Process-based Study of the Dry Biases over Amazonia in CMIP5 Models and Its Implication for Future Projections

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1. Background

- CMIP3 models were shown to have highly variable biases in Amazonia precipitation and its seasonality (Li et al. 2006; Vera et al. 2006).
- Since IPCC AR4, our understanding on what control climatology and variability of Amazonian rainfall has advanced significantly. It has been established that SST anomalies over the adjacent tropical oceans are the primary forcing for drought and extreme events in some part of Amazonian basin (Doi et al. 2012; Liebmann and Marengo 2001), through their impacts on atmospheric circulation patterns and moisture transport (Wang and Fu 2002; Fu et al. 1999). Surface soil moisture and vegetation feedbacks, as well as land, regulate rainfall variability by altering the surface Bowen ratio and buoyancy of air in the boundary layer (Fu and Li 2004; Nepstad et al. 1999; Lee et al. 2011).
- This work determines what biases in Amazonian rainfall still remain and what are the possible causes.

2. Data

Reference data

- GPCP monthly/pentad/daily data
- CMAP monthly data
- NOAA/NCDC ERSST v3b monthly SST data

Reanalysis

- ECWMF ERA-Interim Reanalysis

IPCC Models

- 11 models used in this study (***A*** CCSM3, ***B*** GFDL-CM3, ***C*** GFDL-ESM2M, ***D*** GISS-E2H, ***E*** GISS-E2R, ***F*** HadCM3, ***G*** HadGEM2-CC, ***H*** HadGEM2-ES, ***I*** MPI-ESM, ***J*** IPSL, ***K*** INM-CM4)
- Historical period: 1950-2005 to construct SST indices, 1979-2005 for other variables

3. Methodology

- Moisture convergence is calculated from the water budget. (Trenberth et al. 2007)
- Some models lack of evapotranspiration which can be calculated from its relationship with surface latent heat flux
- The root-mean square error (RMSE) is used to quantify the model performance and rank the models. (Gleckler et al. 2008)
- A Bayesian method is employed to weight the models. The posterior is based on assessments of the mean (step 1) and the distribution (step 2). (Jupp et al. 2010; Murphy et al. 2004)

4. Study Regions

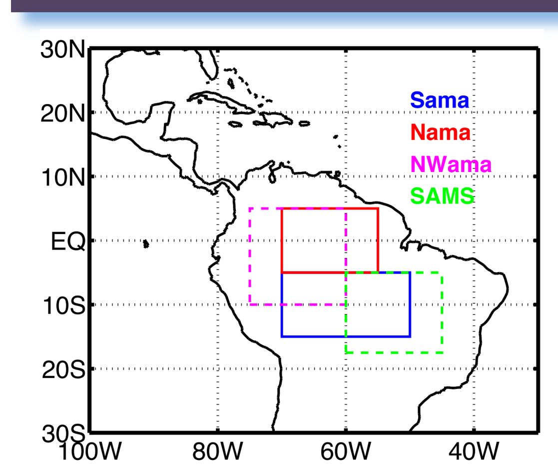


Figure 1. Map of the study regions.

- Southern Amazon (Sama, 70W-50W, 15S-5S)
- Northern Amazon (Nama, 70W-55W, 5S-5N)
- Northwestern Amazon (Nwama, 75W-60W, 10S-5N)
- South American Monsoon System region (SAMS, 60W-45W, 17.5S-5S)

5. Historical Evaluations

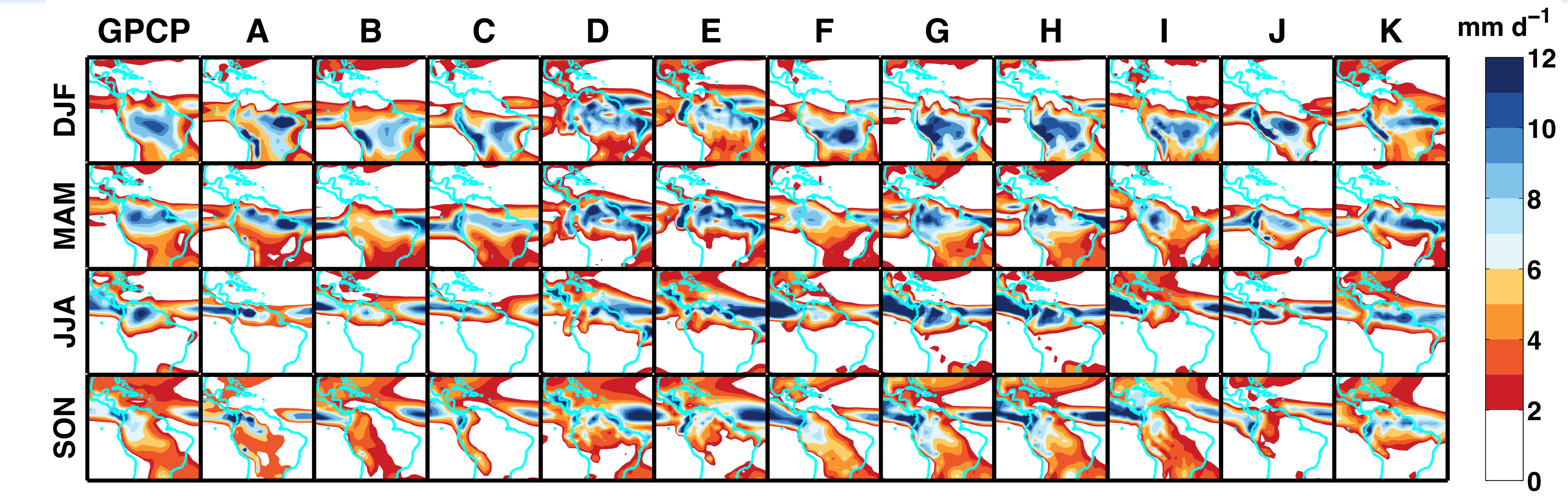


Figure 2. Seasonal mean of total precipitation. (***A*** CCSM3, ***B*** GFDL-CM3, ***C*** GFDL-ESM2M, ***D*** GISS-E2H, ***E*** GISS-E2R, ***F*** HadCM3, ***G*** HadGEM2-CC, ***H*** HadGEM2-ES, ***I*** MPI-ESM, ***J*** IPSL, ***K*** INM-CM4)

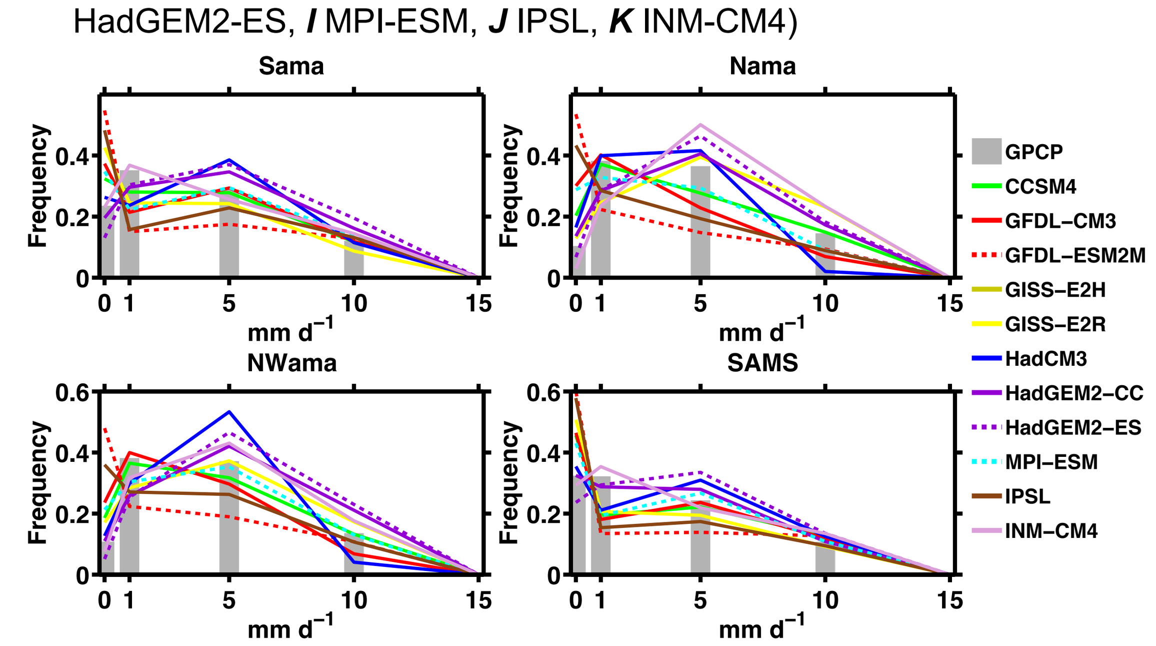


Figure 3. Distribution of pentad precipitation in the four regions.

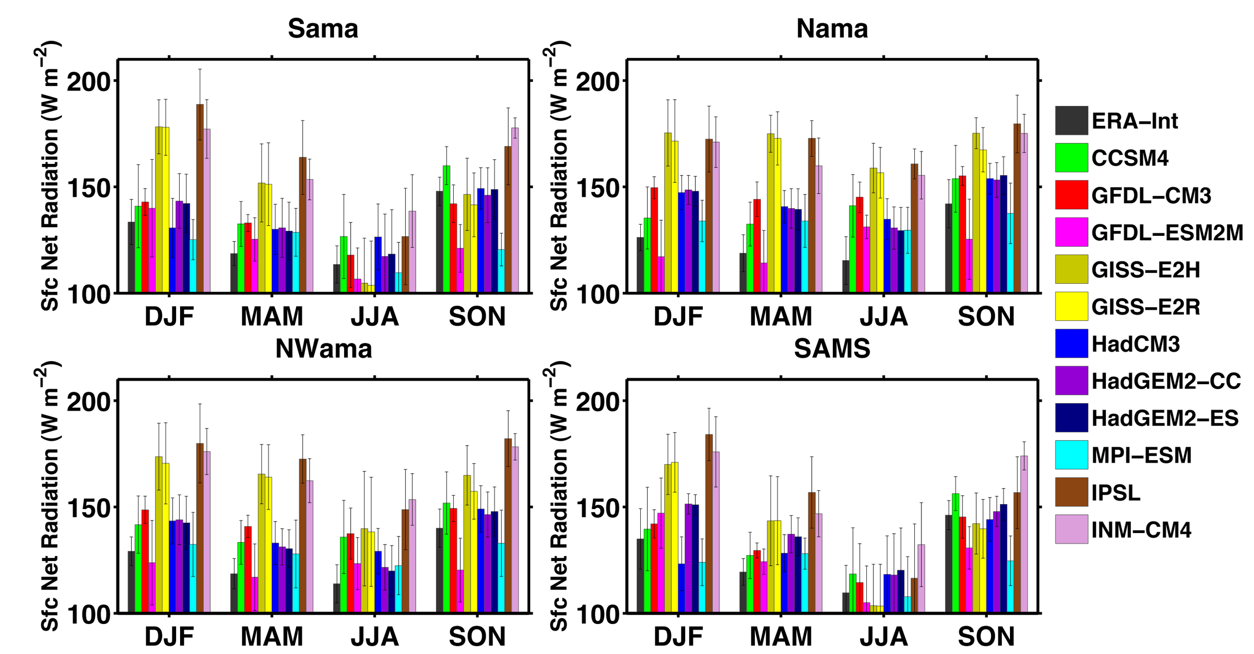


Figure 5. Spatial mean surface net radiation. The grey bars represent the standard deviation.

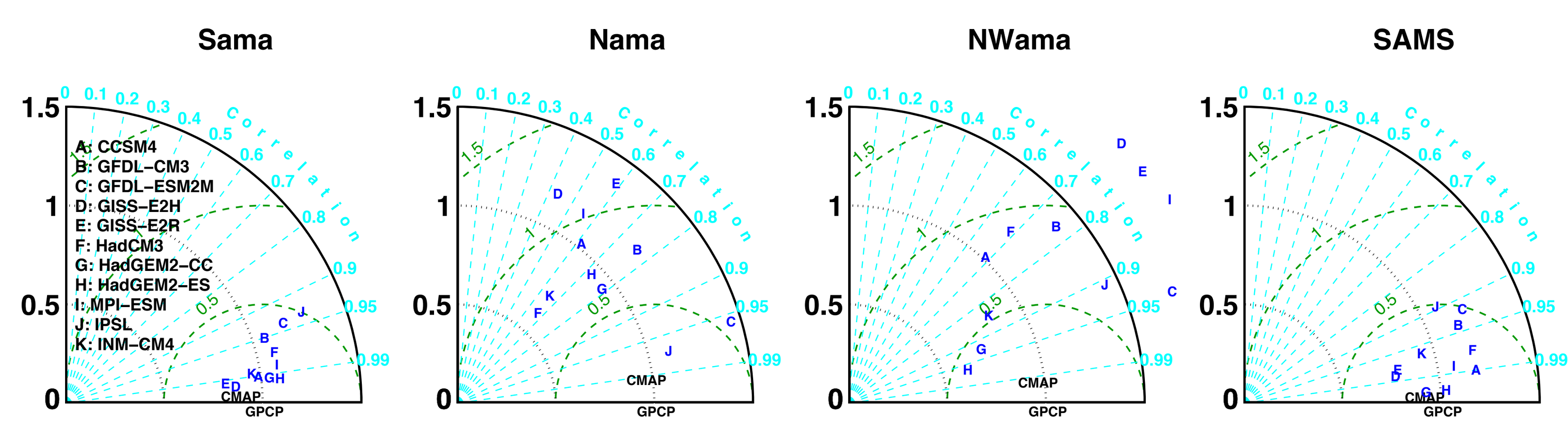


Figure 4. Taylor diagram quantifying the correspondence between the simulated and observed domain-averaged annual cycle of precipitation. The markers are denoted in the top left panel.

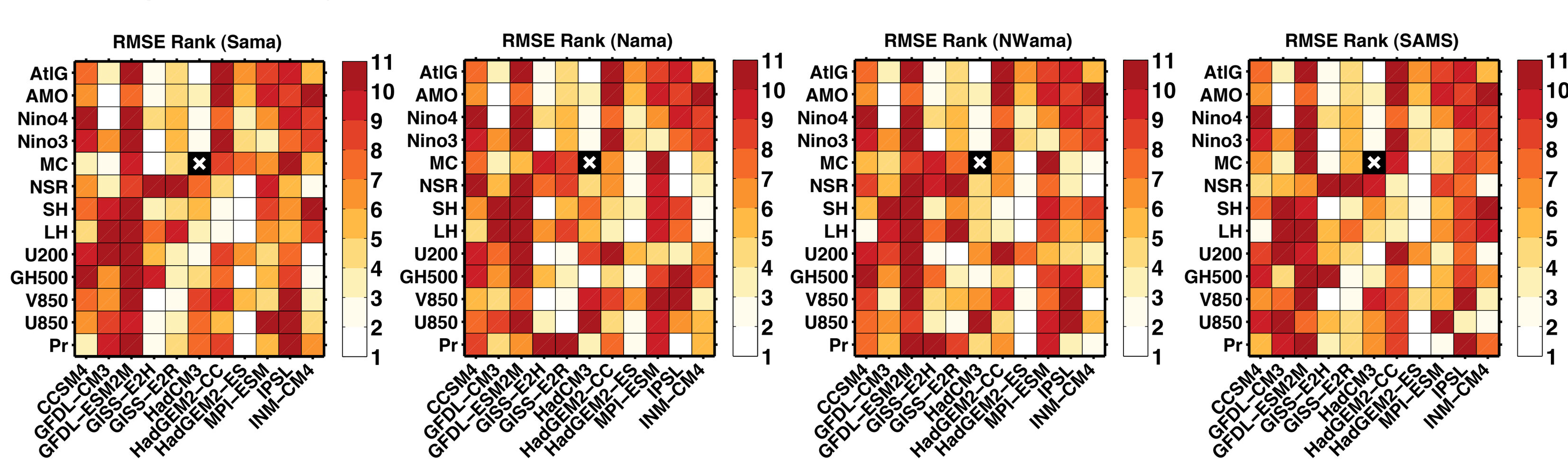


Figure 7. RMSE ranking of precipitation, U850, V850, GH500, U200, Latent heat, sensible heat, net solar radiation, moisture convergence, Nino3, Nino4, AMO, tropical Atlantic SST Gradient. The cross signs indicate the total water vapor change is not provided as an output variable by HadCM3.

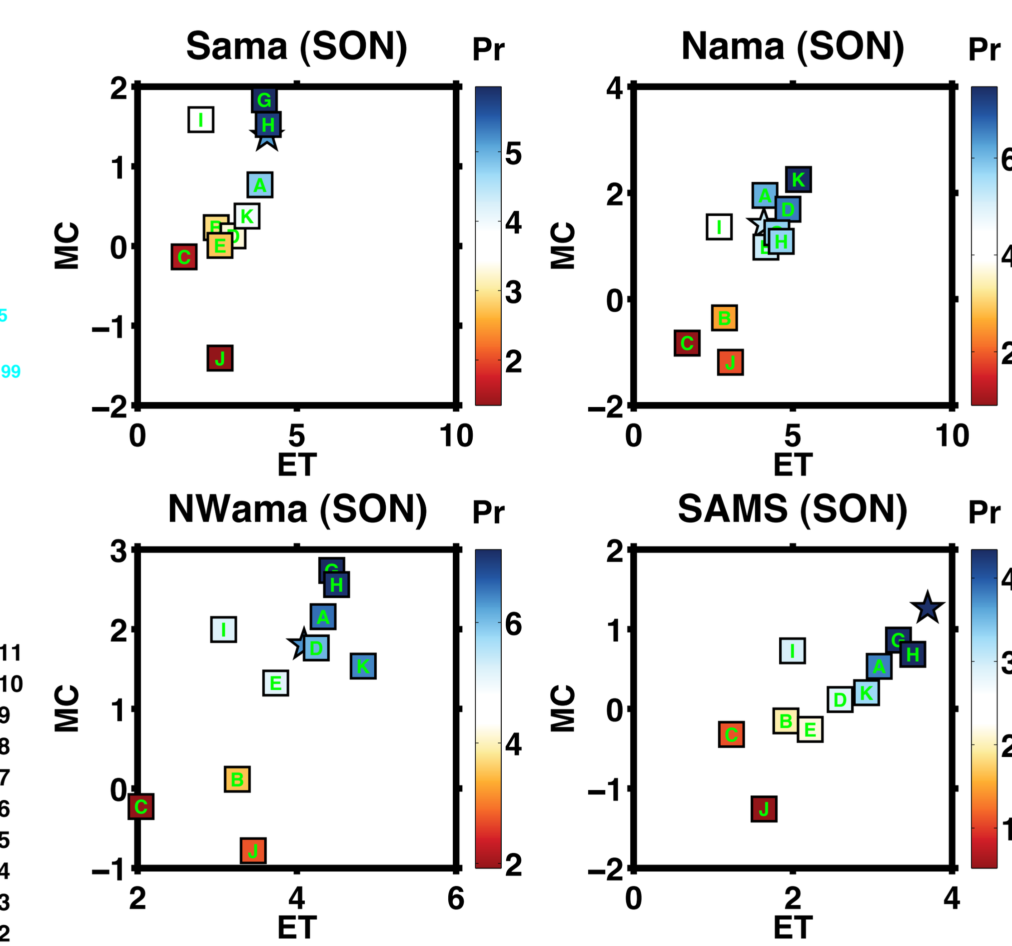


Figure 6. Scatter plot of ET and moisture convergence in SON. Precipitation is color shaded. The unit for ET, MC and Pr is mm d^{-1}. Pentagram represents the reference. (***A*** CCSM3, ***B*** GFDL-CM3, ***C*** GFDL-ESM2M, ***D*** GISS-E2H, ***E*** GISS-E2R, ***F*** HadCM3, ***G*** HadGEM2-CC, ***H*** HadGEM2-ES, ***I*** MPI-ESM, ***J*** IPSL, ***K*** INM-CM4)

6. Future Projection

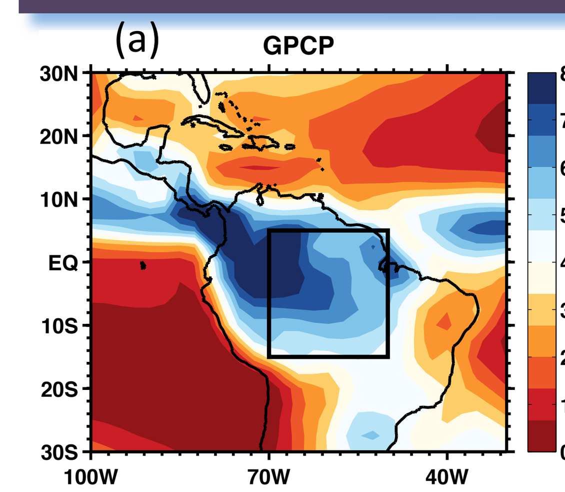
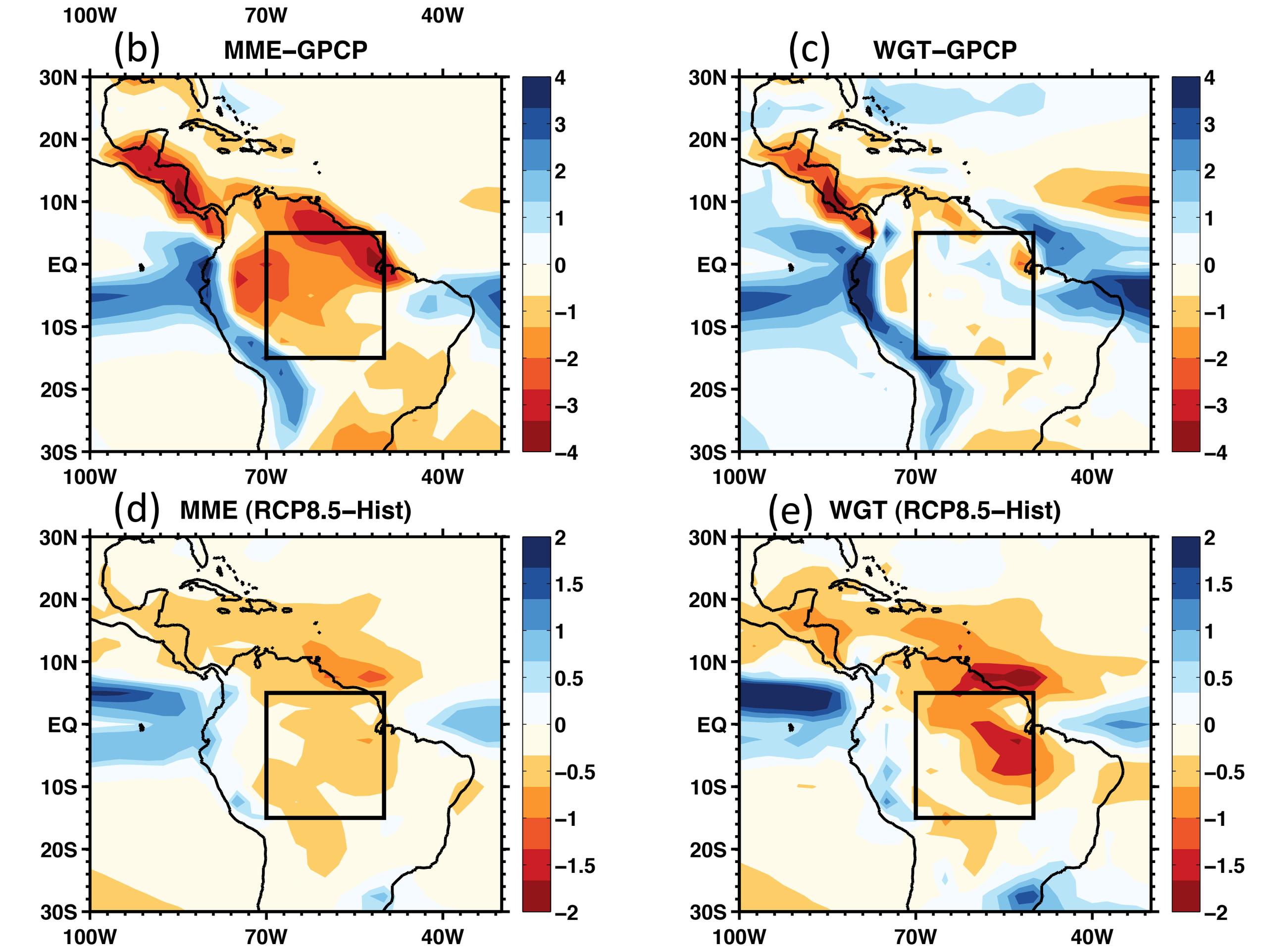


Figure 8. (a) Rainfall climatology in GPCP; (b) The difference between multi-model ensemble (MME) and GPCP; (c) The difference between weighted MME (WGT) and GPCP; (d) The difference between RCP8.5 and historical from MME; (e) The difference between RCP8.5 and historical from WGT.



7. Conclusions

- The models adequately simulate the annual cycles in Sama and SAMS, but have a large range of performance in Nama and NWama. Most models underestimate rainfall and the dry biases are strongest in southern tropical South America.
- Excessive surface solar radiation, strong ITCZs in adjacent oceans and an overestimate of upper tropospheric westerly winds appear to cause the dry biases in those models.
- HadGEM2-ES outperforms other models in most variables especially surface conditions and atmospheric circulations in all the four regions.
- MME has a dry bias over the Amazon, but WGT corrects the biases. The magnitude of drying is about 1 mm/d larger by WGT than MME at the end of the 21st century, mainly over the eastern Amazon.

Acknowledgement

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Main References

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