Global Warming and Future Fire Regimes

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Summary
Climate and weather have long been noted as playing key roles in promoting wildfires. Global warming is generally expected to exacerbate fire problems. After reviewing the scientific studies of fire-climate relationships, the following conclusions can be drawn. 1) Annual temperature is a crude predictor of ecosystem responses since many processes respond to specific seasonal temperature signals. For example, on landscapes where past climate signals are correlated with fire activity, winter and autumn temperatures are generally irrelevant, but spring and summer temperatures play an important role. 2) Annual fire activity in California has been strongly influenced by climate only in the mid- to higher-elevation forests. However, in lower elevations throughout the state, but most particularly in southern California, fires in shrublands and grasslands have not been strongly correlated with annual variations in temperature during any season. 3) Past fire activity has been strongly influenced by land use activities (e.g., suppression of natural fires or human ignitions) and the impacts have been radically different in the northern and southern parts of the state. These two very different landscapes need to be viewed separately when planning future fire management practices. Global warming is occurring along with a number of other global changes that may have greater influences on future fire regimes, including population growth, changes in land management policy, shifts in vegetation types, and patterns of fire ignitions. All of these factors interact in complicated ways, making future forecasts a challenge.

Current realities
Temperature has always been a key factor in wildfire danger indices, and global warming predictions are a major concern. Historical analyses have shown that the *sine qua non* of a severe fire season in California forests is dry spring weather. It is now widely recognized that this relationship between climate and fire activity has important implications for climate change impacts on fire regimes of the future. However, it is important to recognize that temperature effects are seasonally dependent. Based on historical analysis of the last 100 years of fire records, it is apparent that warmer winters or warmer autumns have had no discernible effect on fire activity, whereas spring and summer temperatures do play a pivotal role. It cannot be stressed enough that this fire-climate relationship is largely restricted to montane coniferous forest ecosystems. Lower elevations and most elevations in the lower part of the state are generally less responsive to yearly changes in temperature. These latter landscapes appear to be more strongly affected by direct anthropogenic impacts, including timing and location of ignitions.

California covers a greater latitudinal range than any other western state and, as such, comprises a huge range of climates and very diverse fire regimes. In terms of California fire issues, the recent United States Forest Service (USFS) analysis illustrates two distinct regions within the state (Figure 1). Due to the success of a century of fire-suppression policy, forests in the Sierra Nevada and the northern portion of the state have experienced far fewer fires than historically recorded. In contrast, the nonforested landscapes in the southern part of the state, although managed with the same fire suppression policy, have not experienced a deficit of burning. This is in part due the difficulty of suppressing fires in chaparral-dominated landscapes coupled with the greater numbers of human-caused ignitions in this southern region.

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Scientific opportunities and challenges
Balancing fire hazard reduction and resource protection poses a major challenge in a state as diverse as California. This equation plays out very differently in northern versus southern ecosystems in the state. Most of California's forests have historically experienced frequent low-severity understory burning, and both understory herbaceous and shrubby species as well as overstory tree species are adapted to this fire regime. Managing these landscapes with frequent prescription burning has the potential for both reducing fire hazard and enhancing these resources

Research needs for forested landscapes include parsing out the effects of global warming in different seasons and developing models that equate temperature increases with expected fire activity. Because the effect of global warming may have multiple effects, including increases in the length of fire season as well as increasing fire frequency, this research can be complicated. A further complication is that as fire frequency increases, the current ecosystem may be set on a trajectory for a different vegetation type with different fire regime characteristics.

In the southern half of the state there is a need for a better understanding of other global change issues that will potentially have greater impacts than global warming. In particular, there is need for understanding how population growth and patterns of growth will impact future fire regimes, something that is particularly critical in light of the fact that human activity accounts for more than 95% of all fires. Issues in need of research are causes of ignitions and placement of prefire fuel treatments. On these southern California landscapes, humans dominate the ignitions and as ignitions have increased over the past century there has been a well-documented conversion from native shrublands to nonnative grasslands. These latter systems are much more flammable, increasing the length of the fire season and frequency of burning, which feeds back into even greater landscape conversion and resource degradation. Additional issues in need of research are ignition causes and placement of prefire fuel treatments.

Policy issues
The U.S. Geological Survey has been an active player in the development of wildland fire management policy. The Cohesive Strategy developed by federal agencies has focused on using sound scientific evidence when choosing among alternative management approaches.

On an annual basis, California wildfires are responsible for a small portion of the total acreage burned in the Western United States. However they consume the bulk of federal fire suppression dollars. This is largely due to the high population density of metropolitan areas juxtaposed with watersheds of dangerous chaparral fuels. Since the beginning of the 21st century California has averaged a loss of 1,000 homes a year from wildfires mostly in the southern half of the state.

- **Forested ecosystems.** These ecosystems have missed fires due to past fire-suppression policy (Figure 1) that has resulted in substantial increases in forest fuels threatening to change fire regimes to high-intensity crown fires. Forest restoration requires prescription burning or other fuel reduction tactics. One of the primary constraints on burning is air-quality, which applies to both allowing wildland fires to burn, as well as prescription burning. One solution to reducing surface fuels (e.g., leaves, small dead wood) and ladder fuels (e.g., young trees) could be mechanical treatments. Constraints on this approach are the greatly increased costs associated with mechanical treatments plus economic limitations to such tactics on National Park Service lands. Making these treatments pay for themselves through commercial contracts raises

serious issues about trees of value to be removed versus the impact on fire hazard. These are issues in need of serious discussion.

- **Nonforested ecosystems.** These landscapes comprise shrublands, which are the dominant plant community in southern California. Since the California State Legislature mandates a resource assessment of only timber and rangeland, these shrublands are perhaps not as well understood as is needed to assess their fire potential. On these landscapes the important global changes need to be viewed broadly to include more than climate change. Humans account for the vast majority of fires and human growth predictions are an order of magnitude greater than temperature warming in the coming decades.

  Critical concerns do not only involve increased anthropogenic ignitions, but the spatial distribution of ignitions as well. In the south, the majority of fires that become catastrophic are ones that ignite in the interior and are driven by desert-to-ocean offshore winds known as Santa Ana winds. The more that development expands to the interior landscapes, the more likely such fires will increase in size. A closer relationship between fire management practices and land planning decisions could have positive effects.

  Throughout the western U.S. there has been an inordinate concern on landscape-level fuel treatments for handling wildfire issues. In southern California this issue is doubtful because catastrophic fires are driven more by factors such as weather than the state of the vegetation. We currently lack clear evidence that landscape-level fuel treatments change fire outcomes, particularly with respect to property losses. The model that seems to have the most support is that of fire management focused on "the house out," which describes a concern on focusing fire hazard reduction at the house and Wildland Urban Interface (WUI) zone, and decreasing emphasis as one moves out on the landscape. Particularly in these nonforested landscapes, additional research is needed to determine the appropriate strategic placement of vegetation treatments.

  Other issues that need further discussion include the state-mandated "clearance" requirements. Total clearance is not required for defensible space and thus a change in terminology may enhance communication. Recognition that embers are a major source of home ignition points to the need for more research on specific changes in maintenance required to produce fire safe conditions. The role of evergreen trees as ember catchers needs further research as well.

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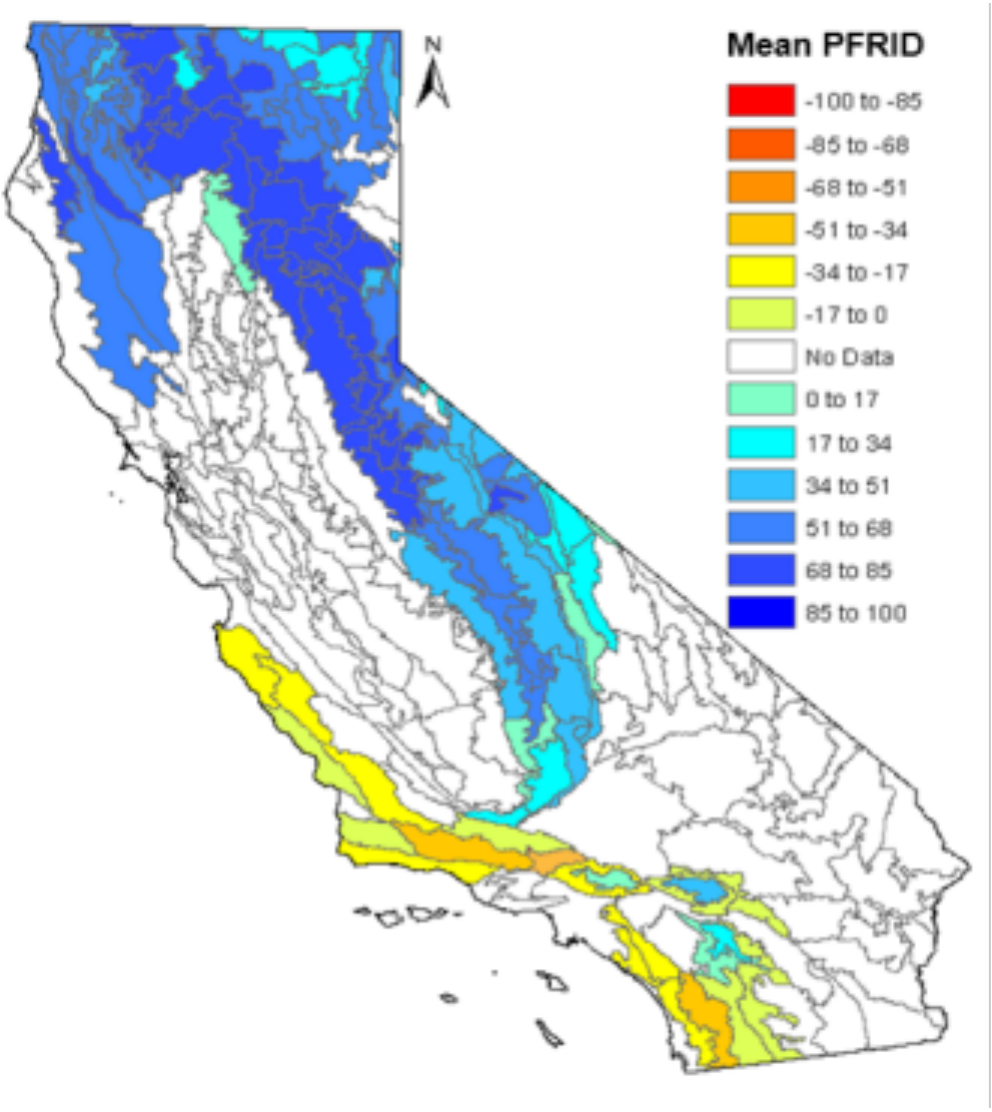
Figure 1



Fire departure map for USFS lands in California. Areas in blue indicate landscapes that, relative to historical fire regimes, have missed fires and are in need of prescription burning or other related vegetation treatments. Yellow and orange represent landscapes that, despite a century of fire suppression, have had more fire than historically was the case and 'restoring' fire is not needed (from Safford and van de waters 2014).