TORNADIC STORMS OF 2008 OVER BANGLADESH: OBSERVED BY RADAR AND SIMULATED BY USING WRF-ARW MODEL

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I. INTRODUCTION

Bangladesh is prone to severe thunderstorms of tornadic intensity due to its geophysical location. In this study the tornadic storms are studied based on field survey, ground and radar observations. Low level moisture influx by southerly flow from the Bay of Bengal coupled with upper level westerly jet stream causing intense instability and shear in the wind fields triggered a series of storms for two weeks during 30 August to 14 September in 2008 . The exact time and locations of the storms are investigated by using the hourly precipitation data retrieved from an S-band radar of BMD located at Dhaka. Subsequently, the storms are simulated by using the WRF-ARW model at 2 km horizontal resolution based on 6 hourly NCEP-FNL data. Past studies of tornadoes over the India and Bangladesh region (Das *et al.*, 2006; Karmakar, 2001) indicated that a horizontal vortex sheet is created by the presence of horizontal and vertical wind shear in association with low/ middle level wind core.

II. PRESENTATION OF RESEARCH

Several tornados were reported in the Northwestern parts of Bangladesh during 27 August to 14 September 2008 by news media. On 30 August, a tornado lashed about 300 houses in Nilphamari and Kurigram districts affecting 300 families at 2100 LST (1500 UTC) according to media reports. On 03 September, a tornado hit Nilphamari region again in the night time. On 14 September, a tornado lashed 10 villages, destroying about 200 houses and uprooting hundreds of trees in Thakurgaon region at 1400 LST (0800 UTC), and lasted several minutes. However, there was no proof of a visible vortex wind or funnel shaped cloud in any of the cases, which may be mainly due to the lack of awareness and availability of appropriate camera among the poor villagers. Finch (http://bangladeshtornadoes.org) has made a detailed documentation of the tornadoes of Bangladesh. Several factors lead to the active thunderstorm season across Bengal. North and central India heats up and dries out in late March or early April. A deep, dry mixed layer develops. Low level flow from the Bay of Bengal increases markedly during this time. Westerly mid-level flow around the Tibetan Plateau advects the Indian mixed layer over the Bengal moist tongue. This leads to the Elevated Mixed Layer (EML). It may be noted that parts of the East Indian plateau are 'elevated' (1-3000 ft) compared to Bangladesh which is near sea level. The mid level flow is fairly strong in April with 30-50 kt (~15-25 ms^{-1}) speed at 700 hPa and 35 to 50 kt (~18-25 ms^{-1}) at 500 hPa. The high level jet is usually over or just north of Bengal in April.

The large-scale synoptic conditions at 500 and 850 hPa during the days of tornadic events were seen. A feeble trough existed over north of Bangladesh at 500 hPa. At lower level 850 hPa, the flow was southerly or south-westerly feeding moisture from the Bay of Bengal over Bangladesh. The low level moisture incursion in the zone of convergence coupled with upper level trough made conditions conducive for development of severe thunderstorms over the region.

In this study, the radar data is converted into precipitation rates for each cases of tornadic events based on the algorithm described in Islam *et al.* (2005).

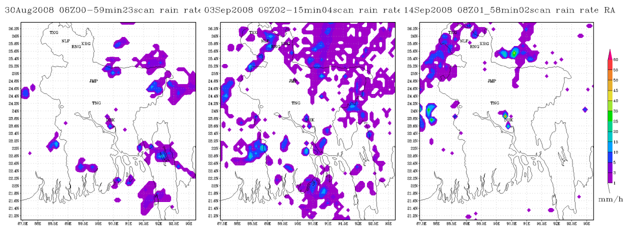

FIG. 1: Precipitation rates (mm/h) derived from the S-band radar.

The precipitation rates observed by radar on 30 August 2008 are depicted in FIG. 1. The maximum precipitation rates observed by radar were in the range of 25-35 mmh^{-1}. The exact rain rate is about 4 times the radar detected values (Islam *et al.*, 2005). Therefore, actual rain rates may exceed 100 mmh^{-1}.

A line of convective cells developed over the northwestern parts of Bangladesh around 06 UTC on 03 September. The convective band gradually organized and intensified like squall line and moved from the northwest to southeast direction.

14 September 2008, in the evening hours the convection occurred mainly in the central and southeastern parts of the country. The radar picture indicated that a convective cloud band passed over the Thakurgaon region at around 8-9 UTC. But the intensity of precipitation rate was very less.

The WRF-ARW Model has been implemented here in this paper in order to simulate the tornadic events. For the purpose of simulating the tornadoes the model was run at 2 km horizontal resolutions with 27 vertical levels using initial and boundary conditions obtained from NCEP-FNL datasets.

III. RESULTS AND CONCLUSIONS

We investigated many simulated characteristics of the 3 tornadic events such as the CAPE, surface wind speed, flow patterns, T-Φ gram, rainfall, Storm-relative Environment Helicity (SREH), Bulk Richardson Number

Shear (BRNSHR), potential vorticity and vertical velocity. Hourly variations of these parameters were studied over the Northwest part of Bangladesh. Table-1 presents a summary of these parameters.

	30 Aug	03 Sep	14 Sep
Observed Time of Tornadoes (UTC)	1500	~0900	0800
Best estimate Time from Radar (UTC)	1400 - 1800	0800 - 1000	0700 - 0900
Max. Temp. (^{0}C)	32.7	34.0	34.6
CAPE (Jkg^{-1})	2975	3688	2902
Wind Speed (ms^{-1})	7.9	9.0	10.0
Rainfall (mmh^{-1})	<10	<10	<10
SREH (m^{2}s^{-2})	1088	776	122
BRNSHR	224	147	66
Potential Vorticity	24 (500 hPa)	04 (350 hPa)	10 (750 hPa)
Vert. Vel. (ms^{-1})	160 (300 hPa)	160 (900 hPa)	40 (950 hPa)

TABLE I: Observed and Simulated Diagnostics by the WRF-ARW Model.

FIG. 2 presents hourly time evolution of SREH obtained from the model simulations of the 3 events. The diagrams indicate that the SREH values reached maximum in the evening hours on 30 August and 03 September 2008, whereas they reached maximum in the morning hours on 14 September 2008. At most of the time the SREH values were higher than the threshold value (150 m^{2}s^{-2}) for the formation of weak tornadoes in all the 3 events.

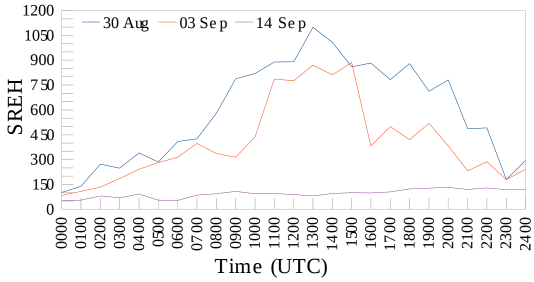

FIG. 2: Time series of SREH (m^{2}s^{-2}) on 30 August, 3 September and 14 September 2008.

In thunderstorm forecasting, CAPE is used to define the region in which convection is possible, SREH is used to define the region in which thunderstorms are likely to be supercells, and BRNSHR is used to define the region in which low-level mesocyclogenesis is more likely. These results highlight the potential value of analyzing various severe weather parameters in forecasting tornadic thunderstorms. By combining the storm characteristics suggested by these parameters, it is possible to use mesoscale model output to infer the dominant mode of severe convection. There are many other parameters that should be used in forecasting severe-weather threat (Johns and Doswell, 1992; Thompson, 1998). But we have focused here on these three parameters CAPE, SREH and BRNSHR for simplicity. It should be recognized that there remains great uncertainty in, and debate about, the best parameters to use for forecasting tornadoes. FIG. 3 depicts the combined graphics of the three fields of CAPE (> 2000 Jkg^{-1} in black contours), SREH (> 200 m^{2}s^{-2} in blue contours) and BRNSHR (> 40 m^{2}s^{-2} in green contours). It highlights areas in which all the three fields are in the ranges that are favourable for low-level mesocyclones in all the three cases of tornadic storms.

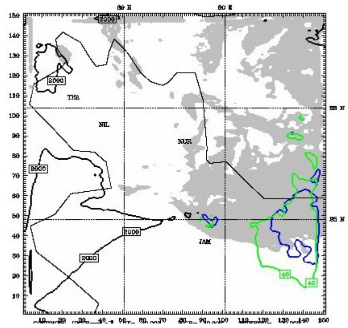

FIG. 3: CAPE (black contours), SREH (blue contours), BRNSHR (green contours) as simulated by the model for 12 UTC, 30 August 2008 and Rainfall (>0.25 mm) are shaded.

This study is the first attempt to simulate tornadic storms over Bangladesh by using the WRF model at 2 km horizontal resolution. Results have provided many interesting findings, but also indicated many weaknesses in our present understanding and capability to forecast the tornadic storms with sufficient lead time and accuracy. There is a severe scarcity of data to understand the observational characteristics of the tornadoes in this region. Such data will have to be supplemented by intensive field observations. The modeling studies will have to be carried out at much higher resolution (few hundred meters) considering the scale of such storms. Many sensitivity studies with the physical processes need to be carried out to unravel the dynamical and physical mechanisms of the tornadogenesis and intensification of the updraft vortex in this region.

IV. ACKNOWLEDGMENTS

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