# IMPACT OF DOPPLER WEATHER RADAR RADIAL WINDS REFLECTIVITY AND CUMULUS PHYSICS ON THE PREDICTIONS OF SQUALLS OVER BANGLADESH


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## 1. Introduction

Modern radars are important equipments for nowcasting Local Severe Storms which appear in the form of Nor'westers or 'Kal Baisakhis' in Bangladesh and eastern region of India during pre-monsoon season (March to May). These systems develop mainly due to merging of cold dry northwesterly winds aloft and southerly low level warm moist winds from the Bay of Bengal. The Three Dimensional Variational (3DVAR) data assimilation approach is one of the most promising techniques available to directly assimilate heterogeneous mesoscale observations in order to improve the estimate of the model's initial state. In this study, Doppler Weather Radar (DWR) observations (radial winds and reflectivity) of Bangladesh Meteorological Department (BMD) are used during 11 May, 19 May, 21 May and 23 May 2011 squall events in order to update the initial and boundary conditions through 3DVAR technique within the Weather Research Forecasting (WRF) modeling system. It indicates that NWP models are very important for obtaining guidelines for the prediction of local severe thunderstorms [1].

## 2. Data and Methodology

The WRF Model has been used over the study domain (Fig. 1). The model is run at 3 km resolution with 27 vertical levels by using 6 hourly NCEP-FNL Data (1°x1°) as IC/BC. GTS and non-GTS data (AWS), BMD Khepupara and Cox'sbazar DWR derived radial wind and reflectivity data are utilized in the Experiments through 3DVAR techniques. Kain-Fritsch (KF) and Grell-Devenyi (GD) ensemble cumulus scheme have been used in the model run. Realized weather phenomena over Bangladesh during May 2011 shown in Table 1.

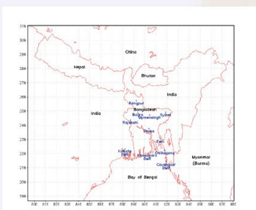



Fig. 1: Model domain under study.

Table 1. Squalls and gusty wind events during May 2011 in Bangladesh.

| Date | Reporting Stations | Events | Wind Speed (kph) | Wind Direction | Occurrence Time (UTC) |
|---|---|---|---|---|---|
| 01/05/11 | Rangpur | Squall | 66 | NW | 1530 |
| | Mymensingh | Squall | 56 | NW | 1900-2000 |
| | Sylhet | Squall | 44 | W | 2045-2056 |
| | Dhaka PBO | Gusty wind | 37 | NW | 2300 |
| | Dhaka MMO | Gusty wind | 48 | N | 2307 |
| 02/05/11 | Rangpur | Squall | 70 | NW | 2135-2137 |
| 04/05/11 | Chittagong | Gusty wind | 41 | W | 0907 |
| | Chittagong | Gusty wind | 52 | NW | 1000-1030 |
| 05/05/11 | Feni | Squall | 56 | S | 1300-1330 |
| 09/05/11 | Bogra | Squall | 111 | NW | 1030-1100 |
| | Dhaka | Gusty wind | 41 | W | 1330 |
| 10/05/11 | Dinajpur | Squall | 56 | NW | 1100- 1130 |
| | Dhaka | Gusty wind | 59 | W | 1535 |
| | Sylhet | Gusty wind | 56 | W | 1722-1723 |
| 11/05/11 | Rajshahi | Squall | 41 | W | 0300-0330 |
| | Dhaka | Gusty wind | 56 | W | 0542-0544 |
| | Chittagong | Squall | 70 | WNW | 0932-0934 |
| 12/05/11 | Rangpur | Squall | 63 | NW | 0130-0200 |
| 13/05/11 | Dhaka | Gusty wind | 56 | W | 1640 |
| | Chittagong MMO | Squall | 52 | NW | 2000-2030 |
| 14/05/11 | Bogra | Squall | 52 | NE | 2030-2100 |
| 17/05/11 | Dhaka | Gusty wind | 37 | N | 0802 |
| 18/05/11 | Ishurdi | Squall | 59 | NW | 2044-2045 |
| | Dhaka | Gusty wind | 56 | W | 2225 |
| | Patuakhali | Squall | 78 | NW | 2235-2240 |
| 19/05/11 | Chittagong MMO | Gusty wind | 56 | NW | 100 |
| | Chittagong PBO | Squall | 44 | NW | 0530-0600 |
| 20/05/11 | Chittagong PBO | Squall | 44 | NW | 2200-2230 |
| 21/05/11 | Dhaka MMO | Gusty wind | 74 | WNW | 1209 |
| | Dhaka PBO | Gusty wind | 67 | W | 1215 |
| | Faridpur | Gusty wind | 56 | NW | 1230 |
| | Patuakhali | Squall | 59 | NW | 1400 |
| | Chittagong MMO | Squall | 80 | N | 1500-1530 |
| 22/05/11 | Chittagong MMO | Squall | 56 | NW | 0950-0953 |
| 23/05/11 | Bogra | Squall | 45 | NW | 0130-0200 |
| 24/05/11 | Dhaka | Gusty wind | 56 | SW | 0800 |
| 25/05/11 | Dhaka | Gusty wind | 37 | NW | 0710 |
| | Chittagong | Gusty wind | 44 | N | 1230 |
| 31/05/11 | Chittagong | Gusty wind | 48 | W | 0950-1005 |

### 2.1 Model configuration

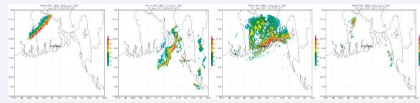
Configuration of the WRF-ARW Model used in the study is given at Table 2.

Table 2. WRF-ARW model configuration.

| Model Feature | Configuration |
|---|---|
| Horizontal spatial resolution | 3 km |
| Grid points | 629X461 |
| Vertical Levels | 27 |
| Topography | USGS |
| Dynamics | |
| Time Integration | Semi Implicit |
| Time Steps | 15 seconds |
| Vertical Differencing | Arakawa's Energy Conserving Scheme |
| Horizontal Diffusion | 2nd order over Quasi-pressure, surface, scale selective |
| Physics | |
| Cumulus parameterization | Kain-Fritsch scheme<br>Grell-Devenyi ensemble scheme |
| PBL | Mellor-Yamada-Janjic scheme |
| Surface Layer | Monin-Obukhov (Janjic Eta) sheme |
| Cloud Microphysics | Eta microphysics |
| Radiation | RRTM (LW), Dudhia (SW) |
| Land Surface Process | Unified Noah Land Surface Model |

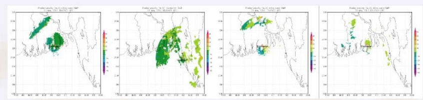
## 3. DWR derived reflectivity and radial wind analysis

BMD DWR recorded reflectivity of 45 dBZ (Fig. 2) and radial velocity between -45 to 50 m/s (Fig. 3). Study of Radar data showed that the Nor'westers propagate in the form of parallel bow shaped squall lines having horizontal length of more than 250 km at the time of squall.



(a) (b) (c) (d)

Fig. 2: DWR derived Reflectivity on (a) 11 May 2011 at 0503 UTC, (b) 19 May 2011 at 0059 UTC, (c) 21 May 2011 at 1203 UTC, and (d) 23 May 2011 at 0217 UTC.



(a) (b) (c) (d)

Fig. 3: DWR derived Radial wind on (a) 11 May 2011 at 0503 UTC, (b) 19 May 2011 at 0059 UTC, (c) 21 May 2011 at 1203 UTC, and (d) 23 May 2011 at 0217 UTC.

## 4. RESULTS AND DISCUSSION

### 4.1 Convective parameterization schemes (CPSs)

The first simulation used the Kain-Fritsch scheme (KF) and the second one used Grell-Devenyi (GD) ensemble parameterization. To compare the differences between the CPSs, simulations are performed for a particular time period utilizing the same IC/BC and other physical parameterizations for each CPSs and then model outputs are compared with observation. An attempt is made to examine 3 hourly accumulated rain with the comparison of TRMM 3B42RT (Fig. 4). Here KF scheme is comparatively better simulated than GD scheme and 3DVAR shows some improvement.

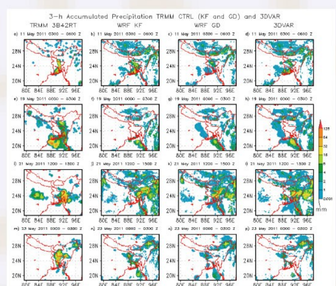



Fig. 4: 3 hrs accumulated precipitation (mm) patterns from TRMM, KF, GD and 3DVAR. Row: row-1: 11 May 2011(a-d), row-2: 19 May 2011(e-h), row-3: 21 May 2011(i-l) and row-4: 23 May 2011(m-p).

### 4.2 T- phi gram analysis:

T- phi grams of Dhaka are analyzed and instability indices are tabulated below (Table 3). 3DVAR results indicate minor improvement.

Table 3. Simulated stability indices over Dhaka at 0000 UTC of 11, 19, 21 and 23 May 2011

| Stability Indices | Thunderstorm Events | 11 May 2011 | 19 May 2011 | 21 May 2011 | 23 May 2011 |
|---|---|---|---|---|---|
| CAPE | Obs. | 688.01 | 10.65 | 1837.68 | 1475.31 |
| | CTRL | 1498 | 54 | 1064 | 1899 |
| | 3DVAR | 1451 | 154 | 1066 | 2050 |
| Lifted index (LI) | Obs. | -5.53 | -0.34 | -5.74 | -3.75 |
| | CTRL | -8 | 0 | -8 | -5 |
| | 3DVAR | -8 | -2 | -5 | -5 |
| K index (KI) | Obs. | 44 | 42.7 | 43.4 | 34.4 |
| | CTRL | 35 | 32 | 39 | 34 |
| | 3DVAR | 38 | 35 | 40 | 34 |
| Totals Totals Index (TTI) | Obs. | 57.7 | 47.8 | 48.9 | 42 |
| | CTRL | 52 | 42 | 50 | 43 |
| | 3DVAR | 53 | 47 | 50 | 43 |
| Precipitable water (mm) | Obs. | 58.81 | 71.87 | 73.74 | 61.74 |
| | CTRL | 33.4 | 46.7 | 40.7 | 37.7 |
| | 3DVAR | 33.8 | 46.8 | 43.1 | 37.9 |

### 4.3 Sea Level pressure (SLP) Time Series

SLP seems to be less than 1002 hPa (Fig. 5) over Dhaka due to existence of heat low during the pre-monsoon and 3DVAR showed the pressure drop and increasing tendency due to convection which is helpful for forecasting.

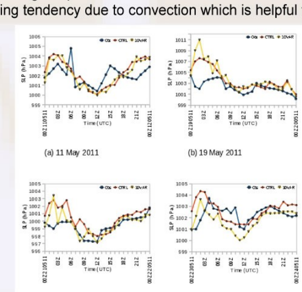



Fig. 5. Comparison of Sea Level Pressure (SLP) among obs, CTRL and 3DVAR (a) 11May 2011, (b) 19 May 2011, (c) 21 May 2011 and (d) 23 May 2011.

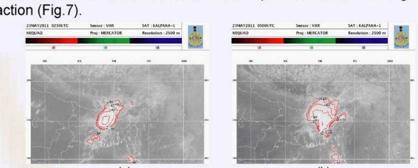
3DVAR shows improvements of predictions in three out of four cases (Table 4).

Table 4. Analysis of CTRL and 3DVAR SLP (hPa) with BMD observations using statistical methods.

| Statistical Analysis | CASES | CTRL | 3DVAR |
|---|---|---|---|
| RMSE | 11 May 2011 | 1.2 | 1.17 |
| | 19 May 2011 | 2.05 | 2.74 |
| | 21 May 2011 | 1.53 | 1.14 |
| | 23 May 2011 | 1.08 | 1.07 |

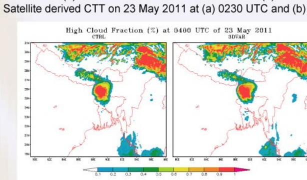
### 4.4 Satellite Derived Cloud Top Temperature (CTT) (°C) and model simulated high cloud fraction (%)

On 23 May 2011, moderate to strong convection was seen over northwest of Bangladesh by Kalpana-1 satellite imagery (CTT -60 °C) which was moving eastwards and expanded over northeast of Bangladesh (Fig. 6). Model simulated results showed some spatial shiftment of high cloud fraction (Fig.7).



(a) (b)

Fig. 6: Satellite derived CTT on 23 May 2011 at (a) 0230 UTC and (b) 0500 UTC.



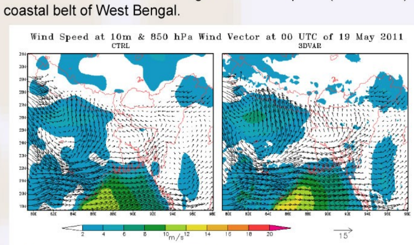

(a) (b)

Fig. 7: Simulated High cloud fraction on 23 May 2011 at 0400 UTC (a) CTRL and (b) 3DVAR run.

### 4.5 850 hPa Wind Vector and 10m Wind Speed analysis

850 hPa horizontal winds in the experimental forecasts are having higher gustiness over the region of the observed system compared to the CTRL forecasts. There is a strong trough at 850 hPa simulated by the 3DVAR; this is absent in the CTRL run (Fig. 8).

The 3DVAR run has simulated high 10m wind speed (12 -15 m/s) along the coastal belt of West Bengal.




(a) (b)

Fig. 8: Vector Wind at 850 hPa and 10 m wind speed (m/s) forecasts valid at 0000 UTC of 19May 2011 with (a) CTRL and (b) 3DVAR run.

## 5. Conclusion

The impact of data assimilation is clearly highlighted as the experimental simulations from the WRF-3DVAR are able to capture the thunderstorm closer to the observations compared to the CTRL run. The position and intensity of the simulated thunderstorms in the experimental runs is close to the observed values, as compared to the DWR derived products.

The thunderstorm event from the model simulation is best highlighted from the spatial distribution of 10 m wind speed and SLP. It is observed that the signature of the thunderstorm activity is well represented in the model generated CAPE. The 850 wind fields also reflects the system captured by the model simulations [2].

The model is still not able to accurately produce the exact location and time of occurrences of the thunderstorms. The genesis and growth of cells, their horizontal distribution, vertical structure, the direction and speed of their movement and time of dissipation are still some of the challenges that remained unresolved.


*Acknowledgements*

NCAR and NCEP of USA are gratefully acknowledged for making the WRF model and IC/BC data freely available to the research community.


## References


[1] Mohan K. Das, Someshwar Das , M. A. M. Chowdhury, Sujit Kumar Debsarma (2010): Simulation of a severe thunderstorm event using WRF-ARW model during the SAARC STORM Pilot field experiment 2009. 13th Asian Congress of Fluid Mechanics (*13acfm)-2010* (2): 733-736.

[2] Someshwar Das, R. Ashrit, M. W. Moncrieff (2006): Simulation of a Himalayan Cloudburst Event. *Journal of Earth System Science* 115 (3): 299-313.



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