IMPROVEMENTS IN THE PREDICTION OF TROPICAL CYCLONES OVER BAY OF BENGAL USING FDDA AND VORTEX INITIALIZATION

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Efforts are continuously being made to improve the prediction of tropical cyclones, due to their devastating nature and socio-economic implications. Siginificant progress has been achieved due to advancements in computer science and technology and developments in atmospheric modelling for numerical weather predictio. At present, high resolution mesoscale models with non-hydrostatic dynamics are used with horizontal resolutions at 1-10 kilometers. Though the prediction errors are decreasing, the losses due to tropical cyclones are increasing because of increased use of coastal space for habitation and industrial purpose. This necessitated the need for further improvements in the precision of the prediction of tropical cyclones.

The predictions from numerical models are critically dependent on the quality of the initial state of the atmosphere. Since tropical cyclones form, develop and translate over ocean region till their landfall, direct observations were not possible. Major breakthroughs in NWP, more for tropical cyclones, came from increasing number of remotely sensed observations from satellites together with developments in data assimilation techniques. A specific problem related to tropical cyclone prediction is that the model initial state of the atmosphere, generally taken from global/ regional analyses, does not reflect the true state of the cyclone vortex. This prompted the researchers to plug in a “bogus vortex”, with defined characteristics as similar to the observed vortex. Despite all these, the model prediction drifts away from reality, as attributed to uncertainties in the initial conditions and errors from model dynamics and physics. In recent times, FDDA (Four dimensional data assimilation) is applied such that the dispersion of model prediction from the analysis and/or observations is restricted during the period of FDDA application.

In this paper an attempt was made to compare the model predictions, with and without bogus vortex in combination with/ without FDDA, of two recent intense tropical cyclone systems (SIDR and NARGIS) over Bay of Bengal. SIDR was graded as a very severe cyclonic storm, nominated as super cyclone at landfall time, and had the life cycle during 11-16 November 2007, with an attained intensity in terms of the minimum central sea level pressure (CSP) of 944 hPa and the maximum wind speed (MW) of 115 knots. This cyclone system had movement first as northwesterly, later northward and finally northeast direction, crossing west Bangladesh coast around 17 UTC of 15 December. Cyclone SIDR was the most powerful cyclone to impact Bangladesh since 1991, with the death toll at approximately 3,406 and with estimated total damage and losses to be US$1.6 billion. NARGIS was graded as a very severe cyclonic storm, had the life cycle during 27 April-03 May 2008, with an attained intensity in terms of the minimum central sea level pressure (CSP) of 962 hPa and the maximum wind speed (MW) of 90 knots. The system moved in an eastnortheasterly direction followed by easterly direction crossing the southwest coast of Myanmar between 1200 to 1400 UTC of 2 May near 16.N**.** NARGIS was the most devastating cyclonic storm over the north Indian Ocean in recent years in terms of loss of life and property, with 84000 human deaths, and a total loss of about US $ 4 billion.

Advanced Research WRF (Weather Research and Forecasting) model, developed and sourced from National Center for Atmospheric Research (NCAR), was used to make the numerical prediction experiments of the two cyclones under study. Numerical prediction experiments were conducted, with/ without bogus vortex and with/ without FDDA for the two cyclone systems taken up for study. The model was designed to have two-way interactive three nested domains of 81-27-9 km, with the innermost domain covering the path of the cyclone system. ARW model was integrated starting from 72 hours prior to the landfall time of the cyclone system to have a prediction of the landfall. The initial and time varying boundary conditions were taken from the NCEP GFS fields, available at 0.5 degree spatial resolution and 6-hour time interval. For all the experiments the parameterization schemes of physical processes were same. For the experiments with bogus vortex, a vortex designed with observed characteristics of central sea level pressure, maximum wind and radius of maximum wind at the corresponding times as available from India Meteorological Department (IMD) was ingested into the analyses. For the FDDA experiments, only analysis nudging was adapted as per the chosen FDDA time. For the experiments with bogus vortex and FDDA, bogus vortex was ingested at the initial time and at every 6-hour interval up to the end of FDDA period. The results from a total of eight experiments for each of the cyclone system were compared with IMD estimates for validation.

The results indicate that ingestion of bogus vortex is necessary to properly initialize the vortex at the initial time, without which the intensity of the vortex is underestimated, especially during the first 24-36 hours of integration. FDDA without bogus vortex leads to underestimation during the FDDA period, as the model is driven towards a lower intensity in the global analyses. However 6-hour FDDA helped to reduce model predicted track errors, as the model integration during the first 6-hours was subjected to analysis nudging. These results are not shown in this abstract. The results from experiments with bogus vortex and FDDA are shown in Figure 1. The results show significant improvements, both in terms of intensification and movement when FDDA is performed along with ingestion of bogus vortex. The experiments with FDDA for 24 hours, with ingested bogus vortex during the FDDA period, show consistent reduction of track errors together with better prediction of intensification. FDDA is noted to reduce the overestimation of intensification and also reduction of track errors by 50% in the 72-hour prediction period. Out of the two case studies, the results pertaining to SIDR were much better as compared to those of NARGIS. In both the cases, the FDDA affects to control the intensity, thereby leading to underestimation of intensity but after the period of FDDA, the prediction improves with the model predicted intensification and movement as of the observations. The general bias of numerical models overestimating the weaker systems and underestimating the stronger systems seems to be alleviated by the adopted strategy to some extent. Though the methodology does not completely rectify the deficiencies, the suggested strategy of combining FDDA and bogus vortex ingestion shows promise in real time prediction.

Track errors (km) for experiments with bogus vortex

(a) SIDR cyclone

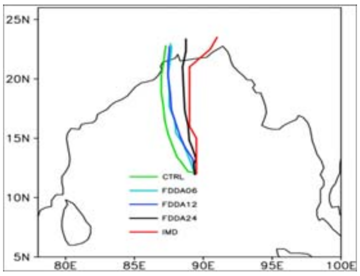
Hour	CTRL	FDDA12	FDDA24
0	25	25	25
6	70	14	14
12	121	31	31
18	157	40	26
24	193	97	52
30	232	130	61
36	208	112	13
42	238	175	96
48	272	209	181
54	244	191	177
60	212	177	150
66	369	331	216
72	421	396	252

(b) NARGIS cyclone

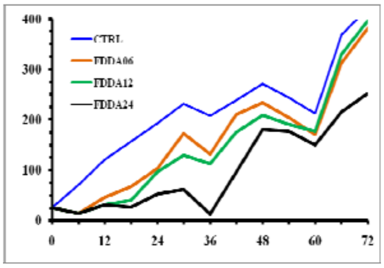
Hour	CTRL	FDDA12	FDDA24
0	34	34	34
6	101	58	58
12	112	28	28
18	67	23	35
24	50	49	29
30	139	51	116
36	199	121	111
42	235	202	138
48	298	279	204
54	358	346	271
60	434	439	348
66	495	509	423
72	639	656	476

Prediction for SIDR cyclone

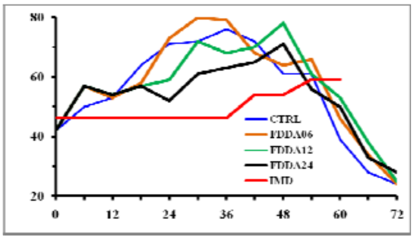
Track of cyclone



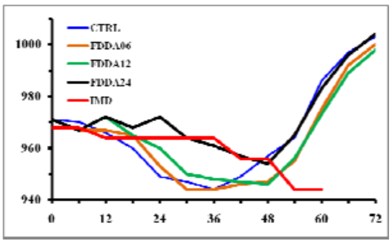
Vector track errors (km)



Central sea level pressure (hPa)

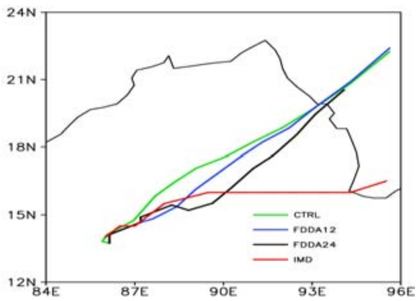


Maximum wind (m/s)

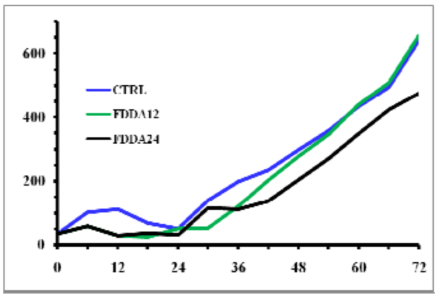


Prediction for NARGIS cyclone

Track of cyclone



Vector track errors (km)



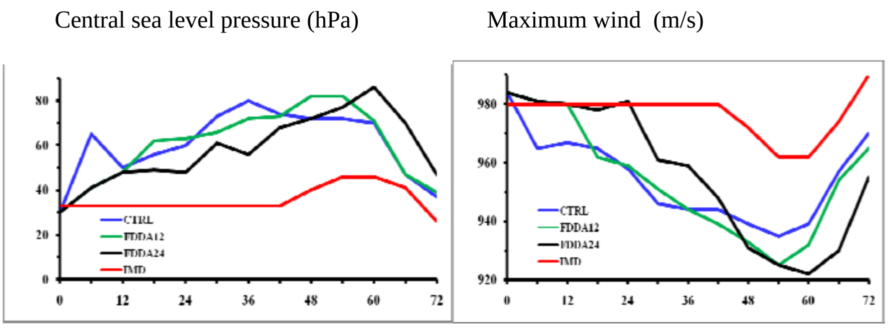


Figure 1. Model predicted results from experiments with bogus vortex and FDDA for the case studies of SIDR and NARGIS cyclones.