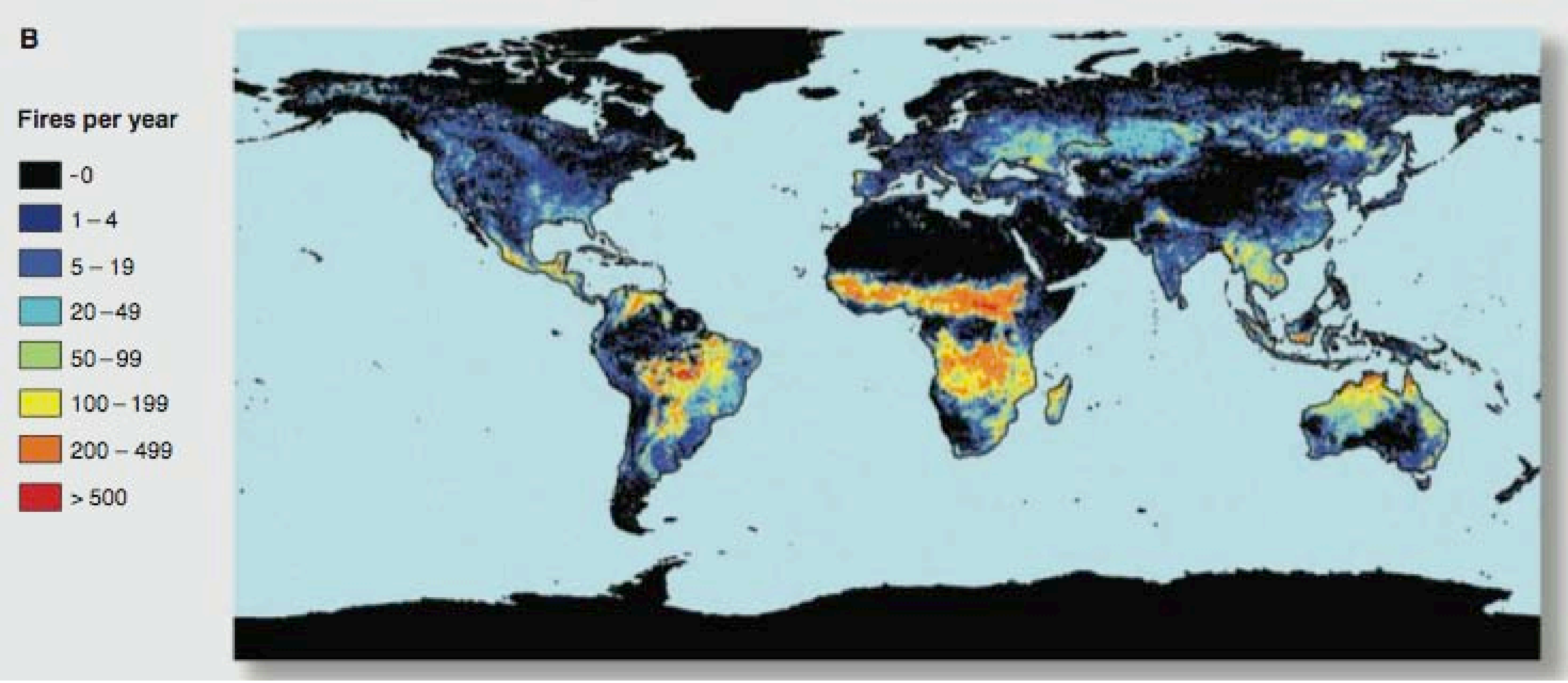
Pyrogeography: the where, when, and why of fire on Earth

Philip Higuera, Assistant Professor, CNR, University of Idaho
REM 244 Guest Lecture, 2 Feb., 2012



Bowman et al. 2009.

Outline for Today's Class

1. **What is pyrogeography?**

2. **What can you infer from the pattern of fire?**

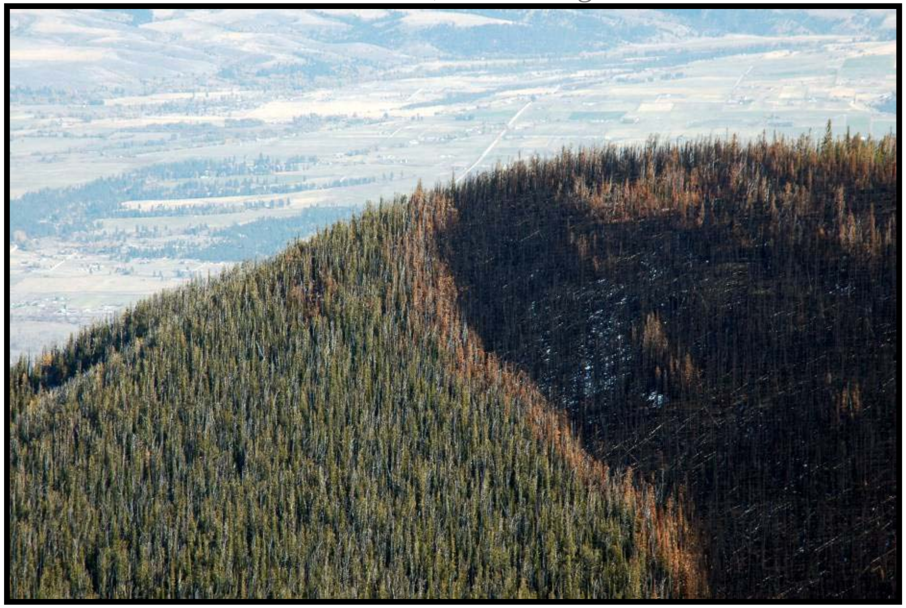
3. **Application – How will fire change with climate?**

What is biogeography?

***The study of life across space and through time:* what do we see, where, and why?**

The view from Crater Peak, in Washington's North Cascades

Solifluction lobes in Alaska's Brooks Range



Fire boundary in Montana's Bitter Root Mountains

What is pyrogeography?

***The study of fire across space and through time:* what do we see, where, and why?**

The view from Crater Peak, in Washington's North Cascades

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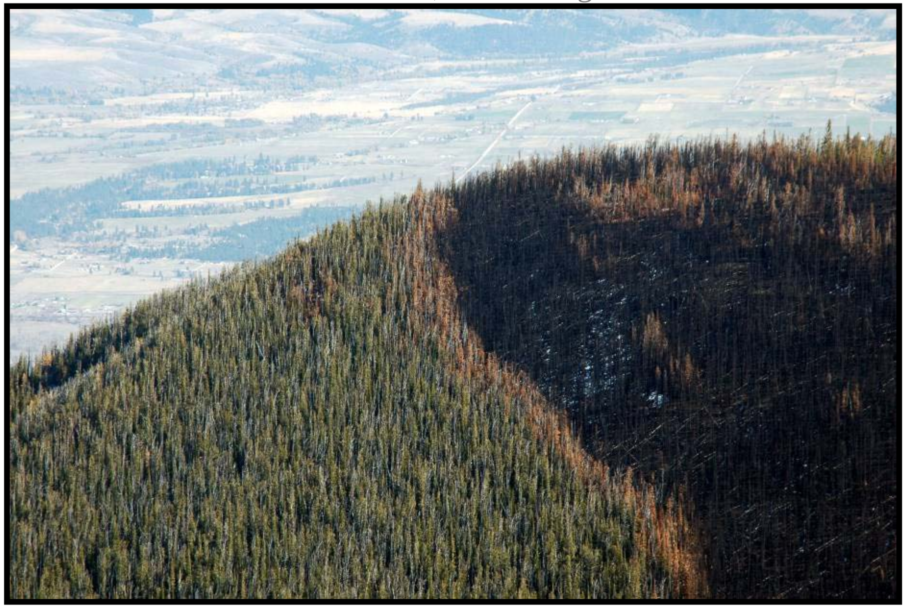

Fire boundary in Montana's Bitter Root Mountains

University of Idaho Experimental Forest, 2009

Fact:

Energy released during a fire comes from stored energy in chemical bonds

Implication:

Fire at all scales is regulated by rates of plant growth

What else does fire need to exist?

Pyrogeographic framework: “fire” as an organism

At multiple scales, the presence of fire depends upon the coincidence of:

(1) Consumable resources

(2) Atmospheric conditions

(3) Ignitions

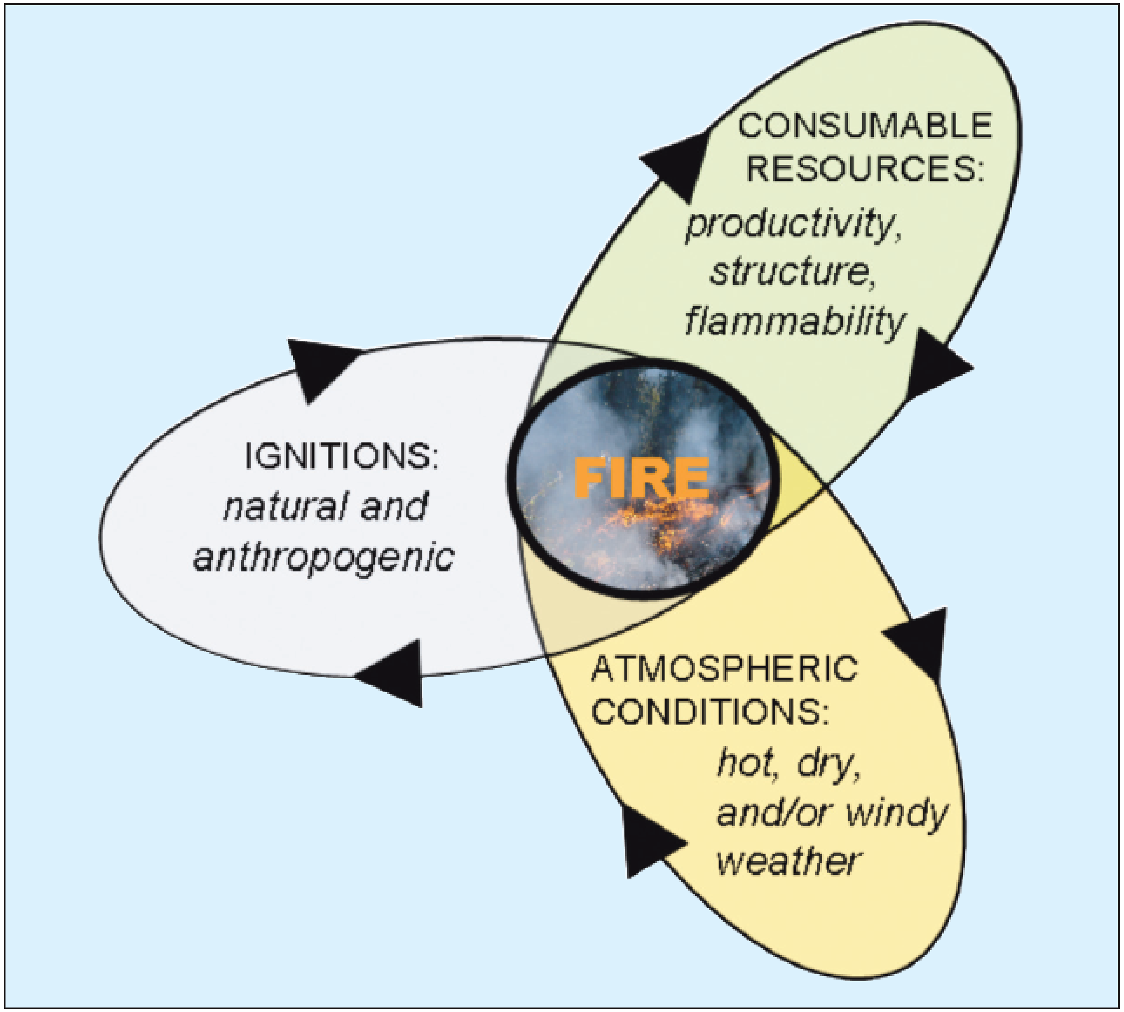

Figure 1: The pyrogeography framework includes vegetation resources to consume, atmospheric conditions, and ignition agents. Each of these components is spatially and temporally variable, as illustrated by arrows, and it is their coincidence that results in fire activity. Variation in their coincidence generates different fire regime types (e.g., frequent low-intensity surface fire versus infrequent high-intensity crown fire).

PAGES news • Vol 18 • No 2 • August 2010

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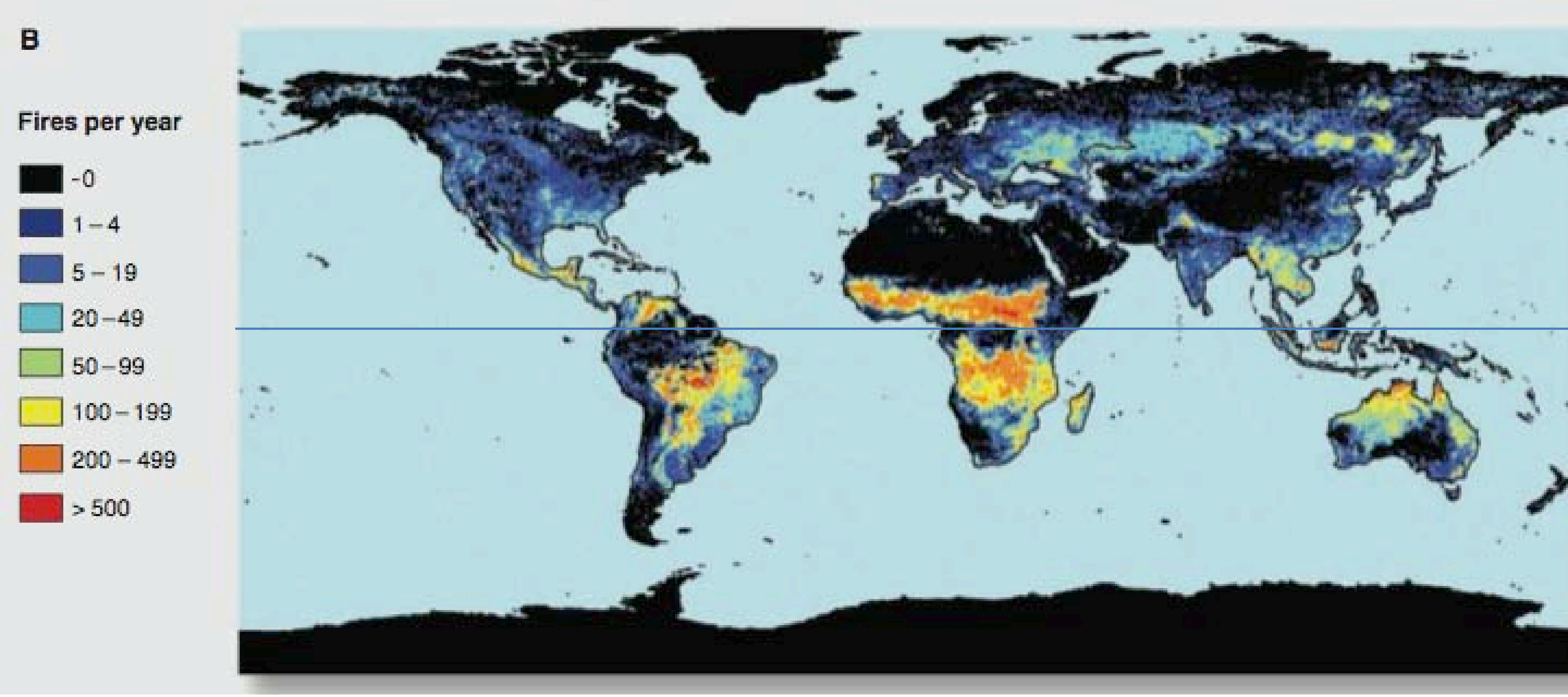
Global patterns of fire – what can we infer?

Fires per year (Bowman et al. 2009)

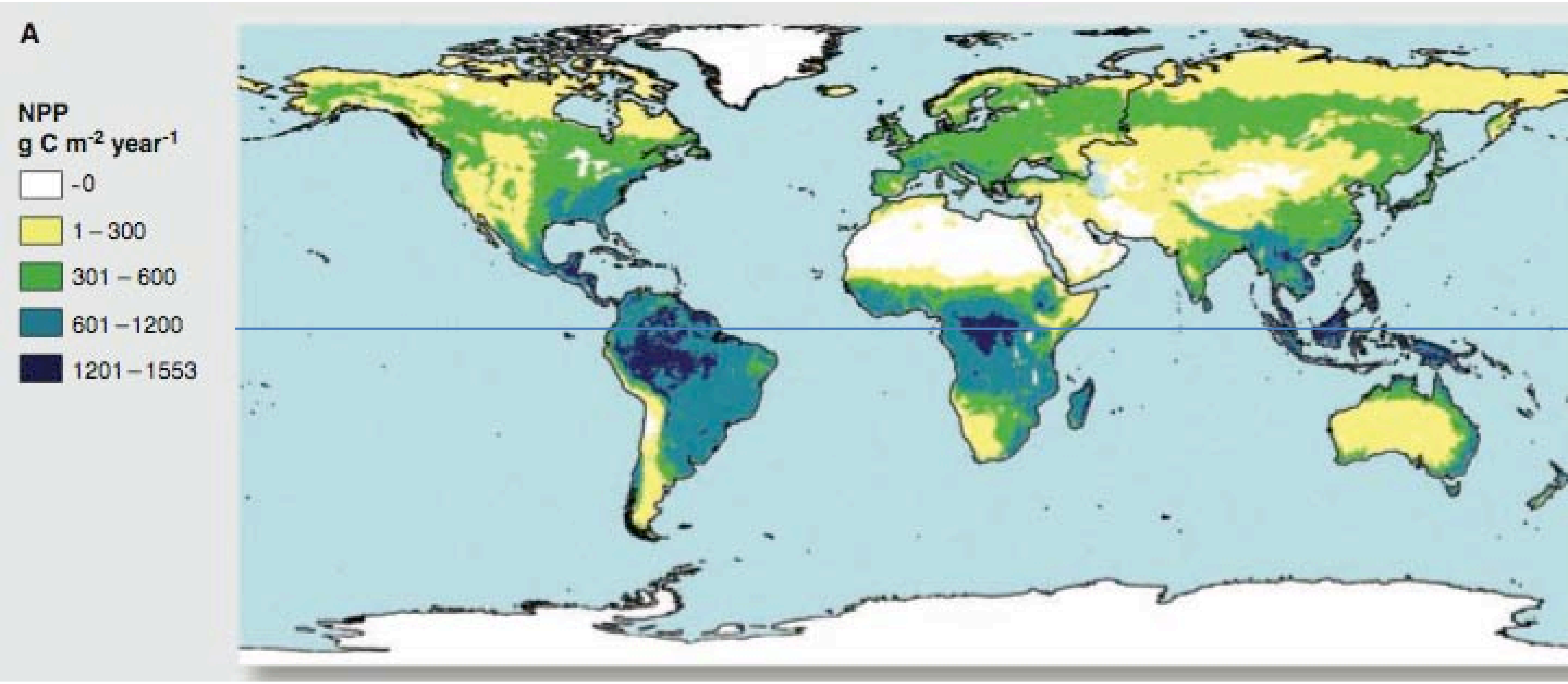


- **80-86% of global area burned: grassland and savannas, primarily in Africa, Australia, and South Asia and South America**

Krawchuk et al., 2009, PLoS ONE: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0005102

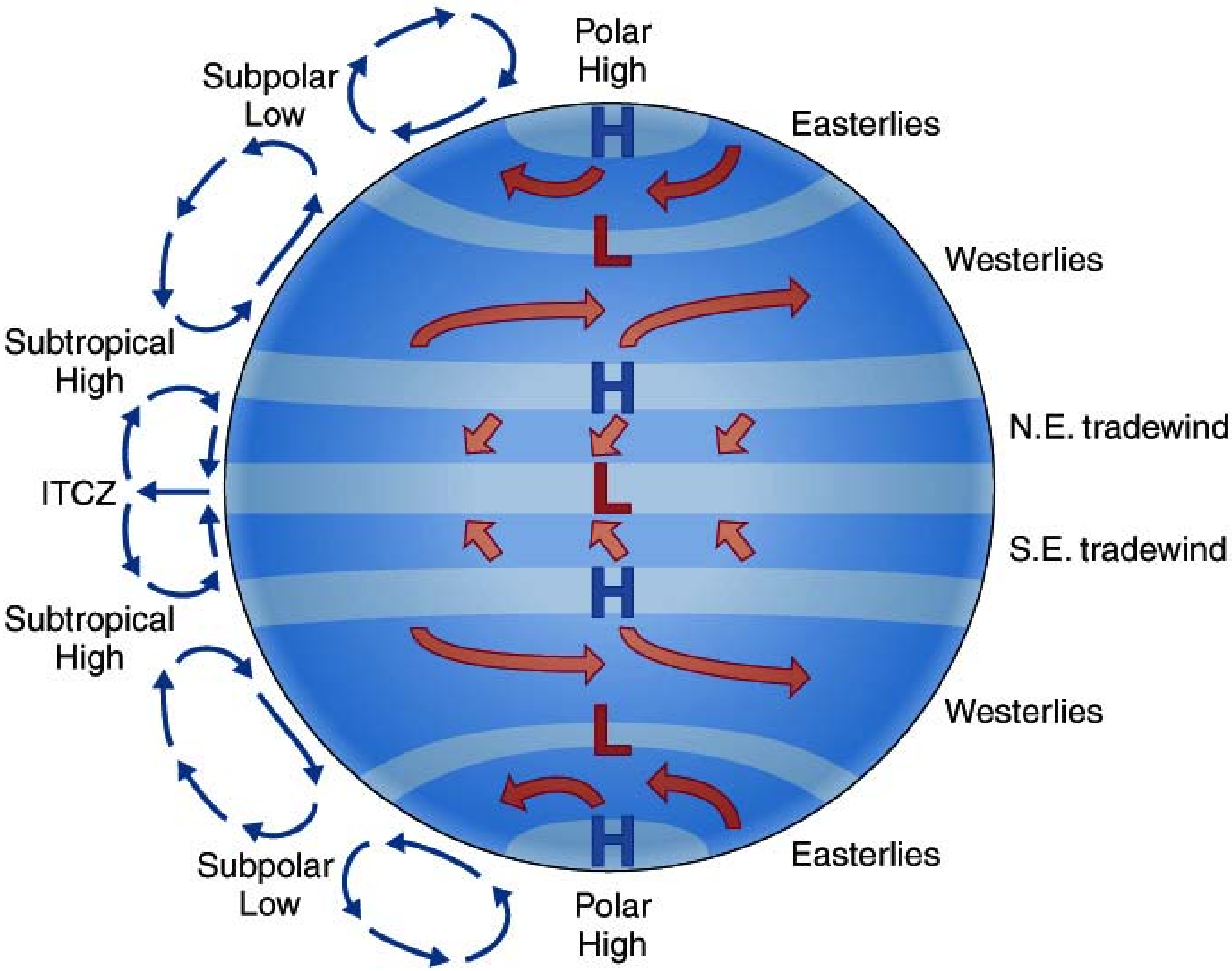
Global patterns of fire – what can we infer?

Net primary productivity (Bowman et al. 2009)

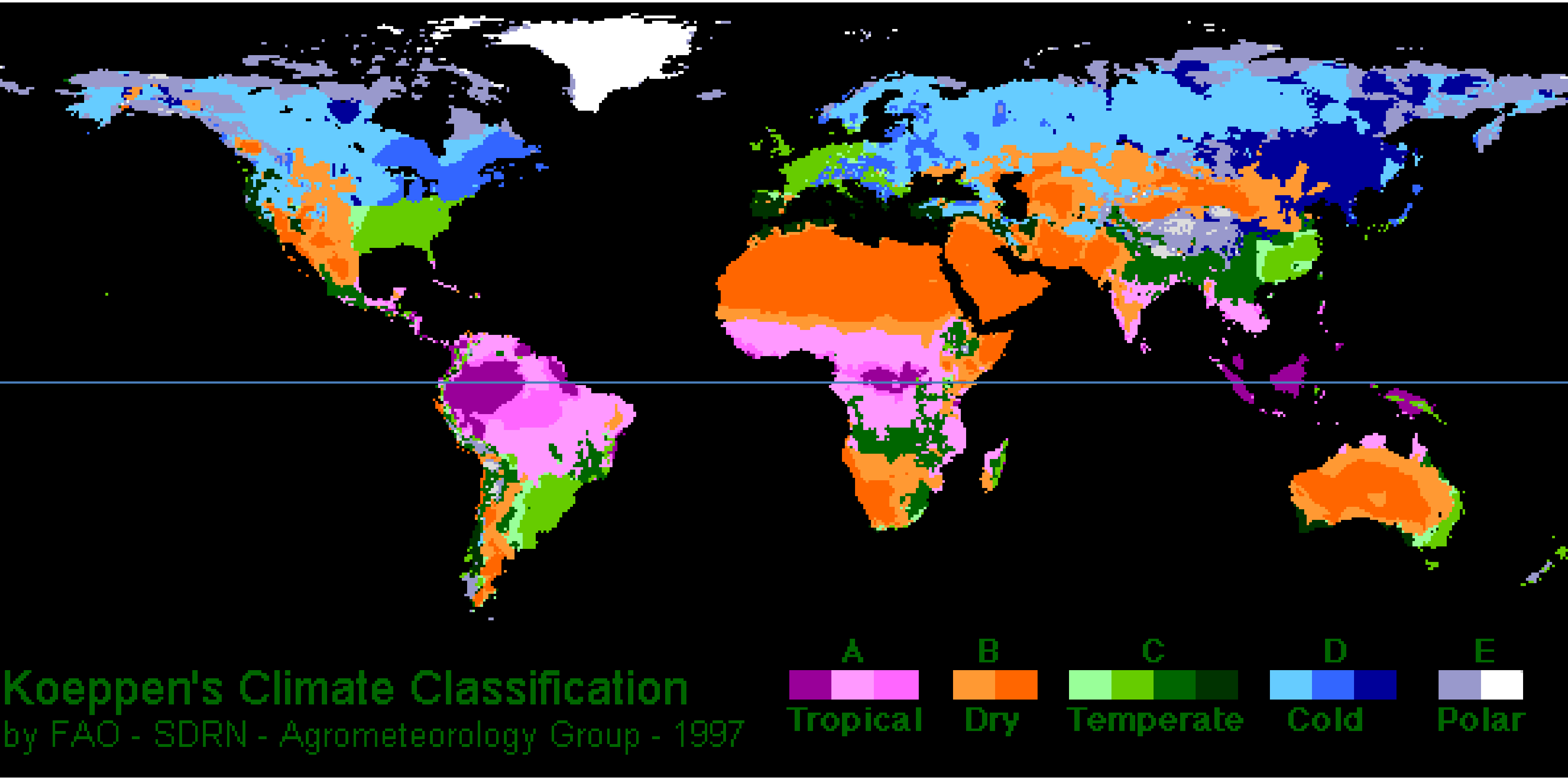


Global Atmospheric Circulation

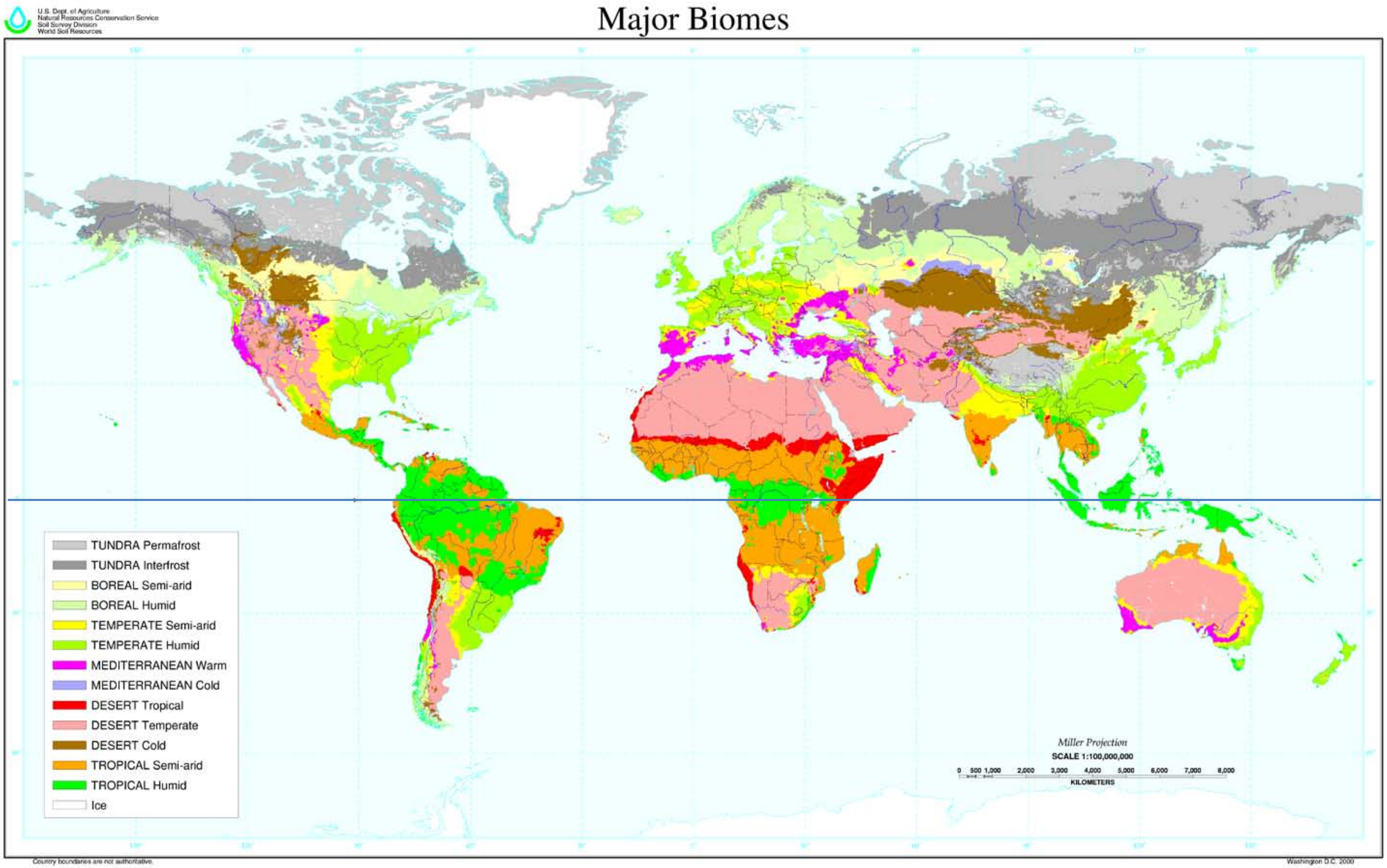
(GEOG 301, Meteorology)



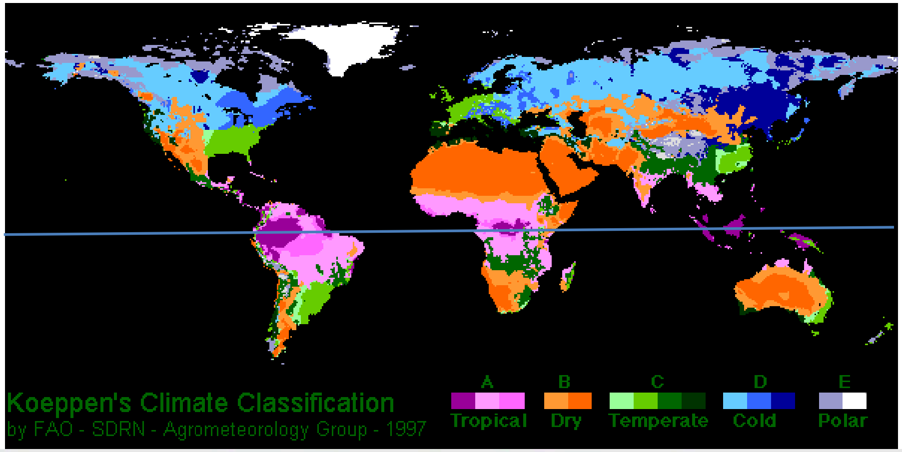
Earth’s major climates



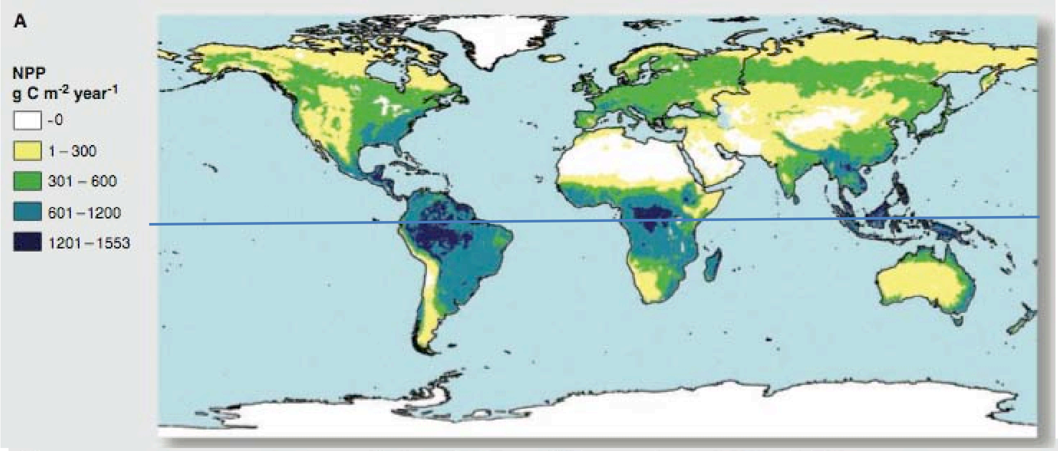
Earth’s major biomes



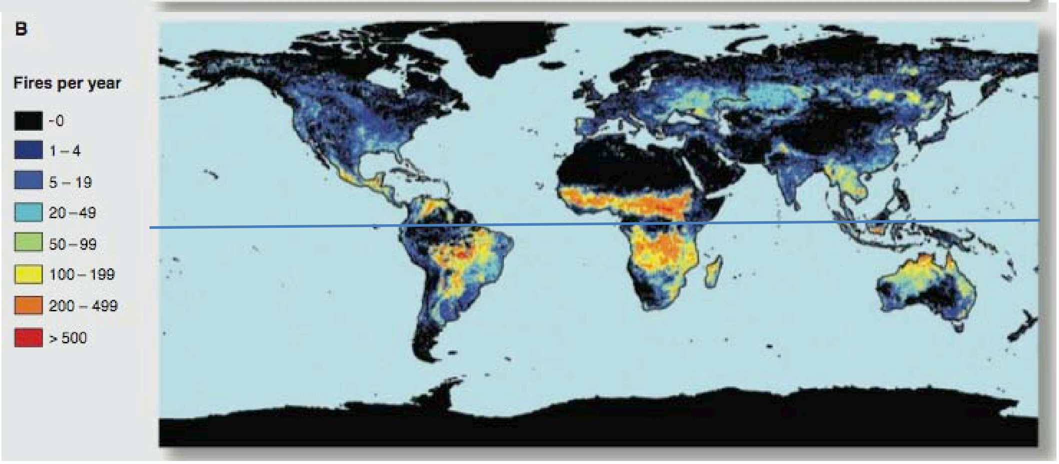
Climate Classification



Productivity (g C m^{-2} yr^{-1})



Fires (# yr^{-1})



With a neighbor or two, develop three hypotheses linking these elements, on a global scale:

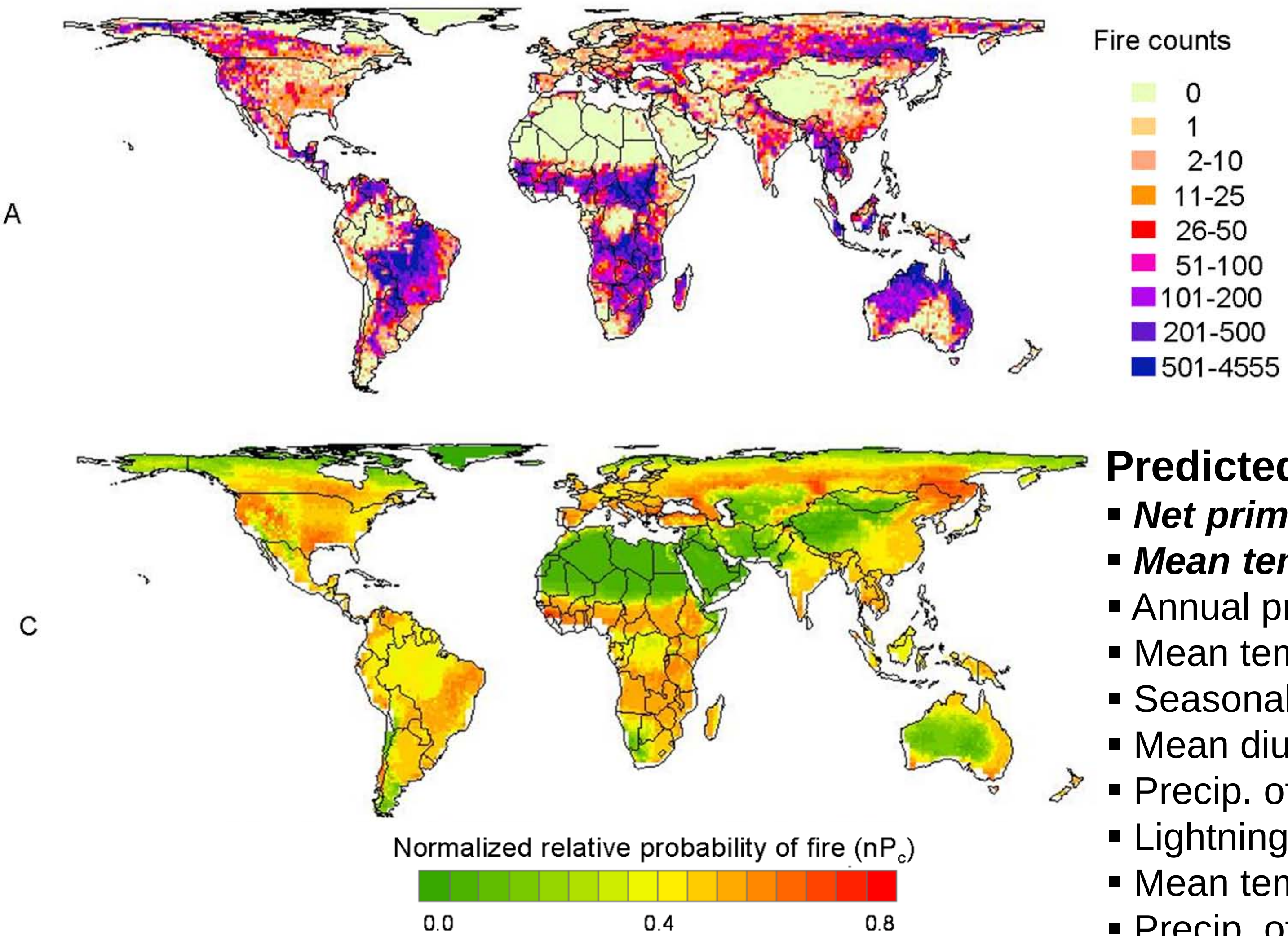
- **vegetation – fire**
- **climate – fire**
- **human – fire**

Variable	Description and Units
Climate	Derived from monthly temperature and rainfall values
Annual mean temperature	°C
Mean diurnal range	mean of monthly (max temp − min temp), °C
Isothermality	mean diurnal range/temperature annual range (×100)
Temperature seasonality	standard deviation of temperature (×100)
Maximum temperature of warmest month	°C
Minimum temperature of coldest month	°C
Temperature annual range	maximum temperature of warmest month – minimum temperature of coldest month, °C
Mean temperature of wettest month	°C
Mean temperature of driest month	°C
Mean temperature of warmest month	°C
Mean temperature of coldest month	°C
Annual precipitation	mm/year
Precipitation of wettest month	mm/day
Precipitation of driest month	mm/day
Precipitation seasonality	coefficient of variation
Precipitation of warmest month	mm/day
Precipitation of coldest month	mm/day
Vegetation	
Net primary productivity (NPP)	amount of solar energy converted to plant organic matter through photosynthesis (g C per 0.25 decimal degree cell/year).
Ignitions	
Lightning flash density	flashes/km^2/day
Human footprint	normalized gradient of human influence (0 to 100)

doi:10.1371/journal.pone.0005102.t001

Krawchuk et al., 2009, PLoS ONE: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0005102

Statistical model: Observed (top) and Predicted (bottom)

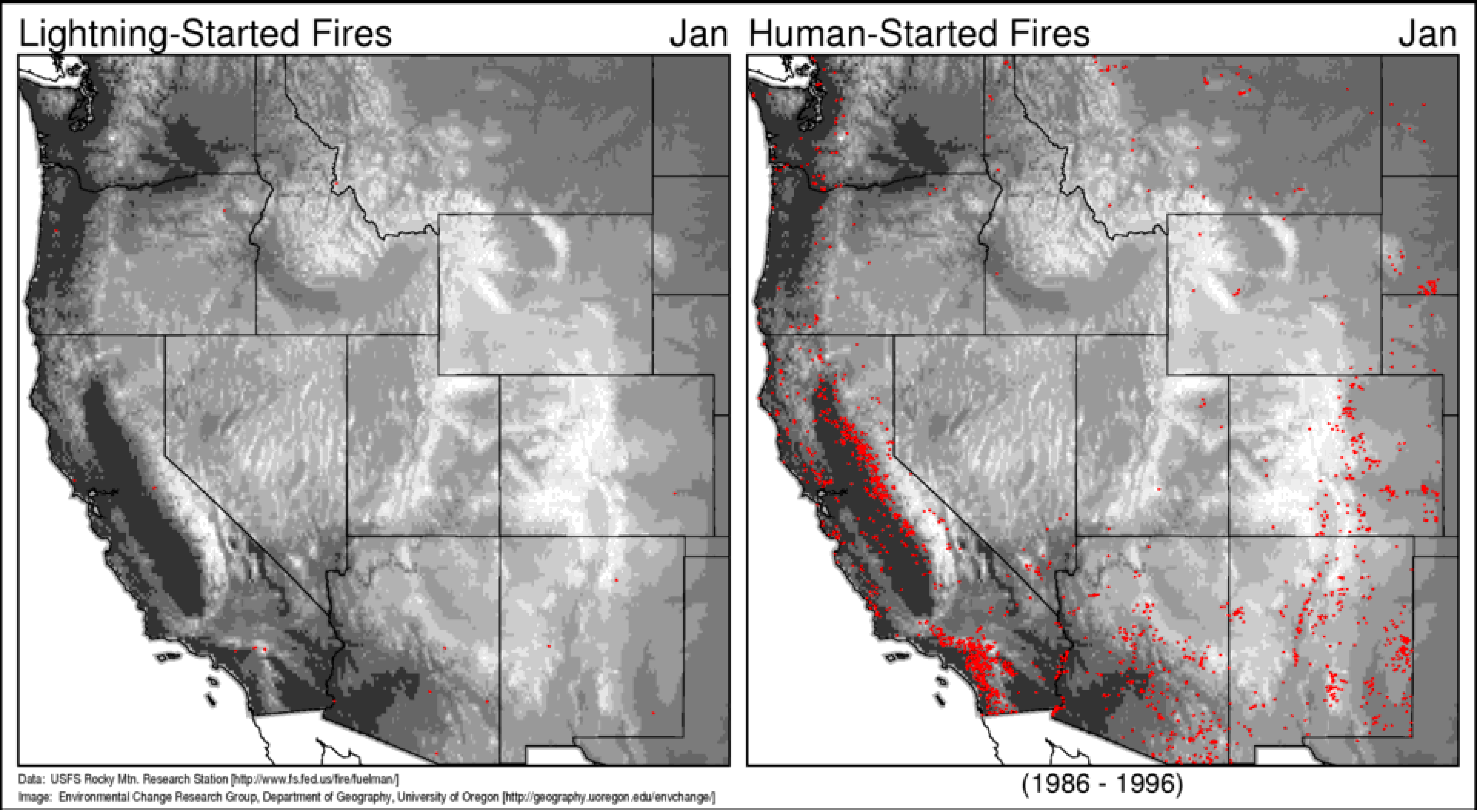


Krawchuck et al. 2009

Predicted based on (in order):

- ***Net primary productivity***
- ***Mean temp. warmest month***
- Annual precipitation
- Mean temp. wettest month
- Seasonality
- Mean diurnal range
- Precip. of driest month
- Lightning flash density
- Mean temp. driest month
- Precip. of coldest month
- Human footprint

Controls of fire across space and time



http://climate.uoregon.edu/fire/content/fire/index.htm#Monthly_Incidence-and-Area_Data

Bartlein, P.J., Hostetler, S.W., Shafer, S.L., Holman, J.O. & Solomon, A.M. (2008) Temporal and spatial structure in a daily wildfire-start data set from the western United States (1986-96). *International Journal of Wildland Fire*, **17**, 8-17.

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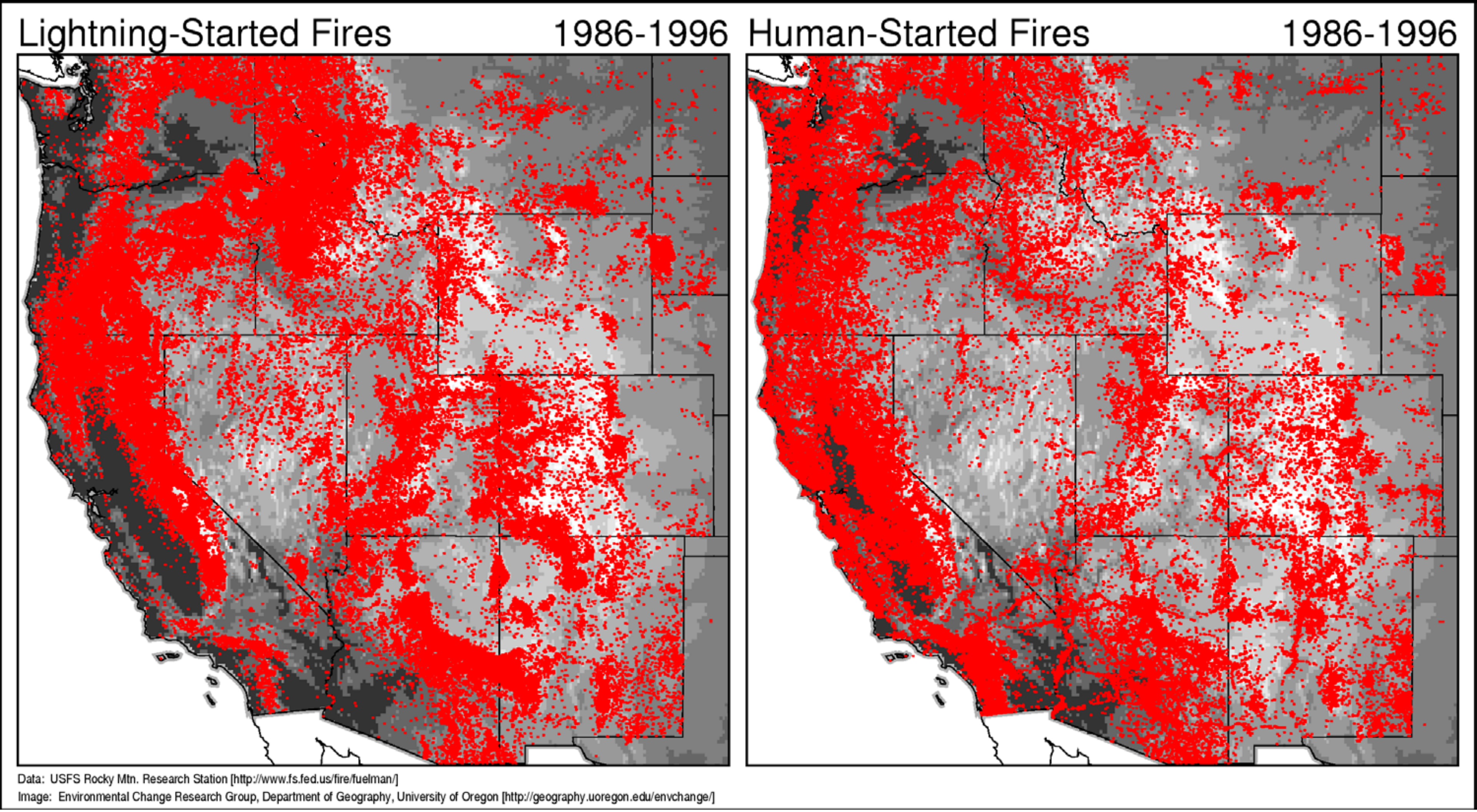

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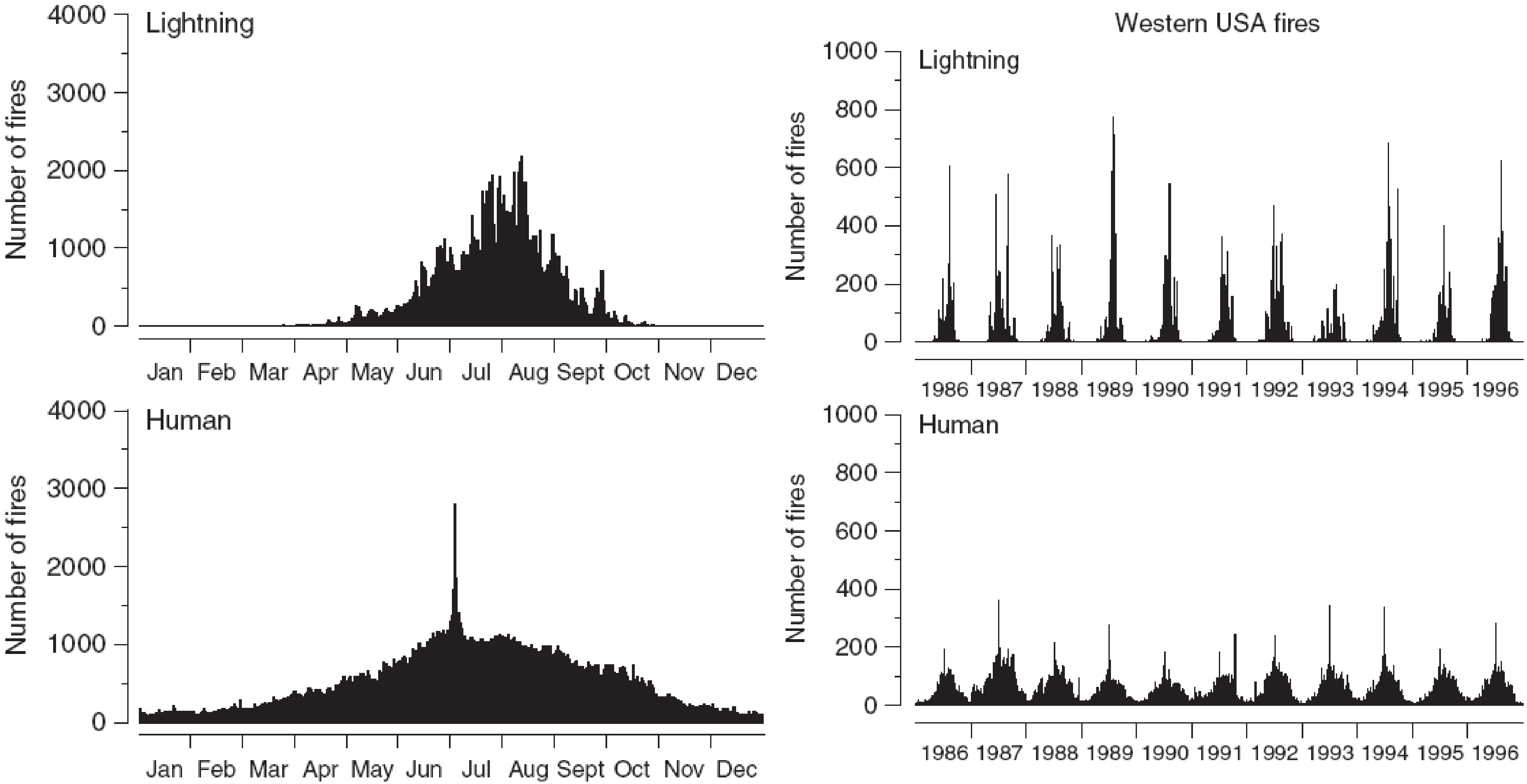

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Generalizations

1. **What explains spatial and temporal variability fire?**

Pyrogeographic framework: "fire" as an organism

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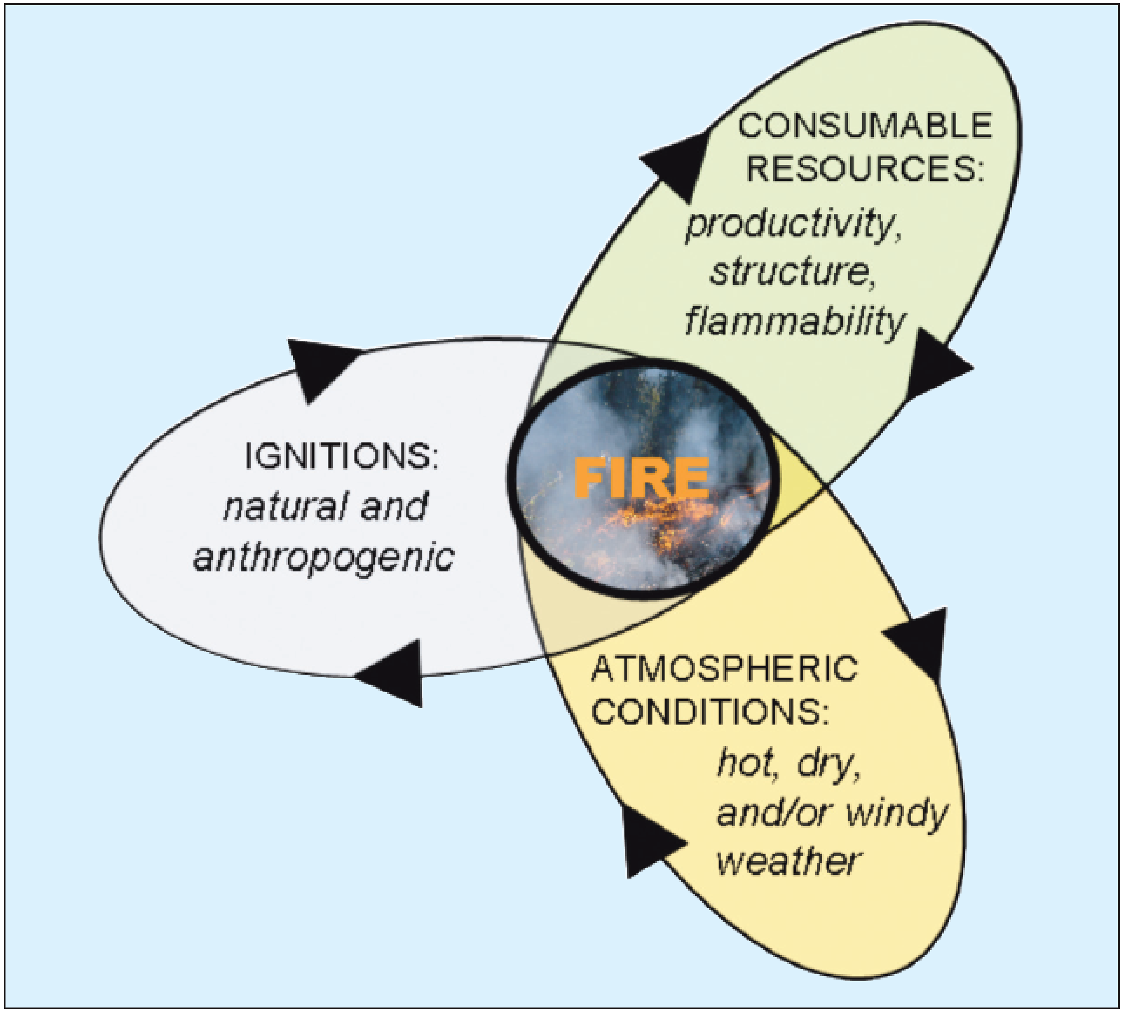
(3) Ignitions



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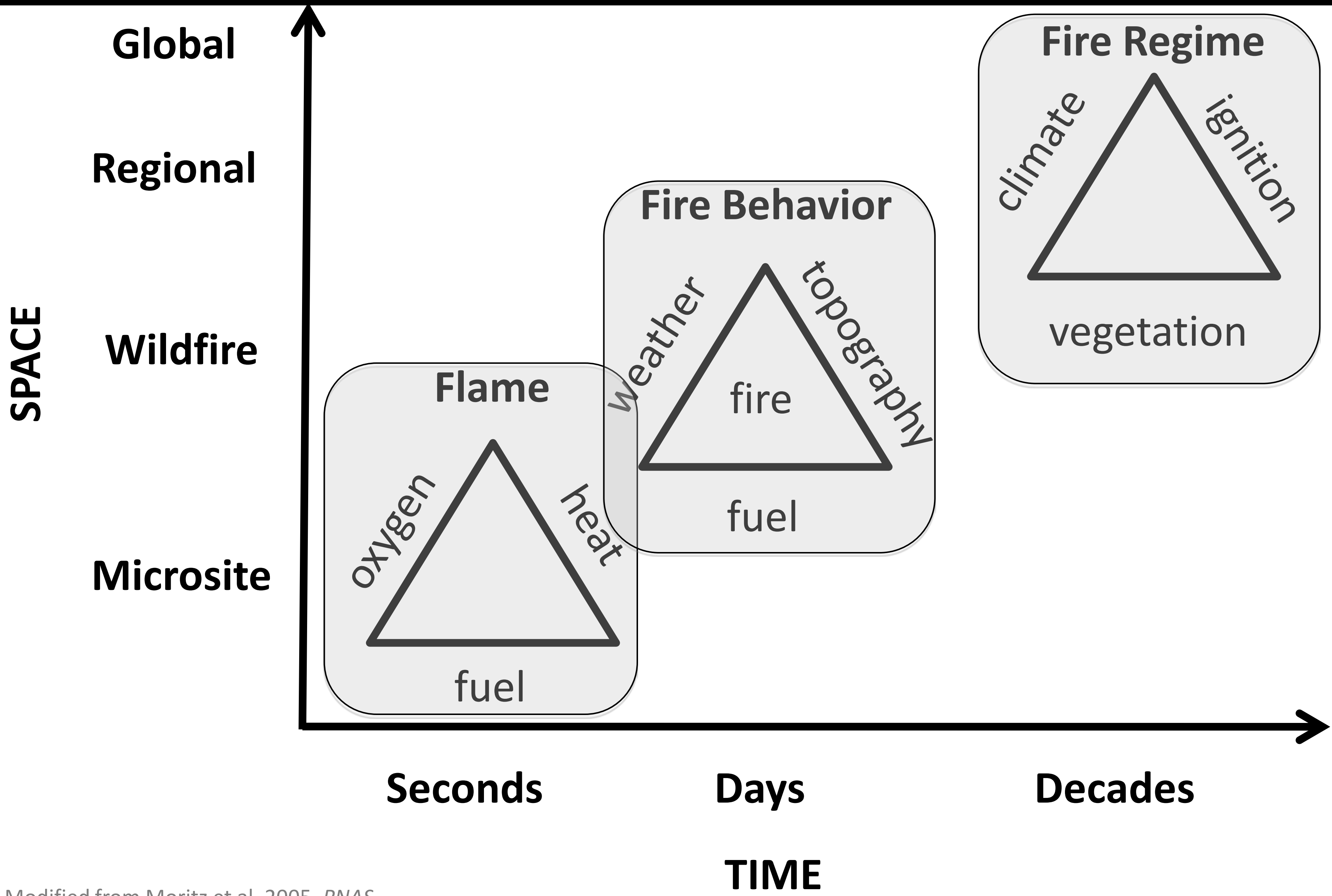
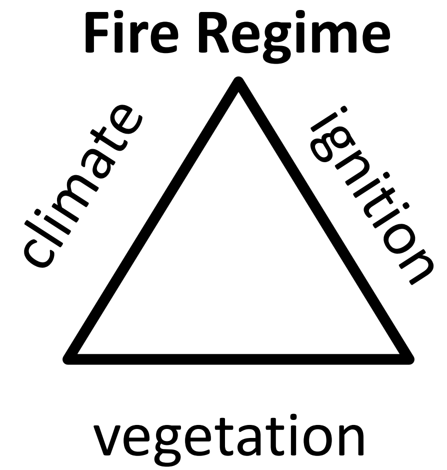
PAGES news • Vol 18 • No 2 • August 2010

Controls of fire across space and time



Modified from Moritz et al. 2005, *PNAS*

Controls of fire across space and time



- **Climate-limited:**

Abundant fuels, but lacking atmospheric conditions needed to dry fuels and promote fire ignition and spread

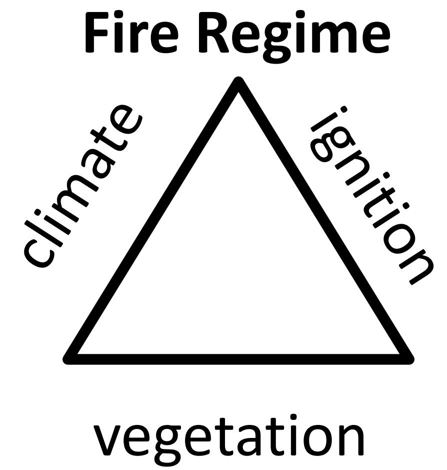
Climate-limited fire regimes: boreal forest

Wildfire in boreal forest of Alaska, 2006

Climate-limited fire regimes: subalpine forest

Needles Fire of 2003, in subalpine forest near Harts Pass, WA

Controls of fire across space and time



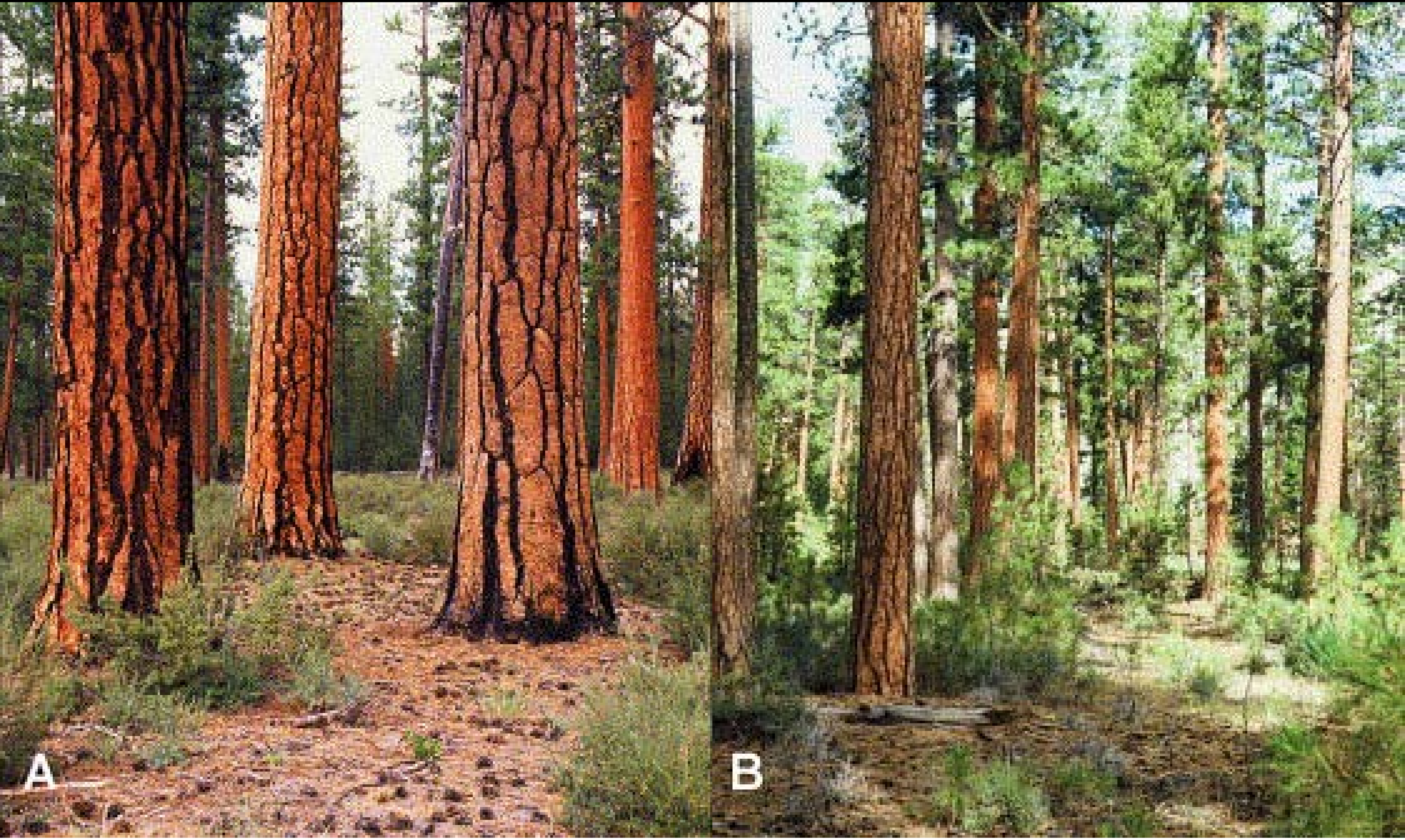
- **Climate-limited:**

Abundant fuels, but lacking atmospheric conditions needed to dry fuels and promote fire ignition and spread

- **Fuels-limited:**

Atmospheric conditions needed to dry fuels and promote fire ignition and spread are common, but fire ignition and spread limited by a lack of continuous fuel

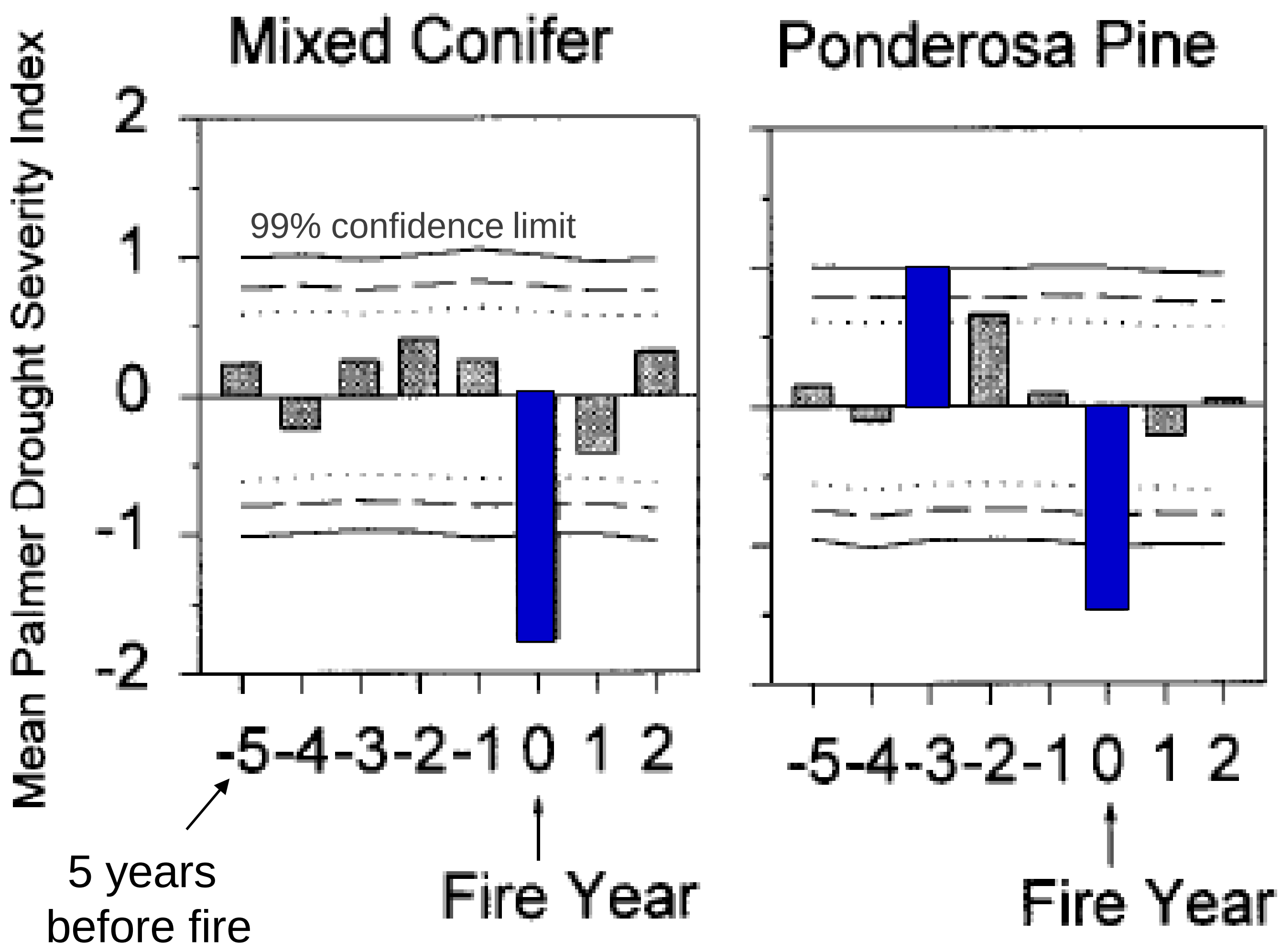
Fuels-limited fire regimes: ponderosa pine



Hessburg, P.F., Agee, J.K., and Franklin, J.F. 2005. Dry forests and wildland fires of the inland Northwest USA: Contrasting the landscape ecology of the pre-settlement and modern eras. Forest Ecology and Management, 211, 117-139.

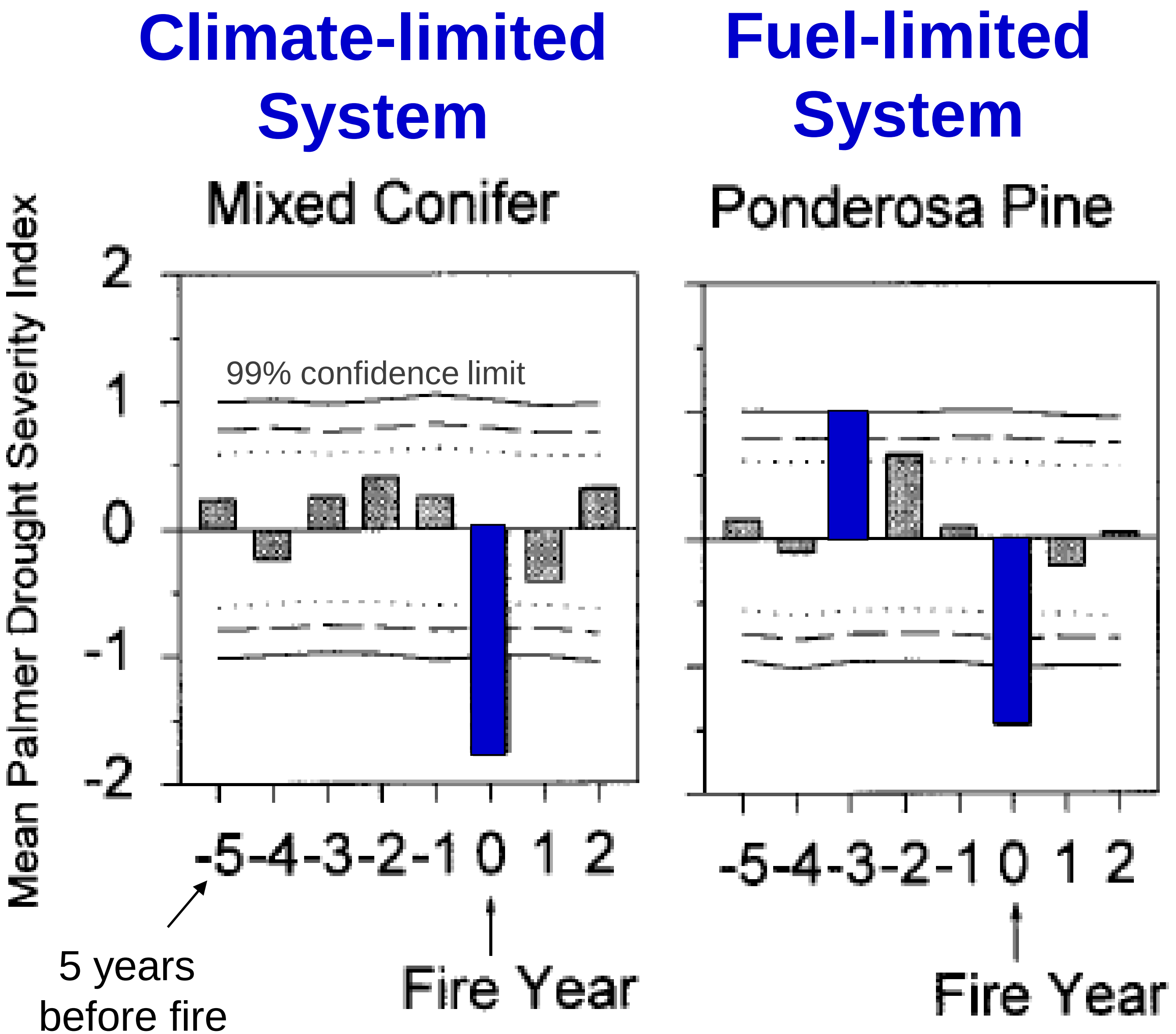
Climate- vs. Fuels-limited fire regimes

- **Drought during year of fire**
- **Moist conditions prior to fire *in low-severity fire regimes.***



Swetnam and Betancourt. 1997

Climate- vs. Fuels-limited fire regimes



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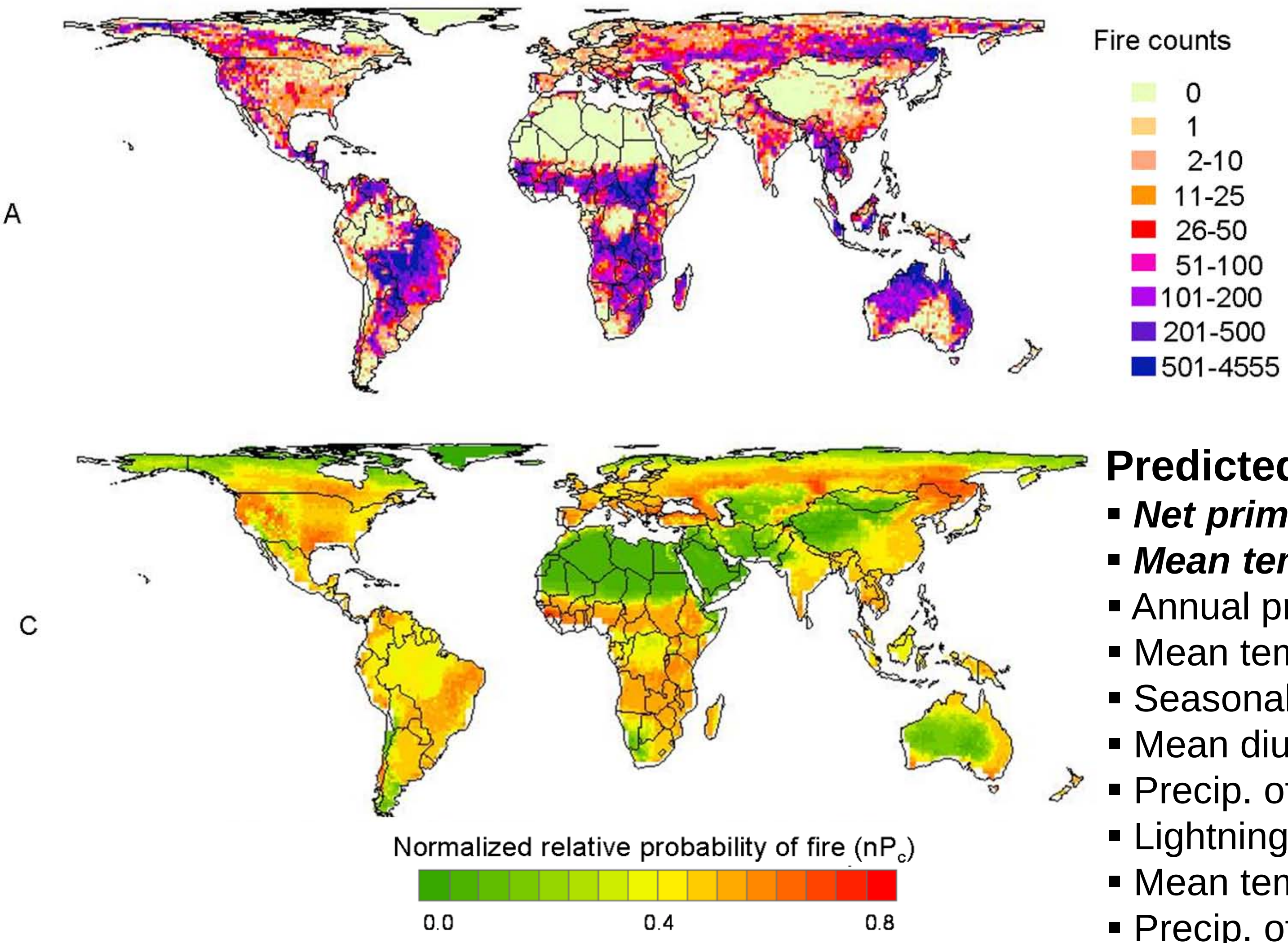

Predicted based on (in order):

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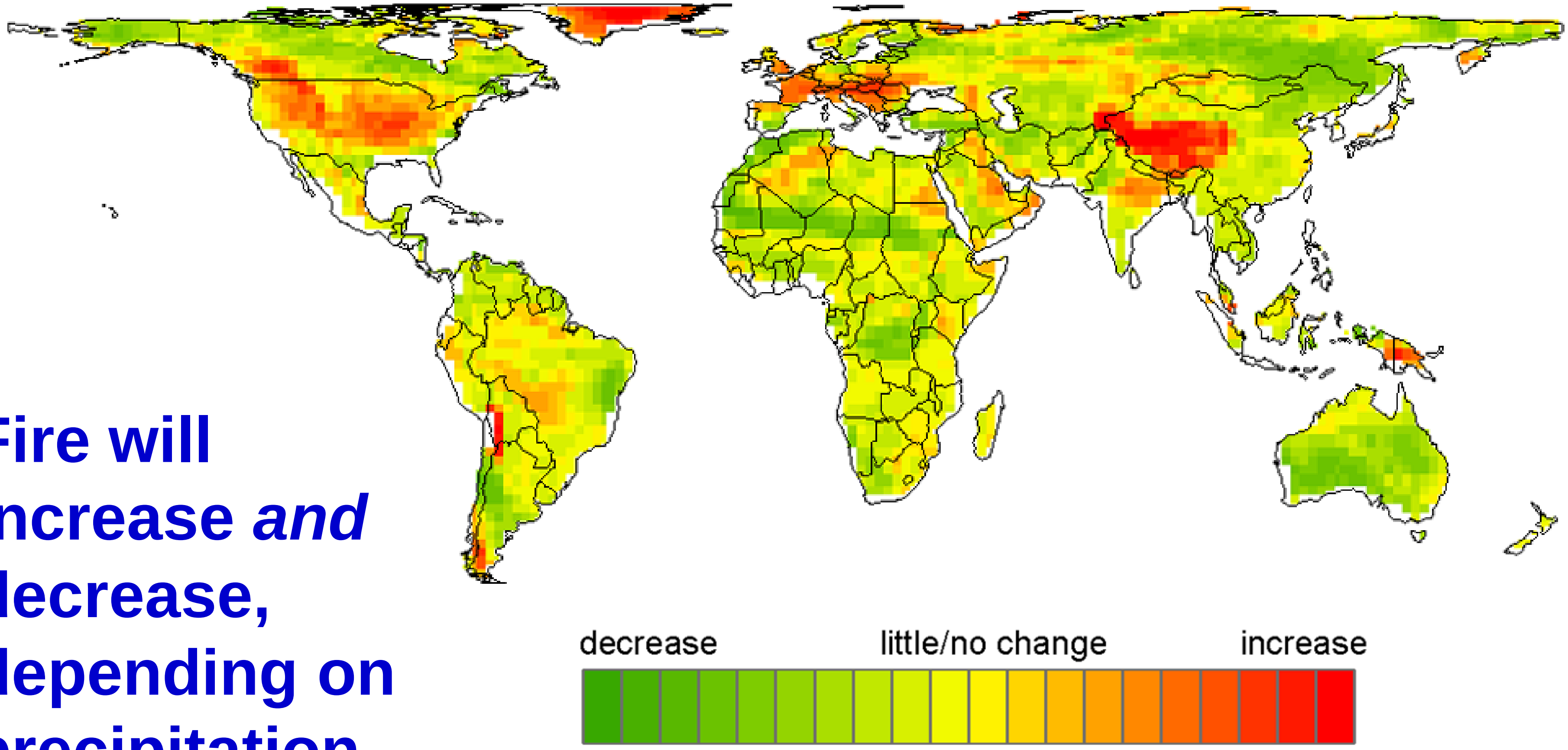
- Human footprint

Krawchuck et al. 2009

Climate Change and Global Fire

- **A2 scenario, 2040-2069, $FIRE_{NPP}$**



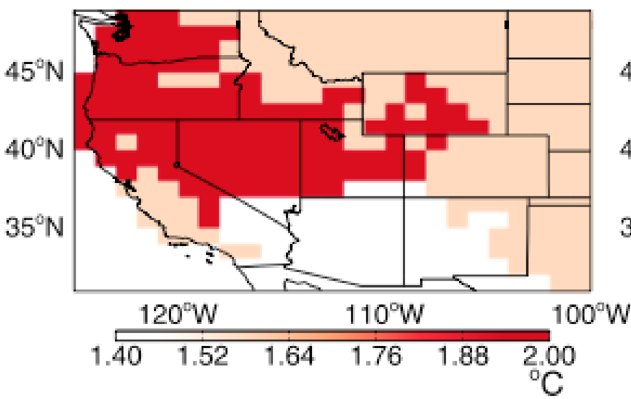
- **Fire will increase *and* decrease, depending on precipitation**

Krawchuk et al., 2009, PLoS ONE: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0005102

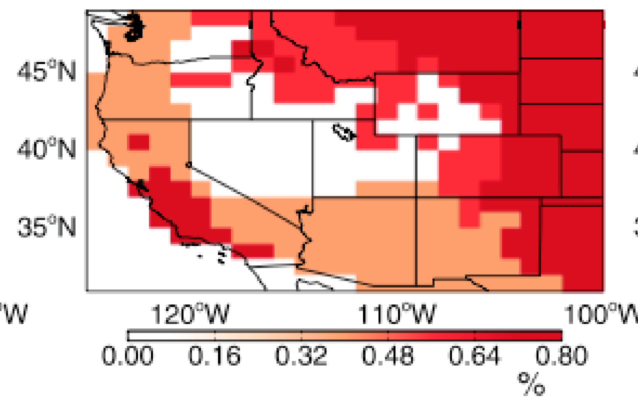
Climate Change and Regional Fire

Western US: climate and fire, 2045-2055

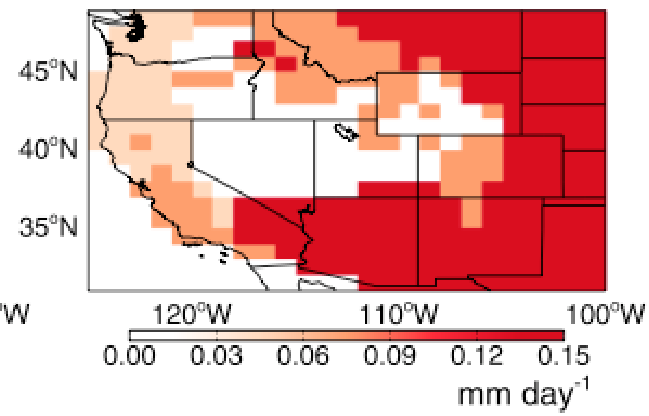
Δ Temperature



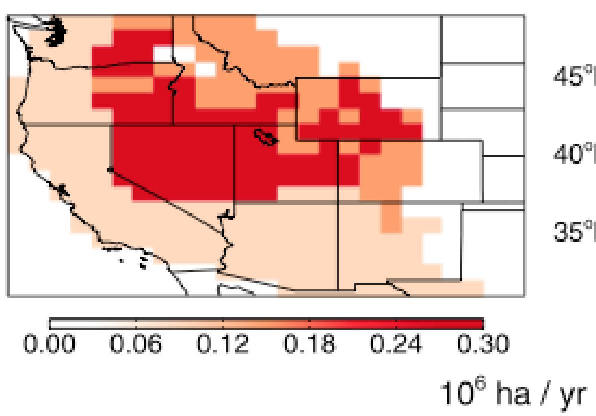
Δ Humidity



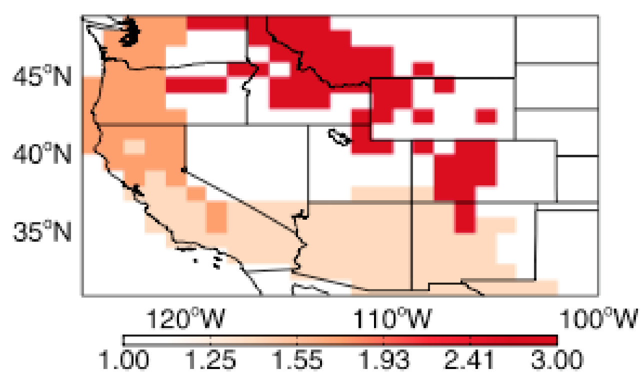
Δ Precipitation



Present day Area Burned



Future / Present



Rocky Mountain forests: ****2.75 x increase by 2050s***

Western US: ***1.54 x increase by 2050***

Spracklen et al. 2009. Climate Change, Wildfire and Aerosols. Geophysical Research Letters.

Summary

- **Fire requires (1) consumable resources, (2) atmospheric conditions (moisture deficit, wind), and (3) ignitions**

- **Broadly, fire can be considered fuel- or climate-limited**

- **When limitations change…fire activity changes, as expected with ongoing and future climate change**

Questions?

High severity 1988 fire in subalpine forest of Yellowstone National Park.