Precipitation in Puerto Rico and U.S. Virgin Islands

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ABSTRACT

The precipitation records in the last years have been broken in Puerto Rico. Several factors could explain why precipitation has been significantly higher in the last years across Puerto and the U.S. Virgin Islands. Precipitation data has been used from XM Climate Access Online. Data from 1972 to 2012 for nine stations was used to compare it with the ONI, precipitable water, and SST values. Data of the ONI was taken from the Climate Data Center. Precipitation data and ONI values were used to compare it with The Local Impacts of ENSO across the Northeastern Caribbean study done in 2010. The purpose of this study is to examine the factors that could explain why precipitation has been higher in the last years and to see if the conditions can be monitored and then, may be able to anticipate extreme rainfall, and associated drought or flooding.

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1. Introduction

Puerto Rico and the U.S. Virgin Islands have experienced an extraordinary period of precipitation in recent years. During 2010 and 2011 the Luis Muñoz Marín International Airport at San Juan recorded over 10 inches more than any other year since 1956. In an earlier study by the National Weather Service in San Juan of ENSO (El Niño Southern Oscillation), the indices were compared with the amount of observed precipitation in the Northeastern Caribbean region. The study can be found at http://www.srh.noaa.gov/sju/?n=enso 2010. In that study, average precipitation was found to be higher than normal during the "dry season" (December-April) through El Niño (warm phase) while the "wet season" (May-November) showed below normal precipitation during El Niño. Conversely, La Niña was found to have an opposite relationship. However, the period from July 2009 through April 2010 was defined by the Climate Prediction Center (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml) to have been a warm episode (El Niño). Unusually high precipitation was observed during most of this period at San Juan Airport (Figure 1) and covered both the wet and dry seasons.

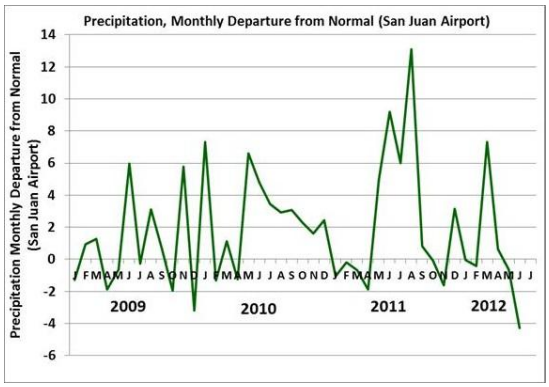

Figure 1. Monthly Precipitation Anomaly for San Juan Luis Muñoz Marín Airport from 2009 to the present.

El Niño is characterized by unusually warm ocean temperatures in the Equatorial Pacific, as opposed to La Niña, which characterized by unusually cold ocean temperatures in the Equatorial Pacific (Figure 2 and 3). El Niño is an oscillation of the ocean-atmosphere system in the tropical Pacific having important consequences for weather around the globe. (NOAA's El Niño Page).

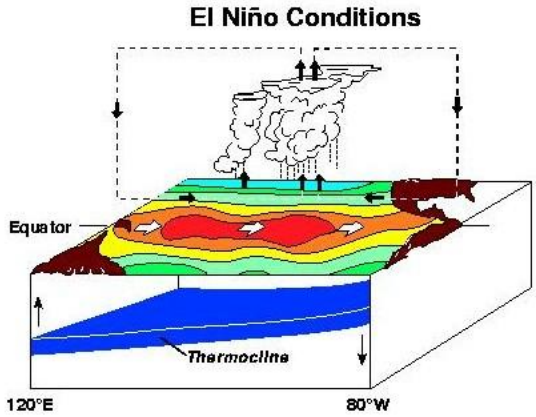

Figure 2. Representation of the warm waters from El Niño event.

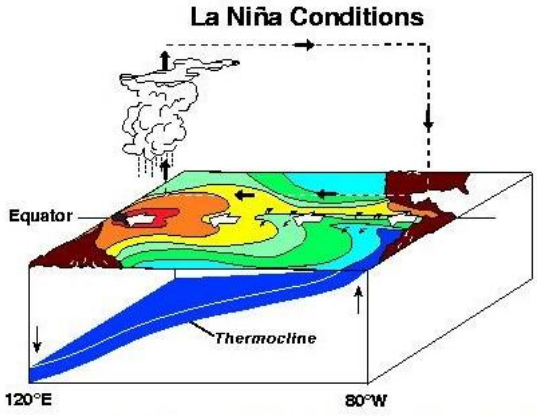

Figure 3. Representation of the cold waters from La Niña event.

The El Niño-Southern Oscillation (ENSO) is a naturally occurring fluctuation that originates in the tropical Pacific region and affects ecosystems, agriculture, freshwater supplies, hurricanes, and other severe weather events worldwide (Guilyardi et al., 2012).

The previous statement determines that ENSO is clearly not the only factor to determine precipitation amounts in the Caribbean region, but what else might be involved?

This study was done to examine several factors that might help explain why precipitation has been significantly higher in the last several years across Puerto Rico and the U.S. Virgin Islands. If slowly changing conditions can be monitored then perhaps we may be able to better anticipate extreme rainfall conditions, and associated drought and/or flooding.

2. Methodology

The Monthly Climate Reports for Puerto Rico and the U.S. Virgin Islands from the National Weather Service San Juan, precipitation data found in www.srh.noaa.gov/sju/?n=climatereports

reported rainfall records at the Luis Muñoz Marín International Airport in San Juan, between the years 2010 and 2011.

Seven locations were chosen across Puerto Rico (including the San Juan Airport Station) and two in the U.S. Virgin Islands (St. Thomas and St. Croix*)* that have a long history and show less missing data for the study period, 1972-2012 (Figure 4). They were also chosen because of their wide sampling across the region, and two were chosen also because they are at relatively high altitude, wanting to evaluate diverse environmental conditions.

Figure 4. Map of locations for the stations chosen for study.

Precipitation data from XM Climate Access On-line, found at http://xmacis.rcc-acis.org/SJU/ was recorded by month into a spreadsheet for each of the nine stations. This web page provides data from stations across the United States and its territories. Along with the precipitation data, was recorded Oceanic Niño Index (ONI) data, taken from the Climate Prediction Center. Also recorded onto the spreadsheet were monthly data for the mean sea surface temperature (SST), and total precipitable water (PW). The latter two parameters were recorded by examining NCEP reanalysis data (Kalnay et al., 1996). As the ONI is already calculated, each of the other parameters were converted into a running 3-month average. Data of the precipitation records were taken from the National Weather Service San Juan web page (www.srh.noaa.gov/sju//?n=toptenwettestyear) and also from XM Access Climate Online extremes routine (http://xmacis.rcc-acis.org/SJU/).

The study from 2010 found in the web page of the National Weather Service San Juan about The Local Impacts of ENSO across the Northeastern Caribbean was taken as a guide. The precipitation data recorded on the spreadsheet and the data of the Oceanic Niño Index from the Climate Prediction Center were also used to compare the values and results with that study done two years ago. 40 years were analyzed, divided into seasons (wet seasons and dry seasons) and then compared.

3. Results and Discussion

3.1 Analysis between ONI, SST, PW and mean precipitation

The ONI is a 3-month running mean of sea surface temperature anomalies in the Niño 3.4 region (5^{o}N-5^{o}S,120^{o}-170^{o}W), (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml). To match this data the monthly precipitation for the nine stations were first averaged among them, and then converted to a 3-month running average. The SST and PW were also converted to running 3-month means.

After analyzing ONI, precipitable water, SST and mean precipitation data for 40 years in those nine stations, some interesting results were noted.

Correlations were examined between the mean precipitation, ONI, PW, and SST, to see which parameters

are more closely related. Table 1 shows the correlations found. The strongest positive correlation of 0.609, was the relationship between total PW and mean precipitation, not surprising since the more PW is available the more precipitation may occur. Another strong correlation is between PW and SST with 0.536. Also not surprising since warmer waters will normally result in more evaporation, leading to higher amounts of precipitable water in the atmosphere. On the other hand the correlation between mean precipitation and ONI was not found to be strong and was negative with -0.105, though it did show a slight tendency for El Niño (ONI values higher than 0.5) to be related to decreasing precipitation while the reverse is true for La Niña.

Correlation Matrix of Variables				
	Mean Precip.	**ONI**	**PW**	**SST**
Mean Precip.	1.000	-0.105	0.609	0.265
ONI	-0.105	1.000	0.240	0.536
PW	0.609	0.240	1.000	0.536
SST	0.265	0.258	0.536	1.000

Table 1. Correlation between the mean precipitation, ONI, PW and SST values.

3.2 Comparison with The Local Impacts of ENSO across the Northeastern Caribbean study due in 2010.

In the study, precipitation data for 55 years for a total of 109 seasons (55 dry seasons and 54 wet seasons); 16 stations were analyzed. In this study, precipitation data for 40 years from a total of 81 different seasons (40 dry seasons and 39 wet seasons) the data from nine stations was analyzed. In the mentioned study precipitation and temperature data were analyzed, in this study only precipitation data was analyzed.

Comparing the precipitation results of this study with the one done two years ago we can see that in the study of two years ago, the dry season presented significantly more precipitation accumulating during El Niño years and in the wet season more precipitation fell during La Niña years. In this year study it can be seen that in both seasons (the wet season and dry season) more precipitation fell or accumulated during La Niña years (Figures 5 and 6). The Neutral Years, the years that are not classified as El Niño or La Niña, have precipitation values that, in the dry season are between El Niño and La Niña but in the wet season, the values are a little bit higher than the ones from La Niña.

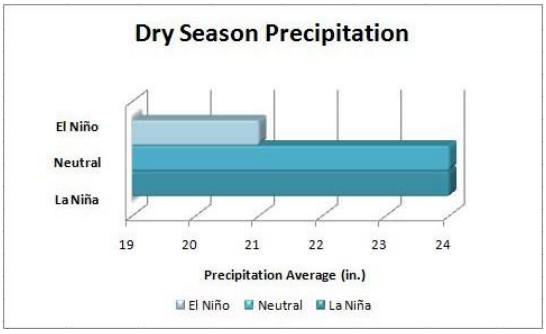

Figure 5. The El Niño/La Niña Southern Oscillation effects during the dry season (December to April).

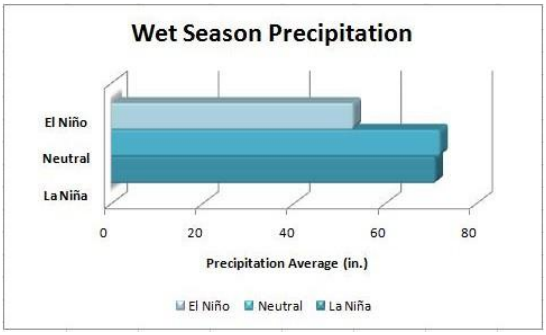

Figure 6. The El Niño/La Niña Southern Oscillation effects during the wet season (May to November).

4. Conclusions

Precipitation in Puerto Rico and the U.S. Virgin Islands has been higher in the last years for many reasons. The levels of precipitation are higher due to their altitude and localization (Figure 7).

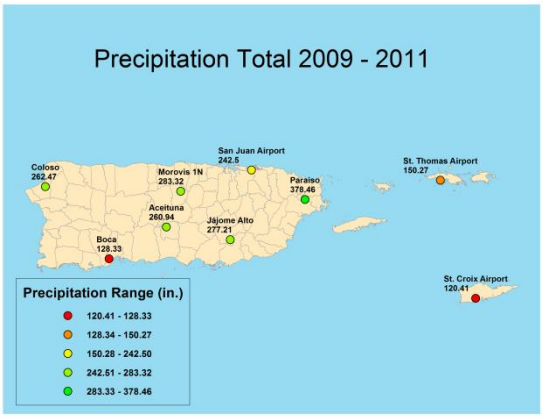

Figure 7. Representation of precipitation for Puerto Rico and the U.S. Virgin Islands from 2009 to 2011. The color illustrate the precipitation for each station, being in green the station with more precipitation and in red the one with less precipitation in that period.

One of the most important or relevant reasons for this increase is because of La Niña effect. During 2010 and 2011 La Niña was dominating the conditions. It makes sense that in both years precipitation was higher because overall Atlantic hurricane activity is reduced during EL Niño and increased during La Niña (Tartaglione et al., 2003) and that means more activity and with it more rain. Other reasons or factors are the increase of the precipitable water and sea surface temperature. This is because, as demonstrated above, at higher PW and SST, more precipitation. Having knowledge of these factors and their effects, it can be said that extreme rainfall conditions and their associated drought or flooding could be anticipated. Considering the data of precipitable water and sea surface temperature was very important because while comparing only the precipitation anomaly versus ONI (Figure 8), the results don't let us see clearly the relationship and effects of the ONI in the precipitation periods.

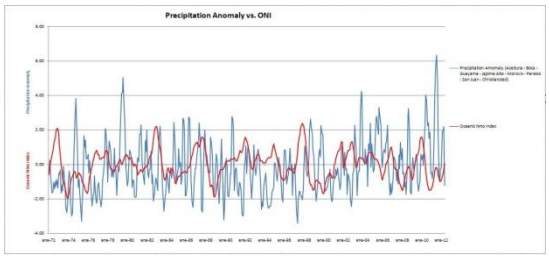

Figure 8. Precipitation anomaly versus Oceanic Niño Index comparative graph.

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References

Climate Acces On-line. Monthly Totals/ Averages Precipitation, http://xmacis.rcc-acis.org/SJU/

Climate Prediction Center/ National Centers for Environmental Prediction, 2012: Cold & Warm Episodes by Season. [Available online at www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml]

Earth System Research Laboratory/ National Oceanic and Atmospheric Administration (NOAA), Monthly Seasonal Climate Composites. [Available on-line at www.esrl.noaa.gov/psd/cgi-bin/data/composites/printpage.pl]

Guilyardi, E. et al., 2012: New Strategies for Evaluating ENSO Processes in Climate Models. Bull. Amer. Meteor. Soc., Volume 93, P. 235-238.

Kalnay, E. and Coauthors, 1996: The NCEP/NCAR Reanalysis 40-year Project. Bull. Amer. Meteor. Soc., 77, 437-471.

National Oceanic and Atmospheric Administration (NOAA), What is an El Niño? [Available on-line at www.pmel.noaa.gov/tao/elnino/el-nino-story.html]

National Weather Service, San Juan, 2012: Monthly Climate Reports for Puerto Rico. [Available on-line at www.srh.noaa.gov/sju/?n=climatereports]

National Weather Service, San Juan, 2012: Puerto Rico and U.S. Virgin Islands-Top Ten Wettest Years. [Available at www.srh.noaa.gov/sju/?n=toptenwettestyear]

National Weather Service, San Juan, 2010: The Local Impacts of ENSO across the Northeastern Caribbean. [Available on-line at www.srh.noaa.gov/sju/?n=enso2010]

Tartaglione, C. et al., 2003: ENSO Impact on Hurricane Landfall Probabilities for the Caribbean. Journal of Climate, Volume 24, P. 1252-1263.