Cyclone Aila Moisture Effects on Heavy Rain and Flooding in Bangladesh, Bhutan, NE-India and Nepal

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1. Introduction

If a cyclone moves towards highland having mountain enclave then due to orographic feature the circulation of the cyclone may be modified to deep convection which in turn may give out heavy precipitation and eventually it may cause flash flood.

Cyclone Aila-2009 was of moderate intensity it ravaged southwestern part of Bangladesh badly. Alongside it ravaged West Bengal of India, eastern Nepal and southern Bhutan. Due to torrential rain these four countries had flooding effects (Table 1). The occurrence of both a frontal and mesoscale flash flood pattern and the entrainment of tropical moisture from western Bay of Bengal (BoB) combined to produce the heavy rainfall.

2. Data and Methodology

Advanced Research WRF (ARW) Model with horizontal resolution of 9 km x 9 km, 50s time step and 27 vertical levels has been used to simulate the nature of cyclone Aila and its associated wind, rainfall etc. with two initial conditions of 24 May 2009 0000Z and 25 May 2009 0000Z. Six hourly Final Reanalysis (FNL) data of National Centers for Environmental Prediction (NCEP) were used as input to WRF-ARW Model for the simulation of cyclone Aila.

Hydro-dynamical storm surge model based on Indian Institute of Technology (IIT) Model [1] with air-bubble Entrainment is a vertically integrated semi-implicit model forward with time. The required meteorological and hydrological inputs are (1) three hourly storm centres of Cyclone Aila, (2) three hourly radii of maximum winds, (3) three hourly pressure drop and (4) topographic and bathymetric data (USGS ETOPO2). Domain of the Storm surge model is 18.0 - 23.0 °N, 83.5 - 94.5 °E with horizontal resolution of 3.7 km x 3.5 km, and time step of 60s. Generic Mapping Tool (GMT) is used for visualization of surge.

3. Severe Cyclonic Storm Aila and its associated Heavy Rainfall

Aila became a severe cyclonic storm for a short while and made landfall at its peak intensity (64 kts, 967 hPa) between 0600Z and 0700Z on 25 May 2009. A low pressure system developed and concentrated into a depression on 23 May 2009 over Bay of Bengal near 16.5 °N/ 88.0 °E (Figure 1). It intensified further with its centre at 15.0 °N/ 85.5 °E. It moved towards northerly direction and intensified into a deep depression and lay centred at 18.0 °N/ 88.5 °E on 24 May 2009. It further intensified into a cyclonic storm Aila, and lay centered near 18.5 °N/ 88.5 °E.

3.1 Satellite Derived Cloud Top Temperature (CTT) (°C)

Moderate to strong convection was seen over northwest Bay of Bengal by Kalpana-1 satellite imagery (CTT -70 °C) which was moving northeastwards and expanded over Bangladesh, Eastern Nepal and Bhutan (Figure 2).

4. Results and Discussion

Rainfall, maximum sustained wind, vorticity, central pressure and position of the tropical cyclone are extracted from the simulated outputs.

4.1 Rainfall Patterns

Model simulated rainfall is over estimated over hilly region like Bhutan and neighbourhood and also over West Bengal and Bangladesh except for Chittagong region where it was under estimated (Figure 3).

4.2 Relative vorticity at 10m

A ring of strong vortices is observed over northwest Bay and adjoining Gangetic West Bengal and Bangladesh coast at 0600Z 25 May 2009 (Figure 4a). Vorticity field moved more or less northwards with the movement of the cyclone and is distorted when the cyclone approached the hilly areas of Nepal, Bhutan and northeast India (Figure 4a-h).

4.3 Estimated Central Pressure (ECP) and Maximum Wind Speed

In the present study, satellite derived ECP and Maximum sustained wind (MSW) data of the cyclone Aila is taken from Colorado State University website (http://rammb.cira.colostate.edu/products/tc_realtime). Comparison of satellite observed and model ECP of cyclone Aila is shown in Figure 5. The simulated lowest ECP of Aila, before the landfall, is found to be about 974 hPa at 48 hour forecast. Satellite derived data shows that it has attained the lowest ECP of about 967 hPa before the landfall.

MSW is the driving force of generating storm surge over the area of landfall. The simulated highest MSW of Aila cyclone is about 30 m/s at 48 hour simulation. Satellite observed data shows that MSW is about 34.2 m/s at 0600Z on 25 May 2009. Comparison of satellite observed and model maximum wind speed of cyclone Aila is given at Figure 6. Model derived MSW is under estimated by 4.2 m/s.

4.4 Errors in Track Forecasting and 3DVAR Data Assimilation Impact

Cold start as well as warm start (0000Z of 25 May - 0000Z of 26 May 2009) was performed besides control (CTRL) run (0000Z of 24 May - 0000Z of 26 May 2009) of WRF model. Track obtained by warm start is found to be close to the observed one (Figure 7). Although the landfall point of the cyclone Aila obtained by warm start coincides with CTRL run [2], error in track position of CTRL run is higher than warm start and cold start runs. During landfall track error is found to be 66.6 km.

4.5 Storm Surge Simulation

Hiron Point of Bangladesh is the nearest place to the landfall point of the cyclone Aila-2009 where there is tide gauge of Bangladesh Inland Waterways Transport Authority (BIWTA). That is why, simulated surge height at Hiron Point is considered. Maximum surge height is attained between 1045Z and 1200Z of 25 May 2010 (Figure 8). 3-D and 2-D storm surge scenarios of Aila during landfall are shown in Figure 9(a) and Figure 9(b) respectively.

5. Summary and Conclusions

There is some spatio-temporal shift in rainfall.

Simulated lowest ECP, before the landfall is 7 hPa higher than observed or satellite derived observations and the maximum simulated wind is 4 m/s lower than the satellite estimated wind.

SYNOP, AWS and TEMP data of STORM Field Exp. 2009 and Khepupara DWR Radial Wind have been used in 3DVAR DA (Cold and Warm start).

Very high resolution topographic data is needed for making better predictions.

Acknowledgements

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References

[1] Dube, S. K., P. C. Singh, and G. D. Roy. 1986: Numerical simulation of storm surges in Bangladesh using multi-level model. *Int. J. for Num. Methods in Fluids* 6: 305-311.

[2] Mohanty, U.C., M. Mandal and S. Raman, 2004: Simulation of Orissa super cyclone (1999) using PSU/NCAR meoscale model, *Natural Hazards*, 31, 373-390.

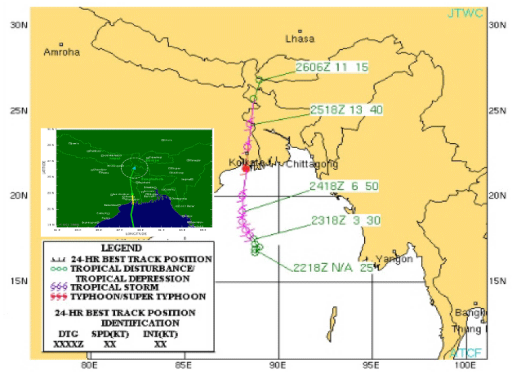


Figure 1: Observed track of Cyclone AILA-2009.

Table 1: Observed Rainfall of 0000Z 26 May 2009 to 0000Z of 27 May 2009.

Country	Stations	Rainfall (mm)
Bangladesh	Chittagong	133
Bhutan	Thimphu	72.5
India	Cherapunji	210
	Sriniketan	170
	Digha	140
	Shilong	120
Nepal	Biratnagar	120
	Dang	80
	Dharang	80

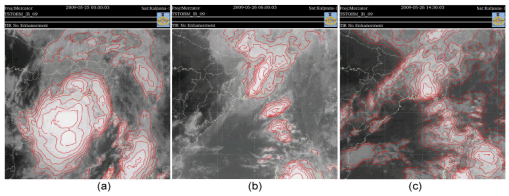


Figure 2: Observed CTT on (a) 25 May 2009 at 0000Z, (b) 26 May 2009 at 0600Z and (c) 26 May 2009 at 1430Z.

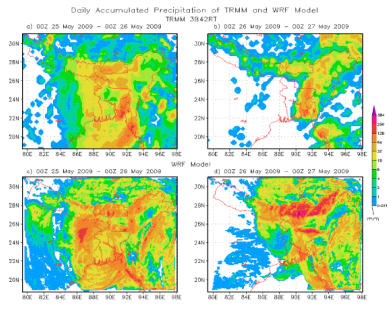


Figure 3: Comparison of daily accumulated rainfall wrf model simulated (c,d) and TRMM (a,b) during Aila Cyclone on 26 May 2009 (a,c) and 27 May 2009 (b,d).

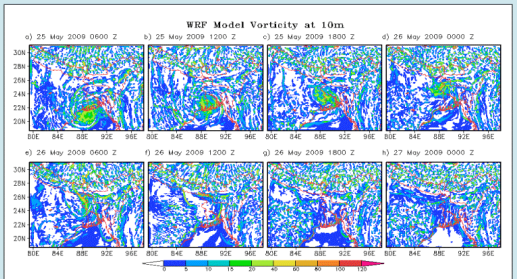


Figure 4: Relative vorticity (* 10-5 sec-1) at 10m simulated by the WRF model.

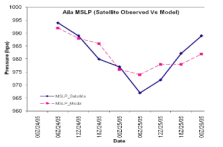


Figure 5: Comparison of satellite observed and model simulated ECP of cyclone Aila.

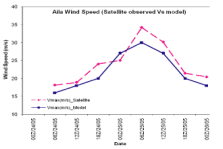


Figure 6: Comparison of satellite observed and model simulated maximum wind speed of cyclone Aila.

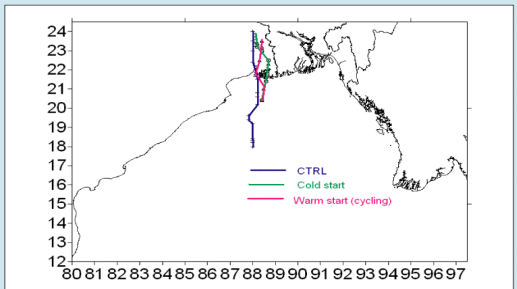


Figure 7: WRF Model Tracks (CTRL, Cold and Warm start).

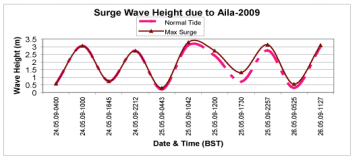
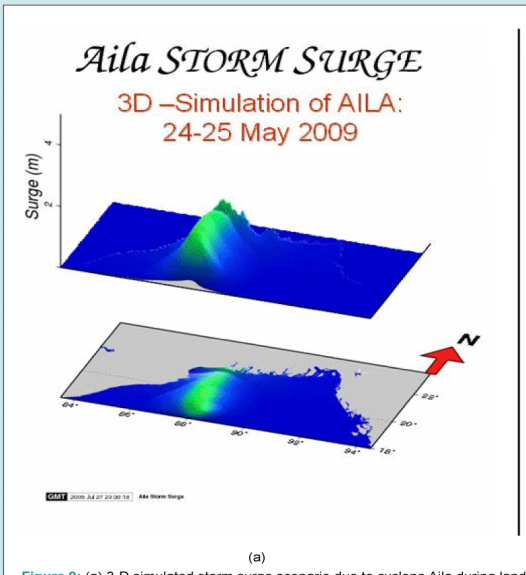


Figure 8: Storm surge wave height at Hiron Point, Bangladesh.



(a) (b)

Figure 9: (a) 3-D simulated storm surge scenario due to cyclone Aila during landfall, (b) 2-D simulated storm surge scenario due to cyclone Aila during landfall.