Impact of spectral nudging in the simulation of summer monsoon rainfall over India

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Introduction

With the advancement in computational facility and dynamical models, the water and disaster management organisations are demanding the high resoultion rainfall information. The monsoon system influenced countries mainly in India, receives (in JJAS) about 80% of annual rainfall. Therefore, the prediction of Indian summer monsoon rainfall (ISMR) is essential for crop yeilding and economic status of India. From last few decades, Global Climate Models (GCMs) are used, which are capable of capturing the large and synoptic scale features, but, the simulated rainfall skill is poor. Since these simulations are at corser resolution results, discripancy in capturing the subgrid-scale physics and dynamics. GCMs at finer resolution is computationally expensive, Therfore an alternative technique is dynamical downscaling of GCM'S forecasts using Regional Climate Models (RCM). Theses simulations are with improved representation of local scale features. During downscalling approach, the supply of lateral boundary condtions from the GCMs to RCMs faces conflict in space and time resolution. Hence large-scale circulations are altered, which gives systematic errors for long-term RCM simulations. This inconsistency is overcome by using spectral nudging technique. It helps to ensure the consistency between large-scale driving fields and model solutions (months to seasonal scales).

Objectives

- ✓ The aims of this study is to assess the impct of spectral nudging in simulating the variablity of ISMR at (i) seasonal and (ii) sub-seasonal time scales over India and its homogeneous monsoon regions (HMR).
- ✓ It also assess the fedility of the model in capturing the monsoon extremes.

Data

- ➢ ERA5 reanalysis data from European Centre for Medium-Range Forecasts (ECMRWF) at 75km is used to force the Weather and Research Forecast (WRF) model.
- ➢ The ISMR simulation (1982-2018) is carried out with spectral nudging (SN) and without spectral nudging (NSN) at 15km grid spacing with 34 vertical level. In SN, wind and temperature fields are updated.
- ➢ The model uses Noah scheme for Land surfae model, The parameterisation schemes used are Mellor-Yamada and janjic for paletary boundary layer, WRF double moment class 5 for microphysics,Betts Miller Janjic for cumulus convection and Rapid Radiative Transfer Model for long wave/short wave radiation.
- ➢ The model rainfall is compared with high resolution(0.25°×0.25°) India Meteorological Department (IMD) data which is prepared using a dense network of rain gauge stations

Results & Discussion

a) Simulation of ISMR:

The spatial distibution of seasonal mean rainfall is well captured by SN experiment over India and it's 5 homogeneous monsoon regions (Peninsular [PEN], hill region in north India [HILLY], west-central India [WCI], and northwest India [NWI], central northeast India [CNE]), except over northeast India [NEI]. It is evident that the SN experiment has shown reduced Bias, RMSE and high correlation coefficients over India and its HMR except over NEI. The all-India area-averaged seasonal mean rainfall simulated from SN (6.7 mm day^{-1}) is close to observation (6.9 mm day^{-1}), while the NSN (6.1 mm day^{-1}) is slighly underestimated.

Figure1. Spatial distribution of seasona rainfall (mm day^{-1}) over India for IMD, SN and NSN.

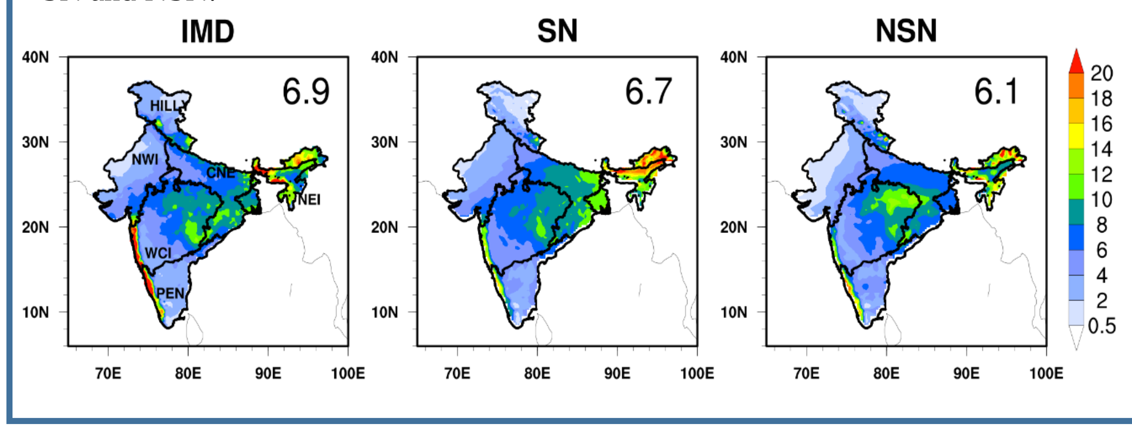


Table.1 Spatial rainfall statistics for SN and NSN againsta IMD.

Exp	PEN	NEI	HILLY	WCI	NWI	CNE	All India
BIAS (mm day^{-1})							
SN	-0.29	1.18	-0.54	-0.25	-0.20	0.76	0.67
NSN	0.45	-1.47	-0.53	-0.23	-1.59	-0.47	-0.65
RMSE (mm day^{-1})							
SN	4.1	7.3	3.6	3.8	3.1	4.7	4.5
NSN	5.6	8.3	4.7	6.4	5.0	6.1	6
CC							
SN	0.39	0.48	0.64	0.77	0.79	0.65	0.62
NSN	0.16	0.33	0.38	0.40	0.42	0.41	0.35

b) Simulation of Sub-seasonal rainfall :

Intrestingly, the SN outperforms the rainfall simulation in first 60 days (June-July). It is becasue the spectral nudging acts as a tendency term, which diminishes the errors in SN. Therfore, the average RMSE in month-1 to month-2 is 1.5-2 mm day^{-1} in SN, Where as in NSN it is much higher 3.5 and 3.5 mm day^{-1}). However the remarkable reduction in RMSE is noticed over in SN compared to NSN. The NSN experiment has shown relatively poor performance in June and July compared to August and September. The NSN giving more errors than in SN over India and HMR. These errors in NSN are becasue of the unavoidable incompatibilities arises between bounday conditions and model soultions.

Figure2. Temporal variation of daily rainfall (mm day^{-1}) over India for IMD, SN and NSN.

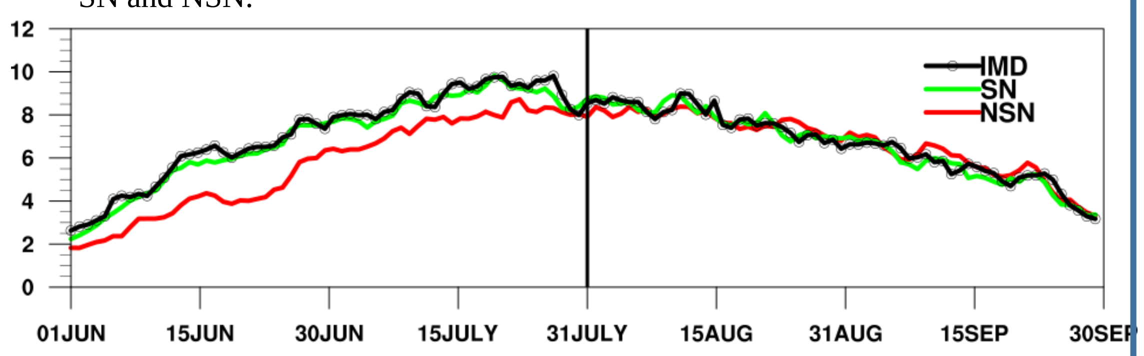
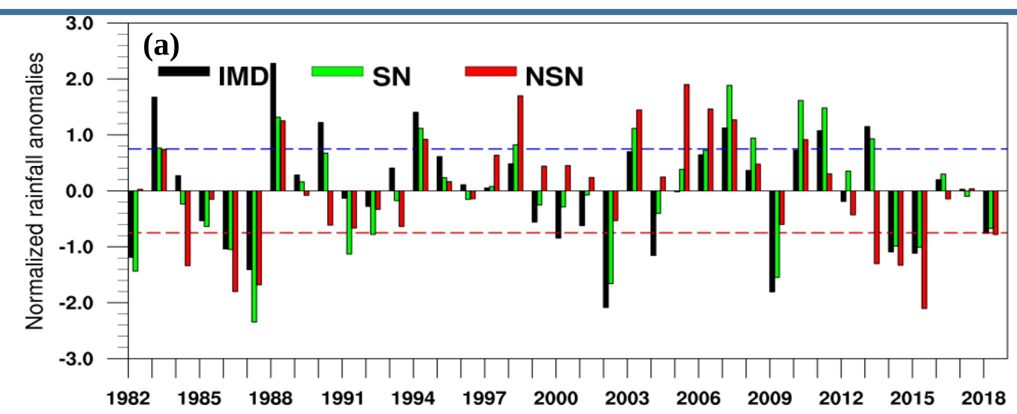


Table.2 Errors of monthly Rainfall over India and homogeneous regions for SN and NSN againsta IMD.

Simulation length	EXP	RMSE (mm day^{-1}) PEN	NEI	HILLY	WCI	NWI	CNE	All India
Month-1	SN	4	8.5	3	3	2	4	1.5
	NSN	7	10	4	6	4	6	3.5
Month-2	SN	4.5	7.5	3.5	4	4	5.5	2
	NSN	5	8.5	5	8	6.5	7	3.5
Month-3	SN	4	7	4	4	3.5	5	2
	NSN	5	7	5	6.5	5	6	2.6
Month-4	SN	4	6	4	3	2.5	4	1.5
	NSN	5	7	5	5	4	5.5	2.5

c) Inter-Annual Variability of ISMR :

The monsoon extremes are identified if the normalized rainfall anomalies grater than +0.75(-0.75) as an excess (deficit). If it lies between ±0.75, it is normal monsoon year. The detection rate of the SN (NSN) for normal, excess, and deficit is 75% (70%), 86% (43%), and 70% (45%) with high TS of 0.6 (0.5), 0.55 (0.25), and 0.58 (0.42) respectively. The SN simulated rainfall of ~9 mm day^{-1} at 55%, 10.5 mm day^{-1} at 58%, 7 mm day^{-1} at 52% is frequent for normal, excess and deficit, respectively, showing close agreement with observation.



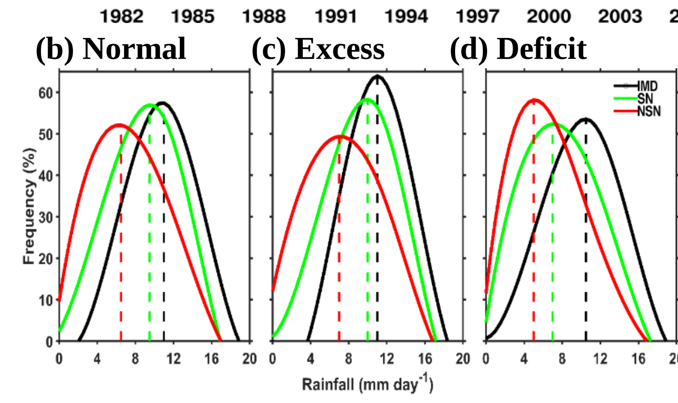


Figure3. a) Interannual variability ISMR for IMD, SN and NSN The PDF of rainfall occurrence from SN, NSN and IMD are for (a) normal, (b) excess and (c)deficit years composites

Conclusions

- ❖ Improved spatial rainfall patterns and magnitudes are found with spectral nudging in seasonal and sub-seasonal scales.
- ❖ Reduced rainfall biases are observed over India as a whole and it's 5 homogeneous monsoon regions out of 6 in SN (Table 1).
- ❖ Significant improvement in daily rainfall is observed in first 60 day's, spectral nudging experiment compared to no spectral nudging.
- ❖ Better signal of interannual variability is acheived by SN.

Acknowledgements & References

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