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Performance of two planetary boundary layer parameterizations in the NCAR-CAM5 model over different climatic zones within Indian land

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PBL parameterization in NCAR-CAM5

1. Holtslag and Boville (HB_PBL) scheme

The scheme was proposed by Holtslag and Boville (1993) and it is based on non-local approach.

$$\overline{w'C'} = -K_c\left(\frac{\partial C}{\partial z} - \gamma_c\right) \quad (1)$$

$$K_c = kw_t z\left(1 - \frac{z}{h}\right)^2 \quad (2)$$

$\overline{w'C'}$ is the vertical kinematic heat flux of any quantity C, K_c is the eddy diffusivity, $\partial C/\partial z$ is the local gradient for C and γ_c reflects the non-local transport.

2. University of Washington Moist Turbulence (UW_PBL) Scheme

The UW_PBL scheme is proposed by Bretherton and Park (2009). Turbulent Kinetic energy (TKE) based approach has been followed in this scheme. The downgradient diffusion of momentum and conserved scalars is given by:

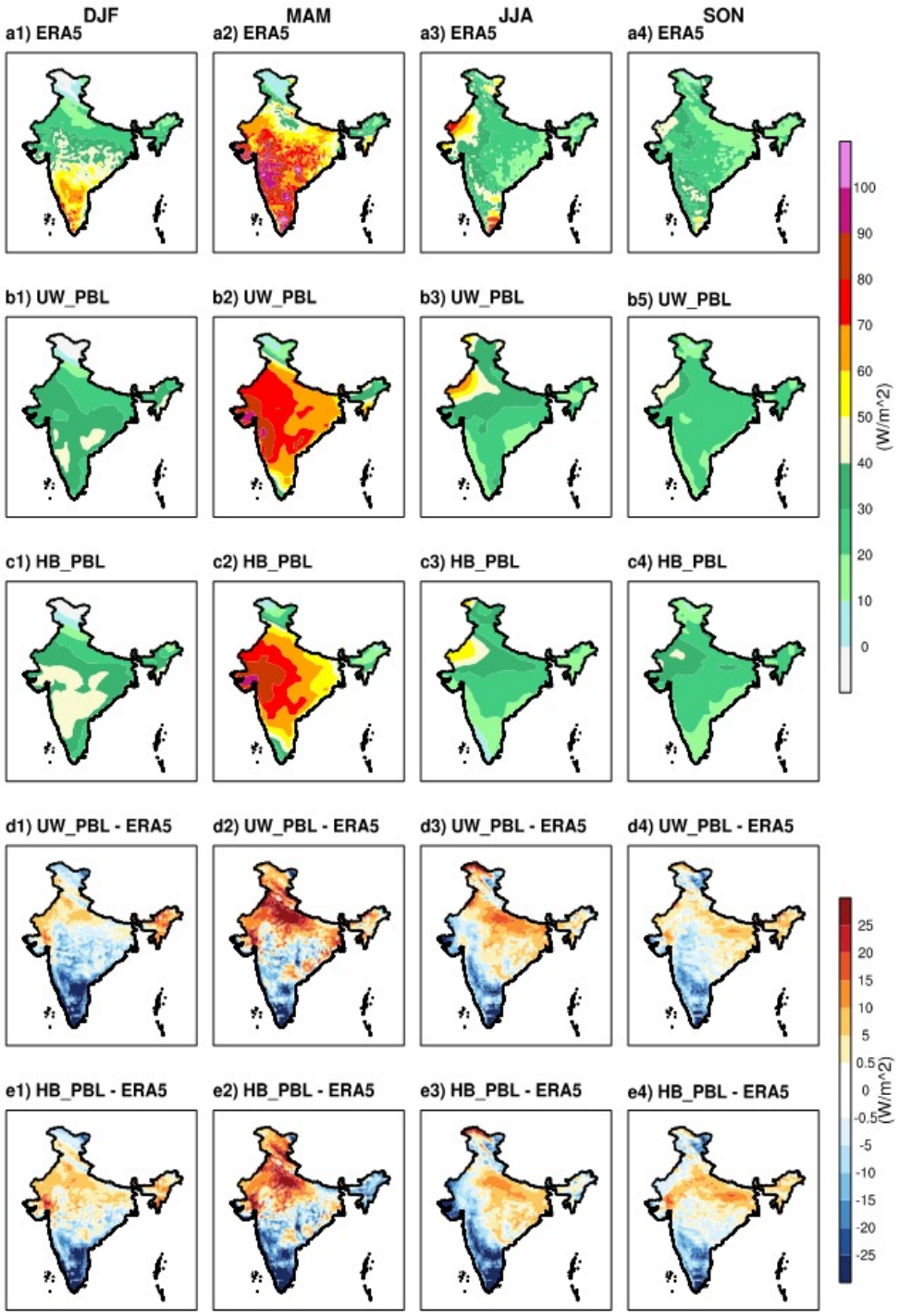
$$\overline{w'C'} = -K_c\frac{\partial C}{\partial z} \quad (3)$$

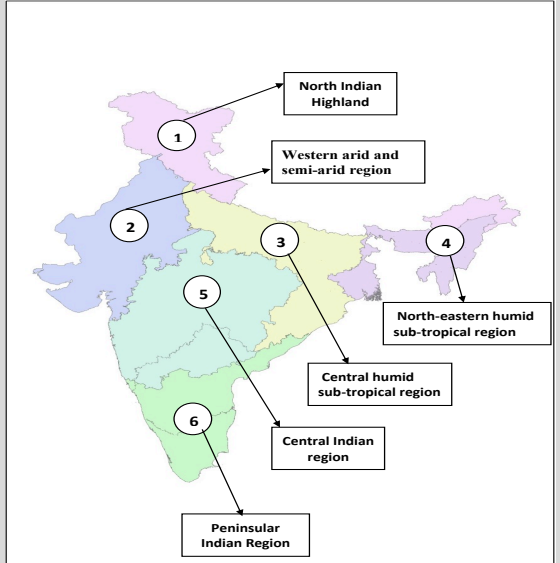
$$K_h = lS_h e^{1/2} \;\; and \;\; K_m = lS_m e^{1/2} \quad (4)$$

e is TKE and l is master turbulent length scale.

Model and Experiments

- This study evaluates the performance of the two PBL schemes available in the National Centre for Atmospheric Research (NCAR) Community Atmosphere Model version 5.0 (CAM5) under the framework of CESM1.2.0. Two simulations have been conducted for 6-year each using NCAR-CAM5 at a horizontal resolution of 0.9^{o} latitude $\times$ 1.25^{o} longitude and 30 vertical levels with different PBL schemes as
  1. UW_PBL (simulation using UW PBL scheme)
  2. HB_PBL (simulation using HB PBL scheme)
- The last five years of the simulation are used in the analysis, discarding the first year as spin-up. The model simulated variables are evaluated against global reanalysis and observational dataset. ERA5 reanalysis has been used for sensible (SHF) and latent (LHF) heat fluxes. Precipitation (PRECT) has been used with IMD (India Meteorological Department) observational data. However, for 2-m temperature (T_{2m}), blended product derived from the observational data by IMD over whole Indian land and ERA5 reanalysis over the north box (Indian land between 33-38.5^{0}N) have been used.

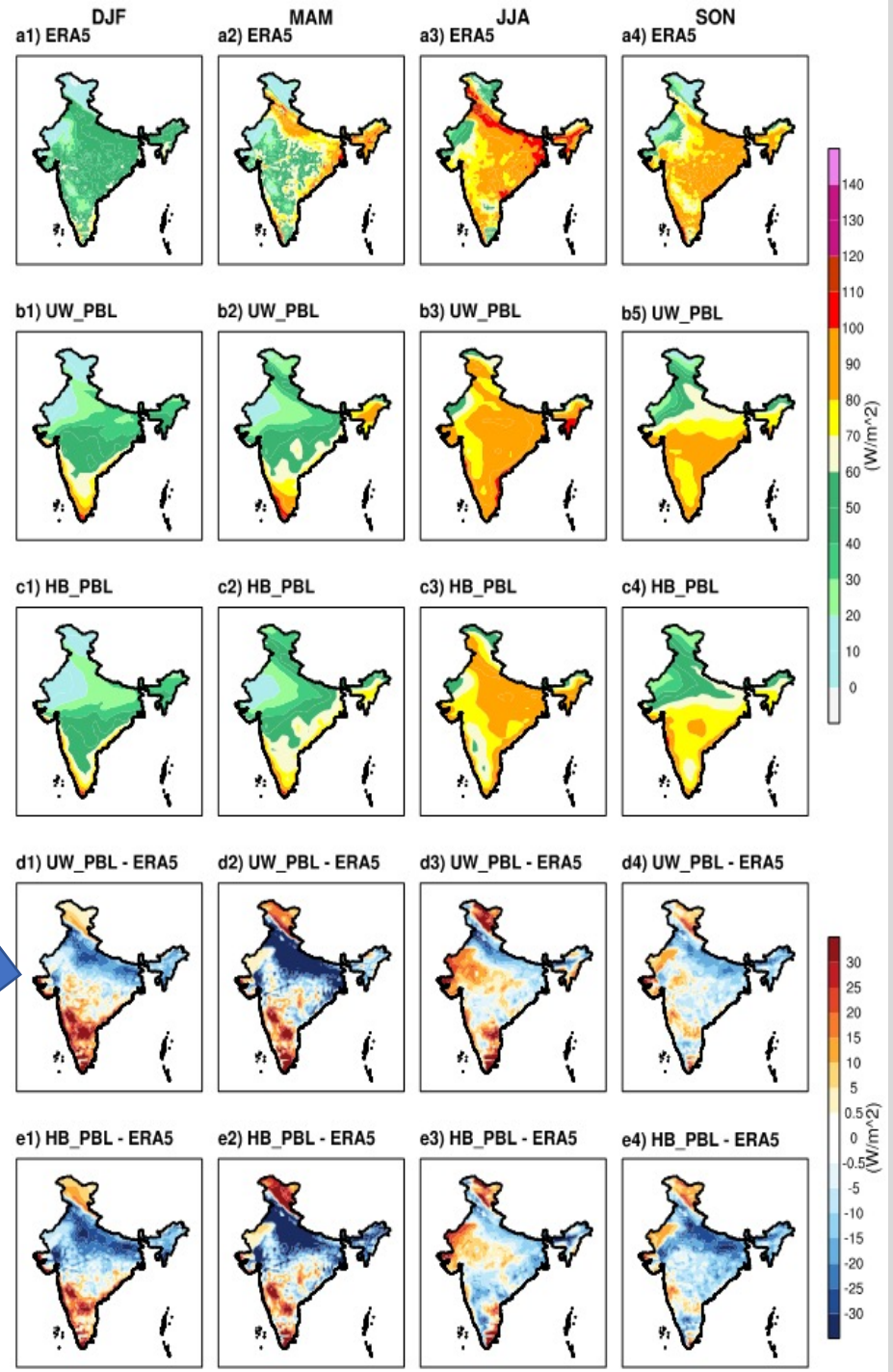


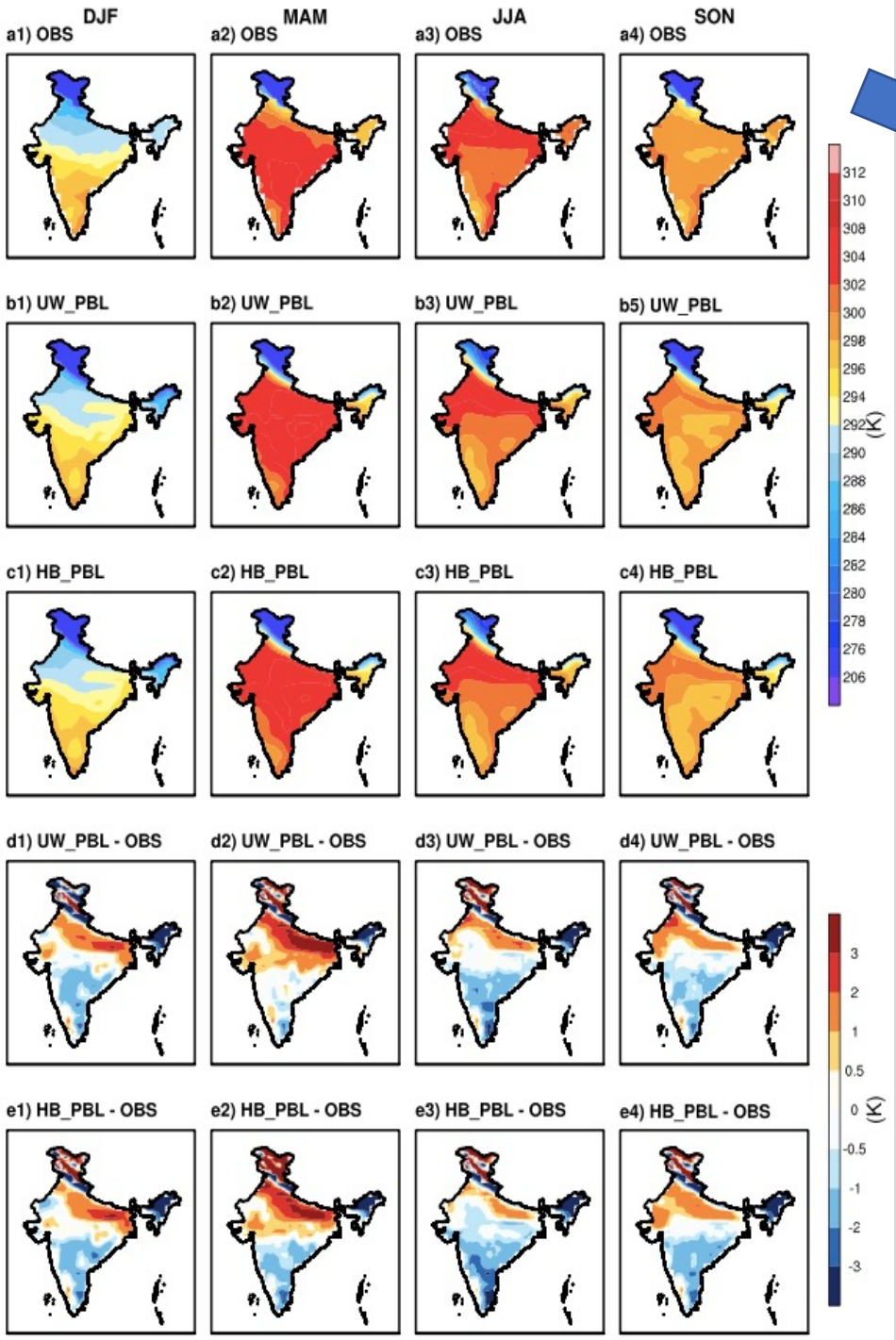


Different climatic zones exist with in Indian land.

Spatial distribution of 5-year average monthly mean SHF simulated by UW_PBL, HB_PBL and their differences compared with ERA5 reanalysis during different seasons.

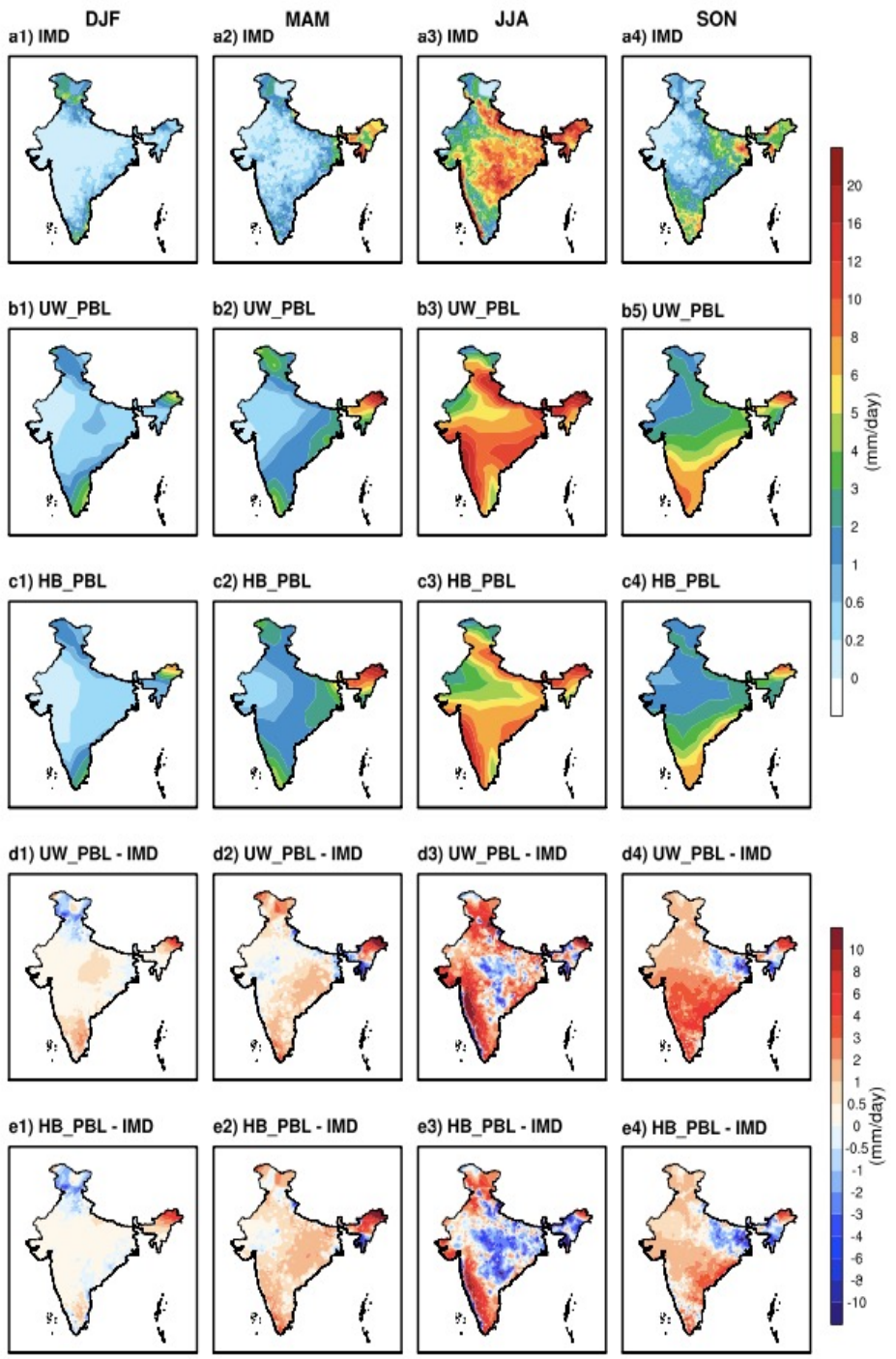
Spatial distribution of 5-year average monthly mean LHF simulated by UW_PBL, HB_PBL and their differences compared with ERA5 reanalysis during different seasons.

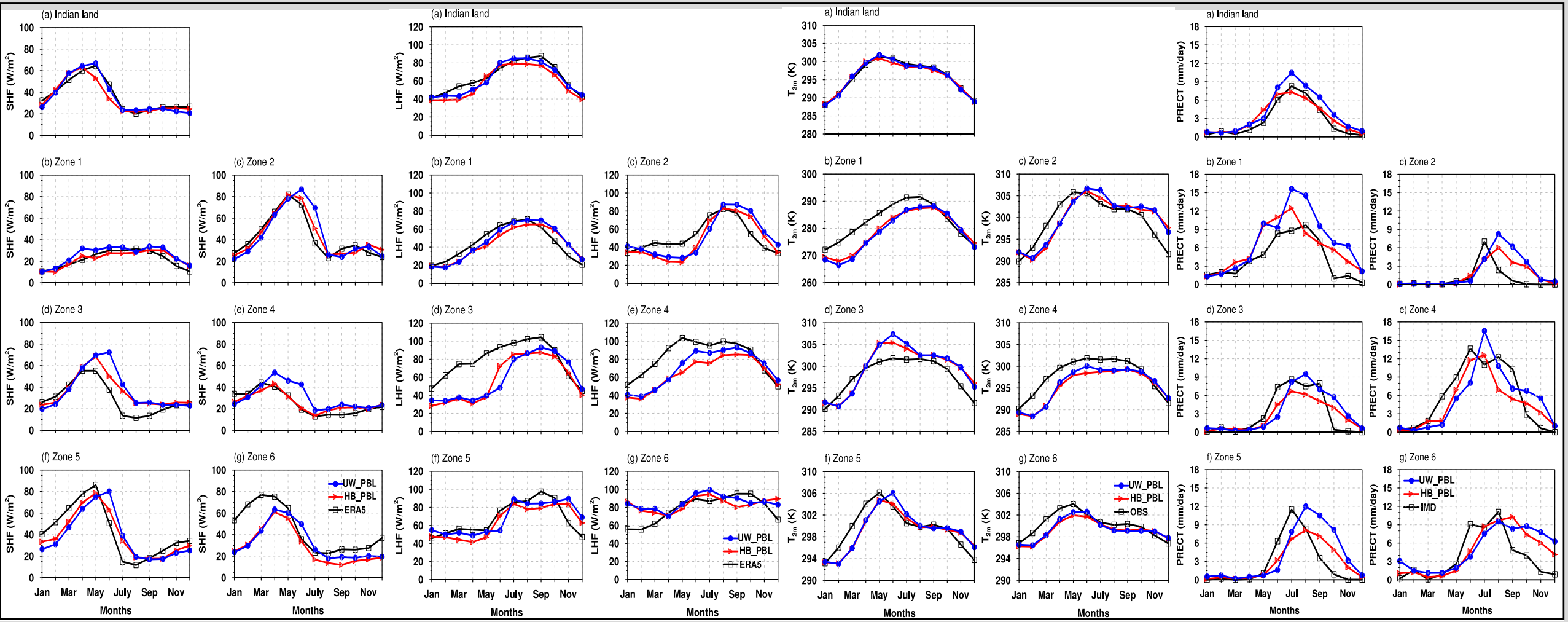




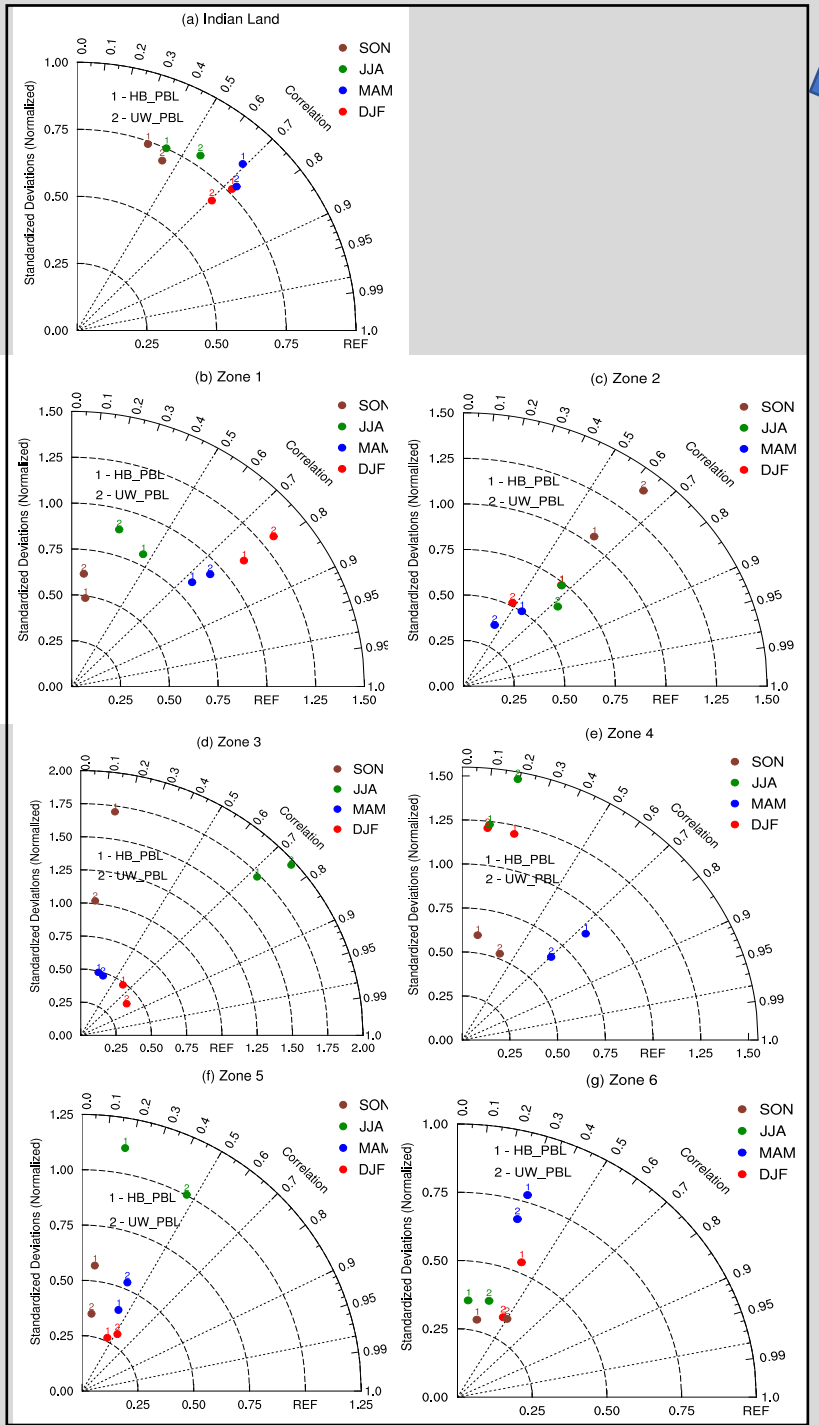
Spatial distribution of 5-year average monthly mean 2-m temperature simulated by UW_PBL, HB_PBL and their differences compared with blended product (OBS) during different seasons.

Spatial distribution of 5-year average monthly mean precipitation simulated by UW_PBL, HB_PBL and their differences compared with observational dataset from IMD during different seasons.



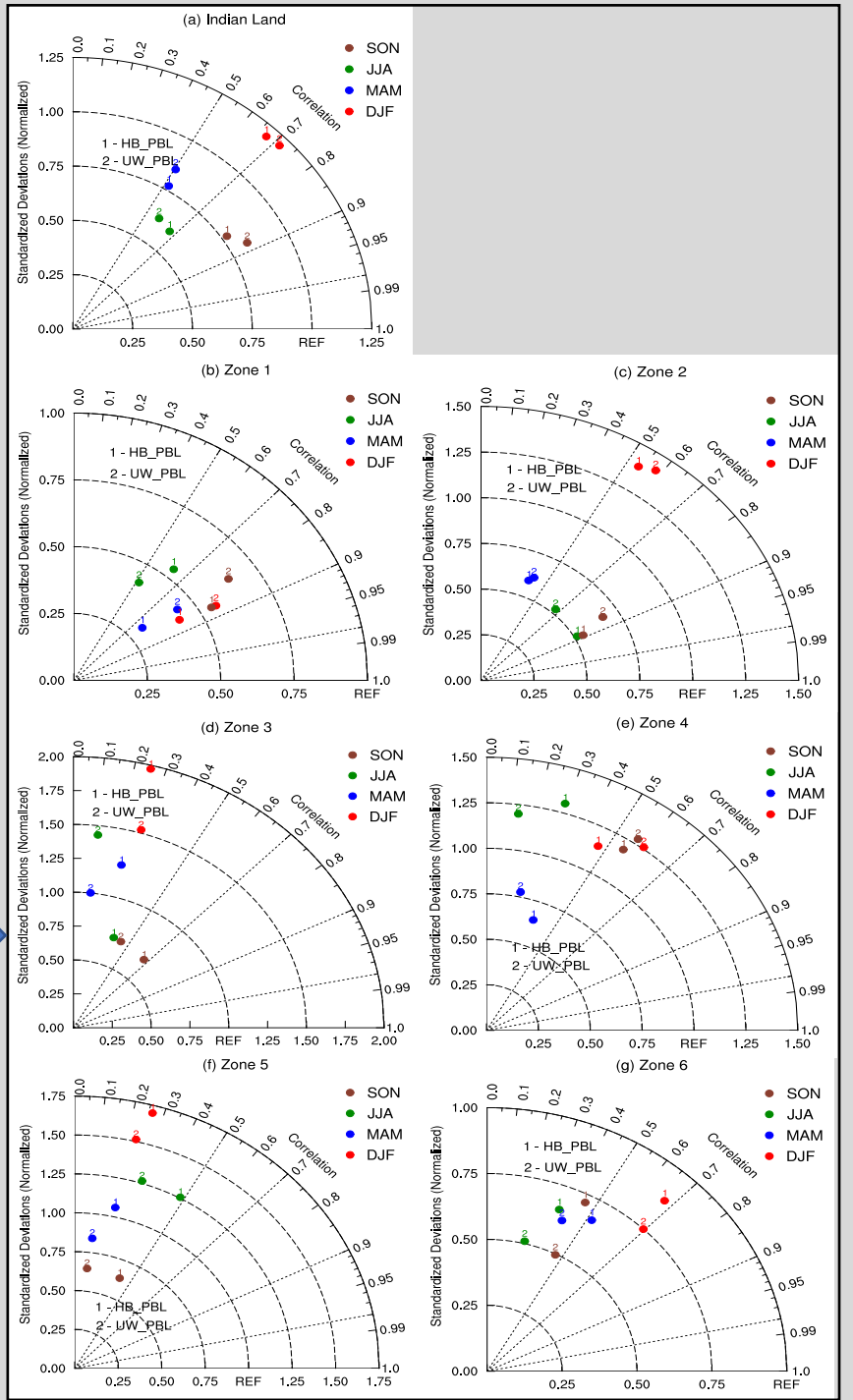


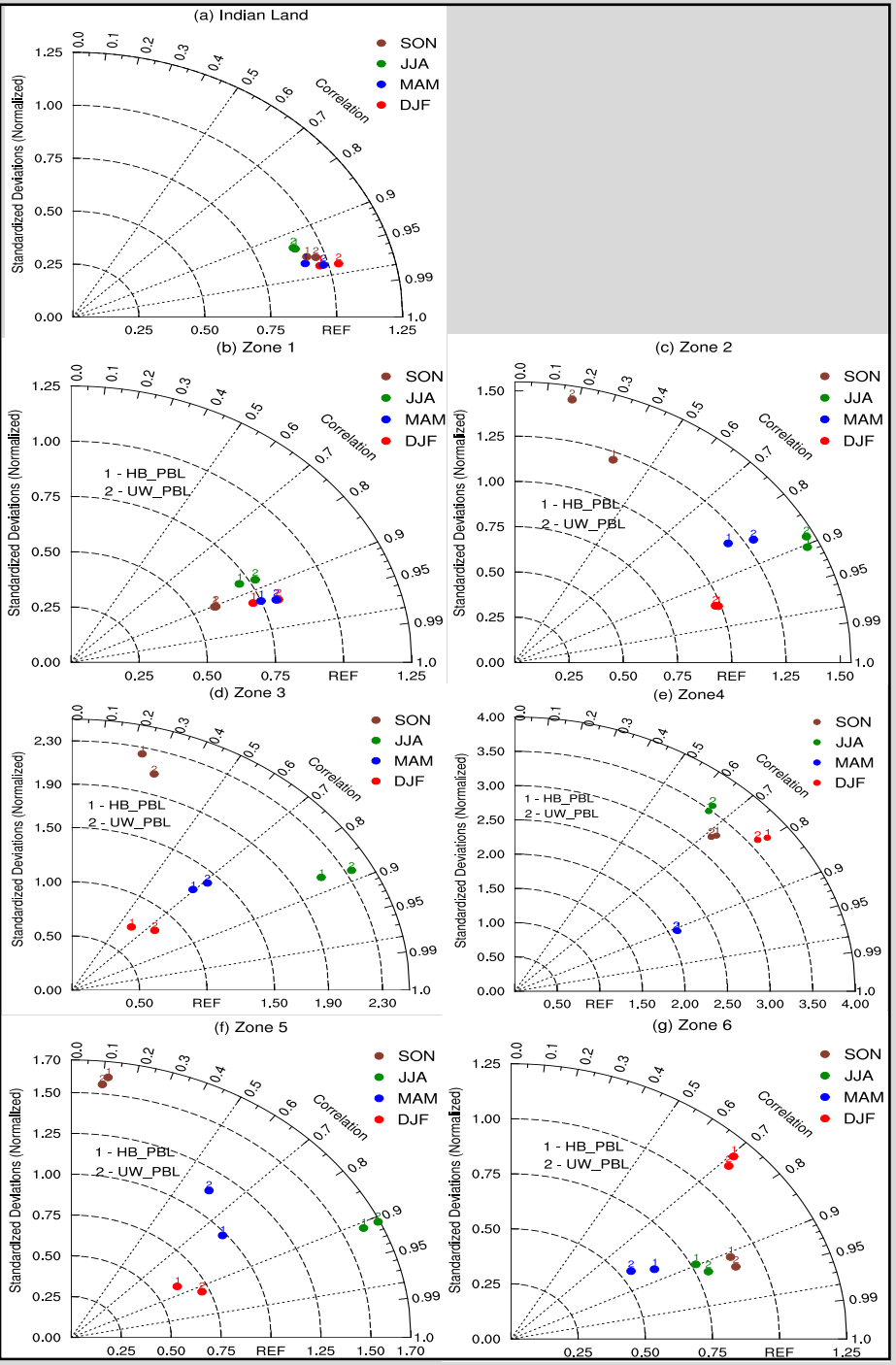
5-year average annual cycle of monthly mean (i) SHF, (ii) LHF, (iii) T_{2m} and (iv) PRECT over Indian land as well as different climatic zones.



Taylor diagram for simulated SHF over Indian land and different climatic zones. Pattern correlations for SHF simulated by HB_PBL over Indian land and different zones scattered approximately between 0.6 to 0.8, which suggests the strong correlation. However, the correlation for SHF simulated by UW_PBL also dispersed between 0.6 and 0.8, mainly for DJF and MAM seasons over Indian land as well as different zones, except zone 2, 5, and 6.

Taylor diagram for simulated LHF over Indian land and different climatic zones. HB_PBL show a strong correlation lying between 0.6 and 0.88 for LHF over Indian land and zone 1, and 2 for most of the seasons, except MAM over Indian land, DJF, and MAM in zone 2. In case of UW_PBL, the correlation lies between 0.6 and 0.88 over Indian land and zone 1, and 2 except MAM, and JJA season over Indian land, JJA in zone 1, DJF, and MAM in zone 2.



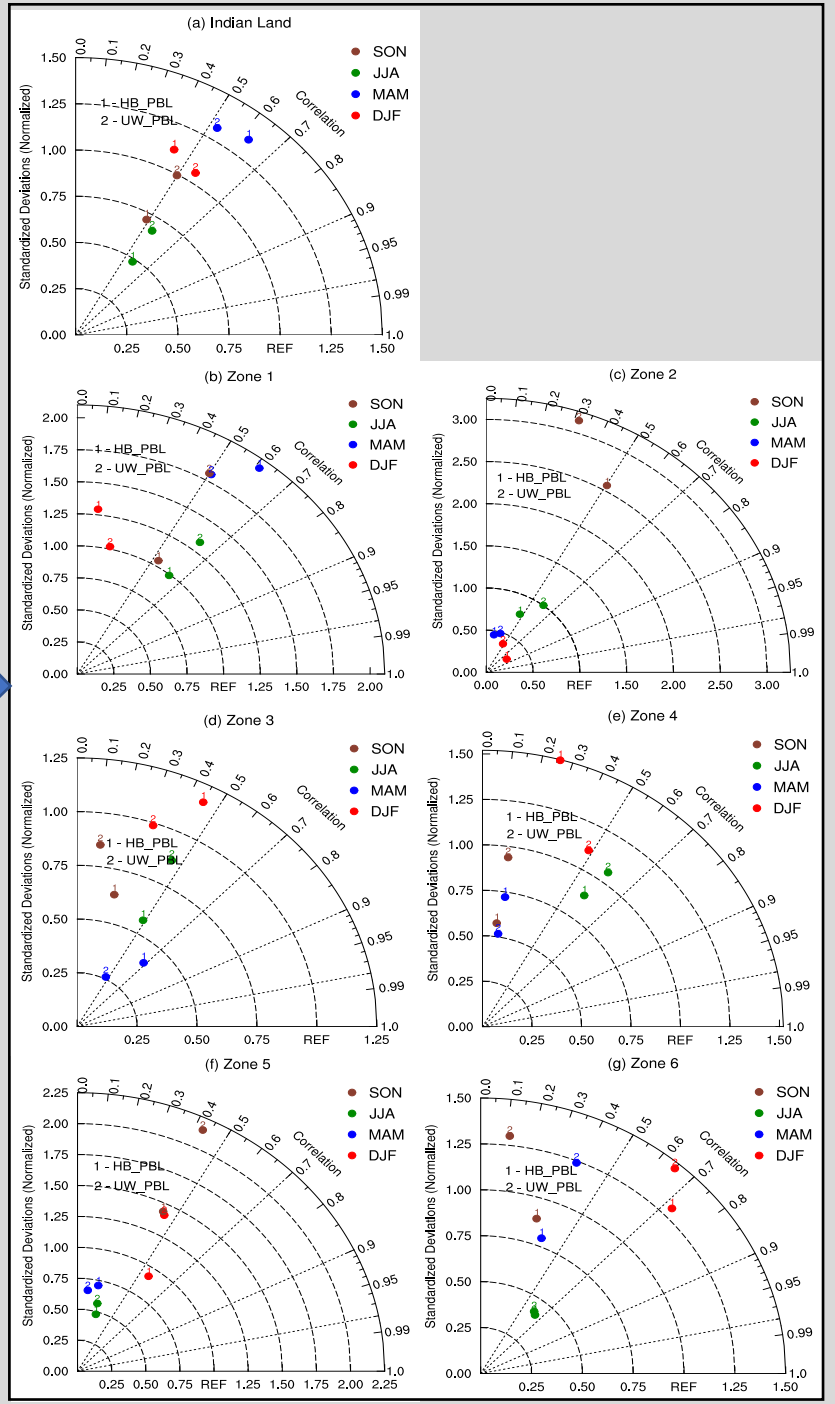


Taylor diagram for simulated T_{2m} over Indian land and different climatic zones.

For most of the seasons, both the schemes show a strong correlation, lying between 0.6 and 0.97, over Indian land as well as different climatic zones, except for the SON season in zones 2, 3, and 5.

Taylor diagram for simulated PRECT over Indian land and different climatic zones.

The correlation is scattered between 0.433 and 0.625 by both the schemes over Indian land as a whole. Furthermore, the HB_PBL shows a strong correlation during MAM and JJA, while the UW_PBL leads to a strong correlation during DHF and SON.



Conclusions

- The study reveals that the performance of PBL schemes is strongly dependent on the considered region and season of interest.
- For precipitation, HB_PBL shows better correlation and smaller RMSE during MAM and JJA while UW_PBL exhibits better results during DJF and SON seasons over Indian land.
- HB_PBL shows better performance for precipitation over zones 2, 3, 4, 5, and 6 in terms of better correlation and smaller RMSE values. However, in zone 1, HB_PBL leads to smaller RMSEs during DJF and MAM, while its counterpart produced smaller values during JJA and SON with comparable correlation values.
- The study recommends that based on the region and season of interest, the PBL scheme may judiciously be chosen for the climate simulations over India and its associated climate zones.

Thank you!

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References:

1. Holtslag, A. A. M., and B. A. Boville, Local versus nonlocal boundary-layer diffusion in a global climate model, J. Climate, 6, 1825–1842, 1993.

2. Bretherton, C. S., and S. Park, A new moist turbulence parameterization in the community atmosphere model, J. Climate, 22, 3422–3448, 2009.

Questions?

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Note: I will be submitting my Ph.D. within a semester and actively seeking post-doc opportunities.