Long-term Quantification of Extreme Precipitation in Relation with Tropical and Extra-tropical Cyclonic Activity over the Carolinas

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Introduction

The precipitation climatology of the Southeastern United States, including the Carolinas region in particular, spans a broad spectrum of precipitation regimes. The warm season is characterized by isolated thunderstorms, squall line mesoscale convective systems, and tropical cyclones, and the winter season is characterized by frontal rain from extra-tropical cyclones, ice, and snowfall (Prat and Nelson 2013a, Prat and Nelson 2014). Each of these types of precipitation systems impacts regional hydrology in very different ways and are associated with a variety of natural hazards.

Previous work used satellite data along with TC Tracks information to evaluate the contribution of tropical cyclones over the Southeastern US (Prat and Nelson 2013a) and on a global scale (Prat and Nelson 2013b) for the period 1998-2012.

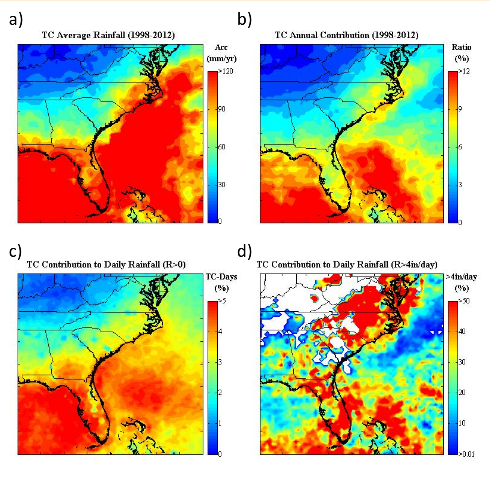

Fig 1. TC rainfall (a) and TC annual rainfall contribution (b) for 1998-2012 derived from TMPA 3B42 satellite observations. TC contribution to daily rainfall: R > 0 (c), and R > 4 in. day^{-1} (d) Figures are adapted from Prat and Nelson (2013b, 2016).

In this work, we use long-term surface observations from the Global Historical Climatology Network (GHCN-Daily) combined with tropical cyclones (TCs) and extra-tropical cyclones (ETCs) track information to quantify the precipitation contribution of each of these storm systems to annual, seasonal, monthly, and daily precipitation over the Carolinas.

Tropical Cyclone Contribution to Annual Rainfall and Extreme Daily Events

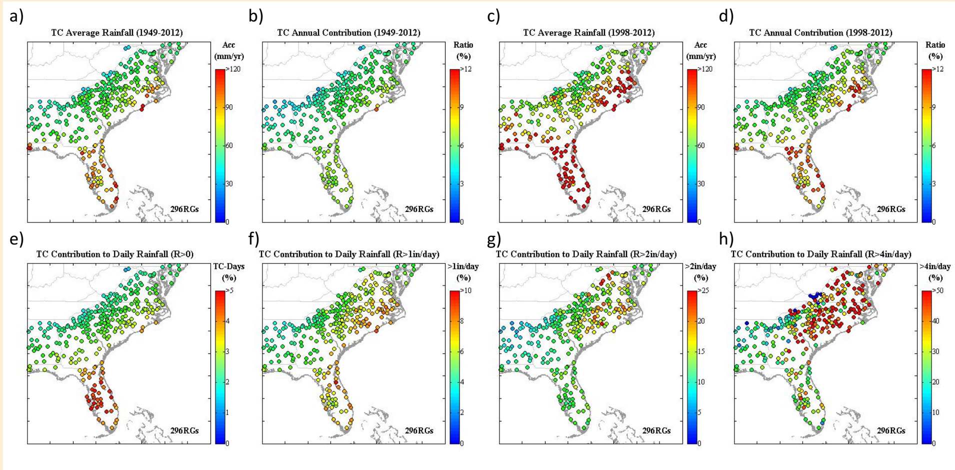

Fig 2. TC rainfall (a, c) and TC annual contribution (b, d) for 1949-2012 (a, b) and 1998-2012 (c, d) derived from the GHCN-D network. TC contribution to daily rainfall: R > 0 (e), R > 1 in. day^{-1} (f), R > 2 in. day^{-1} (f), and R > 4 in. day^{-1} (g) for 1949-2012.

Annual Daily Extreme Value Analysis

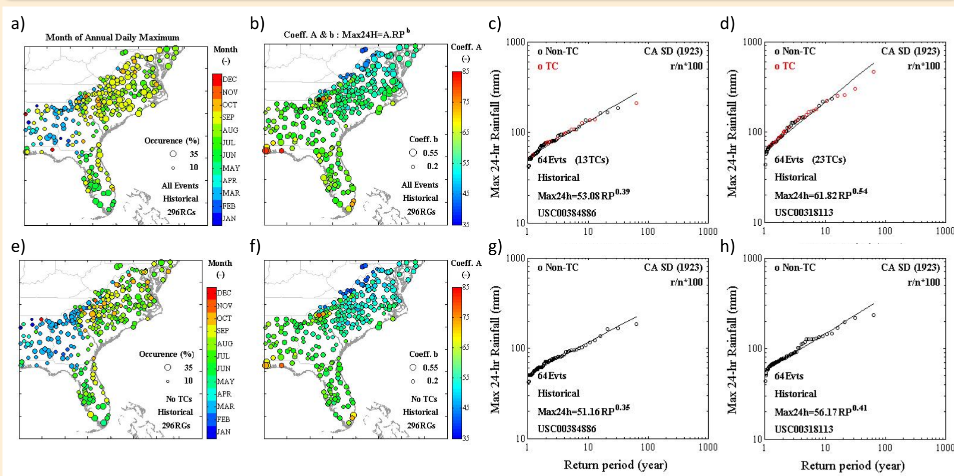

Fig 3. Month during which the annual daily maximum occurs (a). Values of the Coefficients (A,b) from the power law relationship between the maximum annual daily rainfall and the return period computed using the California State Department (CA SD) plotting position (b). Maximum annual daily rainfall as a function of the return period for two selected coastal locations (c, d). The red dots indicate an annual daily maximum associated with a TC. Figures 3-e, -f, -g, -h display similar information as Figures 3-a, -b, -c, -d when daily rainfall associated with TCs is removed from the distribution.

Preliminary Results

- Coastal NC exhibits the highest TC rainfall (>90 mm.yr^{-1}) and contribution (>8%) for 1949-2012 (Figs. 2a-b). The period 1998-2012 indicates higher TC rainfall and contribution than the 1949-2012 period over the Carolinas with totals >120 mm.yr^{-1} over the North Carolina's Coastal Plain (Figs. 2 c-d).
- TCs account for 2-4% of the total number of rainy days over the Carolinas (Fig. 3e). The proportion of extreme events associated with TCs increases with increasing values of the daily extreme threshold (Fig. 3f-g). On a local basis, TCs account for the majority (>50%) of daily extremes above 4 in.day^{-1} (Fig. 3g). Those results are consistent with a recent study using satellite precipitation data (Prat and Nelson 2016).
- The annual daily maximum rainfall is found in September during the peak of cyclonic activity for a significant number of stations over the Carolinas (Fig. 3a). When TCs are removed, the maximum occurs earlier in July-August (Fig. 3e).
- The number of years during the 1949-2012 period for which TCs are associated with the annual daily maximum rainfall can be above 25-30% for stations located east of the Atlantic Seaboard Fall Line (Figs 3c-d). Conversely, to put this into context, only a handful of stations in Florida display a ratio of 30% or higher despite higher cyclonic activity (not shown).

Ongoing Work

- Evaluate the influence of the different methods for estimating the frequency of occurrence of ranked maximum annual daily rainfall (CA SD, Hazen, Weibull, Gringorten, Sevruk and Geiger).
- Determine the optimum probability distribution functions (Log-Pearson Type-III, Log-normal, Gumbel …) for each individual station or cluster of stations as a function of location.
- Extend the analysis to include extra-tropical cyclones over the same period. Evaluate the contribution of each precipitation system both in terms of the precipitation budget and extreme rainfall contribution.

References:

Prat, O.P., and B.R. Nelson (2013a), Precipitation contribution of tropical cyclones in the southeastern United States from 1998 to 2009 using TRMM satellite data. J. Climate, 26, 1047-1062.

Prat, O.P., and B.R. Nelson (2013b), Mapping the world's tropical cyclones rainfall contribution over land using TRMM Multi-satellite Precipitation Analysis. Water Resour. Res., 49, 7236-7254.

Prat, O.P., and B.R. Nelson (2014), Characteristics of annual, seasonal, and diurnal precipitation in the Southeastern United States derived from long-term remotely sensed data. Atmos. Res., 144, 4-20.

Prat, O.P., and B.R. Nelson (2016), On the link between tropical cyclones and daily rainfall extremes derived from global satellite observations. J. Climate, 29, 6127-6135.

Acknowledgement: This research was supported by NOAA through the Cooperative Institute for Climate and Satellites-North Carolina under the cooperative agreement NA14NES432003. Contact: olivier.prat@noaa.gov