Representation of North Indian Winter Precipitation in a High Resolution WRF Model: Sensitivity to different Cumulus Parameterization Schemes

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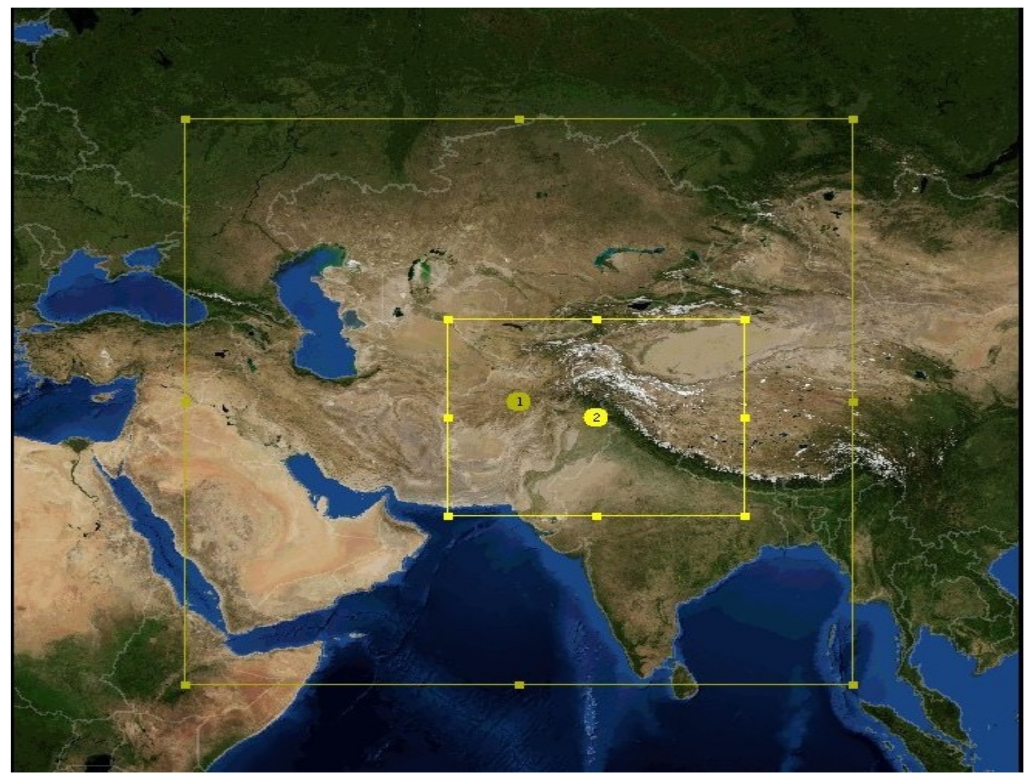
Introduction

- North Indian Winter precipitation (December-March) contributes about one-third of the annually received precipitation over the region (Hunt et al., 2018; Dimri et al. 2016).
- However, limited observations combined with complex Himalayan orography highlights the necessity of high resolution regional climate models over available coarser data to resolve complex topography and simulate precipitation and regional convection processes accurately.
- This work aims to explore the sensitivity of north Indian winter (DJFM) precipitation and underlying dynamical features to three convective physical parameterization schemes (CPSs), namely, Betts-Miller-Janjic (BMJ), Kain-Fritsch (KF) and Grell-Freitas (GF) and their ensemble mean (ENSM) in a high-resolution Weather Research and Forecasting (WRF) model during 2001-2016.

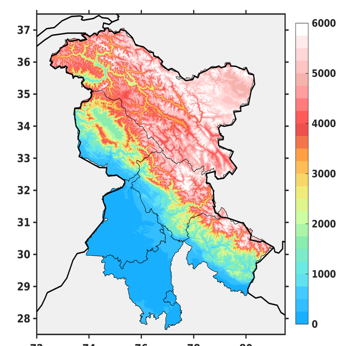
Model Configuration

This study used the Advanced Research Weather Research and Forecasting (WRF) model to simulate sensitivity of winter precipitation characteristics and key dynamics to three different CPSs and their ensemble over NIR during 2001-2016.

Model Configuration	Details
Domain Resolution	15 km and 5 km
Vertical	52 vertical sigma levels
Convection Scheme	BMJ, GF, KF
Radiation Scheme	RRTM (longwave and shortwave)
Microphysics Scheme	Thompson scheme
PBL	MYNN scheme
Land Surface	Noah land surface model
Initial boundary conditions	ECMWF ERA-interim



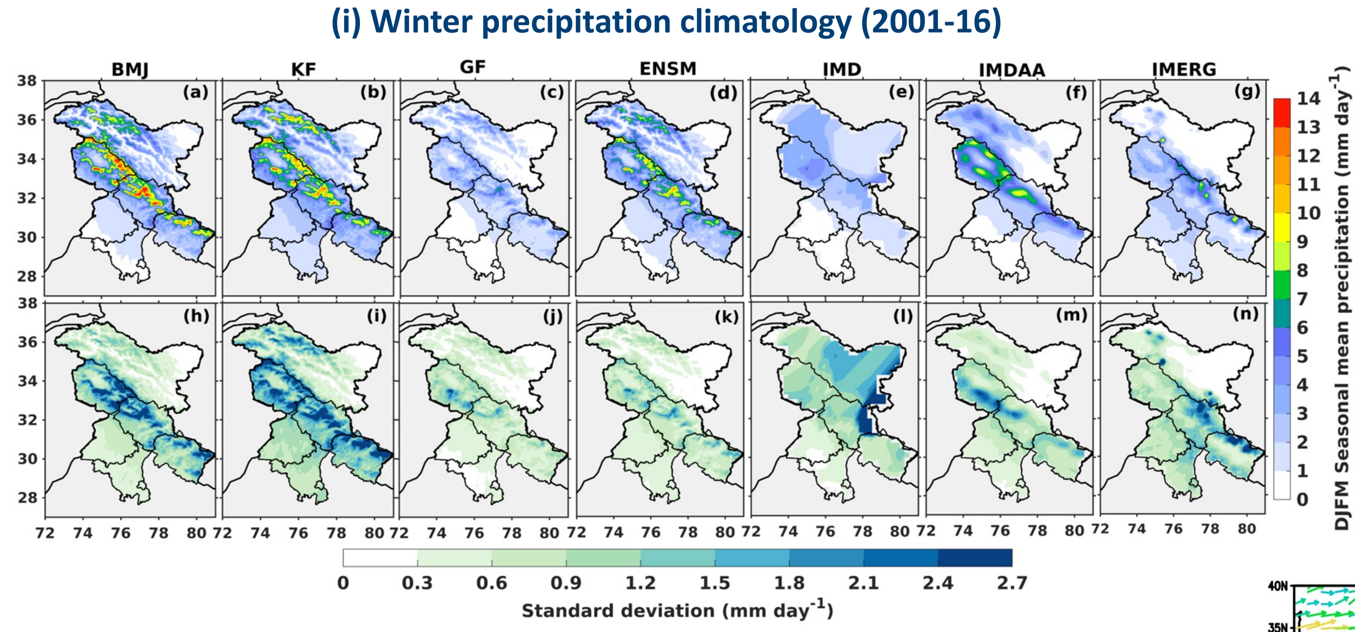
Data and Methodology

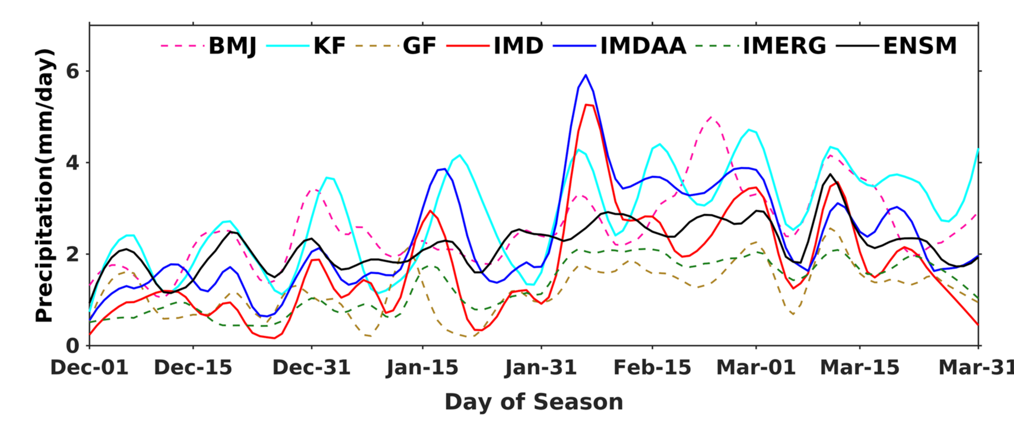


- Different multi-source precipitation datasets including gauge-based (IMD) and satellite (IMERG)observations as well as recently released high-resolution reanalysis dataset, IMDAA (12 km) have been utilized to validate model's simulated winter precipitation over NIR.
- Underlying dynamics and thermodynamics has been evaluated in reference to ERA5 reanalysis.
- **Validation Tools:** Various statistical indices such as root mean square error (RMSE), standard deviation, correlation coefficient etc. have been assessed to evaluate the model performance.

Results

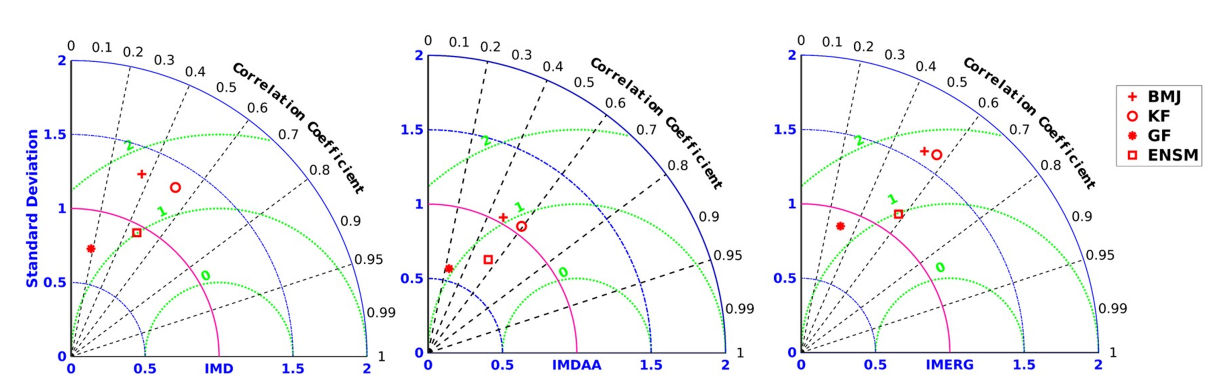
(i) Winter precipitation climatology (2001-16)

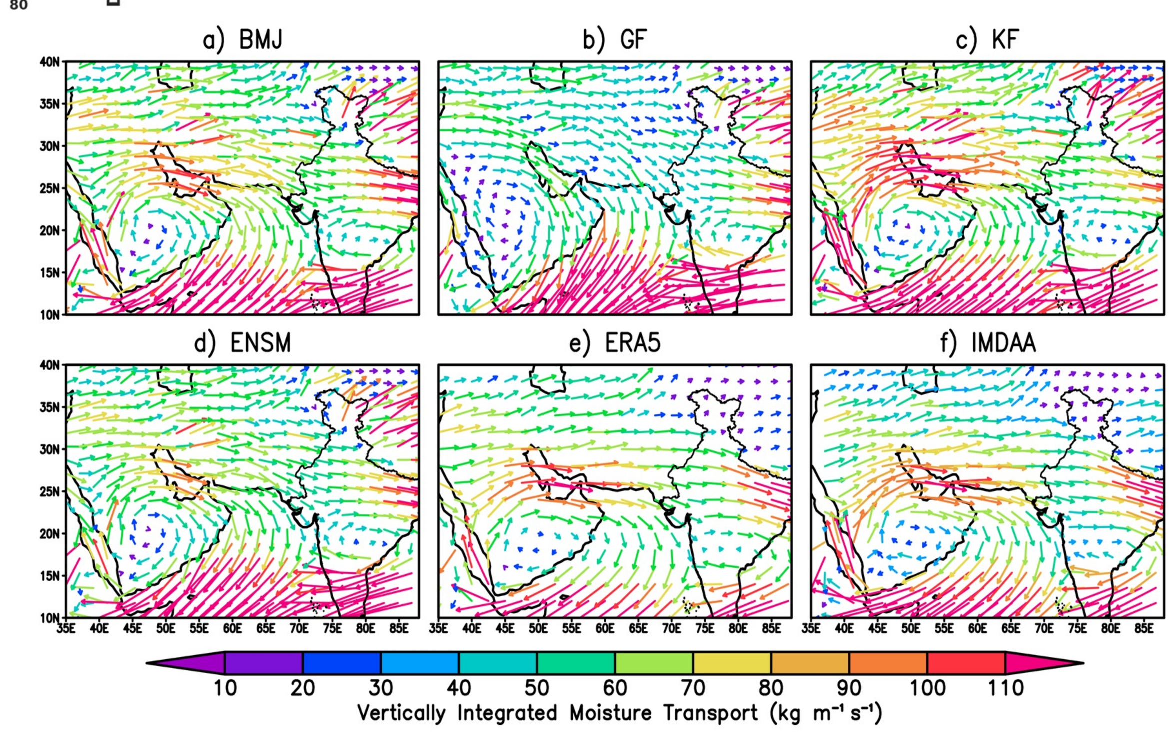




(ii) Seasonal evolution of north Indian winter precipitation

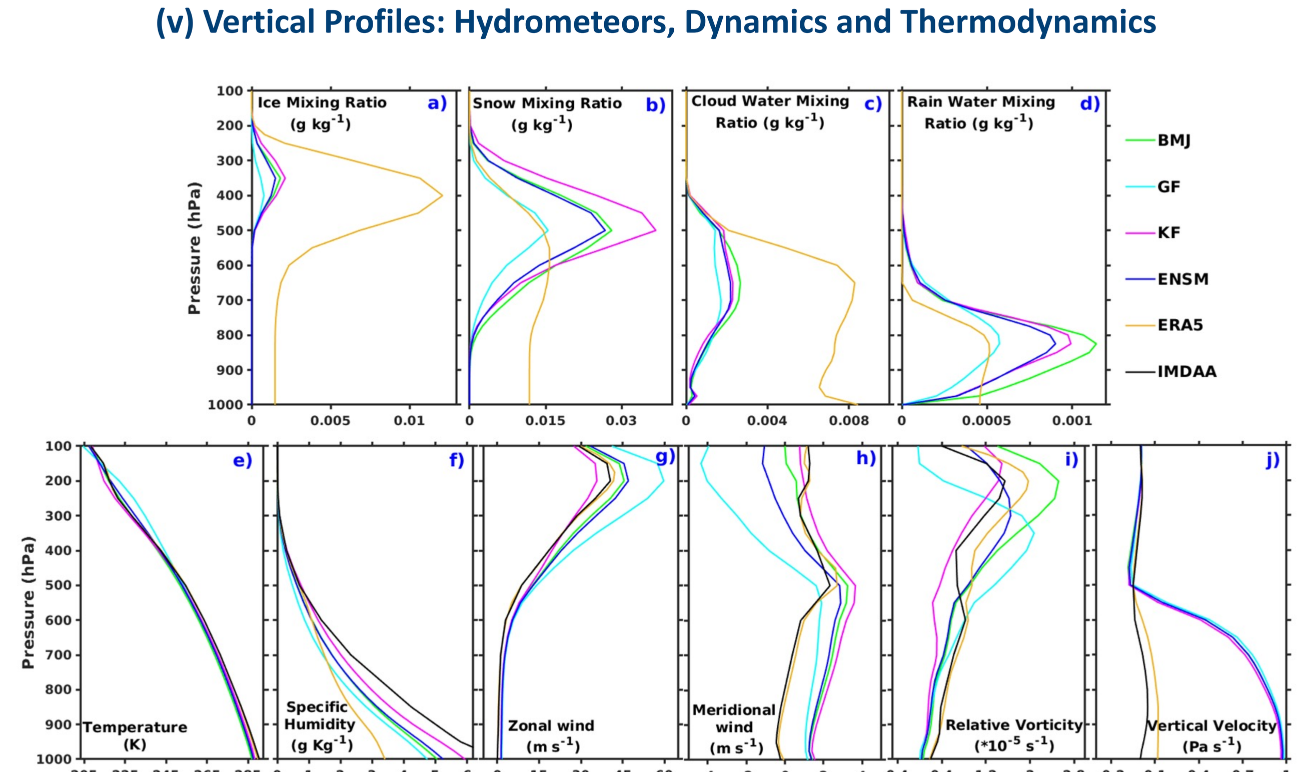
(iii) Taylor diagram depicting RMSE, SD and Correlation

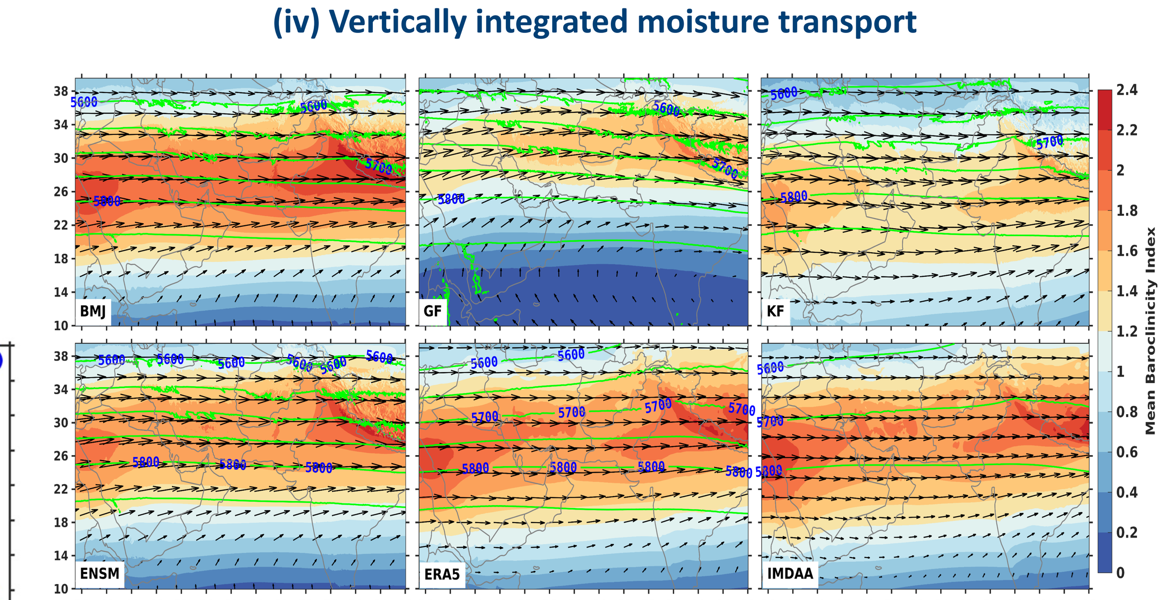




(iv) Vertically integrated moisture transport

(v) Vertical Profiles: Hydrometeors, Dynamics and Thermodynamics





(vi) Mean Baroclinic Index (Shaded), U200 (vectors) and 500hPa Geopotential height (contours)

Conclusion

- The elucidation of winter precipitation and associated dynamical parameters using different CPSs in WRF model suggests that model-simulated north Indian winter precipitation reflects a sensitivity towards the CPSs.
- All CPSs as well as their ensemble are able to represent the zone of maximum seasonal precipitation i.e. Himalayan foothills. Ensemble followed by KF and BMJ produce realistic geographical distributions of winter precipitation.
- Seasonal evolution of precipitation in ensemble and KF appears to be in good patternlike agreement with the references IMD and IMDAA, albeit with slight differences at certain points.
- The statistical analysis reveals low RMSE, standard deviation and stronger correlation for ensemble mean.
- GF exhibits a dry bias of precipitation ,both in terms of climatology and seasonal precipitation evolution, compared to IMD and IMDAA, but agrees more with IMERG.
- Upper tropospheric circulation (sub-tropical westerly jet), in terms of position and intensity, is well captured in ENSM, KF and BMJ.
- The simulated vertical profiles of various atmospheric parameters reveals the highest fidelity of KF, ENSM and BMJ with observed vertical thermodynamical structures compared to GF, thus highlighting realistic representation of convective processes.
- The analysis of atmospheric baroclinic instability, which increases over NIR during passage of western disturbances through the season, suggests that ENSM and BMJ more accurately simulates the baroclinic state of the atmosphere during winter, followed by KF.

References

- Attada, R., Dasari, H. P., Kunchala, R. K., Langodan, S., Niranjan Kumar, K., Knio, O., & Hoteit, I. (2020). Evaluating cumulus parameterization schemes for the simulation of Arabian Peninsula winter rainfall. Journal of Hydrometeorology, 21(5), 1089-1114.
- Argüeso, D., J. M. Hidalgo-Muñoz, S. R. Gámiz-Fortis, M. J. Esteban-Parra, J. Dudhia, and Y. Castro-Diez, 2011: Evaluation of WRF parameterizations for climate studies over Southern Spain using a multistep regionalization. J. Climate, 24, 5633–5651.
- Hunt, K. M., Turner, A. G., & Shaffrey, L. C. (2018). The evolution, seasonality and impacts of western disturbances. Quarterly Journal of the Royal Meteorological Society, 144(710), 278-290.
- Dimri, A. P., Yasunari, T., Kotlia, B. S., Mohanty, U. C., & Sikka, D. R. (2016). Indian winter monsoon: Present and past. Earth-science reviews, 163, 297-322.

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