Changes in the Climate-Fire Relationship:
Patterns Locally and Around the Globe

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Key Findings

Study A

- Fuel aridity was in general strongly associated with forested ecoregions' burned area, and this relationship was even more pronounced in mesic ecoregions, like the forests of the western U.S., where moisture often limits flammability (Figure 1a).
- Contrastingly, precipitation preceding fire seasons by between 14 to 25 months was associated with burned area in non-forested semi-arid ecoregions (Figure 1c).
- Precipitation preceding fire seasons by between 2 and 13 months seemingly decreased burned area in tropical forests like those in Indonesia and Australia (Figure 1b).

Keywords. Time of emergence, fire weather, anthropogenic climate change, fire-weather index, climate-fire relationship, wildfire: fuel aridity, wildfire: forested burn area, fire effects

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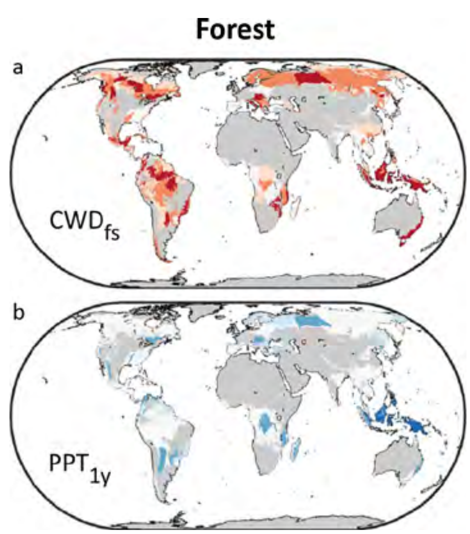
Wildfires are occurring more frequently and with greater severity domestically and around the globe. Across a series of studies, researchers at the University of Idaho set out to identify how and when climate variability affects wildfire frequency and behavior. They studied wildfire on scales ranging from local to ecoregional to global. In one study, researchers investigated the relationship between burn severity and climate across the globe based on prior observations (Study A, Abatzoglou et al. 2018). Similarly, researchers investigated the relationship between burn severity and climate based on prior observations, but this time with a focus on the western United States, where there has been an observed increase in catastrophic wildfires over recent years (Study B, Abatzoglou et al. 2017). In a related study, researchers trained their eyes on the future and the repercussions for fire weather globally as the climate continues to change (Study C, Abatzoglou et al. 2019).

Study A: How has the climate-fire relationship emerged across the globe?

The dynamic nature of weather and climate relative to other factors implies that atmospheric processes are the predominant drivers of variability in fire weather across Earth. Regional studies have shown that climate variability explains the majority of the interannual variability in burned area in some regions, but significantly less in others. So researchers set out to better understand the extent to which climate variability really affects interannual variability in burned areas globally. Specifically, researchers examined the strength and direction of relationships between interannual variability in burned area and climate at ecoregional scales across the globe for forested and non-forested areas. They explored how such relationships vary across gradients of climate, productivity, anthropogenic land use, and tree density. Additionally, researchers asked how much of the interannual variability in fire activity globally over the last two decades was shaped by climate variability.

Researchers analyzed patterns in burned area using a dataset that provides estimates of global fire activity from 1997 through 2016 by combining calibrated active fire counts for the 1997–2000 period with burned area detections from 2000 onwards. They found that climate variability explained around one-third of interannual variations in burned area across ecoregions. As well as highlighting regions in which climate variability enhances fire activity, these results can also help identify regions where climate variability and other influences may facilitate weaker relationships between anthropogenic climate change and wildfire.



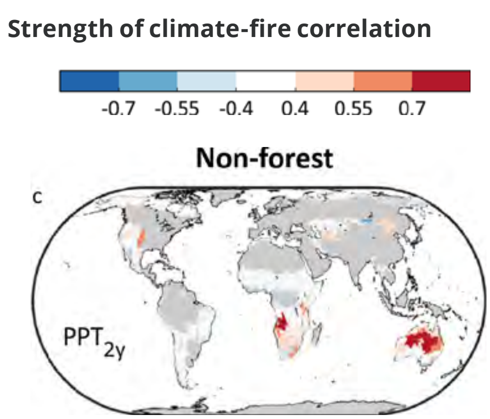


Figure 1. Climate-fire relationships across the globe. The maps show the strength of the correlation (ranging from -1 for a perfect negative correlation to 1 for a perfect positive correlation) between annual burned area and various climatic measures. (a) CWD_{fs}, the climatic water deficit over the fire season (a measure of fuel aridity), was strongly related to burned area in forested ecoregions. (b) PPT_{2y}, the accumulated precipitation ending 14 months prior to the fire season, was strongly related to burned area in non-forested ecoregions. (c) PPT_{1y}, the 12-month accumulated precipitation ending 2 months prior to the fire season, contributed to decreased burned area in tropical forests such as those in Indonesia and Australia. Panels extracted from Figure 2 in Abatzoglou et al. (2018), with permission from John Wiley & Sons Ltd obtained via RightsLink©.

Key Findings

Study B

- Increased burn severity and increased annual burned area at the ecoprovince level were associated with increased fuel aridity.
- No single climate variable was a universally strong predictor of burn severity across ecoprovinces. But longer-term drought severity throughout the fire season was associated with burn severity. Multiyear drought stress also showed some evidence of enhancing burn severity and the proportion of area burned at high severity in the Great Basin.
- More mesic portions of the western U.S. may become more flammable and burn during fire seasons with unusually high fuel aridity.

Study C

- The emergence of fire weather conditions in excess of natural variability is already underway for significant portions of the globe, including southern Europe and the Amazon, while the emergence of these conditions is delayed for much of North America (Figure 2).
- Fire weather conditions are set to exceed natural variability in the first half of the 21st century in many regions, affecting 33-66% of burnable lands globally by mid-century.
- Models project an average of three times the baseline Fire Weather Index for western North America by the end of this century, pointing to significant increases in the risk of wildfire in this region.
- Emergence of extreme fire weather conditions is twice as widespread across the globe when global mean temperature surpasses preindustrial levels by 3°C (an increase of 5.4°F) compared to an increase of 2°C (3.6°F).

Study B: Fuel aridity is likely to increase wildfire risk in the western United States

Researchers analyzed interannual variability in burn severity across forested ecoregions of the western United States, specifically. Their results support some of the findings of the global analyses and suggest that, regardless of other factors, long-term increases in fuel aridity—as expected given the researchers' modeling of future fire weather—will likely lead to increasingly severe wildfires in western U.S. forests.

Study C: Future climate and fire weather on a global scale

Researchers used 17 climate models to evaluate when and where across the globe anthropogenic climate change could lead to fire weather conditions that exceed current natural variability. Measuring changes in fire weather through the Fire Weather Index, researchers found extreme fire weather conditions are set to become more widespread over the coming century. Although their study did not model fire activity, their findings suggest that rising global temperatures will cause weather conditions that enhance the risk of wildfire in regions where vegetation abundance and ignitions are not limiting.

Anthropogenic Climate Change: Time of Emergence

Researchers employed the attribution framework of the time of emergence (ToE) of anthropogenic climate change. ToE is defined when a signal forced by anthropogenic climate change (e.g., mean temperature, sea-level rise, precipitation, etc.) exceeds some measure of the internal climate variability that occurs naturally, in the absence of anthropogenic climate forcings. ToE quantifies the time period when this emergence happens or is expected to happen.

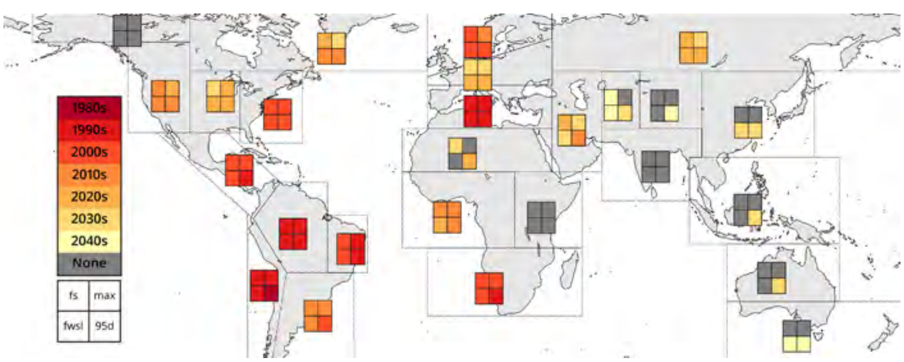


Figure 2. Time of emergence (ToE) of the anthropogenic climate change signal from background natural variability for regions across the globe. The four quadrants show the ToE for four different measures of fire weather: peak 90-day fire weather index (FWIfs; top left quadrant), annual maximum fire weather index (FWImax; top right quadrant), the frequency of FWI extremes (FWI95d; bottom right quadrant), and the length of the fire weather season (FWIfwsl; bottom left quadrant).Light black lines show the geographic delineation of the regions. The lack of regional emergence before 2050 is denoted by dark gray. Results are based on a time series of regional fire weather index metrics from 1861–2100, projected using 17 different global climate models. Figure extracted from Figure 3 in Abatzoglou et al. (2019), with permission from the American Geophysical Union obtained via RightsLink©.

Management Implications

These studies highlight the urgent need to prepare for and adapt to changes in fire disturbances and hazards, both on a global scale and on a local scale. Prolonged drought that persists into the arid fire seasons increases the chances and extent of wildfire in regions such as the western U.S. However, fire suppression, conversion to agricultural lands, greater land fragmentation, and landscapes where intentional burning occurs sometimes reduces the influence of climate change on fire activity. Paradoxically, fire suppression in regions where fuels are more available may amplify the climate-fire relationship as suppression activities may be successful when fire risk is moderate, thereby allowing large wildfires to preferentially occur with unusually arid fuel and fire weather conditions.

Currently, increased fire weather and emergence of climate-forced signals, such as mean temperature increases, are being observed in the western U.S. and across the planet. In the future, such fire weather is likely to further enhance fire activity in flammability-limited regions. This risks potentially overwhelming regional and national resources available for suppression activities, thereby decreasing suppression efficacy for new ignitions. This may require reallocating funds meant for preventative maintenance to fire suppression efforts. While the occurrence of global fire weather might be enhanced by anthropogenic climate change in the near future, fire conditions can seemingly be attenuated by public and policy efforts to keep mean global temperature increases below 2°C (3.6°F) above the natural variability in climate. If, however, temperatures are forced above 3°C (5.4°F) above natural climate variability, the relationship between wildfire and global mean temperatures will likely strengthen, increasing fire risk around the world.

Foundational Publications

Abatzoglou, J. T., Kolden, C., Williams, A. P., Lutz, J. A. & Smith, A. M. (2017). *Climatic influences on interannual variability in regional burn severity across western US forests.* International Journal of Wildland Fire, 26, 269–275. http://dx.doi.org/10.1071/WF16165

Abatzoglou, J. T., Williams, A. P., Boschetti, L. & Kolden, C. (2018). *Global pattern of interannual climate-fire relationships.* Global Change Biology, 24, 5164–5175. https://doi.org/10.1111/gcb.14405

Abatzoglou, J. T., Williams, A. P., & Barbero, R. (2019). *Global emergence of anthropogenic climate change in fire weather indices.* Geophysical Research Letters, 46, 326–336. https://doi.org/10.1029/2018GL080959