Southwestern U.S. Seasonal Precipitation and Fire Occurrence from Tree Rings

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INTRODUCTION

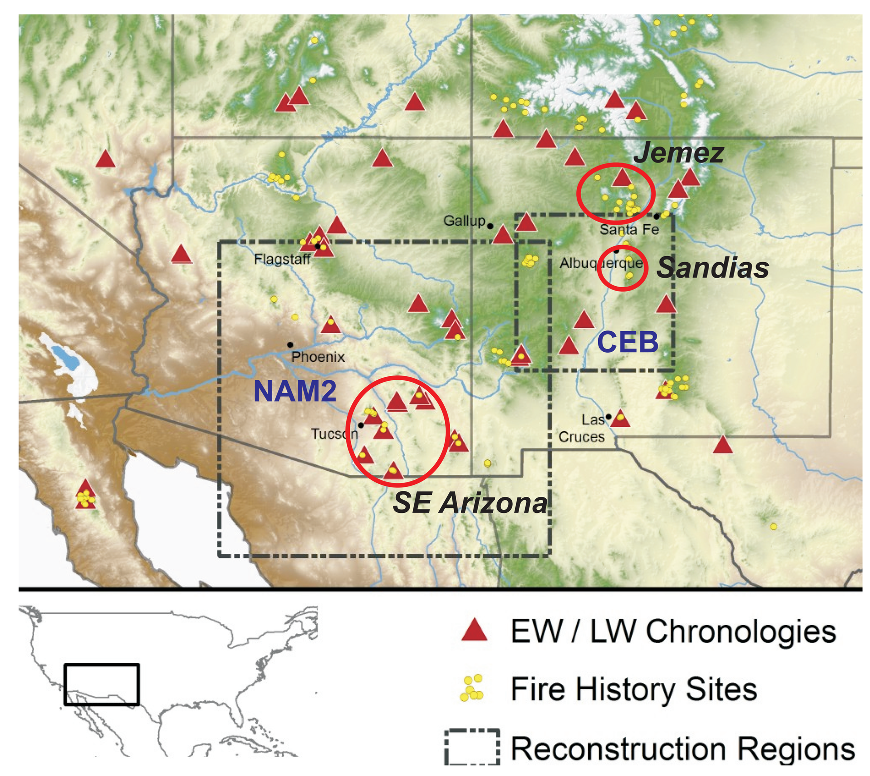
Precipitation and drought drive wildfire in the southwestern US. Because the natural fire regime has been disrupted due to a variety of human activities since the early 20th century, proxy records are needed to assess the relationships between fire occurrence and seasonal precipitation. Fire scar data from tree rings have long been used to assess the natural fire regimes for this region, and more recently, reconstructions of both cool-season and monsoon precipitation have been generated from partial ring-width chronologies for southwestern US. These proxy data allow an evaluation of the seasonal variability of precipitation and its relationship to fire.

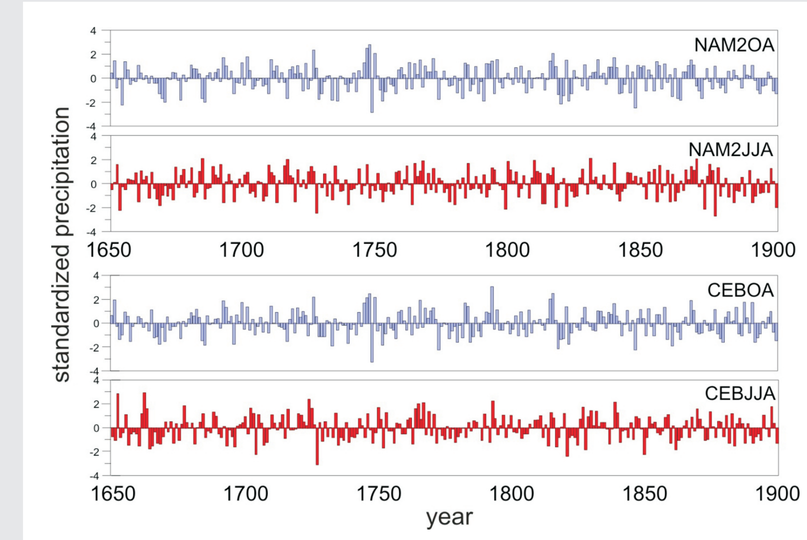
In this preliminary study, we examine and compare seasonal precipitation and fire in Arizona and New Mexico from 1650-1900. Reconstructions of cool (Oct-April, OA) and monsoon season (June-Aug, JJA) precipitation for two regions, central and southeastern Arizona (NAM2) and central New Mexico (CEB) are compared with composite fire scar records.

Regional fire scar records are composites of percent of trees* recording fire in a given year, in three regions: 1) southeastern Arizona (636 trees), 2) the Jemez region, New Mexico (613 trees), and 3) the Sandia region, New Mexico (48 trees). A higher percent of trees recording fire is considered evidence of more widespread fire.

Climate and fire scar regions are shown in the map to the right. Fire scar sites are circled in red, climate regions in black squares.

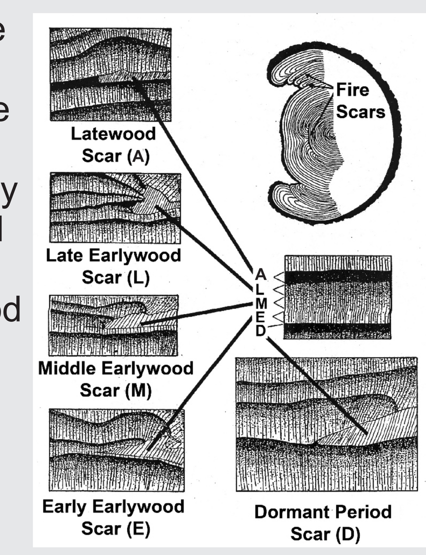
*in trees that have previously been scarred by a fire

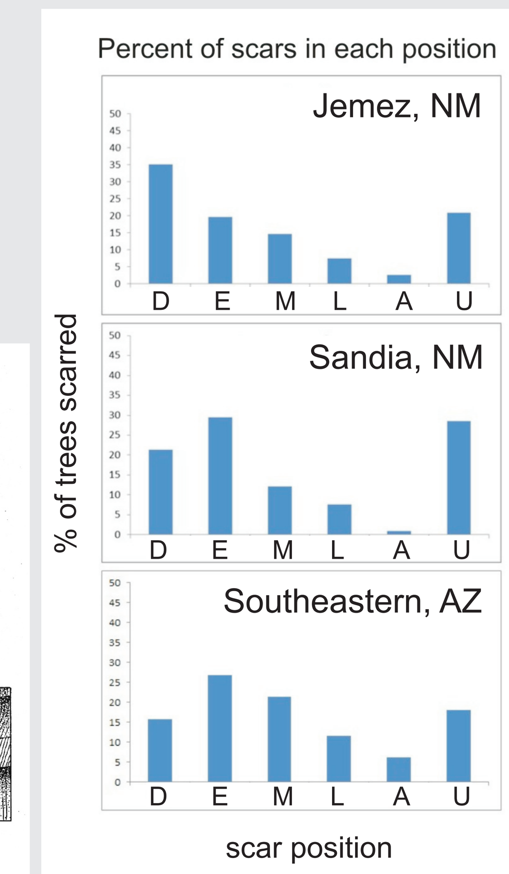




Reconstructed cool season (Oct-Apr) and monsoon (June-Aug) precipitation (standardized) for the NAM2 and CEB regions, 1650-1900 (left).

The timing of fire scarring can be determined by examining the position of the scar relative to the annual ring. Fires occur during the dormant season (D), the early and middle part of the earlywood (E, M), the later part of the earlywood (L) and in the latewood (A) (right). Most commonly, fire scars occur before monsoon onset in positions D,E, and/or M (far right). Here, we are not considering U (undetermined) scars. Example of scars (left).





CLIMATE/FIRE RELATIONSHIPS

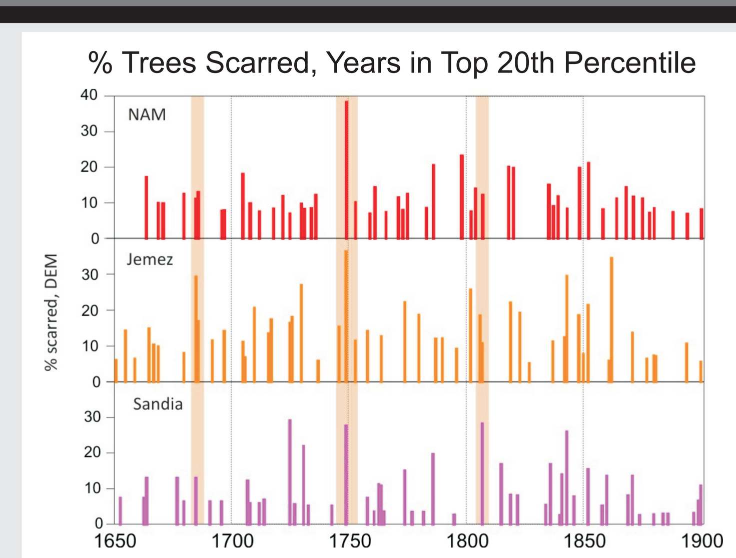
Early Season Fires (pre-monsoon, sum of D, E, & M scars):

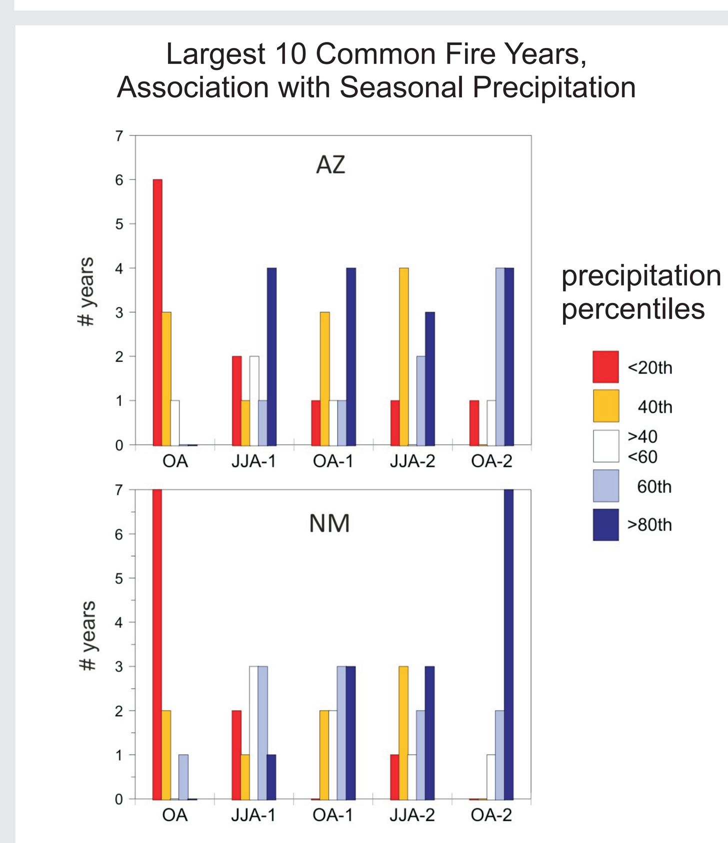
Of the most widespread fires years (highest 20th percentile of percent of trees scarred in a region), about 10% are shared among all three regions (figure, upper right). Although these concurrent, widespread fires across all three regions are relatively rare, widespread large fire in one region is often accompanied by some evident of fire in the other two regions (in two thirds of the years).

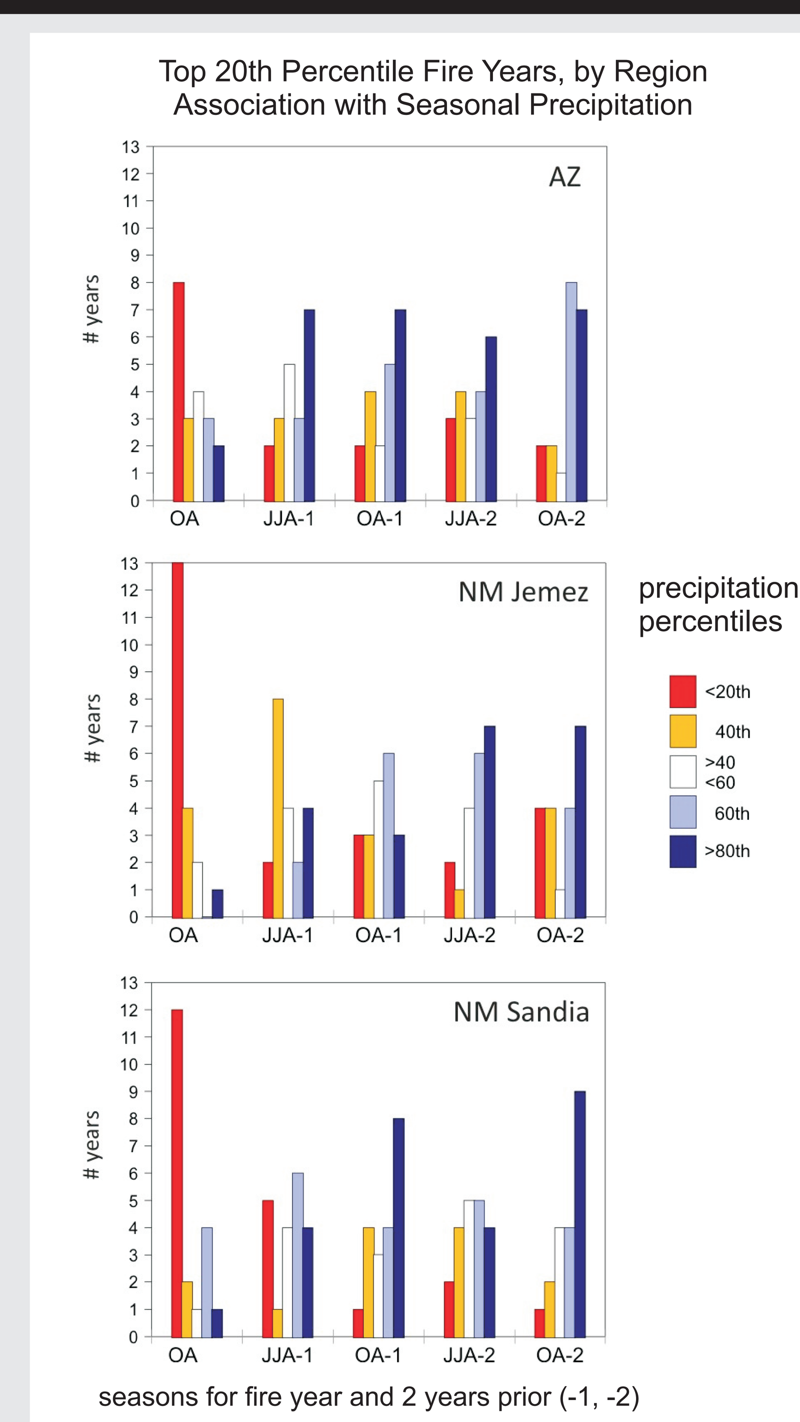
The early season fire is most closely related to cool season moisture deficits in the current fire year. Correlations between DEM series and regional cool season precipitation reconstructions, are r = -0.330 for Arizona, r = -0.471 for Jemez, and r = -0.227 for Sandia (all significant at $p < 0.05$). Cool season climate is synchronized across the region by the westerly storm tracks which bring frontal storms. This precipitation regime influences synchrony in premonsoon season fires across the three regions.

Of the 10 largest fire years (20th percentile, occurring in all three regions; figure, lower right), nine are associated with dry conditions in the cool season of the fire year. Antecedent climate conditions associated with these years suggest wet conditions in prior seasons; cool season wetness two years prior to the fire event may be particularly important.

The middle figure, which illustrates moisture conditions during the 50 years when fire was most widespread within each region, indicates that the fire/seasonal climate relationship may be different for these three areas. For example, a dry cool season in the fire year is common to all regions, but a dry prior monsoon is more common in the Jemez region, while a wet monsoon more often precedes a large fire year in Arizona. Wet conditions in one or both of the cool seasons prior to the fire year appear to be associated with fire years in varying degrees across the three regions.



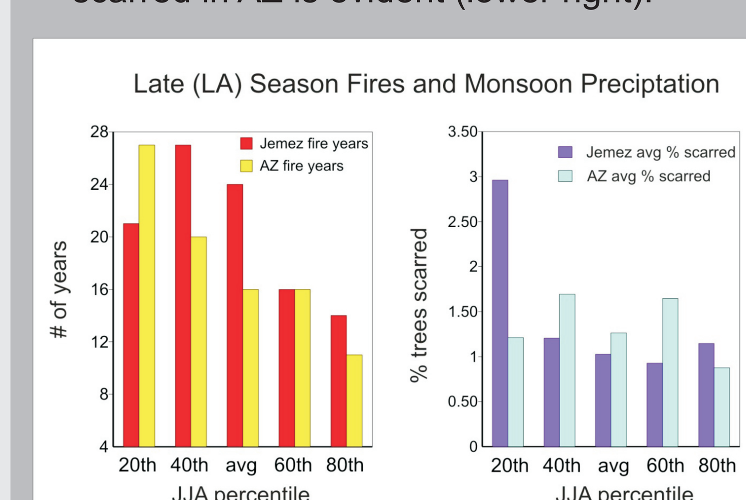




Late Season fires and Monsoon Precipitation

Fire scars in the L and A positions are thought to occur near or after the onset of the monsoon. These fires are much less widespread, and occur in 36%, 42%, and 15% of the years in the Arizona, Jemez, and Sandia regions, respectively. They are almost always preceded by pre-monsoon fires (e.g., 89% in AZ, 92% in Jemez).

Drier monsoons appear to be associated with a higher number of LA fires in both the AZ and Jemez regions (lower left). The % of trees scarred seems related to extreme dry monsoons in the Jemez region, but no relationship between monsoon precipitation and % of trees scarred in AZ is evident (lower right).

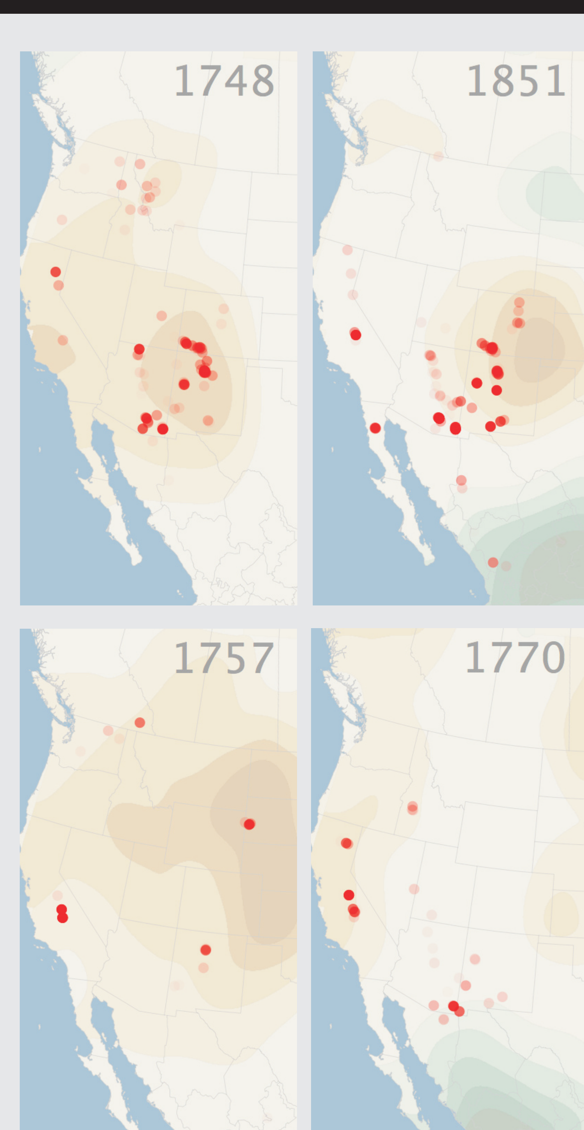


SPATIAL PATTERNS OF FIRE

The widespread fire years in the Southwest can be compared to the spatial distribution of fire occurrence across western North America (FACs project, Falk et al. in prep). For example, fire in 1748 was not restricted to the southwestern US, where it was widespread, but extended into the Pacific Northwest, while in 1851, another big fire year in the Southwest, fire was mostly restricted to this region (maps, top right).

Within the regions we studied, some major fire years in one region did not occur in other regions, indicating spatial heterogeneity. In 1757, no fires were documented in Arizona, but fire in New Mexico was part of a pattern of fire that extended mostly to the north and east. In contrast, fires were documented in Arizona and west in 1770, a year in which the Jemez and Sandia fire scar series documented no fires (maps, bottom right).

The maps to the right document the occurrence of fire in these four years (red dots) as well as the regions under drought and wet conditions from the gridded Palmer Drought Severity Index (PDSI) network of reconstructions (from Cook et al. 2004, interpolated by Falk et al.,in prep). The brown shading indicates negative (dry) PDSI; green is positive (wet) PDSI. PDSI values are in increments of 1.0.



SUMMARY and FUTURE WORK

These very preliminary results suggest the usefulness of combining fire scar data with regional reconstructions of both cool and monsoon season precipitation. While most fires in the southwestern US occur prior to the monsoon season and are strongly influenced by cool season precipitation, other climate/fire relationships may also be important. Wet antecedent cool season precipitation conditions appear to be associated with fire occurrence across the three regions, but monsoon precipitation may also play a role that is variable across the Southwest. The relationship with antecedent monsoon precipitation may be related region-specific vegetation (e.g., grasses) that influences fuels that can support fire. Summer fires are much less widespread, but appear to most often follow premonsoon fires, supported by both dry cool seasons and monsoons.

We have just begun to explore the spatial patterns of fire in this region, and relationships with fire across western North America. Future work will investigate how these patterns are related to climate variability as well as possible drivers of regional fire/climate relationships.

Future work will also explore how seasonal precipitation variability and the occurrence of fire in previous years may be used to estimate fire occurrence in the southwestern US.

photo: T. Swetnam

AGU FALL MEETING
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Reference cited: Cook, E.R. et al.,. 2004. Long-term aridity changes in the western United States. *Science*, 306, 1015-1018.