Representation of moist processes in NCUM operational forecasts during boreal summer monsoon over India

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1. Introduction

Realistic simulation of the mean state of monsoon and its variability at various space and time scales either in climate models (Annamalai et al 2007) and/or in operational numerical weather prediction (NWP) systems is a major concern, due to the systematic errors and biases in model outputs, which pose a large burden for NWP models (Keane et al 2019). In general, these model biases originate from the discrepancies in the parameterization schemes of the physical processes; as a result, climate and weather forecasting communities rely on applying process-oriented diagnostics (PODs) (Maloney et al., 2019). The primary objective of this study is to assess the National Centre for medium-range weather Forecasting Unified Model (NCUM) global forecast (12km horizontal resolution) system's ability in representing PODs associated with enhanced (active) and suppressed (break) phases of the monsoon.

2. Data and Methodology:

In this work, we analysed the daily operational NCUM global forecasts during the 8 monsoon seasons (2015-2022, June through September). To examine the linkage between small-scale convection and its associated macro-scale circulation patterns, we have applied *moist static energy (MSE)* budget. It is regarded as POD that combines the physical processes influencing the moisture and temperature (Su and Neelin, 2002, Maloney et al 2009). The column-integrated moist static budget is given by equation. $\frac{\partial h}{\partial t} = -\omega\frac{\partial h}{\partial p} - V.\nabla h + LH + SH + F_{net}$

$$MSE, h = c_pT + gz + Lq$$

where T is temperature; q is specific humidity, V and ω are the wind components, LH and SH are turbulent latent and sensible heat fluxes, F_{net} is net radiative heating/cooling, and L is the latent heat of condensation ($2.5\text{x}10^6$ J/kg).

3. Results:

A close examination of the seasonal biases at different forecast lead times (Figure 1) depicts wet (dry) rainfall biases over the Arabian Sea (AS) and the Indian Ocean and dry biases over the Bay of Bengal (BoB) regions. Dry biases occupy a majority of the area over the northern parts of AS and the magnitude of these biases is increasing with lead time. Enhanced wet biases (~5mm/day) over the equatorial Indian Ocean (EIO) and southern AS regions influence rainfall variability over other regions of the Indian subcontinent through the interaction of equatorial waves and moist physics (Annamalai 2010). One implication of the rainfall biases is that even a relatively higher resolution model still struggles to simulate the mean monsoon state precisely and the uncertainties can further influence the associated diabatic heating (Q) and large-scale circulation.

Sensitivity of the atmospheric convection, i.e., rainfall binned w.r.t specific humidity, q vertical distribution shows mainly the boundary layer moisture (moisture below 800 hPa) is exhibiting more spread than the free troposphere and it is more apparent over land regions (Figure 2). MSE budget analysis applied to one strong individual break event (13-22 July 2019 having peak intensity on 17th July) depicts, the vertical advection of MSE is negative (positive) between 950-600 hPa (550-100 hPa) levels as expected in descending motion and MSE structure.

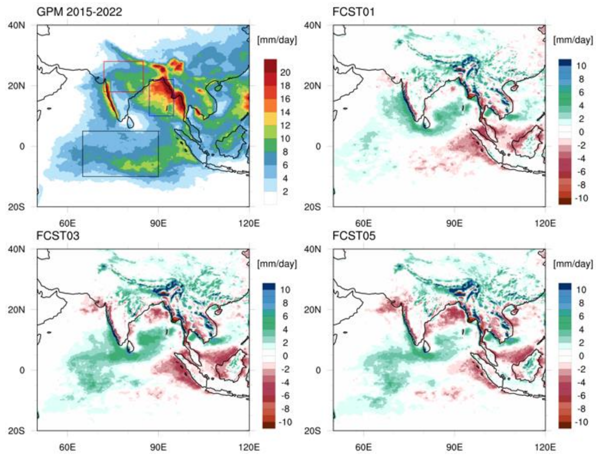

Figure 1: Mean state and forecast biases (c-d) at different lead times computed w.r.t GPM rainfall observations during monsoon.

One disparity is the presence of very high MSE seen in the model layers between the surface to 925 hPa. Horizontal advection of MSE indicates dryness prior to the peak break conditions over Central India (CI). The surface fluxes and net radiation are in phase with MSE, and the contribution of surface turbulent fluxes is relatively minimal compared to other MSE terms. Preliminary results are encouraging and indicate the advantage of using PODs as one of the verification tools for assessing model forecasts.

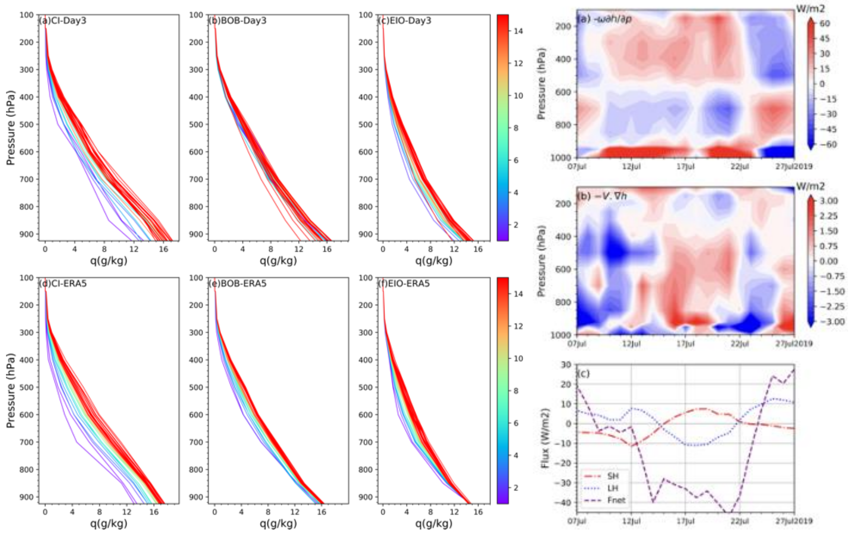

Figure 2: *Left panel:* Specific humidity averaged w.r.t.to rainfall bins over three selected regions (solid boxes in Figure 1). *Right panel:* MSE budget terms for a strong individual break event in 2019 over central India.

4. References

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