A Regional Intercomparison of Rainfall Extremes

Michael C. Kruk*
STG Inc., Asheville, North Carolina

John J. Marra
NOAA National Climatic Data Center, Asheville, North Carolina

1. OVERVIEW

Extreme events: the floods that displace us from our homes, the high waves that wash out coastal roads, or the toppling of trees and power poles from a passing storm. For locations around the Pacific Rim, where remote island chains sit perilously close to sea-level and where rainfall is the primary source of water, questions arise concerning the return frequency and duration of such events, and whether or not they are getting more extreme. Understanding the long-term variability and change in coastal climate extremes has grown in public awareness given the potentially severe impacts related to sea-level rise coupled with coastal storms. To reduce vulnerability to the economic, social, and environmental risks associated with these phenomena, decision-makers in coastal communities need timely access to accurate and contextually relevant information that affords them an opportunity to plan and respond accordingly.

To address this need, the Pacific Storms Climatology Products (PSCP) project – Pacific Storms – under the direction of the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) was established. Pacific Storms is focused on improving our understanding of patterns and trends in storm frequency and intensity – “storminess” – within the Pacific region. Pacific Storms is exploring how the climate-related processes that govern extreme storm events are expressed within and between three thematic areas: strong winds, heavy rains, and high seas.

Theme-specific data integration and product development teams were formed to conduct analyses and create a broad suite of derived data products. These teams included representatives from NOAA’s NCDC, Center for Operational Products and Services (CO-OPS), Coastal Services Center (CSC), and the National Weather Service (NWS), as well as the University of Hawaii, University of Alaska, University of Guam, and Oregon State University.

Sources of information include NOAA’s Integrated Surface Hourly (ISH) mean sea-level pressure and wind speed data, the Global Historical Climate Network-Daily (GHCN-D) precipitation dataset, the National Water Level Observing Network (NWLON) tide gauge records, the University of Hawaii Sea-level Center (UHSLC) Joint Archive for Sea-level: Research Quality Dataset and the GLOSS/CLIVAR "fast delivery" sea-level dataset; the National Data Buoy Center (NDBC) wave buoy records, the U.S. Army Corps of Engineers’ Coastal Data Information (CDIP) buoy data, and other data sources.

The data analysis and product development framework and guidelines outlined in Kruk et al. (2011) are innovative in a number of ways. First, they focus on extreme events, and integrate data and products across a range of storm-related phenomena. Furthermore, they also paint a comprehensive picture of changes and variation in extreme event magnitude and frequency for a mix of theme-specific parameters on seasonal, annual, and interannual time frames. The resulting extremes climatology datasets are unique as are some of the specific products. Finally, success of the project is fundamentally tied to the collaborative efforts of the data integration and product development teams. For a comprehensive review of this project, the reader is referred to Kruk et al. (2011).

2. METHODS

The development of extremes climatology products was limited to the analyses of historical records obtained from in-situ stations (e.g., meteorological stations, rain gauges, sea-level stations, and wave buoys) located throughout the Pacific region. Individual station datasets were selected for analysis and product development on the basis of their suitability with respect to record length and continuity. The station datasets were broken into three distinct levels; 1) only years and months with at least 80% of the record and days with at least four regularly spaced hourly observations and a record length of at least 30 years, 2) only years and months with at least 75% of the record and days with at least one observation in every six hour observing interval and a record length of at least 20 years, and 3) only years and months with 66% of the record and days with at least four hourly observations and a record length of at least 15 years. In all cases, a year must have at least 50% of the “winter season” data, and at least two of the years in the record must appear since 1998. This requirement is intended to ensure that trends or “regime shifts”, which may have occurred more recently in the record, are accounted for. For all regions, the summer season

* *Corresponding author address:* Michael C. Kruk, STG Inc., Asheville, NC 28801; email: michael.kruk@noaa.gov

is defined as May 1 through September 30. The winter season is October 1 through April 30. The same date range is used for American Samoa in the southern hemisphere, though the seasons are transposed. *For the analysis included herein, only Level 1 stations were used for trend analysis.*

Three regions are explored: the central North Pacific (Hawaii), the western North Pacific (including Palau, Micronesia, and Guam), and the central South Pacific (American Samoa). The figures included herein are only a small subset of the overall results. More figures and information can be found on the PSCP website at http://www.pacificstormsclimatology.org.

3. CENTRAL NORTH PACIFIC

The trend in the amount of precipitation over the 95th percentile during a 24-hour period has been increasing over Hawaii since the early 1900s (Fig. 1). This is further seen in both the summer and winter seasons. Interestingly, there is a gradual decrease in the frequency of extreme events across this region.

A regional geospatial view of the changes in the extreme precipitation amounts reveals subtle, but important, changes across the islands and from windward to leeward sides (Fig. 2). In Figure 2, the red dots indicate increasing trends and the blue dots decreasing. The corresponding shade of the dot indicates the size of the trend.

4. WESTERN NORTH PACIFIC

Across the small islands in this region, trends appear to be flat or decreasing slightly in both the frequency of and precipitation amounts from extreme events. Perhaps most noticeably is the change in the frequency of extreme events, as Figure 3 demonstrates via the steepness of the slope of the linear trend line. It is currently hypothesized that this reduction in the frequency of extreme events is directly related to the relative “lull” in tropical cyclone activity across this region (Mark Lander, personal communication).

5. CENTRAL SOUTH PACIFIC

American Samoa is the only station used in this region, as most other stations have a short period of record and include many missing data points. The Pago Pago Airport on American Samoa has at least 30 years of record is more than 80% complete. Other stations were once available but have been discontinued due to lack of sufficient and regular funding to maintain and operate the station.

In American Samoa, using the histogram in Figure 4, it can be deduced that the frequencies of extreme rainfall events in each of the categories (75th, 90th, and 95th percentiles) are remaining fairly constant through the period. In general, there is a low frequency of extreme rainfall events above the 95th percentile; generally 1-3 events per year.

6. SUMMARY

The general results of the regional intercompariſion demonstrate a universal signal of a decrease in the frequency of extreme events. However, the changes in the amount of precipitation exceeding the 95th percentile vary considerably by region and by season. Generally, the biggest changes were found in the western North Pacific region where frequencies and amounts were found to exhibit the largest decreases.

The preliminary findings found in this intercomparison align well with other heavy rain research performed across the region (e.g., Chu et al. 2010; Giambelluca et al. 2010; Kruk and Levinson, 2008; Timm et al. 2011). Despite the varying approaches and datasets used in each of these studies, a stronger signal appears to be emerging in these regions in favor of a gradual decrease in the frequency of extreme rainfall events.

7. REFERENCES

Chu, P.S., Chen, Y.R., and Schroeder, T.A., 2010: Changes in precipitation extremes in the Hawaiian Islands in a warming climate. *J. Clim.,* **23**, 4881-4900.

Giambelluca, T.W., M. Takahashi, O.E. Timm, and H.F. Diaz, 2010: Projections of future changes in heavy rainfall frequency in Hawaii using a statistical downscaling approach. AGU Fall Meeting Abstracts, #GC51A-0749

Kruk, M.C., J.J. Marra, M. Merrifield, P. Ruggiero, D. Atkinson, D. Levinson, and M. Lander, 2011: Pacific Storms Climatology Products: Understanding Extreme Events. *Bull. Amer. Meteor. Soc*., **submitted**.

Kruk, M.C., and D.L. Levinson, 2008: Evaluating the impacts of climate change on rainfall extremes for Hawaii and coastal Alaska. *24th Conference on Severe Local Storms*, Amer. Meteor. Soc., Savannah, GA.

Timm, O.E., H.F. Diaz, T.W. Giambelluca, and M. Takahashi, 2011: Projection of changes in the frequency of heavy rain events over Hawaii based on leading Pacific climate modes. *J. Geo. Res.*, **116**, D04109.

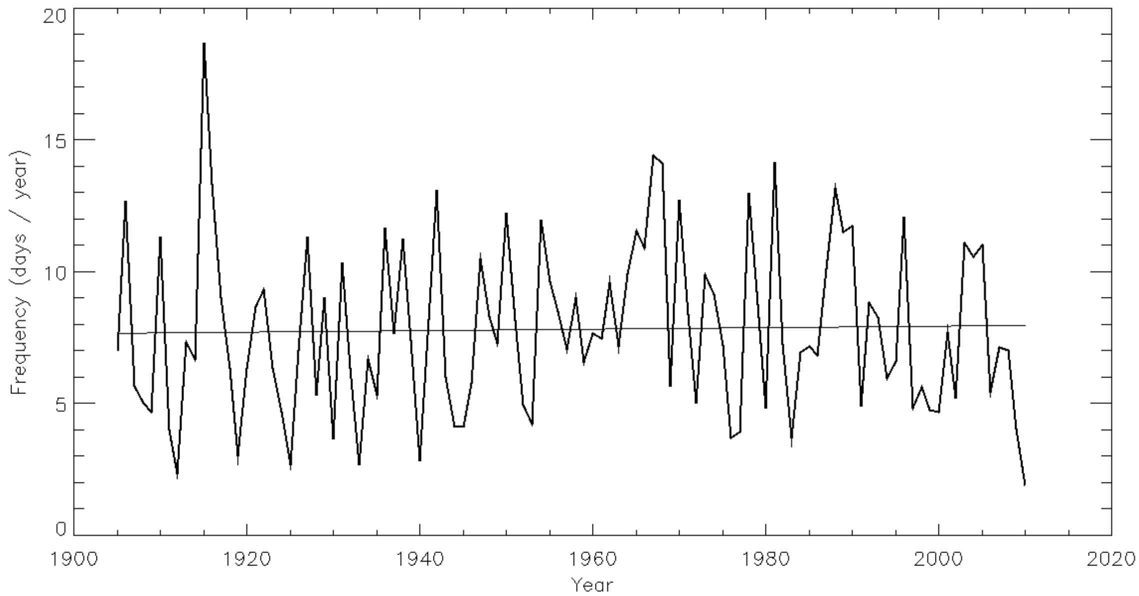

Figure 1. Frequency of extreme rainfall events at the annual 1-day time scale for the Hawaiian Islands. Linear trend denoted by the thin line. Solid thick black lines denote the annual number of extreme events.

Figure 2. A geospatial map showing the annual trend in the amount of precipitation above the 95th percentile. Red, yellow, and orange dots indicate increasing trend and blue, green, and cyan dots decreasing.

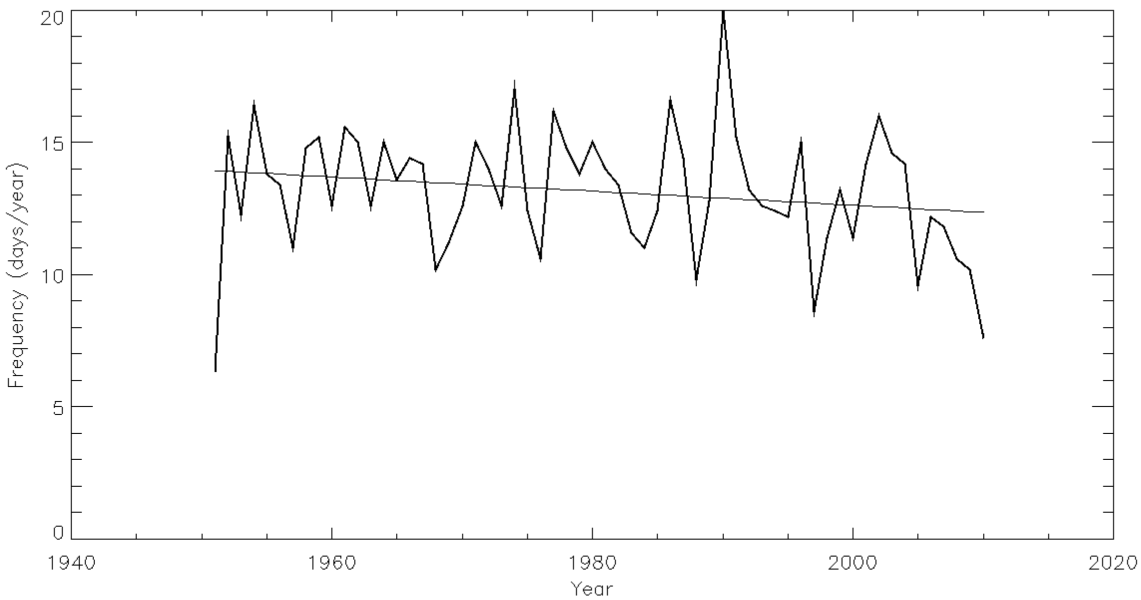

Figure 3. Frequency of extreme events at the 1-day time scale for the western North Pacific region. The decreasing trend in the frequency of extreme events in this region is thought to be related to the growing negative departure in the annual number of tropical cyclones from average.

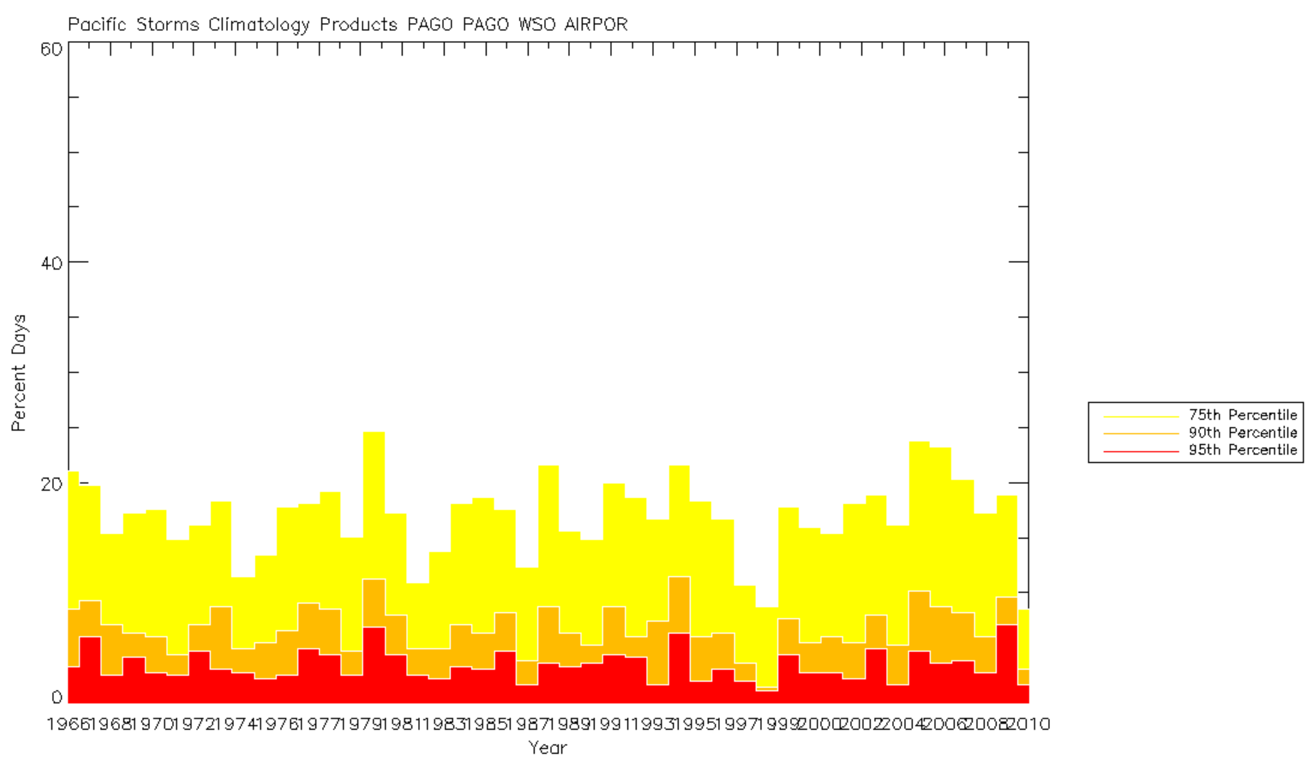

Figure 4. Frequency of extreme rainfall events, according to percentile, for American Samoa, 1966-2010. The bars represent the frequency, in percent days, of events exceeding either the 75th (yellow), 90th (orange), or 95th (red) percentiles of the cumulative distribution of rainfall at the station.