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Tornado over Punjab

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ABSTRACT. A tornado passed over a few villages in the Ludhiana district in Punjab on 10 March 1975. Synoptic situation and meteorological conditions in relation to the stability of the air column, the horizontal and vertical distribution of moisture and the wind flow associated with this tornado have been discussed.

1. Introduction

Severe thunderstorms of tornadic violence are known to occur over northeast India in pre-monsoon months, usually during warm and humid weather. However, tornadoes in association with severe thunderstorms are practically absent in the southern parts of the country. In northwest India their occurrence is rare. A case of tornado was reported by Veryard (1934) in northwestern parts of Indian sub-continent over Peshwar (now in Pakistan) on 5 April 1933. The present one is the second case of a tornado so far reported over northwest India. It was observed on 10 March 1975 near Ludhiana in Punjab. Like a typical tornado its life was short and the path of destruction small. Nonetheless it moved through populated areas and farm lands with standing crops and caused considerable loss to life and property.

2. Life history of the tornado and the damages caused

One of the authors inspected the areas devastated by the tornado soon after the reports of extensive damage to life and property were received. The place of origin of the tornado, its development and life history have been reconstructed based on the information and evidence collected by him.

The tornado seems to have originated from a well developed cumulonimbus cloud near village Ransir about 25 km southeast of Ludhiana at about 1700 IST on 10 March 1975. The track of the tornado as reconstructed is given in Fig. 1. According to an eye witness a revolving and rotating tail was noticed to be coming down very close to the ground frequently from the main cloud mass. As it suddenly descended close to the ground a sound similar to that of an earthquake with mild sonic boom was heard. The cloud mass rotated violently with very strong winds and took northnortheasterly course through a few villages namely Rano, Kudani, Shahpur, Kaddon, Jatna, Mehdoodan and Nellon.

The diameter of the vortex of the tornado increased rapidly to about 200 metres as it moved forward. Its tail was moving up and down and this process was seen to be repeated again and again throughout its life cycle. The actual track was zig-zag. It had definite cyclonic whirl which could be judged from the pattern of destruction. Pressure deficit and updrafts inside the storm were so high that it had sucked in and thrown away many heavy objects like a bullock cart with its two oxen and driver, a grain winnowing machine about 5 quintals in weight and many other items. It travelled along a canal and the track had a tendency to come closer and closer to the canal. The total length of the track was about 16 km. Time taken by the tornado to cover its entire track was about 20 minutes. Thus the speed of propagation is estimated to be around 50 km per hour.

Six villages were affected by the tornado, where 450 houses were destroyed and another 359 houses were damaged. Standing crops over a stretch of 800 acres of land were completely damaged. Ten persons lost their lives and scores of domestic animals perished.

Maximum damage to the buildings was caused at Jatna village, followed by Shahpur and Mehdoodan. The tornado uprooted thousands of trees and almost all the electric poles along its track. Loss to tube-wells and other agricultural machinery was considerable. The average width of the track of damage was about 200 metres extending to about 500 metres at the bends of its zig-zag path. Some photographs of devastation caused by the tornadoes are reproduced in Figs. 2 (a-c).

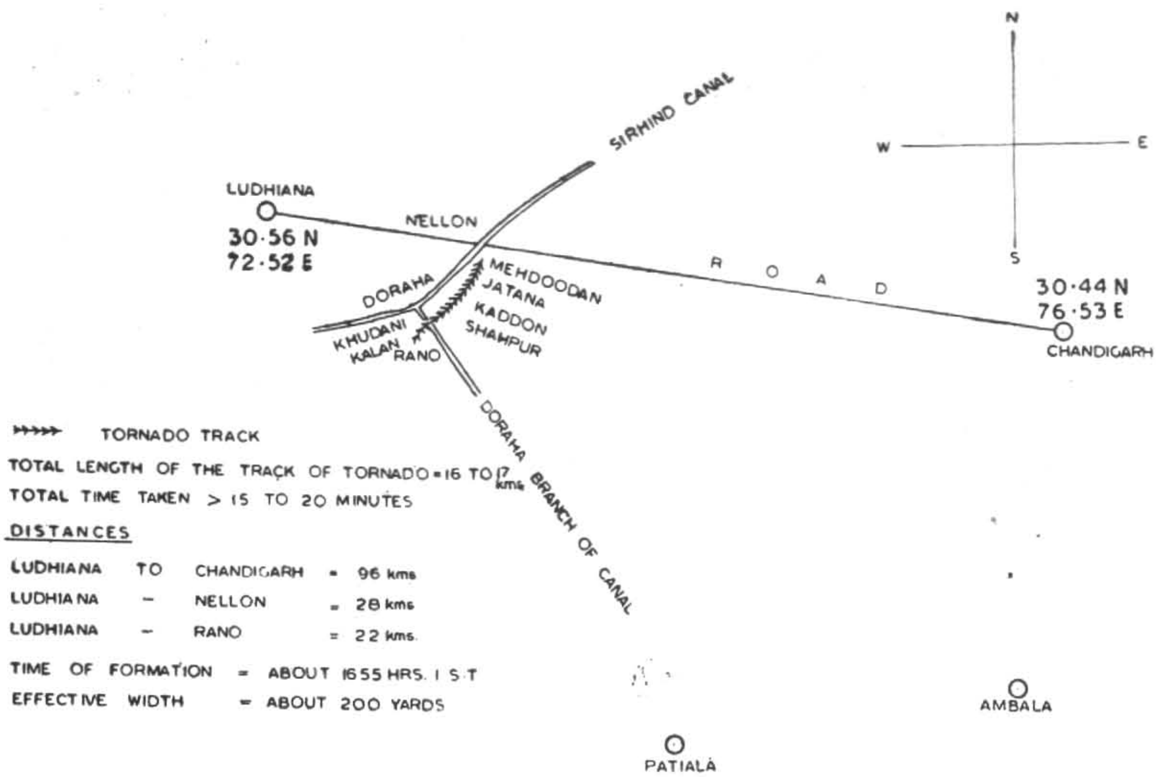

Fig. 1. Track of the tornado near Ludhiana on 10 March 1975

3. Conditions favourable for occurrence of tornadoes

Tornado is a meso-scale phenomenon and thus goes generally undetected in the synoptic analysis. However, based on the measurements made largely at the fringes of the phenomenon it has been observed that for the formation of a tornado presence of layers of air with contrasting characteristics of temperature, moisture, density and wind flow is required. Some of the favourable conditions for the occurrence of tornadoes as revealed from the studies of Showalter and Fulks (1943), Harrison and Orendrof (1941), Fawbush, Miller and Starrett (1951), Newton (1963) and others can broadly be summarised as follows :

(*i*) The tornadoes are related to the large scale synoptic systems although an individual tornado may appear as a local or short-lived phenomenon.

(*ii*) Presence of conditional and convective instability.

(*iii*) Presence of a layer of moist air near the earth's surface with deep layer of dry air aloft.

(*iv*) Presence of moisture wedge or ridge in the moist layer.

(*v*) Generally bands of strong winds in lower and upper levels usually veering with height.

(*vi*) Presence of some mechanism for releasing the instability, like frontal lifting, diurnal heating, general convergence or orographic lifting.

According to Fawbush, Miller and Starrett (1951), most preferred region for the formation of a tornado is the area where the vertical projection of the axis of wind maxima in mid-tropospheric level intersects the axis of the moisture ridge, other conditions being favourable. Saha (1966) in his study of a tornado over north Bengal observed the existence of some of these features. In the light of these empirical rules, present case has been studied and synoptic situation along with the meteorological conditions associated with this tornado have been discussed.

4. Discussion

As mentioned above the affected area was 20 km southeast of Ludhiana. The nearest surface observatory from the tornado site is Ludhiana. Pilot balloon observatories around and close to the site are Ambala, Patiala, Amritsar and Dehradun. The nearest radiosonde and rawin station from the tornado site is New Delhi at a distance of about 300 km south of the affected area. The locations of these observatories and the tornado site are shown in Fig. 3.

4.1. *Synoptic situation*

4.1.1. *Surface features* — On the morning of 10 March 1975 a western disturbance was located as a well marked low with associated upper air cyclonic circulation extending upto 4·5 km a.s.l. over Pakistan and adjoining west Rajasthan. By the evening it intensified into a western depression over Pakistan and adjoining north Rajasthan and Punjab (Fig. 3). The system slowly moved away northeastwards across the Western Himalayas. The tornado developed over an area to the east of the system.

On 10th morning pressure changes of the order of *minus* 4 mb were observed over Haryana and adjoining Punjab. Pressure departures over the area were of the order of *minus* 6 mb. Towards the evening pressure changes of the order of *minus* 7 mb were observed over Punjab and pressure departures over that area were of the order of *minus* 8 mb. This indicates that the system with which the tornado was associated was quite intense.

Ahead of the western disturbance there was widespread thunderstorm activity in the morning of 10 March 1975. Isolated squall was reported on 10th morning when Mandi, a station to the east of the system, reported squall of 35 knots from the west.

4.1.2. *Upper air features* — Available lower level winds for a few stations close to the tornado site have been tabulated in Table 1. Very strong wind (southeasterly 50 knots) over Amritsar at 0·9 km in the evening of 10 March also suggested that the system with which the tornado was associated was quite intense.

A well marked wind shear in the vertical from the lower moist layer to the upper dry layer was noticed. In the evening of 10 March upper wind at 2·1 km in south Punjab was southerly 30 knots while at 9 km the wind was westsouthwesterly 80 knots. The vertical wind shear together with significant veering of the wind was a very good indication of possible severe weather activity around the area (Saha 1966).

On the morning of 10 March 1975 at 500 mb a low was observed over Afganistan with its central region roughly over 65°E and 32°N. A trough

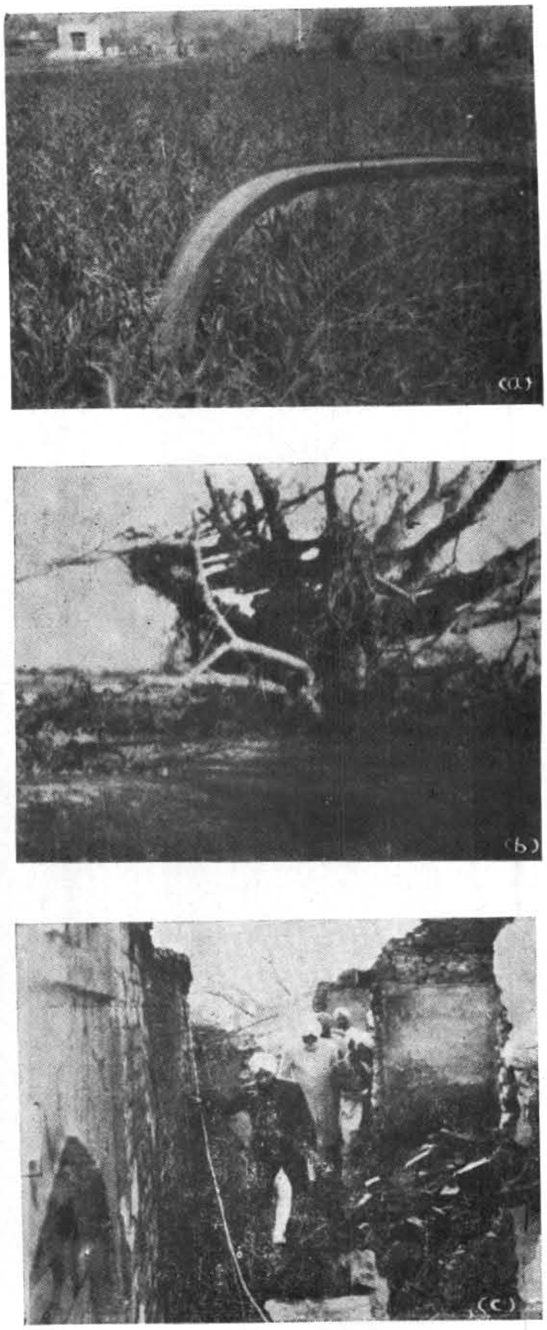

Fig. 2

(a) An electric pole bent and twisted by the tornado

(b) A big tree uprooted from the ground and rotated by the tornado

(c) Chief Minister of Punjab, visiting the worst devastation site where two houses of the sarpanch of village Janta were razed to ground.

(Through courtesy — Publicity Dept., Govt. of Punjab)

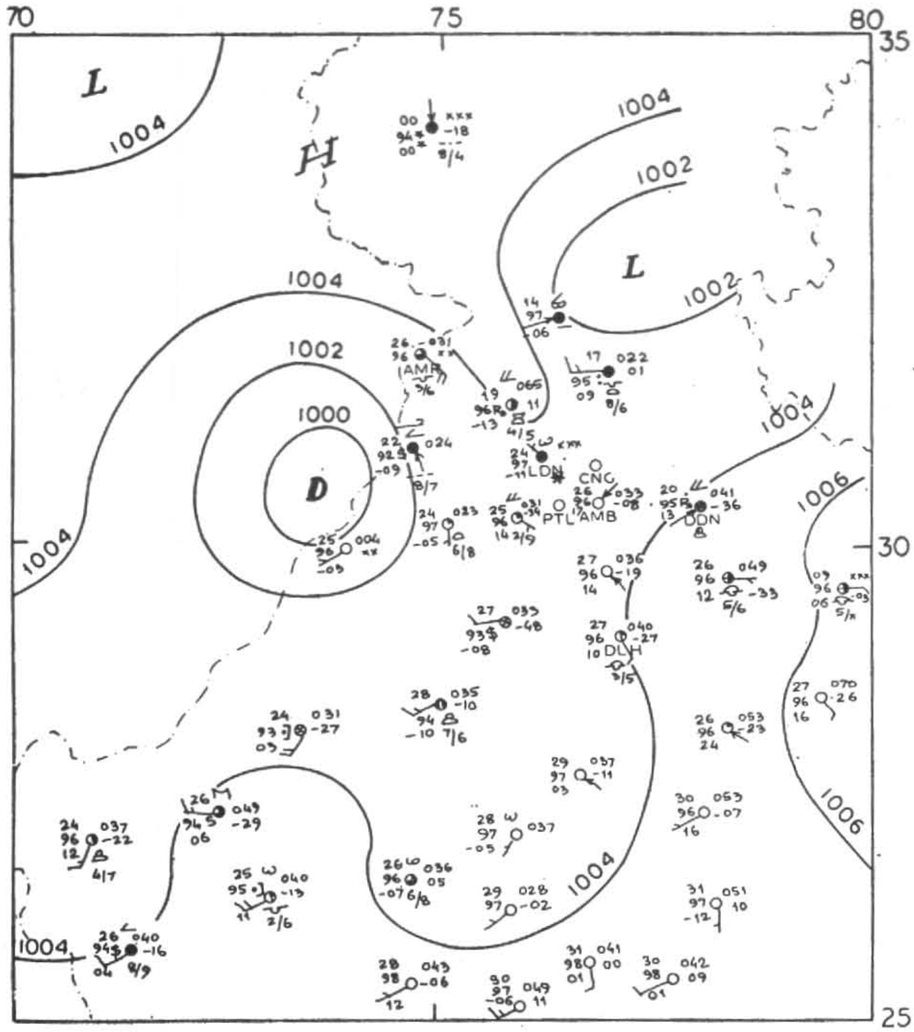

Fig. 3. 1200 GMT surface chart of 10 March 1975 (* Tornado site)

TABLE 1

Lower level wind around the tornado affected area on 10 March 1975

Date & time	Ht. (km)	Amritsar	Ambala	Patiala	Dehra-dun
10 Mar 1975 00 GMT	0·6		135/25	110/25	
	0·9		120/30	120/20	070/15
	1·5		150/30	120/20	080/15
	2·1		160/40		160/15
10 Mar 1975 12 GMT	0 6	130/35	140/15	200/10	
	0·9	140/50	160/20	160/2	100/05
	1·5	160/35	180/25	180/25	160/05
	2·1	160/30	200/30	170/35	

was extending from this low centre at Afganistan towards southeast up to Pakistan and adjoining Punjab. The situation at 700 mb was almost similar. At 300 mb, trough in the westerlies was observed roughly along 65°E and was extending upto 30°N to the south. In the evening the trough at 300 mb was observed roughly along 67°E when it extended further south to 25°N (Fig. 6).

5. Stability conditions and moisture distribution

In comparison to the size of the system the distance of the nearest upper air station (New Delhi) is too large to be representative of the upper air soundings of the tornado affected area. A few significant features obtained from the analysis of Delhi tephigrams are noted here :

Morning and afternoon tephigrams of Delhi on 10 March 1975 show instability favourable for strong thunderstorm activity and the availability of moisture was more than the preceding and succeeding days. Level of free convection (LFC) was lowest on the evening of 10 March 1975 when it was observed at 750 mb (below 650 mb) which is considered to be one of the favourable factors for strong thunderstorm activity (Fawbush, Miller and Starrett 1951).

Showalter Index (S.I.) was significant for strong thunderstorm activity on 10 March when it was — 3°C at Delhi. A table showing L.F.C. and S.I. over Delhi for the period 9 and 10 March 1975 is shown in Table 2.

To find out the horizontal moisture distribution at the surface over the area, dew point temperature around the area for 10 March were analysed (Fig. 4). It may be seen that in the evening of 10 March there was a distinct dew point wedge (ridge) along a narrow band over the tornado affected area where dew point temperatures were above 13°C, which is considered to be another favourable factor for the occurrence of tornado (Fawbush, Miller and Starrett 1951).

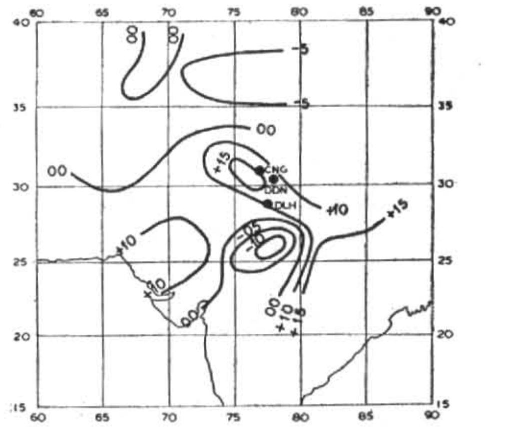

Fig. 4. Dew point temperature for 12 GMT on 10 March 1975

6. Satellite information

Analysis of satellite cloud imageries from 8 to 10 March 1975 revealed that a western disturbance originating in Afganistan had moved systematically towards east roughly along 30°N affecting the weather over north India. It was shallow at the beginning but became intense on 10 March. Cloud pictures taken by the weather satellite ESSA-8 in the morning of 10 March 1975 is reproduced here (Fig. 5). It may be seen that a narrow band of clouds suggested a squall line extending from its main mass towards southwest along Punjab, Haryana, north Rajasthan and Gujarat. Such bands are normally considered to be associated with the frontal or strong discontinuity line. In fact the appearance of squall line type clouds in the morning satellite picture was a forewarner of the possibility of severe weather development in the afternoon or evening when the atmospheric instability was further enhanced due to insolation. It is noteworthy that the tornado affected area was along the border region of this cloudiness and just to the right of the cloud band. During the life period of this system cloud band was not observed on other days.

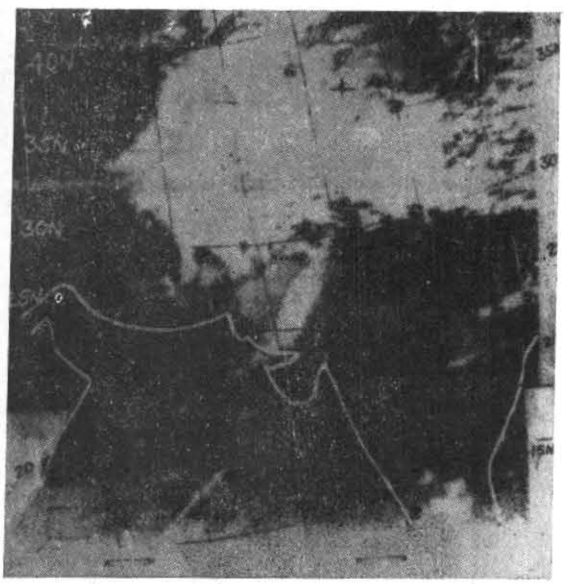

Fig. 5. Cloud picture taken by the Weather Satellite ESSA-8 in the morning of 10 March 1975. Tornado affected area was near 30·5°N, 75·8°E.

TABLE 2

Showalter index (S. I.) and level of free convection (L.F.C.) over Delhi during 9 to 12 March 1975

Date	Time (GMT)	Showalter Index	L.F.C. (mb)
9 Mar 75	0000	+3·0°C	—
9 Mar 75	1200	+1·5°C	450
10 Mar 75	0000	—3·0°C	600
10 Mar 75	1200	*	750

*Could not be calculated due to doubtful Dew Point temperature in the lower level.

7. Position of the jet and mid-tropospheric strong wind core

Fig. 6 shows the positions of the trough and the jet maxima at 300 mb at 12 GMT of 10 March 1975 and the site of the tornado on that day.

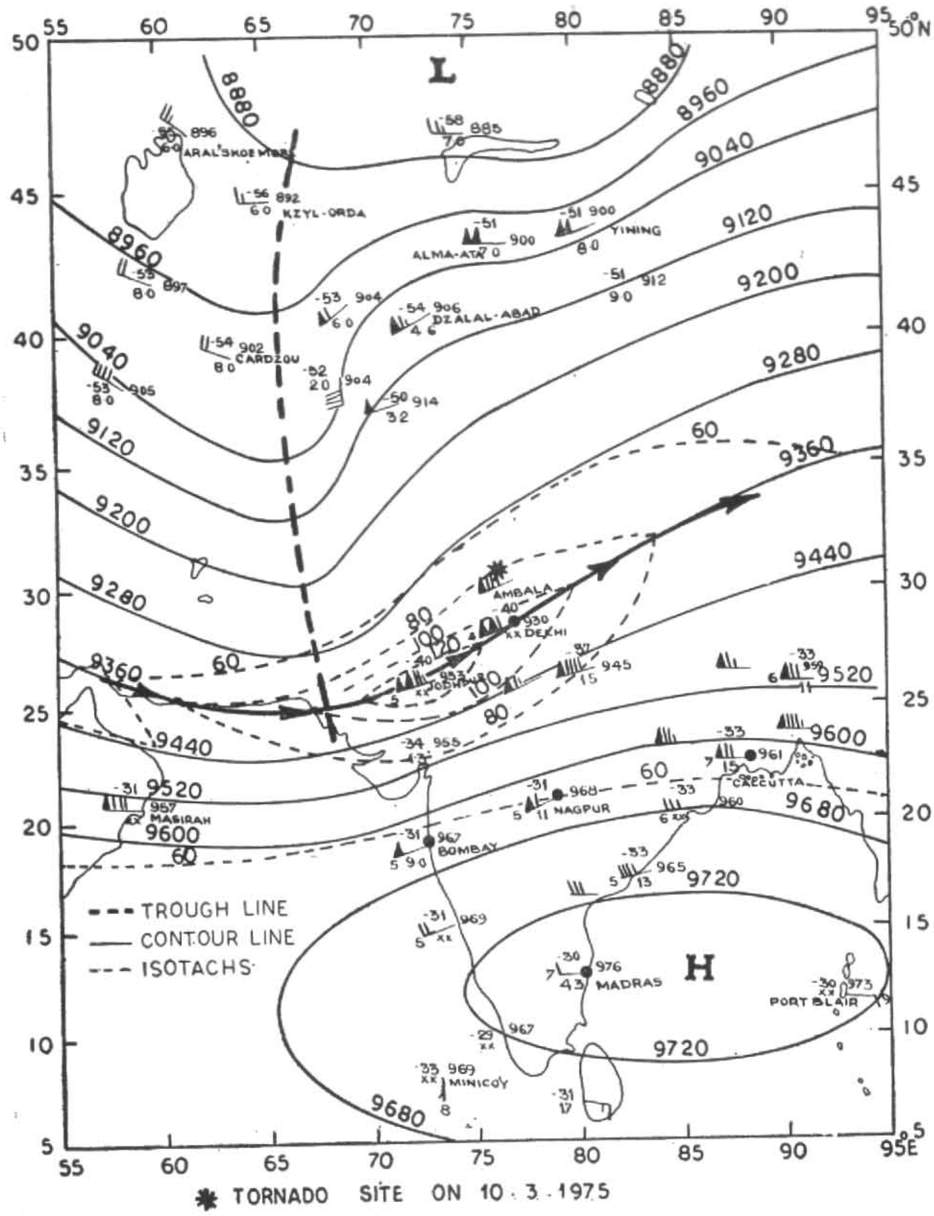

Fig. 6. 300 mb chart at 1200 GMT on 10 March 1975

It may be seen that the tornado affected area was below the left exit of the jet stream which alongwith the upper air trough to the west might have provided necessary divergence and helped intensification of the low level system (Riehl 1952). It has been noted that "Tornado occurring in the presence of subtropical jet stream are normally beneath its interaction with the squall line and to the jet axis" (Anderson and Smith 1969).

Delhi vertical time-section (Fig. 7) for 8 to 14 March indicates comparatively more moist air on 10 March in the lower level with dry air aloft and presence of strong winds of 60-70 knots at 500 mb on 10 to 11 March 1975. Mid-troposphere (700 to 500 mb) around Delhi on 10 and 11 March was comparatively colder than preceding and succeeding days. Axis of the mid-tropospheric jet indicating advection of dry air was occurring close to but slightly to the north of Delhi. Projection of the axis of the strong wind core intersected the moisture ridge on 10th evening near an area where the tornado developed. Out of many factors one very favourable for the development of tornado over that area on 10 March may be this differential advection of moist air near the surface and dry air above in a region where general convergence was already existing (Petterssen 1956).

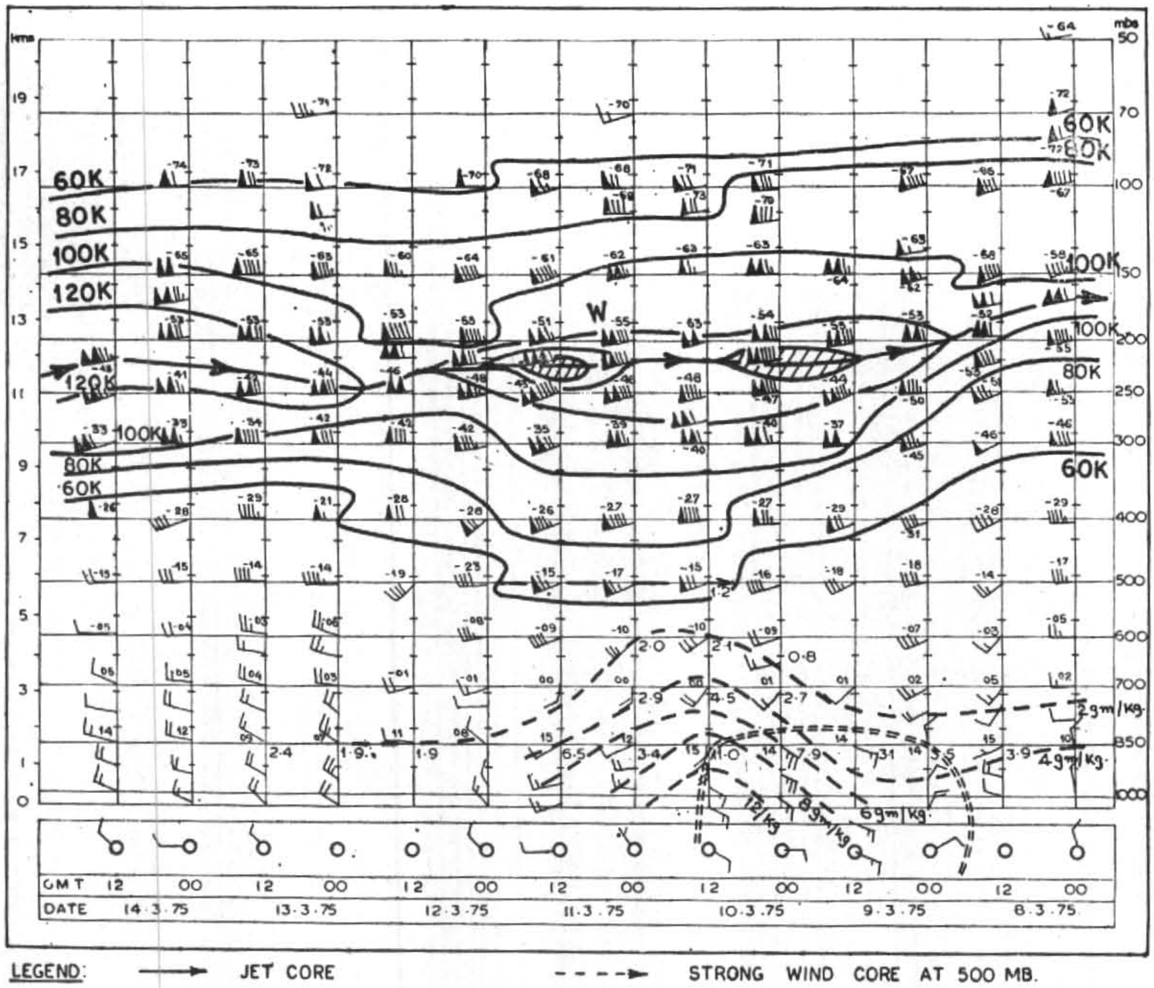

Fig. 7. Vertical time section of Delhi showing wind and moisture distribution for the period 8 to 14 March 1975

8. Conclusion

It is seen that the tornado developed in association with a western depression ahead of a westerly trough and strong discontinuity line below the left exist of the jet core close to the mountain range. Thus the low level convergence was in phase with the high level divergence in the area. The site being close to the mountain range, orographic lifting of the airmasses was possible. Atmosphere around the area was vertically unstable. Lower troposphere was quite moist and higher and mid-troposphere dry. Mid-tropospheric strong wind core was present indicating the advection of dry air to a place where lower troposphere was moist. Consequent to differential advection of dry air above and moist air below increase in lapse rate was possible over the region. Warm advection in lower level also took place in the region during this period. Development of tornado near Ludhiana on 10 March could be attributed to presence of several such factors on that day in the region.

Acknowledgements

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REFERENCES

Anderson, K. and Smith, A. N.	1969	*Application of Meteorological Satellite Data in Analysis and Forecasting*, NESC 51.
Fawbush, E. J., Miller, R. C. and Starrett, L. G.	1951	*Bull. Am. Met. Soc.*, **32**, pp. 1-9.
Fawbush, E. J. and Miller, R. C.	1953	*Ibid.*, **34**, pp. 139-145.
Harrison, H. T. and Orendroff, W. K.	1941	United Air Lines Met. Dep. Circular No. 16.
Newton, Chester W.	1963	*Met. Monographs*, 5, 27, 33 pp.
Petterssen, S.	1956	*Weather Analysis and Forecasting*, **II**, p. 194.
Riehl, H.	1952	*Forecasting in middle latitudes*, Met. Monograph. 5, Am. met. Soc.
Saha, K. R.	1966	*Indian J. Met. Geophys.*, **17**, 3, pp. 427-431.
Showalter, A. K. and Fulks, J. R.	1943	*Preliminary report on tornadoes*, USWB, 22 pp.
Veryard, R. G.	1934	*India Met. Dep. Sci. Notes*, **5**, 56 pp.