Statistical Bias Correction of NCMRWF Unified Model Precipitation Forecasts Based on Quantile Mapping Methods

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1. Introduction

High resolution numerical weather prediction (NWP) model predictions are now possible owing to major advancements in the computational power over the last few decades. The model forecasts, however, frequently show systemic errors in relation to the observations and, more significantly, in relation to the crucial variables, like precipitation, which have a significant impact on the society. Thus, it is essential to correct the model errors in order to efficiently utilize NWP forecasts towards decision-making applications for flood risk management. In this study, we particularly focused on the assessment of location specific bias correction methods for Mumbai (BOM, 72.85^{o}E, 19.117^{o}N), located on India's western coast. This location is chosen here to support the Integrated Flood Warning System (IFLOWS), initiated by the Ministry of Earth Sciences, Government of India, which provides early warning and decision support during flooding. The Mumbai city experiences strong westerly and southwesterly flow as a result of summer monsoon winds from the Arabian Sea because of its geographic location on the windward side of the Western Ghats of India. This causes orographic rainfall with a high magnitude and intensity. In addition, the city also affected by other significant weather features including offshore vortices and troughs, depressions in the Arabian Sea, and most significantly, mid tropospheric cyclones (MTCs), which brings hazardous rainfall during the southwest monsoon. Thus, good/accurate rainfall forecasts is crucial for running flood models to subsequently provide early warning and decision support for flooding during extreme rainfall events in this climate sensitive location.

The novelty and significance of this work lies in using a newly developed high-resolution Indian Monsoon Data Assimilation and Analysis (IMDAA, Rani et al., 2012) reanalysis product in calibrating the National Centre for Medium Range Weather Forecasts (NCMRWF) Unified Model (NCUM) operational forecasts (Sumit Kumar et al., 2021) for improving rainfall forecasts at a local scale. The Numerical Weather Prediction (NWP) dynamical cores used to generate the IMDAA reanalysis data and the NCUM daily operational forecasts are quite similar. Hence, as they employ the same model physics, IMDAA can be efficiently used to correct real- time forecasts. It is also important to note that the calibration methods adjust the model systematic biases that are equivalent to many years of improvement to the basic model.

2. Methodology

Statistical bias correction techniques establish a link/relationship between observed and simulated variables over the historical period, and then utilise functional relationship to bias-correct the model predictions. In this study, we used empirical quantile mapping (EQM), parametric quantile mapping (PQM), and gamma/generalized Pareto parametric quantile mapping (GPQM) techniques (Niranjan Kumar et al., 2021). EQM is a non-parametric bias correction method that calculates quantile-by-quantile

modifications/changes in the simulated cumulative distribution function to correct the mean and variability, including shape errors. However, PQM and GPQM, are parametric bias correction techniques. The PQM technique assumes that both observed and simulated intensities are well approximated with two-parameter gamma distributions and uses a theoretical distribution rather than an empirical distribution. While the GPQM method is based on gamma distribution combined with generalized Pareto distribution (GPD).

3. Quantile Mapping Bias Correction

Figure 1 (left panel) shows the time evolution of India Meteorological Department (IMD) station rainfall (OBS), NCUM Day-1 raw forecasts (FCS), and bias-corrected Day-1 rainfall forecasts based on EQM (FCS_{eqm}), PQM (FCS_{pqm}), and GPQM (FCS_{gpqm}) methods. The observed rainfall over BOM indicates heavy to very heavy rainfall events (>64.5mm/day) defined by IMD during the southwest monsoon season (JJAS 2022). Figure 1 (right panel) indicates skill scores based on raw and bias-corrected forecast. Figure 1 (right panel) clearly depicts the HIR (Hit rate), and ETS(Equitable threat score) scores have higher magnitudes for the rainfall events with magnitudes more than 100mm/day along with low False alarm rate(FAR). Hence, the heavy to very heavy rainfall events are better calibrated based on the parametric methods which will be useful for early warning and decision support for flooding during extreme rainfall events over the Mumbai city.

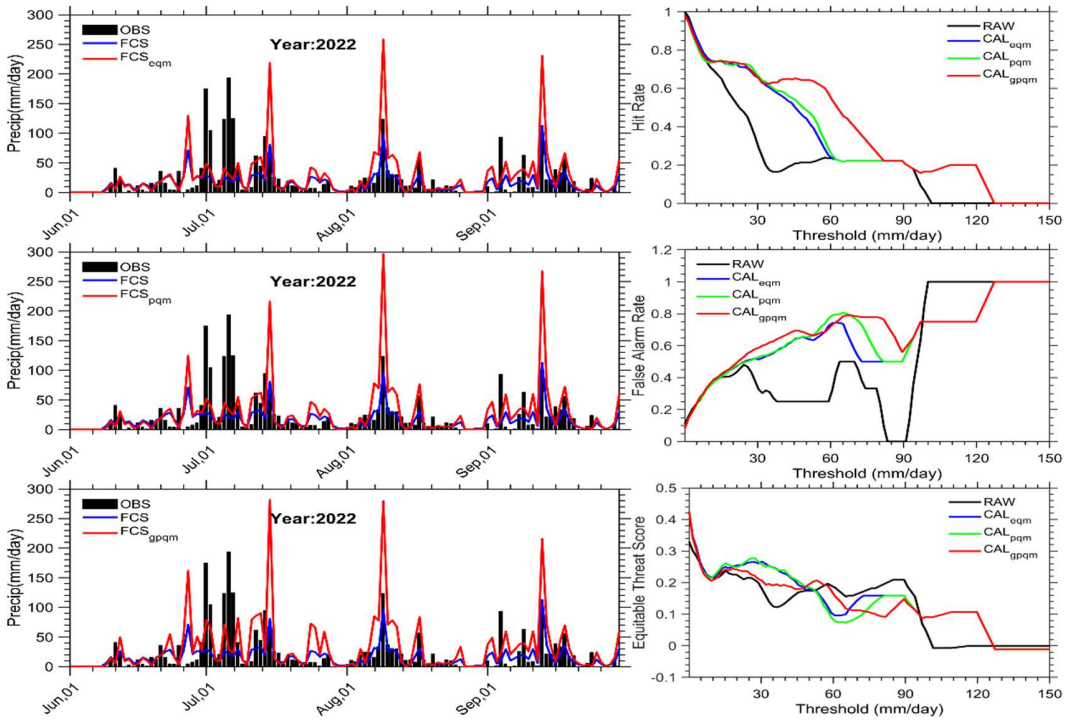

Figure 1 (left panel) Time evolution of observed and model forecast rainfall along with calibrated rainfall based on quantile mapping bias-correction methods for the period between Jun-Sep, 2022. (Right panel) Model skill scores such as Hit Rate (HIR), False Alarm Rate (FAR), and Equitable Threat Score (ETS) estimated based on IMD station rainfall vs raw and bias-corrected model forecasts.

4. References

[1]. Niranjan Kumar et al., (2022) Quantile mapping bias correction methods to IMDAA reanalysis for calibrating NCMRWF unified model operational forecasts, Hydrological Sciences Journal, 67:6, 870-885, DOI: 10.1080/02626667.2022.2049272

[2]. Rani, S.I., et al., 2021. IMDAA: high resolution satellite-era reanalysis for the Indian monsoon region. Journal of Climate, 1–78. doi:10.1175/JCLI-D-20- 0412.1

[3]. Sumit Kumar et al., (2021), NCUM Global DA System: Highlights of the 2021 upgrade, NCMRWF Technical Report No. NMRF/TR/05/2021, https://www.ncmrwf.gov.in/Reports-php/Highlights_upgrade_report.php