case of tornado in the recent memory in the capital of India.

Figs. 2(a) and (b) are the US Defense meteorological satellite (DMS) pictures received in visible and infrared channels, respectively, taken at 1155 hrs IST on 17 Mar. 1978. These pictures depict the development of mild convection over Delhi, north Madhya Pradesh and west Uttar Pradesh. A large
number of cumuliform clouds with small horizontal and vertical extent are seen to align under the influence of strong south-westerly winds in the lower and mid troposphere. The southwest-northeast oriented cumulus lines in the central Arabian Sea are indicative of the incursion of moisture from Arabian Sea to northwest India. The appearance of the southwest-northeast oriented cumuliform cloud clusters over Delhi and neighbourhood seen both in visible and infrared imagery could be a forewarn of the possibility of severe weather development in the evening when the atmospheric instability could further enhance due to insolation.

Figs. 3(a) and (b) are the DMS imagery with 2-nautical-mile resolution received in $H$ and $I$ infrared channels, respectively, taken at 2034 hrs IST on 17 Mar. 1978. The $H$ channel detector is an unfiltered silicon diode with a peak response at 0.8 μ and full width half max. (FWHM) at 0.6 μ and 1.0 μ whereas the $I$ channel detector is a thermistor bolometer with essentially flat response from 8 to 13 μ. The imagery recorded in both $H$ and $I$ channels show two well marked squall lines to the east of Delhi, oriented in southwest-northeast direction and separated by a distance of about 100 km. The squall line close to Delhi is at a distance of about 50 km. Since these pictures are recorded about 2½ hr later than the time of occurrence of tornado, it can be inferred that the squall lines might have been closer to Delhi at the time of severe weather outbreak over north Delhi. The comparison of the pictures taken at 1155 and 2034 hrs IST reveals that the mild convective activity over Delhi and adjoining area in the forenoon of 17 March had become violent towards the evening owing to the strong insolation and suitable moisture flow in the afternoon hours resulting in the formation of active squall lines. Long cumulus lines over Central Arabian Sea aligned in southwest-northeast direction clearly indicate low level moisture flow over the area having squall lines.
Fig. 4 depicts the motion field at 200 mbar at 1730 hrs IST on 17 Mar. 1978. The subtropical jet stream is seen to run south of Delhi and is associated with a large amplitude westerly trough moving towards east along long. 68°E. The place of occurrence of tornado is situated to the northwest of the area just beneath the intersection of the subtropical jet stream with the squall line closer to Delhi.

The current weather records of 17 Mar. 1978 of Meteorological Office, Safdarjung and Indian Air Force, Hindon (near Ghaziabad) were examined and it was found that thundershower commenced at Safdarjung at 1645 hrs IST and at Hindon at 1700 hrs IST. This indicates that the thunderstorm system was moving from west to east. A squall was also reported at Safdarjung Airport at 1835 hrs IST, which confirms the presence of squall line in satellite imagery. The examination of vertical time section over Delhi reveals that a trough in the lower troposphere moved from west to east across Delhi between 1730 and 2330 hrs IST on 17 March 1978. The squall line seems to have developed along this trough and moved eastwards.

3. Keonjhar District Tornado

A severe tornado had also hit a village Purana Band Goda of Keonjhar district (Orissa) at about 1630 hrs IST on 16 Apr. 1978 and subsequently moved through the villages Gorh Band Goda, Karamali, Gondiadiha, Nakoda and Tigiria. It lasted only for 5 min. It moved from northwest to southeast and caused damage in a stretch of about 4 km in length. The houses of about 700 families were razed to ground. The worst affected village was Purana Band Goda. About 150 persons were reported to have been killed and several hundred injured. Property worth more than 50 lakh rupees was destroyed.

Fig. 5(a) shows a DMS imagery recorded in infrared channel at 1132 hrs IST on 16 Apr. 1978. A very strong western disturbance is located over north Afghanistan and adjoining Russian Turkistan with a long well formed cloud band of considerable width, spiralling in towards the central cloud mass. A trough associated with this disturbance extends far south to the Arabian Sea. The subtropical jet stream clouds which originate in association with
this large amplitude trough are seen to emanate from north Arabian Sea and move towards east over Rajasthan. East coast of India is seen to be almost free from clouds.

In the afternoon hours, a well marked wind discontinuity line developed over land close to the east coast, separating warm moist maritime air of Bay of Bengal and warm dry continental air of the Indian Peninsula. An active squall line developed along this wind discontinuity line extending up to extreme northeast India as can be seen in Fig. 5(b). A well defined subtropical jet stream, developed in association with a large amplitude trough shown in Fig. 6 intersected the squall line near Bhubaneswar which is about 150 km south-southeast of the place of occurrence of tornado. The subtropical jet stream clouds can also be seen to emanate from North Arabian Sea [Fig. 5(b)]. The anticyclonic curvature in the jet clouds clearly indicates that jet originates ahead of a large amplitude trough associated with the western disturbance.

4. Conclusions

The following common synoptic features are observed around the time of occurrence of the tornadoes under study.

(i) Both north Delhi and Keonjhar district tornadoes occurred to the northwest/north-northwest
of the area beneath the intersection of the subtropical jet stream with the squall line. Over North American areas also tornadoes are found to occur normally beneath the intersection of the jet stream with a squall line and to the north of the jet axis.\(^4\)

(ii) Subtropical jet which is seen to play significant role in severe weather outbreak appears in association with north-south oriented large amplitude trough.

(iii) Squall lines have been found to develop along the line of wind discontinuity where two airmasses having different physical characteristics meet.

(iv) The environmental conditions in the tornado outbreak were characterized by deep surface moisture, large vertical wind shear and strong veering of the wind between lower and upper troposphere.

These synoptic-scale observations as revealed by satellite imagery and conventional meteorological data will be of immense utility to the weather forecaster in forecasting severe weather over Indian subcontinent. The high resolution visible and infrared imagery at half hourly interval would be available in India by the middle of 1981 after the launch of a geostationary Indian National Satellite (INSAT-1). This will be a very useful tool available to the forecaster in locating the typical cloud features associated with severe weather activity.

References