Some associated features of Severe Thunderstorms in Bangladesh extracted from conventional method and numerical modelling

Presenter: Md. Abdul Mannan, BMD

Collaboration with: Arjumand Habib, Md. Shah Alam and S. M. Quamrul Hassan
Contents of presentation

- Vulnerability of Bangladesh in context of Severe Thunderstorm and Tornado
- Synoptic or conventional analysis of a Severe Thunderstorm in Bangladesh
- Simulation of a Severe Thunderstorm using WRF model
- Simulation of a Severe Thunderstorm using MM5 model
- Conclusion
Tornado occurring areas in the world
# Ten deadliest tornadoes

<table>
<thead>
<tr>
<th>Death Toll</th>
<th>Event</th>
<th>Location</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,300</td>
<td>The Saturia-Manikganj Sadar Tornado</td>
<td>Bangladesh (Manikganj)</td>
<td>1989</td>
</tr>
<tr>
<td>923</td>
<td>1969 East Pakistan Tornado</td>
<td>Bangladesh</td>
<td>1969</td>
</tr>
<tr>
<td>695</td>
<td>The Tri-State Tornado</td>
<td>United States (Missouri–Illinois–Indiana)</td>
<td>March 18, 1925</td>
</tr>
<tr>
<td>681</td>
<td>1973 Dhaka Tornado</td>
<td>Bangladesh</td>
<td>1973</td>
</tr>
<tr>
<td>600</td>
<td>The Malta Tornado</td>
<td>Malta</td>
<td>1551</td>
</tr>
<tr>
<td>500</td>
<td>The Sicily Tornado</td>
<td>Italy</td>
<td>1851</td>
</tr>
<tr>
<td>500</td>
<td>The Narail-Magura Tornadoes</td>
<td>Bangladesh (Jessore)</td>
<td>1964</td>
</tr>
<tr>
<td>500</td>
<td>The Comoro Tornado</td>
<td>Comoro</td>
<td>1951</td>
</tr>
<tr>
<td>440</td>
<td>The Tangail Tornado</td>
<td>Bangladesh</td>
<td>1996</td>
</tr>
<tr>
<td>400</td>
<td>Ivanovo, Yaroslavl Tornado</td>
<td>Russia</td>
<td>1984</td>
</tr>
</tbody>
</table>
A tornado is defined as a violently rotating column of air extending from a thunderstorm to the ground. The most violent tornadoes are capable of tremendous destruction with wind speeds of 250 mph or more. Damage paths can be in excess of one mile wide and 50 miles long. 800 tornadoes are reported/Yr in USA.
Life stages: A sequence of images showing the birth of a tornado.

- First, the rotating cloud base lowers.
- This lowering becomes a funnel, which continues descending while winds build near the surface, kicking up dust and other debris.
- Finally, the visible funnel extends to the ground, and the tornado begins causing major damage.
STAGES OF THUNDERSTORM

Cumulus
Mature
Dissipating
Types of Nor’wester associated with Severe Thunderstorm

**TYPE “A”**

Develop over WB in the afternoon/late evening, speed 48-64 kph. 70-80% are of this type.

**TYPE “B”**

Sub mountainous districts of North Bengal during Night/EM, speed 16-32 kph. 10% are of this type.

**TYPE “C”**

Hills of N/L, Manipur & Mizoram, they are very rare.

**TYPE “D”**

Similar to “B”, but originate near Khashi hills & moves from N to S. 5% are of this type.
In March about 42% severe thunderstorms are associated with northwesterly wind.

14% are associated with westerly wind.

13% are associated with northerly or southwesterly winds.

10% are associated with northeasterly wind.

There is no record of severe thunderstorms associated with easterly wind during this month.

Fig: Distribution of Wind direction in March
In April about 40% severe thunderstorms are associated with northwesterly wind,

21% severe thunderstorms are associated with westerly wind.

17% severe thunderstorms are associated with northerly wind and

7% and 9% are associated with northeasterly and southwesterly winds respectively.

Severe thunderstorms associated with easterly, southeasterly or southwesterly winds are very rare during this month.

Fig: Distribution of Wind direction in April
In May about 37% thunderstorms are associated with northwesterly.

21% thunderstorms are associated with westerly and

17% severe thunderstorms are associated with northerly wind respectively.

The percentages of contribution of northeasterly and southwesterly winds are 8% and 7% respectively.

Severe thunderstorms associated with easterly, southeasterly or southerly winds are very rare wind during this month.

Fig: Distribution of Wind direction in May
HAIL
Causes of Severe thunderstorms

- A lower level warm & moist layer of air extending from surface to 5000-7000 ft.
- An upper level cold & dry layer of air.
- One or more of the following triggering actions:
  - Insolation
  - Inflow of moist wind from Bay
  - Eastward passage of Western Disturbance
FORMATION MECHANISM OF NOR’WESTER

- A low pressure over WB & Bihar during months of March to May.
- Moist air from surface to 7,000 ft.
- Cold & dry air within 20 to 30,000 ft.
- Inversion layer between 10 to 15000 ft.
FORMATION OF A TORNADO
TORNADO GETTING STRENGTH OVER WATER BODIES

WIND GETS TWISTED

DRAWING DEBRIS OVER GROUND
Severe thunderstorm in Bangladesh: 06May 2009

Severe thunderstorm in Bangladesh: 15May 2009
Synoptic analysis of severe thunderstorm
Synoptic analysis

In this method the following meteorological parameters are carefully analyzed in each synoptic observation time based on the surface synoptic and upper air observation over the area of Bangladesh and its surroundings:

- Surface pressure, temperature, relative humidity, dew point temperature fields
- Pressure change fields, temperature change fields during 24 hours and its lower time intervals;
- Pressure departure fields, temperature departure fields from the normal values
- Upper air temperature, humidity and wind field are analyzed based on the pilot balloon observation and Rawin Sonde observational data in each observational period.
- The stability indices like SI, LI etc. are calculated for understanding the instability conditions of the troposphere.
Observed meteorological features

a. surface and lower troposphere

- Existence of a trough of low pressure over Uttar Pradesh and Bihar with its axis extending West-East direction across the plains.
- The orientation of the axis and its intensity are affected by the passage of Western Disturbances in the form of low pressure area. In such a situation the accentuated axis of trough extends SE-wards into Gangetic West Bengal and Bangladesh.
- Around the trough SW/S’ly wind normally blows from the Bay of Bengal upto a level of about 3000ft. (1Km) incurring moisture influx over the region covering Bangladesh, West Bengal and Assam.
- Quite often through northeast Assam, ENE/NE’ly dry and cooler wind descends downwards to the West across the foot of the Himalayas.
- In such a situation with the existence of ENE/E’ly wind over extreme north Assam and SW/S’ly wind from the South, East-West line of wind discontinuity takes place over north Bangladesh and upper Assam.
b. Upper troposphere

- In the upper troposphere, westerlies or northwesterlies prevailed over Pakistan, North Indian Plains, Bangladesh and Assam.
- The passage of upper air trough in the westerlies or the jet can often be detected at 30,000ft to 40,000ft (about 9.0 to 12.0 km) levels.
- The superposition of upper divergence having association with a perturbation like a jet, jet-cum-trough or trough on the convergence having association with a low-level ‘low’ or even straight southerly flow upto 3000ft. (1 km) is quite a significant feature on the days of nor’westers over this area.
Forecasting Technique for severe thunderstorm

The area over which nor’westers occur varies usually from one day to the other mostly depending on the synoptic situation at the surface and upper level. Identification of this area with positive threat of the storms is one of the most difficult problems for the forecasters.

To observe the basic favourable conditions being fulfilled, a forecaster within a short span of time has to adopt certain quick techniques to make a decision about the occurrence or non-occurrence of nor’westers. These are:

- determine the stability indices;
- locate the dynamic heat low over the vulnerable area like north Orissa, Bihar, Gangetic West Bengal or southwestern part of Bangladesh;
- find out the middle and upper-level jet shear;
- see whether the positive area in greater than the negative area in the thermodynamic chart
- find out the 12 hour surface pressure fall;
- see the low-level moisture influx upto at least 3000ft from the pilot balloon chart
- locate the area of low-level convergence from the pilot balloon charts and carefully interpret and follow the radar echoes observed by BMD radars
- interpret the satellite observation received by satellite receiving systems of BMD
Gaps and needs

- Occurrence time of thunderstorm is not forecasted precisely
- Occurrence area of thunderstorm is not forecasted precisely
- Duration of thunderstorm is not forecasted
- Possibility of thunderstorm is not well informed to the public due to updated communication.
- People’s awareness is not in satisfactory level.
- Research on thunderstorms or severe thunderstorm related to tornado in Bangladesh is very limited.
A case study: 03 May 2009
Recorded wind on 03 May 2009

Recorded rainfall (mm) On 03 May 2009
Stability indices:

01 May 2009:
  a. SI: + 8.6
  b. LI: + 7.6

02 May 2009:
  SI: - 4.9
  LI: -5.9

03 May 2009:
  SI: -6.6
  LI: -3.2
Maximum temperature field:
On 03 May maximum temperature gradient was higher.

Minimum temperature field:
On 03 May uniform minimum temperature gradient was across northwest to northeast over the country.
WRF model Set up

- WRF V3.1 MODEL
- May03_09_18hrs
- Point in x-direction: 219
- Lon: 87.68513- 94.12687ºE
- Points in y-direction: 243
- Lat: 20.74589- 27.27317ºN
- Vertical levels: 27
- Considered output: 60m
- No. of Variables: 97
- Centered location: Lat: 24.05ºN & Lon: 90.91ºE
- Resolution: 3 km

Domain Area
Simulated TF(2m) using WRF model: 03 May 2009
Simulated TF(2m) using WRF model: 03 May 2009
Simulated olr (W/m²) using WRF model: 03 May 2009
Simulated olr (W/m²) using WRF model: 03 May 2009
Model Predicted rainfall: 03 May 2009
Model Description

The 5th generation PSU/NCAR mesoscale model (MM5) is a limited-area,

- Non-hydrostatic and terrain-following sigma-coordinate model designed to simulate or predict mesoscale & regional scale atmospheric circulation.

- Two way nested domains i.e. coarse domain (D1) of ~9 km resolutions and fine domain (D2) of ~3 km resolutions with grid cells 57x57 and 93x93 and have been prepared using MM5.

- These domains have covered the areas 18.670-27.6721°N; 84.75-94.8875°E for coarse grid mesh and 21.760-26.674°N; 87.420-92.901E for fine grid mesh.

- The topography in the model has been obtained from six resolutions (1°, 30, 10, 5 and 2 minutes, and 30 seconds) USGS (United States Geological Survey) land cover data set.

- At the boundaries of the coarse domain, 1x1 degree resolution NCEP data have been provided at every 6 hrs as input.
The model has then been run using the Grell or Anthes-Kuo (Anthes, 1977) option for cumulus parameterization and MRF for the boundary layer parameterization (Hong and Pan, 1996).

The simple ice scheme of Dudhia (Dudhia, 1996) is employed for explicit treatment of moisture and water vapor. Cloud radiation interaction is allowed for radiation anticipation. Five layer soil option is used for soil temperature. The model is run with 22 sigma levels in the vertical from the ground to the 100 hPa top surface.

The time frames of simulation for five cases in this study are

- 0000 UTC of 21 April to 0000 UTC of 23 April 2007;

Precipitation outputs of MM5 have been generated at 30 minute intervals and processed using Grid Analysis and Display system (GrADS) software for visual and calculation purpose.
Simulated PF using MM5 model: 21-22 April 2007

21 May_0300UTC  21 May_0600UTC  21 May_0900UTC  21 May_1200UTC

21 May_1500UTC  21 May_1800UTC  21 May_2100UTC  22 May_0000UTC
Simulated PF using MM5 model: 21-22 April 2007
Simulated TF using MM5 model: 21-23 April 2007
Simulated TF using MM5 model: 21-23 April 2007
Simulated WF using MM5 model: 21-23 April 2007
Simulated WF using MM5 model: 21-23 April 2007
Conclusion

- Meteorology is a relatively young science and the study of tornadoes is newer still. Although researched for about 140 years and intensively for around 60 years, there are still aspects of tornadoes which remain a mystery.
- Scientists have a fairly good understanding of the development of thunderstorms and mesocyclones, and the meteorological conditions conducive to their formation.
- Reliably predicting tornado intensity and longevity remains a problem, as do details affecting characteristics of a tornado during its life cycle and tornadolysis.
- Scientists still do not know the exact mechanisms by which most tornadoes form, and occasional tornadoes still strike without a tornado warning being issued.
- Numerical modeling also provides new insights as observations and new discoveries are integrated into our physical understanding and then tested in computer simulations which validate new notions as well as produce entirely new theoretical findings, many of which are otherwise unattainable.
- Importantly, development of new observation technologies and installation of finer spatial and temporal resolution observation networks have aided increased understanding and better predictions.
- Therefore more active research are very much essential.
Thank You for Listening