Trend Analysis of Extreme Daily Precipitation over Contiguous United States using MERRA and NCEP NARR Products

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Abstract

Analysis of climate extremes is an emerging research area which has recently captured increasing interest among climate scientists and statisticians. Particularly in this study, potential trends in extreme precipitation events due to climate change and variability is investigated. For such purpose, two of the most well-known "Reanalysis" products, named NCEP NARR (regional) and MERRA (global), along with gauge measurements are used to investigate the behavior of extreme precipitation events during the past three decades over Contiguous United States.

Introduction

Severe floods happening all around the world claim lots of lives and cause large socioeconomic losses. For instance, in 2011 in the United States alone there were a total of 14 major weather and climate related disasters, each of which resulted in loss of human lives and economic impact of $1 billion dollar or more.

Fig 1. The U.S. weather and climate disasters in year 2011. (NOAA)

One of the most important issues in the context of analyzing extreme precipitation events is whether or not such extreme have been affected by climate change and variability.

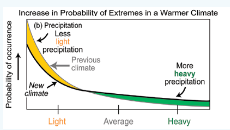

Fig 2. Simplified depiction of the changes in precipitation in a warming climate (Peterson et. al. 2008) .

Possibility of the changes in the distribution of extreme precipitation events with respect to time is investigated in this study. One global and one regional reanalysis products with long term records (+30 years) and high temporal resolution (sub-daily) are utilized. CPC gauge information are included to test the performances of such reanalysis.

Data

Daily Precipitation data from the following three products for the period of 1979-2010 (32 years) were used for the analysis.

1.MODERN ERA-RETROSPECTIVE ANALYSIS FOR RESEARCH AND APPLICATIONS (MERRA): Global, Hourly, 1/2 degrees latitude × 2/3 degrees longitude, 1979-2012.

2. NCEP North American Regional Reanalysis(NARR): Regional, 3 hourly, 0.3 degree (32 km) in the lowest latitude, 1979-2010.

3. NOAA Climate Prediction Center (CPC): U.S. UNIFIED Precipitation, Daily, 0.25x0.25 degree, 1948-2012.

Annual Maximum Daily Precipitation (AMDP)

In this approach, the maximum daily precipitation of each year in CPC, NARR and MERRA for the period of 1979-2010 is taken into account for trend analysis.

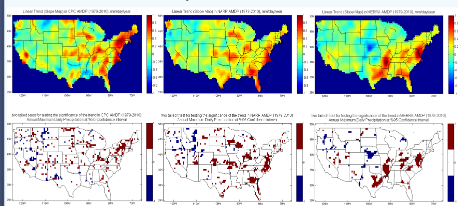

Fig 3. Linear Trend in AMDP (top) and Significance Test (bottom) for CPC (left), NARR (middle) and MERRA (right).

Generally, negative and positive trend in AMDP is identified in the West and East parts of the U.S., respectively. NARR and MERRA generally underestimate the trend in AMD, when compared with CPC. However, NARR seems to depict a more similar pattern to CPC, than what MERRA does. MERRA shows a large negative trend in the middle of the CONUS, unlike CPC or NARR.

• Generalized Extreme Value (GEV) Distribution

Incorporating from Statistics and the Extreme Value Theory, distribution of the block maxima (here AMDP) of a sequence of random variable can be a approximated by GEV Distribution.

$$G(z) = \exp\left\{-\left[1+\xi\left(\frac{z-\mu}{\sigma}\right)\right]^{-\frac{1}{\xi}}\right\} \; for\; z: 1+\xi\left(\frac{z-\mu}{\sigma}\right) > 0$$

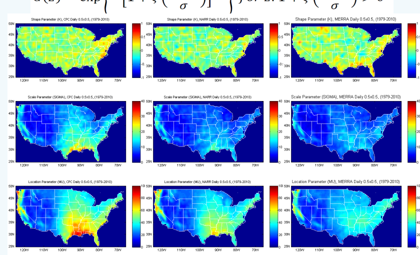

Fig 4. GEV Parameters, Rows (Top: Shape Par., Middle: Scale Par., Bottom: Location Par.), Columns: (Left: CPC, Middle: NARR, and Right: MERRA)

Detailed look at the location parameter maps shows:

1. Mid-West and West Cost: NARR and MERRA are doing a good job in Mid-West to West Coast of the U.S. NARR is doing a better job than MERRA.

2. Gulf States: Both NARR and MERRA have larger biases in the Gulf States, however MERRA shows poorer performances. The reason seems to be due to the high correlation of MERRA with Gulf Coast Cyclones.

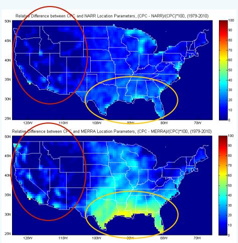

Fig 5. Relative Difference between location parameters of CPC and NARR (top), CPC and MERRA (bottom)

Change in GEV Distribution?

1 . Changes only with respect to "Time"?

Specifically looking at the trend in the location parameter of GEV distribution in 20-year long periods from 1979-2010 shows significant trend in this parameter. This results directly implies changes in the extreme precipitation distribution in time. Negative and positive trends are identified in the West and East of the U.S., respectively.

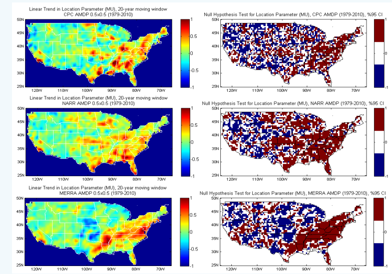

Fig 6. Trend in GEV location parameters of CPC (top), NARR (middle) and MERRA (bottom) Annual Maximum Daily Precipitation.

2 . Changes with respect to "Time" and "ENSO"?

Effects of Sea Surface Temperature (SST) changes in Pacific Ocean on the trend of AMDP was investigated. ENSO doesn't seem to have a significant effect on Extreme Precipitation events. If we notice the coefficient of "Time" before and after including "SST" as another predictor, there are not significant changes to "Time" coefficient, stating the most important factor in the AMDP trend is "Time". "SST" shows some significant effects on the West's precipitation

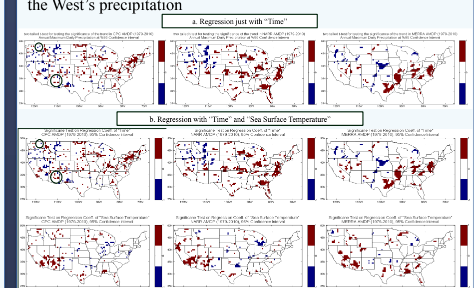

Fig 7. Effects of Sea Surface Temperature Changes in the form of ENSO on Precipitation (b. 2D Regression of AMDP and Time, b. 3D Regression of AMDP with Time and Nino3.5. Column: CPC (Left), NARR (Middle), MERRA (Right)

Generalized Pareto (GP) Distribution

Block maxima approach wastes information about extremes by just choosing one point for each block (e.g. annual maxima) Instead, for a large enough threshold, Generalized Pareto (GP) distribution approximates the peaks over threshold distribution as;

$$\Pr(X > y+u \mid X > u) = H(y) = 1-\left(1+\frac{\xi y}{\tilde{\sigma}}\right)^{-\frac{1}{\xi}} \; for\; y > 0 \; and \; 1+\frac{\xi y}{\tilde{\sigma}} > 0$$

Annual Extreme Daily Precipitation (AEDP)

In this approach, top 1% of all daily precipitation data fro the period of 1979-2010 is extracted to build the AEDP time series.

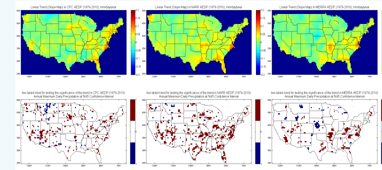

Fig 8. Linear Trend in AEDP (top) and Significance Test (bottom) for CPC (left), NARR (middle) and MERRA (right).

Generally, the trend in AEDP ([-0.2 0.2]) is much smaller than the trend in AMDP ([-1 1]) in all the three products. Large negative trend in mid-US in MERRA data is showing off.

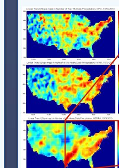

Fig 10. Trend in the number of AEDP, CPC(top), NARR(middle) MERRA(bottom)

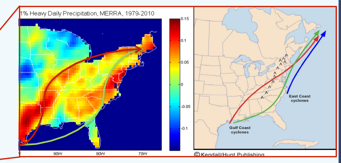

Fig 11. Potential reason for the MERRA biases in the Gulf Stats.

As it's clear in figure 11., MERRA precipitation product seems to be very biased toward **Gulf Coast Cyclones** at the Gulf States.

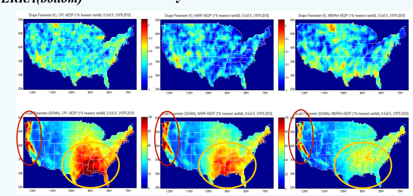

Fig 9. GP Parameters, Rows (Top: Shape Par., Bottom: Scale Par., Columns: (Left: CPC, Middle: NARR, and Right: MERRA)

Conclusions

- Generally, West and East part of the U.S. are respectively experiencing negative and positive trends in AMDP intensity and AEDP frequency. Trend in AEDP is much smaller than the trend in AMDP in all the three products
- Both NARR and MERRA do a good job in capturing the behavior of extremes in the West. However, they both have problem in the Gulf states. (MERRA more than NARR).
- The most probable explanation for such behavior of MERRA could be that MERRA's precipitation product seems to be very biased toward Gulf Coast Cyclones.
- ENSO shows effects on the AMDP of the West, however its influences is not significant on other regions.

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