Precipitation Re-analysis using Q2
Soroosh Sorooshian; (NOAA Collaborator: John Bates)

Background
Satellite-derived precipitation products are gaining recognition as viable source of information on precipitation for research and application. Among these applications is regional hydrologic modeling, data assimilation into weather models, and validation and verification of regional numerical weather models as well as global climate models. However, the applicability of satellite precipitation to hydrologic applications that focus on design and planning is limited due to factors such as their spatial resolution, limitation on record length, and lack of quantitative information about uncertainties in satellite precipitation at the required spatial and temporal scales. This task will focus on addressing these challenges and initiating the development of approaches that can lead to improve utilization of satellite precipitation in hydrologic application and water resources planning and management. This research effort intends to focus on three different thematic areas: (1) climatic analysis of spatial and temporal variability of sub-daily extreme precipitation over United States for past decades, (2) quantification of uncertainty in satellite precipitation estimation, and (3) expanded frequency analysis of extreme rainfall using satellite precipitation data.

The Center for Hydrometeorology and Remote Sensing (CHRS) at the University of California, Irvine, plans to use the expertise of its current interdisciplinary staff of scientists. Our work will focus on the following sub-tasks.

(1) Characterization of spatial and temporal variability of sub-daily precipitation under climate change

The IPCC AR4 report suggests that extreme precipitation events will become more intense as a result of global warming (IPCC, 2007). It also implies that the variability of extreme precipitation, in terms of their intensity, frequency, duration, and spatial/temporal distribution, may be enhanced due to climate change. These changes will impact the applicability of the assumption of stationary process, which is a key assumption in most frequency analysis based engineering applications. In the proposed activity, we will investigate the daily and sub-daily precipitation data from gauge and satellite measurement for a period representing recent climatology (30 years). The goal of the investigation is to provide a statistical summary of recent stationary and non-stationary trends in extreme precipitation events. This involves the following tasks:

a. Collect and analyze data: Collect multiple years of precipitation data from gauge and radar over the continental United States; classify heavy storm
events according to their rainfall intensity, accumulation, and duration.

b. Extend data over un-gauged regions using satellite estimates: Use local gauge/radar measurement to adjust multi-satellite precipitation estimation and extend the precipitation measurements to un-gauged regions using bias corrected satellite-based precipitation estimates.

c. Develop extreme precipitation analysis: Examine the trend of extreme storm events at each climate region based on precipitation intensity and frequency. Analyze the variation of frequency of extreme storm events with respect to the local and regional surface temperature changing over time.

d. Identify stationary or non-stationary features of extreme storms: Evaluate the limitation of the current engineering stationary frequency analysis; investigate the use of variation of statistical moments in the non-stationary process analysis and risk assessment.

(2) Continue and expand research towards quantitative error and uncertainty analysis of satellite based precipitation estimation in comparisons with gauges and NEXRAD data.

Compared with rain gauge measurements, satellite precipitation data provide higher spatial and temporal resolution. However, they data are subject to different types of error such as sampling uncertainty, inherent measurement and retrieval errors, among others (Tian et al., 2009). Despite extensive research, the uncertainties associated with satellite-based precipitation data have not yet been well quantified (Sorooshian et al., 2000). Characterization and quantification of such uncertainties are extremely important, as it is believed that inaccurate input rainfall is one of the main sources of error in hydrologic predictions and climate studies (Yilmaz et al., 2005). In order to understand the characteristics of precipitation error the following analyses are planned:

a. Validation of satellite precipitation estimates for different thresholds of precipitation (e.g., 95, 90, 75, 50, 25 and 10 percentiles) using NEXRAD radar data and rain gauge measurements. The results will lead to characterization of error, particularly its variance, with respect to the magnitude of rain rate. This information may result in significant advancements in data assimilation techniques and ensemble generation. The analysis will focus on sub-daily (hourly, 3 hours, and 6 hours) intervals.

b. Analysis of multivariate probability distribution of precipitation extremes using statistical copulas method at locations where reliable ground reference measurements exist. Copulas will allow us to build a multivariate relationship with probability occurrence of precipitation at different locations. Having developed such relationship, one can quantify the probability of detecting extremes using satellite data, where no ground
c. Investigation of the dependence structure of satellite precipitation error in space using spatial empirical copulas. These techniques can provide valuable information regarding error and its spatial characteristics.

d. Investigating whether the tail dependencies of satellite precipitation estimates correspond to those of radar estimates. While there are some studies on distribution tail dependencies of rain gauge data, satellite and radar estimates are not well researched with regard to their tail dependence.

(3) Investigate spatio-temporal framework for frequency analysis of heavy storm, using high-resolution satellite-derived precipitation estimates

a. Develop a 4-dimensional data base of heavy events (location, incremental depth/intensity, time) from satellite-based and radar observations: Using a spatio-temporal connectivity algorithm developed at CHRS, we will develop a data base of extreme heavy precipitation events that accounts for the spatio-temporal evolution of each event and identifies storm track (origin, pathway, and termination) along with the three dimensional description of the storm at each interval along its track.

b. Utilize the above-described database to conduct seasonal and regional analysis of heavy precipitation events. Initially, the analysis will focus on characterizing heavy events within given regions in terms of their spatial extent, duration, depth, and storm origin.

c. For the period of satellite/radar observation, connect (gauge) point observations of annual maximum/partial duration series of precipitation to spatial storm structure by extracting from satellite and/or radar observations the spatial patterns of storms associated with the said extreme (point-based) event. Repeating the analysis for multiple neighboring gauges within a given region will result in identifying storms that cause maximum depth for a given duration in multiple neighboring gauges as well as in evaluating spatial dependency of extreme events.

Accomplishments

Through the above activities, the research effort establishes characterization of spatial and temporal variability of sub-daily precipitation under climate change. We will continue and expand research towards quantitative error and uncertainty analysis of satellite based precipitation estimation in comparisons with gauges and NEXRAD data. Additionally, the research will investigate spatio-temporal framework for frequency analysis of heavy storm: using high-resolution satellite-derived precipitation estimates.