# Interannual variablity of wildfires and summer precipitation in the Southwest

David S. Gutzler and Laura Van Alst

New Mexico Geology, v. 32, n. 1 pp. 22-23, 29, Print ISSN: 0196-948X, Online ISSN: 2837-6420.
*https://doi.org/10.58799/NMG-v32n1.22*

*This page is intentionally left blank to maintain order of facing pages.*

# Interannual variability of wildfires and summer precipitation in the Southwest

*David S. Gutzler* and *Laura Van Alst**, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131, gutzler@unm.edu *(current address: Department of Geological Sciences, University of Oregon, Eugene, Oregon 97403)

## Introduction

As described in the accompanying Gallery of Geology article, springtime is wildfire season in the Southwest. The table of recent fires in New Mexico on page 25 is dominated by events in May and June. Hot, dry, windy conditions in the spring promote wildfire development. Drought conditions make some years more fire prone than others, and long-term climatic changes in temperature and precipitation affect the general fire regime in the Southwest (Meyer and Frechette, this issue). The onset of the North American monsoon, usually around the beginning of July, brings higher humidity and intermittent rainfall, dampening grass and dry fuel and generally marking the end of the fire season (and the acceleration of plant growth that provides fuel for the next year's fire season).

It is also possible that wildfires affect the regional climate, although this connection is harder to quantify. Large fires inject large quantities of soot and smoke high into the atmosphere. Winds then blow these particulates across the Southwest, so the impact of locally injected particulates can spread far beyond the source. Other sources of particulates, such as widespread air pollution, have been shown to block sunlight and depress precipitation. A study of the South Asian monsoon showed that black carbon soot associated with air pollution decreases the radiative heating of the surface, thereby altering atmospheric stability and large-scale temperature gradients that drive monsoon circulations (Ramanathan et al. 2005).

Compared to the South Asian brown cloud, southwestern wildfires in most years generate much smaller quantities of particulates that remain airborne for a shorter period of time. However the timing of the southwestern fire season in late spring is potentially just right to affect the onset of the monsoon. The onset date is highly correlated with total seasonal precipitation, such that late onset is usually a precursor of low total summer rainfall (Higgins et al. 1997). We describe here a preliminary assessment of the hypothesis that large spring wildfires could depress monsoonal precipitation, by comparing a 25-yr time series of acreage burned in southwestern wildfires in June with the subsequent precipitation observed in July and August (Van Alst 2009).

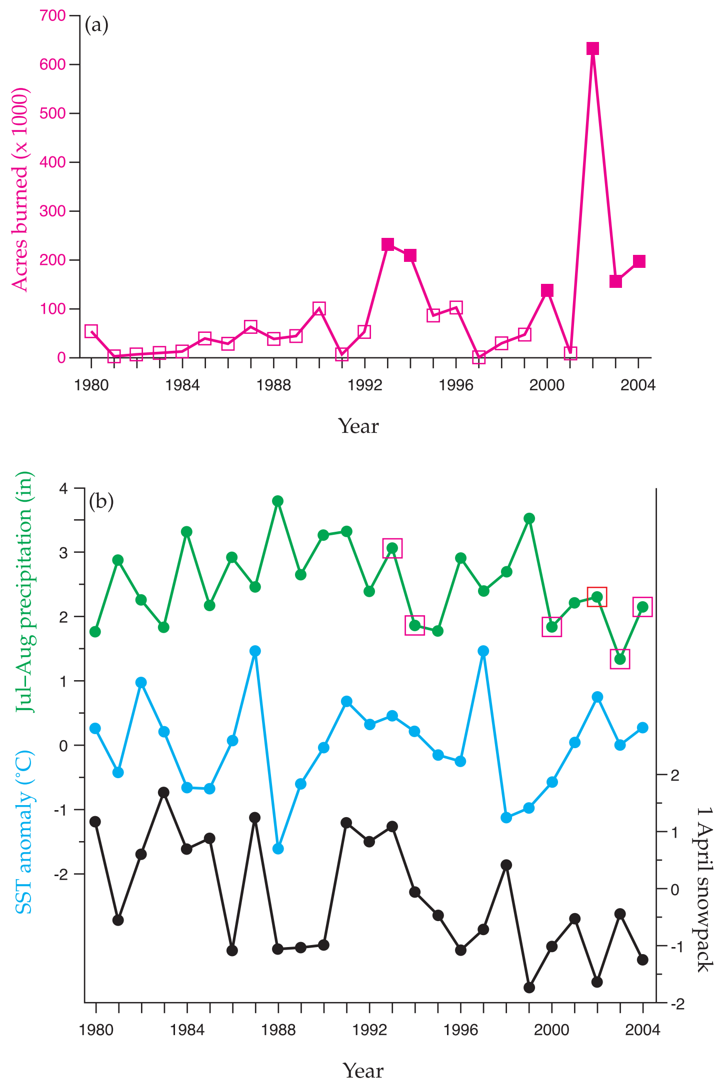


FIGURE 1—a. Annual time series of acreage burned on government-managed lands in Arizona and New Mexico during the month of June for years 1980–2004 (Westerling et al. 2003). Open squares are considered "low-fire years"; solid squares are considered "high-fire years." b. Annual time series of precipitation in eastern Arizona and western New Mexico in July and August (green, units = inches); the Nino3.4 index of equatorial Pacific sea surface temperature anomalies in June and July (blue, units = °C); and a non-dimensional index of 1 April snowpack in eastern Arizona and northern New Mexico (black). The red squares in the precipitation time series denote high-fire years.

## Data

We derived an annual index of southwestern wildfires from a more comprehensive dataset compiled and made available by Professor Tony Westerling of the University of California, Merced (Westerling et al. 2003). He compiled burned acreage data from the Arizona State Lands Department and four federal agencies (the U.S. Forest Service, Bureau of Land Management, National Park Service, and Bureau of Indian Affairs) for a 25-yr period (1980–2004). We summed the acreage burned in fires in Arizona and New Mexico during the month of June, counting all fires that either started in June or started earlier but were still uncontained at the beginning of June.

Precipitation data were obtained as monthly totals, averaged over climate divisions defined by the National Climatic Data Center and archived at the Western

Regional Climate Center. We averaged the precipitation over six climate divisions in southern New Mexico and southeastern Arizona, where the monsoon signal in precipitation is pronounced, for the months of July and August, to form a single regional value of summer rainfall for each year.

One of the challenges in this analysis is distinguishing a possible effect of fire on the monsoon from other sources of climate variability that have been demonstrated to modulate summer rainfall. The monsoon exhibits an inverse relationship with antecedent snowpack in northern Arizona and New Mexico (Gutzler 2000), and with tropical Pacific Ocean sea surface temperatures (or SST; Castro et al. 2001). In other words, more snowpack and warmer tropical SST tend to lead to less monsoon rainfall. We use an index of 1 April snowpack developed by Gutzler (2000), and the "Nino3.4" SST index (available from the NOAA Climate Prediction Center), averaged over June and July, to represent those climate variables. Annual time series of burned acreage (June), Southwest precipitation (July–August), snowpack (1 April) and Nino3.4 SST (June–July) are shown in Figure 1 and described below.

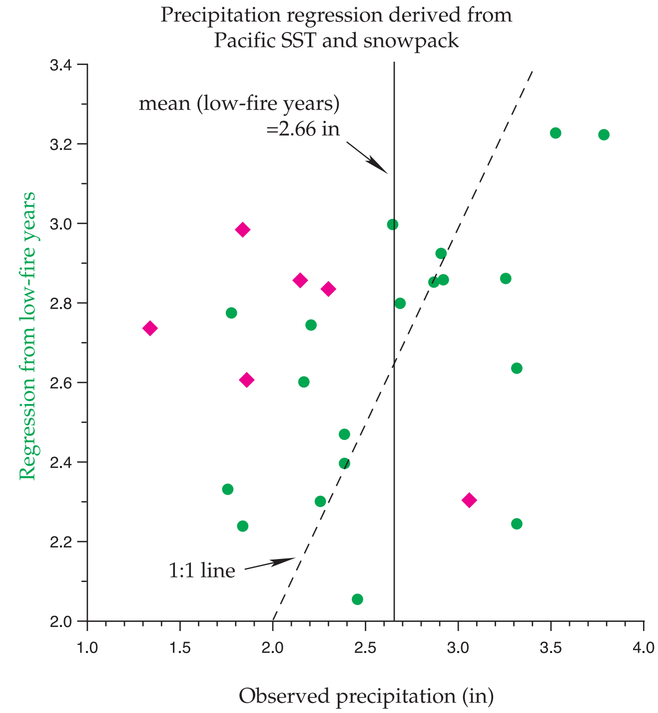


FIGURE 2—Scatter plot of a linear regression of July–August precipitation derived using Pacific SST and 1 April snowpack as predictors, derived from low-fire years. Observed precipitation from Figure 1b is plotted on the x-axis. Predicted precipitation from the regression model is plotted on the y-axis, with the scale expanded relative to the x-axis. The green circles denote the 19 low-fire years used in the regression model. The red diamonds denote the six high-fire years not used in the regression. In a perfect regression model all the data points would line up on the dashed 1:1 line. A solid vertical black line indicates the mean precipitation during low-fire years (2.66 in). All but one of the red diamonds lie to the left of both the vertical and dashed lines, showing that the average precipitation during high-fire years is typically substantially less than both the low-fire year average, and the predicted precipitation derived from SST and snowpack.

## June wildfires and summer precipitation

Visual inspection of the time series of wildfire acreage indicates that its variability can be described as a few high-fire years interspersed among a larger number of low-fire years (Fig. 1a). It can be difficult to define a meaningful "average" in a time series like this, because the mean value will tend to lie in between the actual values observed during low-fire years (often less than 50,000 acres) and high-fire years (sometimes more than 200,000 acres). Precipitation, Pacific SST, or snowpack, in contrast, all exhibit fluctuations about a well-defined mean value (Fig. 1b).

Based on Fig. 1a, we grouped the time series into six high-fire years (1993–94, 2000, and 2002–2004, shown as solid squares), when more than 120,000 acres burned, and 19 low-fire years (all the others, shown as open squares). The 120,000-acre threshold is arbitrary, but modifying this choice somewhat would not change the conclusions much. The increase in fire activity in recent years is obvious, and 2002 (the year of the Rodeo–Chediski fires in the table on page 25) really stands out in this time series.

The average precipitation during the six high-fire years is 2.09 in, and the corresponding average for the 19 low-fire years is 2.66 in. This difference is statistically significant: We can reject the null hypothesis that precipitation during high-fire years is equal to or greater than low-fire years with a p-value of about 0.05. Thus the most basic test of our hypothesis yields a positive result.

However, one could argue that wildfires are not causing low precipitation, because the burned acreage may also be correlated with SST and snowpack. To address this problem, we can try to disentangle the effects of wildfires on summer precipitation in a more subtle way, by examining whether high wildfire activity degrades the interannual relationship between SST and snowpack and subsequent summer precipitation. If we derive a linear regression model for summer precipitation based on tropical Pacific SST and spring snowpack over the entire 25-yr period shown in Figure 1, we find that such a model accounts for only about 10% of precipitation variability. This rather poor prediction can be improved if more sophisticated statistical techniques are employed and careful consideration is given to snowpack or SST anomaly patterns (Gutzler 2000; Castro et al. 2001).

But we can also improve the results by hypothesizing that modulation of the monsoon by snowfall or SST is masked by the effects of significant particulate loading in the high-fire years. If we recalculate the linear regression model based on SST and snowpack using just the 19 low-fire years, we find that the model accounts for about one-third of the precipitation variance. This is illustrated in the scatter plot in Figure 2, where actual summer precipitation is plotted against a prediction from the regression based on SST and snowpack during low-fire years. There is considerable scatter, but the 1:1 line represents some positive statistical prediction skill for the set of green circles (the low-fire years). The predictions from this model for five of the six high-fire years (red diamonds) lie far to the left of the 1:1 line, showing that the regression model tends to overestimate precipitation during high-fire years by about 20% on average. We suggest that this estimate very roughly represents the average effect of widespread fires on monsoon precipitation during high-fire years in these data.

There are many uncertainties and limitations inherent in this analysis. We cannot rule out the possibility that acreage burned is related to some other relevant climate variable not correlated with tropical SST or snowpack. The fire data record is short and incomplete (including just government-held lands in the United States), and acreage burned is, at best, a very rough proxy for particulate loading. These data include no information on the severity of the fires, or the direction and speed of winds that could blow the particulates away. We have

*(D. S. Gutzler and L. Van Alst's report continued on page 29.)*

made no attempt to adjust the boundaries that define the acreage burned or the region of precipitation response. Satellite-based datasets of particulate loading could provide a better, more direct measure of this forcing mechanism. Remotely sensed measurements of particulates are difficult to constrain over land areas, but development of such data is an active area of research.

Similar caveats apply to other climate variables used for monsoon prediction (including the SST and snow data). In view of these observational limitations, model-based sensitivity studies would be necessary to sort out the effects of different forcing functions on monsoon precipitation more definitively. But the simple analysis presented here supports the hypothesis that wildfires tend to suppress summer precipitation during those years when fires are widespread across the Southwest.

## Acknowledgments

Support for Laura Van Alst's senior thesis research from UNM's Caswell Silver Foundation is gratefully acknowledged. Professor Tony Westerling makes his data freely available to researchers, and provided us with an updated and revised fire data record for Arizona and New Mexico. Jane Love and Grant Meyer provided helpful comments on the manuscript.

## References

Castro, C. L., McKee, T. B., and Pielke, R.A., 2001, The relationship of the North American Monsoon to tropical and North Pacific sea surface temperatures as revealed by observational analyses: Journal of Climate, v. 14, pp. 4449–4473.

Gutzler, D. S., 2000, Covariability of spring snowpack and summer rainfall across the southwest United States: Journal of Climate, v. 13, pp. 4018–4027.

Higgins, R. W., Yao, Y., and Wang, X.-L., 1997, Influence of the North American monsoon system on the U.S. summer precipitation regime: Journal of Climate, v. 10, pp. 2600–2622.

Ramanathan, V., Chung, C., Kim, D., Bettge, T., Buja, L., Kiehl, J. T., Washington, W. M., Fu, Q., Sikka, D. R., and Wild, M., 2005, Atmospheric brown clouds: Impacts on South Asian climate and hydrological cycle: Proceedings of the National Academy of Science USA, v. 102, pp. 5326–5333.

Van Alst, L., 2009, The effect of forest fires on the North American Monsoon: Senior thesis, Department of Earth and Planetary Sciences, University of New Mexico, 17 pp.

Westerling, A. L., Gershunov, A., Brown, T. J., Cayan, D. R., and Dettinger, M. D., 2003, Climate and wildfire in the western United States. Bulletin of American Meteorological Society, v. 84, pp. 595–604.