Resilience and sensitivity of high-severity fire regimes to climatic variability from centuries to millennia

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Climate Change and Wildfires

Continued warming could transform Greater Yellowstone fire regimes by mid-21st century

Anthony L. Westerling¹, Monica G. Turner¹, Erica A. H. Smithwick², William H. Romme³, and Michael G. Ryan⁴

The Telegraph

Australian bushfires: Nearly 100 dead in deadliest ever blaze

Australia's worst ever bushfires have left at least 100 people dead and hundreds homeless as blazes continue to rage amid fears the death-toll could rise even further.

Fire in the Earth System


Fire is a worldwide phenomenon that appears in the geological record soon after the appearance of terrestrial plants. Fire influences global ecosystem patterns and processes, including vegetation

The wildfire factor

David Schimel and David Baker

Events such as wildfires, occurring on a tiny area of the globe, can have a huge impact on the global carbon cycle. This much is plain from investigation of the terrible fires that afflicted Indonesia five years ago.

Implementation of National Fire Plan treatments near the wildland–urban interface in the western United States

Tania Schoennagel¹, Cara R. Nelson³, David M. Theobald⁴, Gunnar C. Carnwth⁵, and Teresa B. Chapman⁶
Climate Change and Wildfires

Recent burning of boreal forests exceeds fire regime limits of the past 10,000 years

Ryan Kelly\textsuperscript{a}, Melissa L. Chipman\textsuperscript{b}, Philip E. Higuera\textsuperscript{c}, Ivanka Stefanova\textsuperscript{d}, Linda B. Brubaker\textsuperscript{e}, and Feng Sheng Hu\textsuperscript{a,b,1}

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Long-term perspective on wildfires in the western USA

Jennifer R. Marlon\textsuperscript{a,1}, Patrick J. Bartlein\textsuperscript{b}, Daniel G. Gavin\textsuperscript{b}, Colin J. Long\textsuperscript{b}, R. Scott Anderson\textsuperscript{d}, Christy E. Briles\textsuperscript{c}, Kendrick J. Brown\textsuperscript{f}, Daniele Colombo\textsuperscript{g}, Douglas J. Hallett\textsuperscript{h}, Mitchell J. Power\textsuperscript{i}, Elizabeth A. Scharl\textsuperscript{j}, and Megan K. Walsh\textsuperscript{k}

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Resilience and regime change in a southern Rocky Mountain ecosystem during the past 7,000 years

T. A. Minckley\textsuperscript{1,4}, R. K. Shriner\textsuperscript{1,5} and B. Shuman\textsuperscript{2,3}

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Vegetation mediated the impacts of postglacial climate change on fire regimes in the south-central Brooks Range, Alaska

Philip E. Higuera\textsuperscript{1,2}, Linda B. Brubaker\textsuperscript{1}, Patricia M. Anderson\textsuperscript{2}, Feng Sheng Hu\textsuperscript{3} and Thomas A. Brown\textsuperscript{4}

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Drivers and Interactions

Climate

Vegetation

Fire Regime

Moisture avail.

Biome, stand level

Stand-replacing
Consequences

Moisture avail.

Climate

Vegetation

Biome, stand level

Stand-replacing

Fire Regime
When do we see changing fire regimes in the past?

1. Reconstructing the past

2. Examples of sensitivity and resilience; inferred mechanisms

“…ability of [a] system to absorb changes of…driving variables…and still persist.”

Holling (1973)
Fire history from continuous sediment records

Theoretical / modeling:

\[ C_{\text{air}} = f(d) \]

\[ C_{\text{lake}} = f(C_{\text{air}}, \text{slope wash}) \]

\[ C_{\text{core}} = f(C_{\text{lake}}, \text{redeposition, mixing}) \]

Empirical tests:

Higuera et al. 2007, 2013
Peters and Higuera, 2007

Kelly et al. 2013 PNAS
When do we see changing fire regimes in the past?

1. ...when climate change directly influences fuel moisture

2. ...when millennial-scale climate change results in vegetation shifts that change flammability
1. Increased burning with post-glacial warming

*Sensitivity at multi-millennial time scales

1. Increased burning with post-glacial warming

Climate → Fire → Veg. Regime

Charcoal accumulation (z-score) vs. Mean annual temperature (z-score)

Generalized additive model
Temp. explains ≈ 56% of var.

Daniau et al. 2012, Global Biogeochemical Cycles
2. Increased burning with boreal forest development

Higuera et al. 2009, Ecological Monographs
Brubaker et al. 2009, Ecology
2. Increased burning with boreal forest development

*Sensitivity at multi-millennial time scales*
2. Increased burning with boreal forest development

*Vegetation mediated impacts of climatic change

Climate

Veg. → Fire Regime

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2. Increased burning with boreal forest development

*Relatively stable mean fire return intervals, at 2000-yr scale*
Recent burning of boreal forests exceeds fire regime limits of the past 10,000 years

Ryan Kelly\textsuperscript{a}, Melissa L. Chipman\textsuperscript{b}, Philip E. Higuera\textsuperscript{c}, Ivanka Stefanova\textsuperscript{d}, Linda B. Brubaker\textsuperscript{e}, and Feng Sheng Hu\textsuperscript{a,b,1}
3. Sensitivity to centennial-scale climate variability

*Increased fire severity during MCA

*Biomass burned sensitive to climate variability

*Fire frequency non-varying [except recent decades]

Kelly et al. 2013, PNAS
3. Fire-vegetation-fire feedbacks

*Increased deciduous species limited fire frequency

Johnstone et al. (2010)
# Mechanisms for climate impacts on fire regimes

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Summary

**Lessons from PaleoEcology**

1. Paleo records illustrate both resilience and sensitivity to climate change

2. Direct climate impacts from centennial through millennial scales

3. Vegetation-mediated impacts from decadal through millennial scales, including feedbacks
Lessons from PaleoEcology

1. Paleo records illustrate both resilience and sensitivity to climate change

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