Historical Caribbean Synoptic Types and Downscaling to Northeast Puerto Rico Precipitation Variability

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Background

- El Verde Field Station (EVFS) is located within the boundaries of the El Yunque National Forest in northeast Puerto Rico (Figure 1).
- Extensive ecological, biological, and biogeochemical research has been conducted at EVFS over the past 40 years in connection with the Luquillo LTER.
- Precipitation identified as a primary driver of the systems being studied.
- High spatial and temporal resolution climate information is critical for understanding historical and future precipitation regimes at EVFS due to the steep precipitation gradient.
- A self-organizing maps approach allows for an understanding of the atmospheric drivers of precipitation regimes at El Verde and the surrounding Luquillo Mountains and allows for an empirical downscaling approach to be developed.
- Future changes in these atmospheric drivers and rainfall will have impacts on the biota, municipal water supply, and tourism in the region.

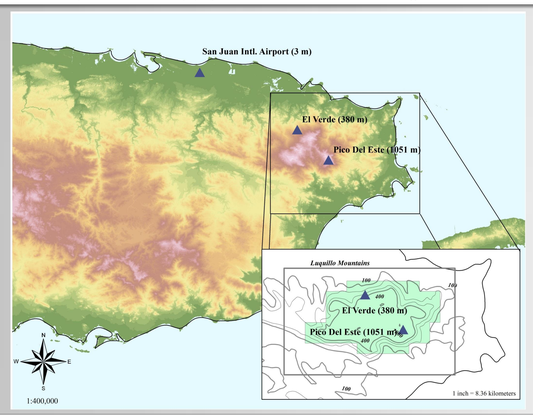

Figure 1. Topographic map of eastern Puerto Rico. The green shading in the inset map represents the boundary of the El Yunque National Forest

Data & Methods

- Daily precipitation data for the EVFS were acquired from the National Atmospheric Deposition program for the period 1985 – 2014.
- 1000 and 700 hPa specific humidity, winds, and geopotential height fields acquired from ERA-Interim reanalysis (1 ° grid spacing) on a 10° x 10° grid centered over eastern Puerto Rico. Ramseyer and Mote (2016) identified these as appropriate predictor variables of precipitation in the region.
- SOM – PAK was utilized to produce self-organizing maps.
- Each training member (day) was represented with an 800-dimensional vector consisting of the 1000 and 700 hPa specific humidity, u-wind, v-wind, and geopotential height at each gridpoint on the 10 x 10 reanalysis grid.
- SOM training involves minimizing the Euclidian distance between the nodes (n=99) and the training vectors.
- Each training vector (day) is mapped to its closest matching node. From which, the reanalysis variables can be composited to produce a representative atmospheric state for each node.
- Precipitation observations from El Verde (n =~8200) are used to produce precipitation probability density functions (pdf) for each node.
- The time period is divided into two epochs (first 10 years and the last 10 years) to test for significant changes in node frequency.
- Data for May 2015 were mapped to the SOM to provide insight on possible forcing mechanisms for the 2015 early rainfall season drought at EVFS.

Results

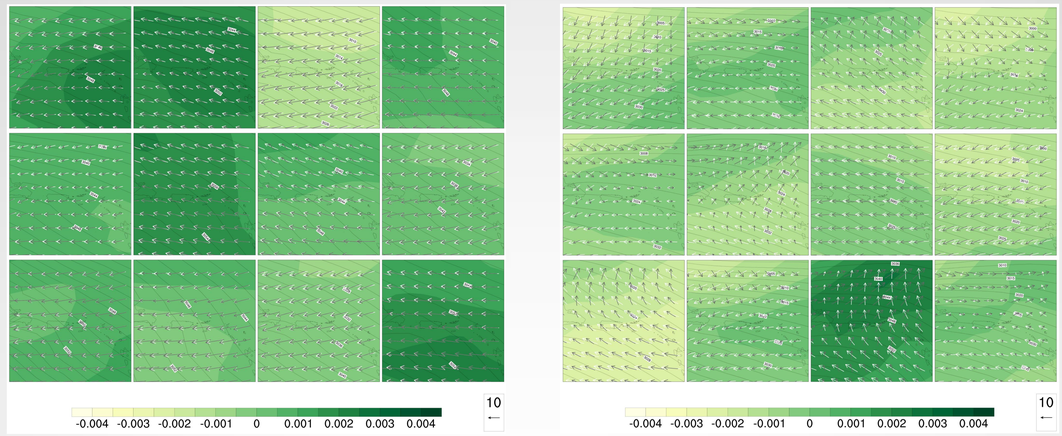

Figure 2. Composite maps of the twelve atmospheric modes of variability in 1000 hPa winds (white vectors), 700 hPa winds (grey vectors), 1000 – 700 hPa thicknesses (black contours), and 700 hPa specific humidity (shading) for the wettest (left) and driest (right) El Verde precipitation pdf's.

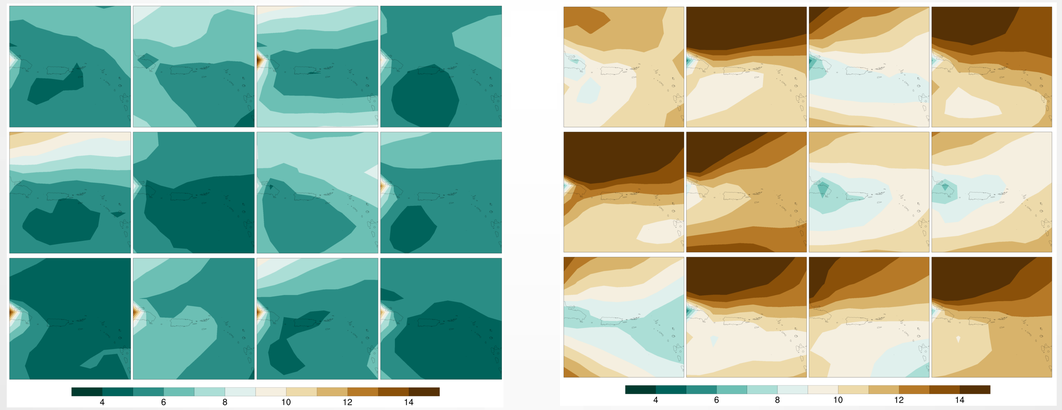

Figure 3. 1000 – 700 hPa bulk wind shear for the wettest (left) and driest (right) El Verde precipitation pdf's.

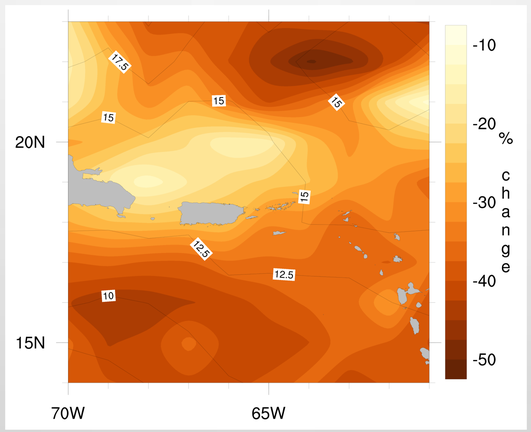

Figure 4. May 2015 monthly mean deviation of 700 hPa specific humidity (shading) and 1000 – 700 hPa thickness.

Conclusions

- Atmospheric conditions in wettest nodes (Figure 2-left):
  - Primarily easterly winds throughout the lower troposphere.
  - Wind speed is variable across the nodes, however, lower tropospheric speed shear is minimal.
  - There is a preference for environments with moderate or high lower tropospheric specific humidity.
- Atmospheric conditions in driest nodes (Figure 2-right):
  - Highly variable 700 hPa wind direction.
  - 1000 hPa winds vary from NE – SE.
  - Lower tropospheric specific humidity can be high.
- Moderate to high lower tropospheric moisture regimes can lead to both wet and dry conditions at EVFS.
- 1000 – 700 hPa bulk wind shear indicates uniformly low shear across the domain for all wet nodes. Dry conditions occur in moderate to high (relative) wind shear environments (Figure 3).
- The 2015 drought appears to have been, in part, forced by a large decrease in low-mid tropospheric moisture as May 2015 700 hPa specific humidity was 10 – 50% lower than May climatology.
- This study indicates that low tropospheric wind shear is a primary limiting factor for high precipitation events at EVFS. Additionally, the driest conditions at EVFS occur in moderate to high shear regimes. The driest conditions can occur over a range moisture regimes, including high specific humidity environments.
- May 2015 was dominated by dry node number nine and adjacent nodes. These regimes consisted of modest shear but substantially lower 700 hPa moisture. Winds throughout the lower troposphere were also shifted south of climatology. This wind shift led to the EVFS and the Luquillo Mountains to be in the rain shadow.
- The authors speculate that the Saharan air layer may be partly to blame for the decreased 700 hPa moisture during the 2015 drought. A positive NAO may have contributed to the deviation in low tropospheric wind direction.

Future Work

- Ongoing work utilizes an ensemble of CMIP5 models will be used to produce projections of future precipitation at EVFS by mapping the CMIP5 vectors to the SOM created here and empirically downscaling via the precipitation pdf's.
- Future work will investigate these atmospheric modes of variability and linkages to NAO and the Saharan air layer.

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