Performance Assessment of WRF Parameterization Schemes on Simulation of Tropical Cyclone

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1. Introduction:

The Indian region is mostly affected by the occurrence of tropical cyclones in pre- and post-monsoon season (Osuri et al. 2015). The importance of the current study on simulation of an extremely severe cyclonic storm (''Fani'', 26 April to 4 May 2019) lies in the fact that this was one of the rare events that originated near the Equator and traveled along distance of 3030 km. Also, ''Fani'' was the most intense pre-monsoon tropical cyclone after 1982, crossing the Odisha coast with a clockwise-recurving track and maximum wind of 115 knots. The India Meteorological Department (IMD) consults on various Numerical Weather Prediction models' outputs and started issuing special bulletins until the dissipation of the storm. Here, the objective of this study is to examine the performance of different parameterization schemes of Weather Research and Forecasting (WRF) model on the predicted track and intensity of ''Fani''.

2. Numerical Experiments and Model Domain:

Experiments are conducted using the full physics options, including cloud microphysics [Lin et al., WRF single moment (WSM)-3 class, WSM-5 class, WSM-6 class, Thompson, WRF double moment (WDM)-5 class schemes], Kain–Fritsch (KF) cumulus, and Yonsei University (YSU) planetary boundary-layer scheme (Hong et al. 2009; Mahala et al. 2019). The experiments are named as MP2, MP3, MP4, MP6, MP8, and MP14 as per the corresponding microphysics schemes mentioned above respectively. Figure 1a presents the single domain with 27 km horizontal resolution and 41 vertical levels used in this study to fulfill the objective and the model integrated up to 150 hrs from 00UTC 28 April 2019. Various diagnostic studies are carried out with the model outputs and the results compared with the available observations.

3. Results and Discussion:

Figure 1b presents the simulated and observed tracks. All the schemes capture the initial position of the storm very well. The tracks are similar to the IMD observation. Analysis of the skill percentage values suggests that the WRF model gained skill in forecasting the track in different forecast hours. However, the MP3 scheme with the lowest direct positional error (DPE) exhibits better performance for predicting the track of ''Fani,'' followed by MP14. The mean zonal error (DX) is negative for all forecast lengths, suggesting that the average forecast position of ''Fani'' lies to the west of the best track position. Also, the mean meridional error (DY) is positive (negative) during 12-h to 48-h (60-h to 120-h), suggesting that the forecast position of the storm is ahead (behind) the observation up to (beyond) 48-h of forecast length. However, the MP14 (MP3) scheme shows the nearest track from the westward (southward) direction to the observed one, followed by MP3 (MP14). The positive (negative) mean cross track (CT) error during 12-h, 84- to 96-h, and 120-h (24- to 72-h, 108-h) indicates that the simulated tracks lie to the right (left) of the observed track (Fig. 1b; Table 1).The mean along track (AT) error is also positive for all forecast lengths, suggesting too fast movement of the storm predicted by all the schemes and hence early landfall. However, the average AT error is minimum for MP3 (68.5 km), followed by MP8 (82.3 km). The MP3 scheme predicted the landfall point closest to the observation (Fig. 1b). Figure 1c presents the 24-h accumulation of rainfall (in cm) by the WRF simulation valid at 03UTC on 3 May 2019 against the Tropical Rainfall Measuring Mission (TRMM) observation data. All the schemes simulate the high intensity rainfall towards the southwest sector of the storm. The overestimation of low intensity accumulation of rainfall is detected in all MP schemes. Analysis of the minimum central sea level pressure (MSLP) and 10m- maximum sustained wind (MSW) using the t-test suggests that the MP2 scheme has better forecast ability, followed by MP6 (Figure 2a, b). The analysis of quantitative/spatial matching of rainfall forecast and TRMM observation by the Method for Object-based Diagnostic Evaluation tool suggests that the MP8 (MP14) scheme is capable of simulating the rainfall beyond (upto) 48hours.

References:

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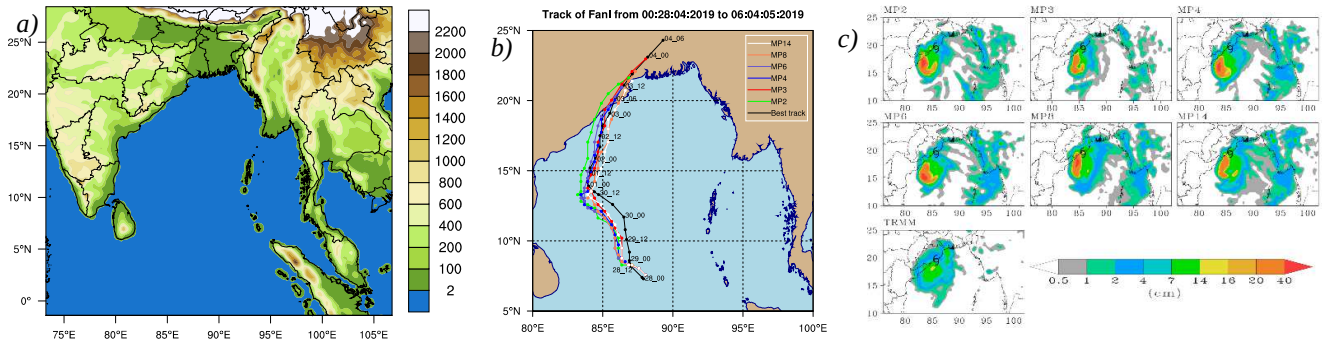

Fig.1 a. Single domain with terrain height (meters) used in the WRF model for ‘‘Fani’’, b. Simulated tracks of ‘‘Fani’’ against best IMD track valid 00UTC on 28 April 2019 to 06UTC on 4 May 2019, initialized at 00UTC on 28 April 2019, c. Model simulated 24- h accumulation valid 03UTC 03 May 2019 along with TRMM observation during the time of landfall valid 03UTC 03 May 2019.

Table 1 Mean DX, DY, CT, and AT errors (in km) of tracks up to 120-h forecast length

WRF Model track errors (km)				
Forecast Length (hr)	DX	DY	CT	AT
12	-3.94	9.31	3.78	9.47
24	-77.47	27.12	-78.46	27.10
36	-72.97	20.10	-68.08	35.39
48	-147.77	1.25	-150.02	25.47
60	-61.67	-75.41	-98.23	28.03
72	-25.23	-67.57	-66.25	30.50
84	-9.79	-104.42	19.05	103.34
96	-30.93	-115.32	29.48	115.99
108	-28.18	-163.05	-29.43	163.23
120	-67.64	-164.39	17.67	177.23

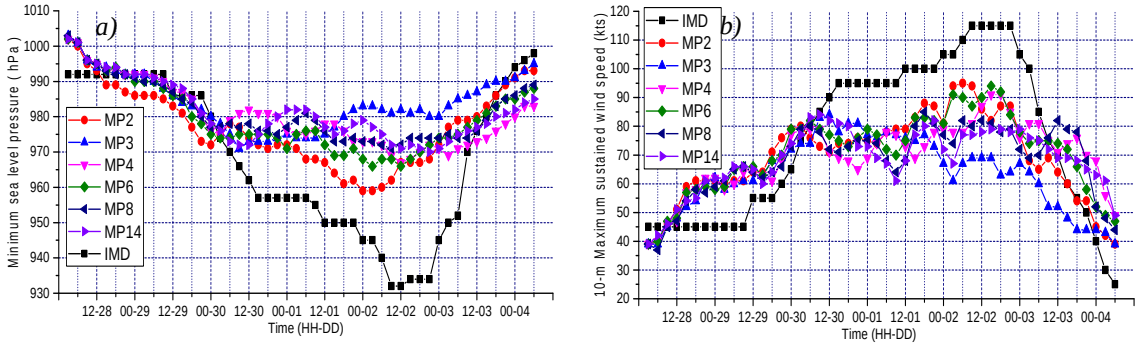

Fig. 2 Model simulated a) minimum central sea level pressure (hPa), b) 10-m MSW (knots) against IMD observation for “Fani”