Implementation of WRF based High Resolution Rapid Refresh system over East Indian Region

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1. Introduction

To mitigate the significant threat to human life and property due to the highly localized severe weather systems high-resolution more accurate forecasts are needed. The high-resolution convection allowing NWP models (≤ 3 km) fulfill this demand. The isolated and highly localized convective features are well monitored by convective scale measurements such as Doppler Weather Radars (DWR), lightning detection networks etc. The information related to the presence of deep, moist, and mixed-phase convective activities from these sources can be utilized to improve the model's initial fields and produce better short-term forecasts (Kong et al., 2018). The High-Resolution Rapid Refresh (HRRR), which is running at NCMRWF on an experimental basis consists of Advanced Research Weather Research to forecast the atmospheric fields and - Gridpoint Statistical Interpolation (WRF-GSI) for creating the assimilated initial fields. It is a state-of-the-art, convection-allowing, storm-resolving, real-time, hourly updated model system that provides short-range (lead time ranges upto 24 h) high-resolution (horizontal resolution 1.5 km with 80 vertical levels) forecasts over East India region (Fig.1). The region of interest is used to impact by heavy rainfall, lightning, and strong winds caused by frequent convective systems. HRRR setup over this region is designed to monitor the high-impact weather events during the summer season.

2. Experimental setup

The details of the physical parameterization options employed in HRRR system is shown in Table 1a. The model is initialized with IMD-GFS T1534 and lateral boundary conditions are updated 3 hourly and the conventional, satellite radiances, radar and lightning flashes are being assimilated hourly (Table 1b). Model initial fields are generated using the GSI based 3DVAR technique. The GSI cloud analysis package is used to convert the lightning flash counts into proxy reflectivity. Both the radar reflectivity and proxy reflectivity calculated from lightning flash counts are converted to latent heat temperature tendencies (LHT) and it replaces the model-derived 3D LHTs. These estimated LHT profiles are substituted to the WRF microphysics scheme during the Digital Filter Initialization (DFI) forward step at every 15 min (Benjamin et al., 2016), which forces the model to initiate convection during the pre-forecast period. For a model column to be categorized as a convective region, the maximum temperature tendency must be more than 0.0002 K/s. To evaluate the importance of high resolution and rapid update, two experiments have been conducted on 31 Mar 2023 heavy rainfall case (i) Control (CNTL) without any data assimilation and (ii) HRRR with hourly assimilation of observations (both conventional and satellite radiances along with the radar and lightning). To evaluate different facets of the forecast quality, a variety of verification metrics like Probability of Detection (POD), False Alarm Ratio (FAR), Threat Score (TS) are used.

3. Results and Discussion

The spatial distribution of rainfall from model experiments (CNTL and HRRR) is compared with NCMRWF-IMD merged rainfall (Fig. 2). The observed rainfall system over Odisha is well captured by HRRR though there are some over-estimations in the amount. The spatial spread of the rainfall system is poorly represented in CNTL. This is reflected in the evaluation metrics. HRRR provides a large POD (0.8), ETS (0.4) and TS (0.7) whereas CNTL shows lower scores. FAR is comparably lesser in CNTL (0.1) than HRRR (0.2), but which is acceptable in the case of HRRR while considering the other scores. It is concluded that rapidly updated hourly assimilation is able to simulate the heavy rainfall event well.

References:

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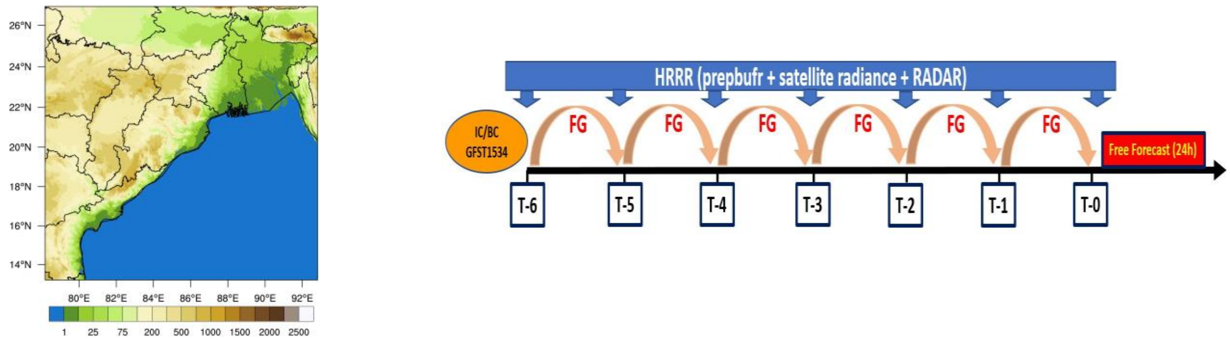

Fig. 1 (a) Study area with a resolution of 1.5 km (Topography of the domain in shading), (b) Schematic of HRRR assimilation and forecast system

Table 1. Model Physics Configuration and Assimilated Observations in HRRR

(a)

WRFV 3.9.1	
Horizontal resolution	1.5 km
Vertical levels	80
Time step	6 seconds
Output frequency	1 hour
Grid points	1050 x 1050 (13.19°N to 26.9 1°N) (78.17°E to 92.83°E)
Physical Parameterization Schemes	
Radiation	RRTMG for both short and long wave radiation
Boundary layer	MYNN-EDMF scheme
Microphysics	Morrison scheme
Cumulus Convection	Turned off
Land surface	Noah Land surface scheme

(b)

Conventional	Satellite Radiance
Radiosondes Pilot Balloon Aircraft observations Satellite AMVs Scatterometer Radar radial winds GPSRO	SSMIS: F17, F18 HIRS: N19, MetOp-B AMSU-A: N15, N18, N19, MetOp-B, MetOp-C INSAT 3DR ATMS: n20 IASI: MetOp-B MHS: N19, MetOp-B & C ATMS: NPP, N20 AVHRR: N19 SEVIRI Clear-sky AHI

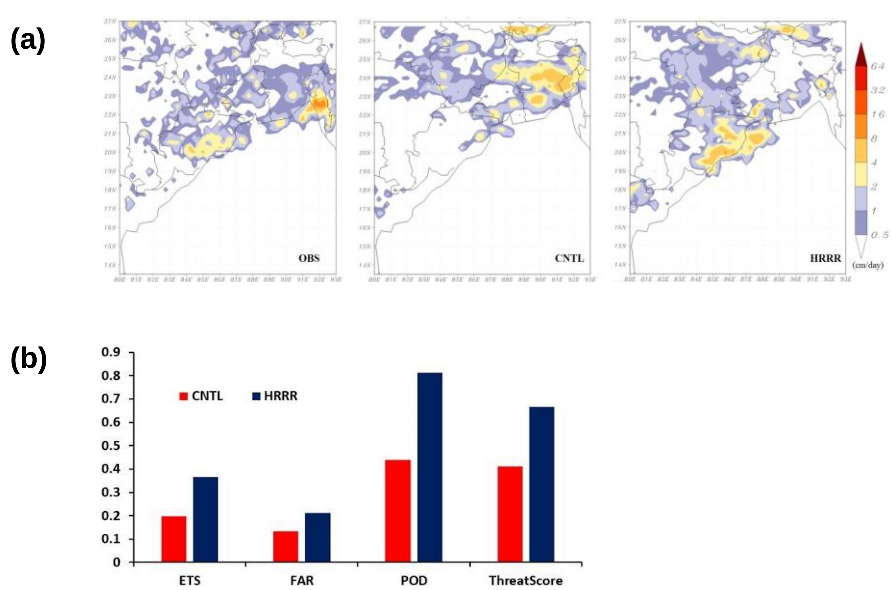

Fig. 2. Spatial distribution of 24 hour accumulated rainfall (cm/day) for the event 31 Mar 2023 from (a) satellite - gauge merged rainfall (NCMRWF-IMD), (b) Verification metrics from CNTL and HRRR experiments