What paleofire records can say about the present and future of fire on Earth

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Insights from Paleofire Records

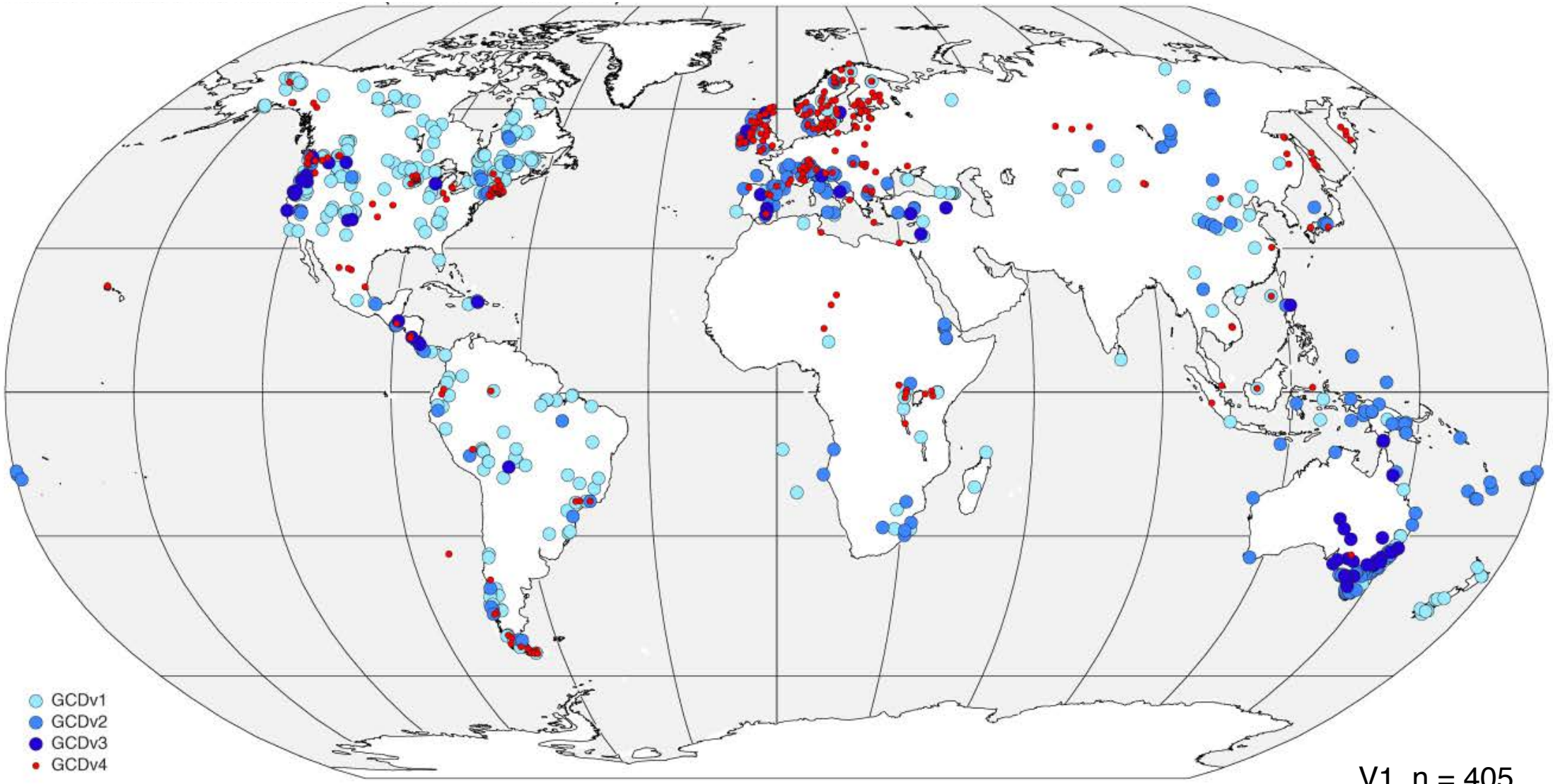
1) Fire regimes track climate changes.

2) “Slow” (interannual- to decadal-scale) socioecological processes essential for predicting the future of wildfire and carbon emissions.

3) Current fire regime changes are unprecedented.

4) Fire scientists have much to offer to improve public understanding of the connections between global warming and wildfire.

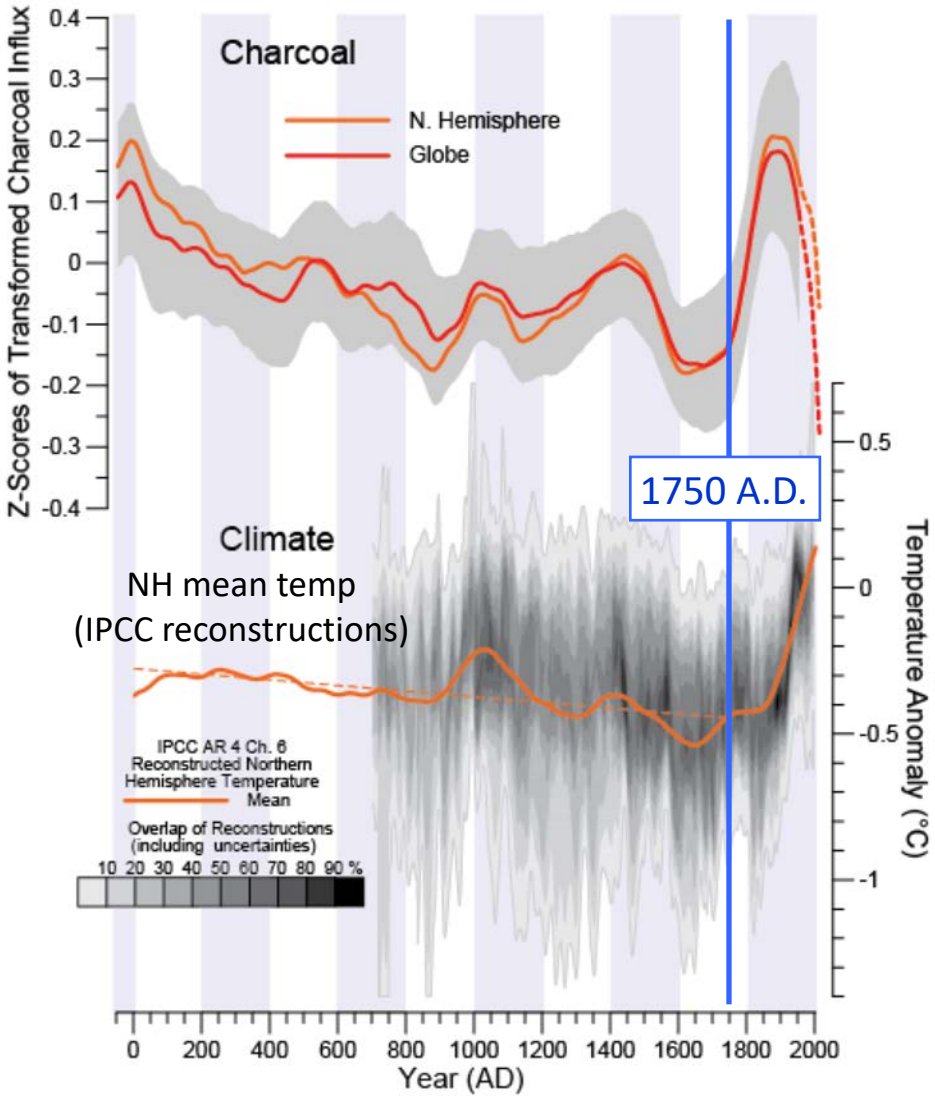
Global Charcoal Database

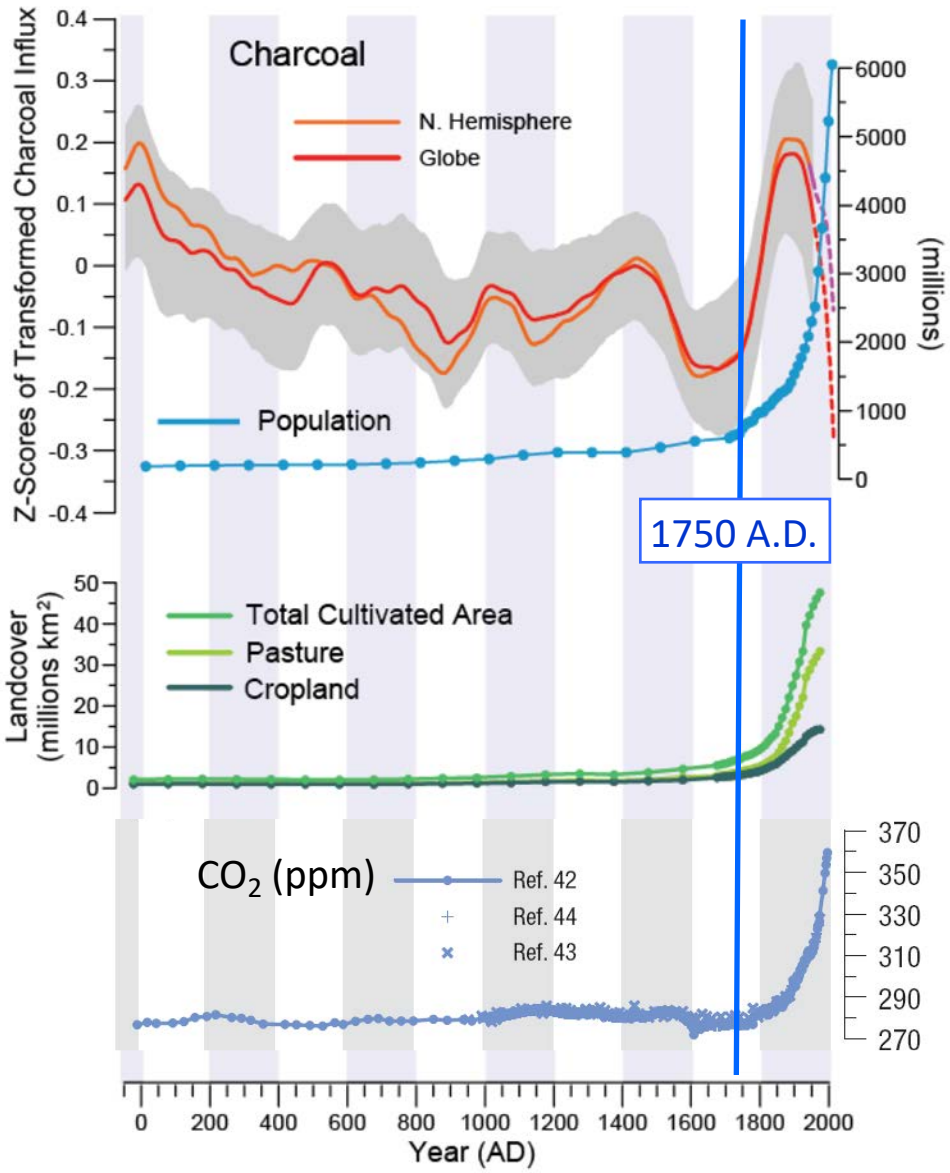


www.paleofire.org

V1, n = 405
V2, n = + 261 = 679
V3, n = + 68 = 734
V4, n = + ? = 1000+

GCDv1: NH biomass burning follows NH temperature until 1750 A.D.

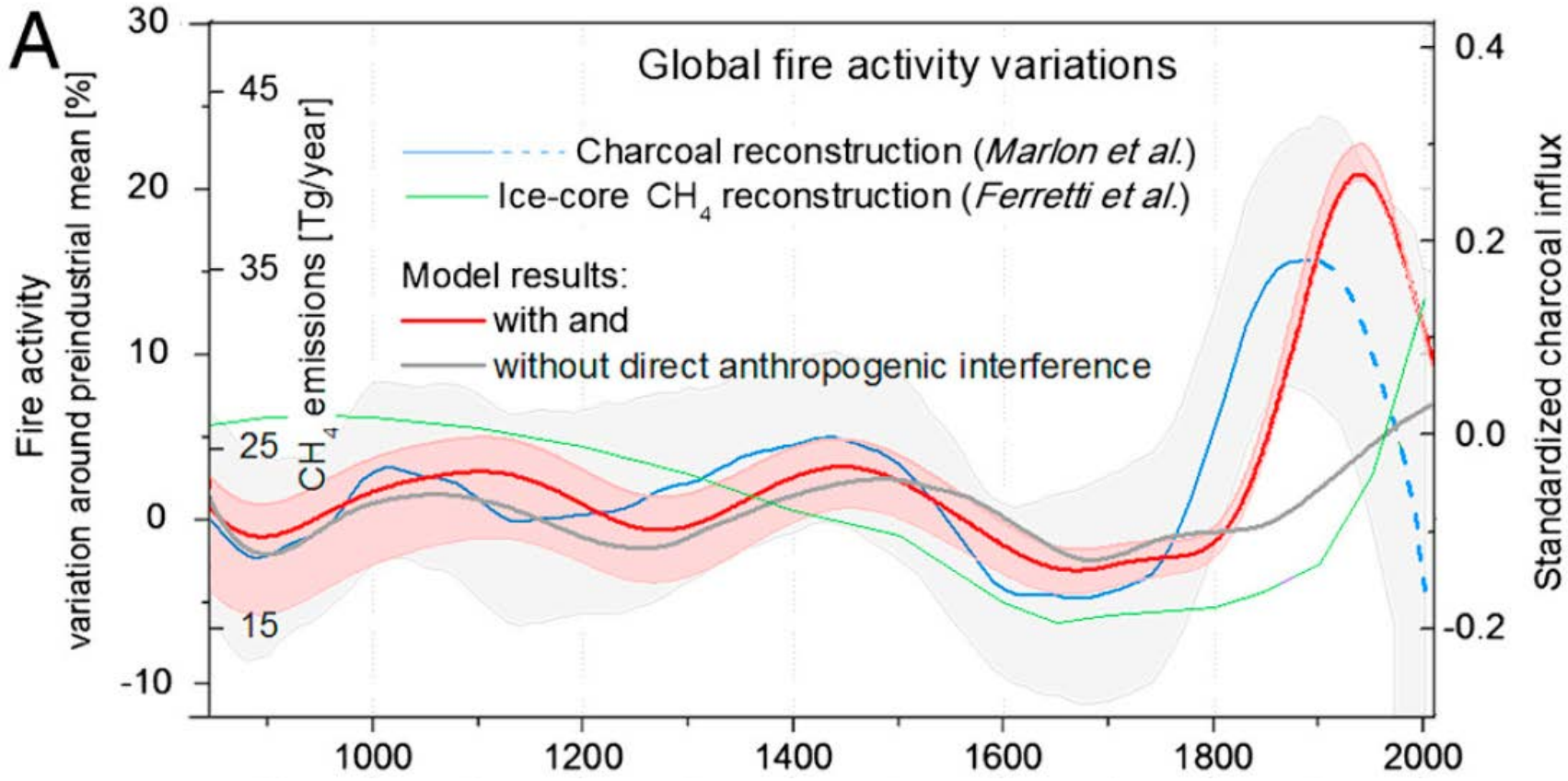




Marlon et al. 2008

Population & land-cover data: Goldewijk & van Drecht, 2006

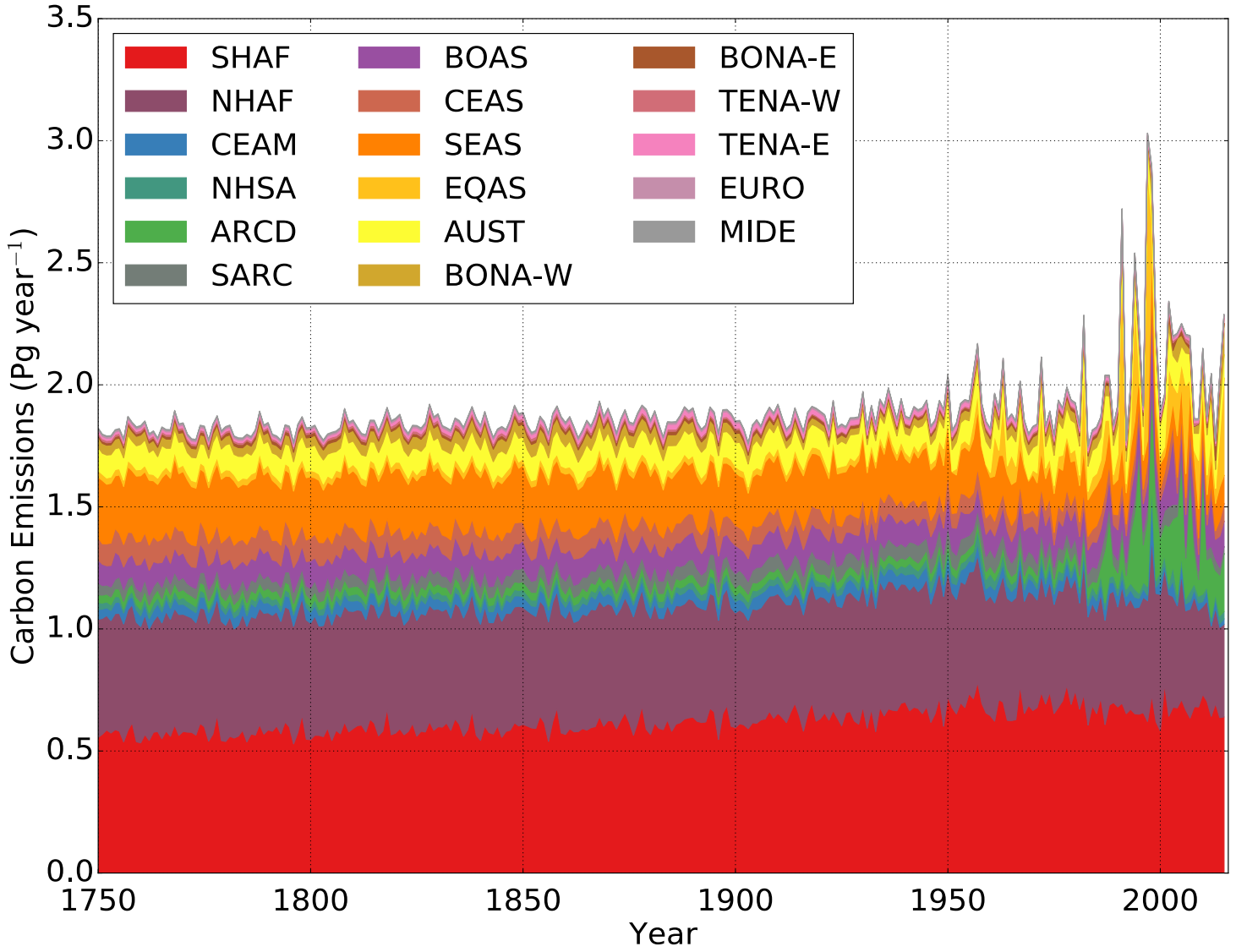
Early fire modeling showed the Industrial Era increase and decrease in global fire (validated by charcoal data in blue)



Simulated Fire Activity (AR4 GISS GCM)

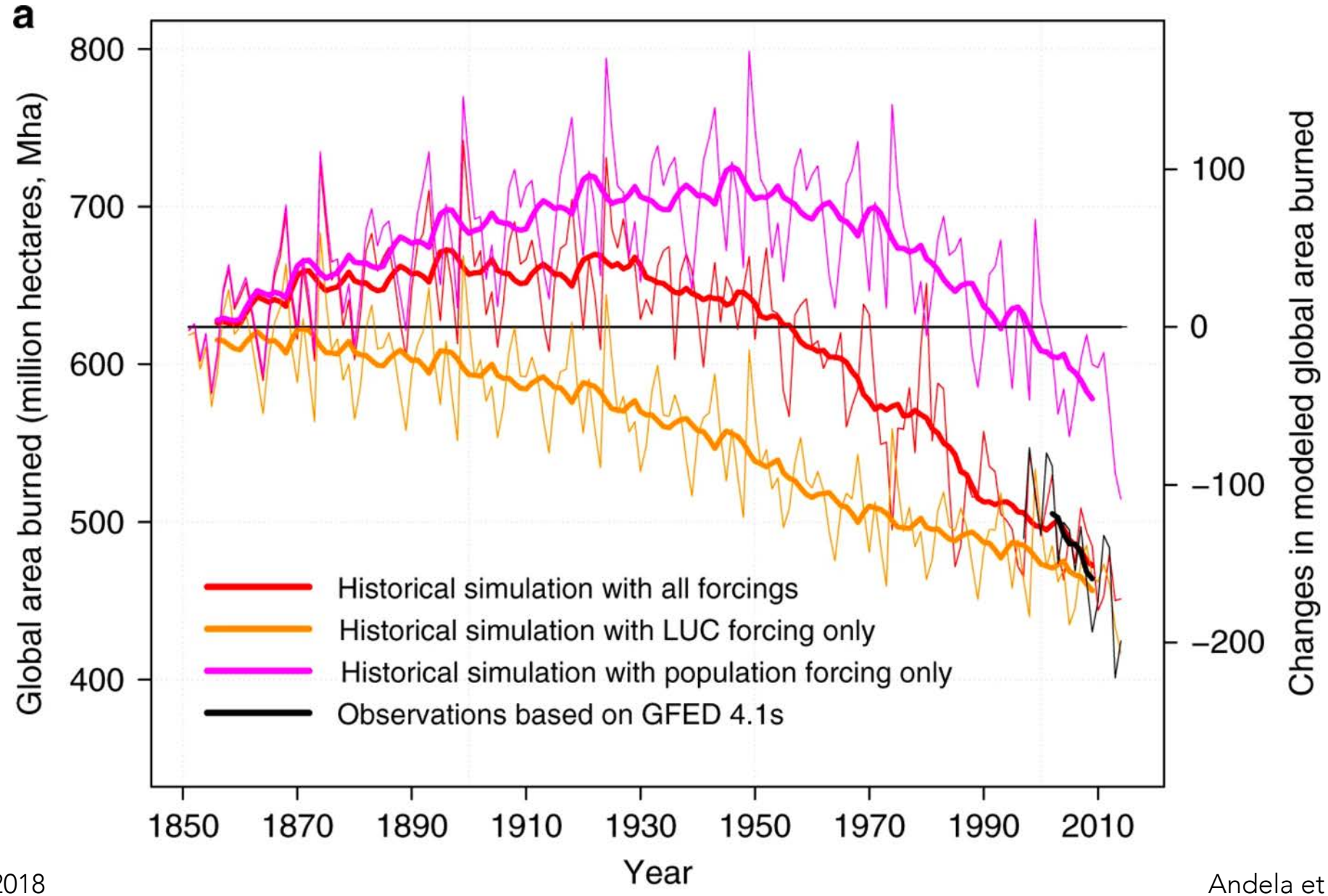
Pechony & Shindell 2010

Current Industrial Era emissions estimates show a very slight increase in biomass burning until the satellite era, and the recent decline



Van Marle et al., 2017

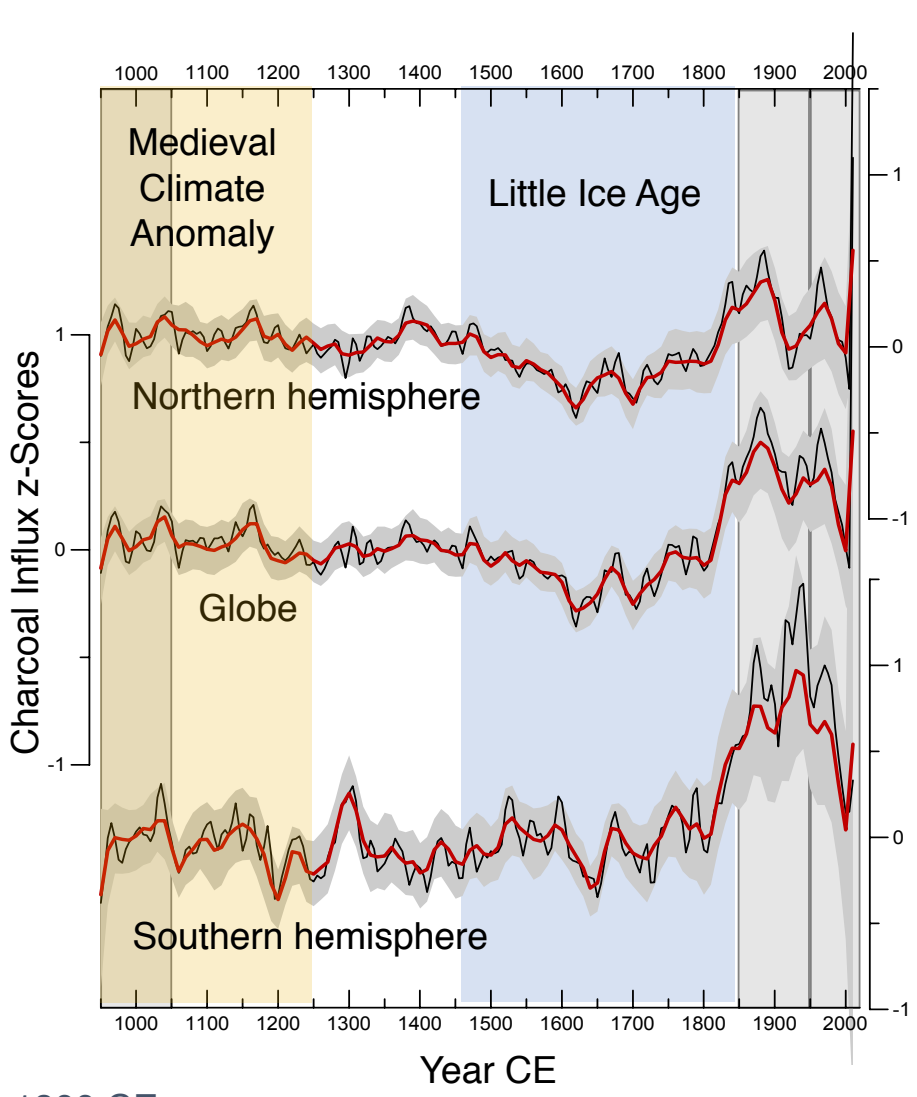
A recent fire simulation broadly consistent with global paleofire data

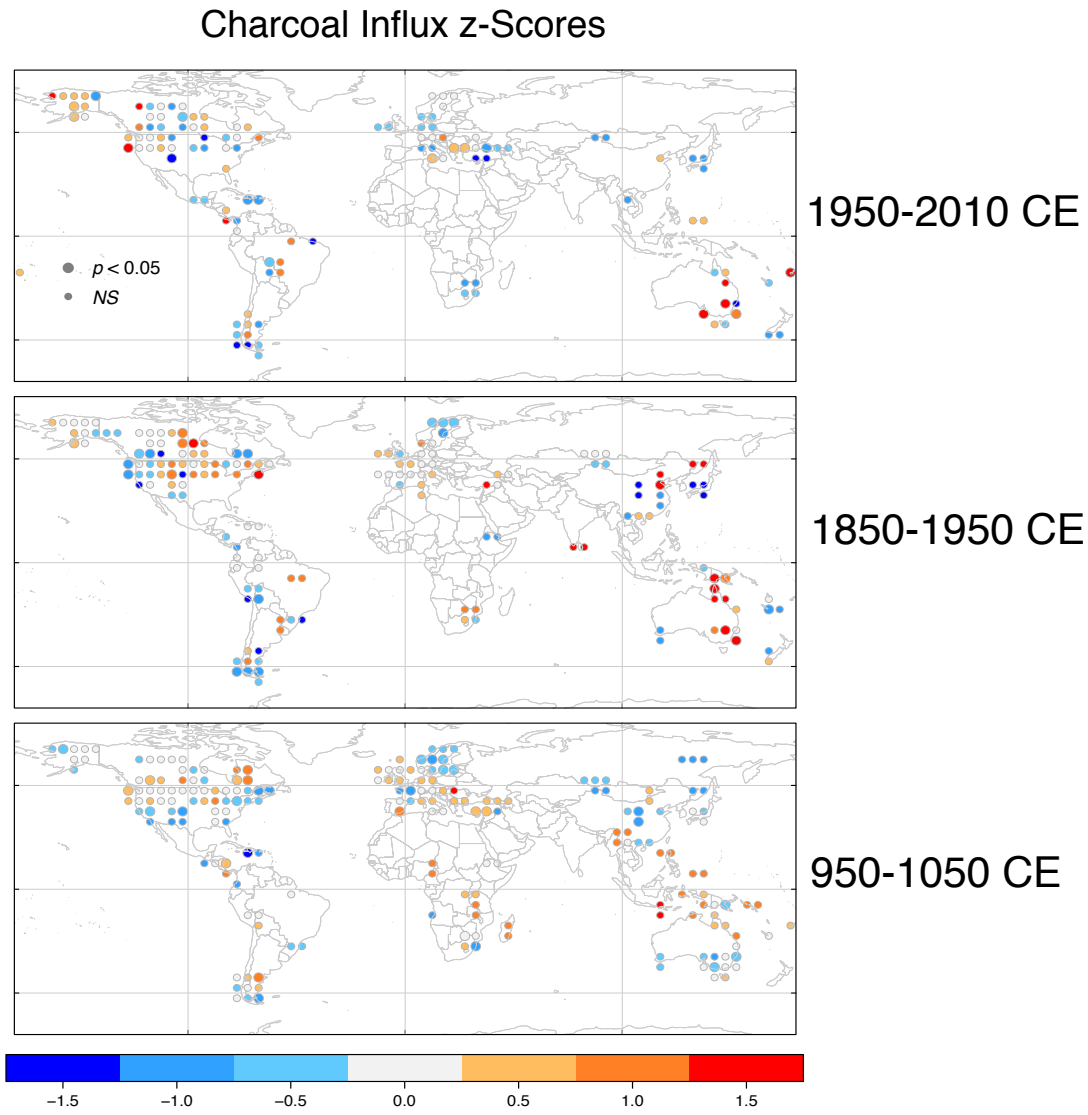


Vivek and Melton, 2018

Andela et al., 2017

GCDv3: past millennium reconstruction includes a recent upturn, but where is this upturn coming from?

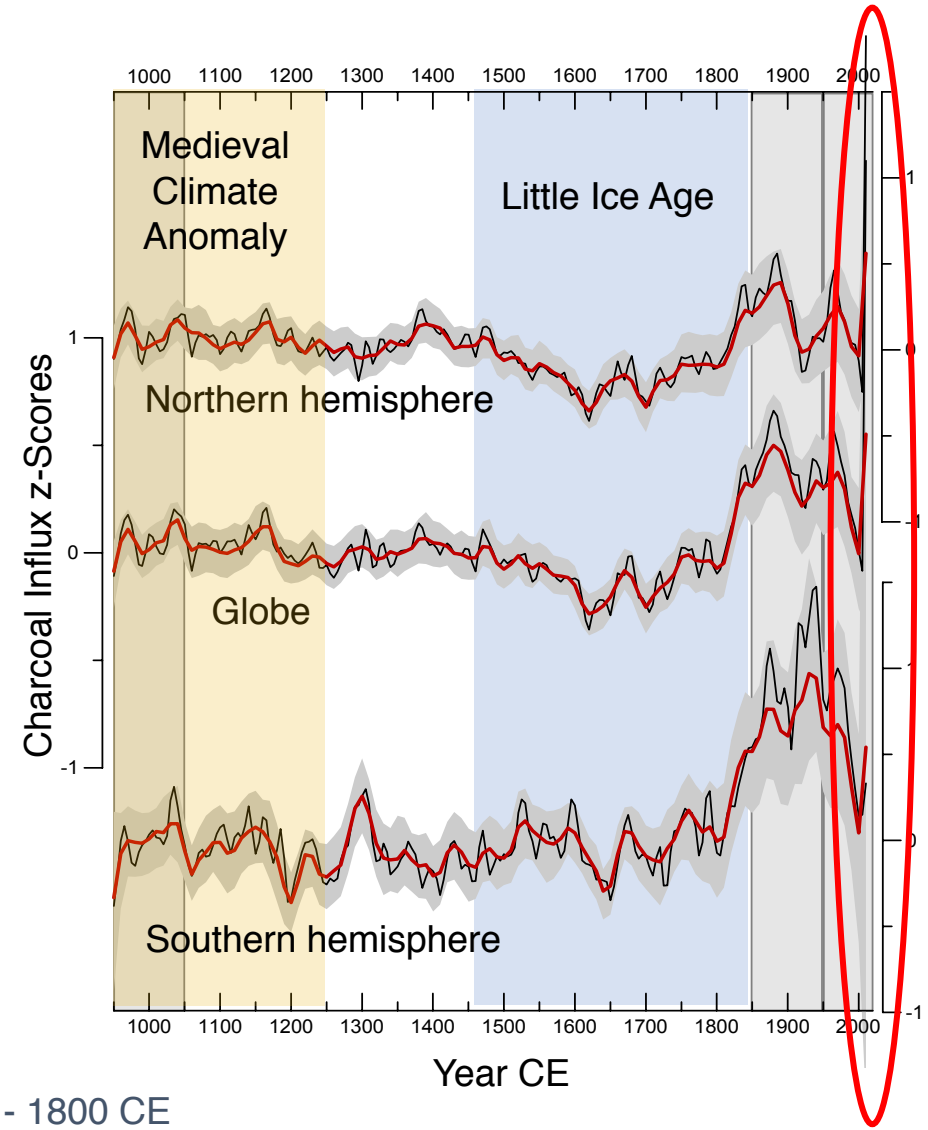


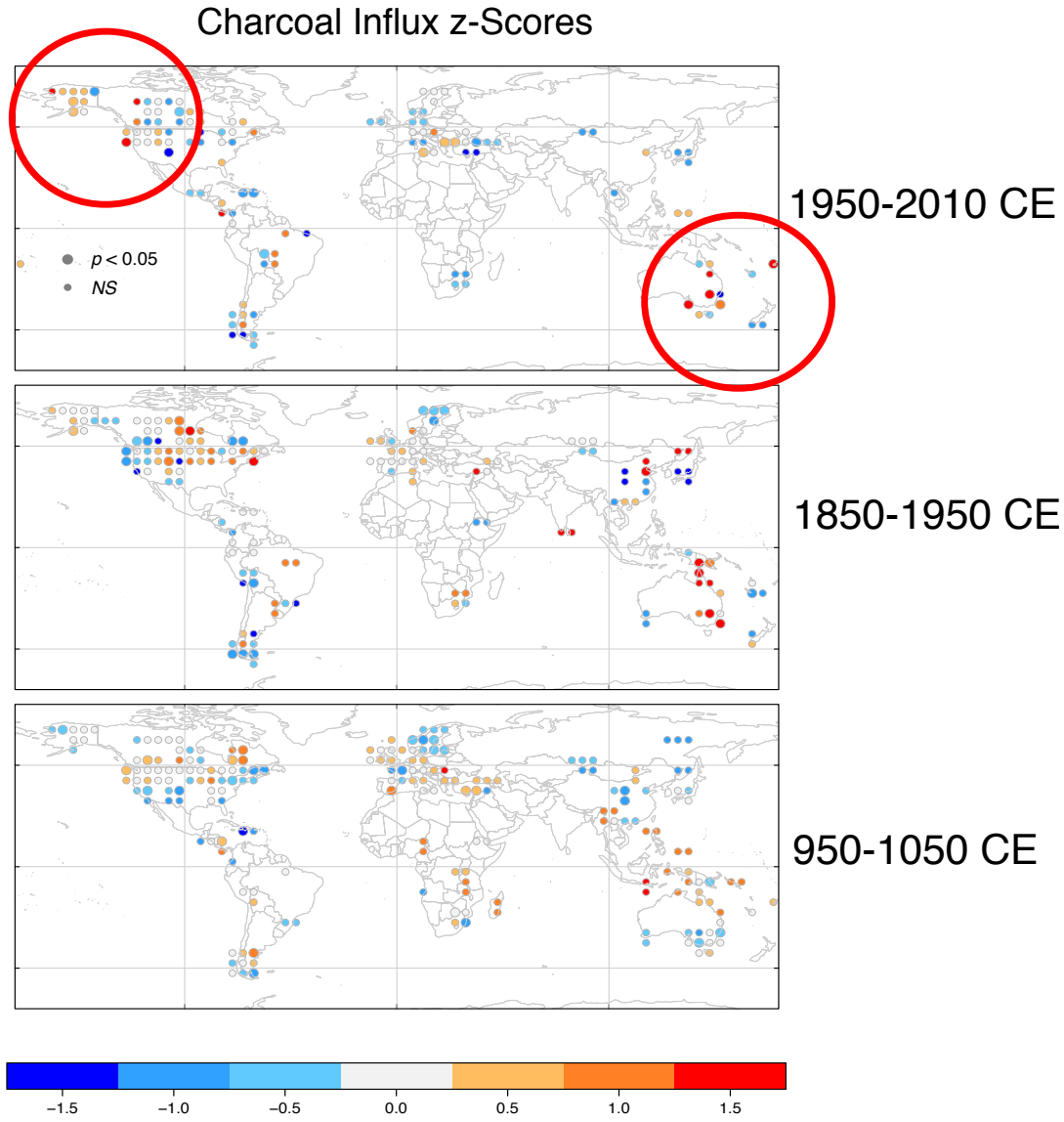


Base: 1000 - 1800 CE

GCD v3; Marlon et al., 2016

GCDv3: past millennium biomass burning driven partially by North America & Australia, but…



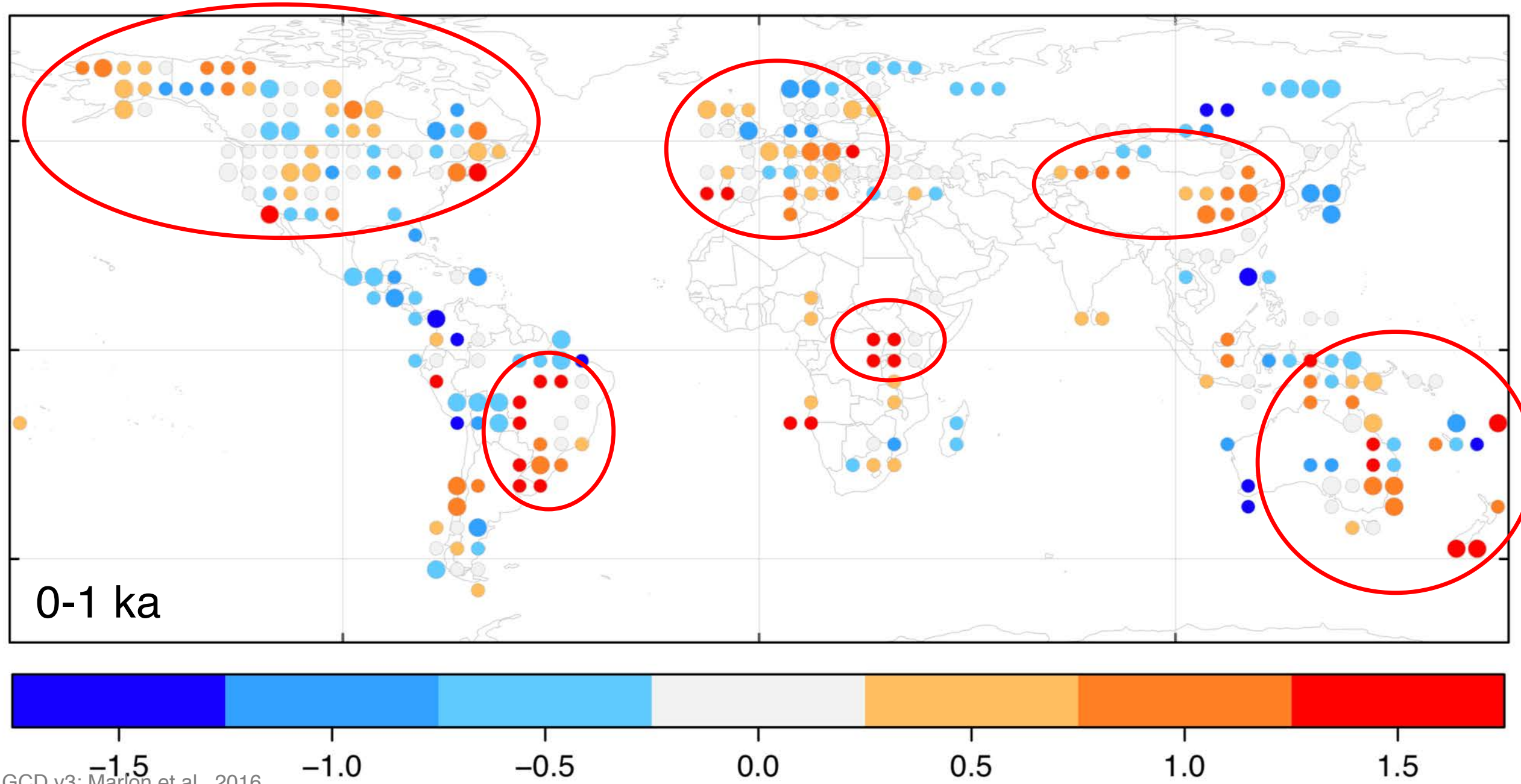


Changes in fire (within each site) relative to long-term mean (21ka-200 cal yr BP)

Base: 1000 - 1800 CE

GCD v3; Marlon et al., 2016

Many places when comparing past millennium (& esp. past 200 yr) to past 21,000 yr



GCD v3; Marlon et al., 2016

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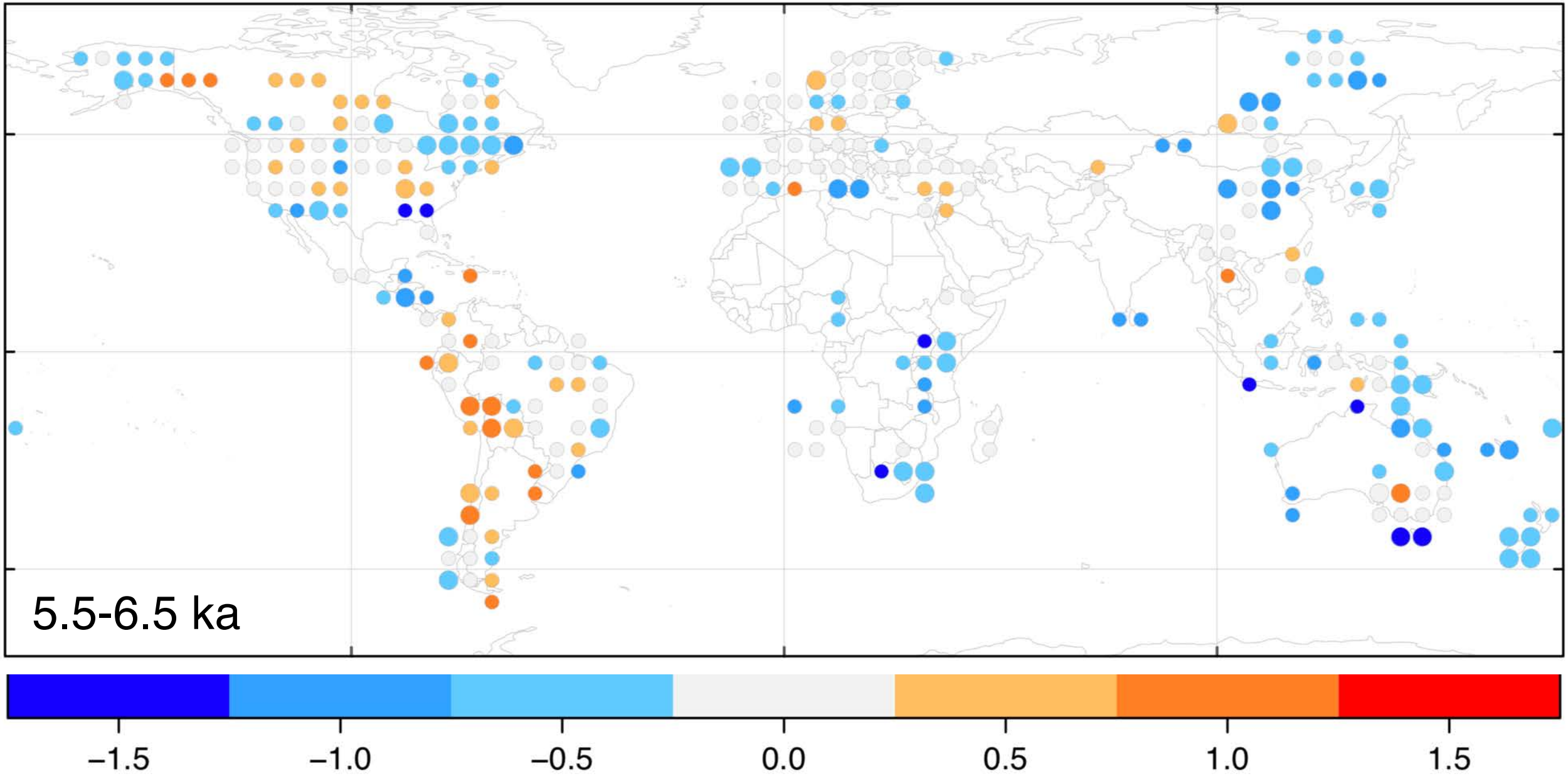

GCD v3; Marlon et al., 2016

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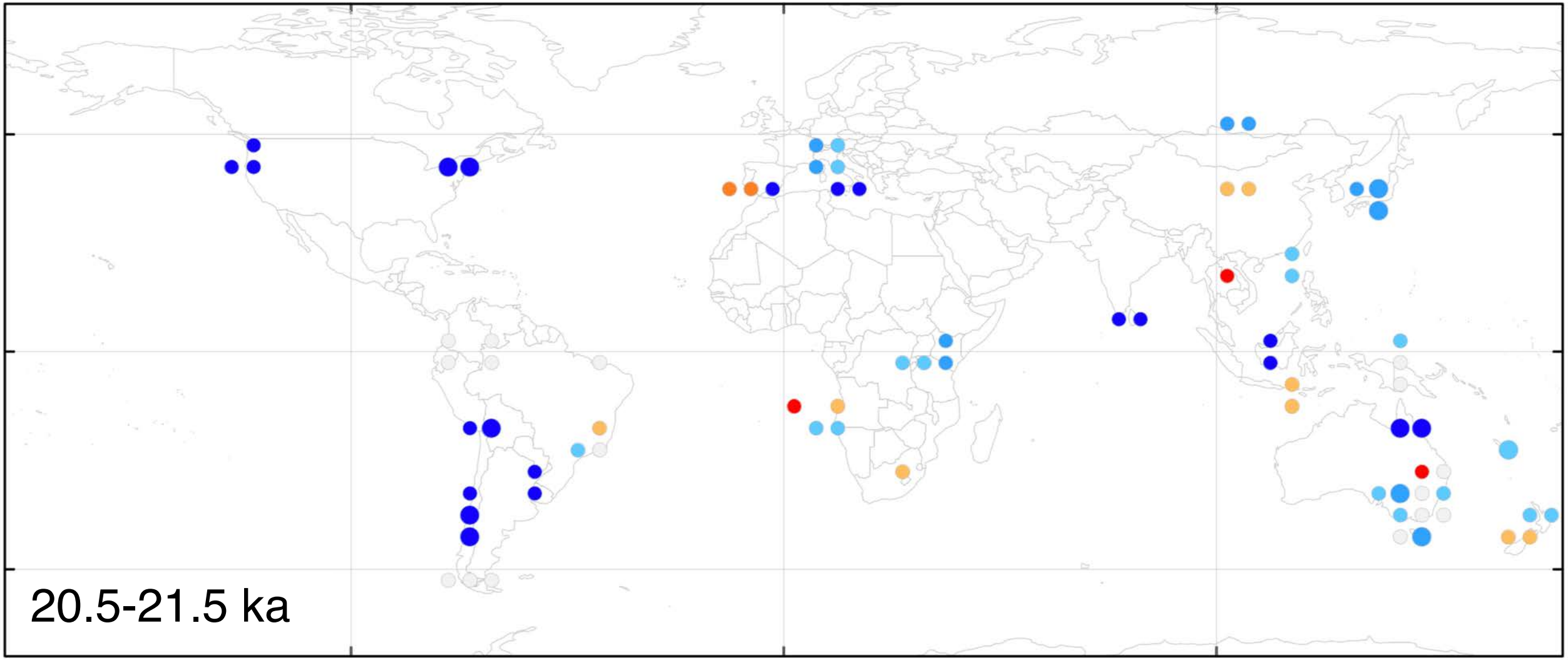


GCD v3; Marlon et al., 2016

A closer look at 12 individual examples that INCREASED rather than decreased *recently*:

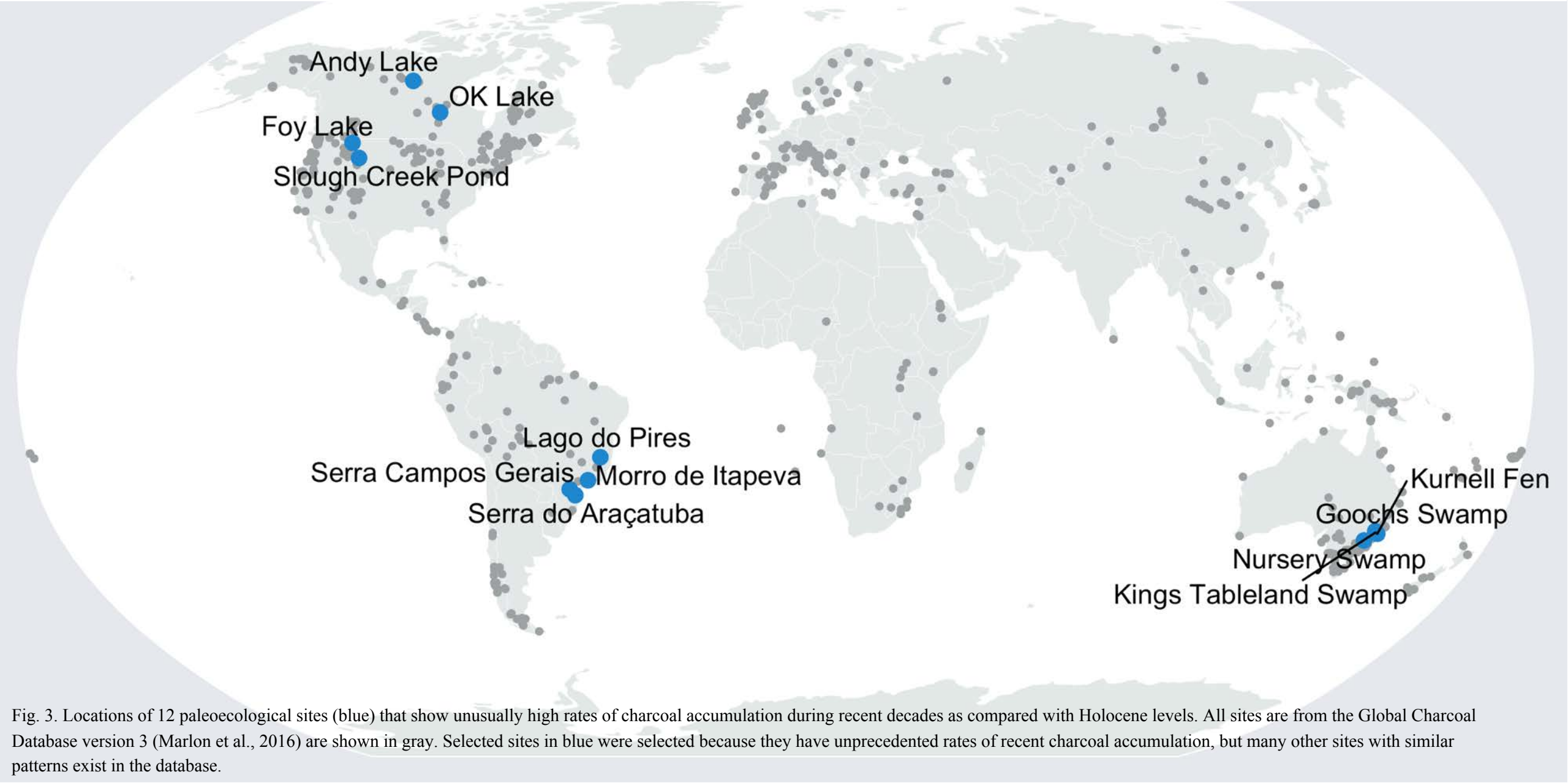
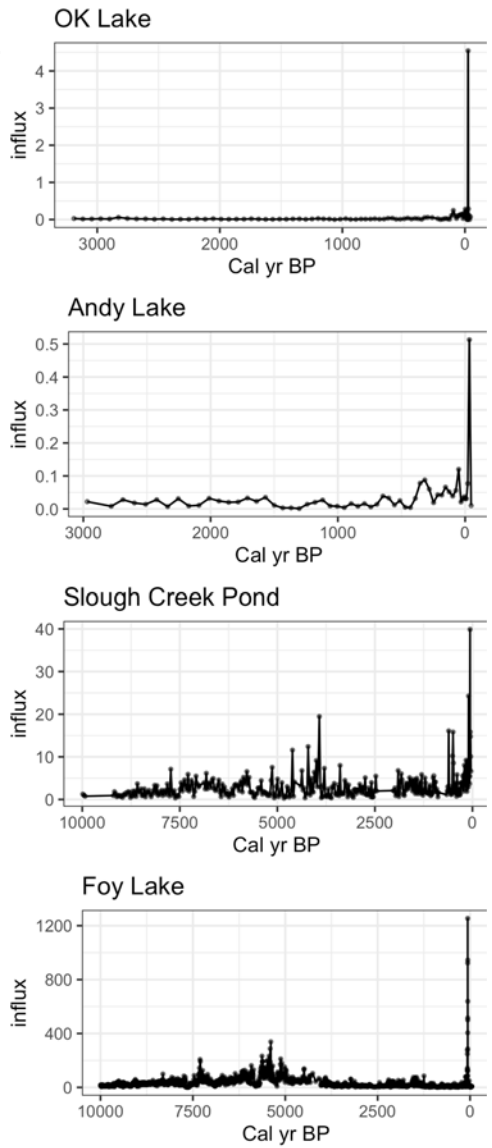


Fig. 3. Locations of 12 paleoecological sites (blue) that show unusually high rates of charcoal accumulation during recent decades as compared with Holocene levels. All sites are from the Global Charcoal Database version 3 (Marlon et al., 2016) are shown in gray. Selected sites in blue were selected because they have unprecedented rates of recent charcoal accumulation, but many other sites with similar patterns exist in the database.

Marlon, accepted

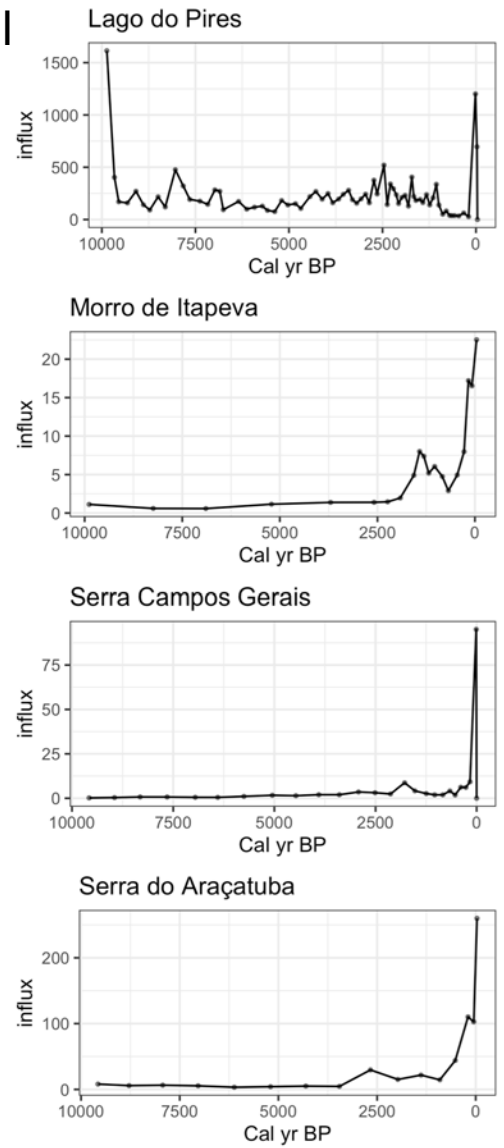
Recent fire changes (up AND down) are unprecedented in past 10,000 yrs

N. America



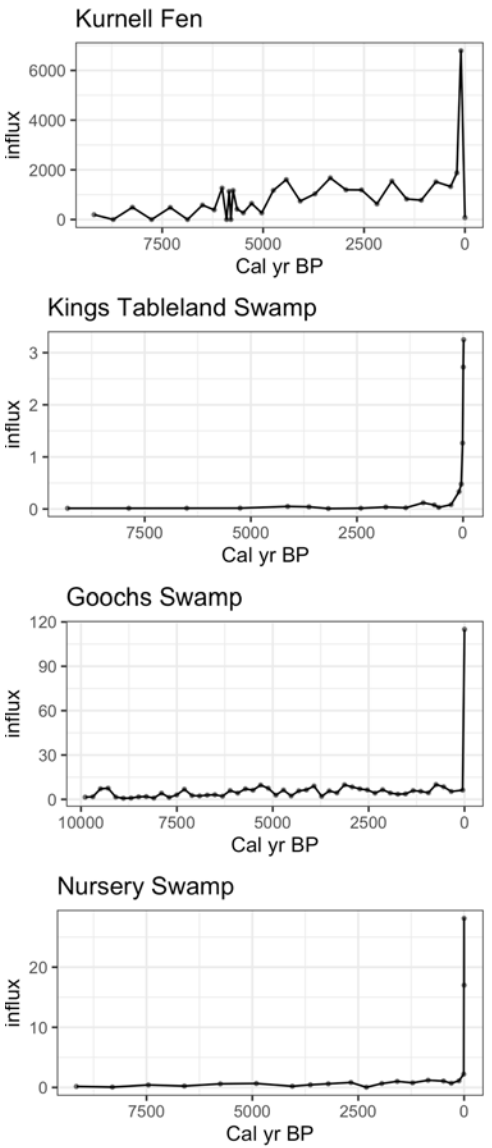
Lynch et al., 2006; Whitlock et al., 2008; Power et al., 2009

S. Brazil



Behling, 1995; Behling, 1997a; Behling, 1997b

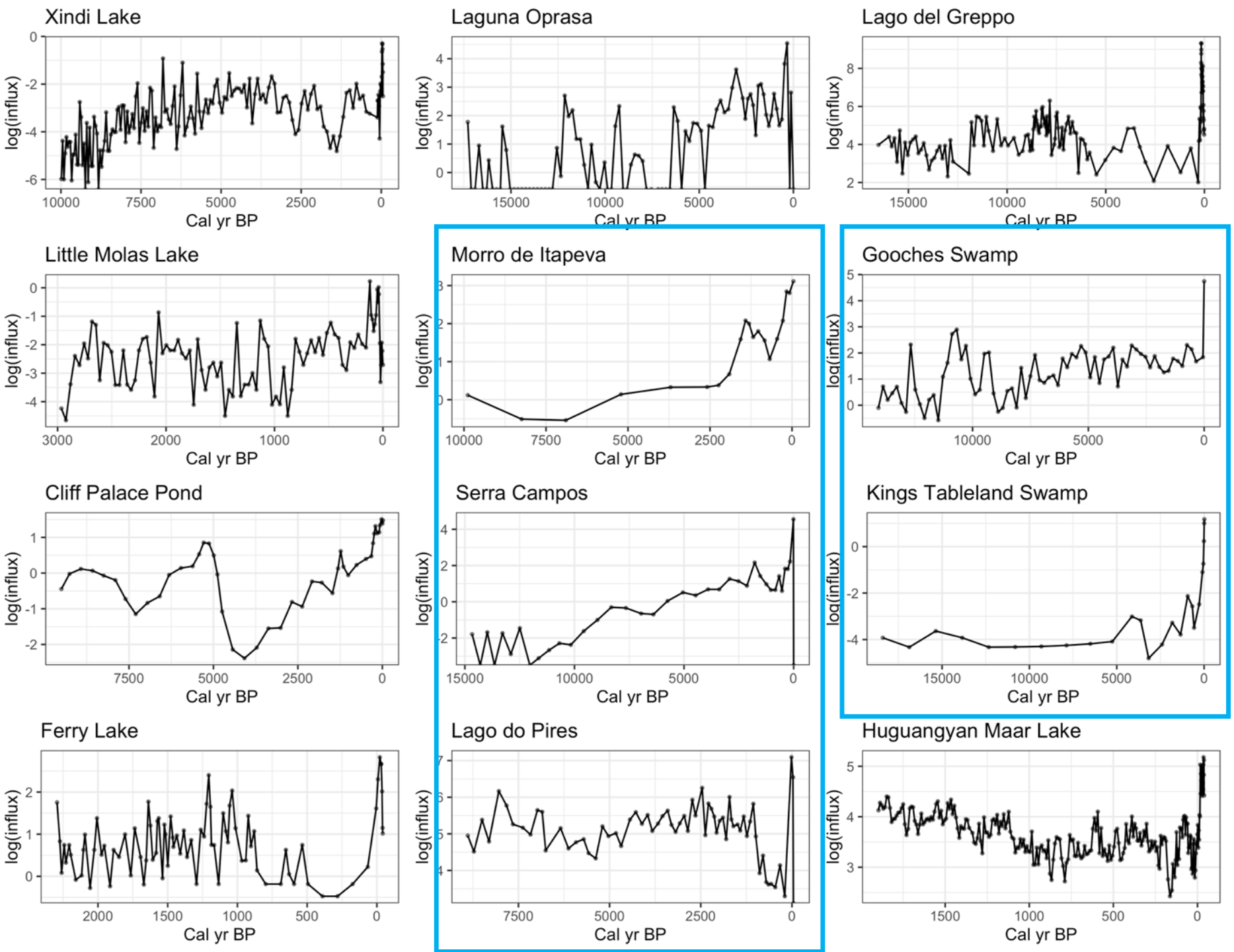
Australia



Black and Mooney, 2006; Rogers and Hope, 2006; Mooney et al., 2011

A log scale reveals the variability prior to the industrial era, which while far more subtle than recent changes, was nonetheless highly dynamic over time.

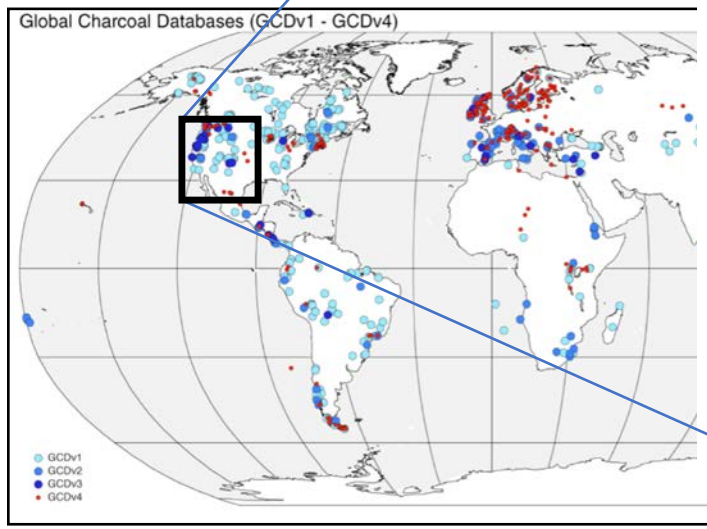
(Examples in blue boxes are also shown on previous slide.)

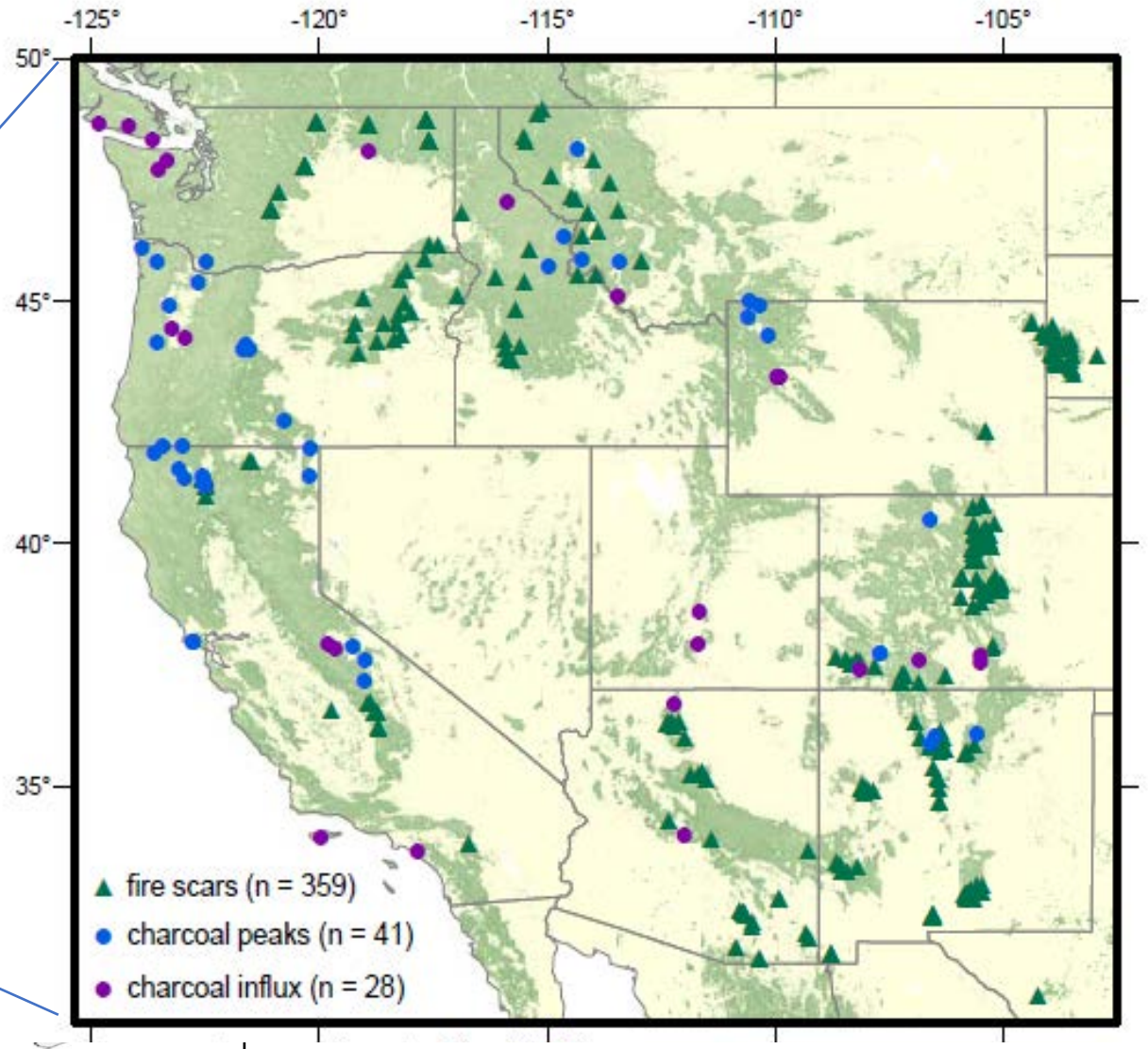


Only regional analyses can reveal nature, scope, & mechanisms of change

Paleofire sites
(*n*=69)

Fire scar sites
(*n*=359)





Charcoal index

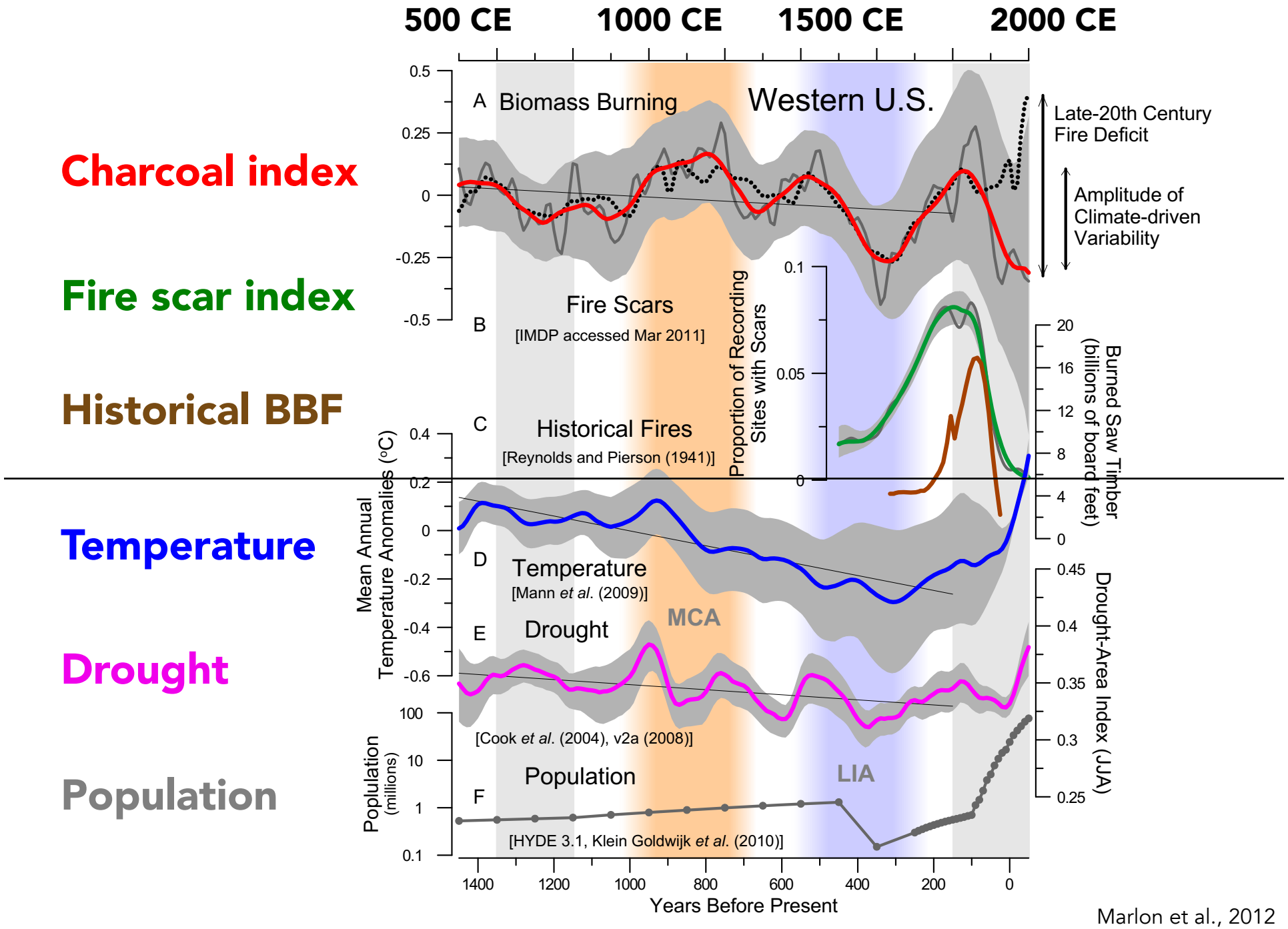
Fire scar index

Historical BBF

Temperature

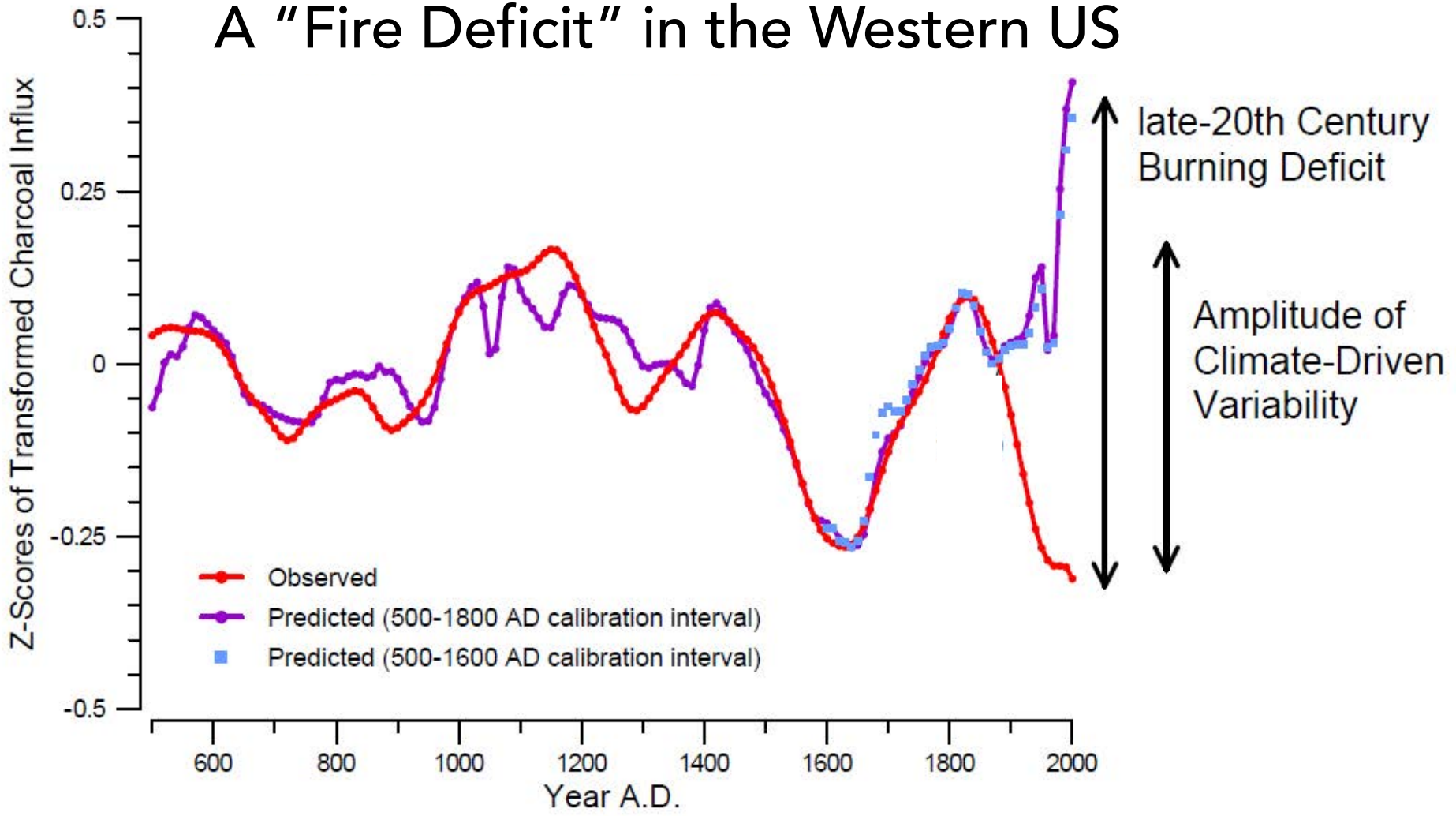
Drought

Population



Marlon et al., 2012

A "Fire Deficit" in the Western US



Full GAM: $R^2 = 0.85$; $F = 47.0$; $p < 0.001$
Temperature alone: $R^2 = 0.53$; $F = 51.2$; $p < 0.001$
Drought area: $R^2 = 0.34$; $F = 24.4$; $p < 0.001$

Marlon et al., 2012

1913

2001

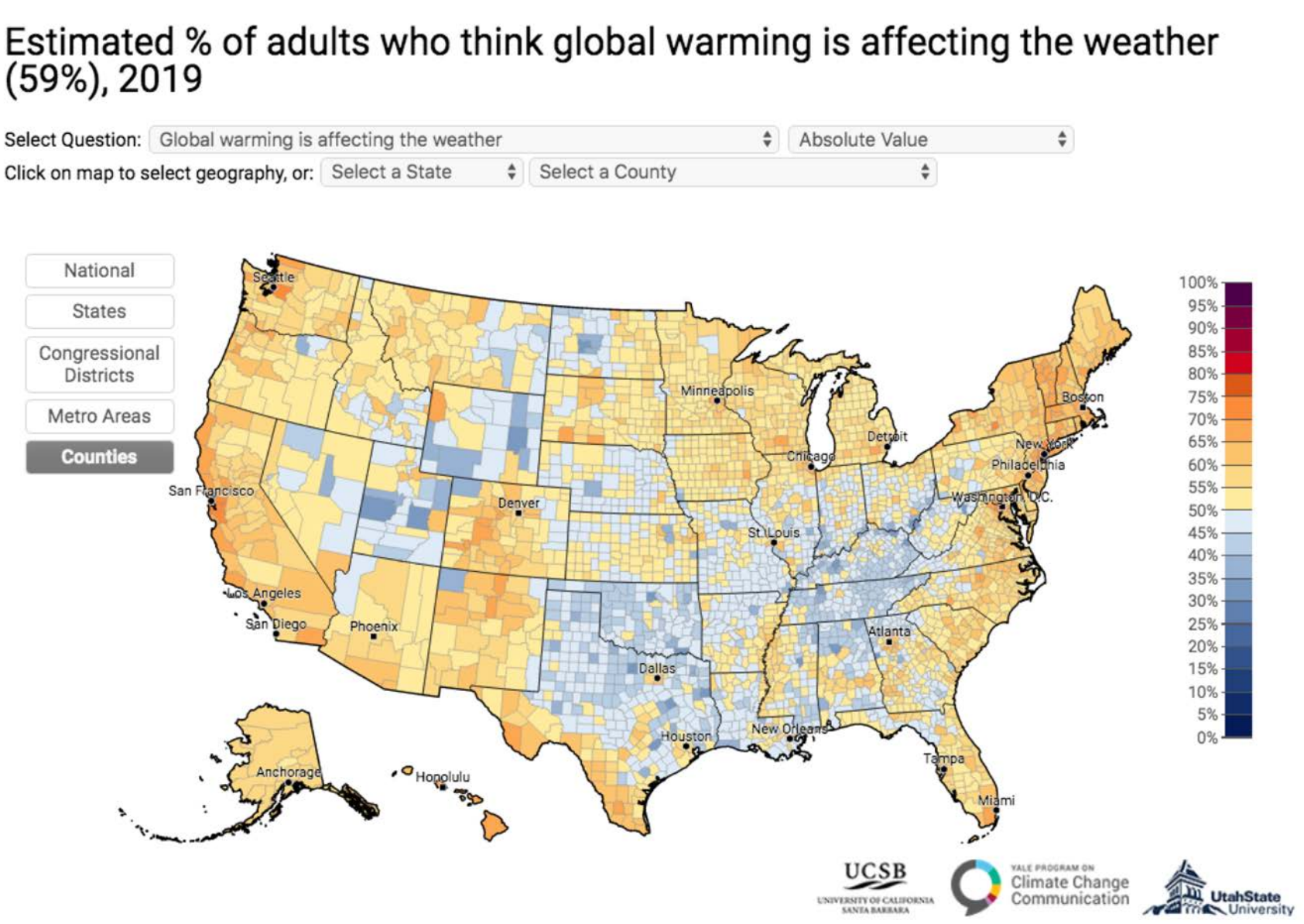
Logging, grazing, fire suppression, and perhaps now CO2 fertilization have all contributed to fuel build up across the West in the past century.

Now global warming is lengthening the fire season and drying those fuels out. More people are around to set fires. And we're still putting all but 0.4% of them out.

And yet…

Many among the American (and perhaps the UK & Australian public) do not yet understand the dangers of global warming for humans and ecosystems.

Fire scientists should speak up about the fire-climate connection and why it matters.



https://climatecommunication.yale.edu/visualizations-data/ycom-us/

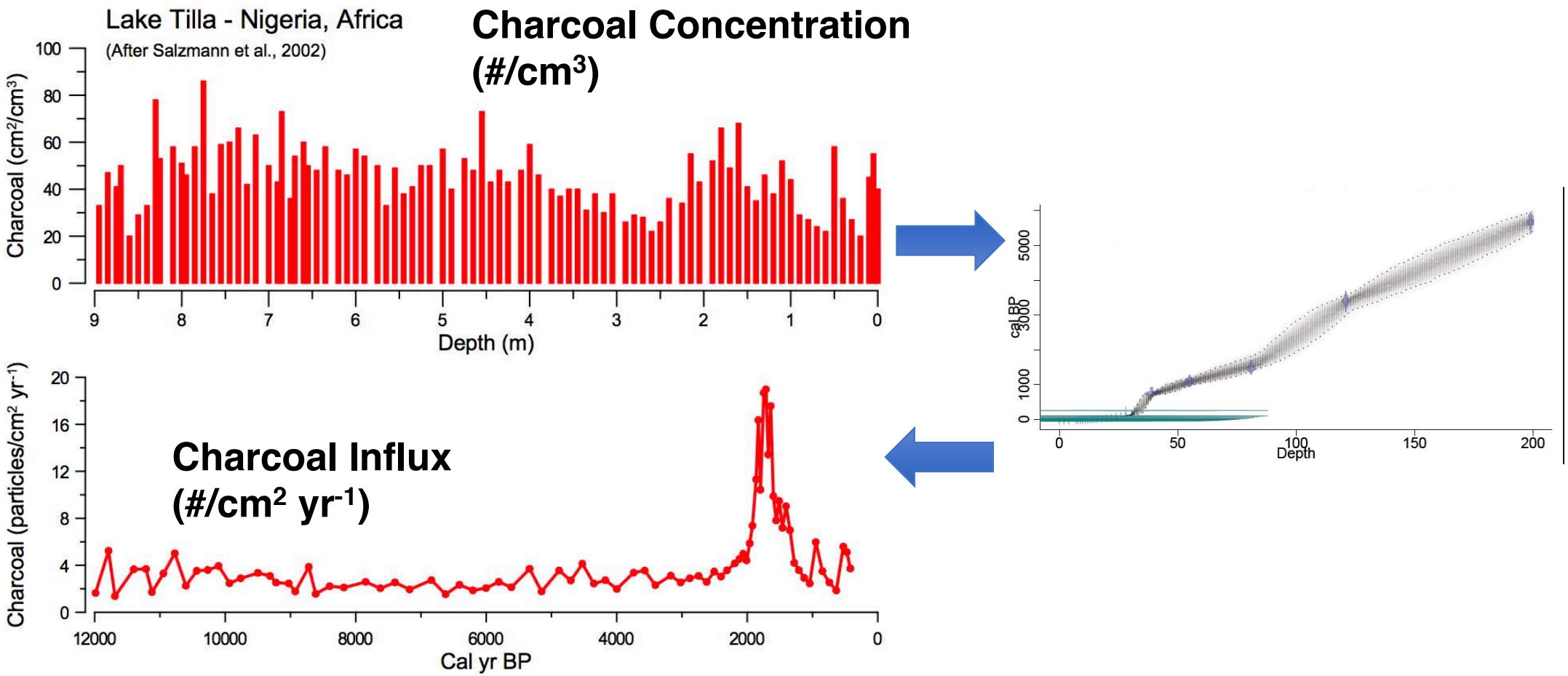
Some Examples from the Paleofire Literature

Salzmann et al., 2000, VHA

Sudanian zone: Lake Tilla (Biu-Plateau)

Northeast Nigeria in the Sahel zone:
Manga Grasslands existed in the early Holocene

Charcoal concentration can show quite different patterns than influx; data should be converted to influx because sedimentation rates vary



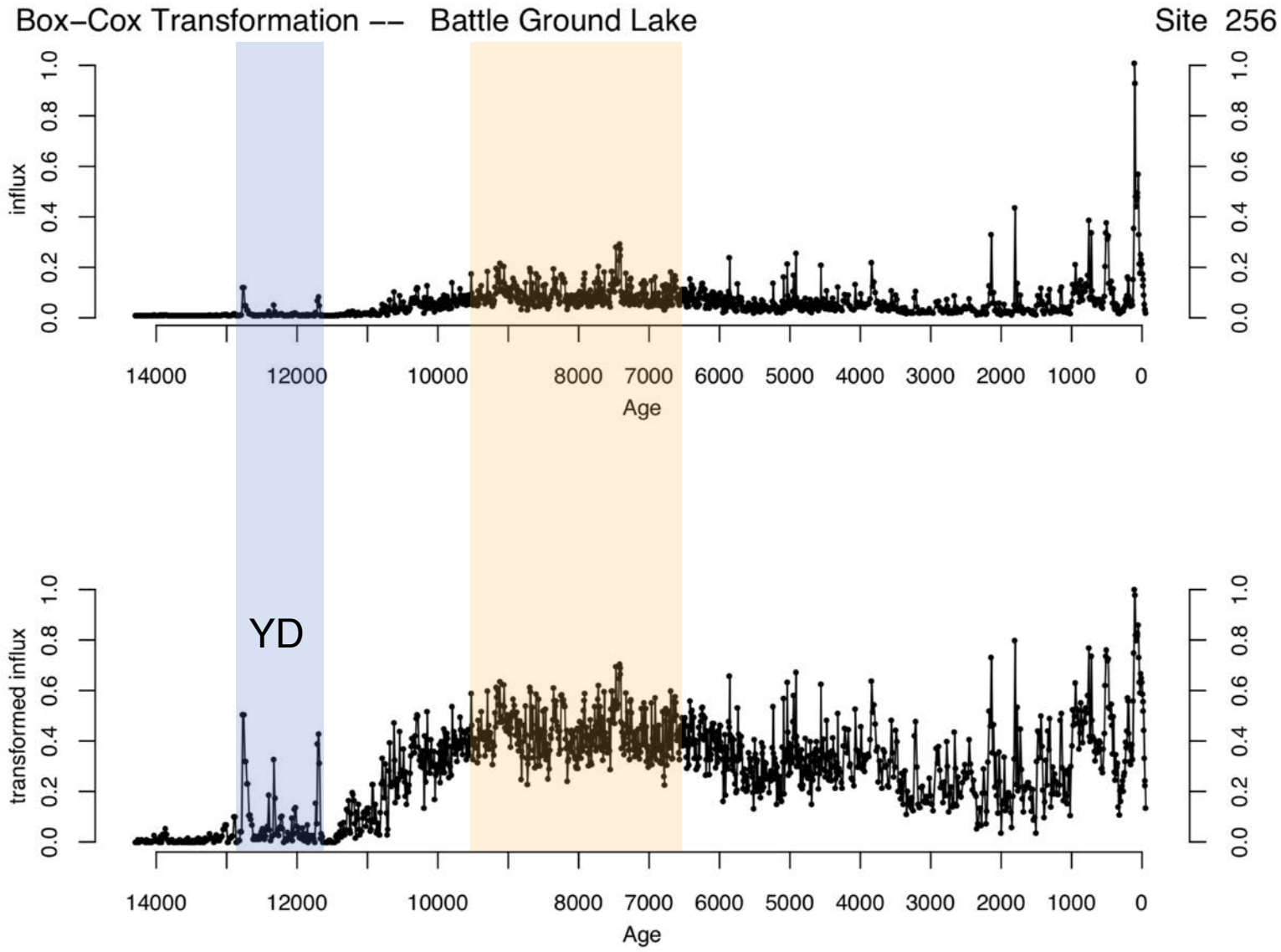
Marlon et al., 2013, QSR

Example of fire response to summer insolation forcing

Battle Ground Lake, Washington, U.S.

Walsh et al., 2008, *Quaternary Research*

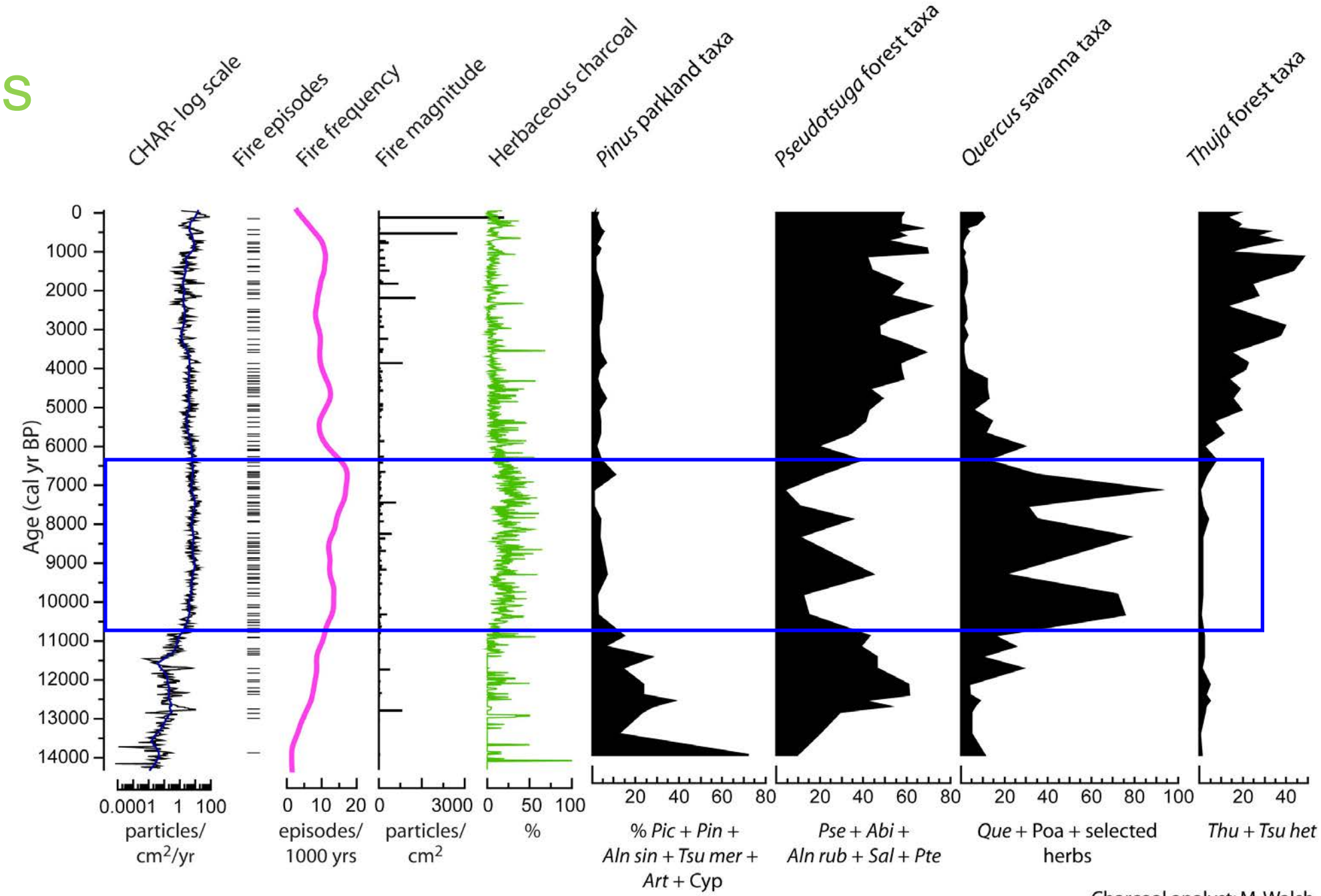
Highest sustained biomass burning ~9.5 – 6.5 kya



Also note abrupt charcoal peaks at beginning & end of Younger Dryas

Herbaceous charcoal shows that grass fires register clearly

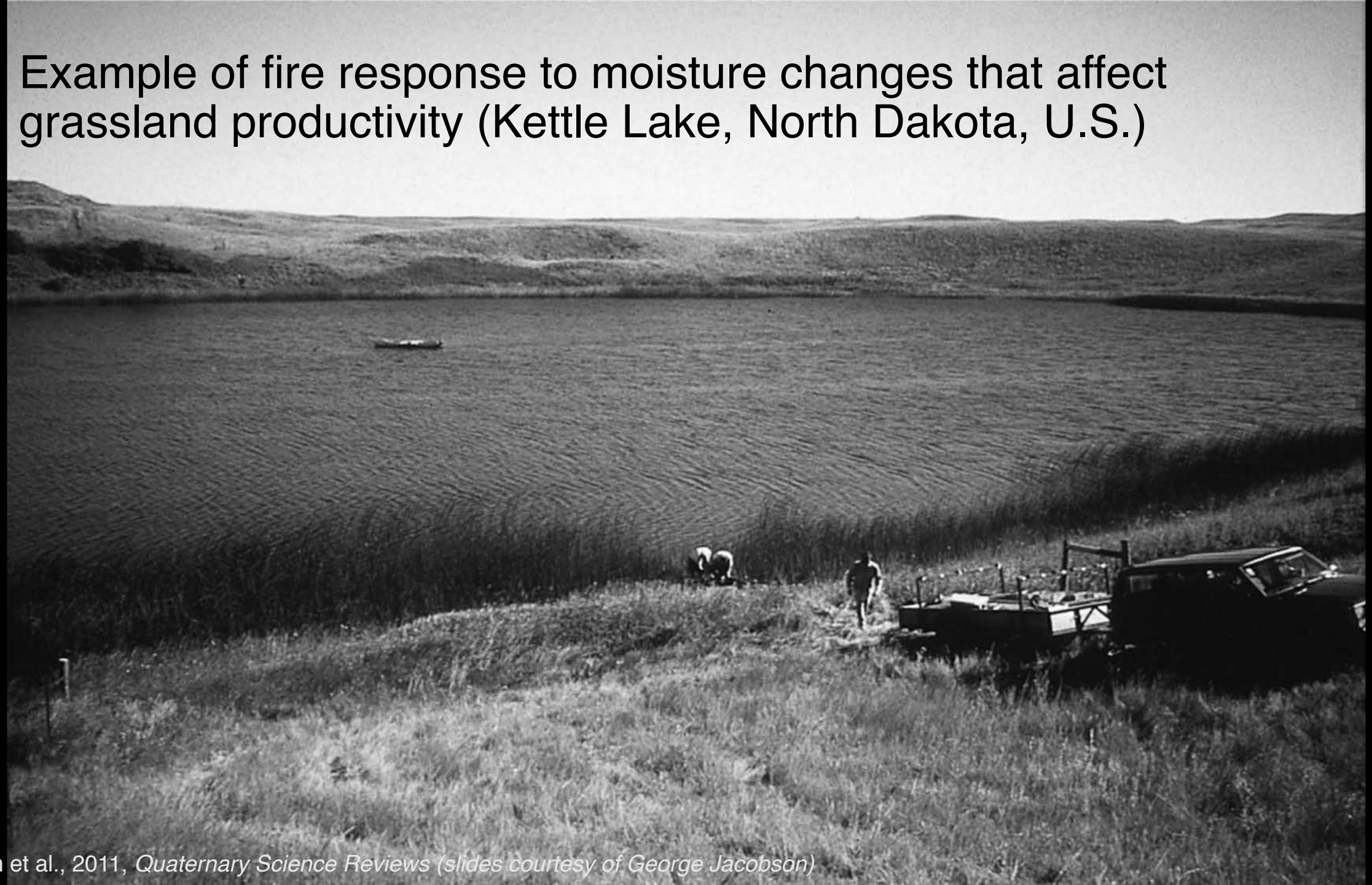
Holocene Changes in Vegetation & Fires around Battle Ground Lake, WA



Walsh et al., 2008, *Quaternary Research*

Charcoal analyst: M. Walsh
Pollen analyst: C. Whitlock

Example of fire response to moisture changes that affect grassland productivity (Kettle Lake, North Dakota, U.S.)



Grimm et al., 2011, *Quaternary Science Reviews (slides courtesy of George Jacobson)*

Prairie fires at Kettle Lake, North Dakota

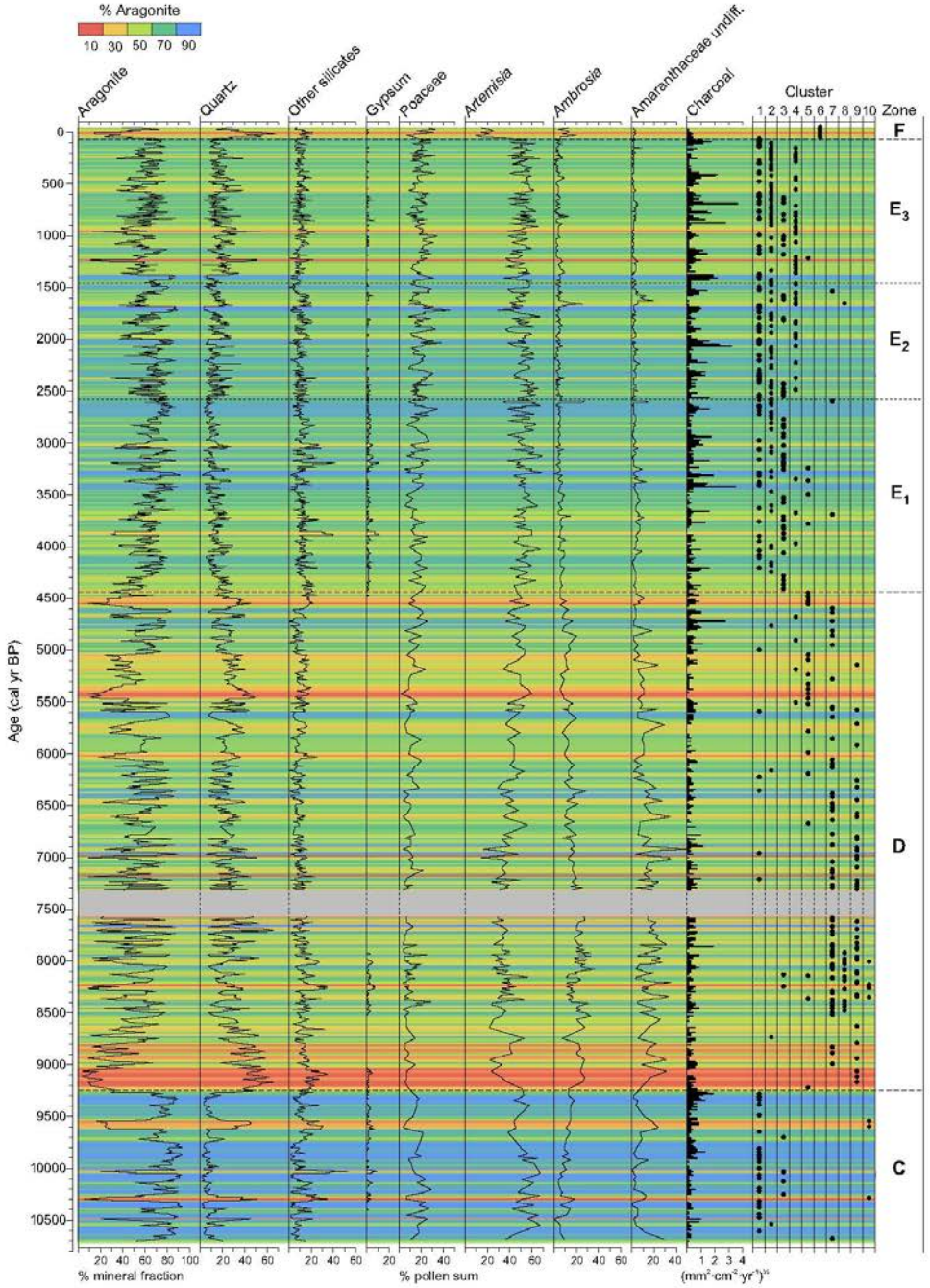
10,000 years of climate, showing moisture variations

blue = moist

green = intermediate

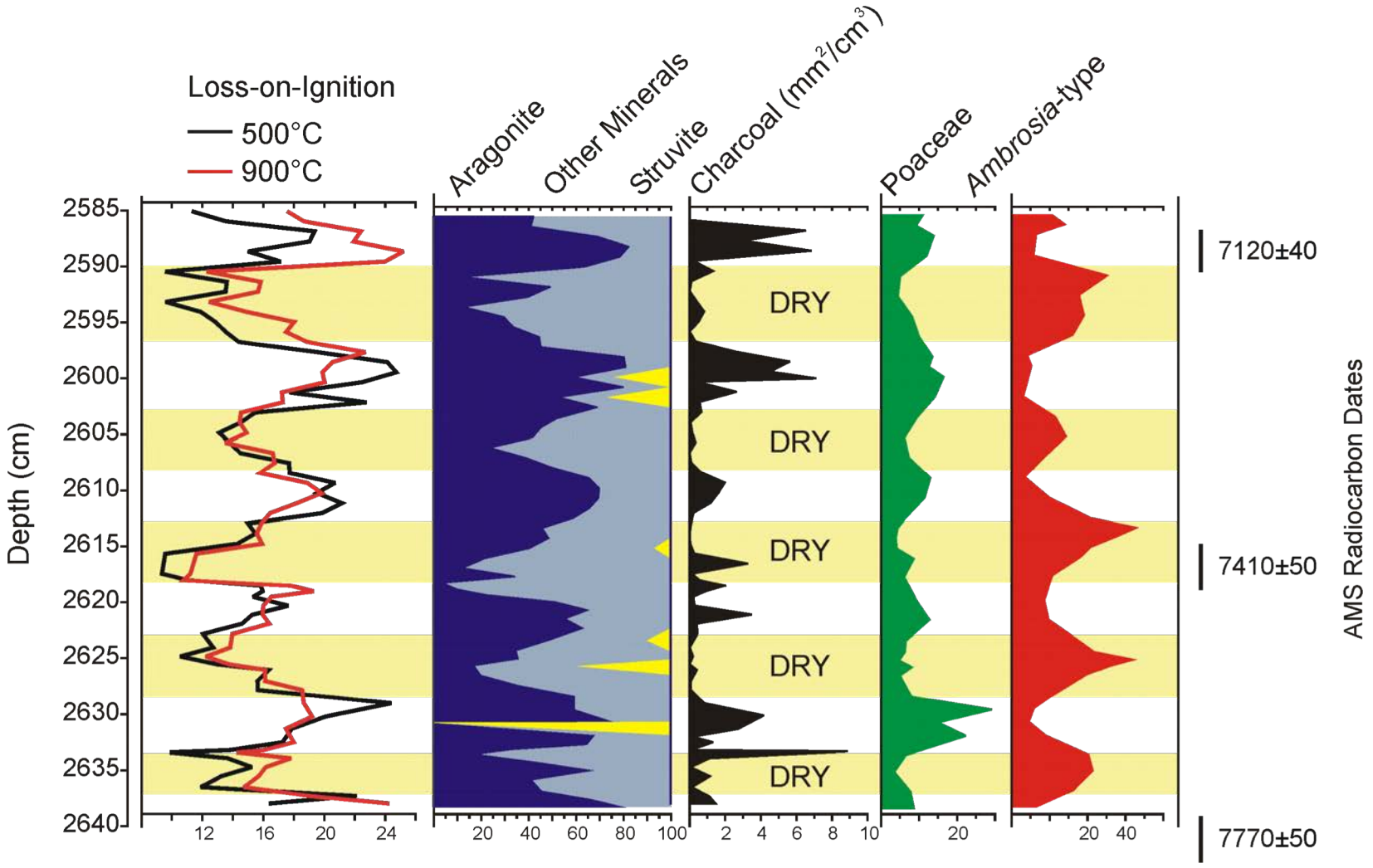
red & orange = dry

Most extreme drought: 9.25 ka



Grimm et al., 2011, *Quaternary Science Reviews (slide courtesy of George Jacobson)*

Fire is dependent on moisture & fuel build-up. Similar cycles are found in South Africa on orbital time scales (Daniau et al. 2013)



Clark et al., 2002, *Ecology (slide courtesy of George Jacobson)*

Summary

1) The GCD is rich with examples of how temperature and moisture availability drive fire on decadal to orbital time scales.

2) Dozens if not hundreds of records document the importance of multidecadal socioecological processes for fire regimes (e.g., human arrival; land-use change; farm abandonment; fire suppression)

3) Many recent (i.e. past decade to past century) fire regime changes are unprecedented.

4) Fire scientists have much to offer to improve public understanding of the connections between global warming and wildfire.