

Wildfire in a Warming World

PART I: TRENDS & THE ROLE OF CLIMATE

SEPTEMBER 20, 2016 / BY JENNIFER HUSHAW

Wildfire has been a hot topic in the media lately, with California ablaze due to a combination of dangerous fire weather, on-going drought, and scores of drought- and beetle-killed trees. Most recently, the Blue Cut Fire burned 37,000 acres and the Soberanes Fire, which began in late July, is still uncontained and has already burned over 105,600 acres. Of course, severe wildfires are certainly nothing new—take the Great Fire of 1910 that burned 3 million acres or the Miramichi Fire in New Brunswick that burned over 3.8 million acres in 1825—but climate change is creating new cause for concern. In fact, the 2014 U.S. National Climate Assessment says climate change-related fire is increasing the vulnerability of U.S. forests to ecosystem change and tree mortality.

In Part I of this two-part piece, we examine recent trends in fire activity, untangle the role of climate change, and outline the most important aspects of climate that drive fire patterns on the landscape.

Wildfire Trends

THE GLOBAL PICTURE

Climate change is expected to increased wildfire activity in certain regions (IPCC AR5), but, so far, there is little evidence of an increase in area burned or an increase in fire severity for many parts of world, and even some evidence suggesting that, overall, there is less fire on the landscape now than centuries ago (Doerr & Santin 2016).

A 2013 study by researchers at the University of Maryland, the University of California, and VU University in Amsterdam showed this **variability in fire trends across different regions** (Giglio et al 2013). They examined global and regional trends in the monthly area burned from 1996 to mid-2012

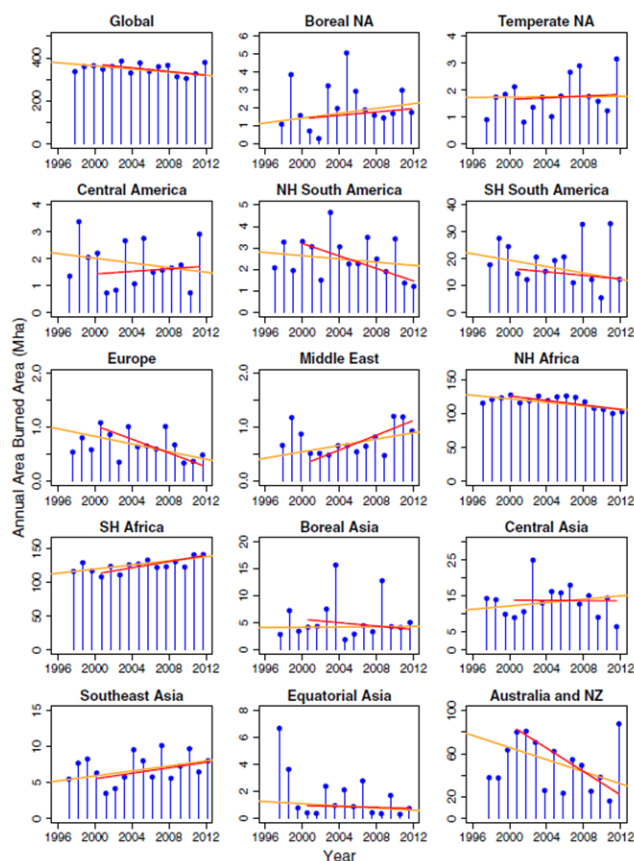


Figure 1: Annual worldwide and regional burned area from 1996 to mid-2012 based on the 4th Global Fire Emissions Database. Source: Giglio et al 2013, Fig. 7.

using information from the fourth generation of the Global Fire Emissions Database (GFED) and they found different, and sometimes opposite, trends depending on the region, as well as a **slight decrease in global area burned over the last 16 years** (see Figure 1). The study did not analyze what *caused* these trends, but researchers did offer some insight into the source of year-to-year variability observed in each region. The level of variability relates to ignition and rainfall—regions with fairly consistent fire activity tend to have widespread and routine human-induced burning (mostly for land maintenance) and similar rainfall from year-to-year (e.g. southern and northern Africa), whereas regions with high variability have more sporadic fire ignition (by humans or otherwise) and more variability in the amount of rain from year-to-year (e.g. Equatorial Asia, where fire activity is closely tied to El Niño events) (Giglio et al 2013).

WILDFIRE IN THE U.S.

In contrast to the global picture, we have seen increasing media reports of large wildfires and more discussion of the ballooning cost of fire control efforts in the United States in recent years. This is especially true when conflagrations break out at the intersection of forests and developed lands, also known as the Wildland Urban Interface (WUI). Given the greater cost of suppression efforts and increased risk of damage to lives and property in these areas, some have suggested that the perceived increase in wildfire may simply be due to increased attention. However, as we will discuss below, **there is ample evidence that large portions of the U.S. have indeed experienced more fire.**

Most studies of wildfire trends in the U.S. are focused on the western part of the country and they have detected an overall increase in fire activity over recent decades. For example, there is evidence that the number of large fires (> 1,000 acres) and/or total area burned per year increased in many parts of the western U.S. from 1984-2011 (Figure 2; Dennison et al 2014).

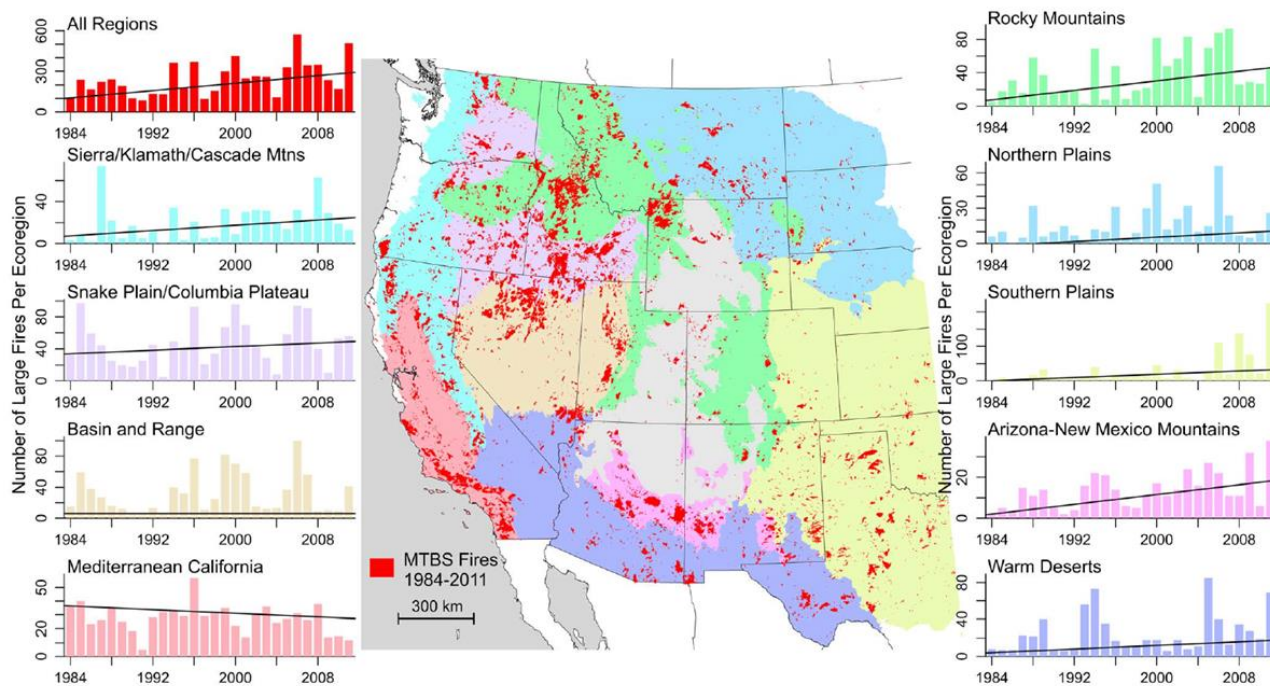


Figure 2: Western U.S. trends for number of large fires (> 1,000 acres) in each ecoregion per year for 1984-2011, based on data from the Monitoring Trends in Burn Severity Project (MTBS). Source: Dennison et al 2014, Fig. 1.

Another research team detected a similar trend since 1970, with a noticeable increase in western forest fire activity beginning around the mid-1980's (see Figure 3, below), including more frequent large fires (> 1,000 acres), fires that burned longer, and longer wildfire seasons (Westerling et al 2006; Westerling 2016).

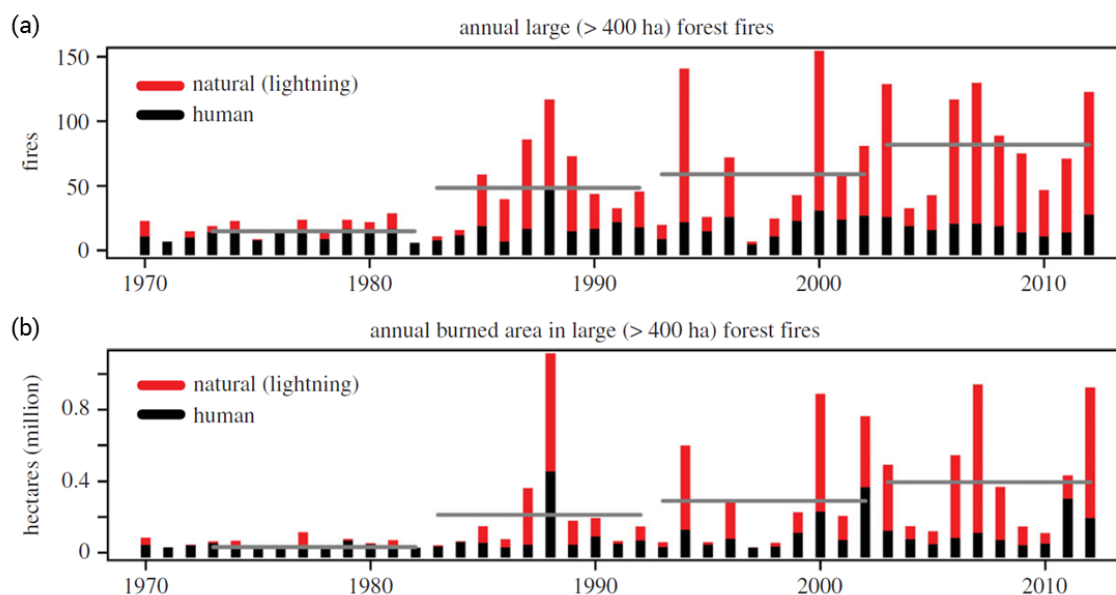


Figure 3: Number of human and lightning-ignited annual large forest fires (> 400 ha/> 1,000 acres) (a) and forest area burned (b) on Forest Service, Park Service, and Indian Lands in the western U.S. Horizontal lines indicate decade averages. Source: Westerling 2016, Fig. 1.

Additionally, there is evidence that the number of *very* large fires (> ~12,400 acres) has also been increasing over the last 30 years, particularly across parts of the southeastern and southwestern U.S. (Barbero et al 2014).

These observations square with another recent study (Jolly et al 2015), which showed that **conditions have become more conducive to fire in many parts of the world**. Researchers used historic climate data from 1979 to 2013 to calculate the length of the fire weather season over the last 35 years, based on several common fire danger indices used in the U.S., Canada, and Australia. They found that, globally, the length of the average fire weather season increased by almost 19% and the amount of land area affected by long fire weather seasons doubled. Their results coincided with evidence of recent trends in the U.S. For example, in 2012, about 47% of the vegetated area of the U.S. experienced a longer-than-normal fire weather season according to their estimates and that resulted in a “near-record setting ~3.8MHa [9.4 million acres] of burned area” (Jolly et al 2015).

Although, even in the U.S., not all regions are experiencing more wildfire. The Northeast, for example, is known for some historic mega-fires, but now has an annual average area burned of only 0.04% of forest area and fire histories show a decline for the last 60 years in both the area burned and the size of fires (Irland 2013). This decline is likely due to better detection, regulation, and control methods since the 1950's, but it also means more fuel has accumulated on the landscape (Irland 2013). Importantly,

extreme fire behavior can still occur in regions with very infrequent fire and, in fact, almost every part of the Northeast has experienced extreme fire years or unusually large fires since that decline began in the 1950's (Irland 2013).

A CLIMATE CHANGE CONNECTION?

A number of factors have contributed to the recent increase in U.S. wildfires, including higher fuel loads from historic fire suppression and large-scale forest mortality due to bark beetle outbreaks, but an important question is: To what extent, if any, has climate change contributed to these observed trends? Evidence suggests it has played a role. The Intergovernmental Panel on Climate Change (IPCC) noted that climate change has already had a major impact on wildfire activity in North America, some parts of Europe (specifically Portugal and Greece), and Africa in recent years (IPCC AR5 SPM, Figure SPM.4). In fact, fire is one of the key climate change-related risks they list for North America and Europe and that risk is projected to increase as we move farther into this century (IPCC AR5 SPM, Figure SPM.8). The 2014 U.S. National Climate Assessment also identified a link between climate change and fire, noting that "Climate change is contributing to an increase in wildfires across the U.S. West." They point specifically to hotter and drier weather and earlier snowmelt, which has increased the length of the fire season and amount of acreage burned (NCA 2014).

Numerous studies suggest changes in climate are largely responsible for observed wildfire trends in the U.S. (Littell et al 2009; Jolly et al 2015; Westerling et al 2006; Westerling 2016; Attiwill & Binkley 2013) and there is evidence for this connection in both modeling and observational studies. For example, Barbero et al (2014) developed models that successfully replicated historic fire patterns across the continental U.S. using ONLY climate variables, which indicates climate is the major mechanism driving fire activity. Another study found that climate was a significant driver of fire activity in the western U.S. from 1916 to 2003—explaining an average of 39% of the variability in area burned—and there was an even stronger linkage in the most recent decades from 1977 to 2003, where climate explained an average of 64% of the area burned (Littell et al 2009). A third example, mentioned earlier, is research from Dennison et al (2014) that found similar wildfire trends across a variety of western U.S. ecoregions with different vegetation types, fire seasons, fuel types, and fire frequencies (see Figure 2), but similar increases in severe drought. This suggests prevailing climatic conditions, rather than site-specific dynamics, are responsible. **Evidence suggests climate change will only continue to play a bigger role in shaping fire trends**, as we move from global fire regimes that were driven by precipitation during the pre-industrial period and by human ignition and suppression during the 18th century, into a new temperature-driven global fire regime (Pechony & Shindell 2010).

Climate & Fire: Take Homes for Forest Managers

CLIMATE DRIVES FIRE ACTIVITY

While there are many factors that determine where, when, and how wildfires burn, **climate is well-recognized as one of the primary controls on fire activity** (Dennison et al 2014). At the simplest level, it influences the availability and flammability of fuels, but fire requires three components—biomass to burn, the right atmospheric conditions, and ignition—and climate affects all of these components "in complex ways and over multiple timescales" (Moritz et al 2012). In the short-term, climate controls

ignition and propagation, while in the long term it affects fuels by influencing primary productivity and vegetation (Urbieta et al 2015).

TIME SCALE MATTERS

The diagram in Figure 4 (below) outlines how different aspects of climate control fire at different scales. For example, in some North American regions, fire regimes are closely related to natural modes of climate variability, such as the El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), and the Atlantic Multidecadal Oscillation (AMO) (Whitlock et al 2010; Fauria & Johnson 2008)—see our previous bulletin on [Global Temperature Trends](#) for an explanation of how the ENSO/PDO system influences fire regimes worldwide. We are accustomed to thinking about the drivers of fire at shorter timescales (i.e. at the level of individual fires—seasonal-to-annual—and how they propagate—hourly-to-annual) because fire management and response systems typically operate at those scales, but the influence of decade-to-decade climate fluctuations and the long-term warming trend are no less important. **Changes in average climate, variability, and long-term trends can shift the fire regime in a given region** and, since climate conditions are projected to continue changing for the foreseeable future, **it is reasonable for forest managers to expect and prepare for deviations from the historic fire regime in their area.**

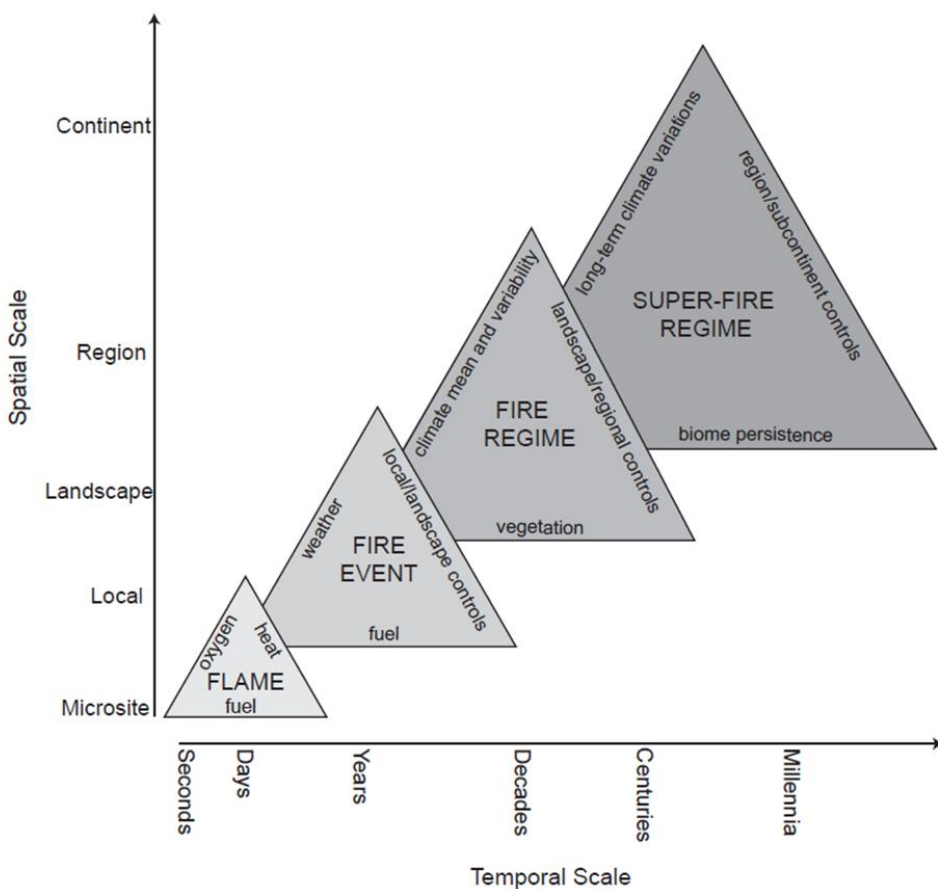


Figure 4: Conceptual diagram of the controls of fire at multiple temporal and spatial scales. The side of each triangle indicates the dominant drivers at different scales and the overlap shows how they are nested within each other. Source: Whitlock et al 2010, Fig. 1.

DROUGHT & FIRE RISK

More immediate fire-climate impacts will most likely come through drought, which also played a role in the record-breaking 2015 U.S. fire season. **Drought is projected to increase in both frequency and severity in many regions and it is known to directly affect fire severity, extent, and frequency** (Littell et al 2016). The uncertainty of future precipitation patterns, as discussed in [an earlier bulletin](#), presents a challenge because there are [very few regions of the world where we have confidence](#) in predictions of future drought. That said, **warmer temperatures alone can increase the intensity of individual drought events (and associated fire risk)** by increasing potential evapotranspiration (as [discussed previously](#))—a factor that has been implicated in the severity of the recent California drought (Diffenbaugh et al 2015).

WHAT'S LIMITING: FUEL OR MOISTURE?

The impact of climate change on fire activity will largely depend on whether an ecosystem tends to be more fuel-limited or climate-limited (Littell et al 2009; Steel et al 2015; Whitlock et al 2010). In the former, fire is limited by the amount of fuel available and these are often drier, more sparsely vegetated areas that experience frequent, lower-severity wildfires. In contrast, fire in climate-limited systems is controlled by fuel flammability and these are generally more moist systems with significant biomass that experience infrequent, more severe wildfires. For example, more precipitation can actually *increase* fire risk in fuel-limited ecosystems by increasing the quantity of fine fuels (Dennison et al 2014), compared to climate-limited ecosystems like the boreal forest where moisture rather than fuel accumulation is the primary determinant of fire behavior and more precipitation would typically *decrease* fire risk (Fauria & Johnson 2008). Factors like human intervention can flip a system from one end of the spectrum to another. For example, researchers studying 130 years of fire history in a Spanish province in the Mediterranean found that rural depopulation and farm abandonment increased fuels and shifted the fire regime in that region from fuel-limited to climate-limited, leading fire activity to become more drought-driven (Pausas & Fernandez-Munoz 2012). **Fire activity in these climate-limited ecosystems is sensitive to changes in temperature, so warming may especially increase fire risk in these systems.**

Coming up...

In Part II, we outline what the latest research suggests in terms of future fire frequency, extent, and/or severity and we discuss the changing context of more fire in the WUI, rising costs, and changing organizational structures, as well as providing useful resources for more information.

~ ~ ~ ~ ~

References

- Attiwill, P., Binkley, D. 2013. Editorial: Exploring the mega-fire reality: A 'Forest Ecology and Management' conference. *Forest Ecology and Management*. 294: 1-3.
- Barbero, R., Abatzoglou, J.T., Steel, E.A., Larkin, N.K. 2014. Modeling very large-fire occurrences over the continental United States from weather and climate forcing. *Environ. Res. Lett.* 9: 11pp.
- Dennison, P.E., Brewer, S.C., Arnold, J.D., Moritz, M.A. 2014. Large wildfire trends in the western United States, 1984-2011. *Geophys. Res. Lett.* 41: 2928-2933.

- Diffenbaugh, N.S. Swain, D.L., Touma, D. 2015. Anthropogenic warming has increased drought risk in California. *PNAS*. 112(13): 3931-3936.
- Doerr, S.H. and Santín, C. 2016. Global trends in wildfire and its impacts: perceptions versus realities in a changing world. *Phil. Trans. R. Soc. B*. 371: 20150345.
- Fauria, M.M. and Johnson, E.A. 2008. Climate and wildfires in the North American boreal forest. *Phil. Trans. R. Soc. B*. 363: 2317-2329.
- Giglio, L., Randerson, J.T., van der Werf, G.R. 2013. Analysis of daily, monthly, and annual burned area using the fourth-generation global fire emissions database (GFED4). *Journal of Geophysical Research: Biogeosciences*. 118: 317-328.
- IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.
- Irland, L.C. 2013. Extreme value analysis of forest fires from New York to Nova Scotia, 1950-2010. *Forest Ecology and Management*. 294: 150-157.
- Jolly, W.M., Cochrane, M.A., Freeborn, P.H., Holden, Z.A., Brown, T.J., Williamson, G.J., Bowman, D.M.J.S. 2015. Climate-induced variations in global wildfire danger from 1979 to 2013. *Nature Communications*. 6: 7537. DOI: 10.1038/ncomms8537.
- Littell, J.S., McKenzie, D., Peterson, D.L., Westerling, A.L. 2009. Climate and wildfire area burned in western U.S. ecoprovinces, 1916-2003. *Ecological Applications*. 19(4): 1003-1021.
- Littell, J.S., Peterson, D.L., Riley, K.L., Liu, Y., Luce, C.H. 2016. A review of the relationships between drought and forest fire in the United States. *Global Change Biology*. 22: 2353-2369.
- Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.
- Moritz, M.A., Parisien, M-A., Batllori, E., Krawchuk, M.A., Van Dorn, J., Ganz, D.J., Hayhoe, K. 2012. Climate change and disruptions to global fire activity. *Ecosphere*. 3(6):49.
- Pausas, J.G., Fernández-Muñoz, S. 2012. Fire regime changes in the Western Mediterranean Basin: from fuel-limited to drought-driven fire regime. *Climatic Change*. 110: 215-226.
- Pechony, O., Shindell, D.T. 2010. Driving forces of global wildfires over the past millennium and the forthcoming century. *PNAS*. 107(45): 19167-19170.
- Steel, Z.L., Safford, H.D., Viers, J.H. 2015. The fire frequency-severity relationship and the legacy of fire suppression in California forests. *Ecosphere*. 6(1): Article 8, 23pp.
- Urbieto, I.R., Zavala, G., Bedia, J., Gutiérrez, J.M., San Miguel-Ayán, J., Camia, A., Keeley, J.E., Moreno, J.M. 2015. Fire activity as a function of fire-weather seasonal severity and antecedent climate across spatial scales in southern Europe and Pacific western USA. *Environ. Res. Lett.* 10:114013.
- Westerling, A.L. 2016. Increasing western US forest wildfire activity: sensitivity to changes in the timing of spring. *Phil. Trans. R. Soc. B*. 371: 20150178.
- Westerling, A.L., Hidalgo, H.G., Cayan, D.R., Swetnam, T.W. 2006. Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. *Science*. 313: 940-943.
- Whitlock, C., Higuera, P.E., McWethy, D.B., Briles, C.E. 2010. Paleoecological Perspectives on Fire Ecology: Revisiting the Fire-Regime Concept. *The Open Ecology Journal*. 3: 6-23.