# Effect of SST Variability on Rainfall Extremes in a Regional Climate Model

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## Introduction

- The distribution of daily rainfall is highly skewed with the peak occurring at zero rainfall (as opposed to temporal or spatial averages) and probability decreasing with increase in rainfall amount.
- The right tail of this distribution (corresponding to extreme rainfall events) is difficult to model and is of considerable importance because of the catastrophic effects of such events.
- In first part of this study, we compare simulated daily rainfall distribution from Weather Research Forecast (WRF) model with observations over continental united states (CONUS).
- We expect that the finer spatial resolution of WRF can provide better simulation of smaller or local scale phenomena often associated with extremes of precipitation.
- In addition to comparing sample mean, variance and 95$^{th}$ percentile value, we fit the two-parameter gamma distribution and use it to highlight the differences in the precipitation statistics.
- Both 95$^{th}$ percentile and the scale parameter (from the gamma distribution fit) are indicators of extremes of rainfall, higher values would imply increased chances of extreme rainfall.
- In order to study the role of the ocean in affecting the rainfall distribution, we compare two WRF runs forced with climatological Sea Surface Temperature (SST) and the observed SST, respectively.
- This analysis can lead to a better understanding of the effect of SST variability on daily rainfall.

## Model and Data Description

### WRF

Weather Research Forecast model is run at 27km X 27km spatial resolution for 1981 to 2000 period. Two experiments were performed,

**WRF IA** is WRF forced with observed SST boundary conditions.

**WRF CL** is WRF forced with climatological SST boundary conditions.

### NARR

North American Regional Reanalysis provides 8 times daily data at 29 levels (~32km resolution) from 1979 to near present . It is carried out using NCEP Eta Model and Regional Data Assimilation System and provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA.

### CPC

A gridded daily precipitation analysis (0.25$^o$ X 0.25$^o$) from Climate Prediction Center (CPC) created by employing the Cressman interpolation scheme on CPC's unified rain gauge data-base. It is provided by NOAA/NWS/NCEP.

**WRF DOMAIN** 130°W-25°E, 33°S-52°N

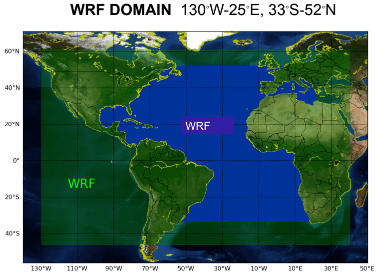



**Figure 1 :** WRF Model Domain

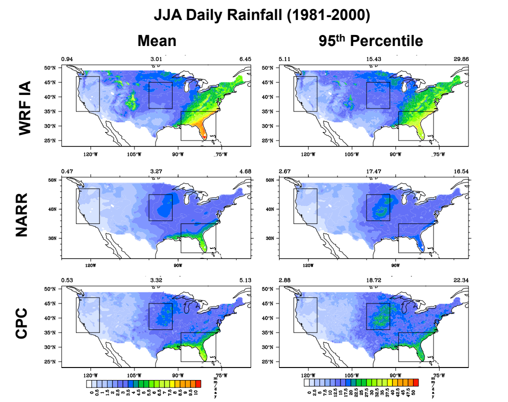



**Figure 2 :** Average daily rainfall (left) and 95$^{th}$ percentile value (right) of JJA daily rainfall (1981-2000) for WRF, NARR and CPC (top to bottom). Spatial Averages over three outlined regions (West, Mid-West, South-East) are shown on top of each panel in that order from left to right.

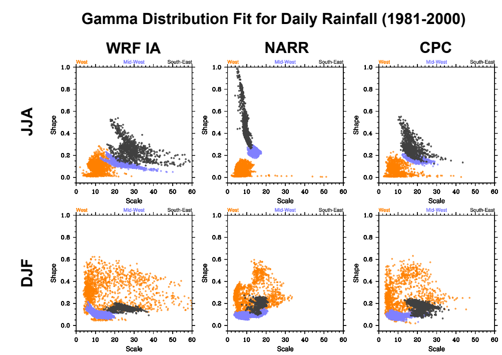



**Figure 3 :** Comparing scatter of shape and scale parameters (gamma distribution) for JJA (top) and DJF (bottom) daily rainfall, 1981-2000, between WRF, NARR and CPC, color coded by three regions of interest (West, Mid-West, South-East) shown in previous figure.

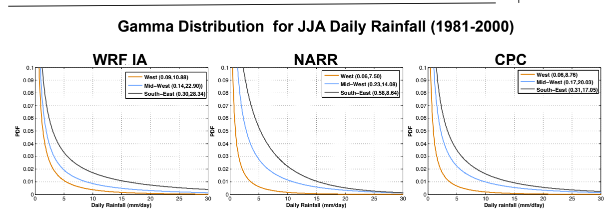
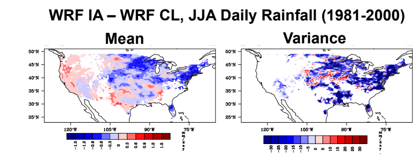



**Figure 4 :** Comparing the gamma distribution fit of JJA daily rainfall, 1981-2000 for the three regions of interest. Shape and Scale parameters for each region are shown along with the region name in the legend.



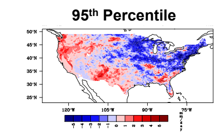




**Figure 5 :** Significant differences in mean, variance and 95$^{th}$ percentile of JJA daily rainfall (1981-2000) between two WRF runs (WRF IA –WRF CL), (1) WRF IA (left; forced with observed SST) and (2) WRF CL (right; forced with climatology SST).

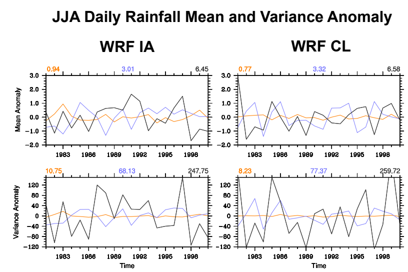



**Figure 6 :** Inter-annual variation in daily mean and variance of JJA daily rainfall for three regions of interest (same color code as in previous figures) for two different WRF runs. Only Anomalies are plotted with subtracted mean for each region indicated at the top of the panels.

## Daily Rainfall Distribution

### From figure 2

- WRF simulates the spatial pattern of JJA daily rainfall well.
- But both daily mean and 95$^{th}$ percentile value of JJA daily rainfall for 1981-2000 period in WRF are overestimated over South-East region and underestimated over Mid-West region of CONUS compared to NARR and CPC.
- NARR and CPC have similar daily mean rainfall over all three outlined regions but disagree on 95$^{th}$ percentile value over South-East region.
- These results highlight discrepancies between observations and simulations of daily rainfall.

### From figure 3

- We use the method of moments to fit the two-parameter gamma distribution to the data.
- For summer months, WRF has greater scatter and higher scale parameter values for Mid-West and South-East regions. On the other hand, NARR shows very low scatter for the same period and regions.

## Daily Rainfall Distribution Continued . . .

Differences in west region becomes more prominent in winter months with WRF having greater scale parameters points than NARR and CPC.

### From figure 4

- Typical gamma distribution fit over three regions of interest for Summer months.
- Higher scale parameter in WRF for South-East region leads to longer tail and and greater chance of extreme rainfall event.

## SST Variability

### From figure 5

- Daily mean rainfall decreases over eastern US and increases over western US, when using interannually varying SST instead of climatological SST. (Only significant changes in the mean are shown).
- This decrease of daily mean rainfall affects variability and we see significant reduction in variance, even when the SST forcing has high inter-annual variability.
- We see similar changes in regions of higher percentile i.e., reduction of extreme rainfall, over eastern US and opposite effect over western US.
- We use non-parametric tests to assess the statistical significance of differences in both mean and variance.

### From figure 6

- Inter-annual variation in daily mean and variance of JJA daily rainfall is greatest over the south-east followed by the mid-west.
- Suggests that reduced variability in the interannual run is due to reduced mean rainfall over the mid-west and south-east region.

## Conclusions

- WRF underestimates both daily mean as well as extreme rainfall over the mid-west region and overestimates them over the south-east region during summer.
- WRF rainfall has higher scale parameter values for JJA daily rainfall distribution and hence longer tails than those obtained from NARR and CPC. On the other hand, NARR has the least values for the scale parameter.
- There is counterintuitive lowering of the variability in daily rainfall when forcing WRF with observed SST (with inter-annual variability) instead of climatological SST (without inter-annual variability).
- The reason for this is the decrease in daily mean rainfall in the inter-annual run leading to decreased variability. In other words, lowering of the mean dominates over SST variability effect.

## References

- Emily J. Becker , E. H. Berbery , 2009: Understanding the characteristics of Daily Precipitation over the United States Using the North American Regional Reanalysis. J. Climate, 22, 6268-6286.
- Peter Caldwell, H. S. Chin, David C. Bader, G. Bala, 2009: Evaluation of a WRF dynamical downscaling simulation over California, Climate Change. 95, 499-521.