Evaluation of Radiation Parameterization Schemes on Simulation of Tropical Cyclone

Kanak Lata Xalxo[1]*, Biranchi Kumar Mahala[1], Pratap Kumar Mohanty[2], Ashish Routray[3], Bhupati Bhusan Mishra[1]

[1]School of Applied Sciences (Mathematics), Kalinga Institute of Industrial Technology (KIIT), Deemed to be University, Bhubaneswar, Odisha, India
[2]Department of Marine Sciences, Berhampur University, Berhampur, Odisha, India
[3]National Centre for Medium Range Weather Forecasting (NCMRWF) Ministry of Earth Sciences, Government of India, Noida, UP, India
E-mail: *kanakmeansgold123@gmail.com, biranchimahala@gmail.com, pratap_mohanty@yahoo.com, ashishroutray.iitd@gmail.com, bmishrafma@kiit.ac.in

1. Introduction

Bay of Bengal (BoB) is a more active basin for tropical cyclones (TCs) genesis than the Arabian Sea (Mahala et al. 2015). Super Cyclonic Storm (SuCS) formation rates reach the maximum (minimum) during pre-(post) monsoon season in the BoB (Li et al. 2021). Track forecasting is one of the crucial components of disaster mitigation and preparedness activities. Accurate forecasting of genesis, development, track, associated rainfall and the intensity of tropical cyclones remains a challenge. We considered a case study "Amphan" because it is the 2nd SuCS in the BoB region and the 1st pre-monsoon SuCS from 1999 to 2020. The main objective of the study is to assess the performance of WRF model radiation parameterization schemes in simulating the track and intensity of the SuCS "Amphan".

Simulation is conducted using single domain (Fig. 1a) with horizontal resolution at 12 km with 51 vertical levels. The experiments are conducted using two longwave (LW) radiation schemes i.e., (a) Rapid Radiative Transfer Model (RRTM), (b) RRTM for General Circulation Models (RRTMG), two shortwave (SW) radiation schemes i.e., (a) Dudhia, (b) RRTMG available in the Advanced Weather Research and Forecasting model with different permutations as S11 (RRTM LW, Dudhia SW), S14 (RRTM LW, RRTMG SW), S41 (RRTMG LW, Dudhia SW), S44 (RRTMG LW, RRTMG SW) and the performance was assessed by computing different error metrics such as direct position error (DPE), along-track (AT), cross track (CT), zonal (DX) and meridional (DY) errors. The tracks, 10m maximum sustained surface wind (MSW), minimum central sea level pressure (MSLP) simulated by the schemes S11, S14, S41, and S44 are evaluated with the India Meteorological Department (IMD) Best Track data to know the best performing scheme. The translation speed (TS) by all the schemes is computed by using the Haversine formula.

2. Results:

Figure 1a represents the simulated and observed tracks of "Amphan". The mean CT error is varying between -12.55 and 9.96 km by all the schemes. S41 (S14) shows the mean CT error of -3.57 (- 4.79) km. S41 exhibits the least AT error during 24 h to 72 h forecast and also during the landfall process i.e., 06 UTC - 12 UTC of 20 May 2020 (Table 1). From the analysis of DPE, DX, DY, CT, and AT errors it is observed that the scheme S41 shows the nearest track. It is envisaged that the schemes S14 and S41 produce the tracks close to the observed track. The average speed at which a TC moves forward, say 6-h is named translation speed (TS). The average speed of "Amphan" in all the schemes is less than the observation data. However, the S14 scheme shows the track length (TS) of ~ 1454 km (15.15 kmph) against the IMD observed track length (TS) of 1478.60 km (15.40 kmph). The intensity of a tropical cyclone is expressed by 10-m- MSW and MSLP (RSMC 2021). All schemes could simulate the MSW of 35–70 kts against the IMD observed value of 40-70 kts from 15 UTC 16 May to 12 UTC 17 May (Fig. 1b). All the schemes underestimate the MSLP for the intensities extremely severe cyclonic storm (ESCS)-SuCS-ESCS-very severe cyclonic storm (VSCS) from 00 UTC 18 May to 15 UTC 20 May (Fig. 1c). Figure 2i shows the vertically integrated moisture transport (vectors, kg/(ms)) and vertically integrated moisture flux divergence (shaded) by different schemes. The center of deep convection with greater coverage in the area on the eastern north-eastern sector of the TC center is evident in the S11 scheme valid at 09 UTC 20 May 2020, which could be due to relatively greater moisture transport from BoB as compared to the other schemes. The analysis suggests that S11 (S14) scheme simulates strong convection before (after) the landfall process. Figure 2(ii and iii) shows the statistical parameters such as critical success index (CSI) and intersection area calculated by the method of object based diagnostic evaluation (MODE) tool in all the schemes with convolution thresholds (CTs) 70mm and 100mm. The analysis suggest that CSI and intersection area values are maximum in the scheme S44. The forecast tendency can also be analyzed through the parameter in terms of intersection area. The scheme S44 also computes the maximum intersection area for the CTs 70 mm and 100 mm and hence has a better rainfall forecast skill.

3. References:

Li Z, Xue Y, Fang Y, Li K (2021) Modulation of environmental conditions on the significant differencein the super cyclone formation rate during the pre- and post-monsoon seasons over the Bay of Bengal. Clim Dyn. https:// doi. org/ 10. 1007/ s00382- 021- 05840-7

Mahala BK, Nayak BK, Mohanty PK (2015) Impacts of ENSO and IOD on tropical cyclone activity in the Bay of Bengal. Nat Hazards 75:1105–1125. https:// doi. org/ 10. 1007/ s11069- 014- 1360-8

RSMC (2021) Report on cyclonic disturbances over the north Indian Ocean during 2020

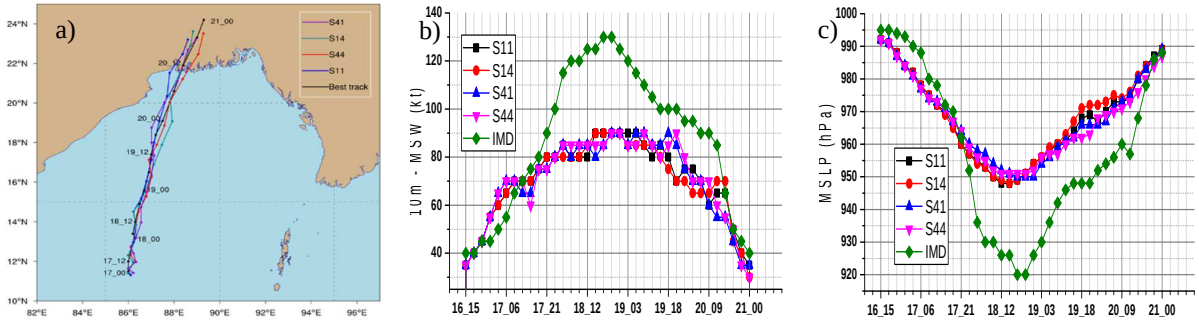

Fig. 1: (a) Simulated tracks of “Amphan” (b) maximum sustained surface wind (knots), (c) minimum central sea level pressure (hPa)

Table 1: Mean DPE, DX, DY, CT, and AT errors (in km) of tracks up to 108-h forecast length

	S11	S14	S41	S44
DPE	48.24	43.23	43.99	43.08
DX	-17.59	-2.22	-4.84	3.33
DY	-39.49	-34.00	-31.43	-36.51
CT	9.96	-4.79	-3.57	-12.55
AT	44.06	37.66	36.80	38.41

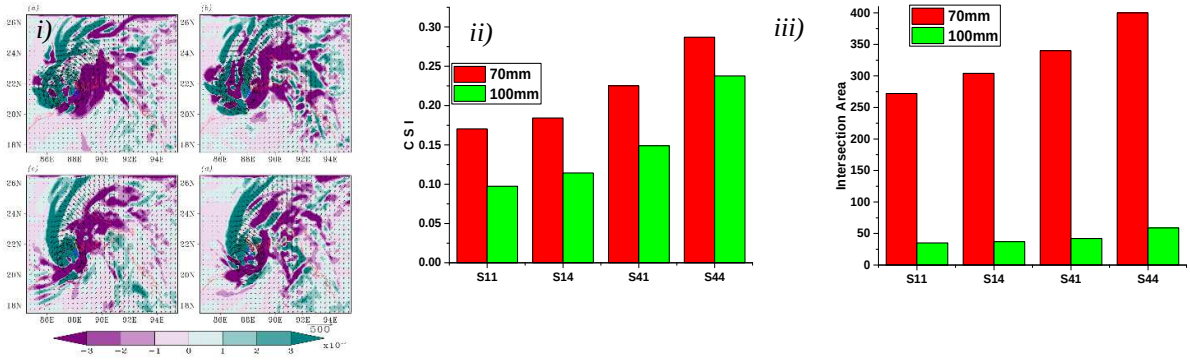

Fig.2: i) Vertically integrated moisture transport (vectors, kg/(ms)) and vertically integrated moisture flux divergence (shaded) in the schemes **a** S11, **b** S14, **c** S41, and **d** S44 valid at 09 UTC 20 May 2020, Mode object scores ii) CSI, iii) Intersection area (square kilometer).