Use of Tree Ring and Long-Term Precipitation Records to Characterize Warm Season Climate Variability in the Southwest U.S.

Brittany Ciancarelli[1], Christopher Castro[1], Connie Woodhouse[2], Dave Meko[2], Ramzi Touchan[2], Steven W. Leavitt[2], and Daniel Griffin[2]
[1]Department of Atmospheric Sciences and [2]Laboratory of Tree Ring Research, University of Arizona, Tucson, Arizona

Introduction

The Southwest United States experiences the greatest amounts of precipitation during two specific times of year, the cool season and the warm season. The cool season is from October-April, where most of the precipitation comes from synoptic scale mid-latitude cyclones. The warm season is from May to September, where localized convective storms associated with the North American Monsoon (NAM) produce most of the precipitation. The variability of precipitation during these two periods is influenced by large scale forcing factors (e.g. sea surface temperature), but in different ways (Castro et al. 2001).

The focus of this analysis is to determine the dominant spatial patterns of the cool and warm season precipitation using standard precipitation index (SPI) computed with Parameter-elevation Regressions on Independent Slopes Model (PRISM) data from 1895-2007. Empirical Orthogonal Function (EOF) and Rotated Empirical Orthogonal Function (REOF) analysis using the Varimax rotation method is done on cool and warm season SPI data. Cool season SPI is computed over 6 months (November-April) and warm season is computed over 2 months (June-July). The seasons are defined this way due to the significant large scale teleconnectivity associated with the two periods (Castro et al. 2001). The principal component (PC) time series is then correlated with the time coincident 500-mb geopotential height anomalies (NCEP Reanalysis Data from 1948-present) and sea surface temperature anomalies (Kaplan SST from 1856-present) to determine relationships with these factors. This information will then be used for the primary goal of this National Science Foundation funded project, which is to develop a reliable reconstruction of warm and cool season precipitation for the Southwest from Ponderosa Pine and Douglas-Fir tree rings. Tree core samples will be taken from various sites around the Southwest U.S. region (Fig. 1). The growth rings from those cores are composed of earlywood and latewood, which correspond to cool season and warm season precipitation respectively (Fig. 3). *In order to determine if the trees are picking up the interannual climate variability* associated with both seasons, the SPI time series extracted from the rings will be compared with the SPI time series computed from the PRISM data. If the trees are accurately representing the dominant spatial patterns of precipitation, then this gives much greater confidence to extend the record of cool and warm season precipitation back hundreds of years.

Figure 1. This map illustrates the distribution of the 41 tree-ring collection sites (red triangles) which have been updated to 2008 for inclusion in our analysis.

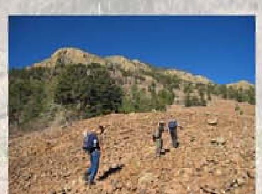

Figure 2. Researchers approach the sparse stand of moisture sensitive Douglas-fir trees at Vick's Peak in central New Mexico. Twenty trees were sampled to update the existing collections from this site, which now cover the time period from 1300-2008 A.D.

Figure 3. A photomicrograph of Douglas-fir tree-rings from Black Mountain in southwestern New Mexico. Each annual growth ring is composed of light colored earlywood, which is related to cool-season moisture variability, and dark colored latewood, which is related to warm-season moisture variability. Note that earlywood and latewood widths vary independently.

Results and Conclusions

The first June-July rotated EOF of SPI shows the well-known continental-scale pattern of interannual precipitation variability, with the strongest loadings reflecting an opposite relationship in precipitation between the southwest and the central United States (Fig. 4). We emphasize the early summer, as this pattern decays in the latter part of the warm season (Castro et al. 2001). The correlation of the first PC time series with the time-coincident 500-mb geopotential height anomalies shows a clear quasi-stationary Rossby wave train teleconnection pattern emanating from the tropical Pacific that affects the positioning and strength of the monsoon ridge over western United States (Fig. 4). The teleconnection pattern extends eastward into northern Europe, reflecting its *influence over almost the entire northern hemisphere. The corresponding correlation of the first PC time series with* the time coincident SST anomalies confirms the relationship to interannual and interdecadal variation in the tropical Pacific, with the strongest correlation occurring in the central Pacific (Fig. 4).

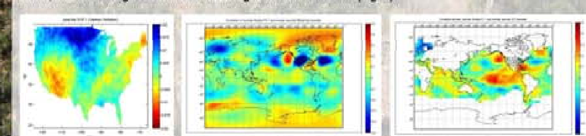

Figure 4. (Left) First rotated EOF (Varimax rotation) computed using June-July SPI. (Middle) The first June-July rotated PC time series correlated with average June-July 500-mb geopotential height anomalies. (Right) The first June-July rotated PC time series correlated with average June-July SST anomalies.

The second June/July rotated EOF of SPI (Fig. 5) has the strongest loadings in the Northwest U.S. and the *southern Great Plains. There is also a correlation pattern with the time coincident 500-mb geopotential height* anomalies as with PC 1, but in this case it is confined to the North American region and the surrounding Atlantic and Pacific oceans (Fig 5). The tie to the tropical Pacific SST anomalies disappears in the correlation with the second PC time series (Fig. 5). The third June/July rotated EOF of SPI (Fig 6) and correlation with the average June/July 500-mb height anomalies (Fig. 6), however, is showing an intensified monsoon ridge that does not have a clear tie to any substantial variability in global SST. The intensified ridge may have a link to anthropogenic climate change through long-term shifts in the global circulation, and this has been established for the cool season (McAfee and Russell 2008). Investigations of the interaction between the North American Monsoon and anthropogenic climate change are currently ongoing.

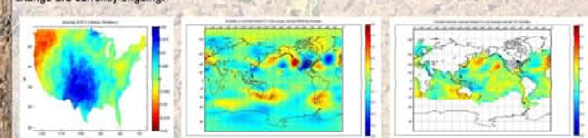

Figure 5. (Left) Second rotated EOF (Varimax rotation) computed using June-July SPI. (Middle) The second June-July rotated PC time series correlated with average June-July 500-mb geopotential height anomalies. (Right) The second rotated PC time series correlated with average June-July SST anomalies.

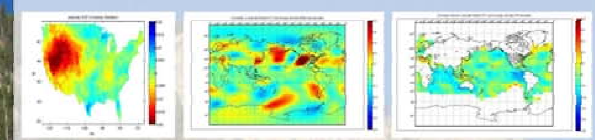

Figure 6. (Left) Third rotated EOF (Varimax rotation) computed using June-July SPI. (Middle) The third June-July rotated PC time series correlated with average June-July 500-mb geopotential height anomalies. (Right) The third rotated PC time series correlated with average June-July SST anomalies.

The first 6 month November-April EOF of SPI (Fig. 7) is picking up on the typical ENSO related precipitation pattern, as stated in many previous works over the past twenty years or so (Ropelewski and Halpert 1986). This pattern reflects heavily in seasonal climate forecasts for the cool season, such as for the present year. The teleconnection pattern revealed by the correlation of the first PC and time coincident 500-mb geopotential height (Fig. 7) and correlation with SST (Fig. 7) clearly reflects the influence of ENSO.

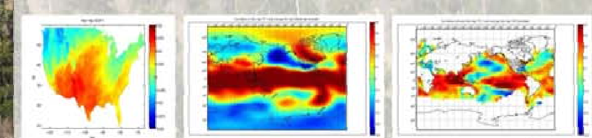

Figure 7. (Left) First EOF computed using Nov-Apr SPI. (Middle) The first Nov-Apr PC time series correlated with average Nov-Apr 500-mb geopotential height anomalies. (Right) The first PC time series correlated with average Nov-Apr SST anomalies.

Future work will evaluate SPI covariability with the 500-mb geopotential height anomalies, global SST anomalies, and outgoing longwave radiation using a canonical correlation analysis technique. This will be done using the NCEP/NCAR Reanalysis and a new Twentieth Century Reanalysis (V1) (that has only pressure level data available) for the period 1900-present. These data can be obtained through Earth Systems Research Laboratory/Physical Science Division website. It is important to note that this is a preliminary investigation of the observed data. The analysis of the SPI time series computed from the PRISM data from 1895-2007 thus far confirms that North American Monsoon precipitation has a strong link to large-scale forcing. We will next investigate whether or not SPI data, as derived from early and latewood tree ring data in our study area, show comparable results. If this analysis confirms that the tree ring data generally show similar climate variability as the PRISM data, then we will have much greater confidence in constructing a North American Monsoon proxy precipitation record for the Southwest that extends back hundreds of years.

References

Ropelewski, C.F., and M. S. Halpert, 1986: North American precipitation and temperature patterns associated with the El Nino/Southern Oscillation (ENSO). *Mon. Wea. Rev.*, **114**, 2352-2362.

Castro, C. L., McKee, T. B., and Pielke Sr., R. A. 2001: The Relationship of the North American Monsoon to Tropical and North Pacific Sea Surface Temperatures as Revealed by Observational Analyses. *American Meteorological Society*, **14**, 4449-4473.

McAfee, S. A., Russell, J. L. 2008: Northern Annular Mode impact on spring climate in the western United States. *Geophysical Research Letters*, **35**, L17701, doi:10.1029/2008GL034828.

Acknowledgments

This work was funded by the National Science Foundation(grant number 310453). Special thanks to Koichi Sakaguchi for assistance in creating this poster.