Post-Processing on GEFSv12 Reforecast products for Extreme Rainfall Event's Prediction on Sub-Seasonal Scale at Regional Level

M. M. Nageswararao[1], Yuejian Zhu[2], and Vijay Tallapragada[2]

[1] CPAESS, UCAR at NOAA/NWS/NCEP/EMC, College Park, Maryland-20740, USA

[2] NOAA/NWS/NCEP/EMC, College Park, Maryland-20740, USA

Email: murali.n.malasala@noaa.gov , murali@ucar@ucar.edu

Acknowledgements:
EMC Coupled Modeling Group

9th NOAA Ensemble Users Workshop at NOAA/NCWCP,COLLEGE PARK, MD 20740, 22-24 Aug 2023

Background and Motivation

- Extreme rainfall (ER) events are responsible for floods that cause widespread destruction of infrastructures, economic damages, and the loss of lives across the world, and it's high over South Asia, particularly in India and Taiwan. The Annual economic loss due to floods in India is 10% ($3 billions) of the global financial loss ($30 billion).
- Since 1980, ER events in the CONUS have resulted in property losses exceeding 0.75 trillion U.S. dollars (USD), as concluded by Kunkel et al. (2020).
- The skillful prediction of ER events on extended range/monthly scale at regional level is one of the challenges of the meteorological scientific community. The existing forecast systems across the world can simulate the year-to-year variation in the seasonal scale rainfall. However, the month-to-month variability during a year is still challenging.
- In September 2020, NOAA NCEP implemented Global Ensemble Forecast System version 12 (GEFS v12) to support stakeholders for sub-seasonal forecasts and hydrological applications. Consistent reforecast data from GEFS v12 for 2000-2019 are available and this data initialized at 00 UTC once per day out to 16 days with 5 ensembles except on Wednesdays when the integration extended to 35 days with 11 members.

Data Used

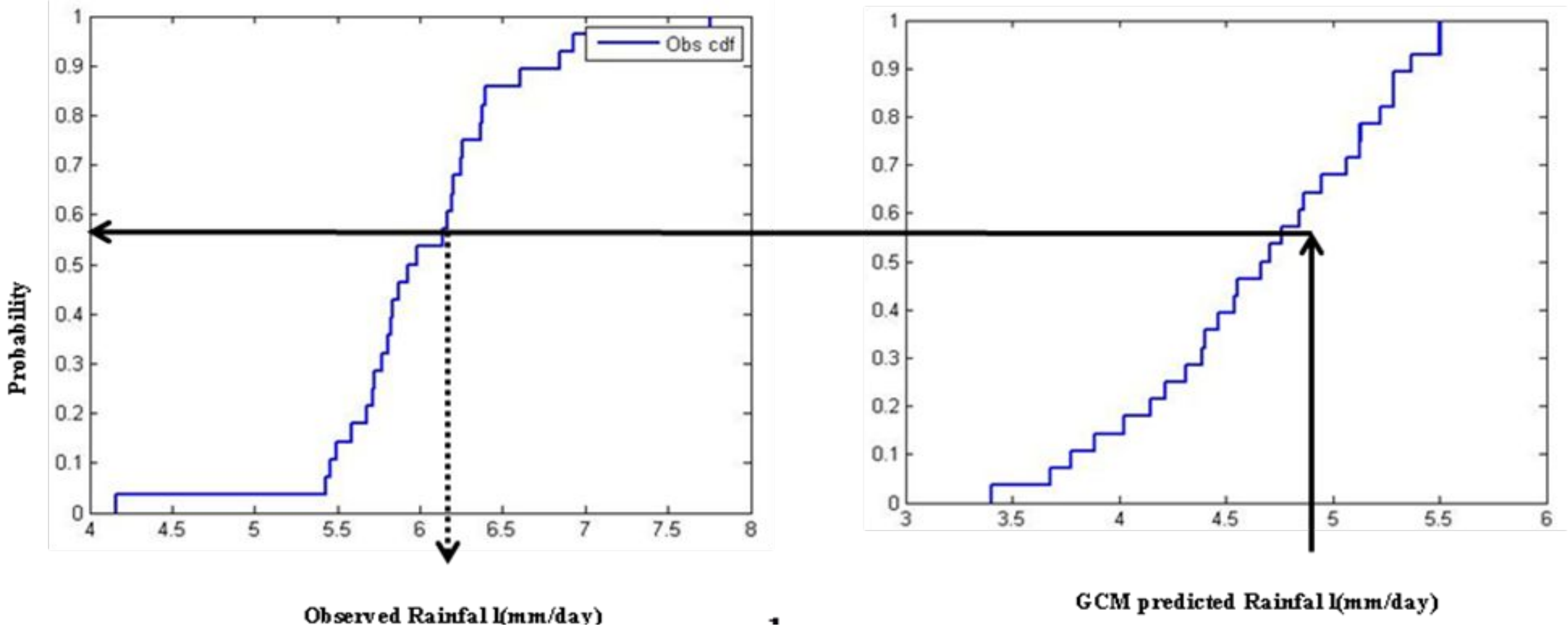
Model : GEFSv12 (Zhou et al. 2019; 2021)
Period used : 2000-2019
Horizontal Resolution : 0.25° X 0.25° for Day-1 to 10 and 0.5° X 0.5° for Day-11 to 35. The entire data is interpolated by using bilinear interpolation over study area with 0.25° X 0.25°
Members used : 11 members (c00, p01, p02, p03, p04, p05, p06, p07,p08, p09, and p10) based on everyday Wednesday 00 UTC initial conditions and 5 members with everyday 00 UTC initial conditions.
Reference data set used : IMDAA from NCMRWF, India (Ashrit et al. 2020, Rani et al.2021), CMORPH, CCPA, etc.

Quantile Mapping Method (Q)

- This technique is mainly used to correct the model (GEFSv12) predicted rainfall distribution by mapping it onto the observed (IMDAA/CMORPH/CCPA) rainfall distribution.
- The process is also referred to as 'histogram equalization and/or 'rank matching' (Wood et al., 2004; Hamlet et al., 2002; Piani et al., 2010).
- In the quantile mapping, method gama probability distributions of observed and forecasted values are used. Suppose CDFs, F_Y for observed data and $F_{\bar{F}}$ for ensemble mean of model forecast are known. For $\bar{F}_t$ the bias-corrected value Q will then be as follows:

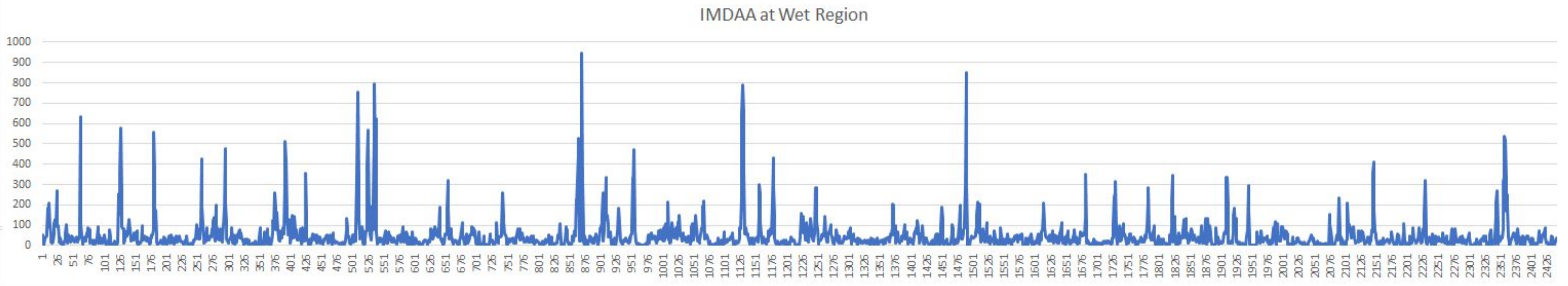
$$Q = F_{Obs}^{-1}\left(F_{\bar{F}}\left(\bar{F}_t\right)\right)$$

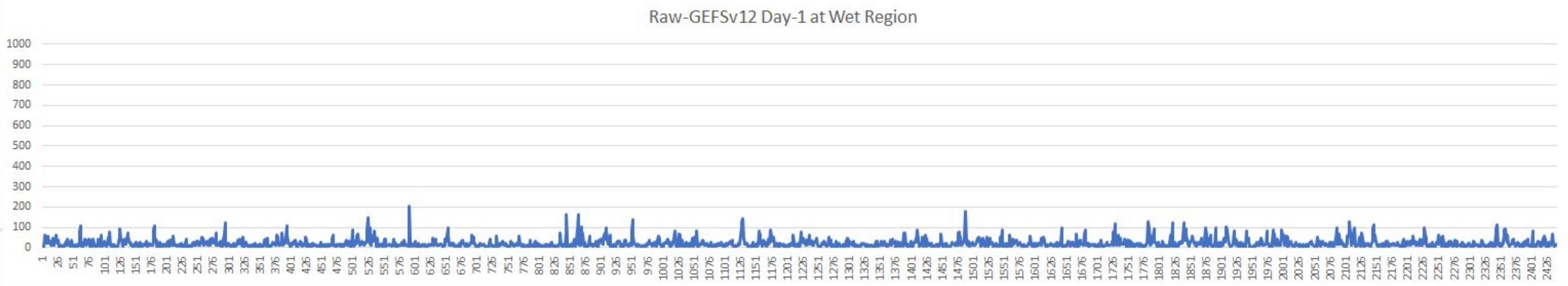
Here, F^{-1} is an inverse of CDF. Thus, the quantile mapping procedure is a transformation between two CDFs. The whole procedure is implemented in the leave one out cross-validation way.

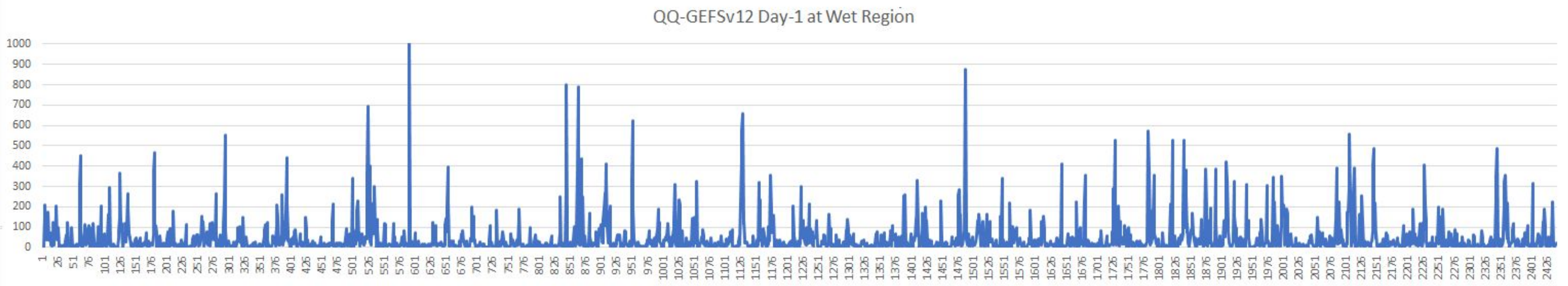


$$Q = F_{Obs}^{-1}\left(F_{\overline{F}}\left(\overline{F}\right)\right)$$

Time Series of JJAS daily precipitation at a gridpoint of Wet Region of India from 01 June 2000 to 3o September 2019







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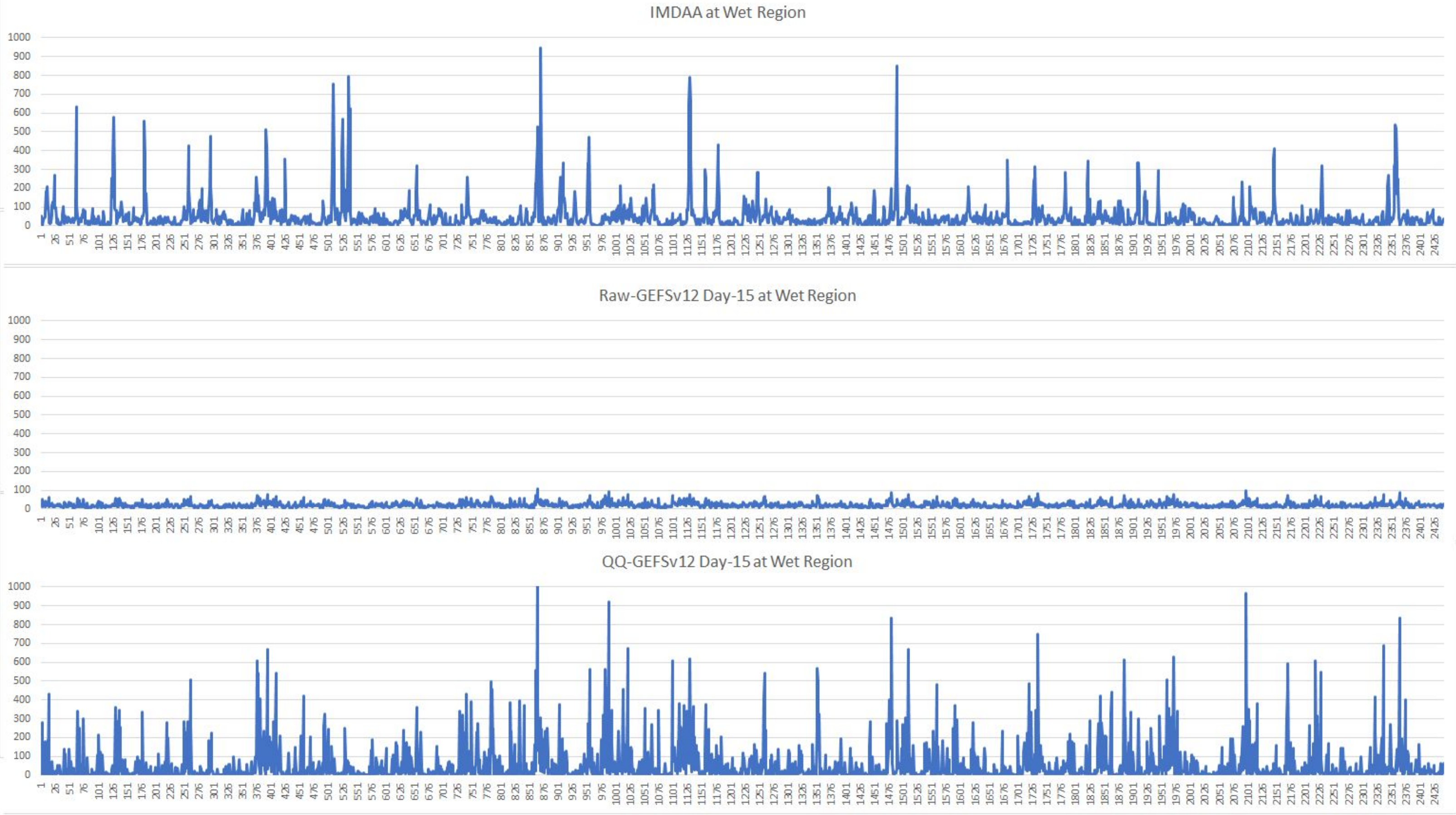
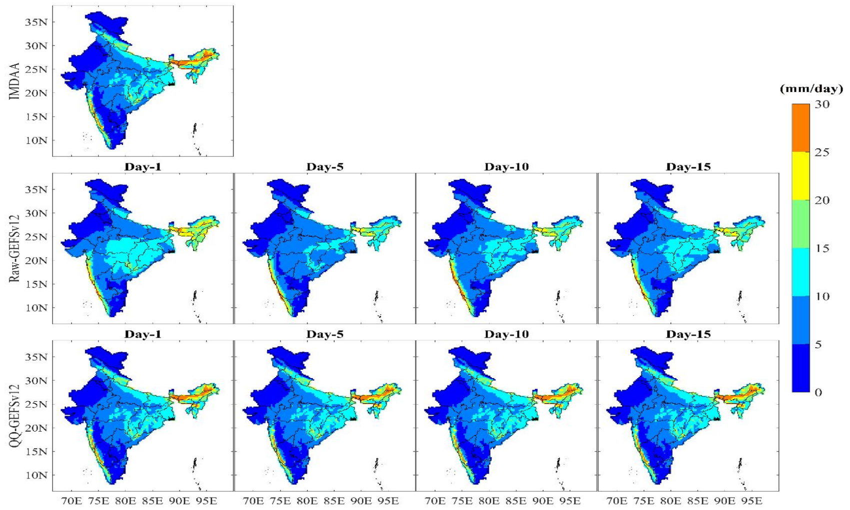
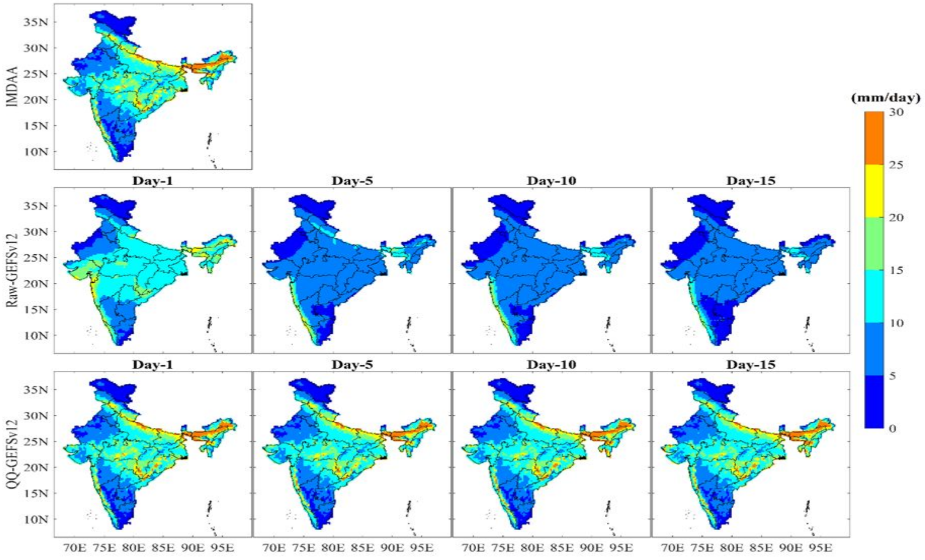


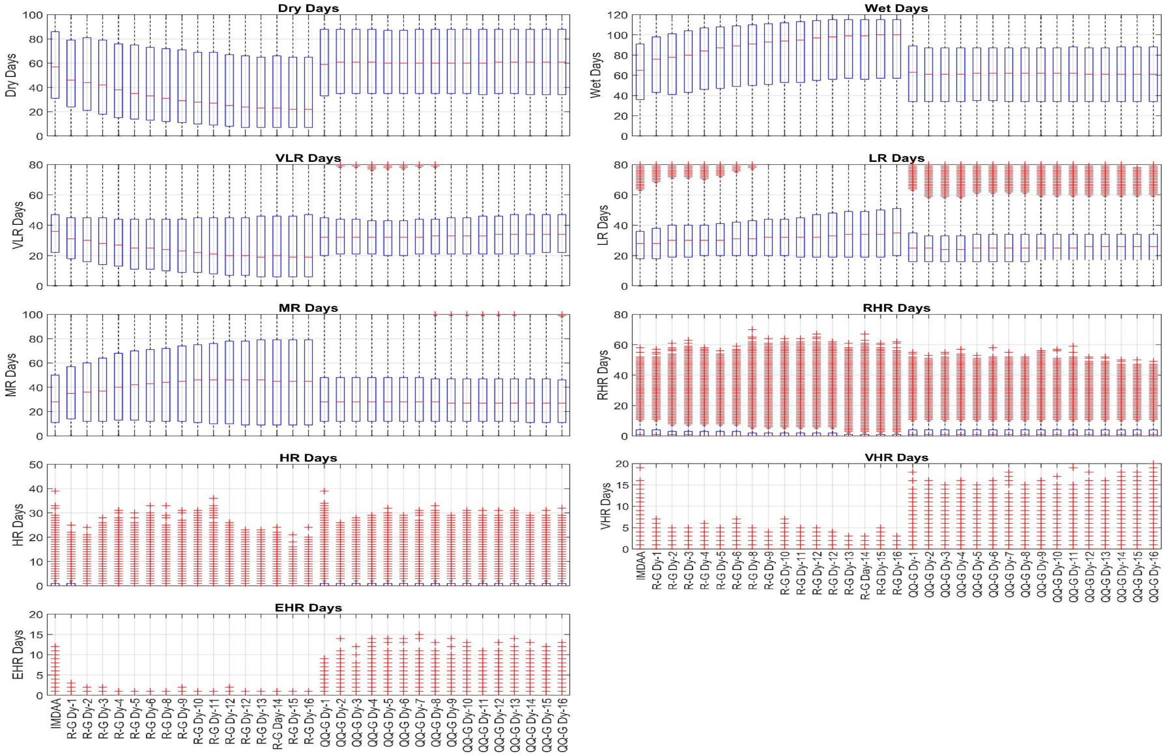
Spatial distribution of JJAS rainfall



Interannual Variability of JJAS rainfall

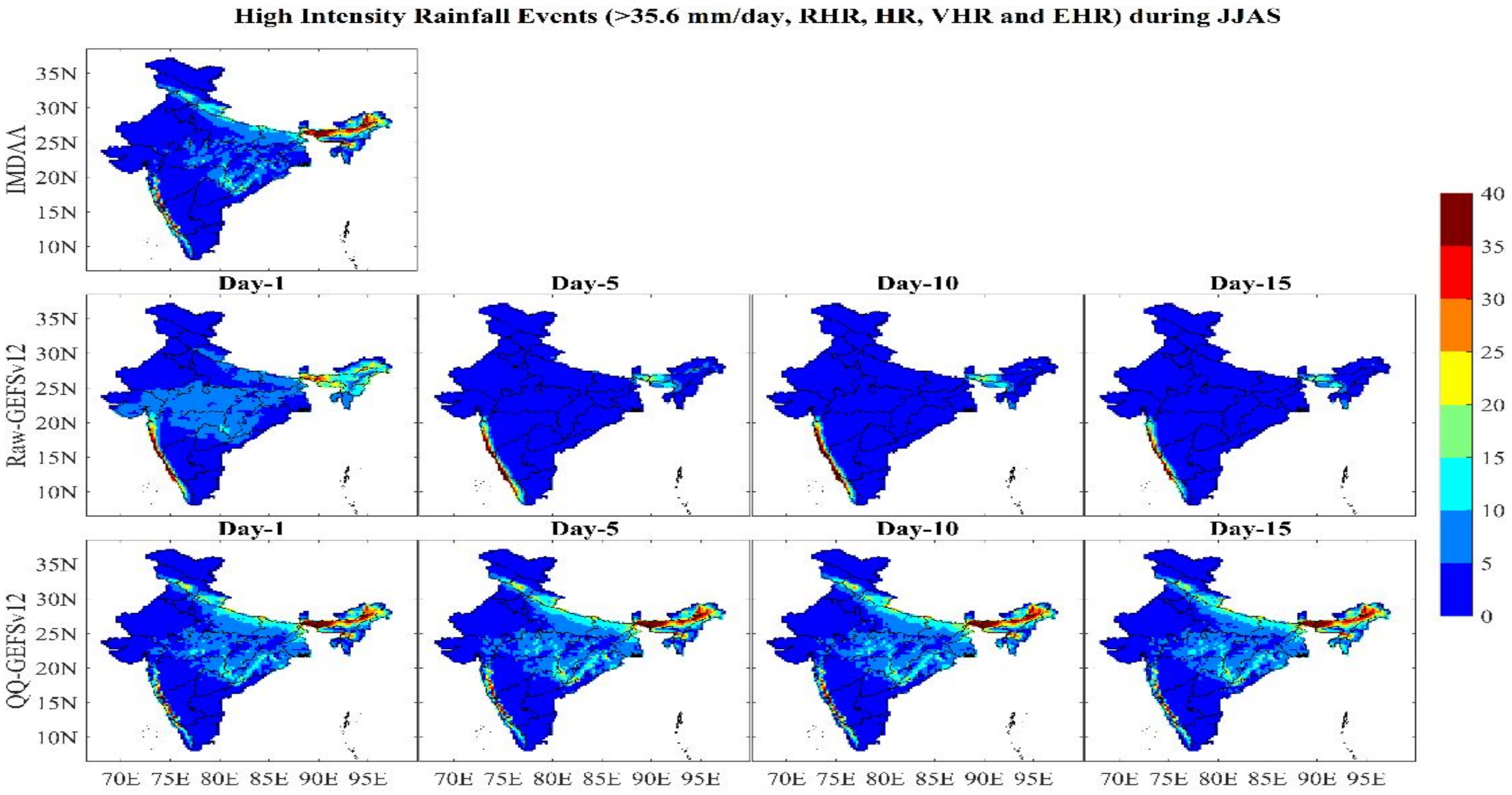


Box plot for various categorical summer monsoon rainfall events over India from Raw and QQ-GEFSv12

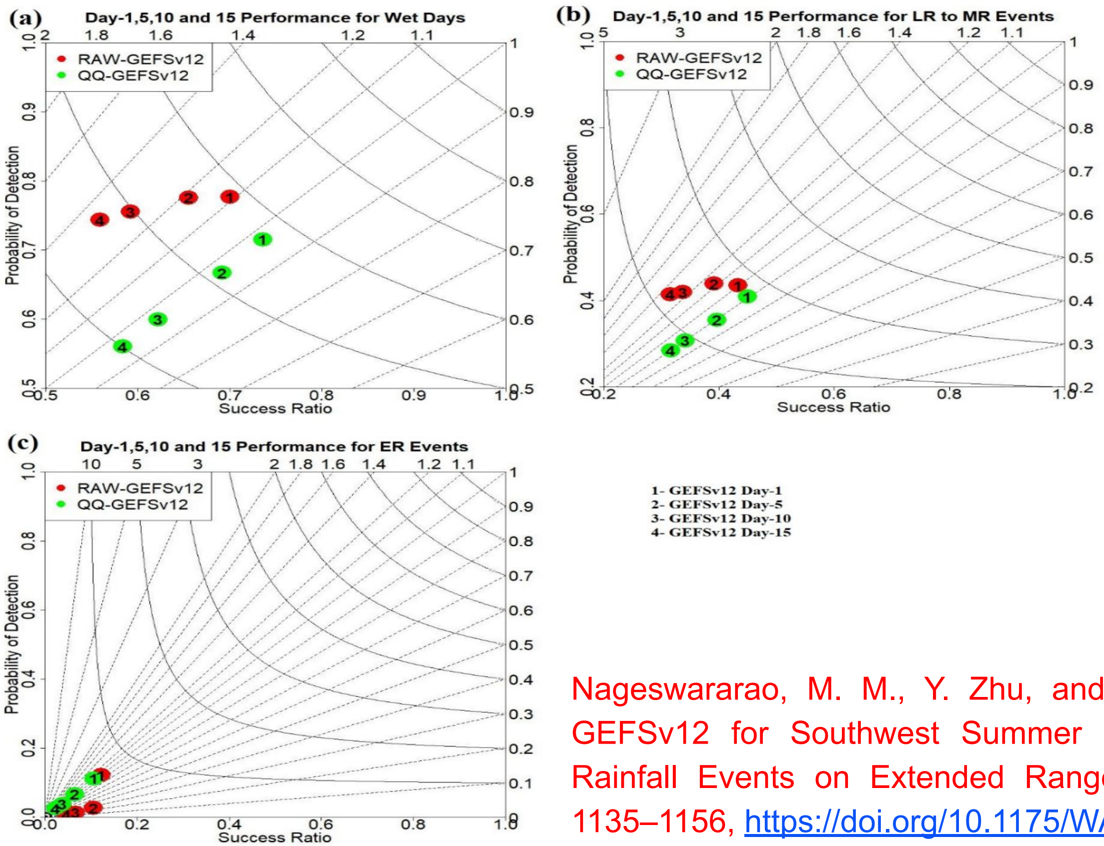


Rainfall categories defined by IMD

Rainfall category (short form)	Range of rainfall per day
Wet days (Wet)	Wet > 2.5 mm
Very light rain (VLR)	0.1 < VLR ≤ 2.4 mm
Light rain (LR)	2.5 mm ≤ LR < 7.5 mm
Moderate rain (MR)	7.6 mm ≤ MR < 35.5 mm
Rather heavy rain (RHR)	35.6 mm ≤ RHR < 64.4 mm
Heavy rain (HR)	64.5 mm ≤ HR < 124.4 mm
Very heavy rain (VHR)	124.5 mm ≤ VHR < 244.4 mm
Extremely heavy rain (EHR)	EHR > 244.5 mm

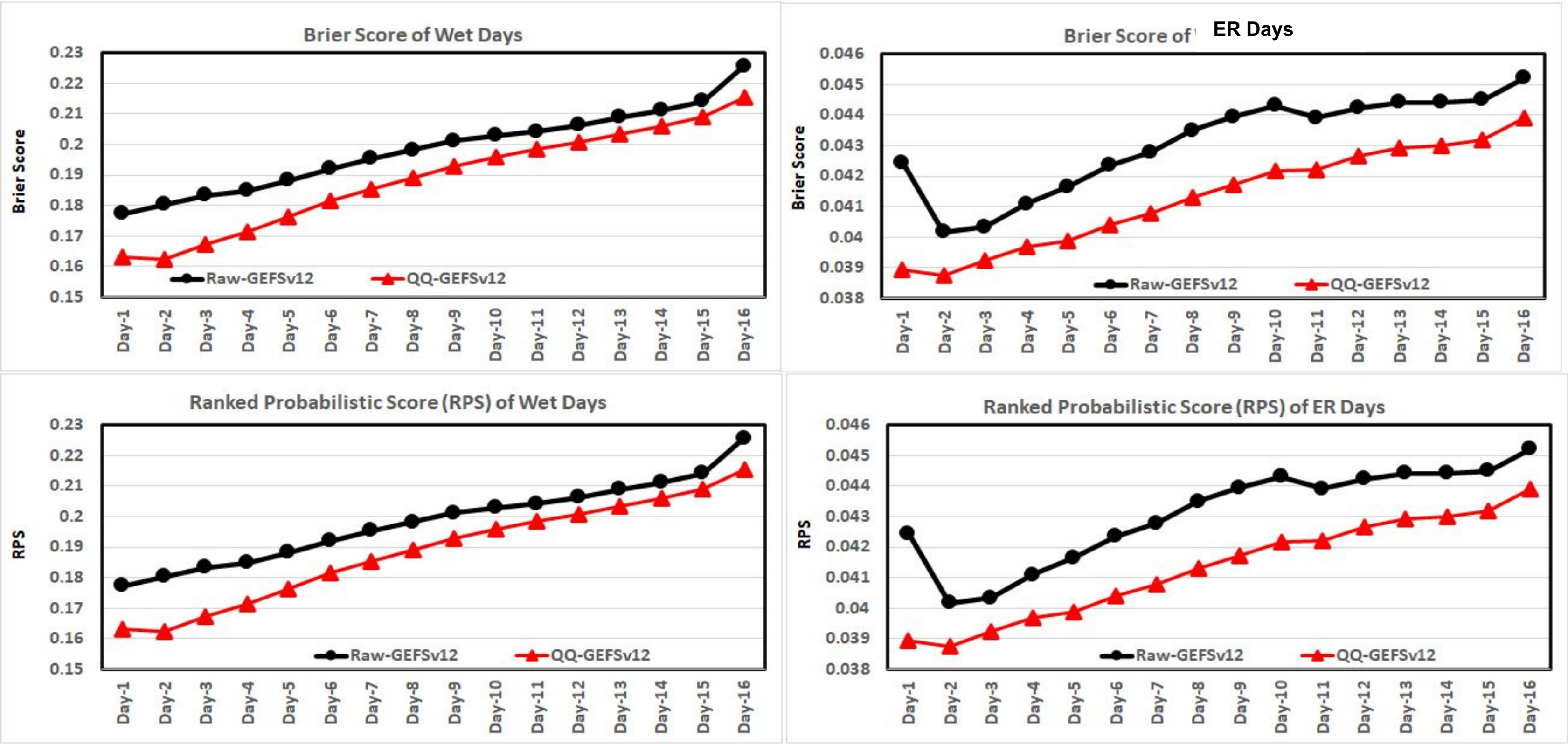

High Intensity Rainfall Events (>35.6 mm/day, RHR, HR, VHR and EHR) during JJAS
IMDAA
Raw-GEFSv12
QQ-GEFSv12
Day-1
Day-5
Day-10
Day-15
35N
30N
25N
20N
15N
10N
70E 75E 80E 85E 90E 95E
0
5
10
15
20
25
30
35
40

Performance diagram

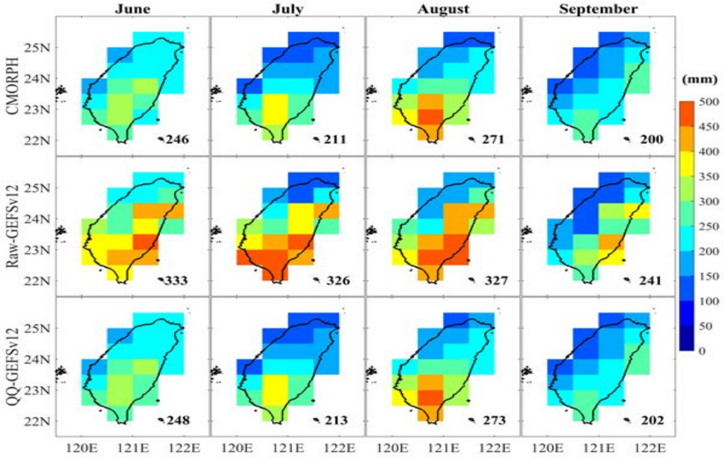


Nageswararao, M. M., Y. Zhu, and V. Tallapragada, 2022: Prediction Skill of GEFSv12 for Southwest Summer Monsoon Rainfall and Associated Extreme Rainfall Events on Extended Range Scale over India. *Wea. Forecasting*, **37**, 1135–1156, https://doi.org/10.1175/WAF-D-21-0184.1.

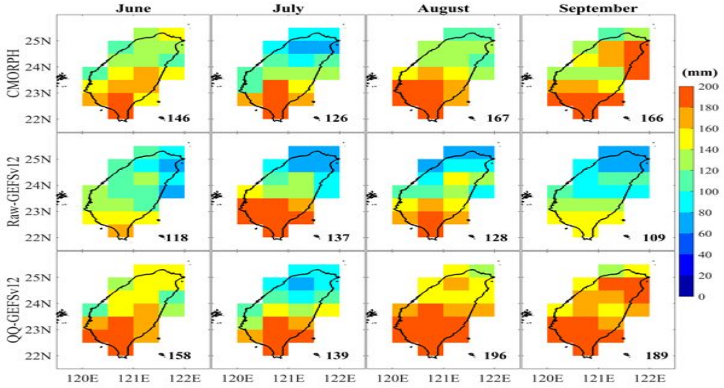
BS and RPS of JJAS Wet and ER events' ensemble probabilistic forecast over India

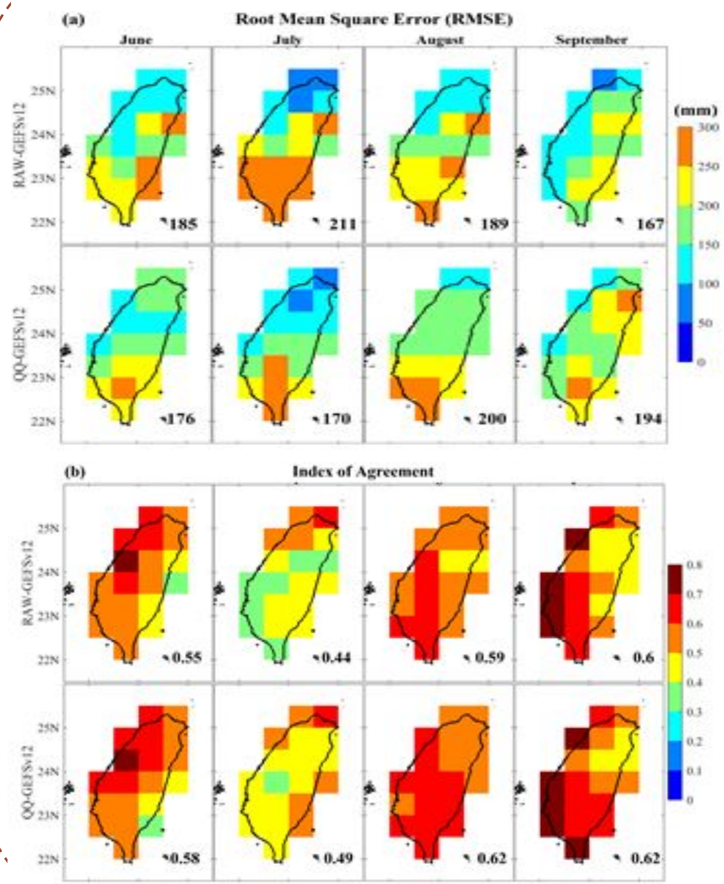


Spatial distribution of monthly rainfall

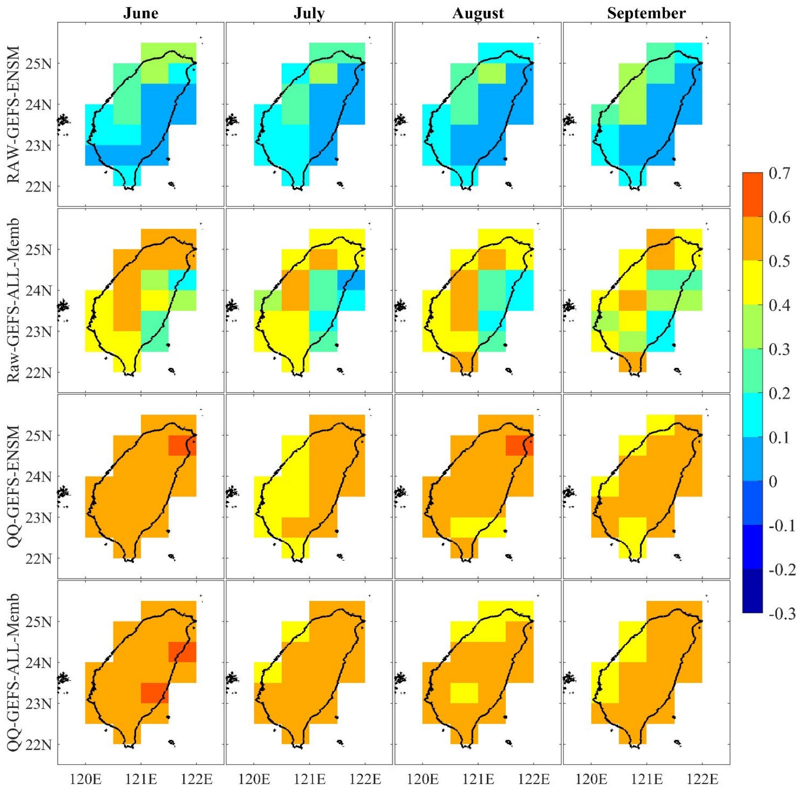


Interannual Variability of monthly rainfall

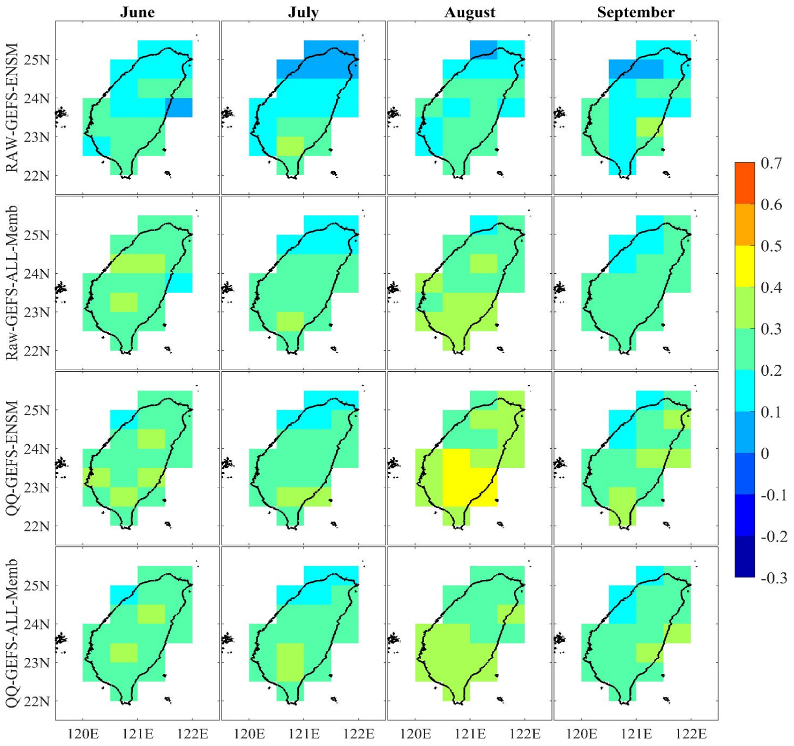


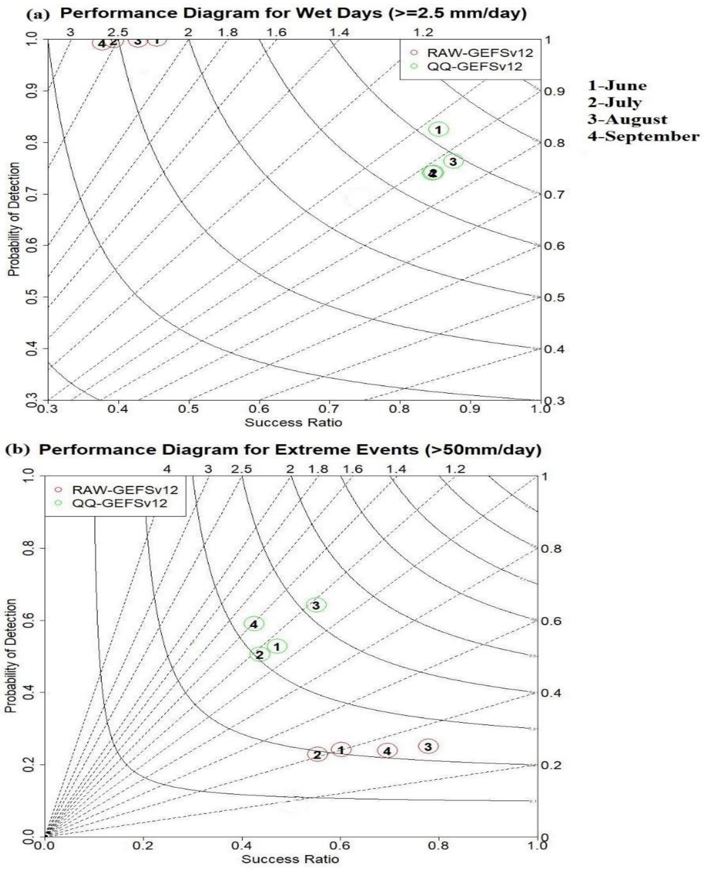


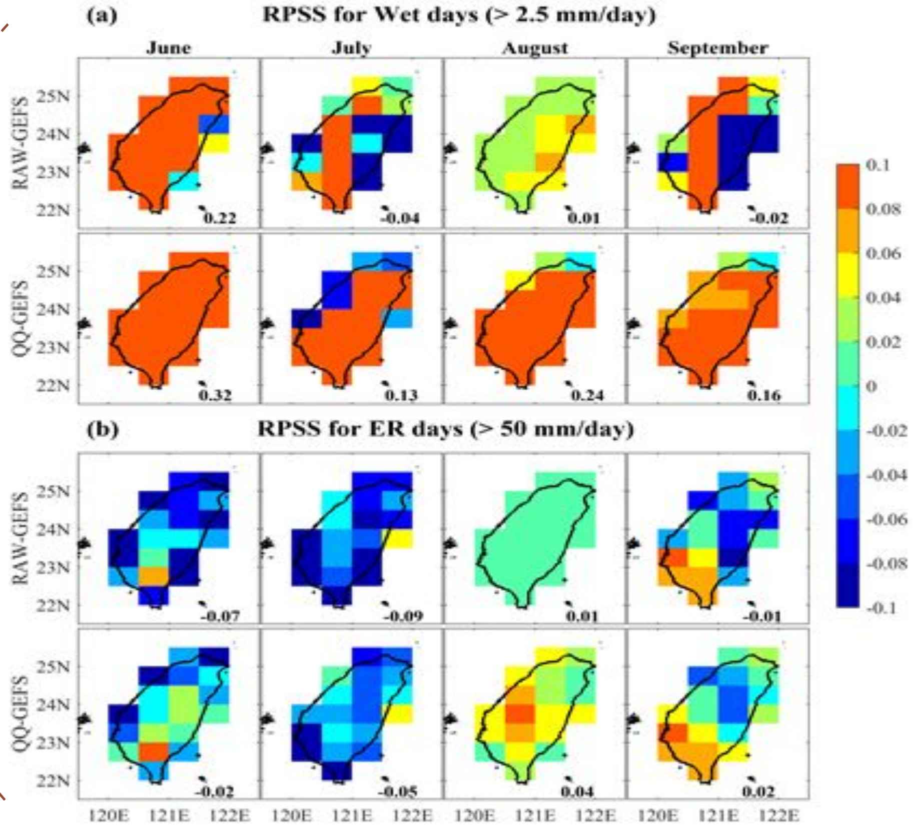
ETS for Wet Days (> 2.5 mm/days)



ETS for ER Days (> 50 mm/days)

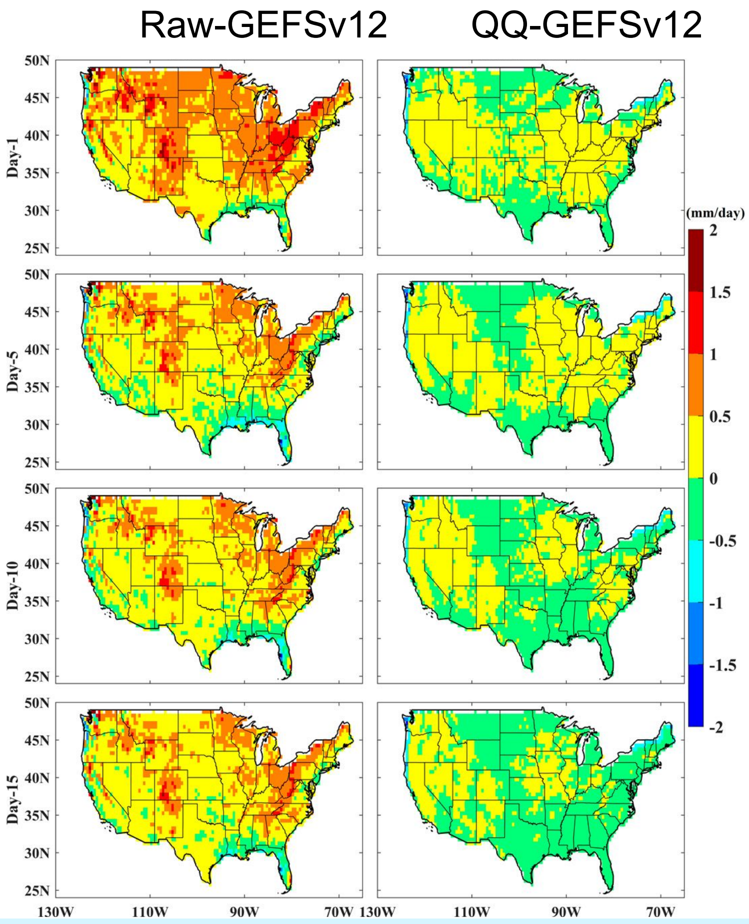


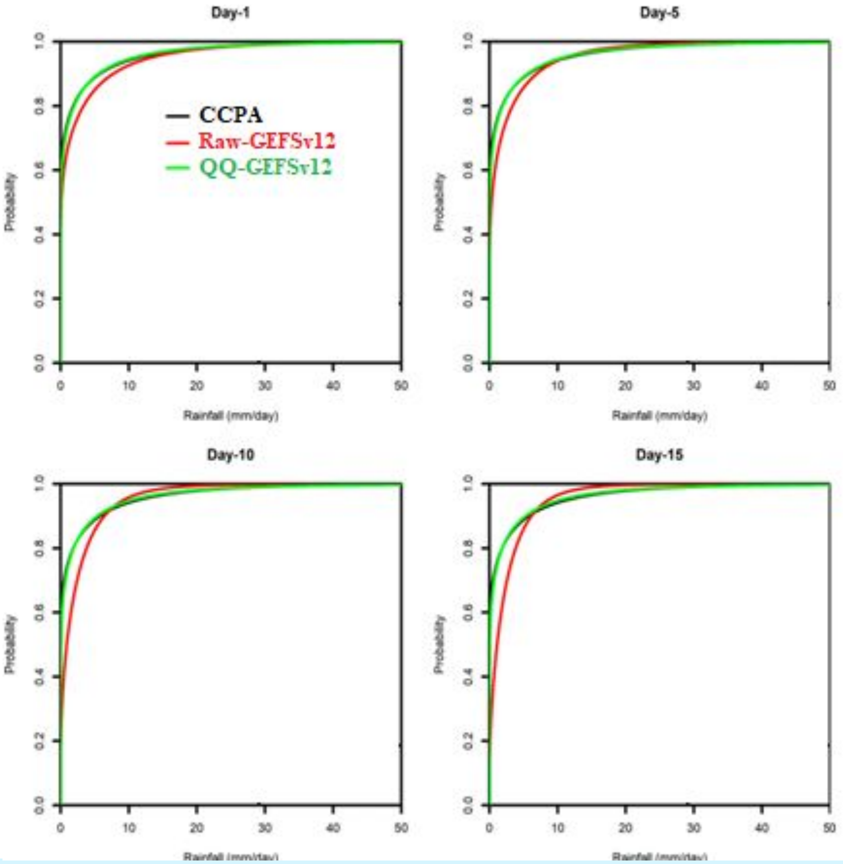




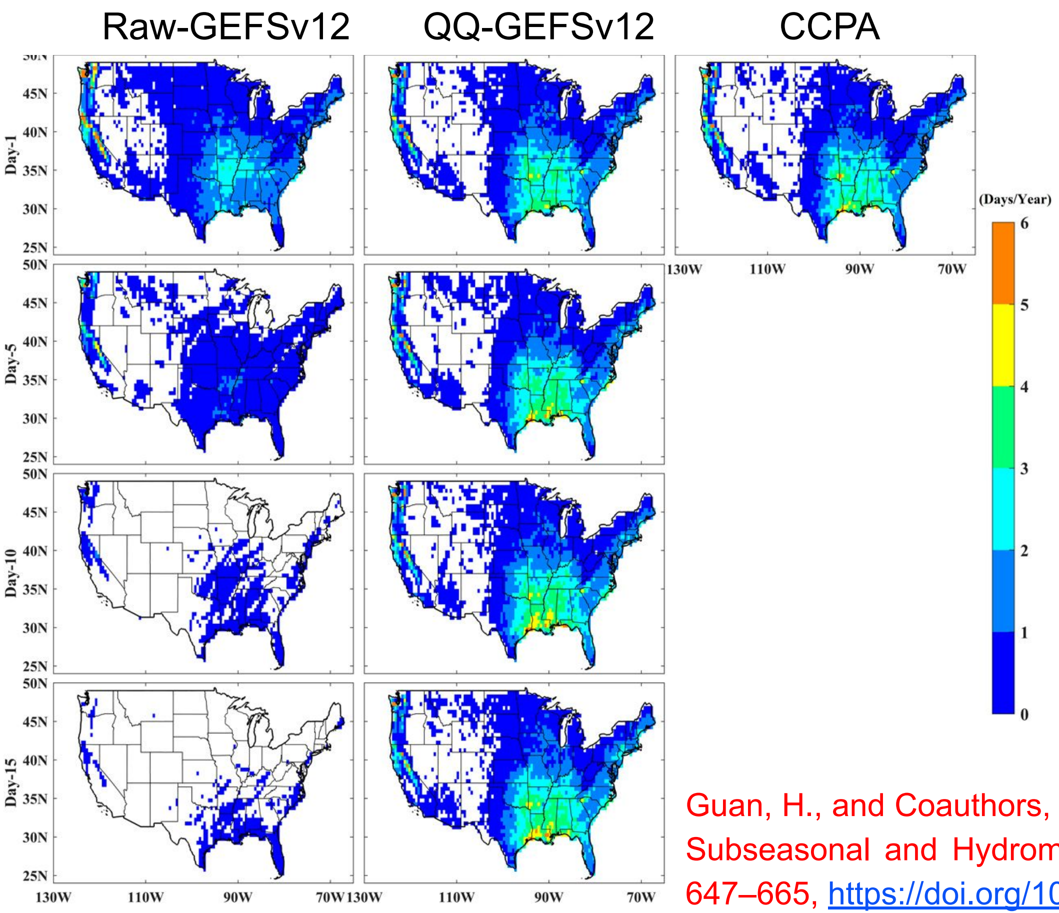
Nageswararao, M. M., et al. "Prediction Skill of GEFSv12 in Depicting Monthly Rainfall and Associated Extreme Events over Taiwan during the Summer Monsoon." *Weather and Forecasting* 37.12 (2022): 2239-2262.

Mean Bias of JJAS Rainfall over CONUS against CCPA





Spatial distribution of JJAS ER (>50 mm/day) events over CONUS



Guan, H., and Coauthors, 2022: GEFSv12 Reforecast Dataset for Supporting Subseasonal and Hydrometeorological Applications. *Mon. Wea. Rev.*, **150**, 647–665, https://doi.org/10.1175/MWR-D-21-0245.1.

Summary and conclusion

- The SMR patterns from GEFSv12 is similar to the observation (IMDAA reanalysis/CMORPH/CCPA) over India/Taiwan/CONUS for all forecast lead times. However, GEFSv12 has a large dry bias in prominent SMR regions, while a wet bias over low SMR regions.
- The RMSE and Mean bias errors of SMR from Raw-GEFSv12 are high over prominent rainfall regions and its IAV are significantly high. After calibration, both errors notably decreased for all forecast lead times for all summer months in India, Taiwan, and CONUS. The prediction skill also notably (IOA) increased.
- The frequency of the low and medium-intensity rainfall events from GEFSv12 is remarkably higher than that observation. In contrast, high to extremely high-intensity rainfall events are significantly less in GEFSv12. After calibration, the probability distribution of various intensity rainfall is well adjusted to the observation for all forecast lead times. The predictability of ER events (> 50mm/days) is increased, in which rainfall events lead to floods and landslides.
- Most of the statistical categorical skill scores (BIAS, ACC, SR, FAR, TS, and ETS) increased after calibration for wet and ER events expect POD for Wet days.
- The assessment of probabilistic forecast reveals that the skill of probabilistic forecast of wet and ER events over prominent rainfall zones from Raw-GEFSv12 is worst (BSS and RPSS <0) than the climatological forecast for all forecast lead times. However, the calibration method notably improved the prediction skill of GEFSv12 for ensemble probabilistic forecasts for both wet and ER events.

THANKS FOR YOUR ATTENTION