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Spatial Variation in Extreme Winds Predicts Large Wildfire Locations in Chaparral Ecosystems

Max A. Moritz,[1] Tadashi J. Moody,[1] Meg A. Krawchuk,[1] Mimi Hughes,[2,3] and Alex Hall[2]

[1]Department of Environmental Science, Policy, and Management;
University of California, Berkeley; Berkeley, CA, USA.

[2]Department of Atmospheric and Oceanic Sciences;
University of California, Los Angeles; Los Angeles, CA, USA.

[3]Earth System Research Laboratory; NOAA; Boulder, CO, USA.

Auxiliary materials

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1. Supplementary Notes

Areas with Mediterranean-type climates experience annual summer drought, and in some cases multi-year droughts, all of which contribute to being fire-prone. With the exception of Chilean matorral ecosystems, all Mediterranean-climate regions are also reported to experience large fires driven by extreme wind events. The following are a sample from the popular press that highlight the importance of hot and dry winds in driving the growth of large fires in these regions. (All accessed September 2009.)

Mediterranean Basin

"Dying Winds Bring Relief to Firefighters in Greece" (August 2009; The Independent)

http://www.independent.co.uk/news/world/europe/dying-winds-bring-relief-to-firefighters-in-greece-1776793.html

"Wind whips up fires on Spain's Canary Islands" (August 2009; Associated Press)

http://www.google.com/hostednews/ap/article/ALeqM5iGje0J6LzVboUR6UxOYwQl-cjyeAD99QUM502

"Forest Fire Destroys 1,000 Hectares of Woodland in Mediterranean Coast" (August 2008; Turkish Press)

http://www.turkishpress.com/news.asp?id=245050

"Wind-whipped Fires Greece Kill 49" (August 2007; The Washington Post)

http://www.washingtonpost.com/wp-dyn/content/article/2007/08/25/AR2007082501311_pf.html

"Summer Fires Char Portugal, France" (July 2004; International Daily Newswire)

http://www.ens-newswire.com/ens/jul2004/2004-07-27-04.asp

Southeast Australia

"Gusty winds fan fire fears in southern Qld" (August 2009; ABC News)

http://www.abc.net.au/news/stories/2009/08/24/2664928.htm

"Savage winds fuel new and deadly fire threat" (March 2009; TV New Zealand)

http://tvnz.co.nz/view/page/536641/2510522?cfb3=3

"Ash Wednesday fires" (January 2008, Associated Content)

http://www.associatedcontent.com/article/531959/ash_wednesday_fires_.html?cat=37

"Bushfires raging on in Australia" (January 2006; BBC)

http://news.bbc.co.uk/cbbcnews/hi/newsid_4570000/newsid_4575000/4575074.stm

"Fresh Fears over Australian Inferno" (December 2001; BBC)

http://news.bbc.co.uk/2/hi/asia-pacific/1728015.stm

South Africa

"Firefighters hope for relief" (February 2009; Cape Argus)

http://www.capeargus.co.za/index.php?fArticleId=4832039

"South Africa bush fires 'kill 20'" (September 2008; BBC)

http://news.bbc.co.uk/2/hi/africa/7591950.stm

"Strong winds cause fire havoc in the Cape" (October 2006, IOL Environment)

http://www.iol.co.za/index.php?set_id=1&click_id=14&art_id=vn20061016130229560C236659

"Fire razes top Cape resort" (February 2006: Cape Times)

http://www.capetimes.co.za/index.php?fSectionId=269&fArticleId=3093497

"Firefighters work through night to quell fire" (January 2005; IOL South Africa)

http://www.int.iol.co.za/index.php?set_id=1&click_id=13&art_id=vn20050114101506917C621144

California

"Santa Ana winds fan fires near Chino Hills, Brea" (November 2008; CBS/Associated Press)

http://cbs2.com/local/yorba.linda.fire.2.865846.html

"Fabled Santa Ana winds fuel wildfires in California" (October 2007; NPR)

http://www.npr.org/templates/story/story.php?storyId=15584420

"California firefighters fear wind could push deadly blaze toward homes, arson probed" (October 2006; Fox News)

http://www.foxnews.com/story/0,2933,225863,00.html

"Mountain resorts under siege" (October 2003; Los Angeles Times)

http://www.latimes.com/news/local/la-fires-06-pulitzer,0,7343763,full.story

2. Supplementary Data and Methods

MM5 Simulations

The weather simulation model has 23 vertical levels, with the vertical grid stretched to place the highest resolution in the lower troposphere. Lateral boundary conditions and sea surface temperatures come from the National Center for Environmental Prediction's 40-km resolution Eta model reanalysis data and were updated continuously throughout the run at 3 hourly intervals. Gridpoint dimensions in each domain (Figure 1 inset) are 35x36, 37x52, and 55x97 for the 54, 18, and 6 km domains, respectively, and the nesting was two-way for both interior domains. In the outer two domains, the Kain-Fritsch 2 cumulus parameterization scheme [*Kain*, 2004] was used. In the 6 km domain only explicitly resolved convection could occur. In all domains, we used the MRF boundary layer scheme [*Hong and Pan*, 1996], Dudhia simple ice microphysics [*Dudhia*, 1989], and a radiation scheme simulating longwave and shortwave interactions with clear-air and cloud [*Dudhia*, 1989].

Three previous studies have shown this simulation accurately reproduces circulation variability. Synoptic time-scale variability in the daily-mean wind speed and direction are captured well, based on correlating the simulation's daily-mean winds with available point measurements [*Conil and Hall*, 2006]. This simulation also reproduced the observed diurnal cycles of wind and surface air temperature found in a network of 30 observation stations in the region [*Hughes, et al.*, 2007]. Finally, and most relevant for our study, the simulation captures variability in offshore Santa Ana winds [*Hughes and Hall*, in press].

Fire history data

Fire history data was obtained from the California Department of Forestry and Fire Protection (CAL FIRE), Fire Resources and Analysis Program (FRAP). CAL FIRE, along with several Federal land management agencies, has compiled and maintains annually a statewide geodatabase of historical fire records, including GIS perimeters and information on wildfires, prescribed burns, and other fuel treatments covering both public and private lands. While it is currently the single most comprehensive database of fire history in California, it is still incomplete in some respects (See FRAP website metadata http://frap.cdf.ca.gov/projects/fire_data/fire_perimeters/methods.asp for additional details).

For the purposes of our analysis, we chose to limit our use of these records to fires greater than 120 ha (300 acres) in size which occurred between 1950 and 2007. This represented the most complete and reliable subset of fire records of substantial temporal length in the database. The minimum mapping unit of 120 ha is that for which all participating agencies recorded fires in southern California. While the database includes records from some agencies back as far as 1878, all participating agencies (except one) have submitted records dating back to 1950; records for the Bureau of Land Management only go back to 2002, but this does not affect our study area. The database includes various fuel modification treatments such as mechanical thinning and hand piling/burning projects, but we only included treatments that were classified as broadcast burns or wildland fire use fires. The final subset was screened and edited for potential duplicate records, and a layer of points representing the centroids of each of the fire perimeters was created (Figure 3). Each point maintained the attributes of the fire it represented, so we were able to filter the records (e.g. by fire size) for use in comparison with fire weather patterns. Fire data were then spatially filtered to exclude human-dominated landscapes (e.g., urban and agricultural land uses) and non-shrubland vegetation types [*Davis, et al.*, 1998]. A small number of fires (~1%) had the year but not the month recorded in the date field; these events were omitted from any calculations and statistical tests performed exclusively on October data. Although the total number of shrubland fires is not known (i.e., including those <120 ha), the 1277 fires available for subsequent analyses (i.e., those from 1950-2007, >120 ha in size, and in shrubland vegetation) account for the vast majority of area burned across all vegetation types over the period of record.

Spatial dependence in K-S tests

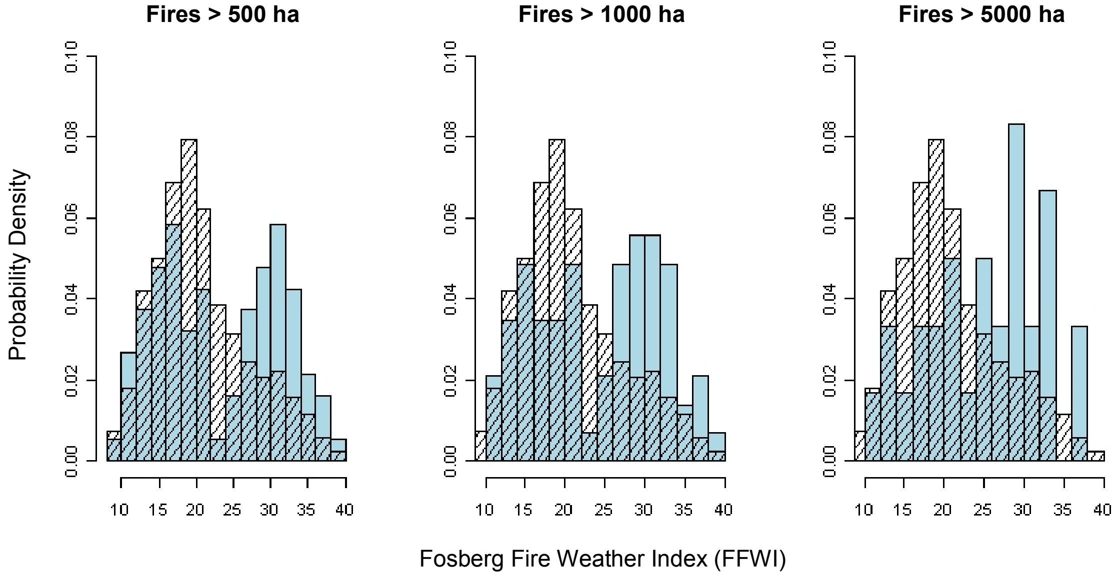
Our general hypothesis is that the distribution of FFWI for large fire events would differ from, and include higher FFWI values, than the region-wide distribution in FFWI values observed during Santa Ana winds (Figure 2). As a test of this hypothesis, analyses were restricted to 610 FFWI grid point values in shrublands, contrasted against those associated with October shrubland fire centroids (Supplementary Table S1). Histograms illustrated that FFWI values corresponding to fire centroids were not normally distributed, so we used the Kolmogorov-Smirnov two-sample test (K-S test) to assess differences in the two distributions [*Sokal and Rohlf*, 1981]. The K-S test required a modification to account for spatial dependence in our FFWI data, but there is no accepted spatial adjustment for this particular test. There are many ways to deal with spatial autocorrelation in statistical tests [*Fortin and Dale*, 2005], and the goal is generally to determine an effective sample size that reflects spatial independence of observations. A simple method is to adjust significance level required in statistical testing, making the Type I error rate a more conservative value, such as lowering the *p*-value from 0.05 to 0.01 for significance; however, depending on the true autocorrelation in data, this may be much too conservative[*Fortin and Dale*, 2005]. To adjust the K-S tests of significance, we used a *p*-value that was a full order of magnitude more conservative than the standard level of 0.05 (i.e., significance at 0.005).

We found that the difference between the distribution of FFWI values for large fire centroids in shrublands (Figure 3) and for the region-wide distribution of FFWI (Figure 2) in shrublands was increasingly obvious with higher cutoff values for the “large” fire categories, as shown in frequency histograms here (Supplementary Figure S1) and smoothed density distributions in the paper (Figure 4). Regardless of the cutoff for “large” fires used in our analysis, and despite a very conservative test for significance, K-S tests demonstrated that these events occur significantly more often in regions that are exposed to higher severity conditions when Santa Ana winds are blowing (Supplementary Table S1). Analysis of large fires during any month of the year (data not shown) showed a similar spatial coherence with FFWI patterns from the October Santa Ana events we modelled, although not as strong statistically. We also created a spatial dataset of the number of times an area had burned over 1950-2007 from the same official fire history dataset described earlier. Spatial analysis of these fire occurrence maps (data not shown) indicated a positive but weak relationship between the number of times a given area has burned and spatial patterns of high fire weather severity.

Supplementary Table S1. Tests for “large” fire correspondence with higher fire weather severities.

Fire size (ha)	Month	n	D	*p*	Fires where FFWI > 25	Area burned where FFWI > 25
> 500	October	94	0.27	<0.0001	45.2%	62.3%
> 1,000	October	72	0.31	<0.0001	50.0%	63.2%
> 5,000	October	30	0.36	0.0007	50.0%	65.3%

D is K-S test statistic; n is full number of points used for sample in K-S test.



Supplementary Figure S1. Histograms of FFWI distributions for large October fires (blue) versus the entire study region (hatched white), using different fire size cut-offs to define "large" events.

Supplementary References

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