Sensitivity of enhanced vertical resolution in the Global Forecast System (GFS) T1534 on the short to medium range forecast of Indian summer monsoon

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Using GFS T1534 model, we have incorporated the enhanced vertical resolution by increasing the hybrid vertical level to 128 levels from existing 64 hybrid levels. This makes the lowest model level resolution to 20m compared to 45m in the default model. The model changes are made as follows.

Current Status	Proposed
64 Levels	128 Levels
Levels Below 850hPa	levels below 850hPa
14	29
Levels below 2KM	Levels below 2KM
16	34
levels between 700hPa to 200hPa	levels between 700hPa to 200hPa
16	33
Levels above 15KM	Levels above 15KM
25	47
Model top at	Model Top at
0.27 hPa	0.01hPa
Total time it takes to run the forecast of 10 days with nodes	Total time it takes to run the forecast of 10 days with nodes
130 nodes in ~40 minutes	130 nodes in ~210 minutes

Model physics for GFS L64 and L128

Physics	Description
Radiation	Rapid Radiative Transfer Model (RRTM) for both Shortwave and Longwave (Iacono et al., 2000; Clough et al., 2005) with Monte Carlo Independent Column Approximation (McICA)
Microphysics	Formulated grid-scale condensation and precipitation (Sundqvist et al., 1989; Zhao and Carr, 1997)
Convection	Aerosol aware and Mass flux based Simplified Arakawa-Schubert (SAS) shallow convection (Pan and Wu, 1995; Han and Pan, 2011; Arakawa and Wu, 2013; Han et al., 2017)
Planetary Boundary Layer (PBL)	Hybrid Eddy-Diffusivity Mass Flux vertical turbulent mixing scheme (Han and Pan, 2011; Han et al., 2016)
Gravity Wave Drag (GWD)	Mountain blocking (Alpert et al., 1988; Kim and Arakawa, 1995; Lott and Miller, 1997) and stationary convective-forced GWD (Chun and Baik, 1998)

Model run is carried out for 2020 JJAS season for L64 (CTRL) and L128 (EXPT) respectively.

Conclusions and future plan

- The improved precipitation distribution is noted over majority of the Indian landmass areas except considerable overestimation over the northeast India, Himalayan foothills, WGs, and BOB region.
- The model skill is improved over the Central Indian landmass region.
- Model shows better fidelity in retaining the intensity of heavy rainfall for longer lead times.
- Improved diurnal cycle of precipitation over the central Indian region.
- It is noted that increasing vertical resolution alone may not be sufficient in improving the overall model performance. The model's physical schemes should be tuned for the higher vertical resolution model as the closure assumption of a physical scheme has been tested in relatively low-vertical resolution model.
- Our next plan is to test the fidelity of L128 in GFS TCo (~6.5 km resolution) model which will be operationally implemented for short and medium range weather prediction model.

Reference: Ganai et al. (2024), Climate Dynamics, https://doi.org/10.1007/s00382-024-07316-w

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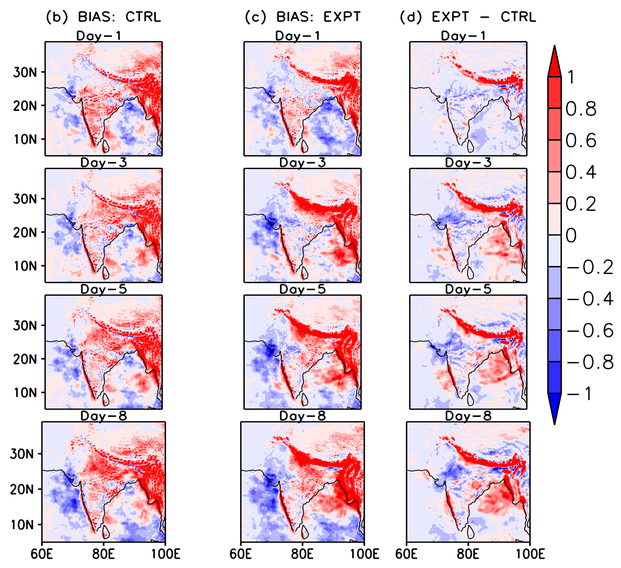
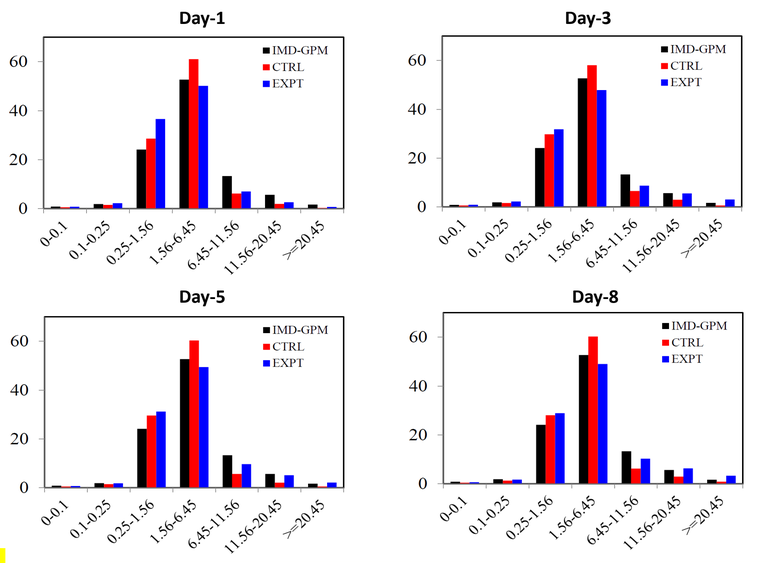
JJAS mean rainfall bias (cm/day) during 2020



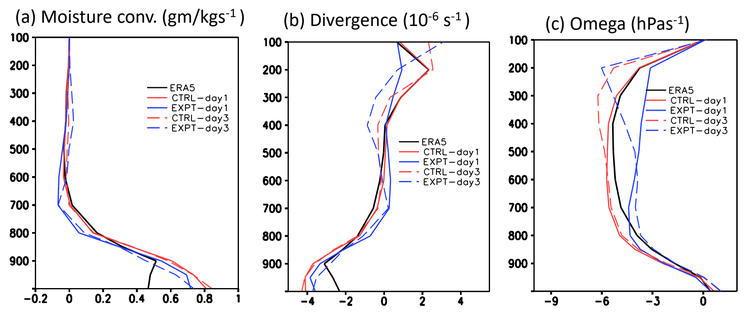
Rainfall PDF (%) over all India landmass during JJAS 2020



Various statistical parameters over central India (CI) during JJAS 2020

	Lead day	Mean (mm/day)	CC	RMSE (mm/day)	Standard Deviation (mm/day)
IMD-GPM		8.3			11.6
CTRL	Day-1	9.9	0.38	17.8	9.4
EXPT	Day-1	8.0	0.51	16.9	8.5
CTRL	Day-3	9.9	0.29	19.5	10.1
EXPT	Day-3	7.9	0.33	20.2	10.3
CTRL	Day-5	10.4	0.17	20.2	9.9
EXPT	Day-5	9.2	0.34	21.6	11.2
CTRL	Day-8	11.5	0.10	21.5	10.9
EXPT	Day-8	10.0	0.39	23.3	12.8

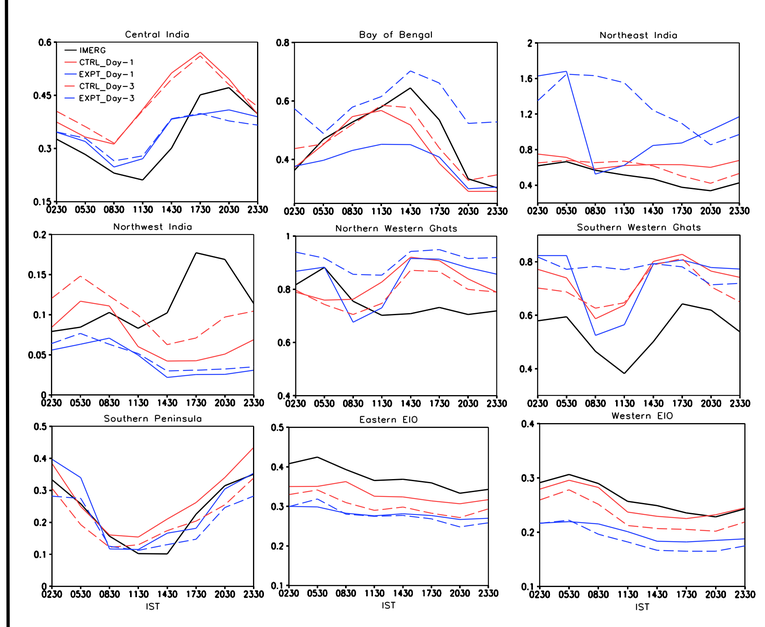
Various dynamical parameters over CI during JJAS 2020



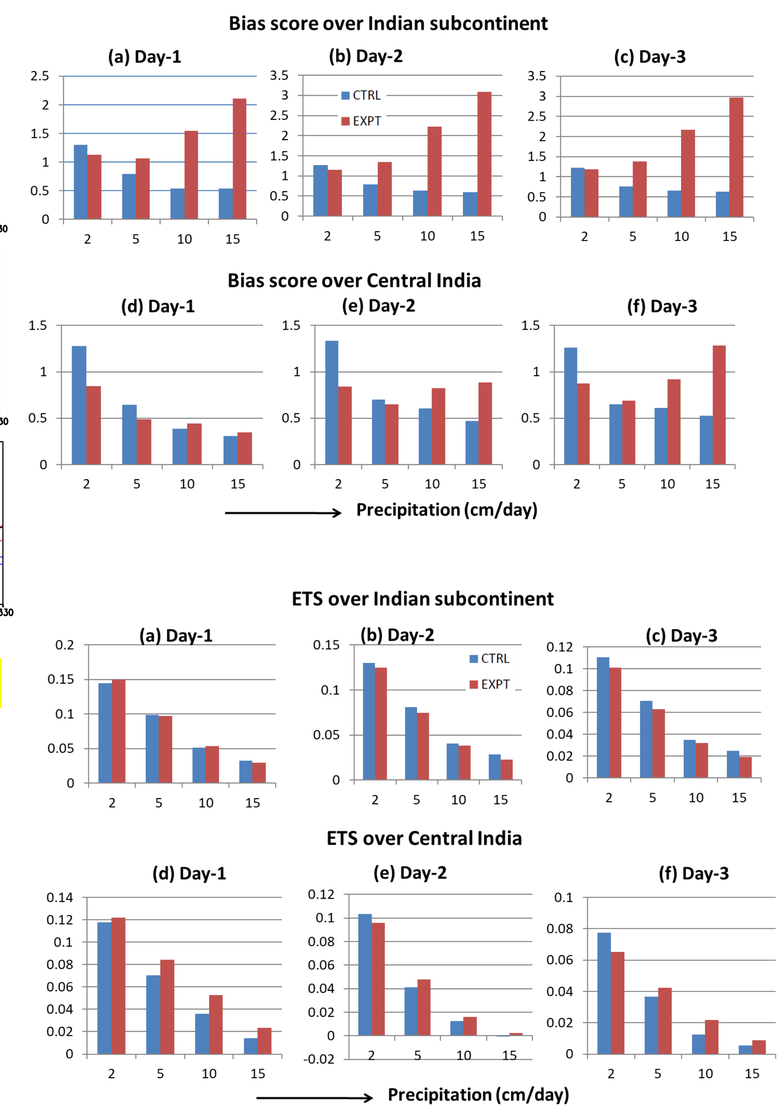
Model difference of convective and large-scale rainfall (cm/day)

Vertical profile of RH (shaded in %) vs rain rate (mm/day) over CI

Diurnal cycle of rainfall (mm/hr)



Skill scores over all India landmass and CI region



Evaluation of extreme rainfall event