Reproducibility of Indian summer monsoon rainfall in convection permitting Weather Research Forecasting model

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Abstract

Dynamical downscaling of Indian summer monsoon rainfall (ISMR) by using regional climate models (RCMs) portrays the inability of the RCMs in simulating the ISMR, and certain systematic biases appear in the seasonal monsoon rainfall climatology. The inconsistency in RCMs simulation of ISMR can be due to the improper representation of convection by convective and/or microphysical parameterization schemes in different RCMs. In this study, we conducted convection permitting simulations in WRFv3.8.1 and compared with parameterized simulations, to understand the difference of reproducibilities of time-space patterns in the ISMR. Our experimental set-up consists of two sets of simulations with parameterized and explicit convection on a grid resolution of 25 km. The simulations are conducted for three different monsoon seasons: flood, drought, and normal years, to ascertain robustness in the analysis of the model output. These simulations are forced by using ERA-Interim reanalysis as the lateral boundary and large-scale forcing input. The mean large-scale circulation, the spatial distribution of rainfall, seasonal northward propagation of rain bands, and magnitude-phase of the Indian summer monsoon rainfall are verified against the JRA55 reanalysis and India Meteorological Department gridded rainfall datasets. The results show that regional simulations with explicit convection have benefited in the simulation of ISMR features. Simulated seasonal mean rainfall in parameterized convection shows positive bias over Gangetic plains and the Western Ghats. The same bias reduced in explicit simulations and seasonal mean ISMR behaves realistically concerning IMD observations. The added value in the simulation of ISMR in explicit experiments is found to be consistent during the flood, drought, and normal monsoon seasons. Further evaluation of the results reveals that over Indian region, explicit convection simulations of Indian summer monsoon are more realistic than parameterized convection simulations. Therefore, the current study tried to show up the uncertainties in ISMR simulation associated with parameterizations, and explicit convection experiments highlight the reduction of these uncertainties.

Realistic simulation of Indian summer monsoon rainfall in convection permitting Weather Research Forecasting model

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Dynamical downscaling of Indian summer monsoon rainfall (ISMR) by using regional climate models (RCMs) portrays the inability of the RCMs in simulating the ISMR, and certain systematic biases appear in the seasonal monsoon rainfall climatology. The inconsistency in RCMs simulation of ISMR is due to the improper representation of convection by parameterization schemes in different RCMs. In this study, we conducted convection permitting simulations in WRFv3.8.1 and compared with parameterized simulations. Our experimental set-up consists of two sets of simulations with parameterized and explicit convection on a grid resolution of 25 km. The simulations are conducted for three different monsoon seasons: flood, drought, and normal years, to ascertain robustness in the analysis of the model output. These simulations are forced by using ERA-Interim reanalysis as the lateral boundary and large-scale forcing input. The mean large-scale circulation, the spatial distribution of rainfall, seasonal northward propagation of rain bands, and magnitude-phase of the Indian summer monsoon rainfall are verified against the ERA-Interim reanalysis and India Meteorological Department gridded rainfall datasets, respectively. The results show that regional simulations with explicit convection have benefited in the simulation of ISMR features. Simulated seasonal mean rainfall in parameterized convection shows positive bias over Gangetic plains and the Western Ghats. The same bias reduced in explicit simulations and seasonal mean ISMR behaves realistically concerning IMD observations. The added value in the simulation of ISMR in explicit experiments is found to be consistent during the flood, drought, and normal monsoon seasons. Further evaluation of the results reveals that over Indian region, explicit convection simulations of Indian summer monsoon are more realistic than parameterized convection simulations. Therefore, the current study tried to show up the uncertainties in ISMR simulation associated with parameterizations, and explicit convection experiments highlight the reduction of these uncertainties

Introduction

- ✓ Indian summer monsoon (ISM) realistic simulation and efficient prediction a challenge to the climate modelers.
- ✓ Indian summer monsoon exhibits large heterogeneity in the rainfall space-time distribution. Due to that its simulation in Global climate models (GCM) is debatable.
- ✓ In order to capture regional hydrological features of ISM, Regional climate models (RCM) are employed to downscale the GCM outputs.
- ✓ Even then there are large biases in the RCMs representation of ISM rainfall and mean dynamical features.
- ✓ Lucas-Picher et al. (2011) and Fersch et al. (2014) rightly pointed out the reason for RCM ISM biases are processes & feedbacks are not represented properly in RCMS. Also, convective parameterization contribute to the major bias
- ✓ Current study attacks on the convective parameterization problem and able to resolve the model biases in the in the explicit convection setup of the model. It is first time to simulate continental scale simulation of ISM in explicit mode.

Datasets and Model utilized

Model Utilized : WRF3.8.1

Kain Fristch Convection Scheme (On/Off)
MYJ boundary layer scheme
Noah land surface scheme.
WSM6 cloud microphysics microphysics

- ▪Era-interim (ERAI) reanalysis is used as initial condition and OISST as lower boundary condition
- ▪ Contrasting ISM years are simulated from April 1st to October 31st.
- ▪2012 : Normal Year; 2009 : Drought Year; 1994 : Flood Year

Dataset for verification

- ▪IMD 25 km gridded daily rainfall
- ▪Era-Interim reanalysis pressure levels and surface data.

Results and Discussion

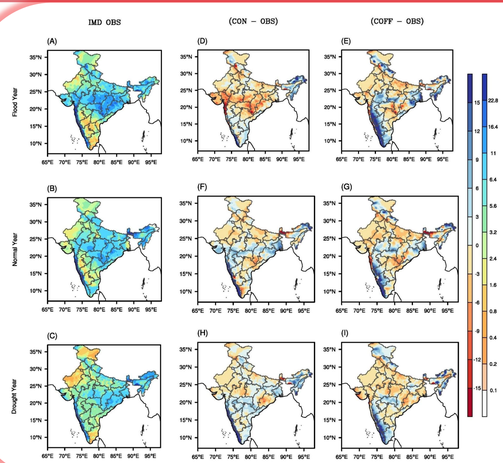


Fig 1: Seasonal mean plot of model and observations

- ✓ Convection on : CON
- ✓ Convection off : COFF
- ✓ COFF experiments better captures the drought, normal and flood years as compared to the CON.
- ✓ A dry bias in CON over central India is reduced in COFF.

Results and Discussion

Fig 2: Scatter plot of pattern correlation coefficient and ISM rainfall bias.

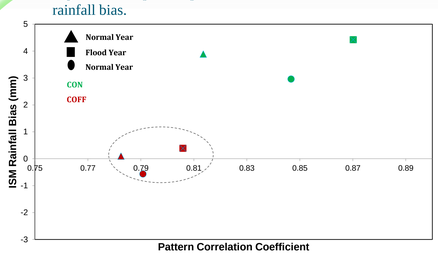
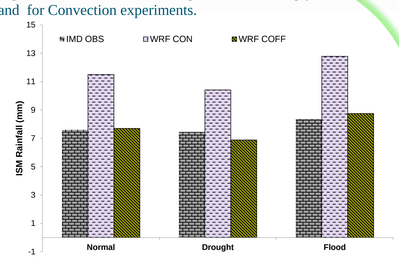
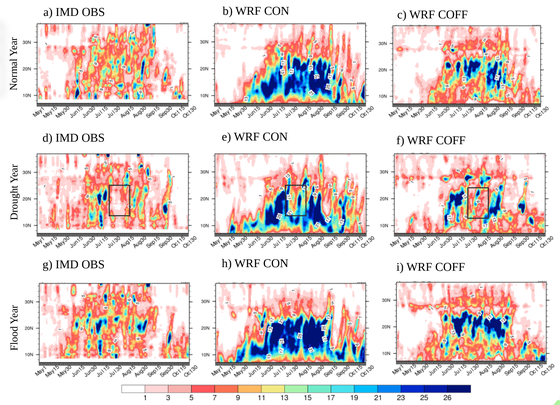


Fig 3: ISM rainfall area averages for contrasting years and for Convection experiments.



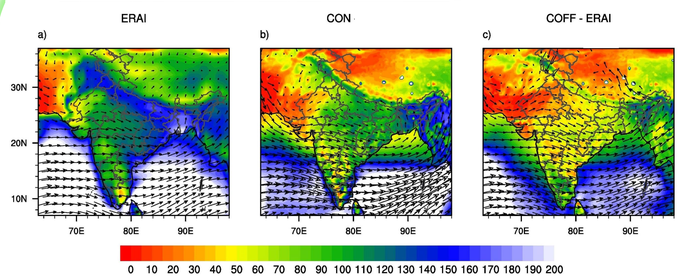
- ✓ ISM area averaged rainfall biases are drastically reduced and the simulated rainfall is very close to the observations as explained from fig 2 and fig 3.
- ✓ It is very important to understand what kind of overestimation in CON is reduced in the COFF simulations.

Fig 4: The large-scale representation of the ISMR propagation during summer monsoon season.



- ✓ CON simulations overestimate the ISM rainfall.
- ✓ COFF experiments significantly reduces the rainfall and tries to capture the rainfall phase (time of occurrence of rainfall).
- ✓ Northward propagation is only up to 24°N in CON but it extends up to 27°N in the COFF.
- ✓ Both simulations have dry bias over Ganges plains.

Fig 5: Near surface and lower atmosphere changes in the CON and COFF simulations.



- ✓ In CON simulation southwesterly jet is overestimated and near surface is moist.
- ✓ COFF simulation very clearly captures southwesterly ISM winds.
- ✓ Near surface moisture availability is less in COFF as compared to CON.
- ✓ Near surface conditions are dry over central Ganges plains in COFF simulation.

- ✓ In CON simulation southwesterly jet is overestimated and 850 hPa geopotential heights are negatively biased.
- ✓ 850 hPa geopotential heights Biases has reduced in COFF.
- ✓ Dry North westerlies dominant over north-central India and over Ganges plains.

Fig 6: Lower atmosphere biases in the CON and COFF simulations.

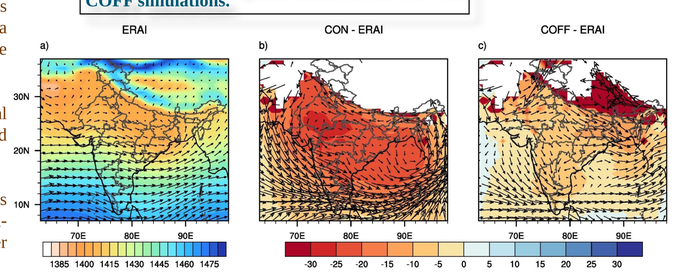
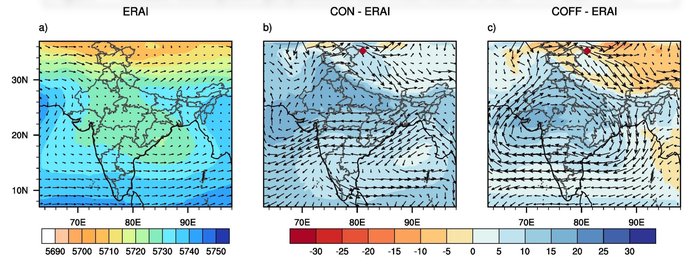
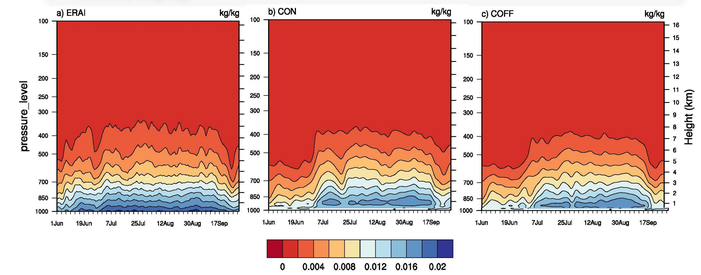


Figure 7: Middle atmosphere geopotential and wind biases in the CON and COFF.



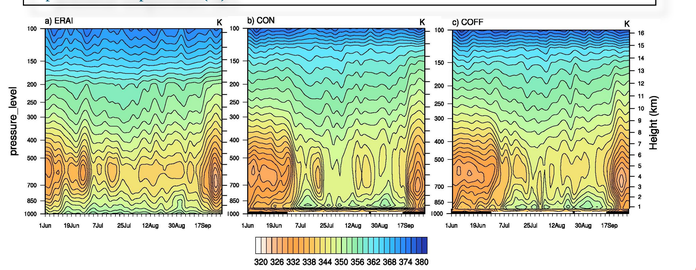
- ✓ COFF very clearly captures middle atmosphere anticyclone, which is corresponds to the lower atmosphere monsoon trough over central India.
- ✓ Surface Analysis and winds analysis portrays the betterment of the biases and representation of wind patterns.

Figure 8: Height vs Time diagram over monsoon core region (MCR) for a) specific humidity (kg/kg).



- ✓ Specific humidity representation in both of the simulations is almost similar but much not as much deep as shown in ERAI.
- ✓ During initial phase of monsoon specific humidity found to be low as compared to ERAI.

Figure 9: Height vs Time diagram over monsoon core region (MCR) for b) equivalent potential temperature (K).



- ✓ Middle atmosphere low convective instability is captured well in the COFF than in CON.
- ✓ Low specific humidity during initial phase of monsoon is due to the low or no convective instability in the lower atmosphere.

Summary

- ❑ **Current study very clearly shows the proper representation of the large scale features of the monsoon and resolving appropriately the convective behavior in the lower atmosphere improved Indian summer monsoon simulation in the explicit convection (COFF) mode.**
- ❑ **The overall biases shown in parameterized convection (CON) are reduced in explicit convection (COFF) mode, thus contributed in the reduced in the all India average rainfall bias in COFF.**
- ❑ **More feature and interaction based analysis was performed, which is getting ready for publication.**

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Keywords: Indian summer monsoon rainfall, Regional climate models, explicit convection, parameterization, JRA55 reanalysis, ERA-Interim reanalysis