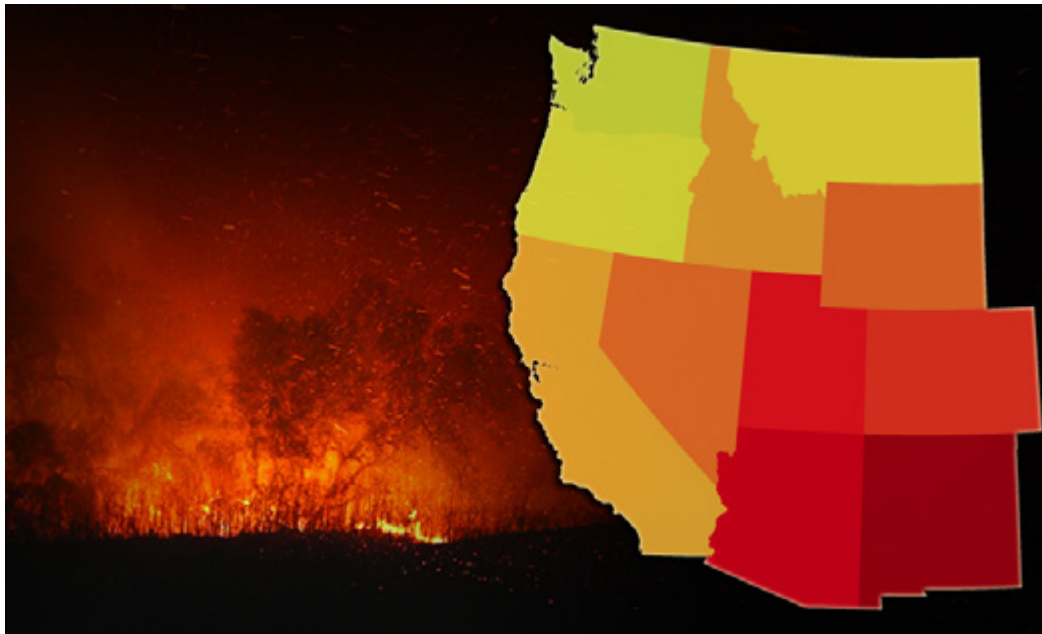


# The Age of Western Wildfires



## Western Wildfires 2012

### Princeton

One Palmer Square, Suite 330  
Princeton, NJ 08542

Phone: +1 609 924-3800

### Palo Alto

895 Emerson Street  
Palo Alto, CA 94301

Phone: +1 877 425-4724

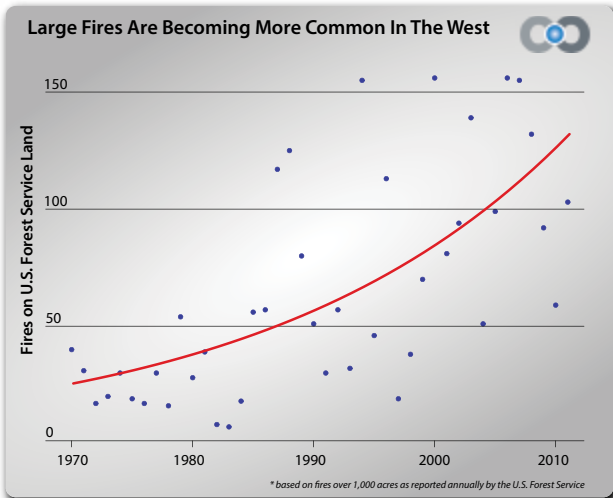
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# Summary

The 2012 wildfire season isn't over yet, but already this year is shaping up to be the one of the worst on record in the American West. According to the National Interagency Fire Center, with nearly two months still to go in the fire season, the total area already burned this year is 30 percent more than in an average year, and fires have consumed more than 8.6 million acres, an area larger than the state of Maryland.



*The annual number of wildfires greater than 1,000 acres on U.S. Forest Service Land has been increasing across the West.*

Yet, what defines a “typical” wildfire year in the West is changing. In the past 40 years, rising spring and summer temperatures, along with shrinking winter snowpack, have increased the risk of wildfires in most parts of the West.

Studies show that continued climate change is going to make wildfires much more common in the coming decades.

The National Research Council reports that for every degree Celsius (1.8°F) of temperature increase, the size of the area burned in the Western U.S. could quadruple. According to the IPCC 4<sup>th</sup> Assessment Report, summer temperatures in western North America could increase between 3.6°F and 9°F by the middle of this century.

## Key findings

Our analysis of 42 years of U.S. Forest Service records for 11 Western states shows that:

The number of large and very large fires on Forest Service land is increasingly dramatically. Compared to the average year in the 1970's, in the past decade there were:

- 7 times more fires greater than 10,000 acres each year
- Nearly 5 times more fires larger than 25,000 acres each year
- Twice as many fires over 1,000 acres each year, with an average of more than 100 per year from 2002 through 2011, compared with less than 50 during the 1970's.

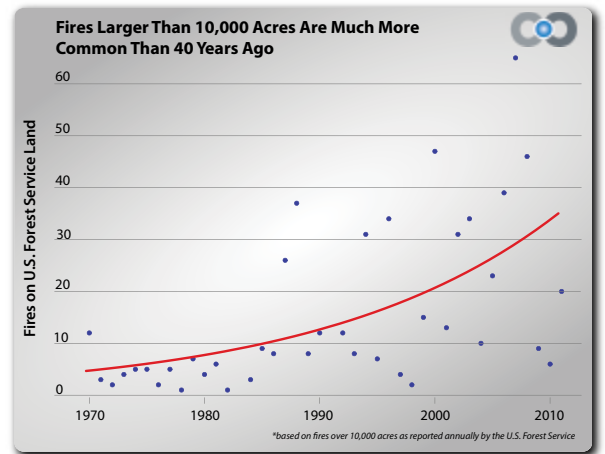
In some states the increase in wildfires is even more dramatic. Since the 1970's the average number of fires over 1,000 acres each year has nearly quadrupled in Arizona and Idaho, and has doubled in California, Colorado, Montana, New Mexico, Nevada, Oregon, Utah and Wyoming.

On average, wildfires burn twice as much land area each year as they did 40 years ago. In the past decade, the average annual burn area on Forest Service land in the West has exceeded 2 million acres – more than all of Yellowstone National Park.

The burn season is two and a half months longer than in the 1970s. Across the West, the first wildfires of the year are starting earlier and the last fires of the year are starting later, making typical fire years 75 days longer now than they were 40 years ago.

Rising spring and summer temperatures across the West appear to be correlated to the increasing size and numbers of wildfires. Spring and summer temperatures have increased more rapidly across this region than the rest of the country, in recent decades. Since 1970, years with above-average spring and summer temperatures were typically years with the biggest wildfires.

Previous research reveals that climatic changes, including increasing temperatures and the earlier onset of spring snowmelt, have been linked to increasing levels of atmospheric greenhouse gases and are likely influencing these damaging fire trends. As average global temperatures rise, researchers project that the risk of wildfires in America's West will accelerate.



*Wildfires larger than 10,000 acres are about seven times more common now than they were 40 years ago on U.S. Forest Service Land.*

## Increasing Wildfires in the Western U.S.

To study how wildfires are changing across the American West, we analyzed more than 40 years of wildfire data from the U.S. Forest Service (USFS), which administers the majority of public forested land in the West. Using USFS records of wildfires greater than 1,000 acres in size from 1970-2011,<sup>1</sup> we calculated changes in the annual number of fires and the total area burned in 11 Western states: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

As illustrated in Figure 1, the frequency of wildfires on USFS land in the West has increased dramatically. In the 1970s, across all USFS land, there were on average fewer than 50 fires larger than 1,000 acres. In the past decade however, there have been an average of 100 fires that size each year, and in four of the past 10 years, more than 125 such fires.

There has only been one year since 1998 where there were as few fires as the record year in the 1970s.

The total area burned in large fires each year is also growing. Figure 2 shows that the annual burn area in the West has more than doubled in the past 40 years. In the 1970s, the cumulative burn area on USFS land in any given year was typically about 200,000 acres. Since 2000, there have been dramatic year-to-year variations, but some of the biggest fire years have seen more than 2 million acres burned; even years with fewer fires have seen total burn areas reach the 1 million-acre mark.

The frequency of very large fires — often termed “megafires” — is also increasing in the West. The average number of annual fires larger than 10,000 acres is now about seven times greater than it was in the 1970s (Figure 3) and each year the average number of fires larger than 25,000 acres is about five times more than it was 40 years ago (Figure 4).

The above analysis is based on a thorough record of wildfires dating back to 1970, but it is limited to the public area monitored by the U.S. Forest Service. While experts generally agree that fire behavior on this land is representative of trends across the entire region,<sup>3</sup> we also examined the extent to which wildfires have increased on all federal lands in the American West.<sup>2</sup> This includes land managed by the

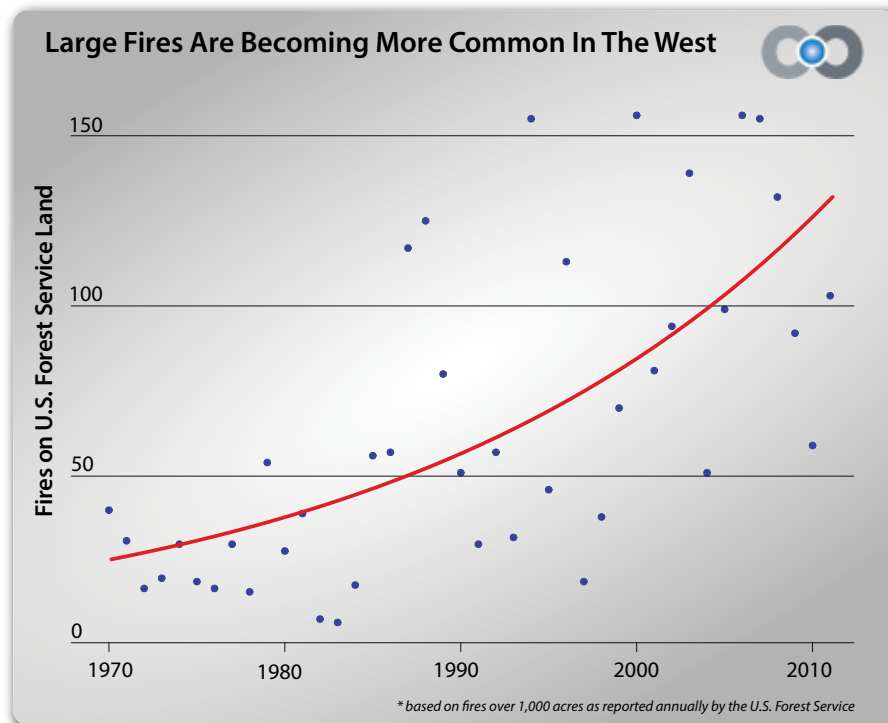
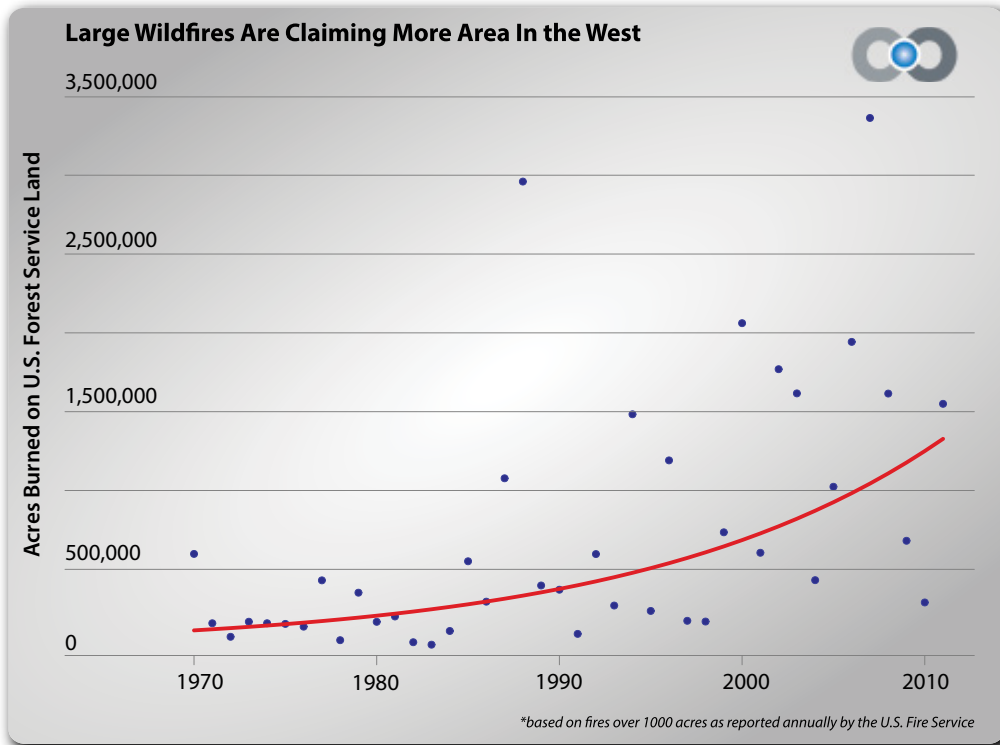
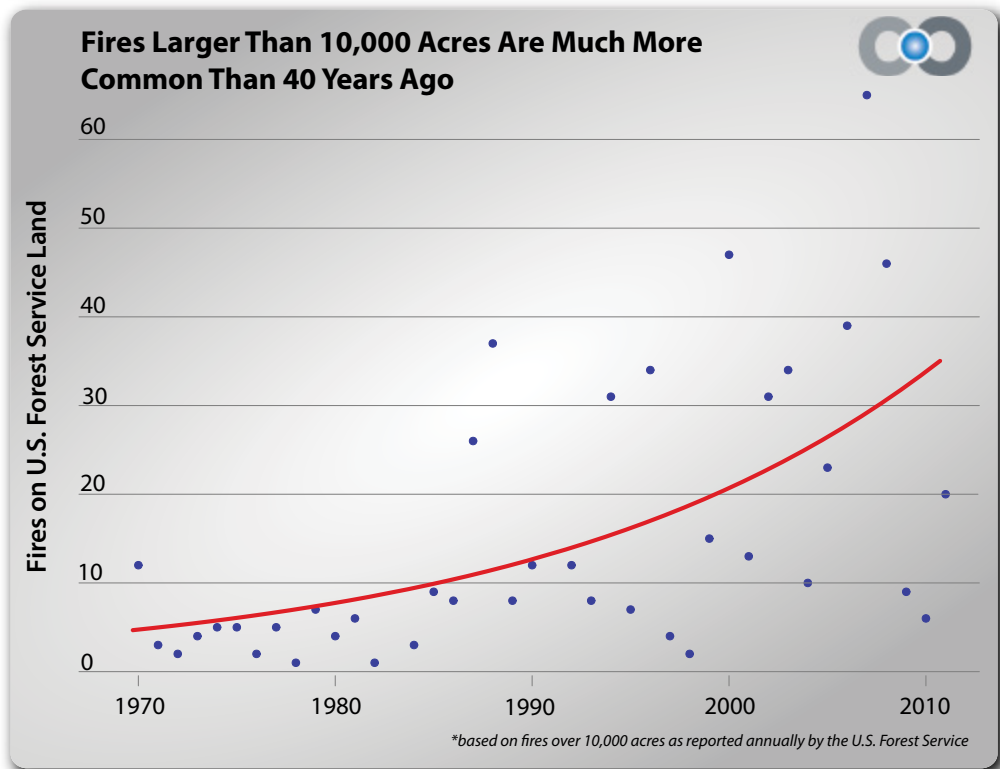


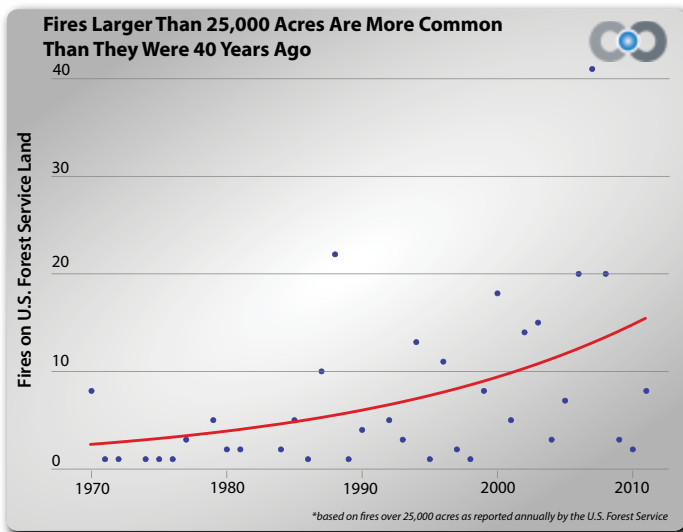
Figure 1. The annual number of wildfires greater than 1,000 acres on U.S. Forest Service Land has been increasing across the West.



**Figure 2.** The total area burned in Western U.S. wildfires has more than tripled since the 1970s on U.S. Forest Service Land.



**Figure 3.** Wildfires larger than 10,000 acres are about seven times more common now than they were 40 years ago on U.S. Forest Service Land..



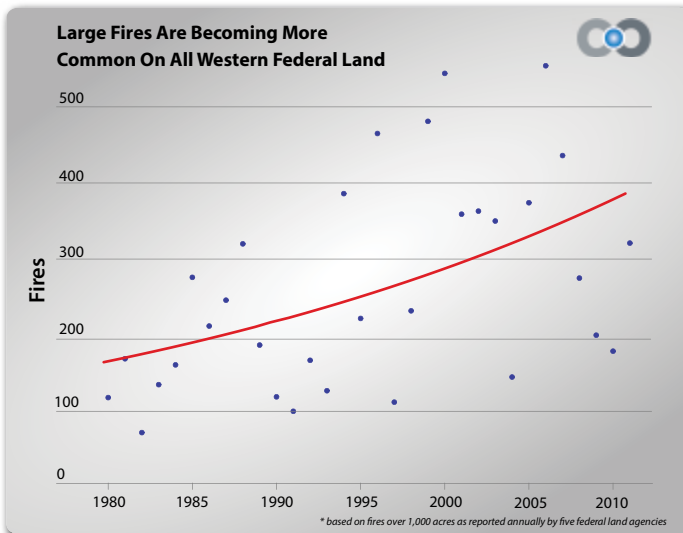
**Figure 4.** Wildfires larger than 25,000 acres are about five times more common now than they were 40 years ago on U.S. Forest Service Land.

Bureau of Land Management, the Fish and Wildlife Service, the National Park Service, and the Bureau of Indian Affairs, as well as the U.S. Forest Service. When all agency lands are considered, complete and reliable records are limited to a 32-year time span. Nevertheless, the larger data set shows trends comparable to those from the 42 years of USFS data.

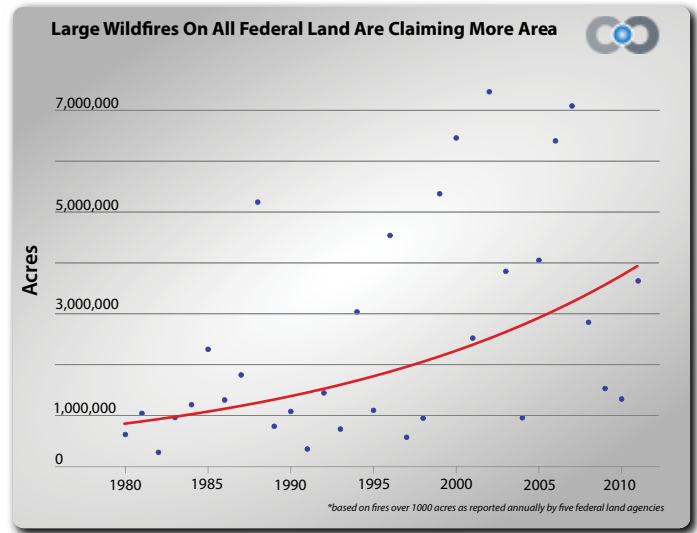
Between 1980-2011, the average annual number of fires has more than doubled on all federal land (Figure 5) and the total area burned in a typical year has more than tripled (Figure 6) to more than 3 million acres. Since 2000, there have been four years where more than 6 million acres burned on federal lands in the West, whereas the 20 years prior to that saw only two years where total burn area exceeded 4 million acres.

While there is a lot of variability from year to year, and there are (and will continue to be) years with small numbers of damaging wildfires, the long-term trend demonstrates that the average year now has twice as many large fires — that collectively burn hundreds of thousands of acres — than 40 years ago, and the likelihood of a particularly devastating fire year is growing rapidly.

Among the Western States, Arizona, California, Colorado, Idaho and Montana have seen the most dramatic increases in wildfires since 1970 (Figure 7). According to our analysis, the average annual number of large fires has nearly quadrupled in Arizona and Idaho, and at least doubled in California, Colorado, Montana, New Mexico, Nevada, Oregon, Utah, and Wyoming. On the other hand, the frequency of fires in Washington has remained steady.

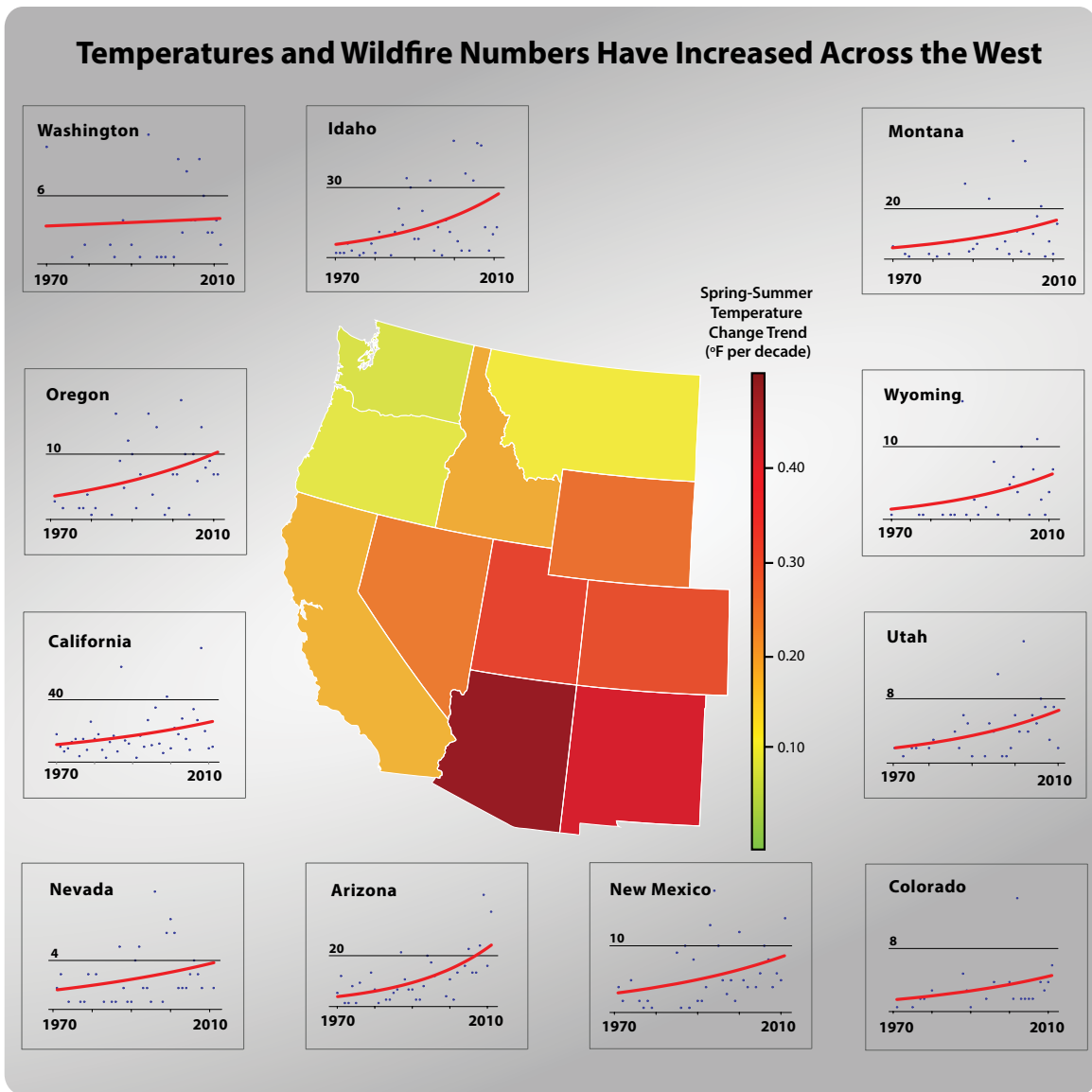


**Figure 5.** On all federal lands in the West, the annual number of large wildfires has increased in the past 30 years



**Figure 6.** On all federal lands in the West, the area claimed each year by large wildfires has increased in the past 30 years.

## Temperatures and Wildfire Numbers Have Increased Across the West



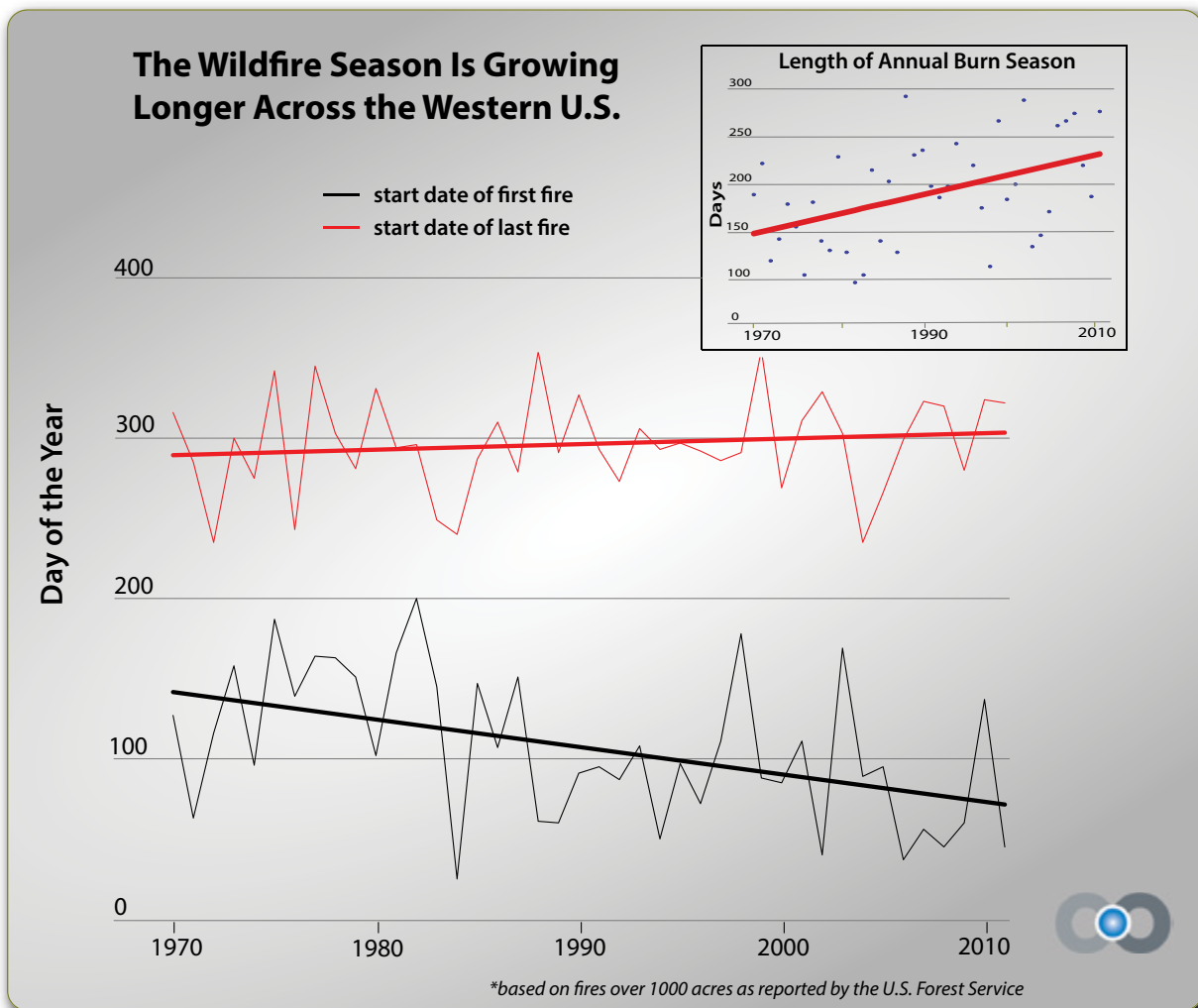
**Figure 7.** Across the West, the annual number of large wildfires has increased over the past 42 years, though to varying degrees. For full-size graphs of each state, see the Appendix.

## Fire Season Is Getting Longer

During the past 40 years, wildfires have started earlier in the year and have continued to burn later in the year, lengthening the overall “burn season.” Figure 8 illustrates the start date of the first wildfire each year on USFS land and the start date of the last recorded fire. The inset shows how the average time span between these two dates has increased by about 75 days since 1970.

This analysis adds to an existing body of research that analyzed changes in Western wildfire trends up until 2003. Anthony Westerling of the University of California at Merced and colleagues have previously shown that in the mid-1980s, trends in large wildfires (more than 1,000 acres) changed suddenly and markedly; fires began burning more frequently, raged over larger areas, lasted longer, and the overall length of the wildfire season increased dramatically.<sup>3</sup> With our additional consideration of more recent years, up to and including 2011, it is clear that the trend toward more and bigger fires is continuing.





**Figure 8.** Across the West, the first wildfires of the year are starting earlier and the last fires are starting later than they were 40 years ago, which has extended the average wildfire season by about 75 days.

## Climatic Factors in Western Wildfire Trends

### Increasing Temperatures

When we compared the average annual spring and summer (March-August) temperatures to the number of large wildfires burning across all 11 Western states, we observed a relationship similar to that reported by Westerling et al.;<sup>3</sup> years with higher-than-average spring and summer temperatures also tended to be years with more large fires (Figure 9).

Seasonal temperatures are a key determinant of annual wildfire risk. Long stretches of warm weather in the spring and summer dry trees and

brush, making them both easier to ignite and more likely to burn. Additionally, warmer spring temperatures can cause mountain snowpack to melt earlier and, when followed by a hot summer that keeps moisture out of the ground, these higher temperatures create ideal conditions for big fires. Westerling et al. primarily attributed the changes he observed in wildfires to warming spring and summer temperatures and earlier melting of snowpacks in Western mountain ranges.<sup>3</sup>

Average annual temperatures across the contiguous U.S. have warmed about 1.3°F in the past 100 years, but warming has been even higher in the West, rising 1.8°F over that same time period.

Increasing spring and summer temperatures across Western states since 1970 have been

particularly dramatic (Figure 7). Spring has warmed approximately 1.9°F and summer has warmed about 1.6°F, with the Southwestern states of Arizona, Colorado, New Mexico and Utah seeing some of the fastest rising spring and summer temperature trends (Table 1).

In recent years, researchers have begun to investigate how human-induced climate change has influenced wildfires.<sup>4</sup> The warming across North America over the second half of the 20th century has been attributed, in part, to rising concentrations of greenhouse gases in the atmosphere.<sup>5,6,7</sup> At the regional level, however, the precise degree to which human activity has influenced the increase in spring and summer temperatures is unknown. While Westerling<sup>3</sup> and others<sup>8</sup> have shown a strong correlation between these rising temperatures and increasing wildfire activity, there are other natural

and human factors that likely play an important role in these observed changes in wildfires trends.

### Earlier Snowpack Melt

Across the mountainous and forested regions of the West, spring snowpack and the timing of its melt have a strong influence on wildfire susceptibility. Below-average snowpack means there is less water available in the ground and streams in the hotter months. And when the snow begins to melt earlier, dictated by warm spring temperatures, the forests will remain drier for longer spans of the year. Once snowmelt is complete, the forests can become combustible within just one month.<sup>9</sup>

According to the U.S. Geological Survey, snowpacks across most of the West are now

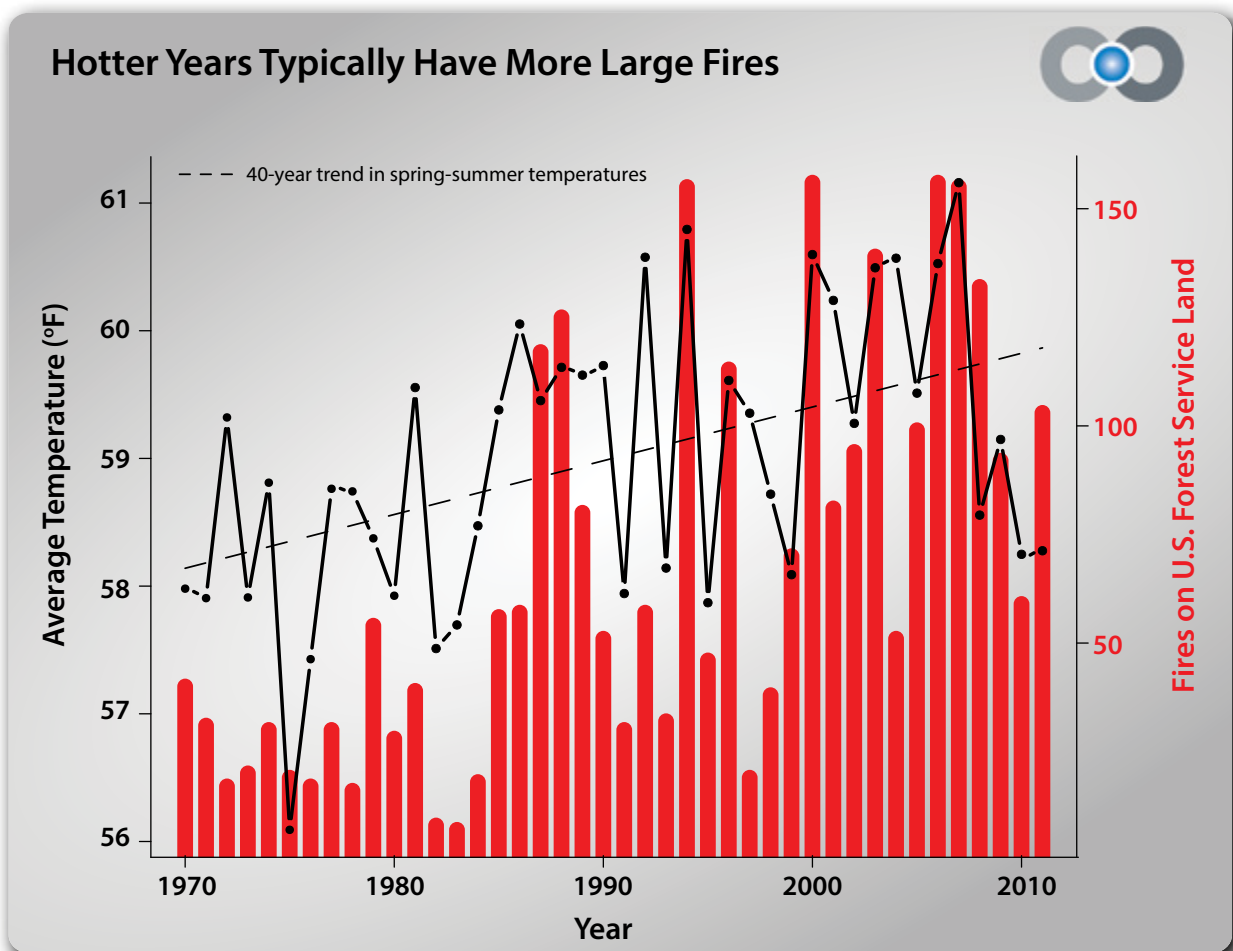
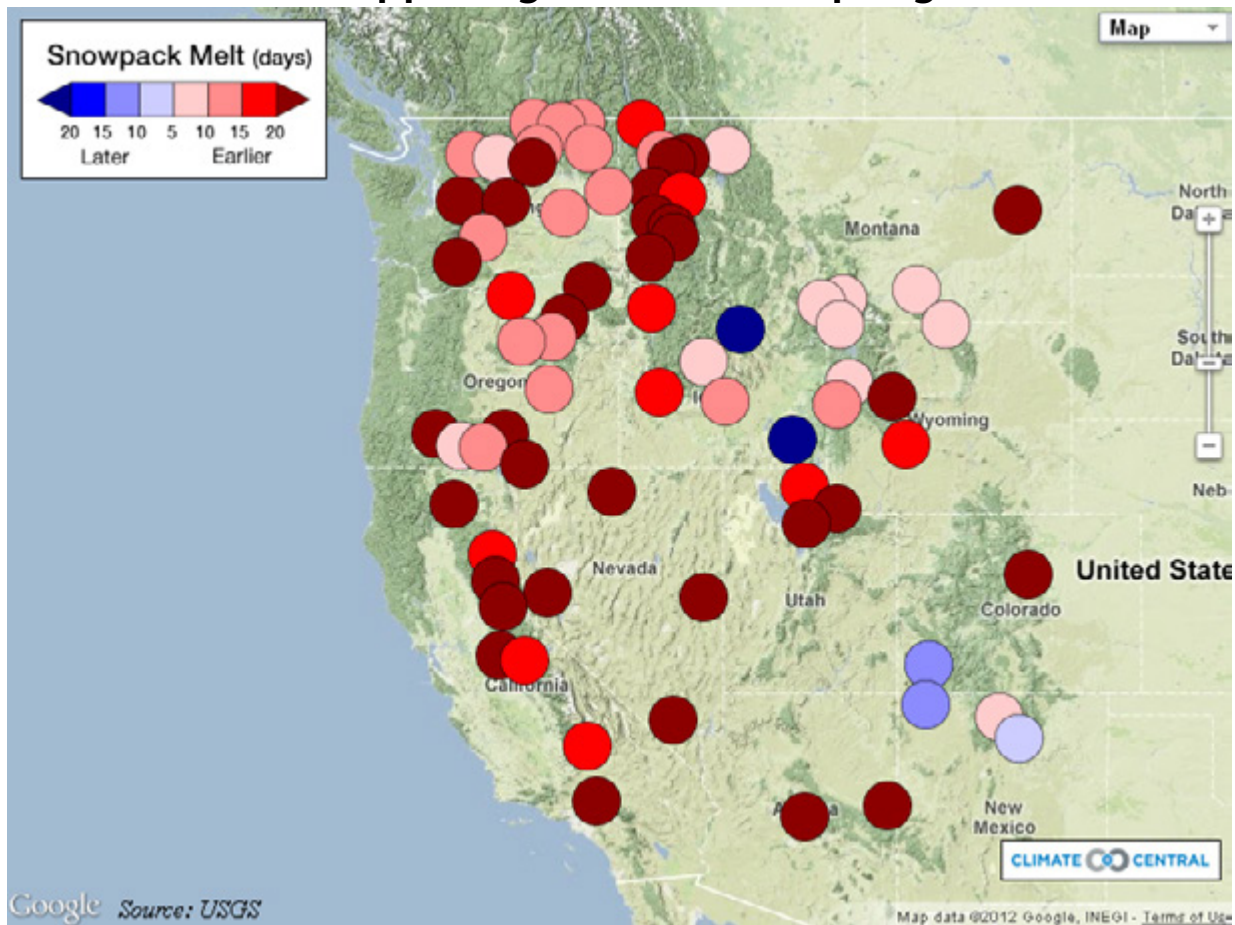


Figure 9. Average annual temperatures overlaid with number of fires.

**Table 1.** Spring (March, April and May) and summer (June, July, August) temperatures have been warming in all western states, but changes are happening faster in the Southwest and Southern Rocky Mountain States.

Temperature Change Trend (°F per decade) 1970 - 2011				
Rank	State	Spring	Summer	Spring-Summer
1	Arizona	0.892	0.583	0.466
2	New Mexico	0.769	0.675	0.385
3	Utah	0.665	0.588	0.332
4	Colorado	0.632	0.408	0.316
5	Wyoming	0.509	0.368	0.255
6	Nevada	0.485	0.475	0.242
7	Idaho	0.366	0.347	0.183
8	California	0.346	0.308	0.173
9	Montana	0.206	0.089	0.103
10	Oregon	0.193	0.295	0.097
11	Washington	0.163	0.163	0.082

## Snowmelt is Happening Earlier in the Spring in the West



**Figure 10.** Spring snowpack melt is happening earlier across the Western U.S. than it did 50 years ago. Adapted from USGS (2005).  
Western Wildfires | 7

melting 1-4 weeks earlier than they did just 50 years ago (Figure 10), and streamflows are also peaking earlier in the year.<sup>10</sup>

While we have not specifically tracked the correlation between annual wildfire behavior and the timing of snowpack melt, Westerling et al. showed that between 1970-2003, years with early snowmelt corresponded to years with much higher wildfire frequency.<sup>3</sup> This influence was particularly prevalent at higher elevations, in forested regions between 1700-2600m, and in the Northern Rockies specifically.

Recent research has shown that up to 60 percent of the observed changes in the hydrology of the West — including these trends in snowpack and melt — that have taken place since the last half of the 20<sup>th</sup> century can be attributed to human caused climate change.<sup>11</sup>

## Other Factors Influencing Western Wildfire Trends

### ***Natural Climate Variability***

While there is a high-level of confidence amongst scientists in attributing much of the recent warming trend globally to human activity, natural climate variability also plays a role, particularly at the regional scale of the Western U.S. Drought levels from year-to-year can influence fire patterns for several seasons.<sup>8,12</sup> Additionally, natural oscillations, such as El Niño, the Pacific Decadal Oscillation and others, have an important influence on climate variability, particularly in the Western U.S. The extent to which global warming will alter these large-scale natural patterns is an active area of research.

### ***Insects and Pests***

The spread of bark beetles and similar pests across mountain forests of the West have been rapid and devastating in the past few decades. Warmer

winters have allowed more insects to survive through the cold seasons and hotter summers have, in some cases, accelerated the insect's life cycle. Together, these higher temperatures have fostered a growing infestation and to date nearly 11 million acres of Western U.S. forest have been overwhelmed by bark beetles, spruce beetles, pine beetles and budworms. Researchers project that as the planet warms, the outbreak and spread of these insects will increase.<sup>13</sup>

The spread of these pests across the West is also a potential driver in wildfire activity.<sup>14</sup> As more trees die upon beetle infestation, there is more woody debris left on the forest floor, which means that there is more fuel available for burning in the short term. Recent research has shown, however, that over the long term, forests destroyed by beetle infestation may not be any more likely to burn than healthy forests.<sup>15</sup>

### ***Natural and Human Factors***

From year to year, the size and frequency of wildfires changes and natural variations in the climate have always been important drivers of changing fire trends.<sup>16</sup> Tree ring and sediment data have painted hundreds of years of fire history in the West and shown that fires have typically been worse during warm and dry periods, and less extensive during cooler, wetter times. Conversely, research has also shown that during the early 20<sup>th</sup> century, fire activity was lower than would be expected for the warmer and drier climate experienced (compared to the previous 3000 years).

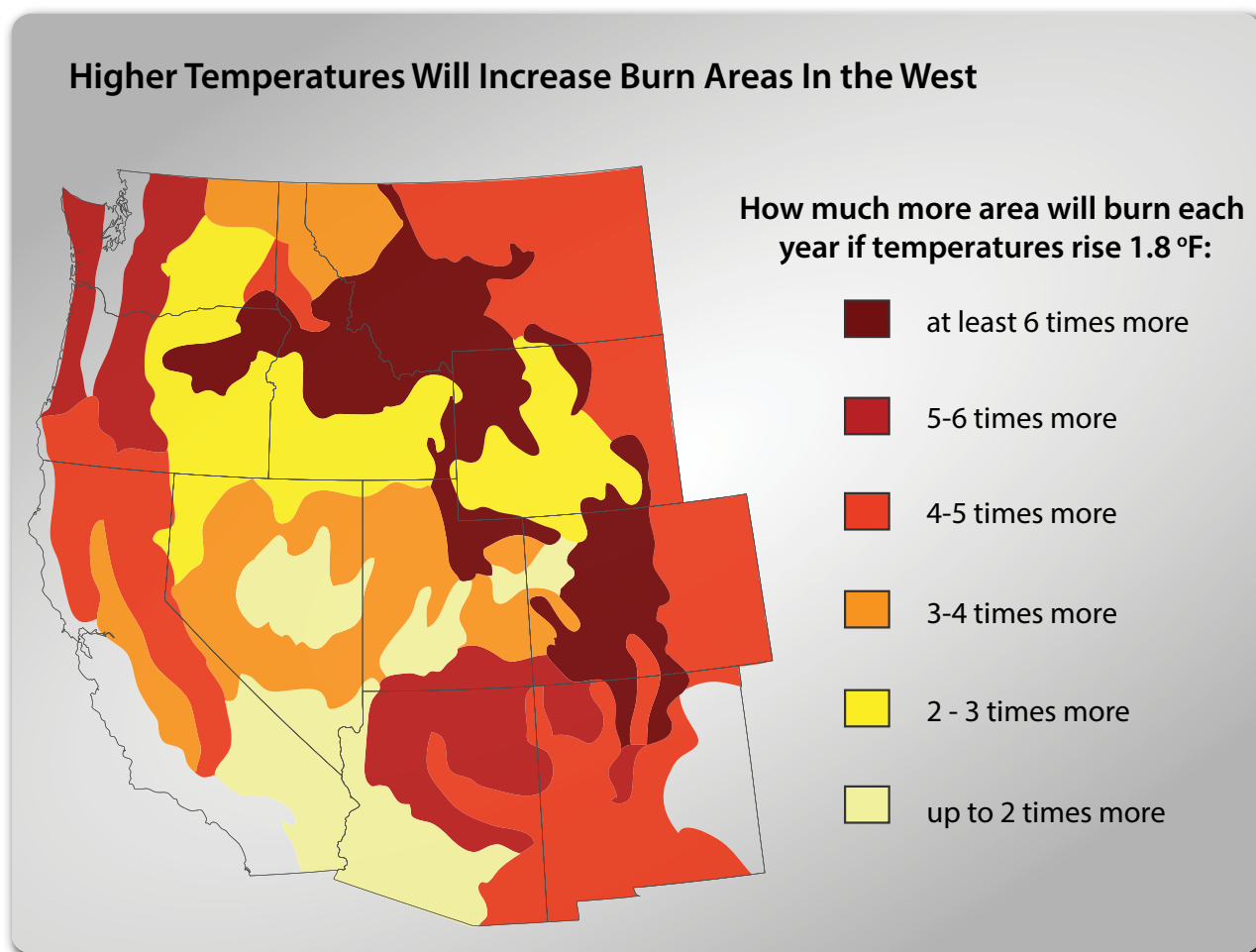
Human behavior has undoubtedly had an influence on this lower fire activity. Logging in some parts of the West have simply reduced the amount of forested area available to burn and livestock grazing has cut down on the grasses that might otherwise ignite and burn. And when fires have started, humans have tended to fight them vigorously to prevent home and property damage. Some researchers suggest, however, that recent wildfire activity may have naturally increased in response to this "fire-deficit;" decades of reduced fire activity may have left the forests of the West particularly vulnerable to big fires.<sup>16</sup>

## The Future of Western Wildfires

Given the connection between wildfire trends and climatic factors such as temperatures and seasonal snowpack, it's not surprising that scientists project that fires will increase in the coming decades. If atmospheric greenhouse gas concentrations continue to increase globally, climate models predict the Western U.S. will get even hotter and drier by the end of this century. According to the United Nations Intergovernmental Panel on Climate Change (IPCC) 4<sup>th</sup> Assessment Report, summer temperatures could increase

between 3.6-9°F in western North America by the middle of this century.<sup>17</sup> And as winter conditions turn to spring earlier in the year, the fire season will also continue to grow longer.

A recent report from the National Research Council also reports that for every degree Celsius (1.8°F) of temperature increase, the amount of area burned each year in the Western U.S. could quadruple (Figure 11).<sup>17</sup> Even with remaining uncertainty of how precipitation trends will change in the West, climate and wildfire research clearly show that more and bigger fires will become the norm as the climate continues to change.<sup>15,18,19</sup>



**Figure 11.** A 1.8°F rise in temperature is projected to dramatically increase the area burned each year by wildfires, in some regions by as much as five or six times. Adapted from the National Research Council's *Climate Stabilization Targets* report (2009).

# Methodology

Wildfire data was accessed from the Federal Wildland Fire Database, provided by the U.S. Geological Survey (ranging from 1980-2011) and from a federal land wildfire database compiled by the Desert Research Institute (from 1970-2006). Both databases draw on wildfire data reported by five federal agencies: U.S. Forest Service, Bureau of Land Management, Bureau of Indian Affairs, National Park Service, and Fish and Wildlife Services. Only fire data from Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming were analyzed.

For analyses that span 1970-2011, only U.S. Forest Service (USFS) data was employed, as these records are the most complete and consistent over this period of time. Data from all sources was processed to delete duplicate fire entries. Prior to combining data from the different databases, we conducted an internal review of data quality, testing years where both databases overlay (1980-2006). For USFS data, there was less than 1 percent discrepancy in the 2,737 large reported during that 26-year period.

For the analyses that span 1980-2011, fires reported by all five federal agencies were included (and thus only data from the U.S. Geological Survey's database was used).

Analyses of "large fires" reported here are restricted to fires over 1,000 acres in size. As described by Westerling et al.,<sup>3</sup> these large fires represent less than 1 percent of reported wildfires

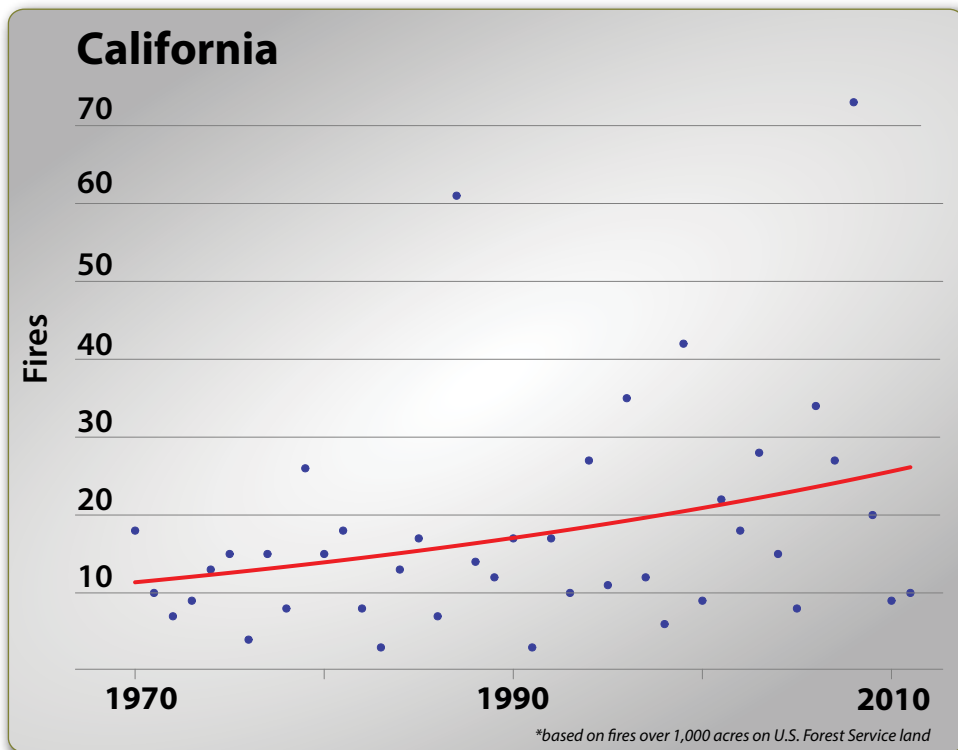
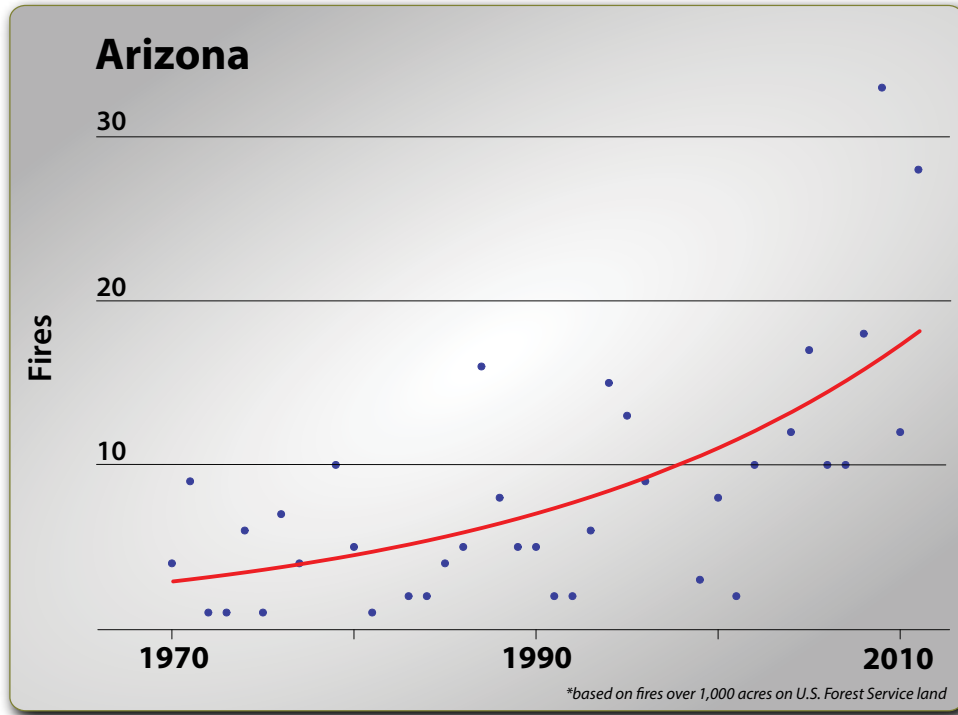
but they represent more than 70 percent of the total area burned. In other words, these are truly the most damaging fires, and are likely to be the ones more heavily influenced by climatic factors. In addition, the land management units from which we drew our data contain more than 60 percent of the forested land in America's West. To consider "very large" fires, we restricted fires to those over 10,000 or 25,000 acres.

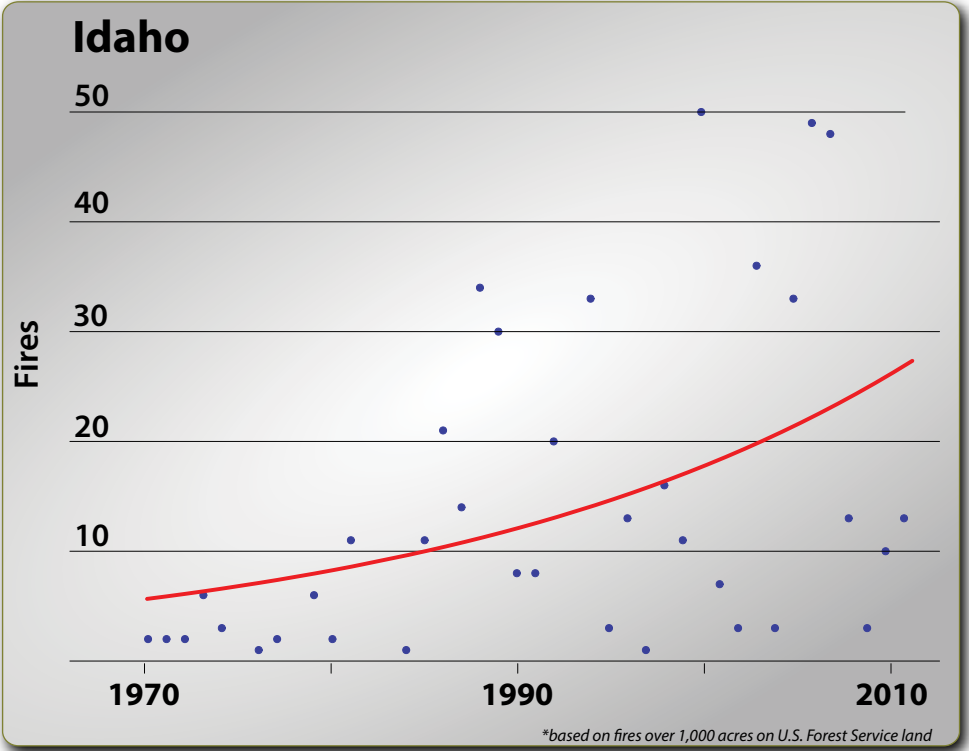
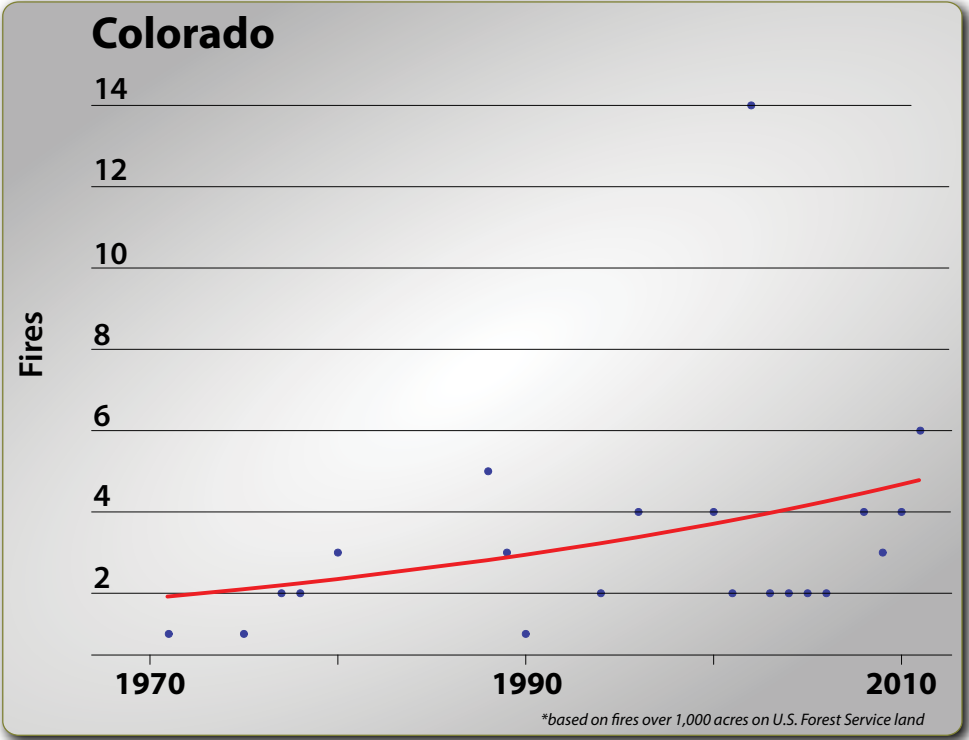
The trend lines in the plots presenting number of fires and acres burnt have been estimated by a linear regression between year and the logarithm of the numbers on the y-axis, or through a so-called Poisson regression, hence the upward curvature of the line (which would appear straight if the y-axis reported the logarithm of the respective quantities). This methodology is known to be appropriate in the case of values spanning a large range of orders of magnitude (as is the case for number of acres burnt), or representing counts (as is the case for number of fires). The methodology also takes into account the obvious increase in the variability of the yearly values in step with their average magnitude.

Average annual spring and summer temperature data was calculated from temperature records from stations that make up the United States Historical Climatological Network (USHCN), restricted to the 11 Western states listed above. These stations are maintained by the National Climatic Data Center. These records were also used to evaluate the temperature change trends between 1970-2011.

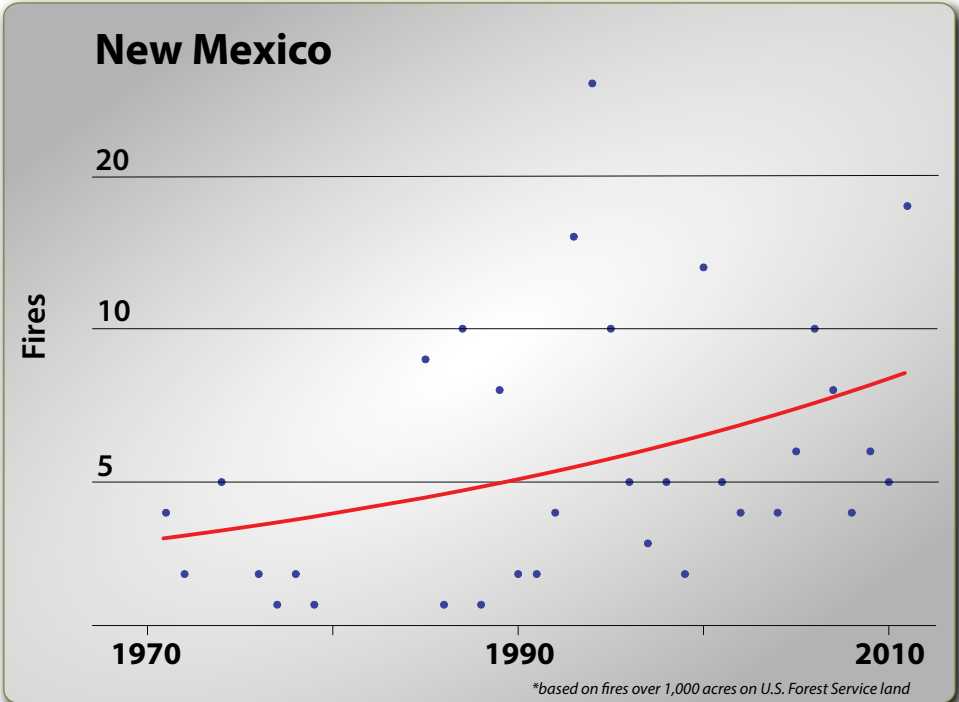
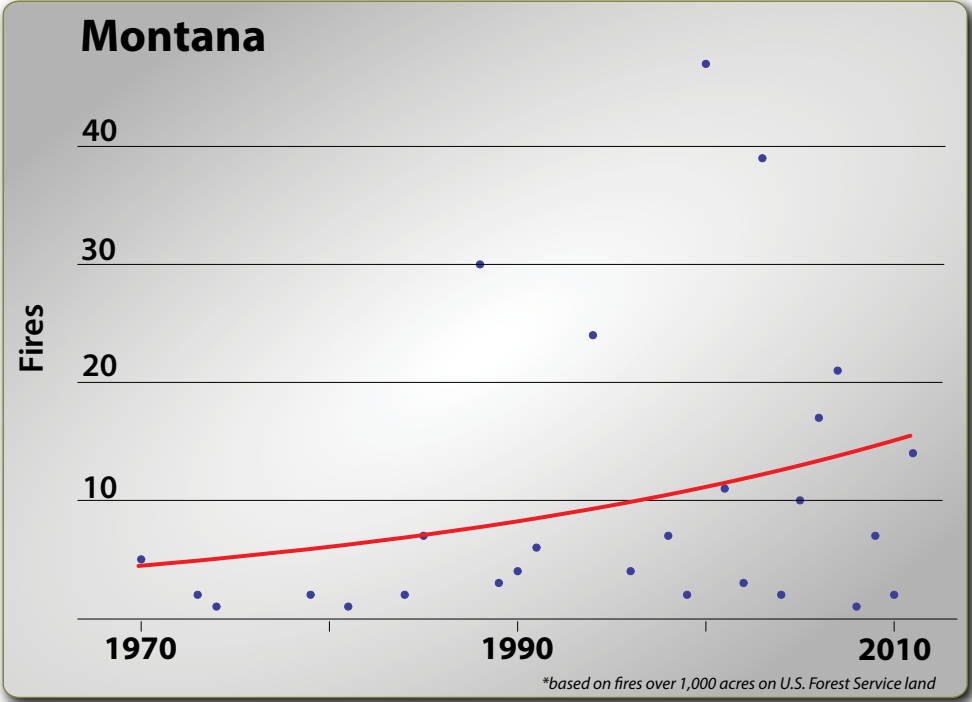
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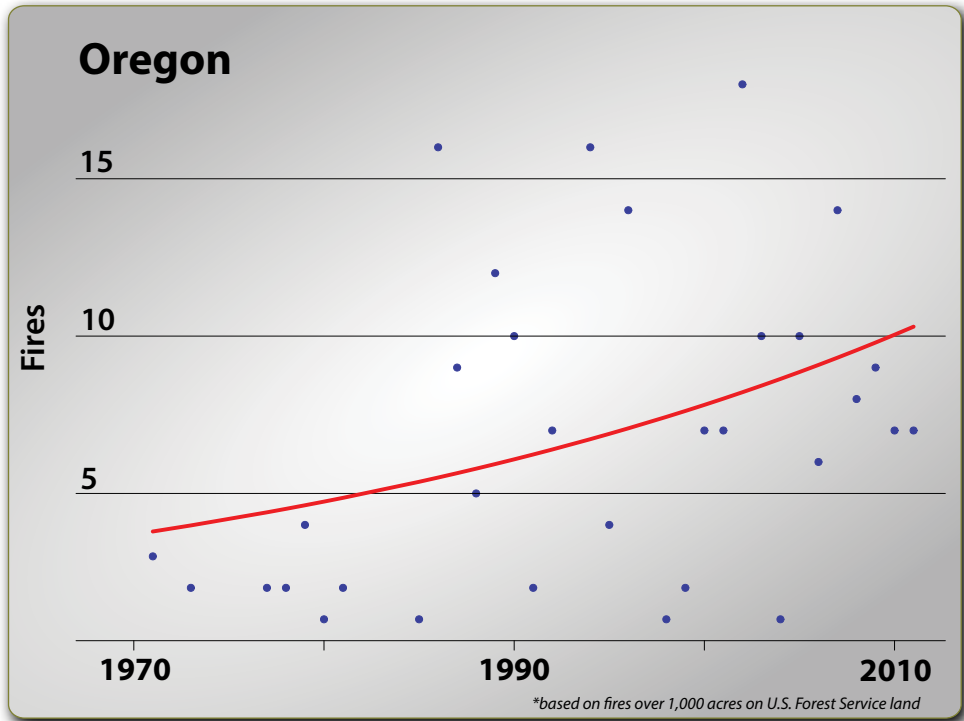
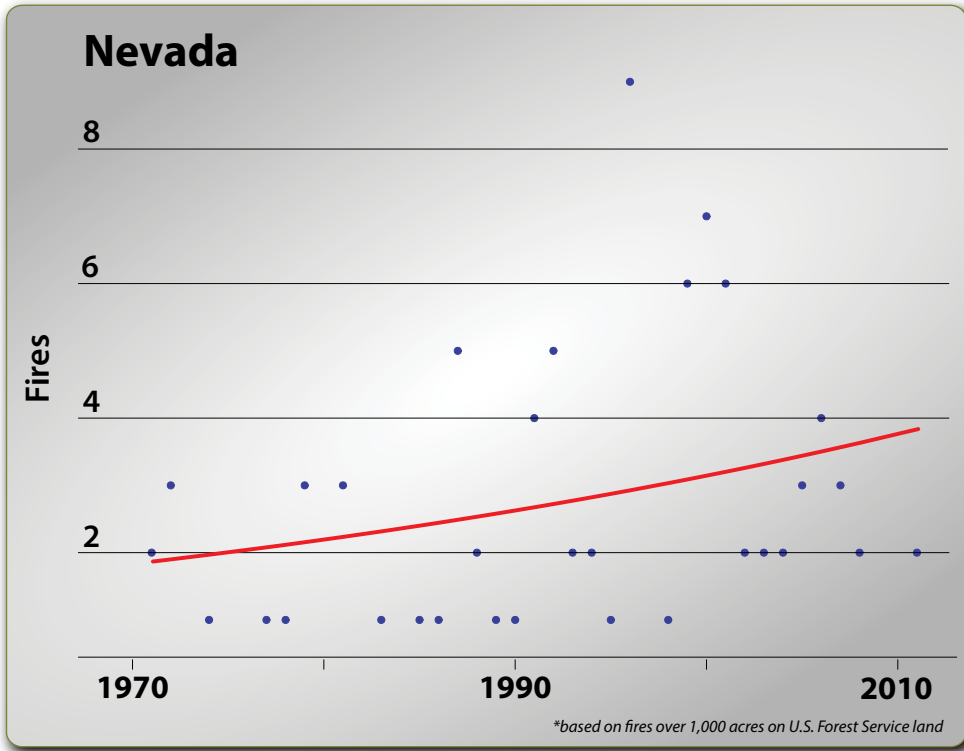
## Individual State Graphs

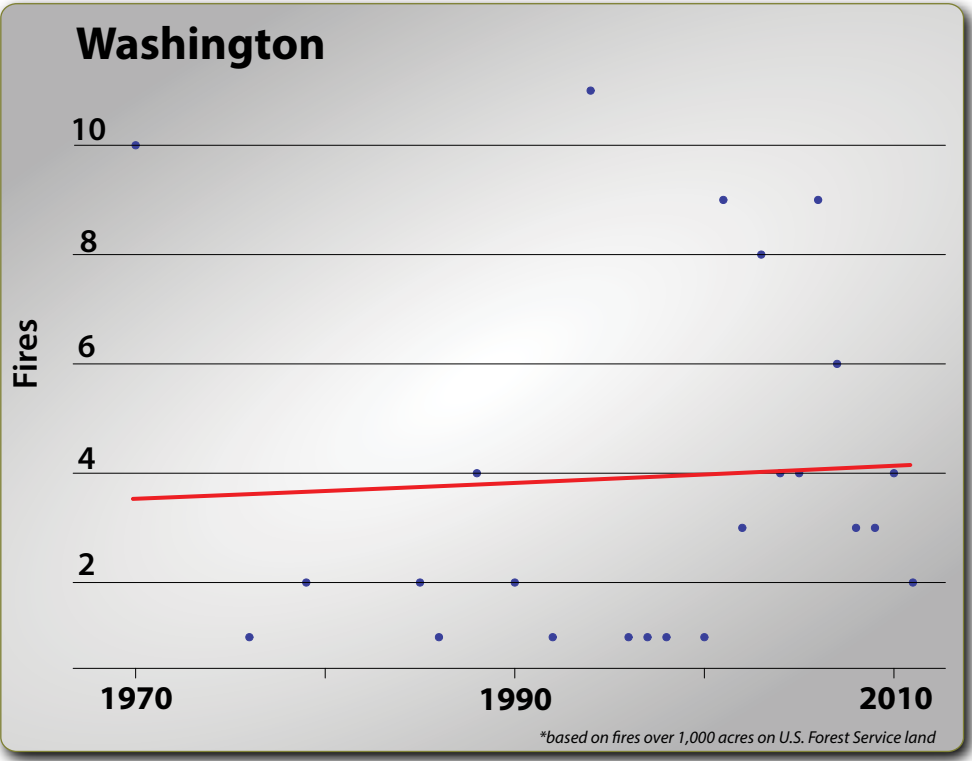
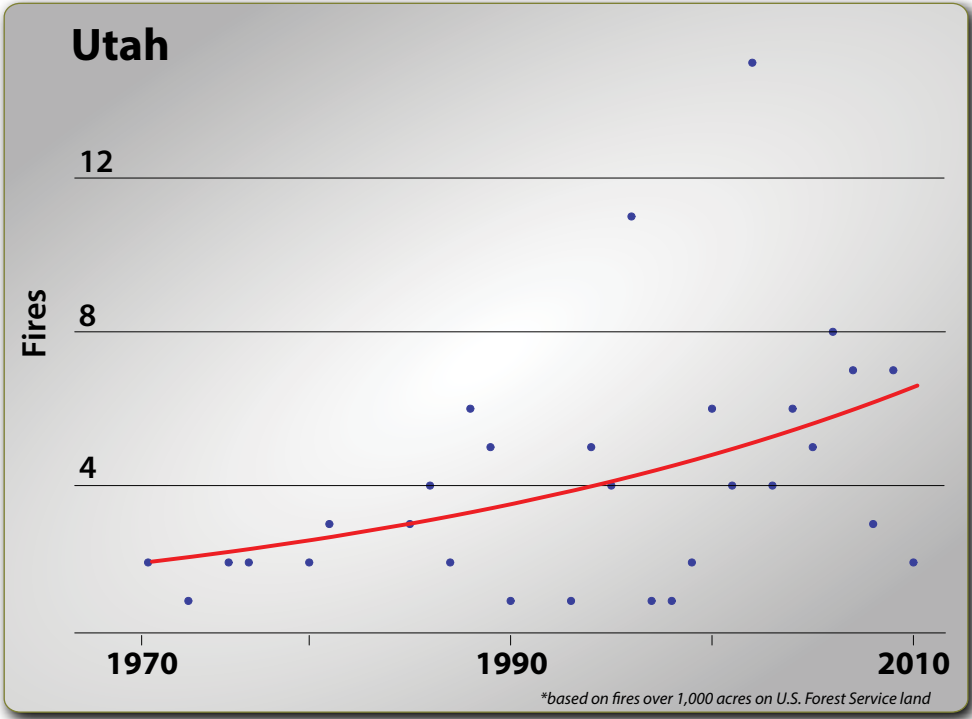




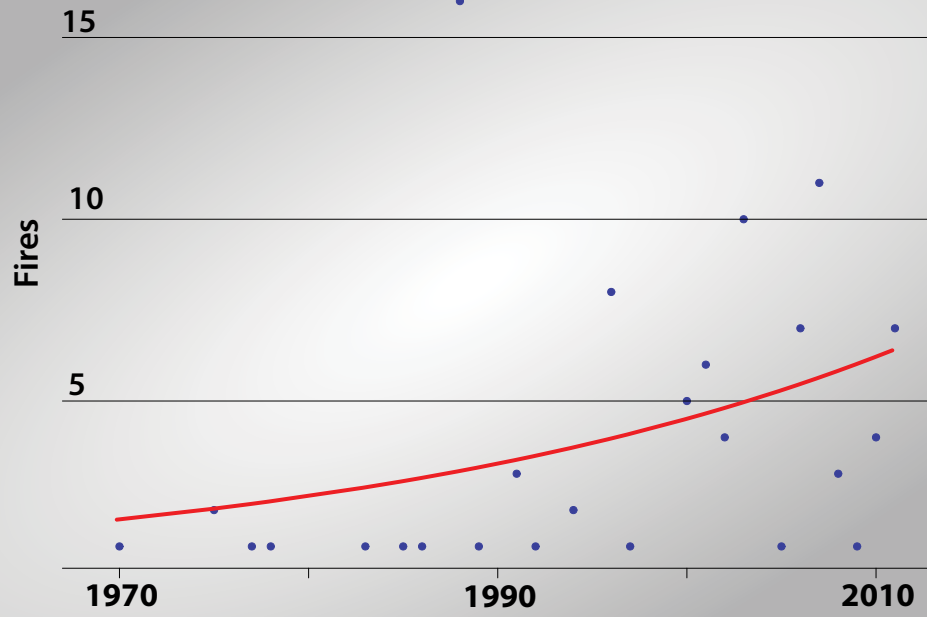








# Wyoming



*\*based on fires over 1,000 acres on U.S. Forest Service land*

# References

- (1) In order to have as long and as consistent a data set as possible for large Western wildfires, we limited our initial analysis to fires documented by the U.S. Forest Service between 1970-2011. See Methodology section for more on this rationale, a description of our selected data and the conditions of analysis.
- (2) The U.S. Geological Survey provides a consistent source of USFS and DOI fire data range that ranges only from 1980-2011 (and does not extend back to 1970). You can access this data set at <http://wildfire.cr.usgs.gov/firehistory/data.html>.
- (3) Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam, **2006**: Warming and Earlier Spring Increases Western U.S. Forest Wildfire Activity. *Science*. 313: 940-943.
- (4) To date the only study that shows a connection between human-induced climate change and increased wildfire burn area is limited to the forests of Canada. See, Gillett, N.P., A.J. Weaver, F.W. Zwiers, and M.D. Flannigan, **2004**: Detecting the effect of climate change on Canadian forest fires. *Geophys. Res. Lett.* 31: L18211.
- (5) Karoly, D.J., K. Braganza, P.A. Stott, J.M. Arblaster, G.A. Meehl, A.J. Broccoli and K.W. Dixon, **2003**. Detection of a Human Influence on North American Climate. *Science*. 302:1200-1203.
- (6) Zwiers, F.W. and X.Zhang, **2003**: Toward Regional-Scale Climate Change Detection. *J. Climate*. 16: 793-797.
- (7) Stott, P.A., **2003**: Attribution of regional-scale temperature changes to anthropogenic and natural causes. *Geophys. Res. Lett.* 30: 1728.
- (8) Littell, J.S., D. McKenzie, D.L. Peterson, and A.L. Westerling, **2009**: Climate and wildfire area burned in western U.S. ecoprovince, 1916-2003. *Ecological Applications*. 19: 1003-1021.
- (9) Running, S., **2006**: Is Global Warming Causing More, Larger Wildfires? *Science*. 313:927-928.
- (10) Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier, **2005**: Declining mountain snowpack in western North America. *Bulletin of the American Meteorological Society*. 86: 39-49.
- (11) Barnett, T.P., D.W. Pierce, H.G. Hidalgo, C. Bonfils, B.D. Santer, T. Das, G. Bala, A.W. Wood, T. Nozawa, A.A. Mirin, D.R. Cayan, and M.D. Dettinger, **2008**: Human-Induced Changes in the Hydrology of the Western United States. *Science*. 319: 1080-1083.
- (12) Westerling, A.L., A. Gershunov, T.J. Brown, D.R. Cayan, and M.D. Dettinger, **2003**: Climate and Wildfire in the Western United States. *Bulletin of the American Meteorological Society*. 84:595-604.
- (13) Global Climate Change Impacts in the United States. **2009**. Karl, T.R., J.M. Melillo, and T.C. Peterson (eds). New York: Cambridge University Press.
- (14) Hicke, J.A., M.C. Johnson, L.H.D. Jane, and H.K. Preisler, **2012**: Effects of bark beetle cause tree mortality on wildfire. *Forest Ecology and Management*. 271: 81-90.
- (15) Simard, M., W. H. Romme, J.M. Griffin, and M.G. Turner, **2011**: Do mountain pine beetle outbreaks change the probability of active crown fire in lodgepole pine forests? *Ecological Monographs*. 81: 3-24.

- (16) Marlon, J.R., P.J. Bartlein, D.G. Gavin, C.J. Long, R.S. Anderson, C.E. Briles, K.J. Brown, D. Colombaroli, D.J. Hallett, M.J. Power, E.A. Scharf, and M.K. Walsh, **2012**: Long-term perspective on wildfires in the western U.S.A. *Proc. Natl. Acad. Sci.* Published online, February 14, 2012.
- (17) Intergovernmental Panel on Climate Change, **2007**: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.). New York: Cambridge University Press.
- (18) National Research Council, **2011**: Climate Stabilization Targets: Emissions, Concentrations, and Impacts Over Decades to Millenia. Washington, D.C.: National Academies Press.
- (19) Westerling, A.L., and B.P. Bryant, **2008**: Climate change and wildfire in California. *Climatic Change*. 87: S231-S249.



## **Princeton**

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