Future Rainfall Variability during the Early Rainfall Season in Puerto Rico

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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 and is the primary study site for this research.
- 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.
- Dynamical downscaling techniques typically can't be run at high enough resolution to resolve the steep precipitation gradient, thus, statistical downscaling techniques are utilized to downscale "to a point".
- **This study uses an artificial neural network to predict early rainfall season (April – July) wet/dry days using a suite of nine atmospheric variables.**

Figure 1. Photo of the Luquillo Mountains facing south toward the north facing slopes.

Data & Methods

- Daily precipitation data for the EVFS were acquired from the National Atmospheric Deposition program for the period 1985 – 2016.
- 1000, 950, 850, 700, and 500 hPa specific humidity as well as 1000 and 700 hPa u- and v- winds data were acquired from ERA-Interim reanalysis (0.25 ° grid spacing). Ramseyer and Mote (2016) identified these as appropriate predictor variables of precipitation in the region.
- Daily 1000, 850, 700, and 500 hPa specific humidity and 1000 and 700 hPa u- and v-wind CMIP5 data for both the historical and future RCP8.5 runs of four GCMs with complete records for the variables used in this study Beijing Climate Center – Climate System Model (BCC-CSM)
  - Canadian Centre for Climate Modelling and Analysis Earth System Model (CanESM2)
  - Institut Pierre Simon Laplace CM5A Model (IPSL CM5A-LR)
  - National Center for Atmospheric Research Community Climate System Model (NCAR CCSM4)
- The Gálvez-Davison Index (GDI) was calculated for all ERA-Interim and CMIP5 daily data. The GDI has three components, a convective potential index (ECI), a mid-level warming index (MWI), and a trade wind inversion index (II). All four of these values were included in the artificial neural networks (ANNs) produced in the study.
- Using the historical runs of the GCMs and ERA-Interim reanalysis, all model data was bias corrected using a quantile mapping methodology.
- A suite of ANNs were constructed in MATLAB to predict wet/dry days during the early rainfall season (ERS) at EVFS. Each ANN was constructed using different quantities of hidden nodes, the ANN selected had 50 hidden nodes and utilized gradient descent minimization and was selected due to its sufficient predictive ability and reasonable computational cost.
- The ANN selected used nine predictor variables including: GDI, ECI, MWI, II, 1000 – 700 hPa bulk wind shear, and specific humidity at 1000, 850, 700, and 500 hPa.

Results

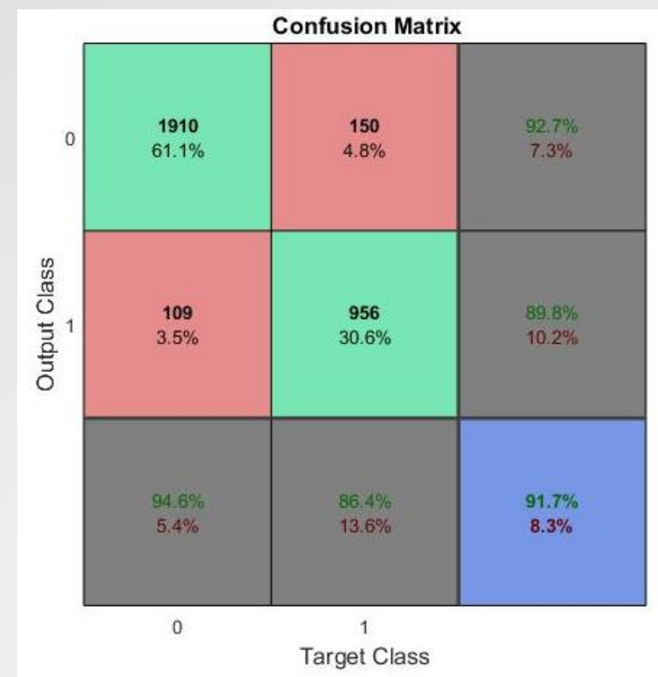

Figure 2. Confusion matrix for ANN using 50 nodes indicating a 91.7% accuracy in correctly predicting wet/dry days.

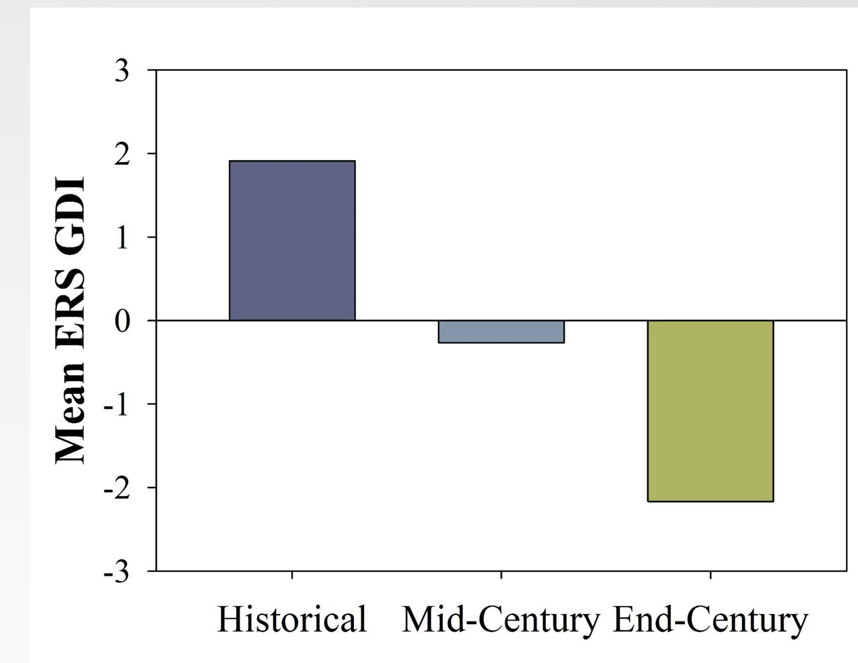

Figure 3. ERS GDI between historical (ERA-Interim) and mid- and end-century as predicted by the CMIP5 RCP8.5 ensemble.

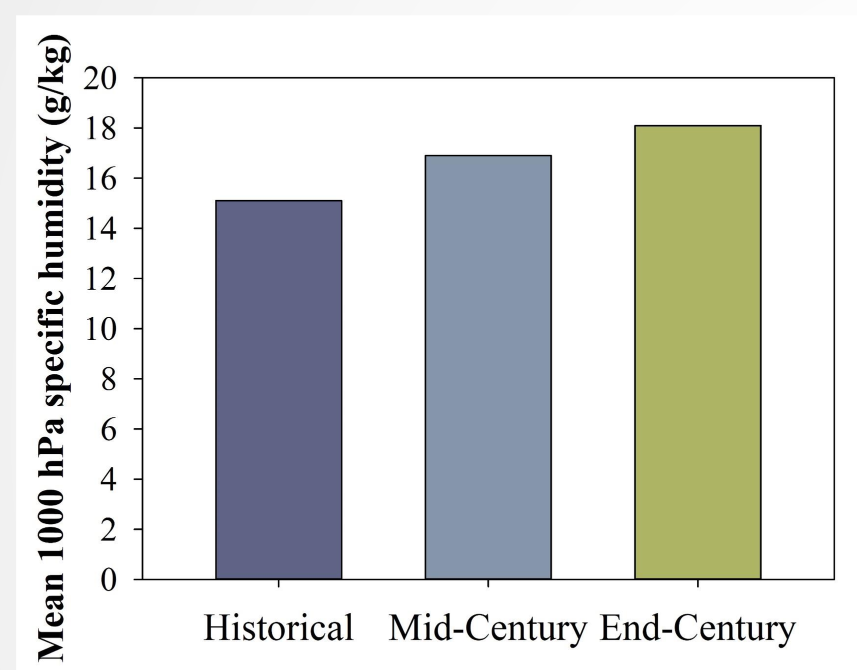

Figure 4. ERS 1000 hPa specific humidity between historical (ERA-Interim) and mid- and end-century as predicted by the CMIP5 RCP8.5 ensemble.

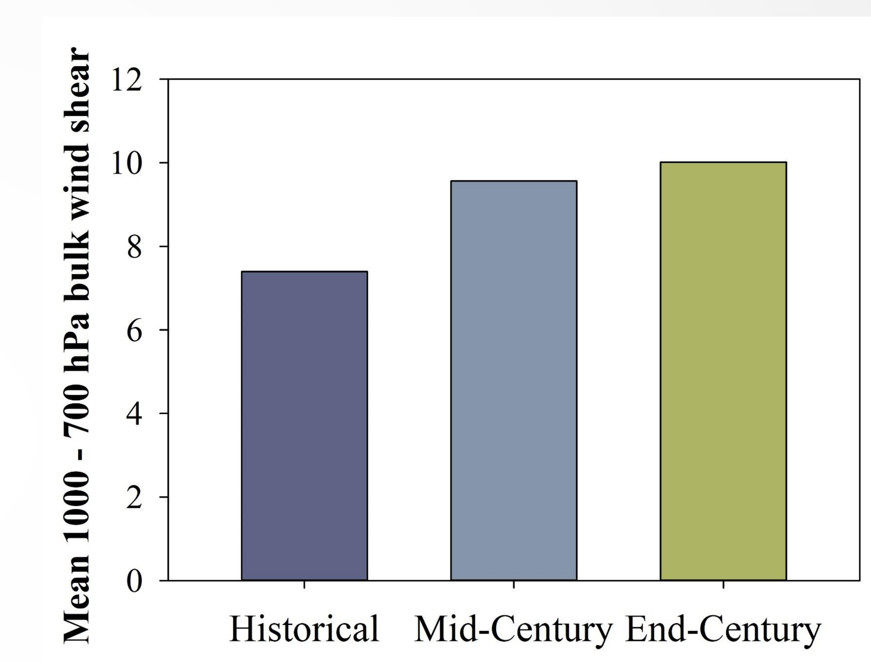

Figure 5. ERS 1000–700 hPa bulk wind shear between historical (ERA-Interim) and mid- and end-century as predicted by the CMIP5 RCP8.5 ensemble.

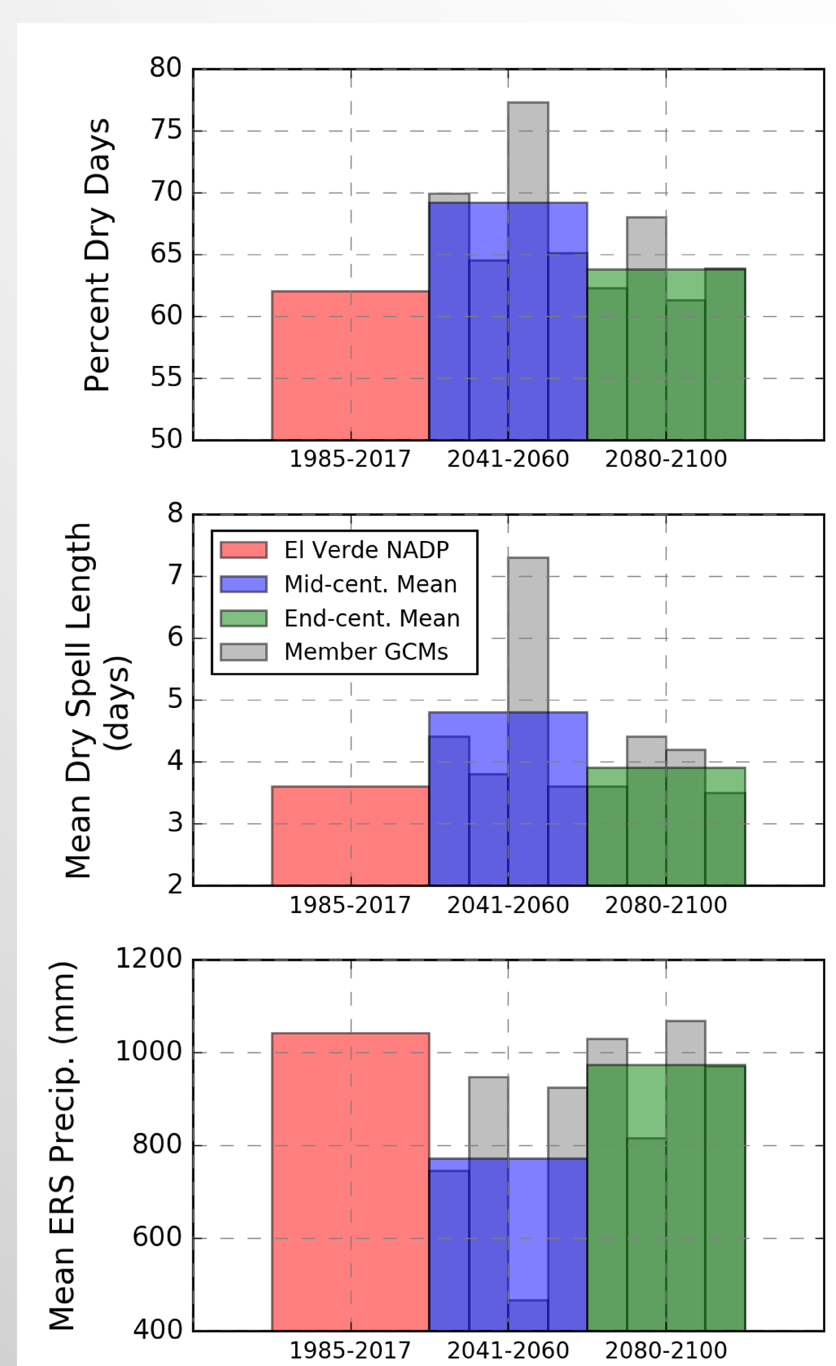

Figure 6. Changes in ERS percent dry days (top), mean dry spell length (middle), and mean ERS precipitation (bottom) as derived from linear model between ERS dry day frequency and mean ERS precipitation (not shown).

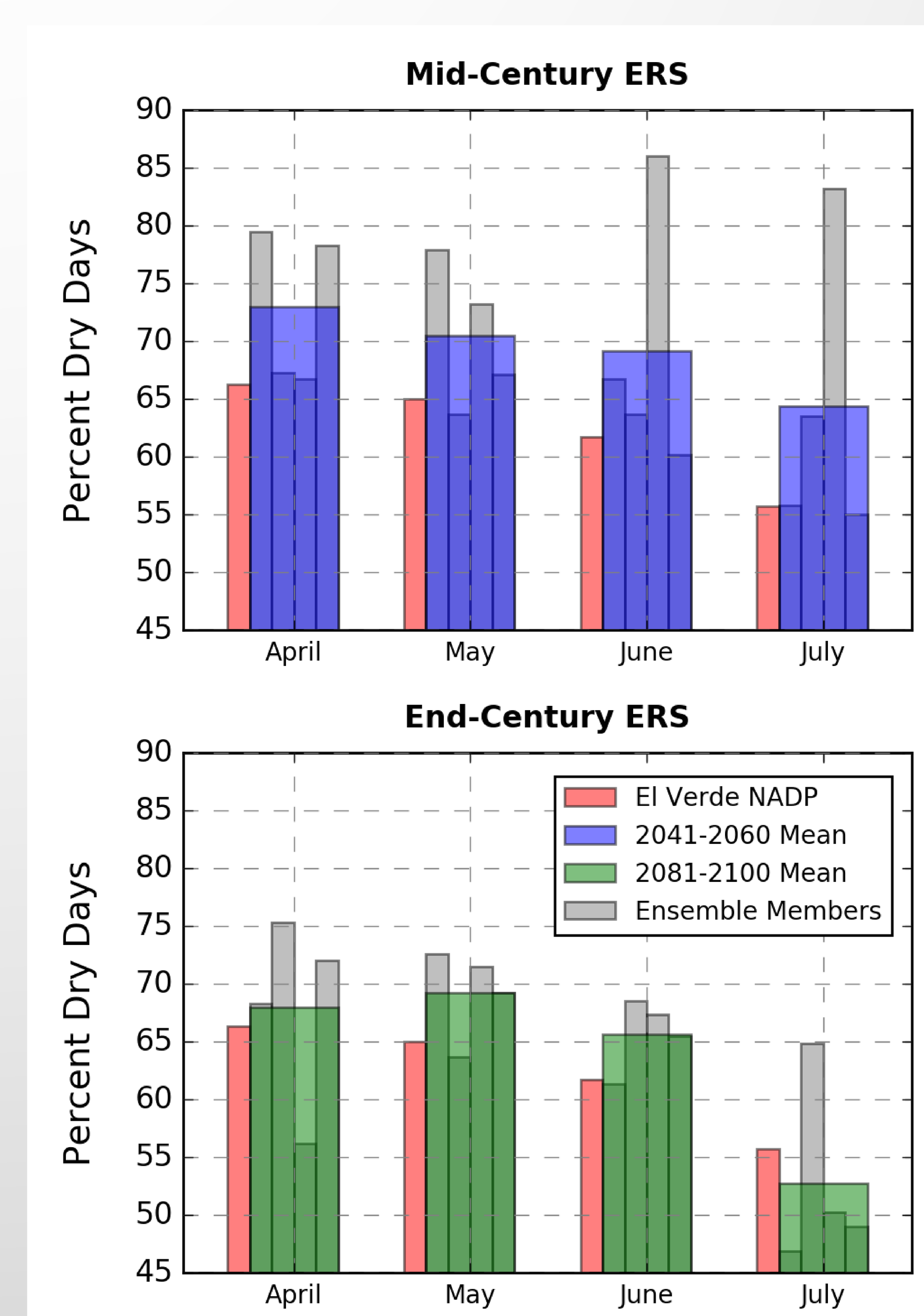

Figure 7. Monthly analysis of changes in ERS dry days between mid-century (top) and end-century (bottom).

Conclusions

- The 50 hidden node ANN was able to predict his ERS dry/wet days with almost 92% accuracy through the historical period (Figure 2).
- As variables were removed from the ANN and re-run, performance dropped below 85%, thus the authors kept all nine predictor variables as they all appear to have some positive predicative capability.
- Analysis of the weight matrix associated with the 9-50-1 ANN architecture reveal that 1000 hPa specific humidity and 1000–700 hPa bulk wind shear are the most important variables in the model.
- The CMIP5 model ensemble predicts a decrease in the mean ERS GDI in mid- and end-century (Figure 3). This suggests a decrease in convective potential during the ERS in the future.
- The CMIP5 model ensemble predicts an increase in 1000 hPa specific humidity (Figure 4) and an increase in wind shear (Figure 5) in mid- and end-century. These two signals work in opposite directions in terms of changes to wet/dry frequency. More moisture is available for precipitation but an increase in wind shear would decrease convective efficiency and trade wind cumuli development.
- **The model suggests a large increase in dry day frequency and dry spell length during the ERS by mid-century with a bit of a recovery back towards the historical values by end-century (Figure 6). This suggests a large decrease in precipitation in mid-century with a recovery in the end-century (Figure 6, bottom).**
- The monthly analysis of dry day frequency shows that most months in the ERS will experience a large increase in dry day frequency by mid-century and a recovery by end-century (Figure 7). However, the recovery is very modest for the month of May and quite large for July.

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