- Characterization of Precipitation Features in the Southeastern United States Using a Multi-sensor Approach: Quantitative Precipitation Estimates

Task Leader	Olivier Prat
Task Code	NC-CDR-12-NCICS-OP
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Percent contribution to CICS Themes	Theme 1:20%; Theme 2:75%; Theme 3:5%
Percent contribution to NOAA Goals	Goal 1:20%; Goal 2:80%

Highlight: We use a multi-sensor approach to characterize precipitation features at high spatial and temporal resolution. Focused over the Southeastern United States, this work represents a first step toward the development of rainfall climatologies at high spatial and temporal resolution. More broadly, this work is part of an on-going effort to provide high-resolution precipitation estimates for hydrological applications and to derive trends in the evolution of precipitation patterns over time

BACKGROUND

The primary goal of this project is to investigate long-term precipitation characteristics in the Southeastern United States at fine spatial and temporal resolution using a multi-sensor approach. The frequency and spatial distribution of precipitation extremes are evaluated using an ensemble of satellite and radar rainfall estimates. We use the precipitation reanalysis from the National Mosaic and Multi-Sensor Quantitative precipitation Estimates (NMQ/Q2) in order to derive yearly, seasonal, and sub-daily precipitation trends at high resolution (1-km/5-min) for the period 1998-2010, with an attention to intense precipitation events.

This particular task is focused on the intercomparison of satellite observations from the Tropical Rainfall Measurement Mission (TRMM) and ground based (Q2) precipitation estimates in terms of precipitation intensity, accumulation, diurnal cycle, event duration, precipitation type (stratiform/convective), and precipitation systems (localized thunderstorms, mesoscale convective systems, tropical storms). In addition we investigate the impact of the spatial and temporal resolutions on each of these quantities, as well as the ability of satellite products to capture extreme precipitation events.

ACCOMPLISHMENTS

1. Previous work concerned the development of long-term (1998-2010) precipitation datasets at fine scale using the National Mosaic and Multi-Sensor QPE reanalysis (NMQ/Q2: 1km/5min) and satellite products TRMM Precipitation Radar (TPR 2A25: 5km/daily) and TRMM Multisatellite Precipitation Analysis (TMPA 3B42: 25km/3hr). Subtasks included: (A) The derivation of yearly, seasonal, and diurnal precipitation trends from both datasets (TPR 2A25 and TMPA 3B42) (Prat and Nelson 2013a); (B) The

quantification of the rainfall contribution originating from tropical cyclones (Prat and Nelson 2013b).

2. Completed the comparison between TRMM satellite data versus NMQ/Q2 reanalysis over the Carolinas. Figure 1 displays the daily average rainfall derived from the different sensors (Q2: Fig. 1a, TPR: Fig. 1c, TMPA: Fig. 1e) for summer (JJA).

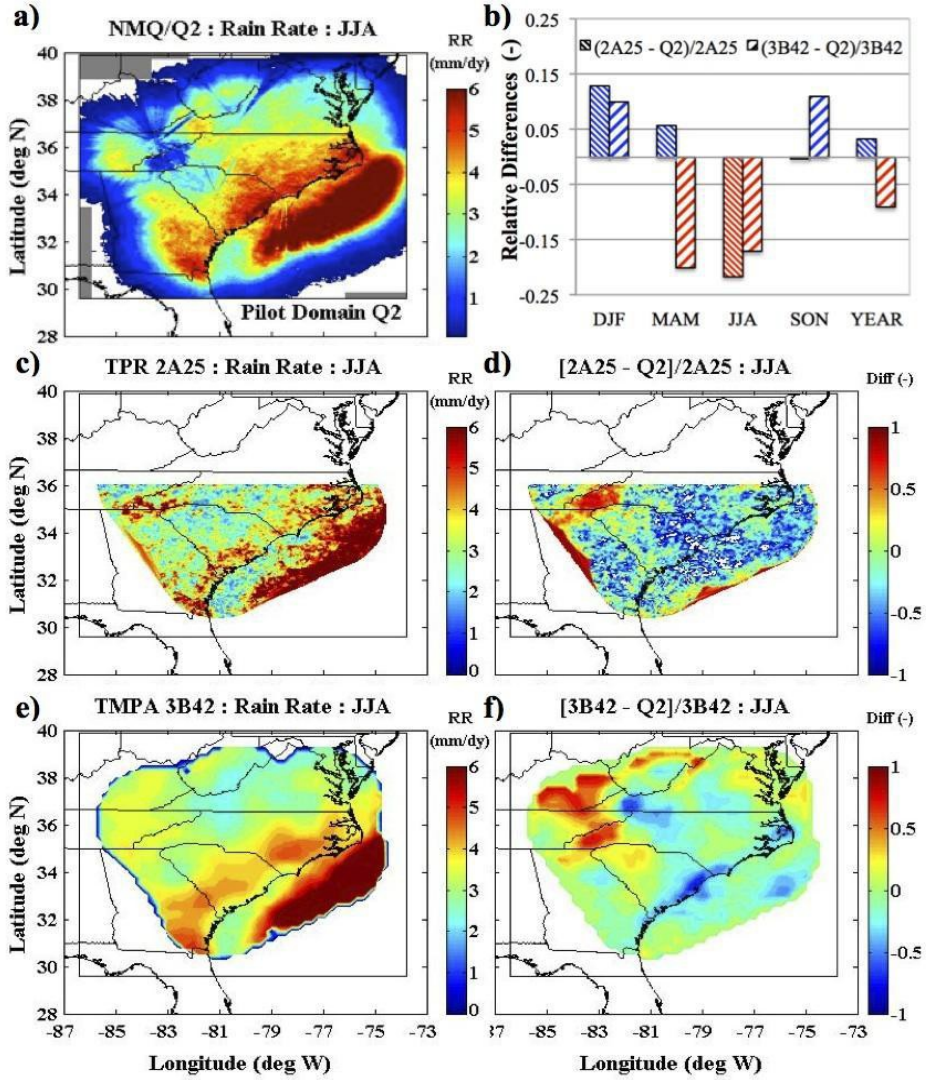

Figure 1: a-c-e) Mean precipitation derived from NMQ/Q2 (1km), TPR 2A25 (5km), and TMPA 3B42 (25km) respectively. b) Seasonnal differences between TRP 2A25 and NMQ/Q2 and TMPA 3B42 and NMQ/Q2. d-e) Difference between TPR 2A25 and NMQ/Q2 (5km) and TMPA 3B42 (25km) for summer (JJA).

Over the Southern Appalachians, we observe important local differences between Q2 and satellite estimates due to beam blocking effects, causing Q2 to underestimate rainfall because neither of the two radars located in TN and SC is able to fully capture rain-

fall events (Fig. 1d,f). Along the coast, Q2 displays higher average daily precipitation for summertime due to the fact that the higher spatial and temporal resolution of Q2 allows it to better resolve the diurnal cycle of precipitation, which is dominated by afternoon events (sea breeze effect). We also note a higher rainfall accumulation over the ocean (Gulf Stream). Figure 1b presents the seasonal and annual differences between the satellite estimates TPR 2A25 (5km) and TMPA 3B42 (25km) and NMQ/Q2 regridded at the same resolution. Over the pilot domain, satellite estimates (TPR and TMPA) tend to produce higher daily average rain rates than NMQ/Q2 during the cold season (or transition to/from the cold season: SONDJF or DJFMAM). On the oppositive, rainfall retrieved from NMQ/Q2 is higher than satellite estimates during the warm season (or transition to/from the warm season: MAMJJA or JJASON) because the higher spatial and temporal resolution of NMQ/Q2 allows capturing short-lived localized precipitation events that occur during the warm season. On an annual basis, NMQ/Q2 averaged rain rates fall between rainrates retrieved from TMPA 3B42 (lower) and TPR 2A25 (higher).

Performance Metrics	**FY12**
# of new or improved products developed	
# of products or techniques transitioned from research to ops	
# of peer reviewed papers	3
# of non-peered reviewed papers	
# of invited presentations	2
# of graduate students supported by a CICS task	
# of undergraduate students supported by a CICS task	

PLANNED WORK

* Shorter-term goal includes extending the domain of study for CONUS using the available NMQ/Q2 for the period 2009-2012. Longer-term goal is to perform the same comparison for the period 1998-present using the using the reanalysis currently underway.
* Continue the intercomparison effort using Stage IV data with a focus on extreme events (extreme rainfall, droughts).

PUBLICATIONS

Prat, O.P., and B.R. Nelson, 2013a. Yearly, seasonal, and diurnal precipitation trends in the Southeastern United States derived from long-term remotely sensed data. *Atmospheric Research.* Conditionally accepted.

Prat, O.P., and B.R. Nelson, 2013b. Precipitation contribution of tropical cyclones in the Southeastern United States from 1998 to 2009 using TRMM satellite data. *Journal of Climate.* 26, 1047-1062.

PRESENTATIONS

- Prat, O.P., B.R. Nelson, and S.E. Stevens 2012. Characterization of precipitation features in the Southeastern United States using high spatial and temporal resolution quantitative precipitation estimates derived from National Mosaic and Multi-sensor QPE (NMQ/Q2). *ERAD 2012: 7th European Conference on Radar in Meteorology and Hydrology*, June 25-29 2012, Toulouse, France.
- Nelson, B.R., O.P. Prat, and S.E. Stevens, 2012. Diurnal cycle of precipitation using high spatial and temporal resolution quantitative precipitation estimates and radar-reflectivity products derived from National Mosaic and Multi-sensor QPE (NMQ/Q2). *2012 AGU fall meeting*, December 3-7 2012, San Francisco, CA, USA.

OTHER

- Chair: Session on Scaling and Fractals in Climate, Hydrology, and Exploration Geophysics (I), *2012 AGU Fall Meeting*, December 3-7 2012, San Francisco, CA, USA.
- Reviews for Journal of Atmospheric and Oceanic Technology, Water Resources Research, Tropical Cyclone Research and Review.
- Prat, O.P., A.P. Barros, and F.Y. Testik, 2012. On the influence of raindrop collision outcomes on equilibrium drop size distributions. *Journal of the Atmospheric Sciences.* 69(5), 1534-1546.

- Mapping the World's Tropical Cyclone Rainfall Contribution Over Land Using Satellite Data: Precipitation Budget and Extreme Rainfall

Task Leader	Olivier Prat
Task Code	NC-CDR-13-NCICS-OP
Main CICS Research Topic	Climate Data and Information Records and Scientific Data Stewardship
Percent contribution to CICS Themes	Theme 1:50%; Theme 2:50%; Theme 3:0%
Percent contribution to NOAA Goals	Goal 1:30%; Goal 4:70%

Highlight: This work examines the over-land rainfall contribution originating from tropical cyclones for basins around the world for the period 1998-2009. Using the global database IBTrACS and satellite precipitation data from the Tropical Rainfall Measuring Mission (TRMM) Multi-satellite Precipitation Analysis (TMPA) product 3B42, the precipitation budget and extreme rainfall were determined for different TC basins around the world

BACKGROUND

Tropical cyclones (TC) constitute one of the major natural disasters around the world as well as an important source of fresh water over areas prone to tropical cyclones. Annually, an average of 119 million people are exposed to tropical cyclone hazards (United Nation Development Program 2004). This exposure is explained by the fact that about half of the world population is living within 200-km of a coastline, with some of the most cyclone-prone coastal domains coinciding with highly populated areas. While previous studies that investigated TC rainfall contribution and their hydrological impacts have focused mainly on North America, East Asia, or over entire TC basins, the present study focuses on over-land and coastal areas of the different TC basins around the world.

In this study, precipitation associated with tropical cyclones for the different basins around the world is quantified in terms of spatial distribution and average contribution to the total precipitation budget on an annual and monthly basis for the period 1998-2009. Furthermore the relationship between tropical cyclone activity and extreme precipitation events is also investigated. The precipitation data are taken from the TRMM Multi satellite Precipitation Analysis (TMPA) 3B42 (Huffman et al. 2007). TMPA 3B42 provides 3-hourly/0.25-degree precipitation estimates, which allow deriving annual, seasonal, monthly, and daily precipitation trends. The TC track information is taken from the IBTrACS database that provides the location of the center of the TC every 6 hours (Knapp et al. 2010). A simple linear interpolation is performed to derive the position of the TC center every 3 hours. Finally, the tropical-cyclone-related rainfall was identified as TMPA 3B42 pixels found within a 500-km radius from TC center (Prat and Nelson 2013a among others).

ACCOMPLISHMENTS

1. *Tropical Cyclone Contribution* (Prat and Nelson 2013b): From 1998 to 2009, rainfall data, showed that TCs accounted for 8%, 11%, 7%, 10%, and 12% of the annual over-land precipitation for NCA, EAS, SWA, OCE, and EAF respectively, and that TC contribution decreased importantly within the first 150-km from the coast. At the local scale, TCs contributed on average to more than 40% and up to 77% of the annual precipitation budget over very different climatic areas with arid or tropical characteristics (Fig. 1).

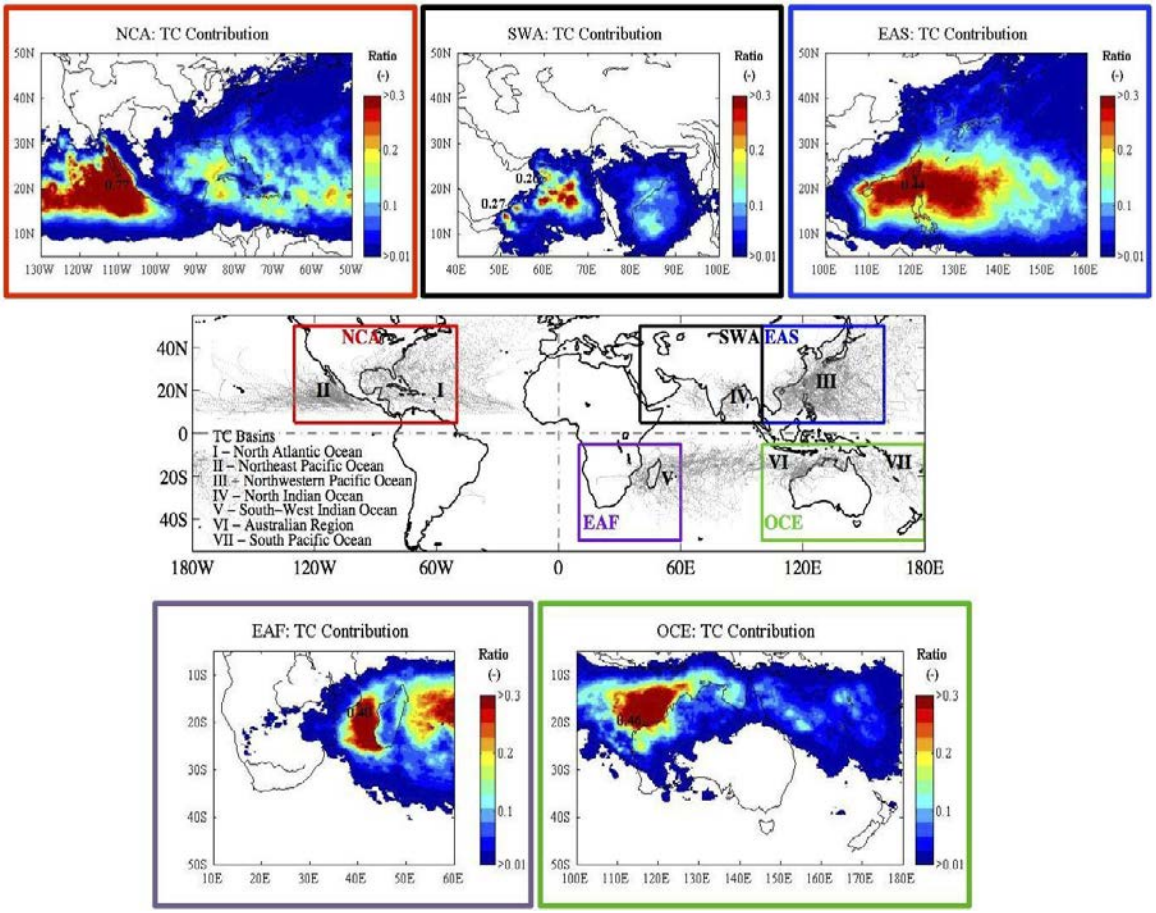

Figure 1: TC contribution for North and Central America (NCA), East Asia (EAS), South and West Asia (SWA), Oceania (OCE), and East Africa (EAF) for 1998-2009. The TC tracks are from the IBTrACS database (Knapp et al. 2010).

The EAS domain presented the higher and most constant TC rain (170±23%-mm/yr) normalized over the area impacted, while the EAF domain presented the highest variability (130±48%-mm/yr), and the NCA domain displayed the lowest average TC rain (77±27%-mm/yr) despite a higher TC activity. The maximum monthly TC contribution (9-13%) was found later in the season and was a conjunction between the peak of TC activity, TC rainfall, and the domain annual antagonism between dry and wet regimes if any.

2. *Link Between Tropical Cyclones and Extreme Rainfall* (Prat and Nelson 2013c): Results showed that while TC days that accounted globally for 2±0.5% of all precipitation events for all basins, they represented between 11-30% of rainfall extremes greater than 4inches/day (>101.6mm/day: EPD4) (Fig. 2). In addition, an important spatial variability was observed in the repartition of TC-related precipitation extremes, with over 70% of extreme rainfall (>4in/day) for NCA (Baja California, FL, NE), EAS (Taiwan, coastal China), EAS, NW Australia, and EAF (Madagascar, La Réunion, Mozambique Coast) associated with TC rainfall.

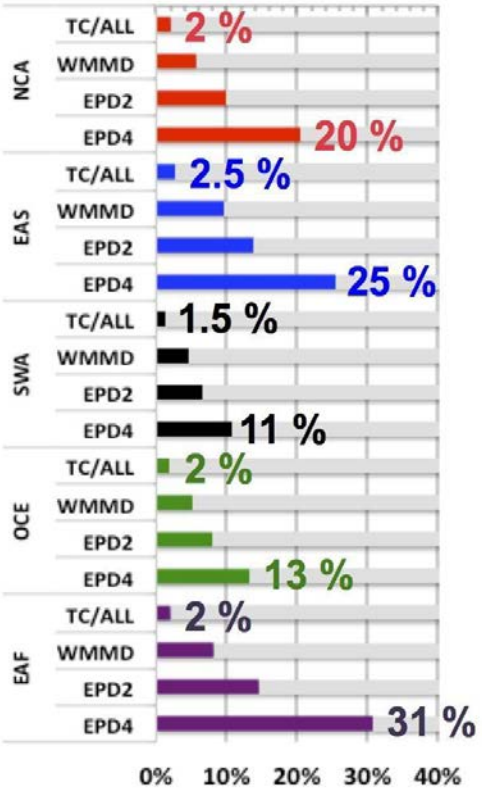

Figure 2: Percentage of extreme rainfall originating from TCs for different metrics: WMMD (Wet Millimeter Days), EPD2 (daily accumulation > 2inches/day) and EPD4 (daily precipitation >4inches/day). Data are for each domain overland: NCA (North and Central America), EAS (East Asia), SWA (Southwest Asia), OCE (Oceania), and EAF (East Africa).

PLANNED WORK

- The main part of the data and results analysis for this task is completed. The current work includes addressing reviewers comments (Prat and Nelson 2013b) and finalizing the third publication to be submitted shortly (Prat and Nelson 2013c).

PUBLICATIONS

Prat, O.P., and B.R. Nelson, 2013c. On the link between tropical cyclones and extreme rainfall for hurricane basins around the world. *Natural Hazards and Earth System Sciences*. To be Submitted.

Prat, O.P., and B.R. Nelson, 2013b. Mapping the world's tropical cyclone rainfall contri- bution overland using TRMM precipitation data. *Water Resources Research*. Un- der revision.

PRESENTATIONS

Prat, O.P., and B.R. Nelson, 2012. Mapping the world's tropical cyclone contribution overland using TRMM satellite data: precipitation budget and extremes rainfall. 2012 AGU fall meeting, December 3-7 2012, San Francisco, CA, USA.

OTHER

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. Jour- nal of Climate. 26, 1047-1062.

Performance Metrics	**FY12**
# of new or improved products developed	
# of products or techniques transitioned from research to ops	
# of peer reviewed papers	2
# of non-peered reviewed papers	
# of invited presentations	1
# of graduate students supported by a CICS task	
# of undergraduate students supported by a CICS task	