Improved Skill in Predicting Extreme Rains over Complex Terrain in India during recent Years

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Abstract

The aim of this study is to evaluate the performance of UK Met Office Unified Model (UM) in predicting heavy and very heavy rainfall exceeding 80th and 90th percentiles which occurs mainly due to the forced ascent of air parcels over the mountainous regions of the Western Ghats (WGs) and North East (NE) – states of India during the monsoon seasons of 2007 to 2018. Apart from the major upgrades in the dynamical core of UM from New Dynamics (ND) to Even Newer Dynamics for General Atmospheric Modeling of the environment (ENDGame), the horizontal resolution of the model has been increased from 40 km and 50 vertical levels in 2007 to 10km and 70 vertical levels in 2018.

1 Introduction

Forecasting of orographically induced heavy rainfall is one of the most challenging problems for numerical weather prediction (NWP) models. This is because of the complexity of the meteorological phenomena occurring over the orographic regions and the difficulty of obtaining detailed and precise observational data sets. Both these factors leads to the poor representation of initial conditions required to run the NWP models. However, there is a significant improvement in the forecasting skill of NWP models in recent times. Some of these improvements can be attributed to the increased horizontal and vertical resolutions as well as improved physics parameterization schemes [1], while major credit to the substantial improvements in weather forecasting goes to the sophisticated data assimilation systems which utilize the satellite data.

Most of the heavy and extreme rainfall events occur during the southwest monsoon season (June to September, JJAS). Western Ghats (WGs), North-Eastern (NE) states (Assam, Meghalaya, Mizoram, Arunachal Pradesh, Sikkim, Manipur and Tripura) of India and central India are the most prominent regions of heavy rainfall. The WGs and the NE states of India are regions characterized by steep orography and the heavy rainfall in these regions are often due to forced ascent of air parcels over the mountains. These two mountainous regions of India have the highest annual rainfall [2]. Here, evaluation of operational UM rainfall forecasts is focused on mountainous regions of India (over WGs and NE-states). The study period extends over twelve monsoon seasons (2007-2018). The evaluation is carried out with special emphasis on heavy rainfall. Unlike earlier studies [1] [3], the verification is based on quantile based rainfall thresholds rather than absolute rainfall amounts.

2 Data and Methodology

The observed and rainfall data over India used in this study are briefly described in this section.

2.1 Observed Rainfall Data

This study uses IMD-NCMRWF merged rainfall product (0.5° x 0.5°grid) over India during twelve monsoon (JJAS) seasons from 2007-2018. This rainfall analysis is based on merging of gauges measurements with satellite based rainfall estimates The satellite rainfall estimates are based on **T**ropical **R**ainfall **M**easuring **M**ission Multi-satellite Precipitation Analysis (TMPA)-3B42 (TRMM) during 2007-2015 and on Global Precipitation Measurement (GPM) from 2016. The two domains selected for the study are WGs (72-78°E, 8-23°N) and NE- states (88-100°E, 21-30°N).

2.2 Model Forecast Rainfall Data

Daily rainfall forecast up to Day-3, produced by the global operational Unified Model used for NWP have been evaluated over two mountainous regions of WGs and NE-states. The rainfall forecast is also interpolated at 0.5**°** x 0.5**°** **)** for direct comparison with the observed rainfall. During 2007–2018, the horizontal and vertical resolution of the global NWP configuration improved from about 40 km and 50 levels in 2007 to about 10 km and 70 levels in 2018. The more details about the major upgrades are available in [4].

2.3 Methodology

To evaluate the skill of the NWP forecast system, verification metrics focus on the correspondence between the observation and forecast [5]. The 24-hour rainfall exceeding 80th (hereafter CAT-1) and 90th percentiles (hereafter CAT-2) thresholds are events of interest in the present study. The categorical verification approach based on the elements of the 2x2 contingency table (Table1) has been used. Probability of Detection (POD), False Alarm Ratio (FAR), Critical Success Index (CSI) and Symmetric Extremal Dependence Index (SEDI) are some of the metrics used in this study [6]

Table 1: Contingency table representing the frequencies of forecast-observation pairs for which the event and non-event were forecasted and observed

		Observed		
		Yes	***No***	***Total***
Fcst	***Yes***	Hits(a)	False alarms(b)	Fcst yes
	No	Missed(c)	Correct negatives(d)	Fcst no
	Total	Obs yes	Obs no	total

3 Results

The categorical verification is carried out for JJAS 2007-2018.

3.1 Rainfall forecast verification over WGs and NE-states

Figure 1 displays the seasonal verification scores of four metrics (POD, FAR and CSI) computed based on the 2x2 contingency table (Table 1) for two rainfall thresholds of CAT-1 and CAT-2 over WGs and NE-states respectively. It is evident from Figure 1 that the prediction of orographic rainfall during the monsoon seasons of 2007 to 2018 has been improved up to Day-3 of the forecasts over both the regions of study for the chosen thresholds of CAT-1 and CAT-2. However, the seasonal CSI values show a decrease with increase threshold for Day-1 to Day-3 forecasts (Figure 1(g-i)). While analyzing the model's performance over both the mountainous regions, CSI has a higher magnitude over WGs compared to NE-states for CAT-1 and CAT-2 thresholds

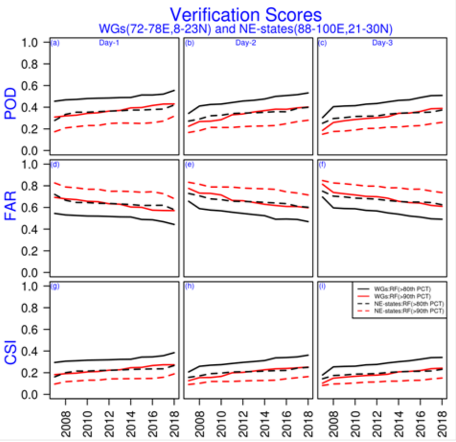

Figure 1. Probability of Detection (POD; (a-c), False alarm Ratio (FAR;(d-f) and Critical success index (CSI(g-i)) computed for Day-1 Day-2 and Day-3 forecasts for CAT1 and CAT2 rainfall thresholds during JJAS 2007-2018 over WGs and NE-states .

3.2 Improvement in rainfall forecast: Extreme scores

To overcome the shortcomings of the traditional verification metrics in predicting rare events, SEDI verification metrics for two thresholds of CAT-1 and CAT-2 during the twelve monsoon seasons are displayed in Figure 2 (a-c) over WGs and NE-states at all lead times. It is clear from Figure 2 that the skill of the model has improved in predicting heavy rainfall (CAT-1) and very heavy rainfall events (CAT-2) during the recent monsoon seasons and at all forecast lead times. Also, the magnitude of SEDI is higher compared to traditional verification metrics (CSI).

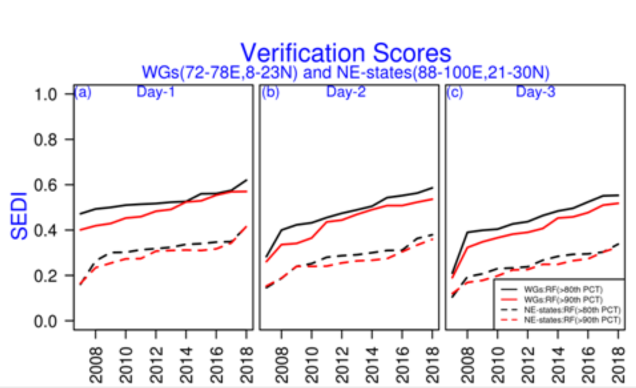

Figure 2. Symmetric extremal Dependence Index (EDI; (a-c)) computed for Day-1 Day-2 and Day-3 forecasts for CAT1 and CAT2 rainfall thresholds during JJAS 2007-2018 over WGs and NE-states

4 Summary

The work reported in this paper evaluates and documents the skill of Met Office's operational Unified Model (UM) (global) rainfall forecasts over the hilly regions of India during the monsoon seasons of 2007-2018. The changes in the operational UM during 2007-2018 include improvements in the representation of physical processes, improved dynamics and increased grid resolution from about 50km in 2007 to 10km in 2018. Rainfall forecast for CAT-1 and CAT-2 has been improved in the case of CSI, POD and FAR from 2007-2018 over both the regions of WGs and NE-states of India. Also, the improvement Further, An increase in SEDI has been noted over WGs (NE-states) in SEDI for CAT-1. The improvement in SEDI is quite impressive over WGs for CAT-2.

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