Extreme precipitation in reanalyses

Nir Y Krakauer

Associate Professor, Department of Civil Engineering and NOAA-CESSRST, The City College of New York, USA

`https://nirkrakauer.net  nkrakauer@ccny.cuny.edu`

Increasingly heavy extreme precipitation episodes, typically lasting from hours to days, inflict large amounts of damage. Reanalyses can be an important source of quantitative information on the climatology and trends of precipitation extremes, particularly for areas where dense station or radar measurements are not accessible, but accuracy is a concern.

Here, the ERA5, MERRA2, and JRA55 analyses are compared with the US Climate Prediction Center (CPC) national grid-based monthly precipitation product. The comparison focuses on individual heavy precipitation events, such as those that cause billion-dollar flood damage, as well as correlation in heavy precipitation over their entire period of overlap.

The CPC Unified Gauge-Based Analysis of Daily Precipitation over the Coterminous US is available since 1948, with 0.25° spatial resolution. The monthly version is used here to make exploratory analysis easier. Nearest neighbor interpolation was used to regrid all reanalyses to the CPC grid. Correlations are computed over the period 1980-2023, when all the reanalyses are available.

As an example, Figure 1 shows precipitation amounts for August 2014, which included widespread billion-dollar flooding in the northeast US on the 11th-13th, including in Maryland, Michigan, and New York, where Islip, in Long Island, set a new 24-hour state precipitation record of 345 mm. In this case, none of the reanalyses capture the precipitation maximum seen in southern New Jersey in the CPC product, and the CPC product itself does not show the intense precipitation around Islip. MERRA2 shows overly heavy precipitation in parts of Michigan, compared to available observations.

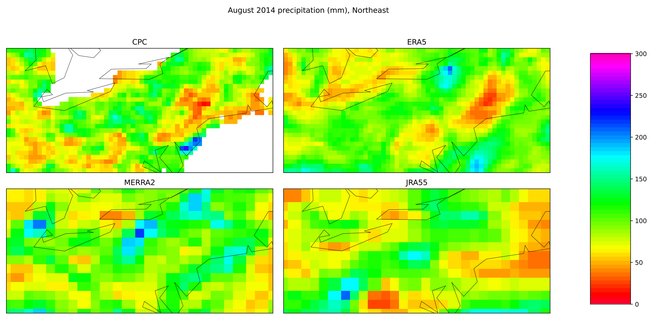

Figure 1:

The time series for August precipitation at Islip (Figure 2) shows that the CPC product misses the 2014 flood and shows the highest accumulation in 2011, under Hurricane Irene.

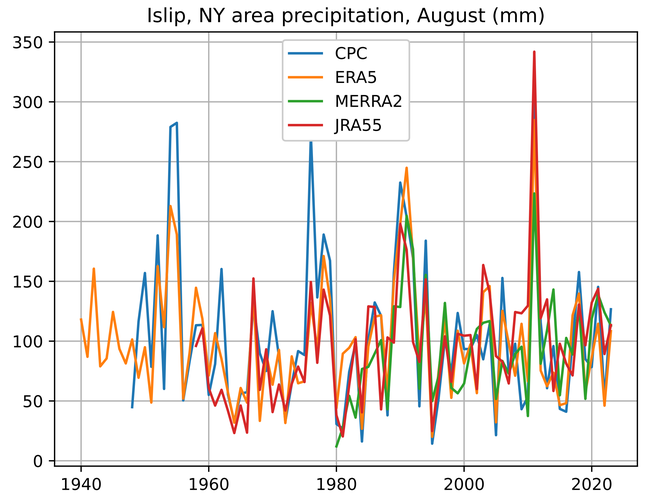

Figure 2:

As another example, April 2023 featured billion-dollar extreme flash flooding over a small area of south Florida centered on Fort Lauderdale on the 12th-13th. Reanalyses do not fully capture the small area of observed extremely heavy rainfall (Figure 3).

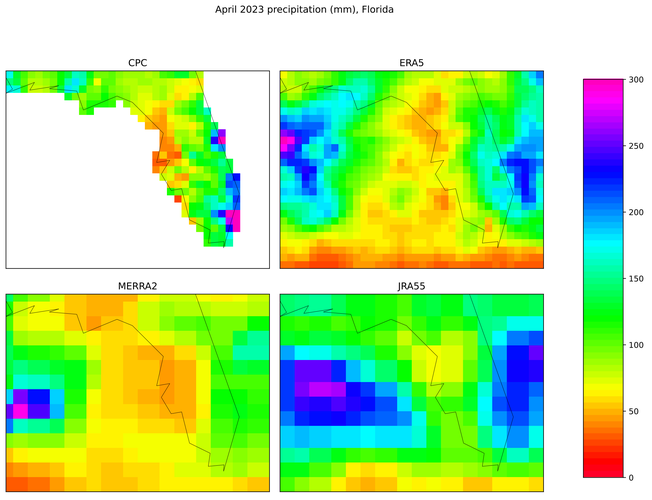

Figure 3:

For Figure 4, the correlations between reanalysis and CPC precipitation amount time series by month, computed for each CPC grid cell and then averaged. Reanalyses better represent interannual precipitation variability during the cold season than in the summer, particularly in the east, where small-scale convection is most prominent in summer. ERA5 outperforms the other reanalyses, especially in summer, and JRA55 does better than MERRA2 in summer and about the same in winter.

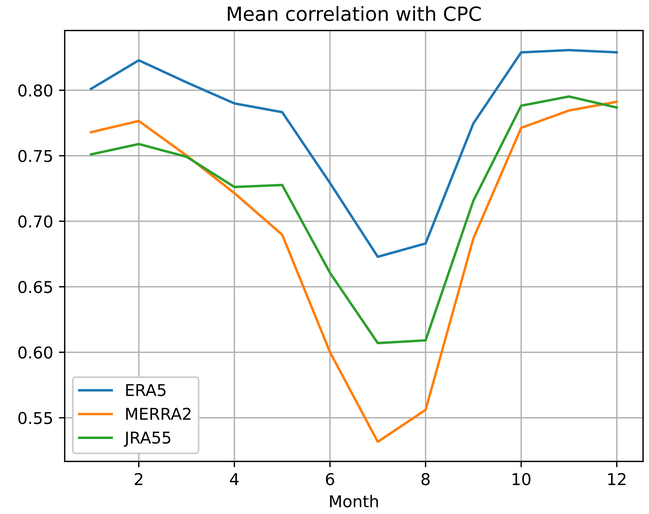

Figure 4:

Figure 5 shows the overall correlation coefficient of monthly precipitation dichotomized at different thresholds. Reanalyses' overlap with the CPC location of the heaviest precipitation events decreases as the event magnitudes get more extreme and rare. MERRA2 does better than ERA5 for the highest precipitation thresholds, above 200 mm per month.

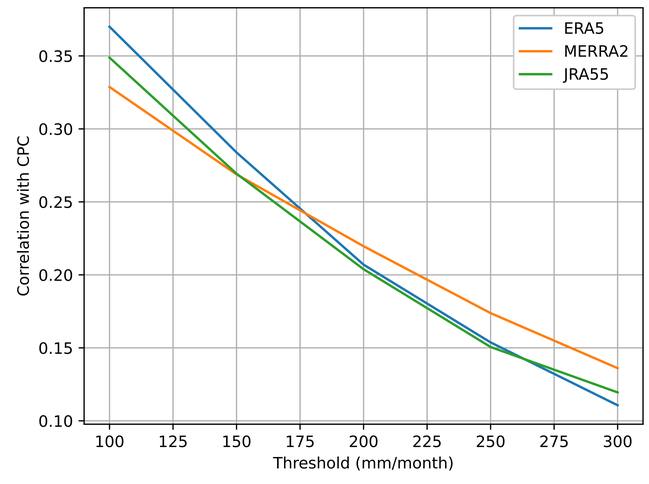

Figure 5:

Conclusions: Precipitation extremes over the US leading to billion-dollar floods are mostly represented in the reanalyses, but magnitudes tend to be underestimated especially for spatially smaller, convection-dominated events.
ERA5 slightly outperforms MERRA2 and JRA55 by most measures.
Need to extend comparison to newer products (JRA-3Q, ERA5 4D-Var) and other parts of the world.
Python notebook for the comparisons shown is available by request.