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A Tree-Ring Record of Monsoon Climate in the US Southwest

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Griffin D., D.M. Meko, R. Touchan, S.W. Leavitt, and C.A. Woodhouse. 2011. Latewood chronology development for summer moisture reconstruction in the US Southwest. Tree-Ring Research, 67: 87-101.

Southwestern North America is characterized by seasonally distinct and dynamically independent precipitation regimes (e.g., Sheppard et al. 2002). Cool-season precipitation comes from frontal storms associated with the westerly-driven winter storm track. In contrast, warm-season precipitation is delivered by convective thunderstorms associated with the summer monsoon (Fig. 1; Douglas et al. 1993; Adams and Comrie 1997), which emanates northward from western Mexico from July through September. Although regional water supplies derive primarily from winter precipitation, the summer monsoon contributes substantially to annual precipitation totals across the region (Fig. 2). Monsoon precipitation is particularly dramatic over the southwestern U.S. (e.g., Higgins and Shi 2000), and this variability impacts the social and environmental systems of the southwest (Ray et al. 2007). For example, monsoon precipitation modulates wildfires, ecosystem structure and health, dryland and rangeland agricultural productivity, and demand for imported surface water supplies. As southwestern resource managers begin adapting to 21st century climate changes, understanding the nature of long-term monsoon variability is more important than ever. This was our motivation for turning, once again, to tree-ring records as proxies for paleoclimatology.

In the Southwest, cool-season precipitation dominates the annual water balance and is primary driver of annual tree growth (St. George et al. 2010). Accordingly, most of the regional tree-ring studies of hydroclimate have targeted annualized or cool-season variability. However, it has long been hypothesized (e.g., Douglass 1919; Schulman 1951) that "latewood," the dark-colored summer growth component of annual conifer tree rings (Fig. 3), contained monsoon-specific precipitation signal. Over the past decade, the potential for latewood reconstruction of monsoon hydroclimate has been clearly demonstrated (Meko and Baisan 2001; Therrell et al. 2002; Wright and Leavitt 2006; Sheppard and Wiedenhoeft 2007; Stahle et al. 2009). Drawing on these findings, we recently developed the first systematic network of monsoon-sensitive latewood chronologies for the southwestern U.S. (Fig. 2; Griffin et al. 2011). We made new collections at over 50 historic sampling sites, and for the first time, analyzed earlywood-and latewood-width on archived and newly collected tree-ring specimens. Our recently minted database of earlywood and latewood chronologies offers a novel means for evaluating the Southwest's dual-season hydroclimatic history.

Targeting the Arizona-Sonora sub-region of the North American monsoon (Fig.2; NAME 2012), we used principal components multiple linear regression to develop high-quality reconstructions of standardized precipitation (Guttman 1999) for the cool season (Oct-Apr) and summer monsoon (Jun-Aug). These reconstructions explain over half of the variance

Figure 1. A monsoon thunderstorm (right) moves across the Tucson Valley, July 17, 2009. Summer rains eventually extinguished the naturally ignited "Guthrie" wildfire (left). Photo: D. Griffin.

in the instrumental precipitation records (Fig.4), pass standard validation tests, and extend from CE 1539-2008 (Fig.5). Analysis of the monsoon reconstruction points to a period of dry summers in the late 19th century more persistent than any during the instrumental era. Comparison with the companion reconstruction (Fig. 4) indicates that persistent monsoon drought often coincided with cool-season drought periods, including the 16th century Megadrought (e.g., Stahle et al. 2000), the 17th century Puebloan drought (e.g., Parks et al. 2006), and the ongoing 21st century drought (Cook et al. 2010; Woodhouse et al. 2010).

We are currently developing monsoon precipitation reconstructions for other regions in the southwest (i.e. New Mexico; Four Corners) and are in the process of evaluating the relationship between these records and large-scale modes of ocean-atmosphere variability. This research offers a novel paleoclimatic perspective on the current drought and underscores the importance of precipitation seasonality in the Southwest. The new latewood dataset establishes an accurate, precisely-dated geochronology for comparison with other paleorecords of monsoon climate (e.g., speleothem, terrestrial and marine sediment proxies), and provides a target for comparison with regional climate model output.

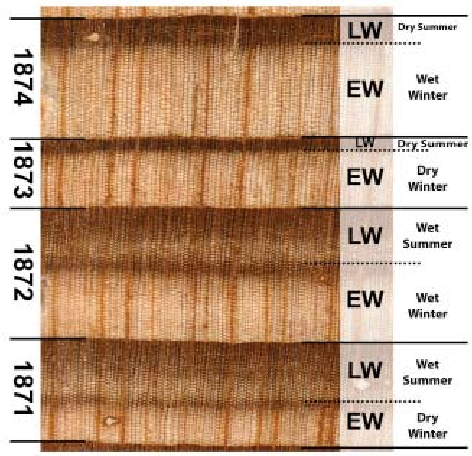

Figure 3. A photomicrograph illustrates four annual Douglas-fir (*Pseudotsuga menzeisii*) growth rings (1871-1874) from the Gila Wilderness of southwest New Mexico. Note the independent width variability of the light-colored earlywood (EW) and the dark colored latewood (LW), which correspond to season-specific moisture variations.

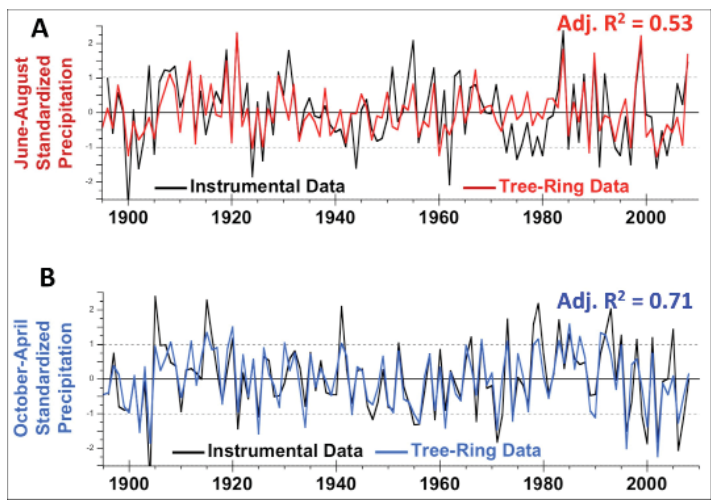

Figure 4. Time series of observed (black) and reconstructed (colored) standardized precipitation indices for the summer monsoon (a; red) and the cool season (b; blue). R^2 has been adjusted downward for the degrees of freedom lost in regression.

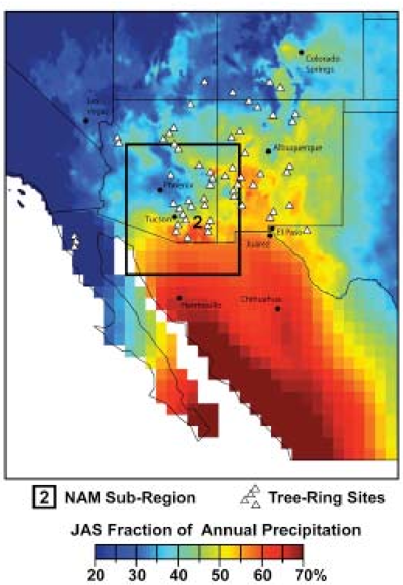

Figure 2. Map showing the July-September fraction of annual precipitation (color ramp), sub-region 2 of the North American monsoon (NAME 2012; black box), and location of new monsoon-sensitive latewood chronologies (triangles).

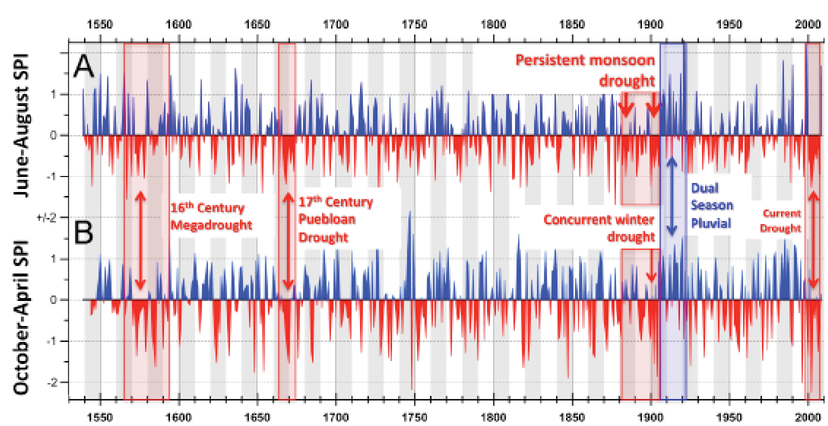

Figure 5. Reconstructed standardized precipitation indices for the summer monsoon (a) and cool-season (b), CE 1539-2008.

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