Prediction skill of GEFSv12 in depicting Monthly Rainfall and Associated Extreme Rainfall Events over Taiwan during Summer Monsoon Season

by

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

[1]CPAESS, UCAR at EMC/NCEP/NWS/NOAA
[2]EMC/NCEP/NWS/NOAA

Background and Motivation:

- The skillful prediction of monthly scale rainfall at small regions like Taiwan 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.

- Taiwan is one of the sub-tropical islands in Asia. It experiences rainfall extremes regularly, leading to landslides and flash floods in/near the mountains and flooding over low-lying plains, particularly during the summer monsoon season (June through September; JJAS).

- Although Taiwan has a lot of water scarcity due to steep topography that hardly holds rainwater, and it is 18th rank of the water-scarcity country of the world. Therefore, there is high demand for accurate prediction of monthly rainfall and associated extreme rainfall events over Taiwan.

- In September 2020, NOAA NCEP implemented Global Ensemble Forecast System version 12 (GEFSv12) to support stakeholders for sub-seasonal forecasts and hydrological applications. Consistent GEFSv12 reforecast data for 2000-2019 are 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 Taiwan with 0.5° X 0.5°

Members used : 11 members (c00, p01, p02, p03 p04, p05,p06,p07,p08,p09 and p10) based on weekly once 00 UTC initial conditions.

Reference data set used : CMORPH analysis data.

Benchmark data set used : GEFS-SubX with same horizontal resolution based weekly once 00UTC initial conditions with 11 members for the same reforecast period (Zhu et al. 2018).

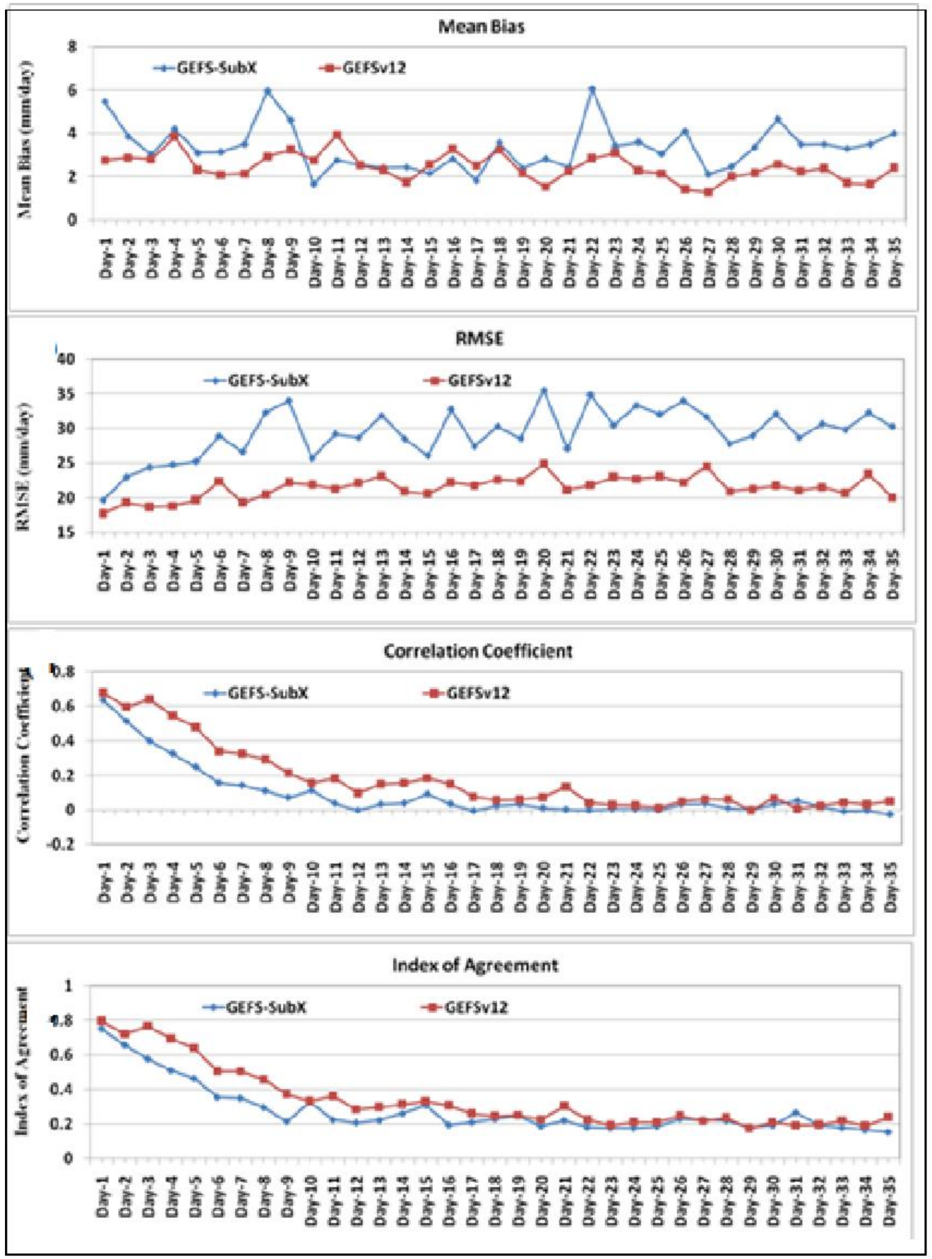
Quintile Mapping Method (Q)

This technique mainly used for to correct the GEFSv12 predicted rainfall distribution by mapping it onto the observed (CMORPH) 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. In the quantile mapping method, the bias is not calculated explicitly. 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:

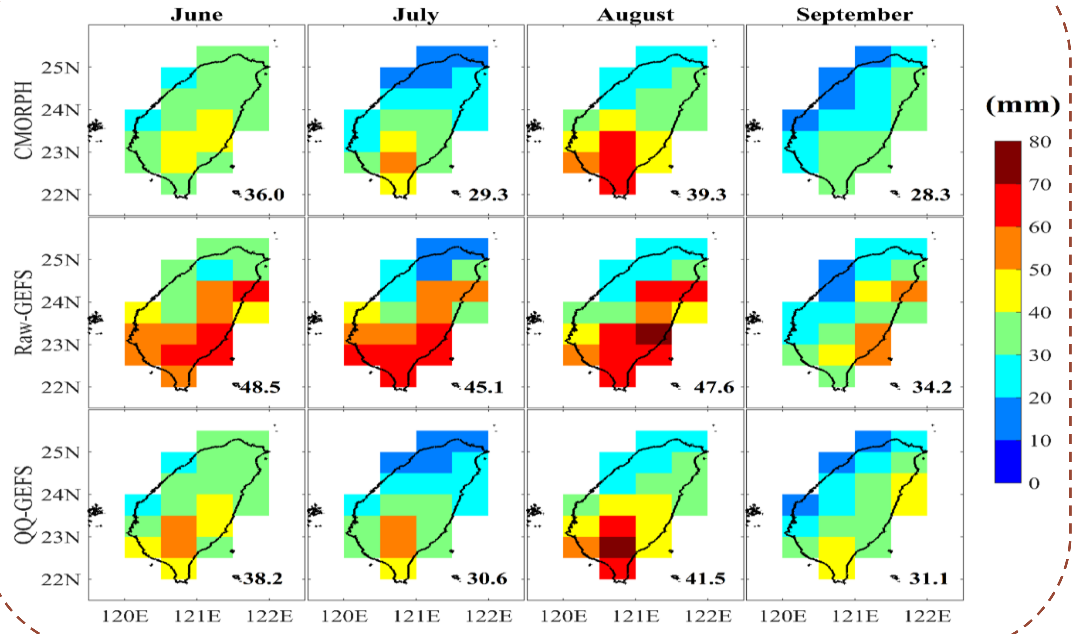
$$Q = F^{-1}_{Obs}\left(F_{\bar{F}}\left(\bar{F}_t\right)\right)$$

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.

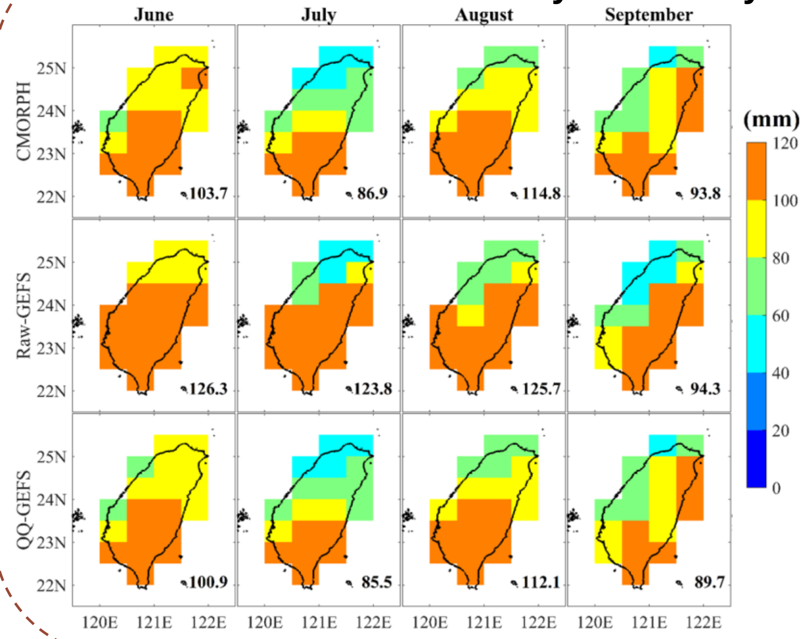


Mean Bias
GEFS-SubX
GEFSv12
Mean Bias (mm/day)
RMSE
RMSE (mm/day)
Correlation Coefficient
Index of Agreement
Day-1
Day-35

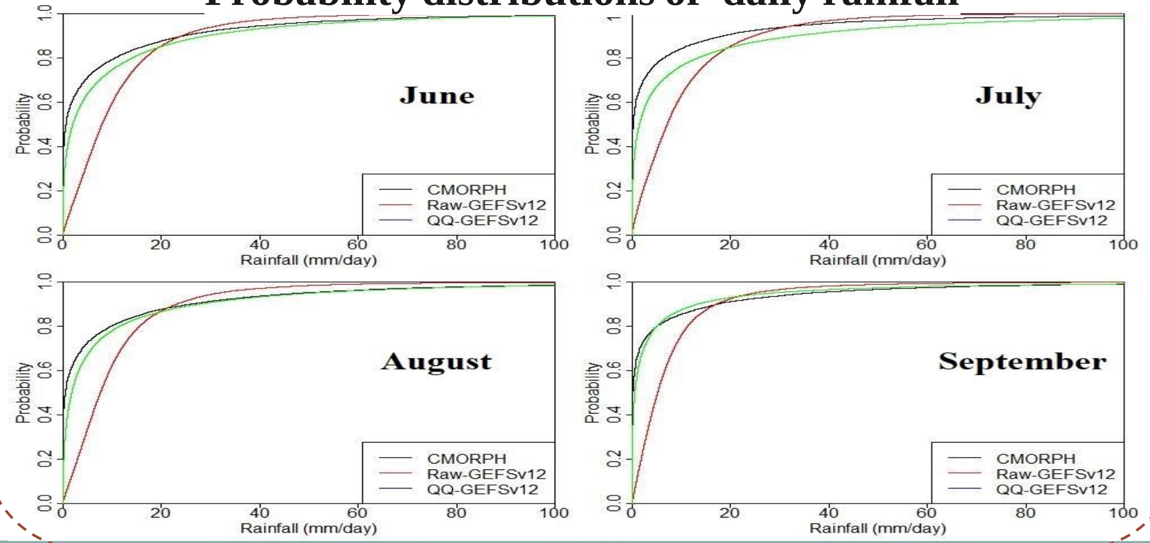
Spatial distribution of monthly rainfall

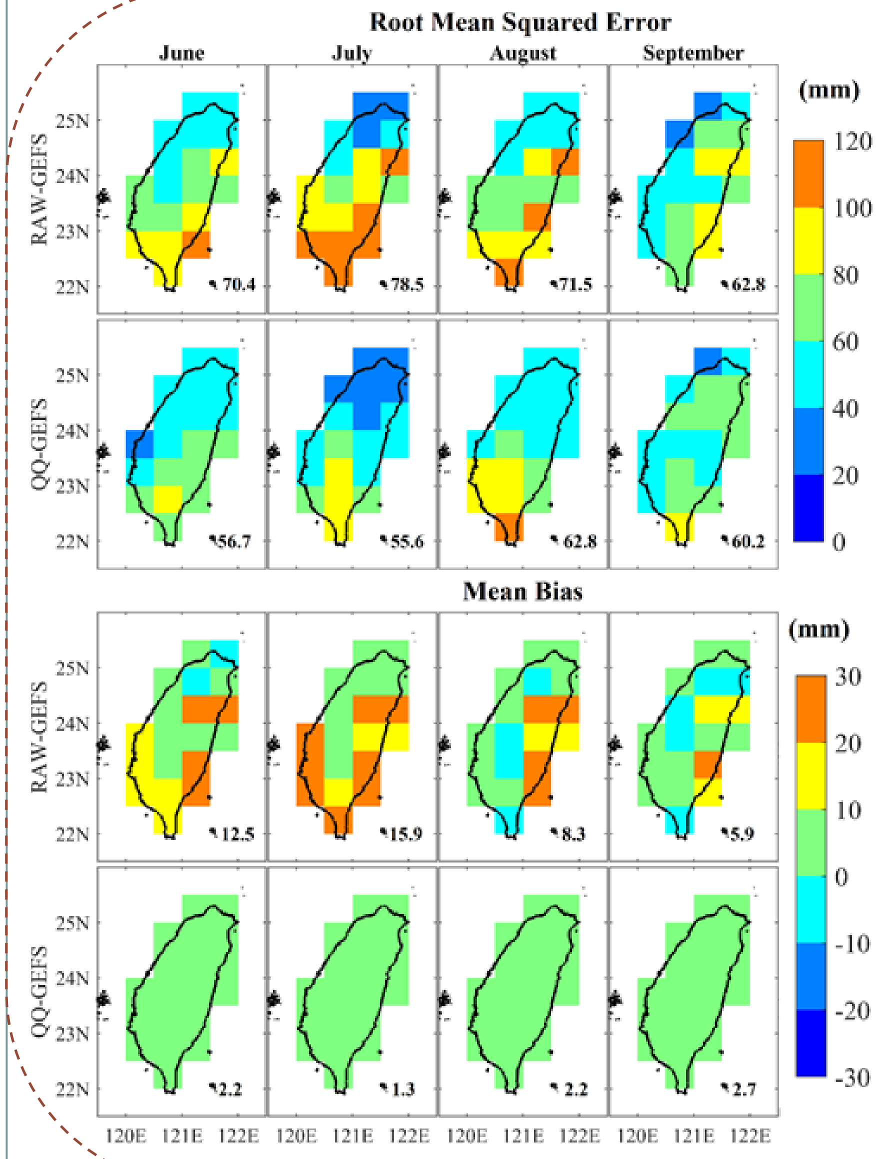


Interannual Variability of monthly rainfall

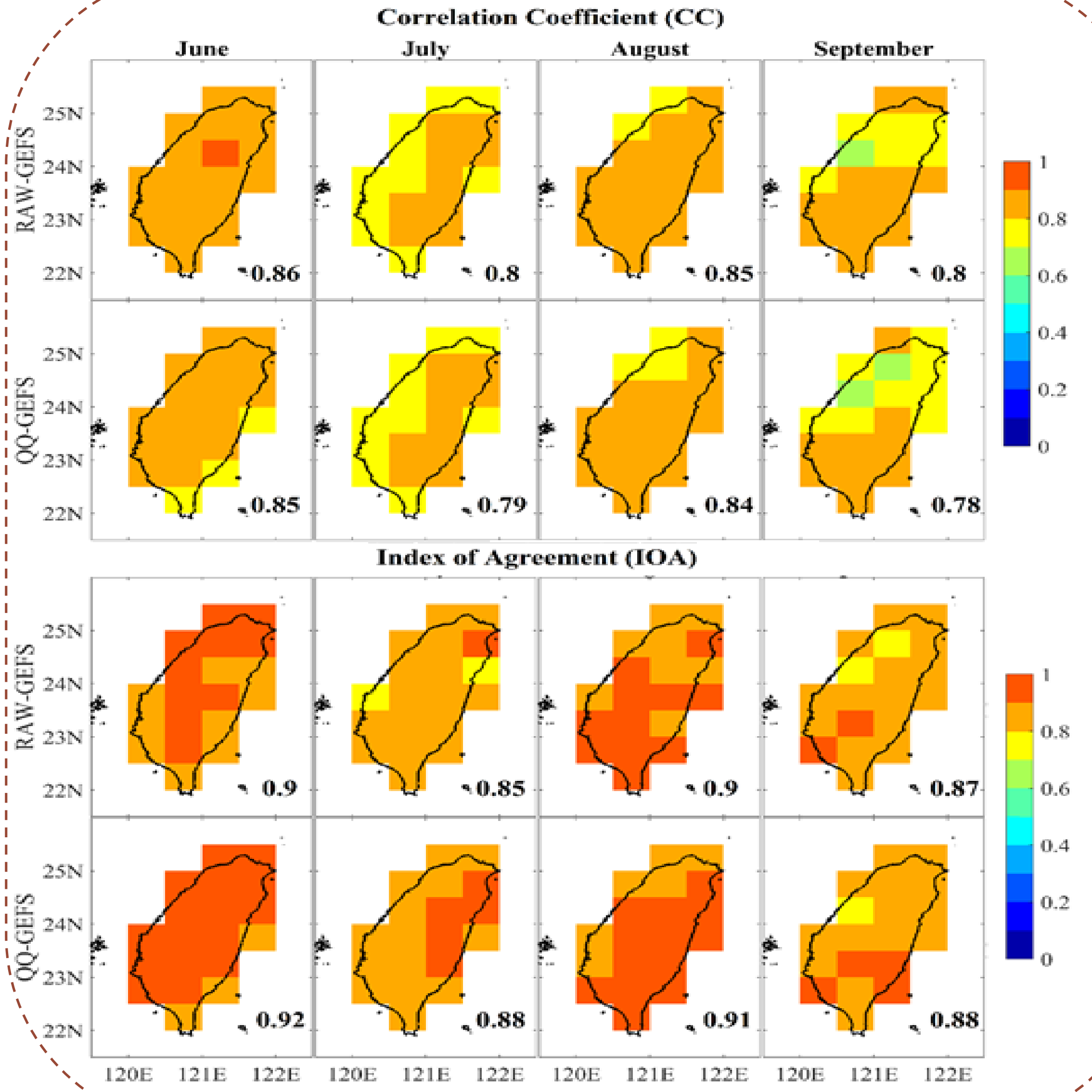


Probability distributions of daily rainfall



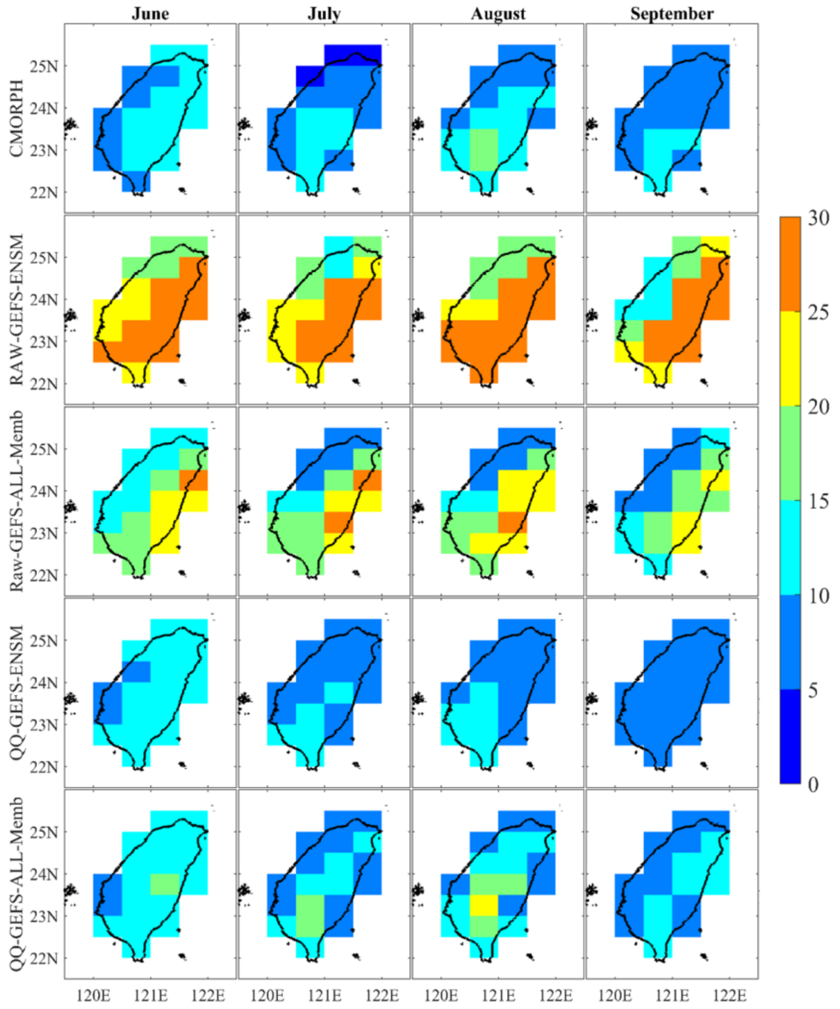


Root Mean Squared Error
June
July
August
September
RAW-GEFS
QQ-GEFS
(mm)
70.4
78.5
71.5
62.8
56.7
55.6
62.8
60.2
Mean Bias
12.5
15.9
8.3
5.9
2.2
1.3
2.2
2.7

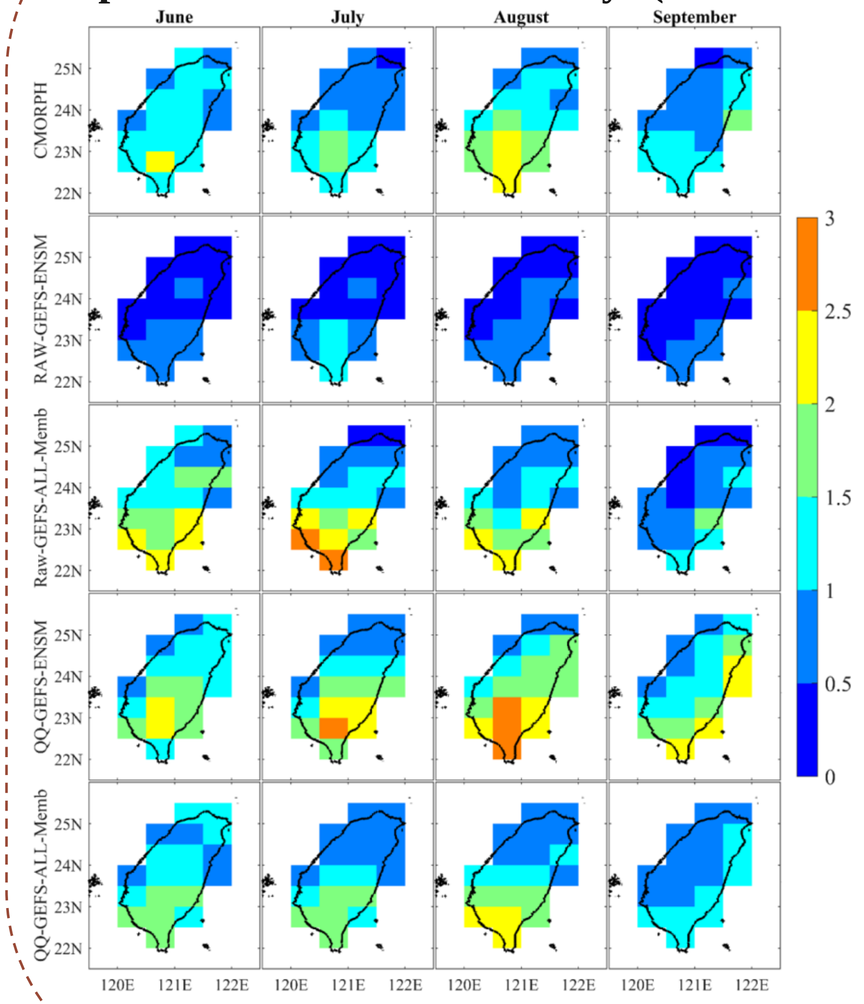


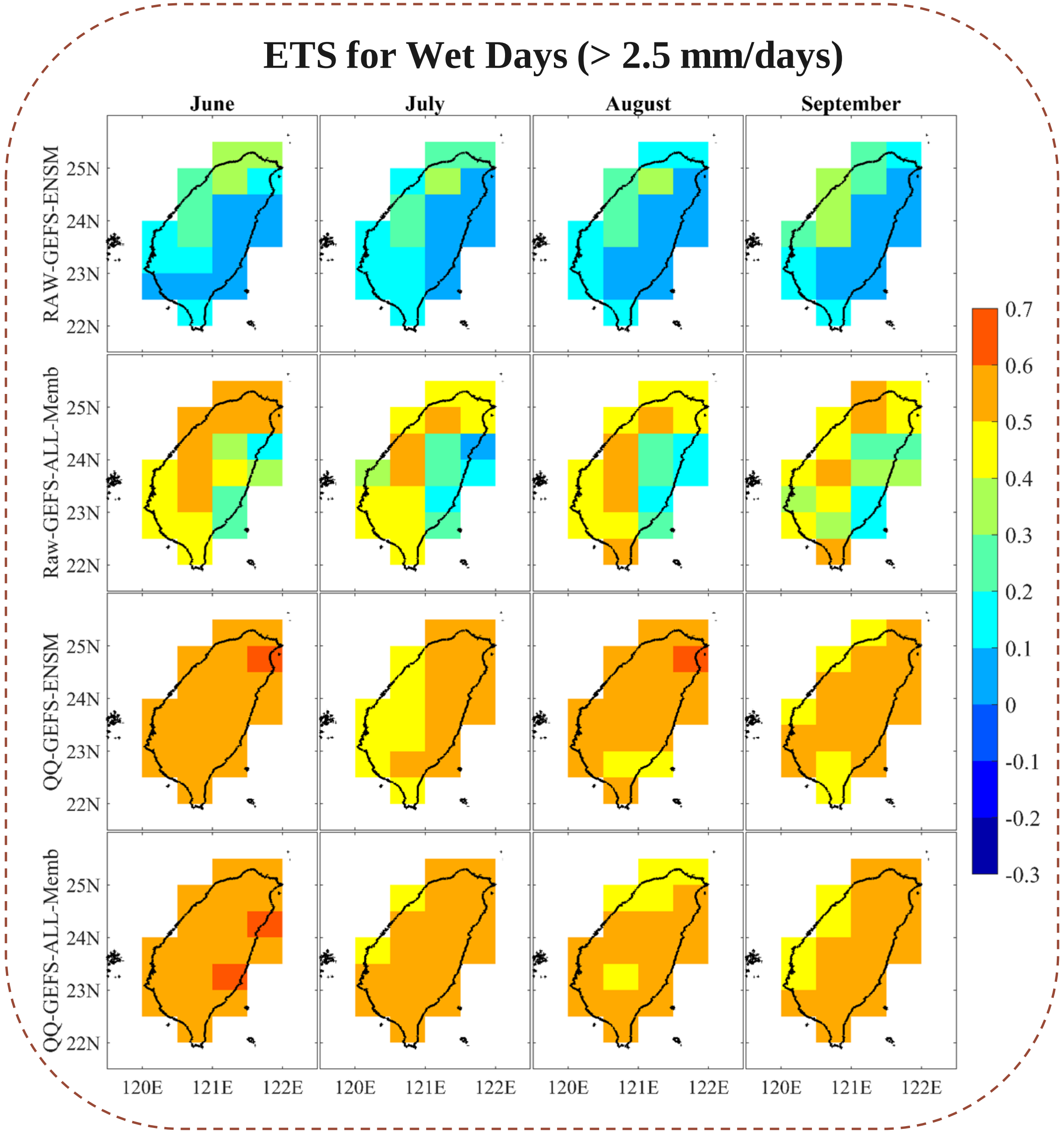
Correlation Coefficient (CC)
June
July
August
September
RAW-GEFS
QQ-GEFS
0.86
0.8
0.85
0.8
0.85
0.79
0.84
0.78
Index of Agreement (IOA)
0.9
0.85
0.9
0.87
0.92
0.88
0.91
0.88

Spatial distribution of Wet days (> 2.5 mm/day)

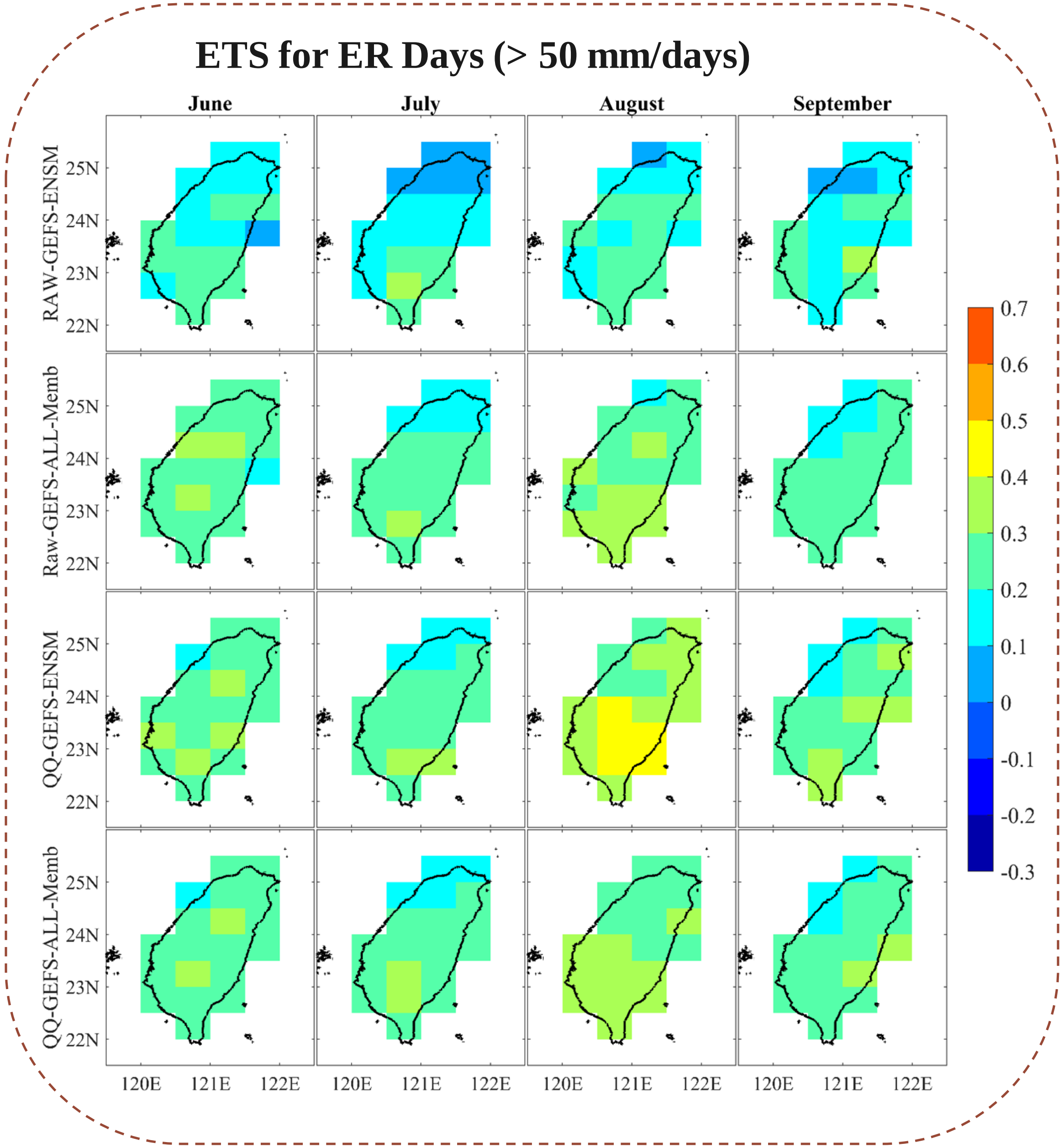


Spatial distribution of ER days (> 50 mm/day)

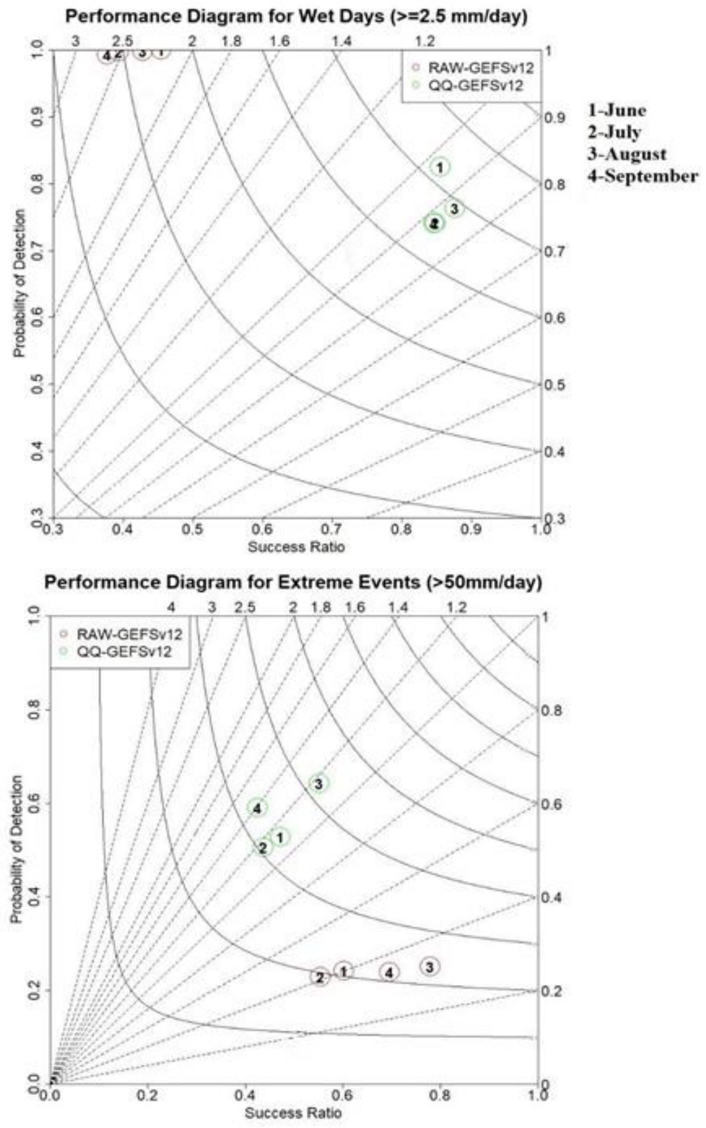


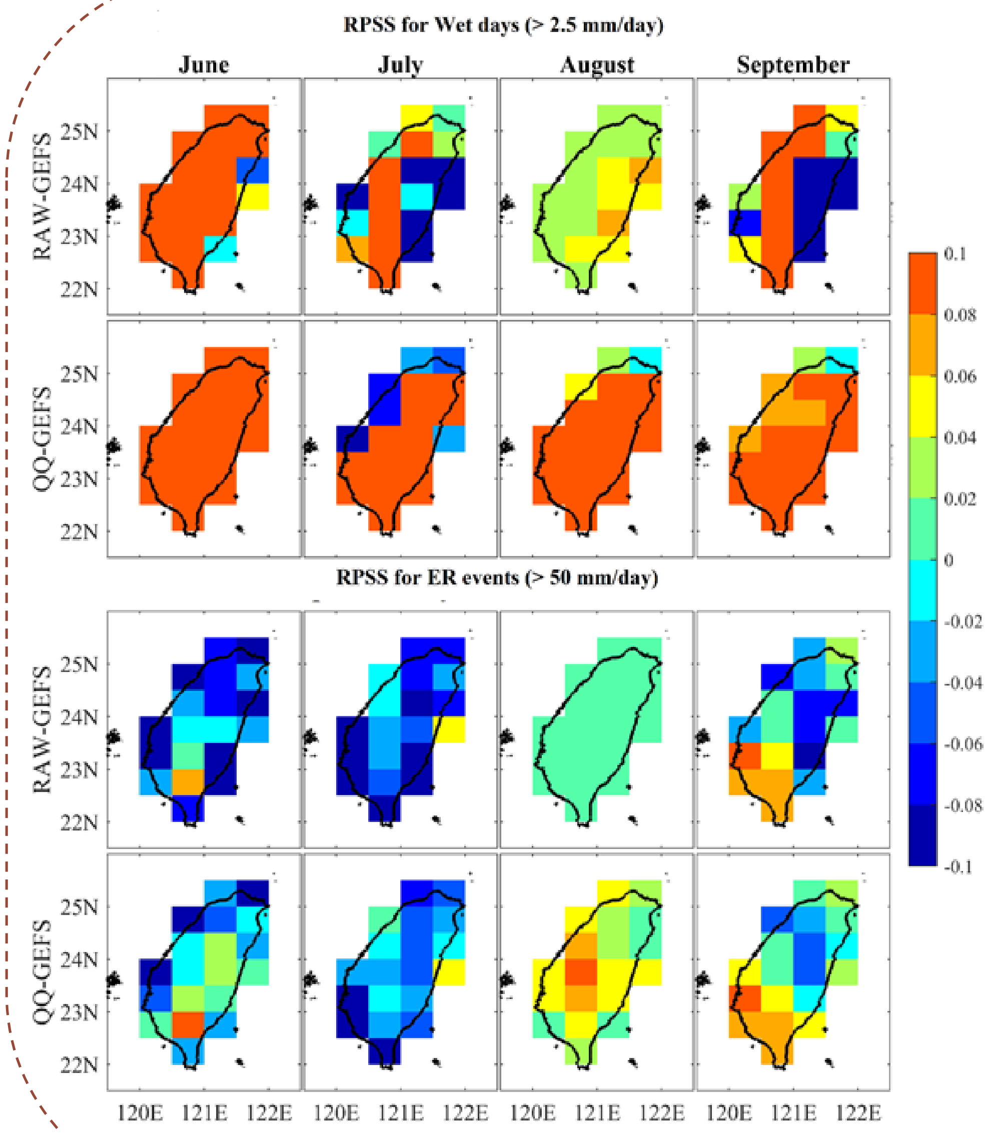


ETS for Wet Days (> 2.5 mm/days)
June
July
August
September
RAW-GEFS-ENSM
Raw-GEFS-ALL-Memb
QQ-GEFS-ENSM
QQ-GEFS-ALL-Memb
25N
24N
23N
22N
120E
121E
122E
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3



ETS for ER Days (> 50 mm/days)
June
July
August
September
RAW-GEFS-ENSM
Raw-GEFS-ALL-Memb
QQ-GEFS-ENSM
QQ-GEFS-ALL-Memb
25N
24N
23N
22N
120E
121E
122E
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3


Performance Diagram for Wet Days (>=2.5 mm/day)
RAW-GEFSv12
QQ-GEFSv12
1-June
2-July
3-August
4-September
Probability of Detection
Success Ratio
Performance Diagram for Extreme Events (>50mm/day)
RAW-GEFSv12
QQ-GEFSv12
Probability of Detection
Success Ratio


RPSS for Wet days (> 2.5 mm/day)
June
July
August
September
RAW-GEFS
QQ-GEFS
RPSS for ER events (> 50 mm/day)
RAW-GEFS
QQ-GEFS
25N
24N
23N
22N
120E
121E
122E

Summary

- There is a remarkable improvement in prediction skill of GEFSv12 as compared to GEFS-SubX. These improvements may be attributed to the combined influence of better initial conditions, more advanced microphysics schemes, finer resolution and a new FV3 dynamic core.

- The GEFSv12 can represent the climatological features Mean, IAV, and CV of monthly rainfall over Taiwan during the summer monsoon season. However, it has a significant overestimation for mean and IAV of monthly rainfall and it is particularly more during peak monsoon months. After calibration, the overestimation in mean and IAV of monthly rainfall over Taiwan is remarkably decreased.

- The RMSE and Mean bias errors of monthly rainfall from Raw-GEFSv12 are high in the south and eastern part of Taiwan, whereas prominent monthly rain and its IAV are significantly high. The errors of RMSE and mean bias decreases from south to north and east to west during all the months. After calibration, both errors notably decreased for all the months.

- The prediction skill (Correlation coefficient and Index of Agreement) of GEFSv12 in depicting the summer monsoon monthly rainfall over Taiwan for all the months is significantly high (CC and IOA >0.8) in most parts of Taiwan and particularly more during peak monsoon months August and June.

- There is a considerable overestimation of Wet days in most parts of Taiwan from Raw-GEFSv12 has been found during all months, whereas a large underestimate of ER events has observed. After calibration, the probability distribution of various intensity rainfall events from QQ-GEFSv12 is well adjusted to the CMORPH in most parts of the country during all the months. The QQ-GEFSv12 can depict ER events (> 50 mm/days), in which rainfall events lead to floods and landslides over Taiwan.

- The calibration method significantly improved the most statistical categorical skill scores (BIAS, ACC, SR, FAR, TS, and ETS) for wet and ER events expect POD for Wet days.