An Outbreak of Tornado on March 28, 2001: A Case Study

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Abstract

Pakistan has the history of occurrence of severe weather phenomena in different parts of country - mainly in northern and central parts of country. A tornado occurred at Chak Misran, Bhalwal in Sargodha district on the evening of March 28, 2001 at about 1530 PST. This tornado reaches F2 intensity (120 miles/hour) and caused considerable loss of lives, injuries and destruction across the path of the Tornado. A well marked low pressure area was lying over Northern Areas of the Punjab, as evident on surface level charts of March 28, 2008 from 0000 UTC to 0900 UTC, appreciable pressure gradient existed further north-westwards of he low pressure system. The system was extended upto mid-tropospheric level (500 hpa). There was appreciable incursion of moisture from North Arabian Sea and a cold air was penetrating into North Western parts of the country. Thunderstorms activity has been reported by a number of meteorological observing stations of North Punjab. In this study effort has been made to understand the synoptic feature of this particular event. Suggestions have also been presented to better forecast the tornadoes and its preparedness.

Introduction

Tornadoes, local storms of short duration, may be ranked as one of the most destructive natural phenomena. Also called twisters, tornadoes are violent windstorms taking the form of rotating column of air, or vortex extending downward from a cumulonimbus cloud. Tornadoes are usually in the form of visible condensation funnel, whose narrow end touches the ground and is often encircled by a cloud of debris. They are approximately 250 feet (75 m) across and travel a few miles (several kilometers) before dissipating. Most tornadoes have wind speed between 40 mph (64 km h-1) and 110 mph (177 km h-1). Some attain wind speed of more than 300 mph (480 km h-1), stretch more than a mile (1.6 km) across, and stay on the ground for dozens of miles (more than 100 km). In a study of Nebraska tornadoes over a 22 year period, found that 95% of the tornadoes formed with the surface cold front, 1 % with the surface warm front, 3 % indicated similar places of inception, and 1 % gave no clues as to the places of origin. (Joseph G. Galway). Weightman (1933) found that tornadoes occurred under a great variety of meteorological conditions: for example, with warm-front thunderstorms, hurricanes, ill-defined discontinuities, the centre of lows, and the passage of the surface cold fronts. (Joseph G. Galway), Tornadoes usually form in spring and summer season, but they can occur any time of the year. Tornadoes are most likely to occur between 3 and 9 p.m. but have been known to occur at all hours of the day or night. The average forward speed is 30 mph but may vary from nearly stationary to 70 mph.

Tornadoes are not very common in Pakistan. The phenomena which usually occur in plain areas of the NWFP and Punjab are the same like tornado but of very low intensity and they usually cannot be categorized as tornado. People of Pakistan generally do not know the name of tornado. They call it “Bhanwar” “Chakkari” and “Wahwaraila” in their local languages. The intensity of tornado is measured in Fujita Scale. Fujita scale classifies tornadoes into six categories of wind speed F0 to F5 based upon the damages. F0 (light damage) with wind speed 40 – 72 mph to F5 (incredible damage) with wind speed 261 – 318 mph. This intensity is based on the damages caused by tornado on human built structure and vegetation. The category of the tornado is determined by the meteorologists and engineers after making a ground/aerial survey of the destruction and damages of the affected area. The scale was introduced in 1971 by Tetsuya "Ted" Fujita of the University of Chicago who developed the scale together with Allen Pearson. Enhanced Fujita Scale has been introduced in 2007 in USA (Wikipedia).

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Synoptic Situation

On March 28, 2001, at about 1530 PST, a tornado of F2 intensity was produced in village Chak Misran, Bhalwal in Sargodha district. A well marked low pressure area was formed over northern areas of the Punjab on March 28, 2001 as evident in surface charts of 0000 to 0900 UTC. Appreciable pressure gradient existed further north-westwards of the low pressure system. The system was extended upto mid-tropospheric level (500 hpa). There was appreciable incursion of moisture from North Arabian Sea and cold air was penetrating into northwestern parts of the country. Thunderstorms activity has been reported by a number of meteorological observing stations of North Punjab.

Surface chart of 0000 UTC

At surface chart of 0000 UTC, a well marked low pressure area of 1000 hpa was seen over central areas of the Punjab. Strong pressure gradient was observed in northwest and northeast of the low pressure system. Cold air ridge penetrated into northwestern parts of the country. A southward flow of wind was evident to the west of the system, penetrating up to the coastal areas which indicate a cold air incursion to the system.

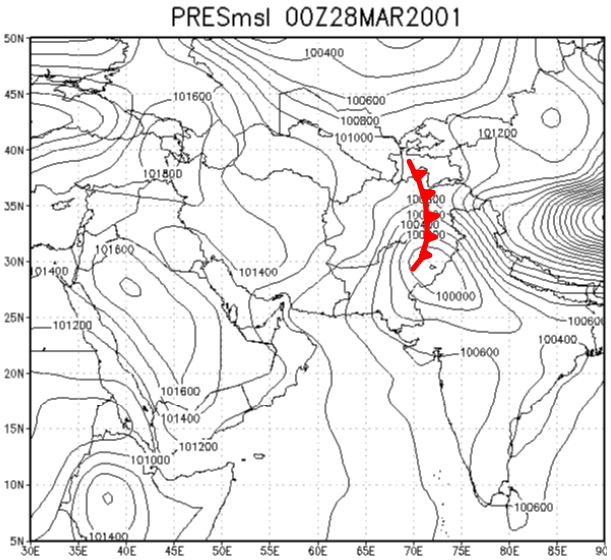

Figure 2: Surface Chart 28th March, 2001

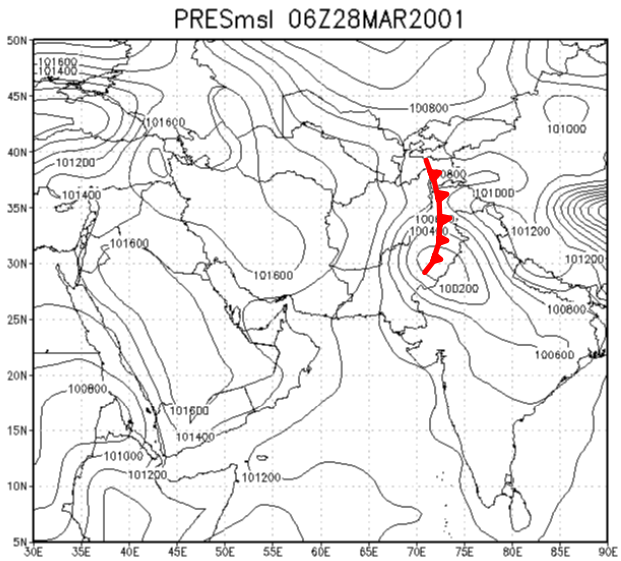

Figure 1: Surface Chart 28th March, 2001

Surface chart of 0600 UTC

At surface chart of 0600 UTC, the system persisted over the area. The pressure gradient persisted towards west of the system. Dry and cold continental air penetrated southwards from the west of the system and picked up moisture from Arabian Sea.

Surface chart of 0900 UTC

The well marked low over central parts of Punjab was clearly evident on the surface chart of 0900 UTC. A number of stations in northern areas of the country showed rain and thunderstorm activity. Strong pressure gradient was seen northwestwards of the system. Cold air ridge was penetrating into northwestern parts of the country. A southerly trend of the isobars from the west of the system was clearly seen on the chart, dipping into the Arabian Sea and picking up moisture to the system from there.

At 850 hpa level chart of 0000 UTC of March 28, 2001, the well marked low on the surface level was clearly evident on central areas of the Punjab and neighborhood. Dry continental air was penetrating

from the North to coastal areas of Balochistan and Sindh. Moisture incursion to this low pressure system was clearly evident from 850 hap level chart.

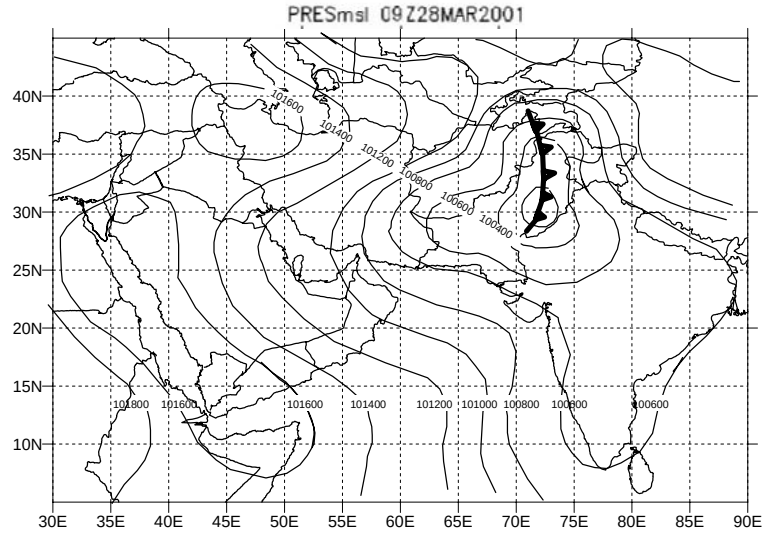

Figure 3: Surface Chart 28th March, 2001(0900 UTC)

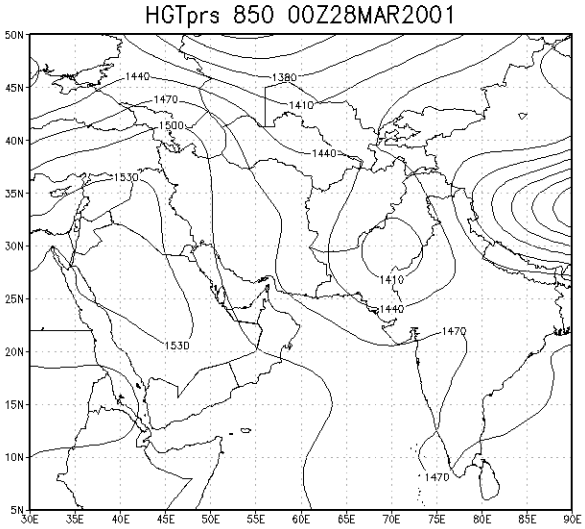

Figure 4: 850 hpa level chart March 28, 2001 (0000) UTC)

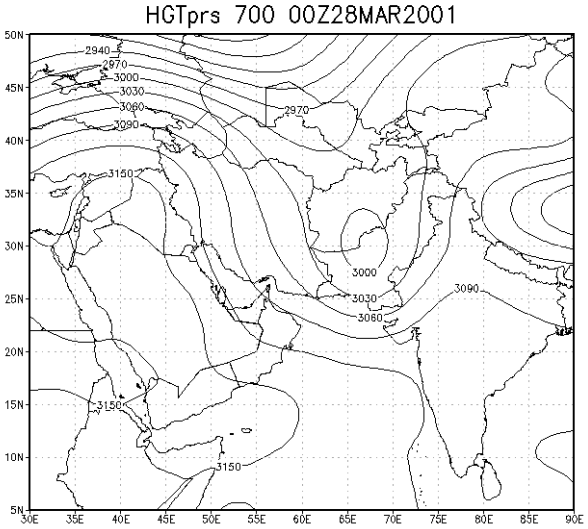

Figure 5: 850 hpa level chart March 28, 2001 (0000) UTC)

At 700 hpa level chart of 0000 UTC of March 28, 2001, the well marked low pressure at surface level was clearly evident at this level too. The low at this level was slightly shifted northwestwards over northeastern parts of Balochistan and adjoining Afghanistan. Cold air from north northwest was sweeping downwards towards coastal areas of the country and picking up moisture from Arabian Sea as evident from Fig -05.

At 500 hpa level of 0000 UTC of March 28, 2001, the surface level well marked low pressure was extended up to mid-tropospheric level. The low was shifted further northwestwards as compared to 700 hpa level chart. Contours from north northwest were sweeping downwards up to the coastal areas of the country as shown in Fig-06.

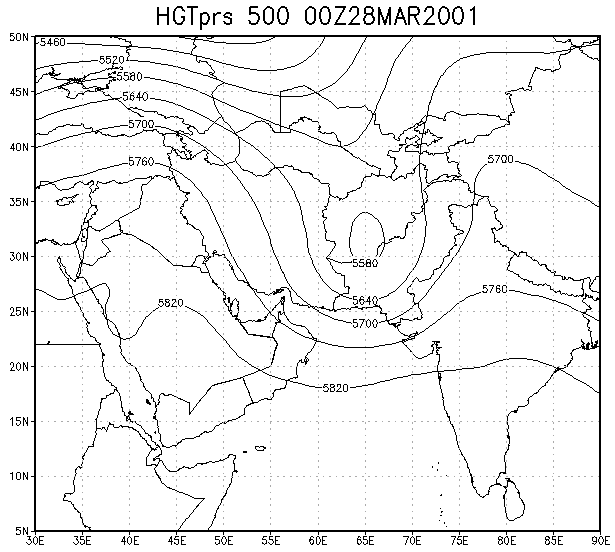

Figure 6: 500 hpa level chart March 28, 2001 (0000 UTC)

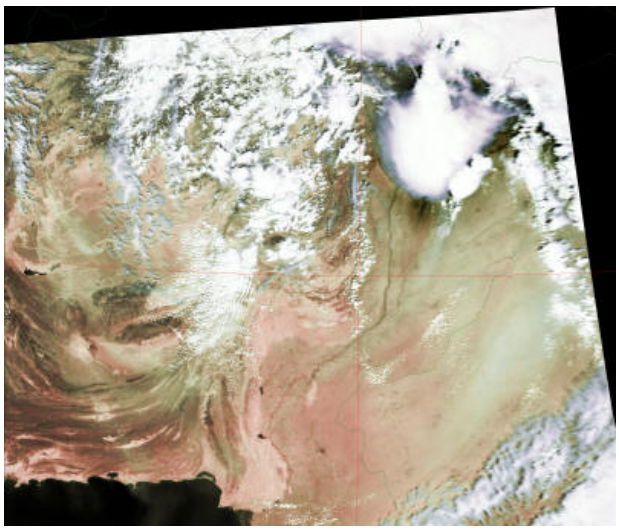

Figure 7: Satellite imagery (0938 UTC)

Right from surface to 18000 ft, charts depicted some what intense circulation over central Punjab with centre near Sargodha area that acted as a vortex of southwest relatively warm-moist currents and cold continental air from north-northwest. (Khan, A. H.). Consequently a squall line of thunderstorms developed. A number of stations in North Punjab and Upper NWFP including Lahore, Sargodha, Mianwali, Rawalpindi and Peshawar reported thundershowers in their respective synop messages of 0900 & 1200 UTC (Table-1). The vortex formation was further accentuated as the day progressed and moist atmosphere absorbed maximum energy. Vortex formation further intensified during afternoon as evident from the satellite imagery of 0938Z (Khan, A. H). A very thick cloud mass is visible between longitude 71° E to 74 ° E and latitude 32° N to 35° N over Sargodha and surrounding area, which indicate thunder storm activity over Sargodha and neighboring area (Fig-7).

Impact of the Tornado

Very heavy equipments and buildings were damaged by the Tornado. Steel electric poles were uprooted and some of them were found far away from their original position. This reflects that poles were carried away aloft quite high. Wind whirl pulled up heavy equipment like tractor trolleys and wheat thrasher showing the spinning motion of the air and thrown far away from their original locations. Loss of 10 lives with human and animal dead bodies and their dismembered parts were dispersed quite far off. Also injuries to more than 100 persons were reported due to flying debris. It is a clear indicator that the destruction was outcome of a tornado. (Khan, *A*

Forecasting of a Tornado

Even today's advanced radar technology and other sophisticated equipments, it is very difficult to forecast tornadoes, as they can form suddenly and unexpectedly. Being a small and short – lived phenomenon tornadoes are among the most difficult weather features to forecast precisely. A forecaster can make advance weather forecasts of weather conditions favorable for severe storms over a general area, but these predictions cannot give the exact time a severe storm will be at a definite point. Specific warnings can be made only after a storm is in progress and a report has been received on the type and location of the storm. The forecaster can then determine the direction of the path of the storm to a very accurate degree for the next few hours and warn people who may be affected. (Joseph G. Galway).

However Doppler radars can detect air movement towards or away from the radar. Early detection of increasing rotation aloft within a thunderstorm can allow life-saving warnings to be issued before the tornado forms. A tornado watch is issued when meteorological parameters favor tornado development. A severe thunderstorms watch is issued when meteorological parameters favor large hail and damaging thunderstorm wind gusts. The average watch is valid for approximately six hours and is a parallelogram that covers an area of approximately 59800 km2 (23000 n m2) (Richard W. Anthony and Preston W. Leftwich, Jr.) Besides having all that modern equipment and radar technology available, there are some environmental clues for a forecaster, which are as follows:

- Dark, often greenish sky
- Wall cloud
- Large hail
- Loud roar; similar to a freight train

Some tornadoes appear as a visible funnel extending only partially to the ground. Look for signs of debris below the visible funnel.

Some tornadoes are clearly visible while others are obscured by rain or nearby low-hanging clouds. There are some meteorological points which may be extremely helpful in forecasting of a tornado.

* There should be a cyclonic wind shear at surface level.
* At forecast time, pressure fall should be more than 6 hpa over that particular area.
* Narrow dew point ridge extends into area with dew point 13° C or higher.
* Sign of any lifting mechanism approaching e.g. Squall line, frontal system, thunderstorm area or precipitation area.
* Widespread heavy rain is unfavorable for tornado formation.
* Location of threat area within favorable region (SE quadrant) of cyclone – especially for family types of tornadoes.
* Large irregular 3 hourly pressure changes.
* Low level (850 hpa) moist southerly current of 30 knots or more into the area.
* Upper level (about 14000 ft.) westerly current of dry and cooler air into area.
* 700 hpa temperature advection pattern showing warm advection east of trough and cold advection to west of trough.
* Strong 500 hpa temperature gradient to west of area.
* Cold air pocket at 500 hpa to west of area.
* Upper level (500 or 300 hpa) trough to west of threat area deepening or accelerating toward area
* An approaching 300 hpa jet maxima. (Joseph G. Galway)

Time of the day, season and geographical location of threat area should also be taken into consideration by the forecaster.

Preparedness

Although tornadoes are not very common in Pakistan and people generally don't know what precautionary measures have to be adopted in case of an outbreak of tornado. Awareness of the capability of destruction of the tornado needs to be developed in general public through electronic and print media.

There are some precautionary measures taken into consideration in case of occurrence of any threatening weather.

Before the Storm

- Develop a severe weather plan for home, work, school and when outdoors.
- Know the area where you live, and keep a highway map nearby to follow storm movement from weather bulletins.
- Listen to radio and television for latest information.
- If planning a trip outdoors, listen to the latest forecasts and take necessary action if threatening weather is possible.

If Warning is Issued or If Threatening Weather Approaches

- Occasionally, tornadoes develop so rapidly that advance warning is not possible but however the amount of time between the issuance of a Tornado warning and the touchdown of a Tornado ranges from 12 minutes to 55 minutes, providing critical time for emergency message to sound from radio, television and tornado sirens(if available).
- In a home or building, move to a pre-designated shelter, such as a basement.
- If an underground shelter is not available, move to an interior room or hallway on the lowest floor and get under a sturdy piece of furniture.
- Stay away from windows and doors.
- Opening windows allows damaging winds to enter the structure. Close the windows and immediately go to a safe place.
- Get out of automobiles.
- Do not try to outrun a tornado in your car; instead, leave it immediately.
- Remain alert for signs of an approaching tornado. Flying debris from tornadoes causes most deaths and injuries.

With these measures taken we can mitigate the would-be losses and damages.

Conclusion

The synoptic conditions on the surface charts of 0000 UTC to 0900 UTC and upper air charts of 850 hpa, 700 hpa and 500 hpa level, satellite imagery of 0900 UTC were thoroughly investigated and found that synoptic situation as well as season and time of the formation of a tornado fulfill the criteria as mentioned under the caption “forecasting of a tornado”. Tornadoes are not very common in Pakistan, hence the level of its preparedness is insufficient and the March 28 Tornado resulted in substantial casualties. Most people were and are still not aware of what to do in the event of Tornado. With the recent introduction and operational use of various Numerical Weather Prediction models in PMD, the capacity of forecasting & warning system has been enhanced, especially for major events. The preparedness program still need improvement, the collaboration between public and private sector institution can provide excellent warning and information to the

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Table 1: Significant weather on March 28, 2001

Hour/ Station	Pressure MSL (hPa)	Temperature (°C)				Relative Humidity %	Clouds (Oktas)			Progressive total since 0300 hours GMT (mm)	Wind		Weather	
		Dry Bulb	Wet Bulb	Max.	Dew point		Type and amount	Type and amount	Total amount		Direction	Speed (Kts)	Past weather	Present weather
Lahore AP														
0900Z	999.9	29.0	22.5	---	19.1	55	SCCU4	---	4	Trace	E	12	96	5
1200Z	999.3	27.0	21.5	30.0	18.5	60	SCCU3	AC1	4	Trace	E	15	611	5
Sargodha														
0900Z	999.2	29.0	22.0	---	18.9	52	SC2	AC5	7	0.0	NE	5	1	4
1200Z	998.8	24.0	17.0	---	11.7	46	CBTRSC3	AC5	7	0.0	N	10	9	4
Mianwali														
0900Z	1002.9	20.0	17.0	---	14.9	73	CB1SC4	ACAS7	7	7.0	NE	12	9	95
1200Z	1000.3	20.0	16.0	23.5	13.0	64	SCCU3	AC5	7	14.0	N	16	9	2
Peshawar														
0900Z	1005.5	16.5	14.5	---	13.5	80	CBTSCCU	AC4	7	20.0	NE	6	9	4
1200Z	1005.0	15.5	14.5	30.5	13.2	89	CB1SCCU4	ACAS7	7	21	SE	10	96	99
Islamabad														
0900Z	1001.2	24.2	16.7	---	11.1	---	CBTSCCU	AC5	7	0.0	NW	16	---	---
1200Z	1001.9	17.8	13.3	33.8	9.4	59	CB1SC4	ACAS7	8	3.0	W	40	17	99