Tundra Burning in Alaska: Rare event or harbinger of climate change?

Presented By: Dr. Philip Higuera, University of Idaho

Hosted By: Jennifer Northway, AFSC

http://akfireconsortium.uaf.edu

May 24, 2012

Alaska Fire Science Consortium

Tundra burning in Alaska: Rare events or harbinger of climate change?

AFSC Webinar, May 24th, 2012

Philip Higuera[1]
Jennifer Barnes[2], Paul Duffy[3], Feng Sheng Hu[4]
Melissa Chipman[4], Ryan Kelly[4], Adam Young[1]

[1]U. Idaho, [2]NPS, [3]Neptune Inc., [4]U. Illinois

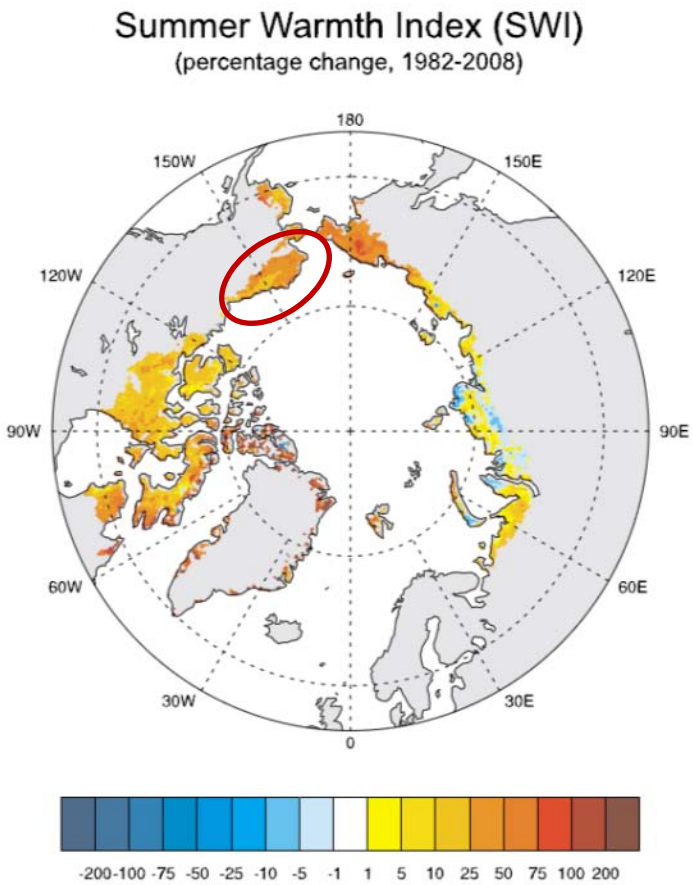
Joint Fire Science Program
Research Supporting Sound Decisions

National Science Foundation

Tundra burning in Noatak National Preserve; NPS staff

Arctic Environmental Change

24% mean increase in summer warmth



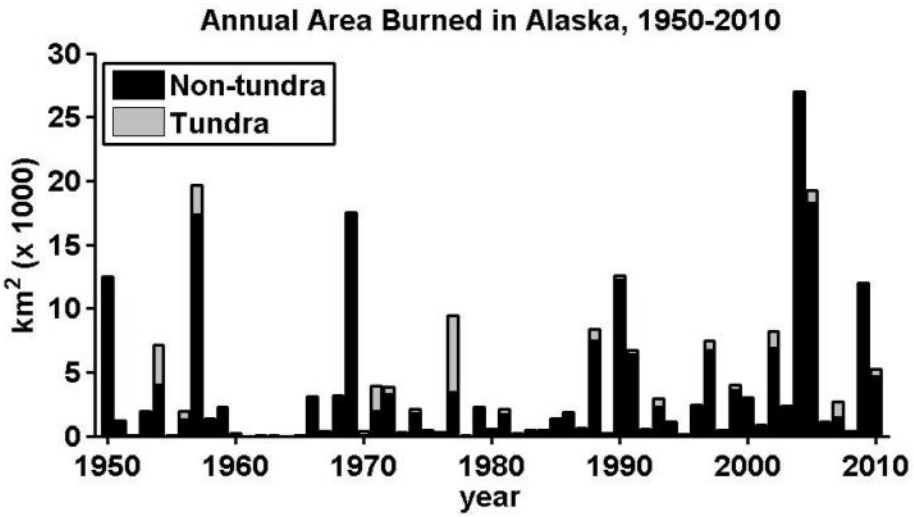
Shrub expansion and ↑ NPP

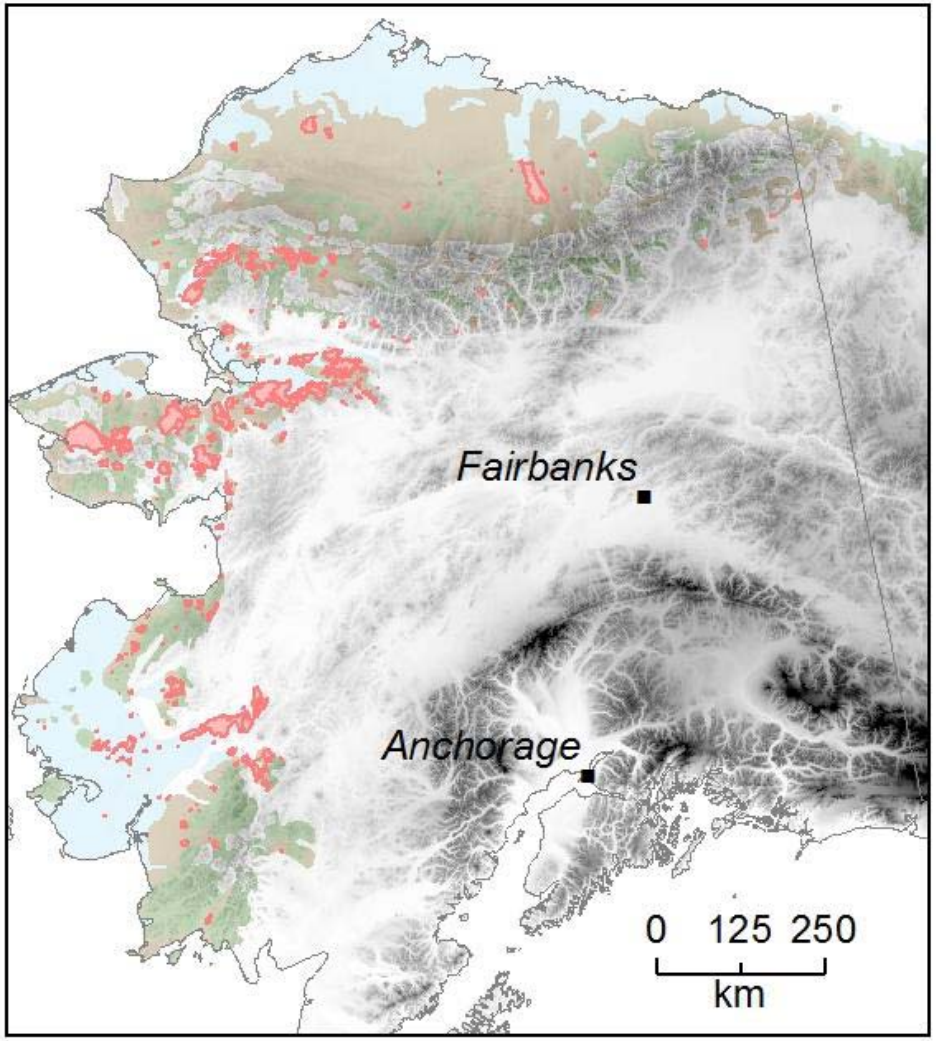
Will tundra burning increase?

Bhatt et al. 2010

Stow et al. 2004

Fire in the Far North





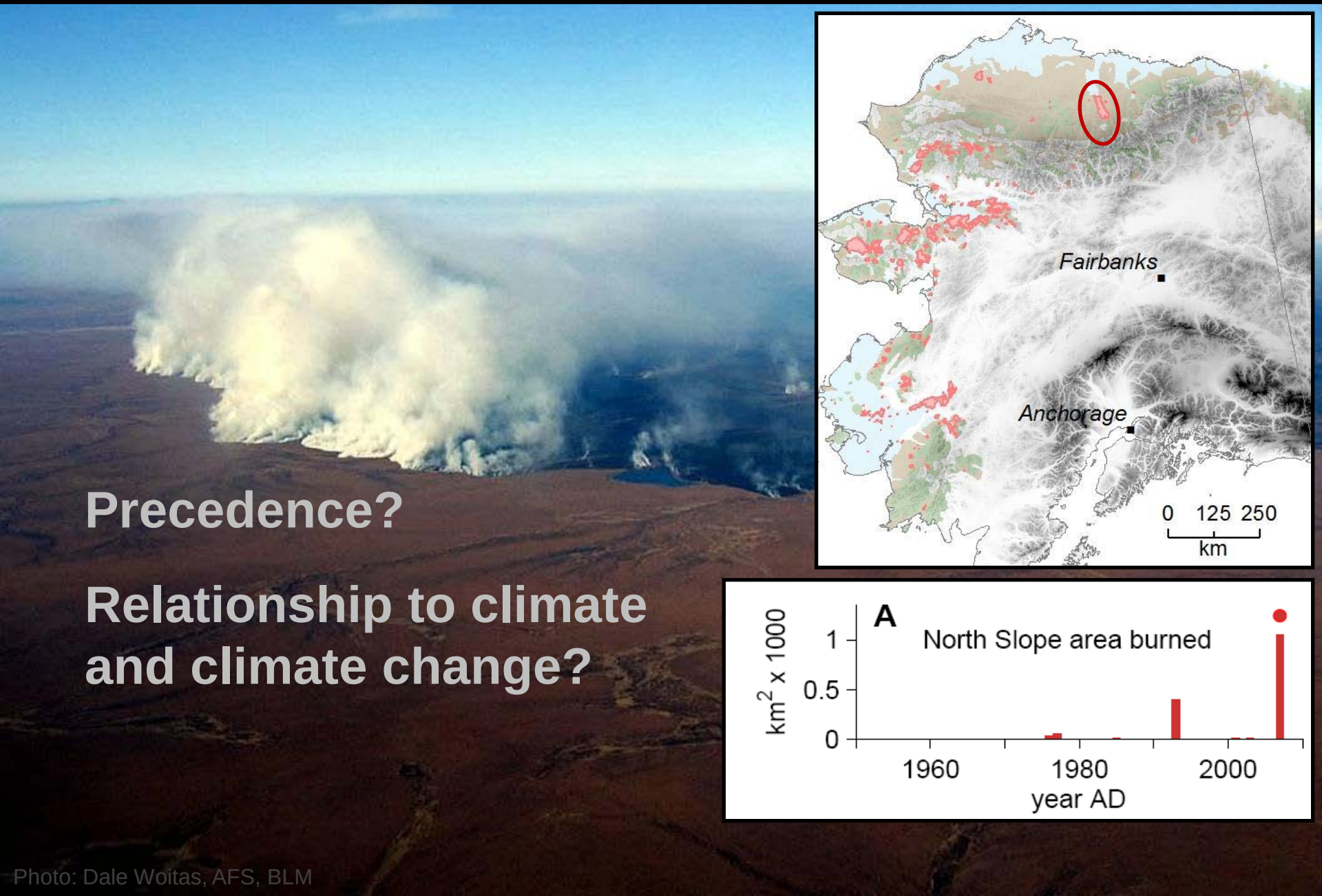
- **≈ 90% area burned in boreal forest**
- **> 2.5 million ha**, 6.2 million acres **burned in tundra (≈ 41,000 ha / yr,** 100,000 acres / yr**)**
- **2243 citations: "boreal forest + fire"**
- **230 citations: "tundra + fire"**

Overarching questions

What will happen to tundra ecosystems as climate warms?

1. **Is ongoing burning unprecedented in the context of *natural variability*?**
2. **What controls tundra burning?**
3. **What can we expect in the future?**

2007 Anaktuvuk River Fire



Precedence?

Relationship to climate and climate change?

Photo: Dale Woitas, AFS, BLM

http://www.nteinternain.com/inventory.asp?CatId=

Paleoecology – reconstructing the past

Anaktuvuk River Fire, North Slope, Alaska (2008)

http://www.riteintherain.com/inventory.asp?CatID=

Paleoecology – reconstructing the past

pollen:

charcoal:

macrofossils:

Anaktuvuk River Fire, North Slope, Alaska (2008)

http://www.riteintherain.com/inventory.asp?CatID=

Paleoecology – reconstructing the past

pollen:

charcoal:

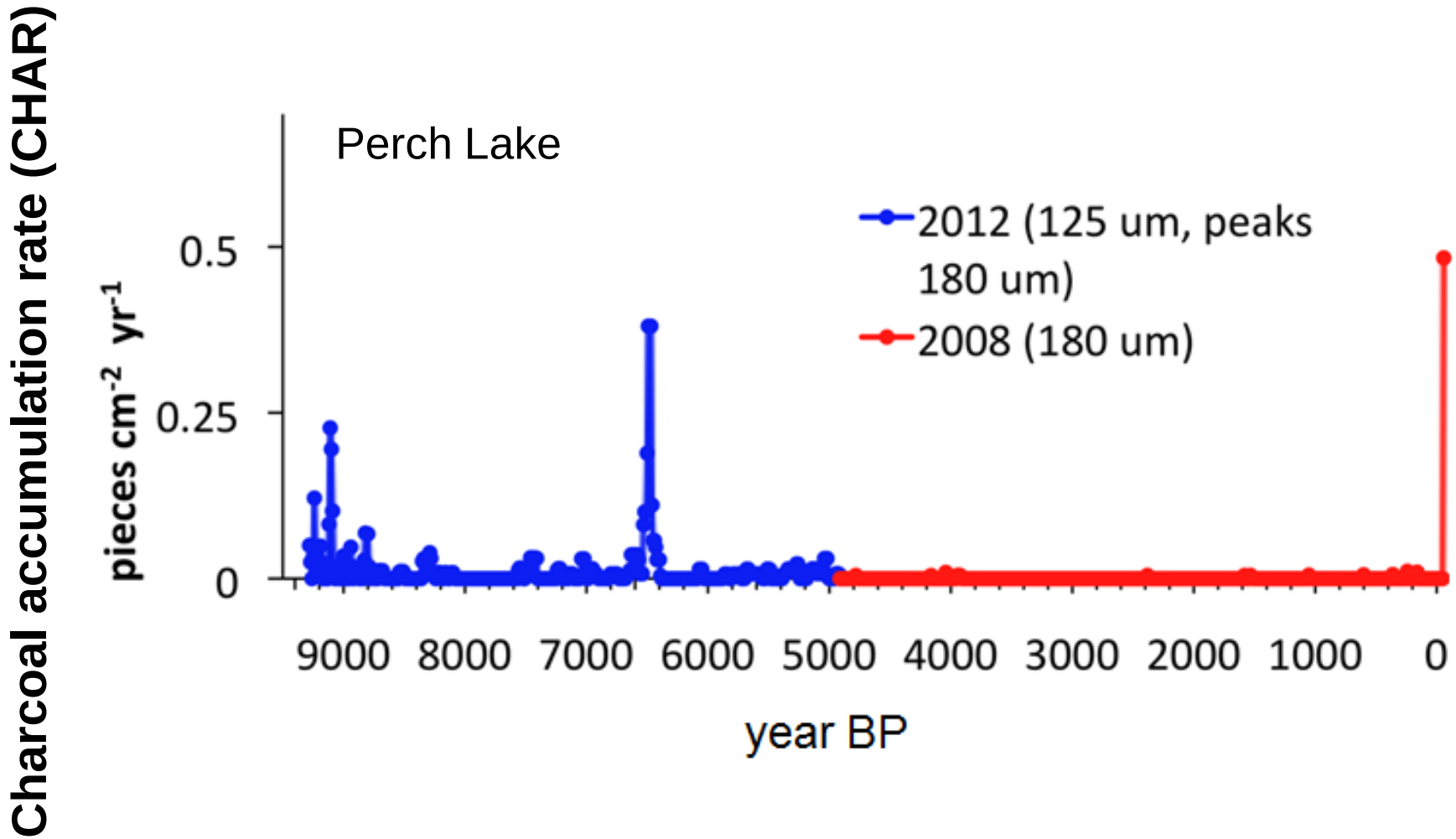
macrofossils:

Anaktuvuk River Fire, North Slope, Alaska (2008)

Unprecedented in at least 5000 years!

Hu, Higuera, et al. 2010, JGR

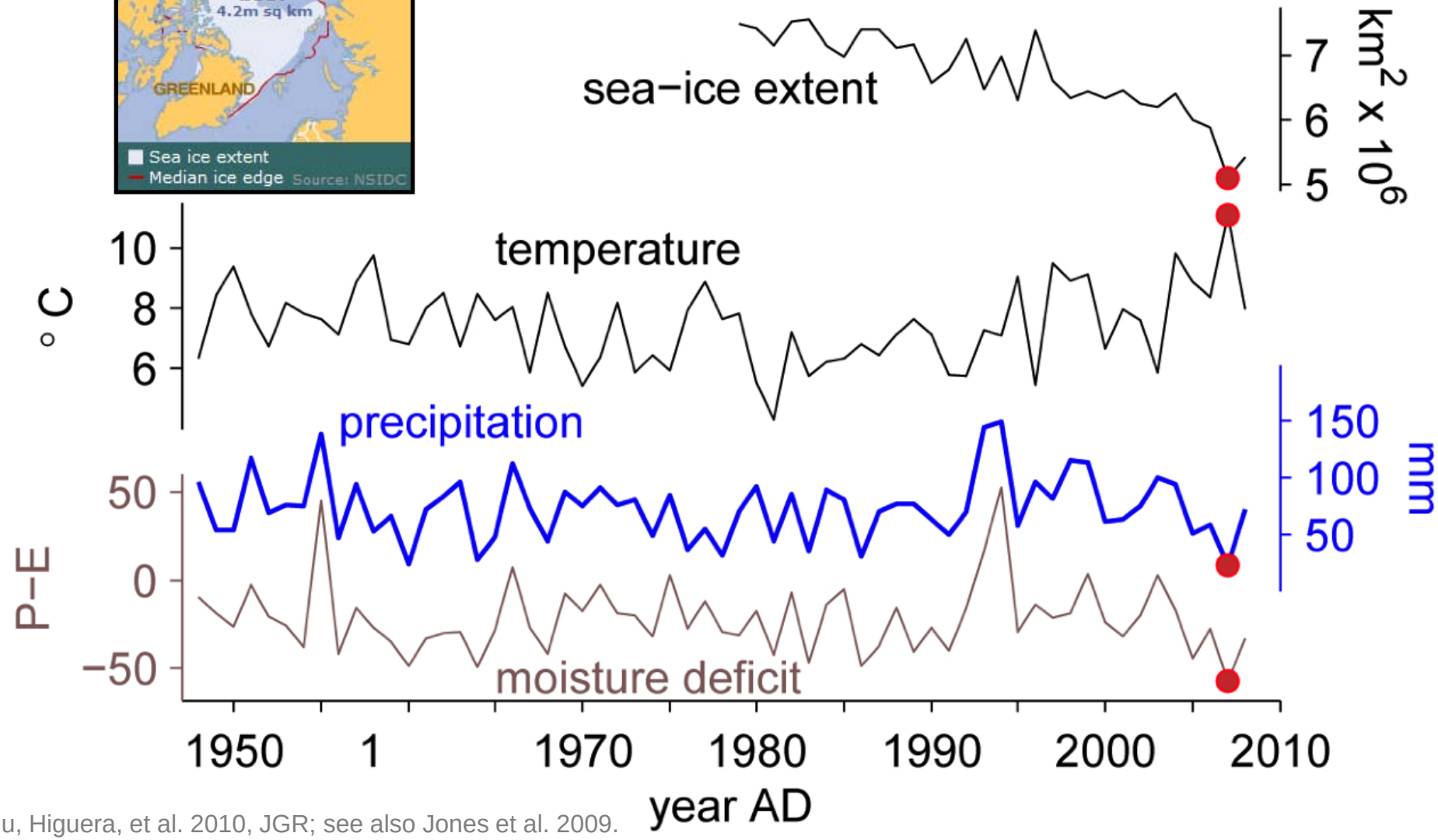
But what about before…?
Return intervals of 2500-6500 yr



Chipman et al., in progress

Coincident with highly unusual seasonal climate

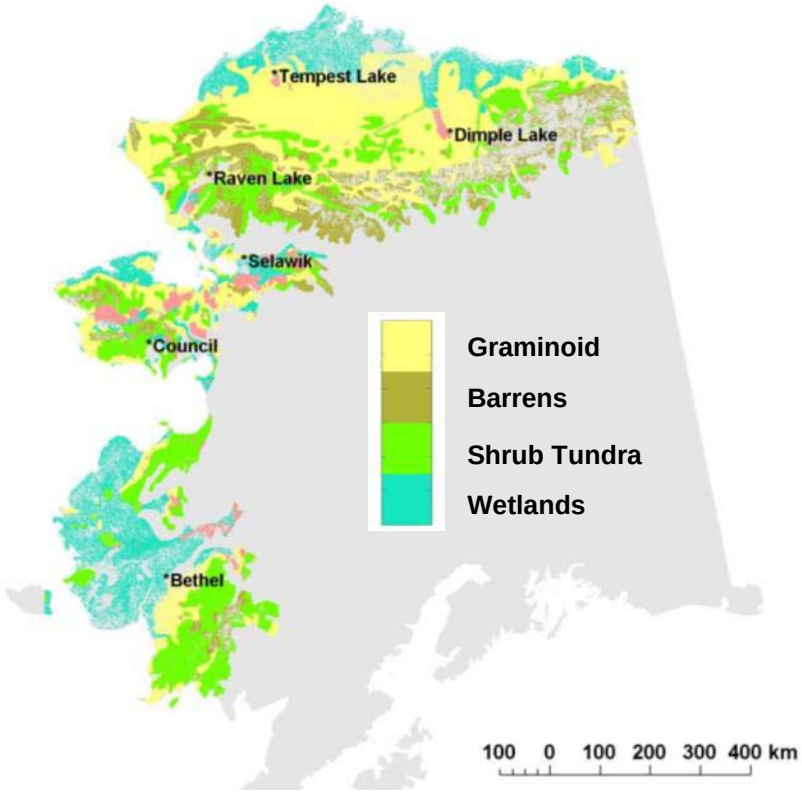
June, July, Aug., Sep. averages:



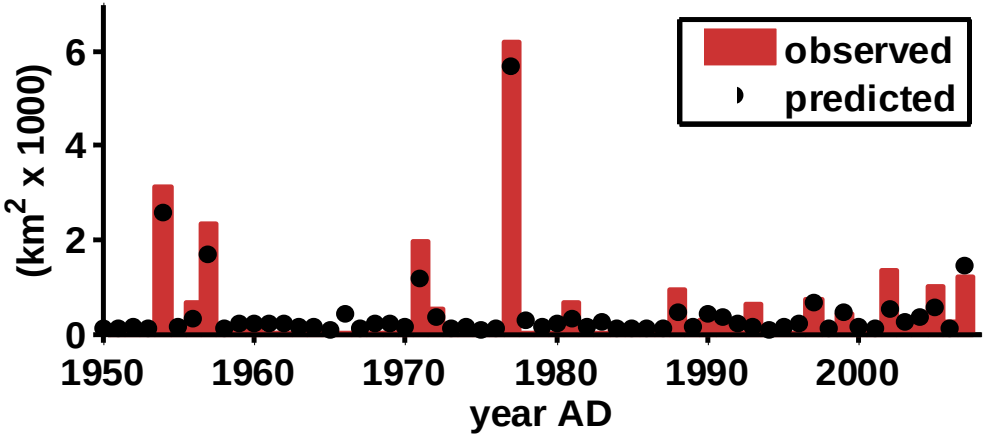
Hu, Higuera, et al. 2010, JGR; see also Jones et al. 2009.

- Warm, dry growing season

Tundra Vegetation with AK Fire History

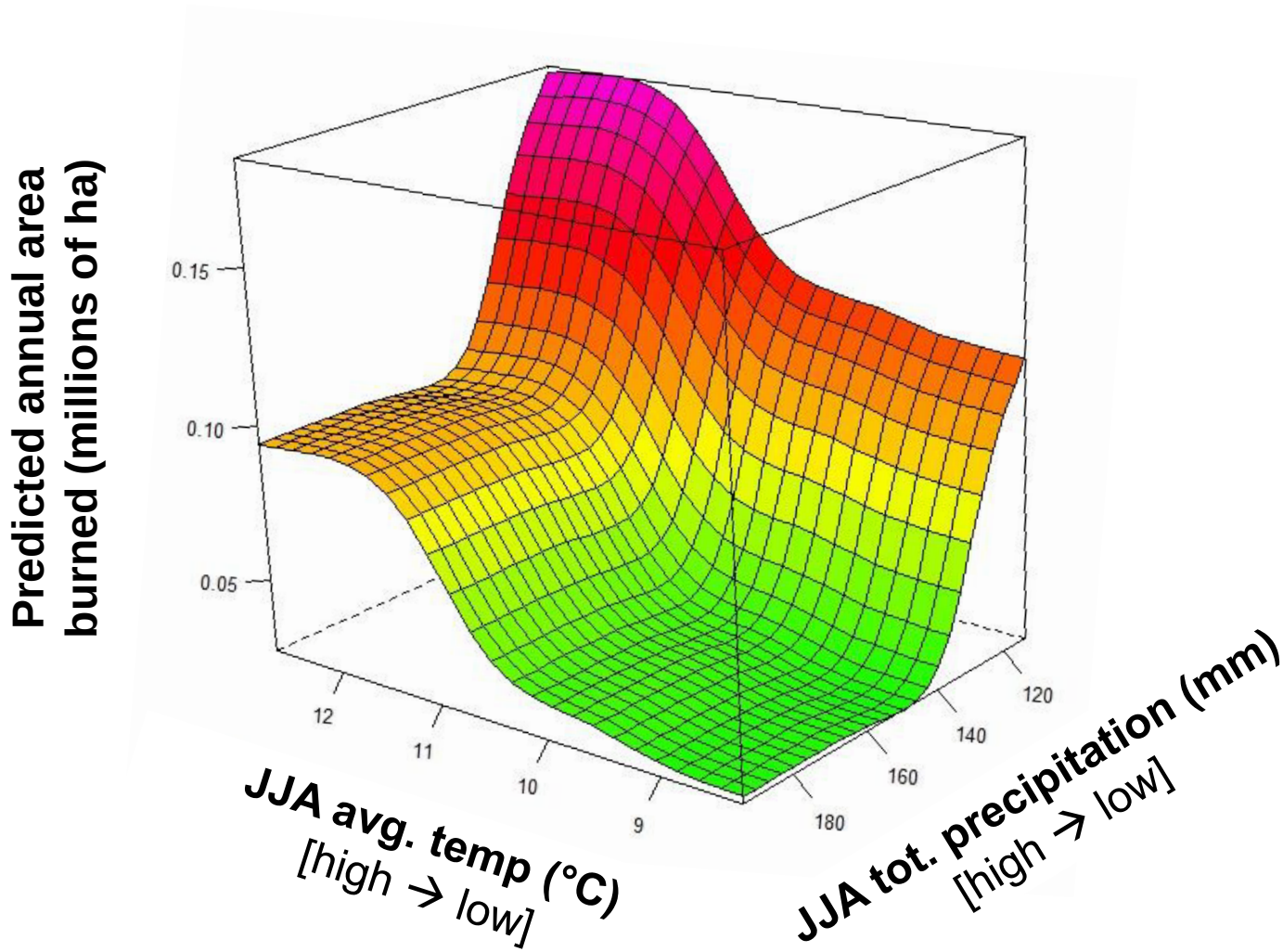


Tundra area burned in Alaska: $r^2 = 0.94$



Hu, et al. 2010, JGR, Duffy et al., ongoing work

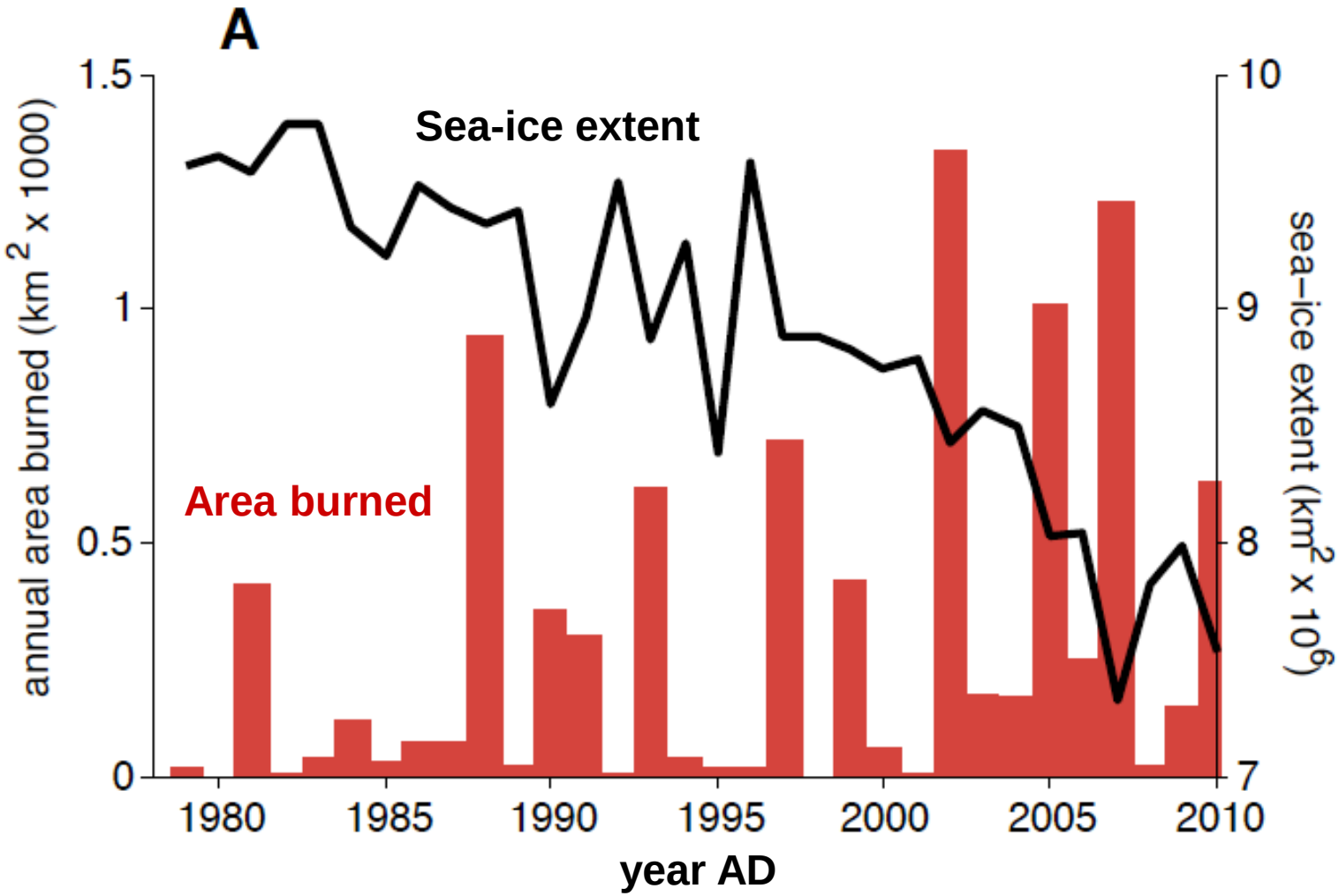
- Nonlinear response to seasonal (JJA) temp. and precip.



Hu, et al. 2010, JGR, Duffy et al., ongoing work

Surprises:

- Sea-ice extent (?)

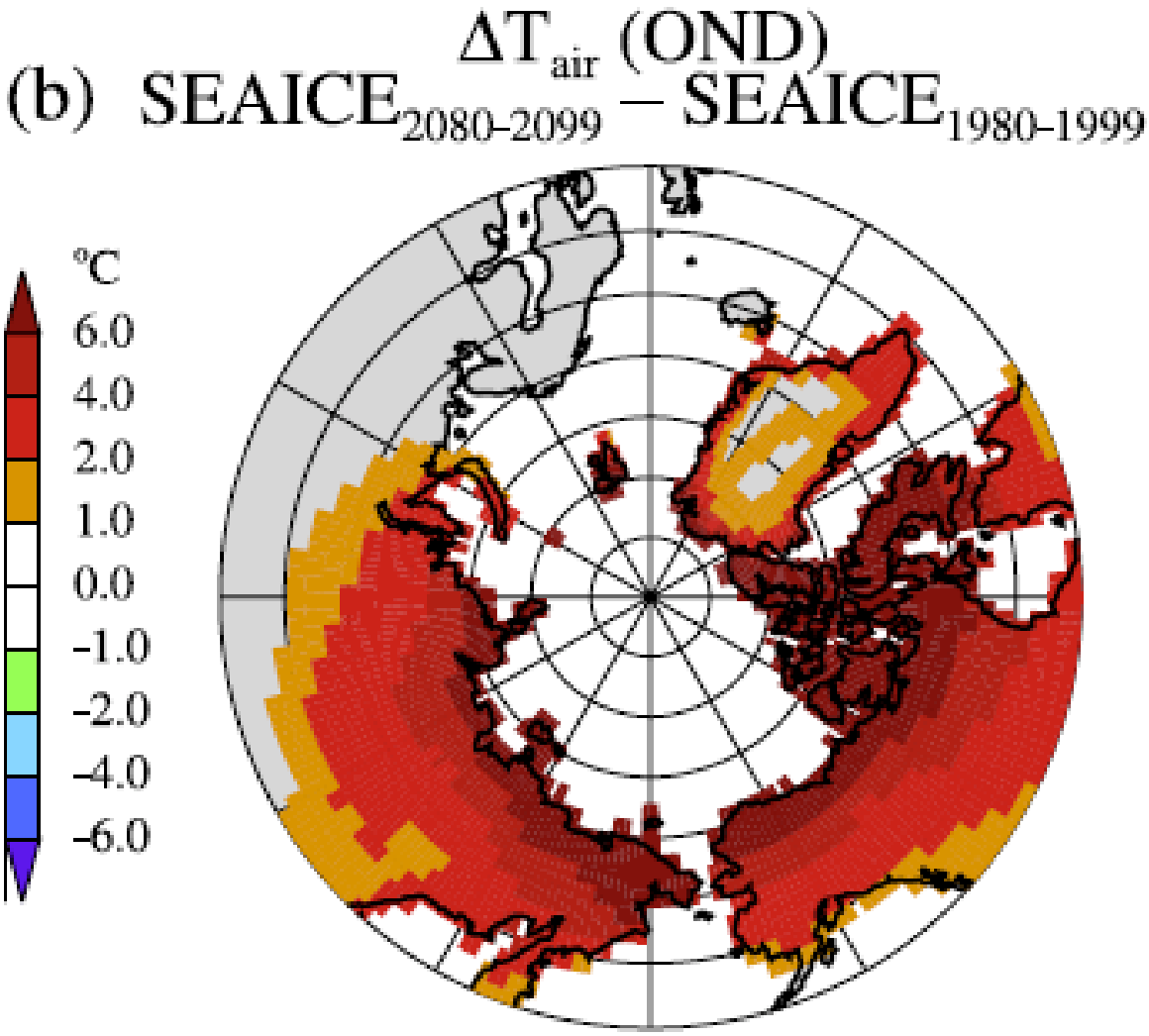


B

$r_s = -0.49$; $p_{auto} = 0.03$

Hu, Higuera, et al. 2010, JGR

Mechanisms linking sea ice and tundra burning:

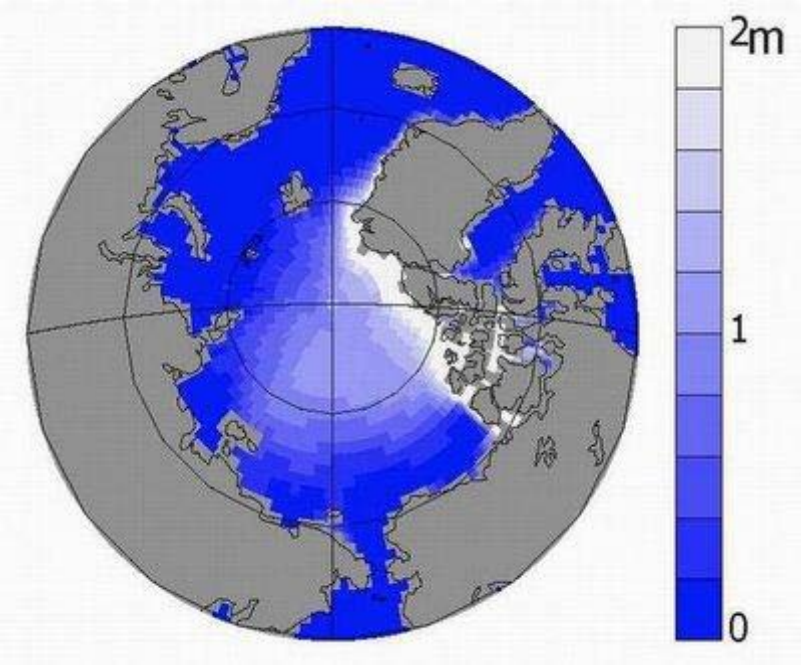


Lawrence et al. 2008 GRL

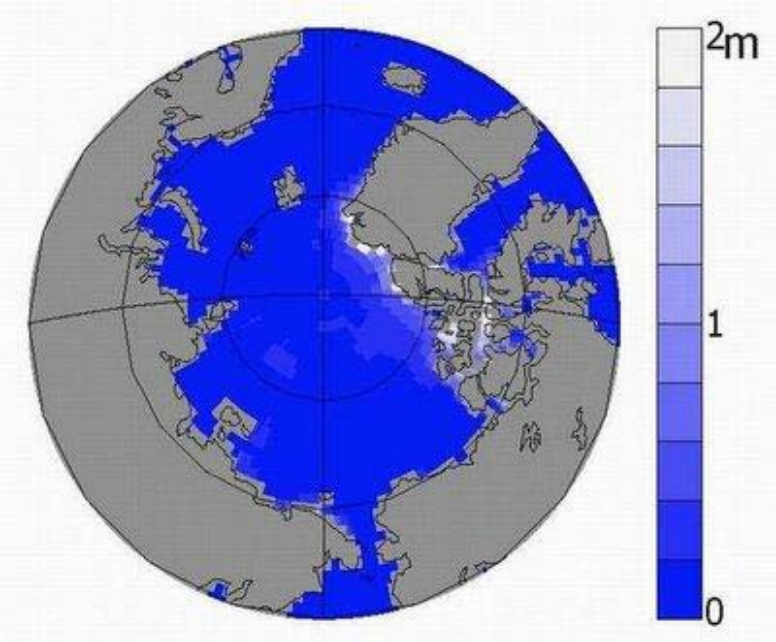
So what?

GLOBAL WARMING

Arctic Summer Sea Ice Could Vanish Soon But Not Suddenly



2008



2038

Kerr 2009, Science

Wang and Overland 2009, GRL

But tundra fire regimes are diverse

How variable are tundra fire regimes?

What controls tundra fire regimes?

Figure 1. One of the 37 tundra fires that burned in Noatak National Preserve in the summer of 2010. The Kaluktavik River fire (Fire #561) burned more than 23,000 acres (9,300 ha) in July.

NPS photograph

But tundra fire regimes are diverse

How variable are tundra fire regimes?

What controls tundra fire regimes?

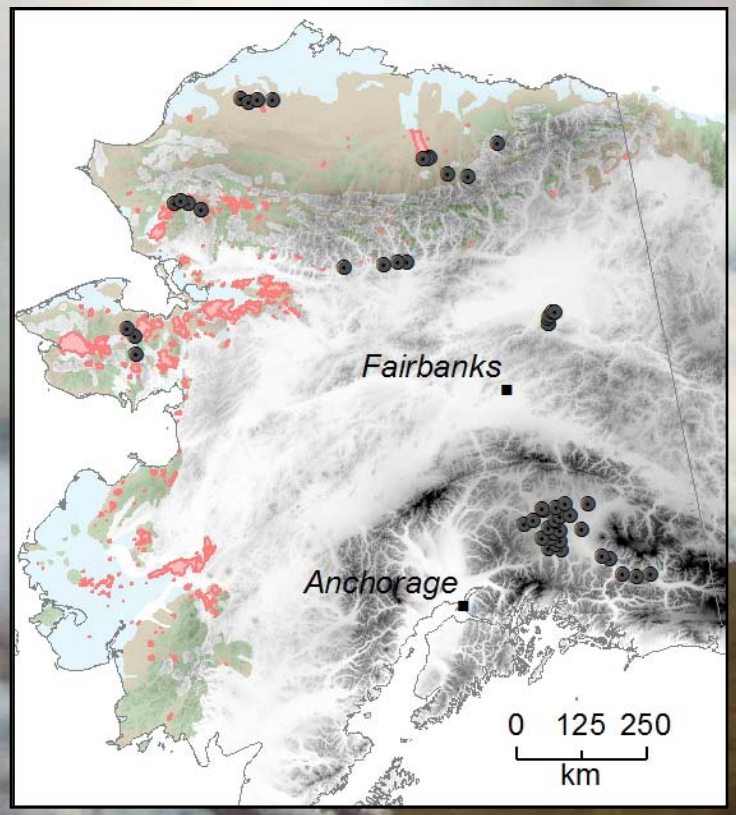


Figure 1. One of the 37 tundra fires that burned in Noatak National Preserve in the summer of 2010. The Kaluktavik River fire (Fire #561) burned more than 23,000 acres (9,300 ha) in July.

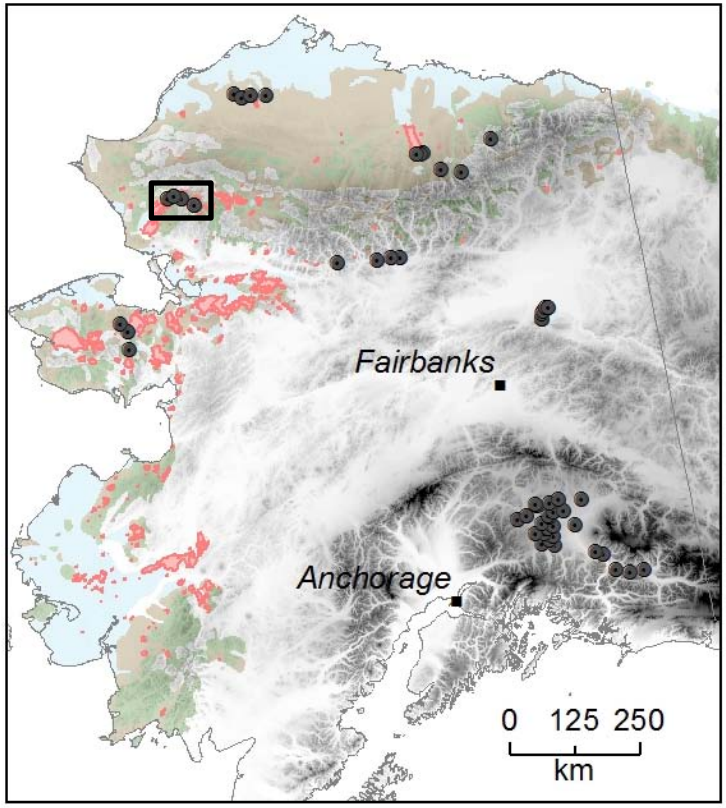
NPS photograph

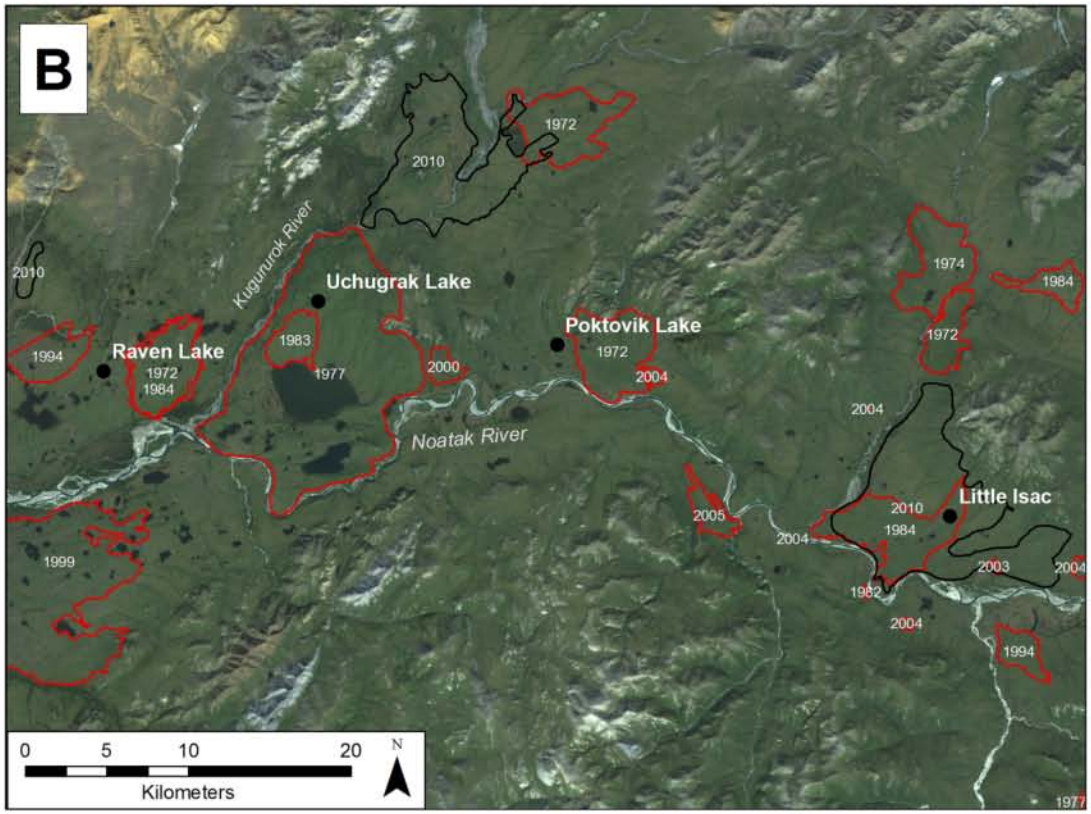
The Burning Tundra: A Look Back at the Last 6,000 Years of Fire in the Noatak National Preserve, Northwestern Alaska

By Philip E. Higuera, Jennifer L. Barnes, Melissa L. Chipman, Michael Urban, and Feng Sheng Hu

Variability of tundra fire regimes in Arctic Alaska: millennial-scale patterns and ecological implications

Philip E. Higuera,[1,5] Melissa L. Chipman,[2] Jennifer L. Barnes,[3] Michael A. Urban,[2] and Feng Sheng Hu[2,4]

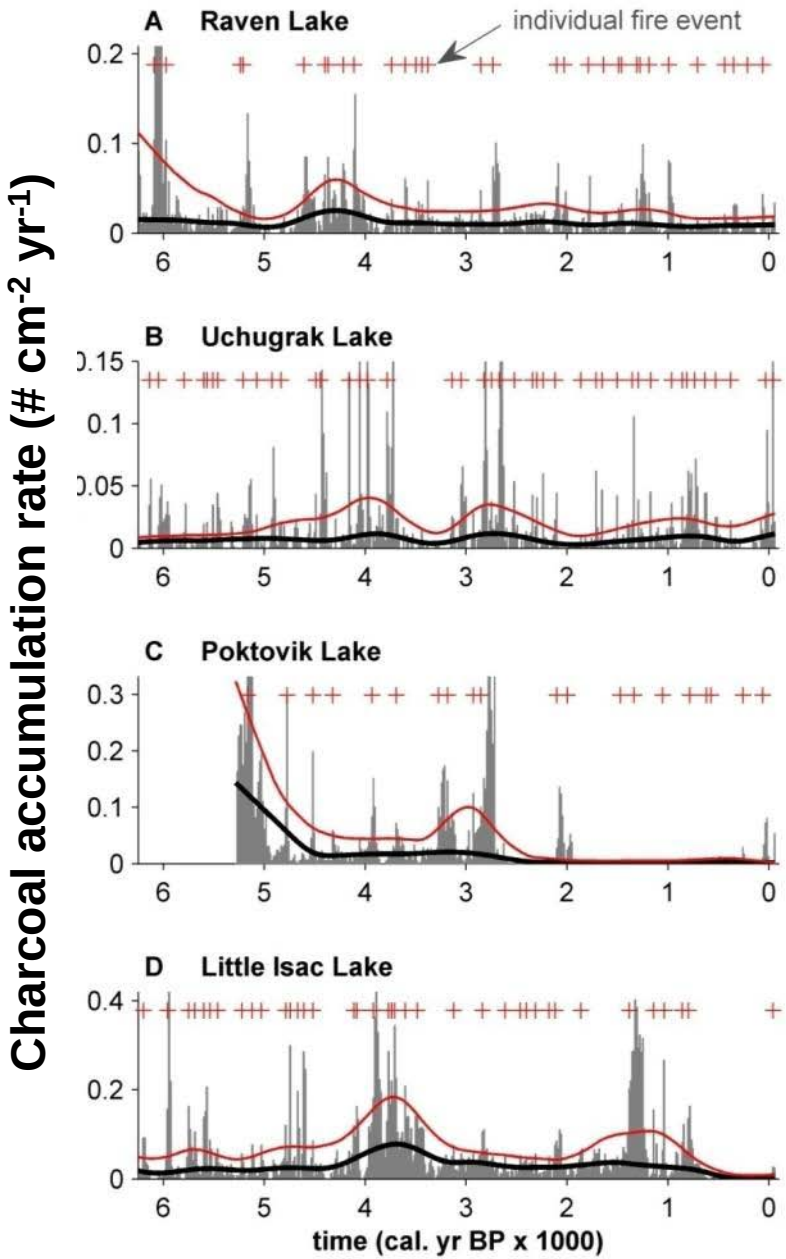




Unequivocal evidence of frequent burning

Poktovik Lake, Noatak Nat. Preserve, 11:30 pm.

Charcoal acc. & fire events



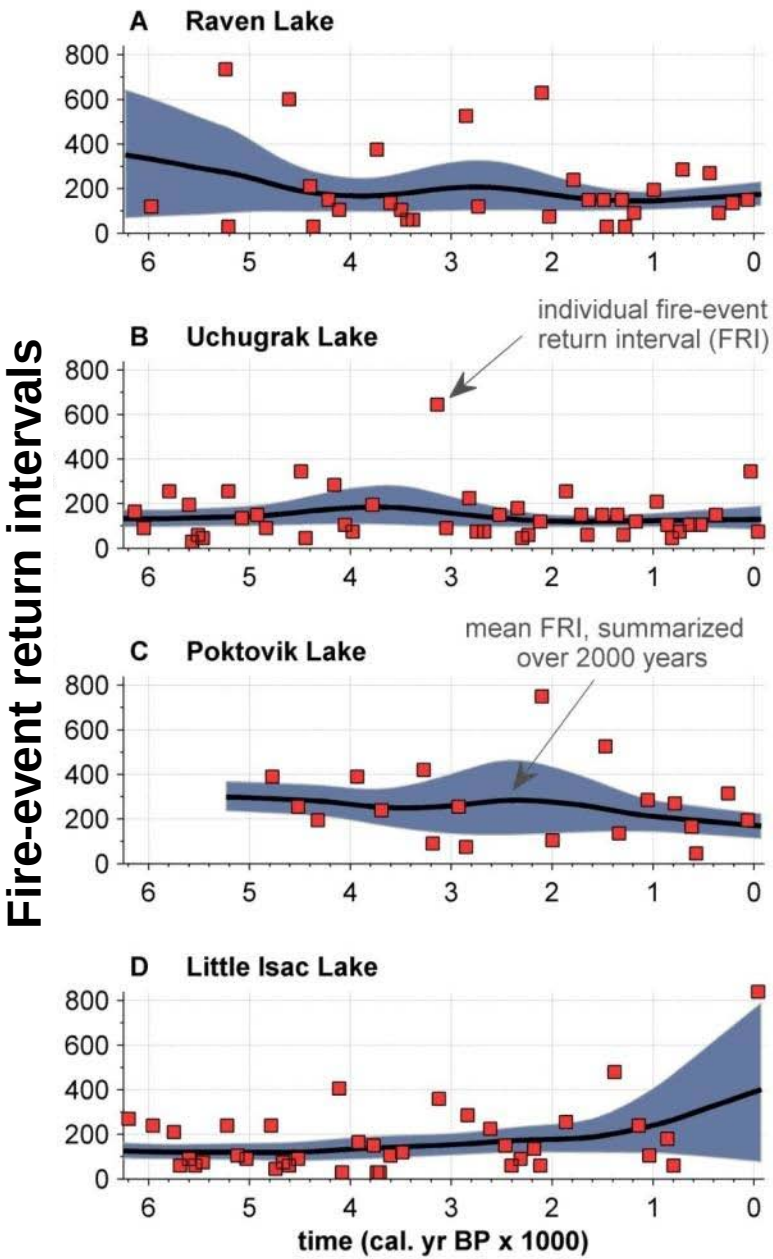
Higuera et al. 2011, AK Park Science; Higuera et al. 2011. *Ecological Applications*

Return intervals and 2000-yr mean (+/- CI)

Fire regimes and variability:

- FRI vary from 30 – 840 yr
- Mean FRI (over 2000 yr) vary from ≈ 100-400 yr
- Mean FRI varies over time
- Mean FRI varies across space

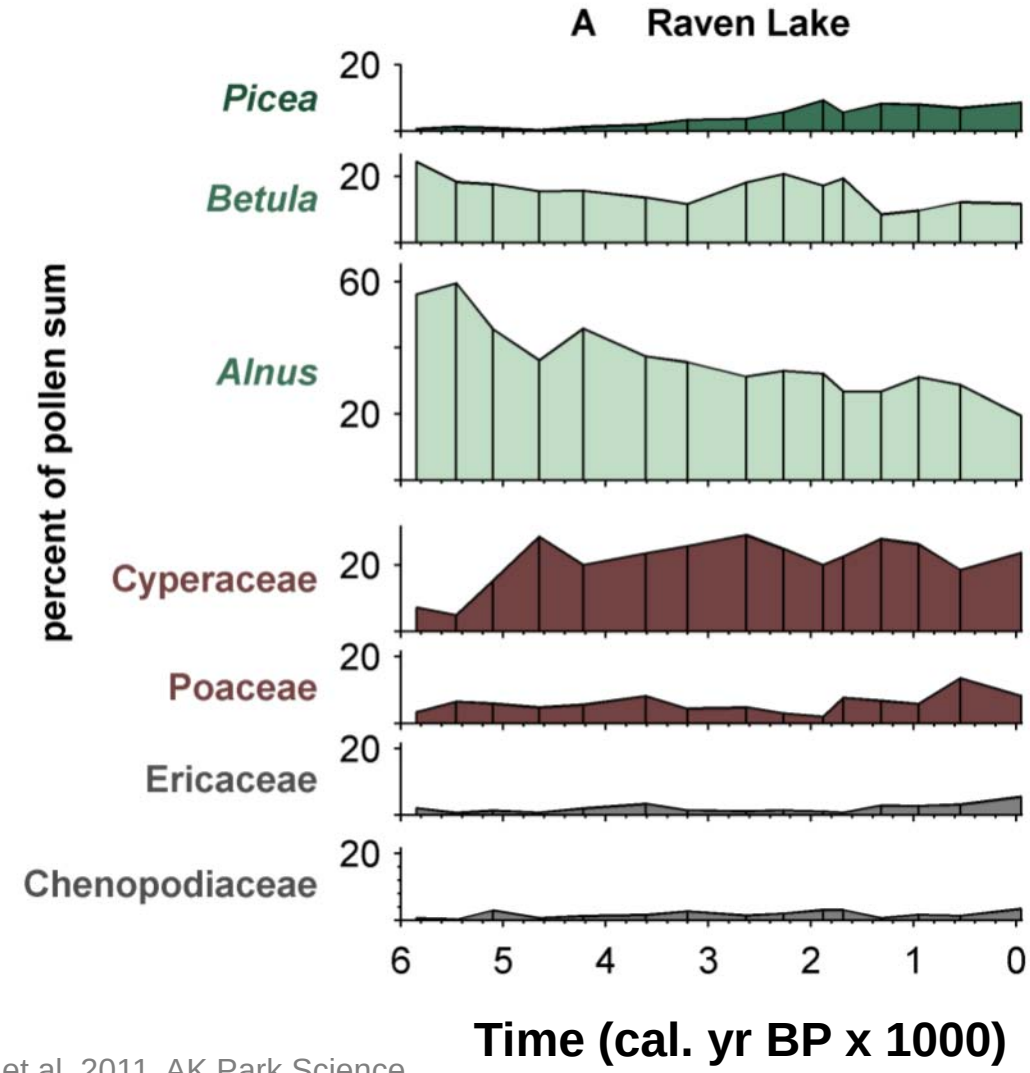
Poktovik Lake, Noatak Nat. Preserve, 11:30 pm.

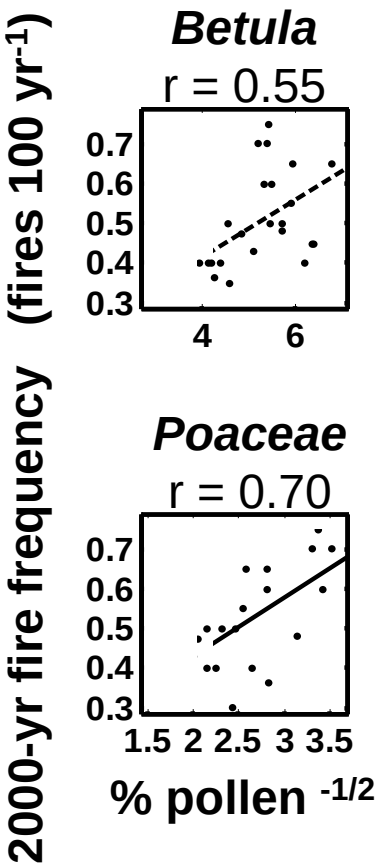


Higuera et al. 2011, AK Park Science; Higuera et al. 2011. *Ecological Applications*

Controls of Tundra Burning: Vegetation

Vegetation and fire correlated over millennial time scales

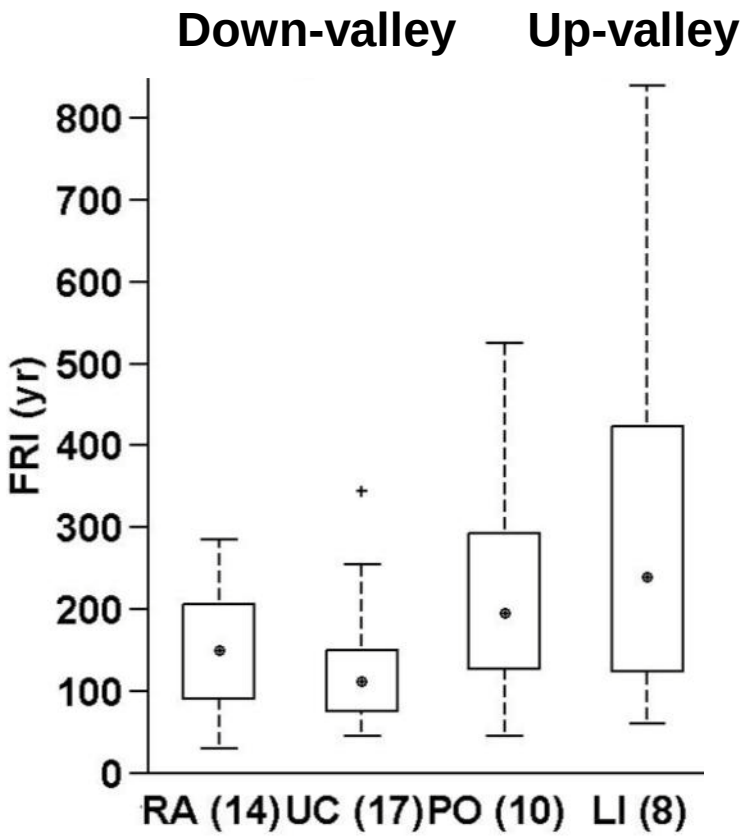


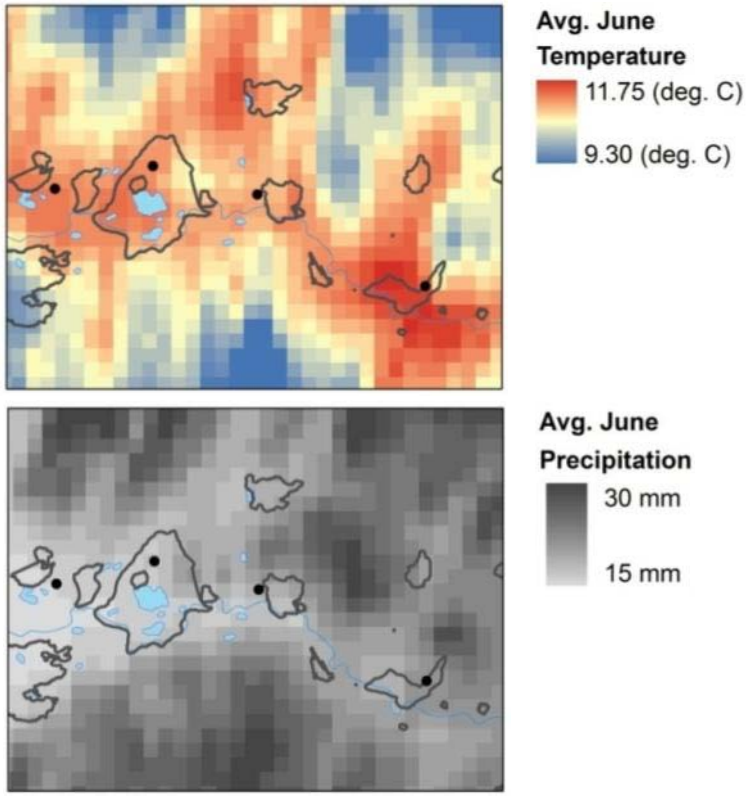


Higuera et al. 2011, AK Park Science

Controls of Tundra Burning: Climate & Veg.

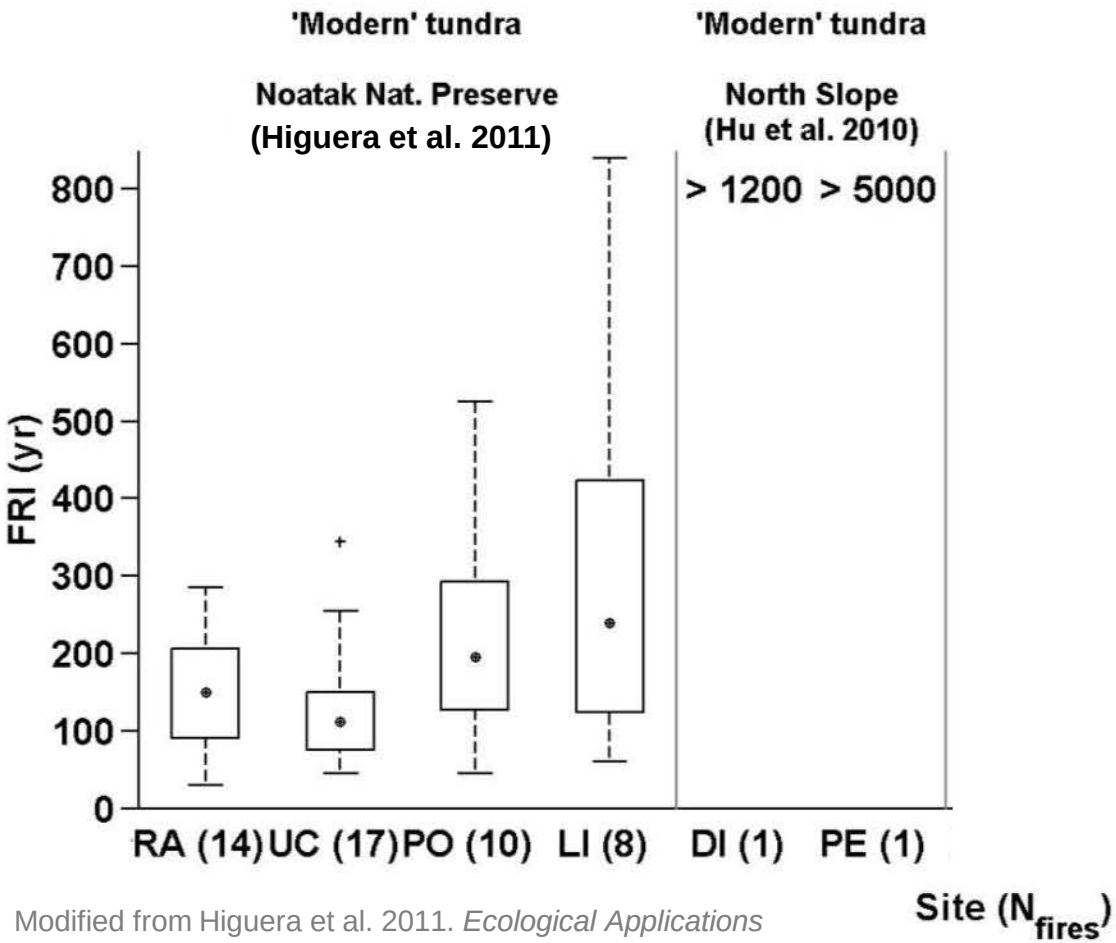
Recent fire activity varies along modern gradients in climate and vegetation





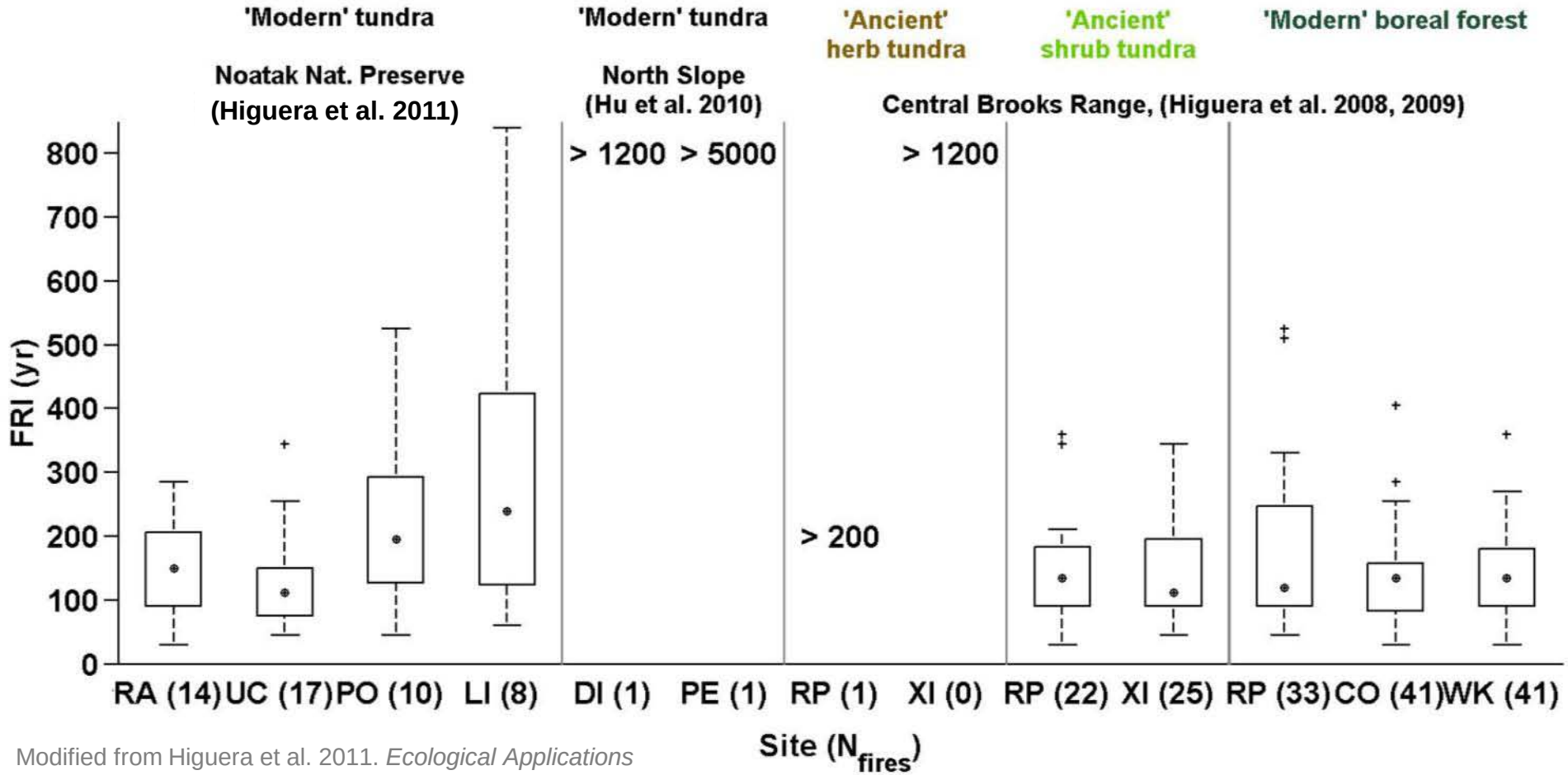
Higuera et al. 2011. *Ecological Applications*

Diverse fire regimes across space and time



Modified from Higuera et al. 2011. *Ecological Applications*

Diverse fire regimes across space and time



Modified from Higuera et al. 2011. *Ecological Applications*

Take-home messages

1. ***Diverse tundra fire regimes suggest diverse responses and impacts***
2. ***Tundra burning associated with warm, dry conditions, with interactions with vegetation***

Anaktuvuk River Fire, 2011

Overarching questions

What will happen to tundra ecosystems as climate warms?

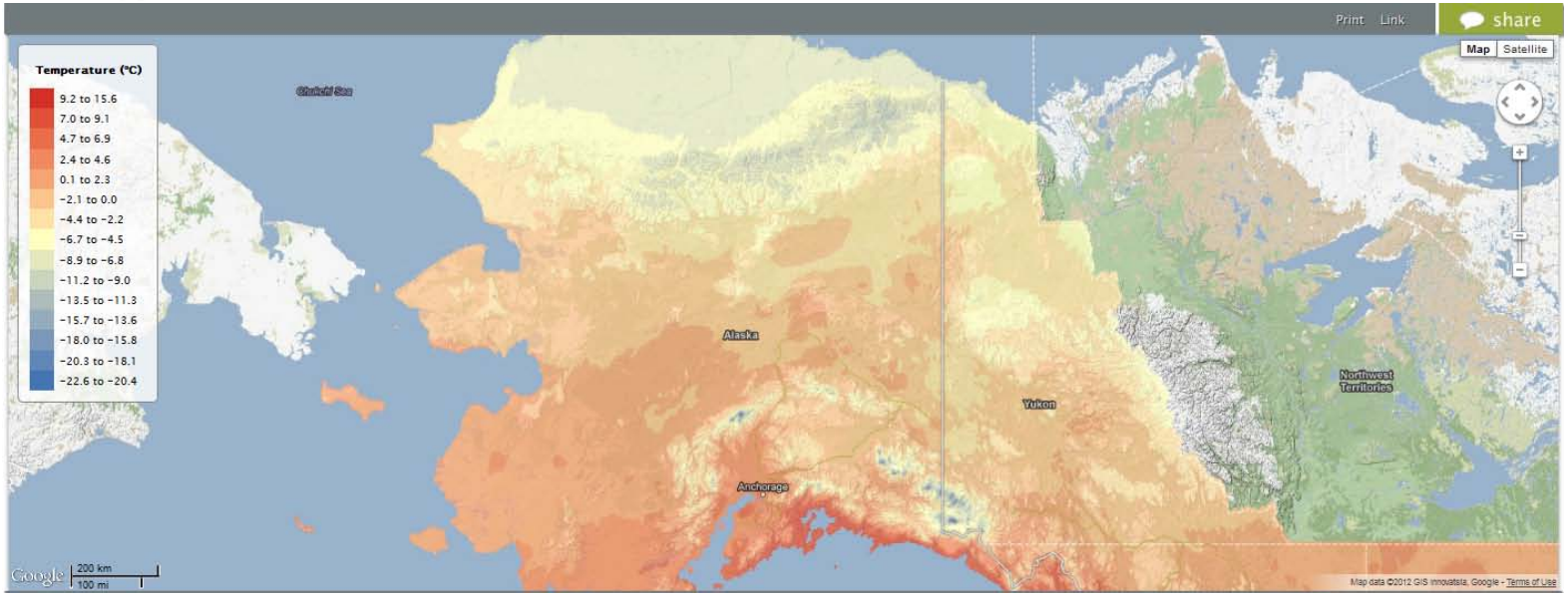
3. **What can we expect in the future?**

Future climate and tundra burning

- We drove five GCMs with the A1B (middle of the road) emission scenario

- The monthly temperature and precipitation maps from each GCM-A1B scenario were downscaled to 800-m using PRISM climatology grids

SNAP Scenarios Network for Alaska & Arctic Planning



Future climate and tundra burning

- We drove five GCMs with the A1B (middle of the road) emission scenario
- The monthly temperature and precipitation maps from each GCM-A1B scenario were downscaled to 800-m using PRISM climatology grids

Averaged over time and compared to modern **climatology**

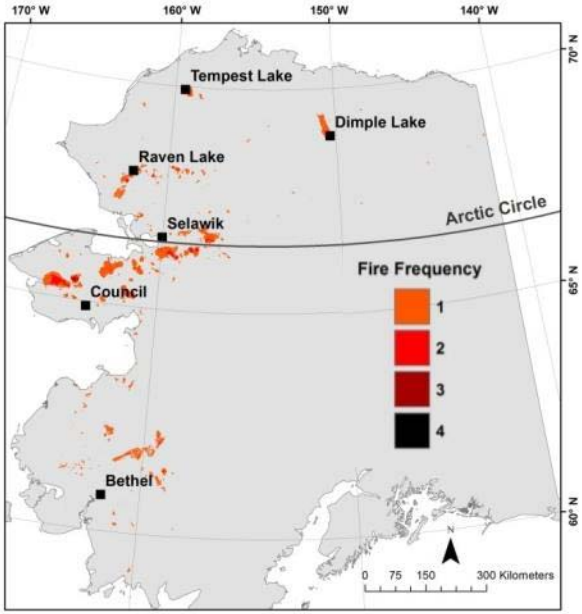
Young et al., ongoing work

Spatially averaged to drive GBM-model forecasting **annual area burned**

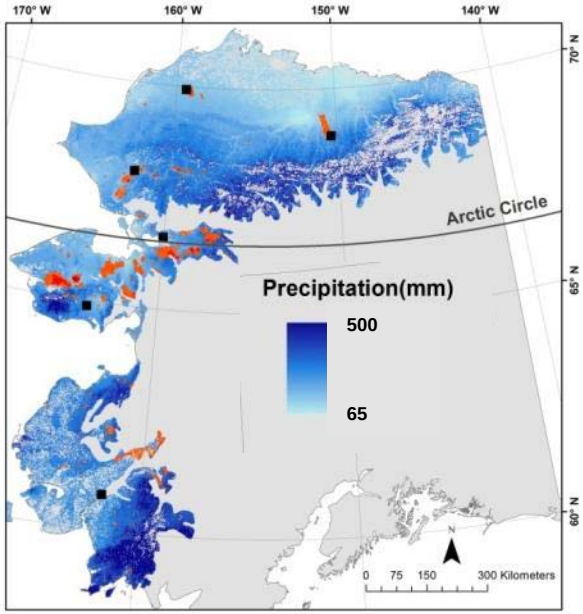
Duffy et al., ongoing work

Where does tundra burn today?

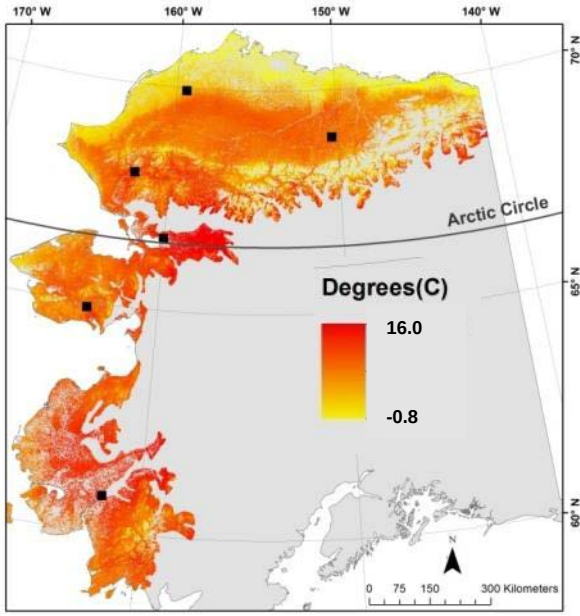
Fire frequency
(1950-2008)



JJA precip.
(1971-2000)

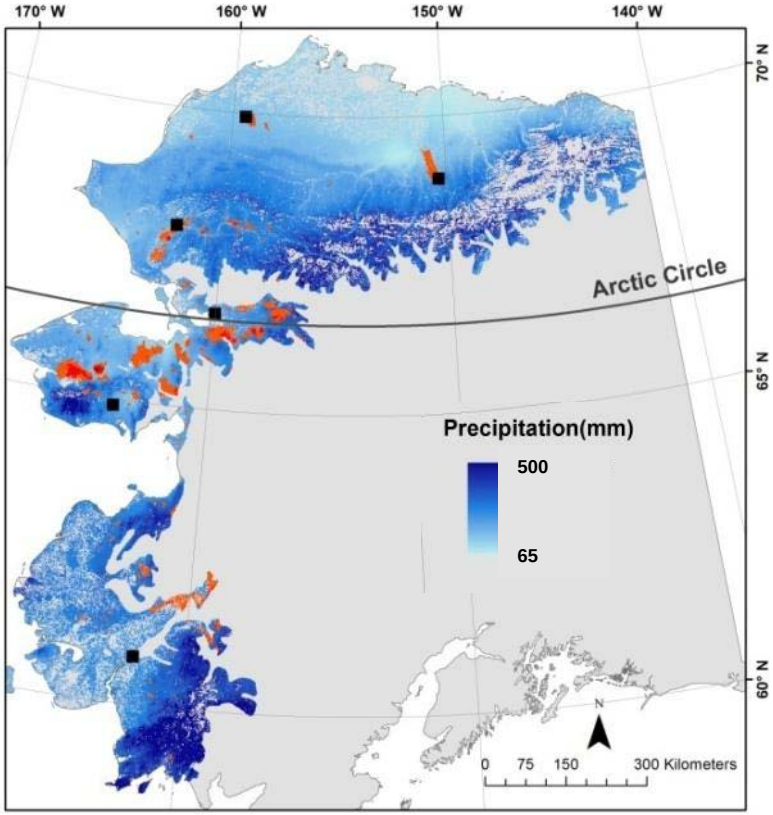


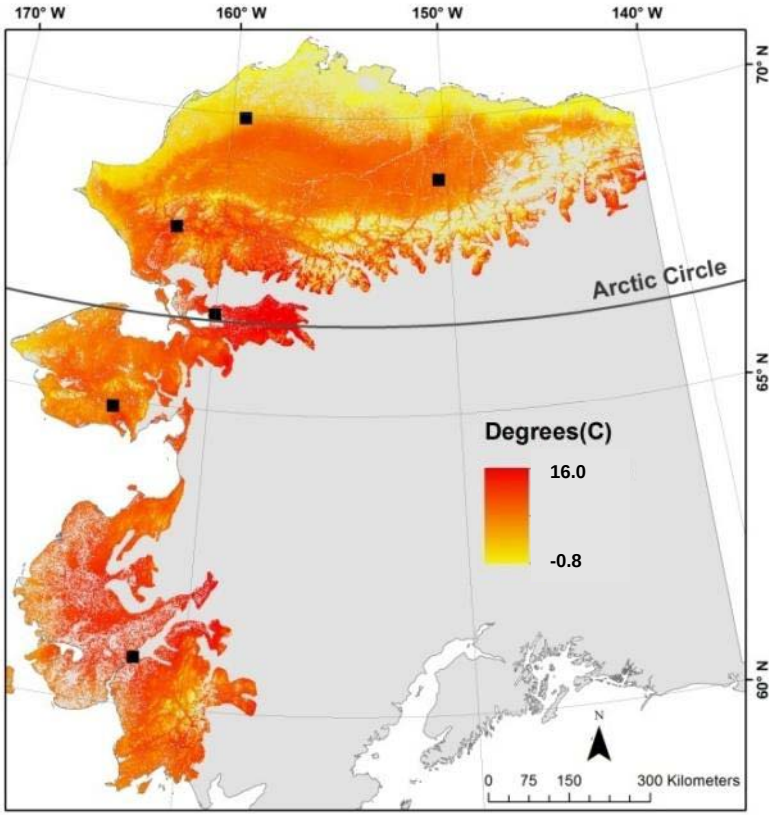
Mean temp.
of warmest month
(1971-2000)

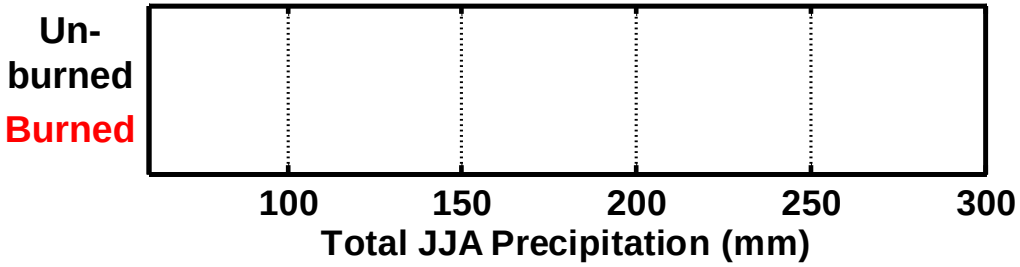


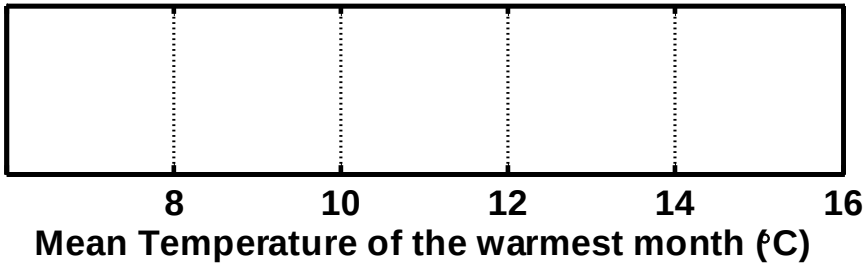
Young et al., ongoing work

- Tundra burning biased toward warm, dry regions









Young et al., ongoing work

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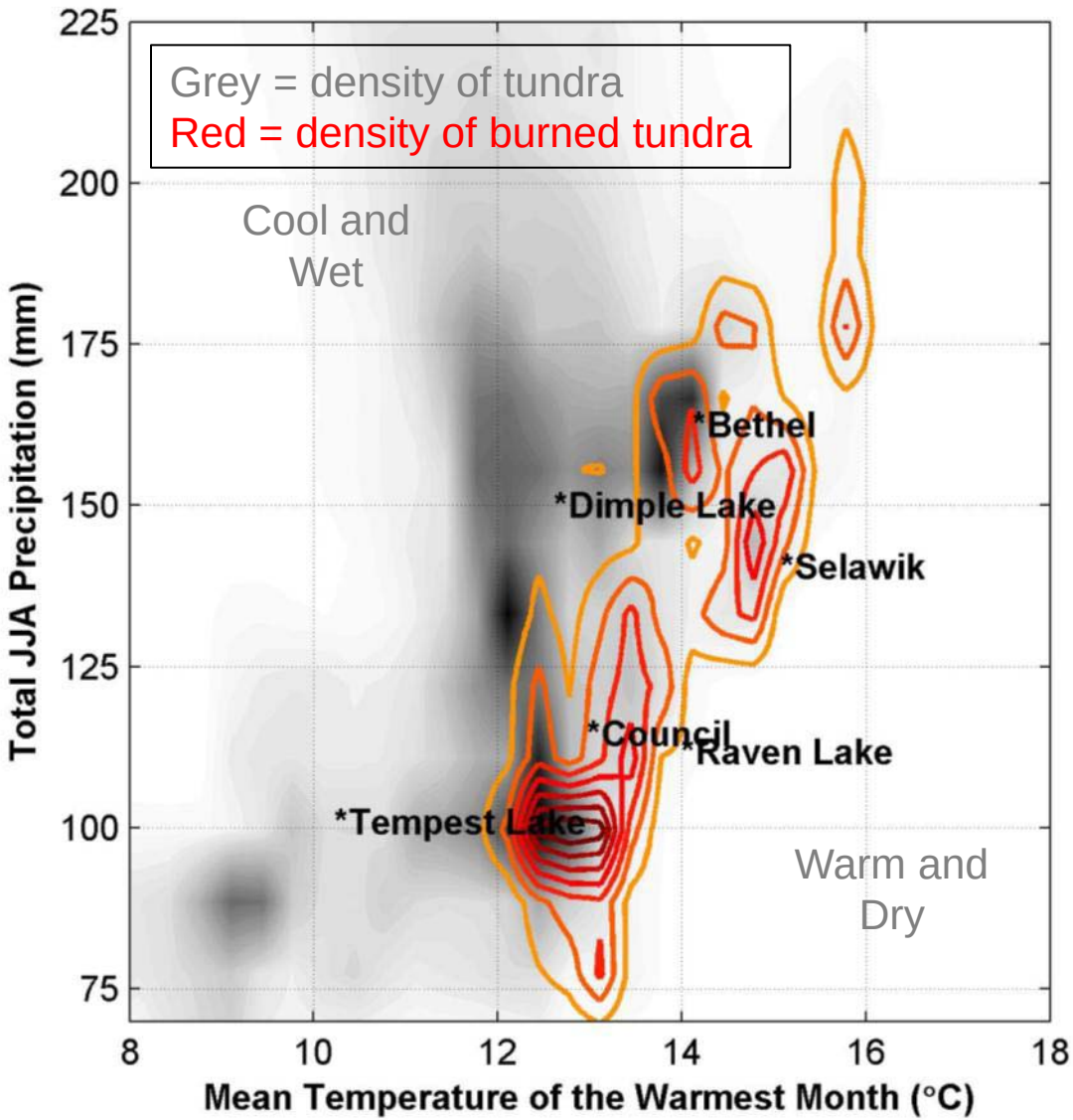
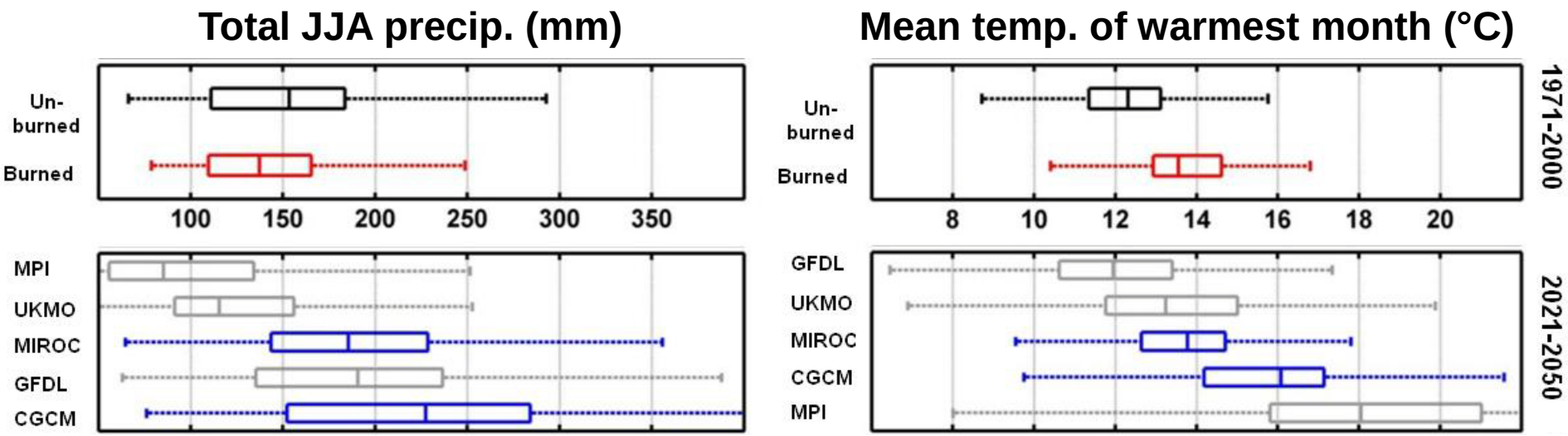


Young et al., ongoing work

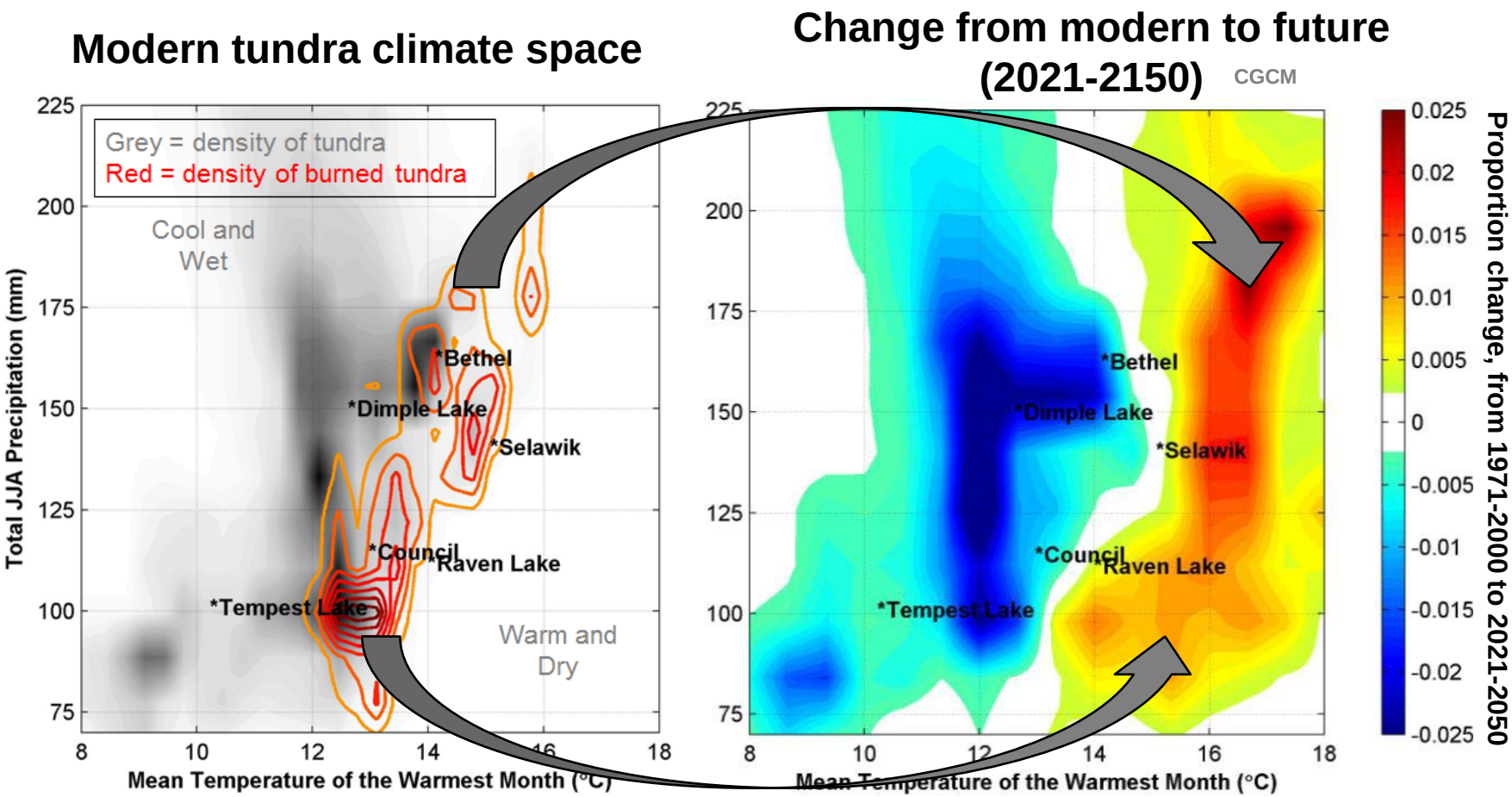
Future tundra burning

- Increased warmth, increased precip. **(state-wide)**

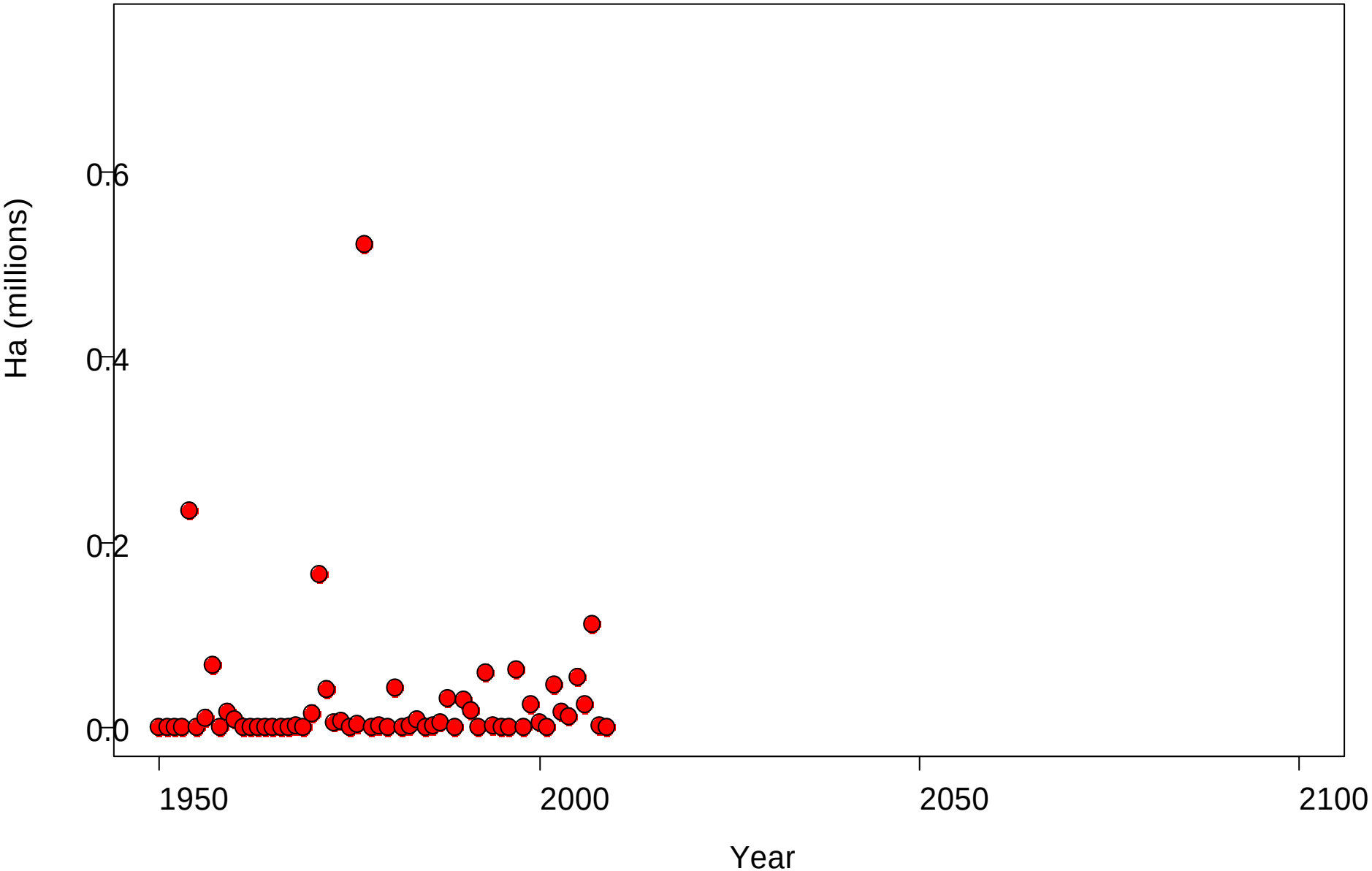


Young, Duffy et al., ongoing work

- More tundra in flammable climate space



Young et al., ongoing work


Ha (millions)
0.0
0.2
0.4
0.6
1950
2000
2050
2100
Year

Take-home messages

1. *Diverse tundra fire regimes suggest diverse responses and impacts*
2. *Tundra burning associated with warm, dry conditions, with interactions with vegetation*
3. ***Evidence increasingly suggests that Arctic environmental change will favor tundra burning, with potential surprises***

Anaktuvuk River Fire, 2011

So what?

LETTER

doi:10.1038/nature10283

Carbon loss from an unprecedented Arctic tundra wildfire

Michelle C. Mack[1], M. Syndonia Bret-Harte[2], Teresa N. Hollingsworth[3], Randi R. Jandt[4], Edward A. G. Schuur[1], Gaius R. Shaver[5] & David L. Verbyla[6]

- **Total loss ≈ 2.1 teragrams ≈ annual C sink of entire Arctic tundra biome**

Photo: Dale Woitas, AFS, BLM

Mack et al. 2011, *Nature*

So what?

Mann et al. 2010

So what?

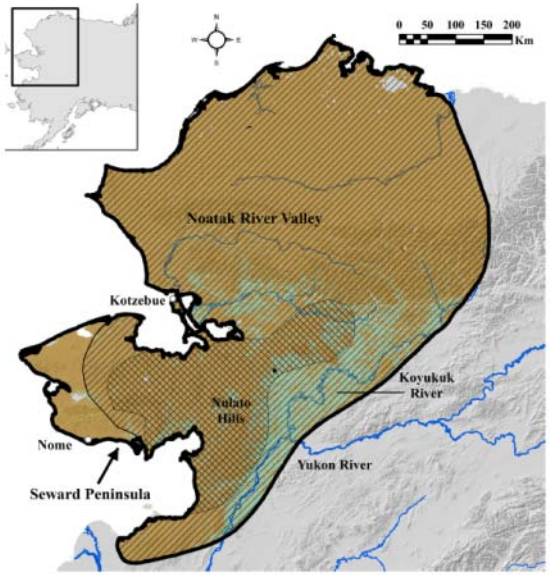


Fig. 1. Study area (outlined by thick black line) in northwest Alaska. Tundra-dominated areas are shaded brown and forest-dominated areas are in green. The range of the Western Arctic Caribou Herd is contained within the domain and is depicted with hatching, while the herd's core winter range is cross-hatched (courtesy of the Alaska Department of Fish and Game).

NPS photograph by Robert Winfree

Figure 1. Grazing caribou.

Fire in the range of the Western Arctic Caribou Herd

By Kyle Joly, T. Scott Rupp, Randi R. Jandt, and F. Stuart Chapin, III

ECOSCIENCE 17 (3): 321-333 (2010)

Winter habitat selection by caribou in relation to lichen abundance, wildfires, grazing, and landscape characteristics in northwest Alaska[1]

esa ECOSPHERE

Simulating the effects of climate change on fire regimes in Arctic biomes: implications for caribou and moose habitat

Kyle Joly,[1,2,†] Paul A. Duffy,[3] and T. Scott Rupp[4]

Decrease of lichens in Arctic ecosystems: the role of wildfire, caribou, reindeer, competition and climate in north-western Alaska

Kyle Joly,[1,2] Randi R. Jandt[3] & David R. Klein[4]

1 National Park Service, Gates of the Arctic National Park and Preserve, 4175 Geist Road Fairbanks, AK 99709, USA
2 Department of Biology and Wildlife, 211 Irving 1, University of Alaska Fairbanks, Fairbanks, AK 99775, USA
3 Bureau of Land Management, Alaska Fire Service, 1541 Gaffney Road, Fort Wainwright, AK 99703, USA
4 Institute of Arctic Biology, University of Alaska Fairbanks, P.O. Box 757000, Fairbanks, AK 99775, USA

Joly et al., 2009, 2010 a,b, 2012

Rare events or harbinger of climate change?

YES!

- Rare in some regions, but increased burning consistent with impacts of a warming climate

Photo: Dale Woitas, AFS, BLM

Acknowledgements, Funding

- Scott Rupp, UAF
- NPS personnel
- Mike Dietze, U of IL
- Mike Urban, U of IL
- Triet Vuong, U of IL
- Jennifer Schwarz, U of IL

National Science Foundation

Joint Fire Science Program
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www.firescience.gov

National Park Service
U.S. Department of the Interior

esa Ecological Society of America
National Park Service
National Park Foundation

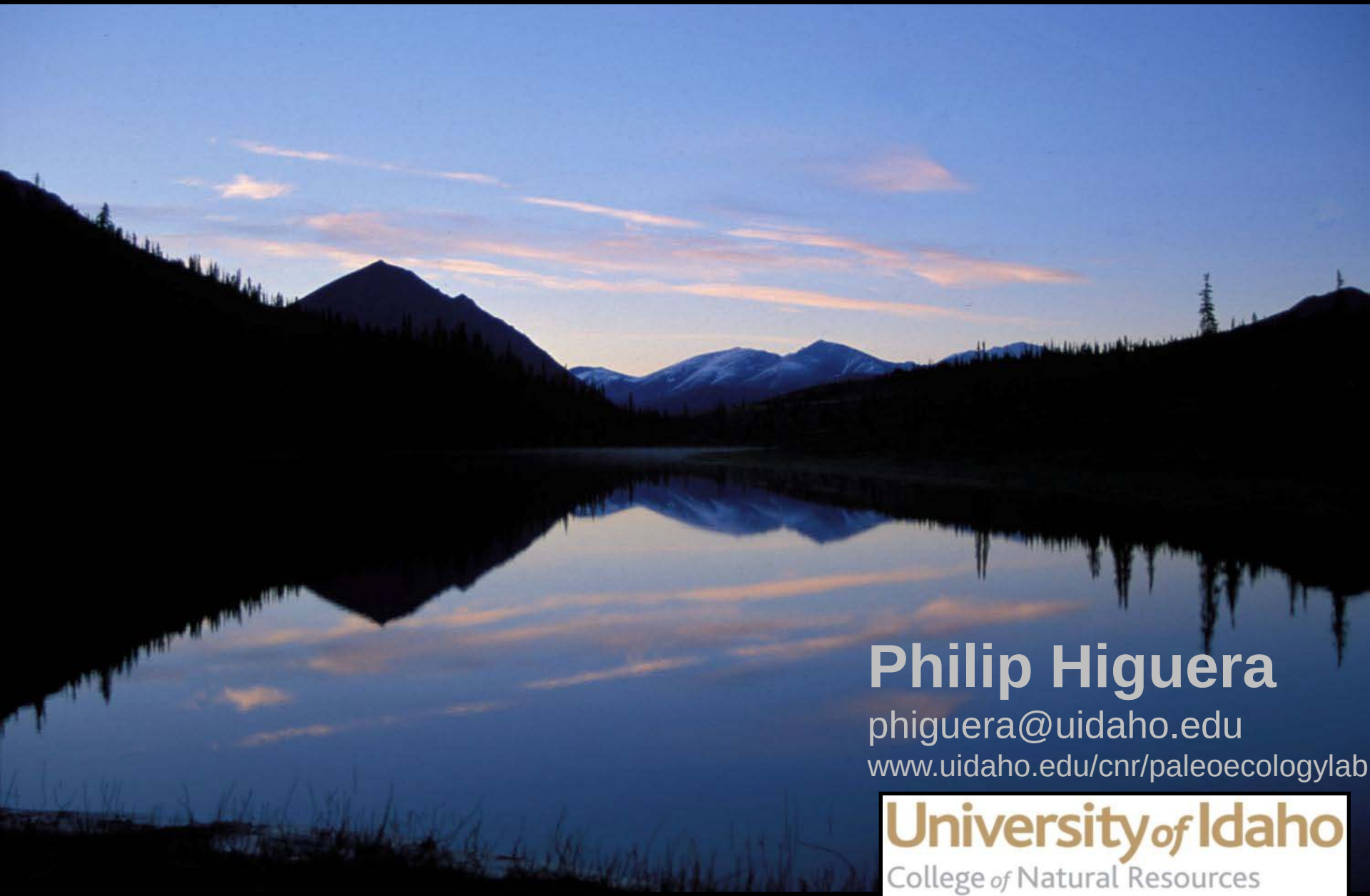
University of Idaho
College of Natural Resources

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

SNAP Scenarios Network for Alaska & Arctic Planning

NEPTUNE AND COMPANY, INC.
Improving the quality of environmental decision making

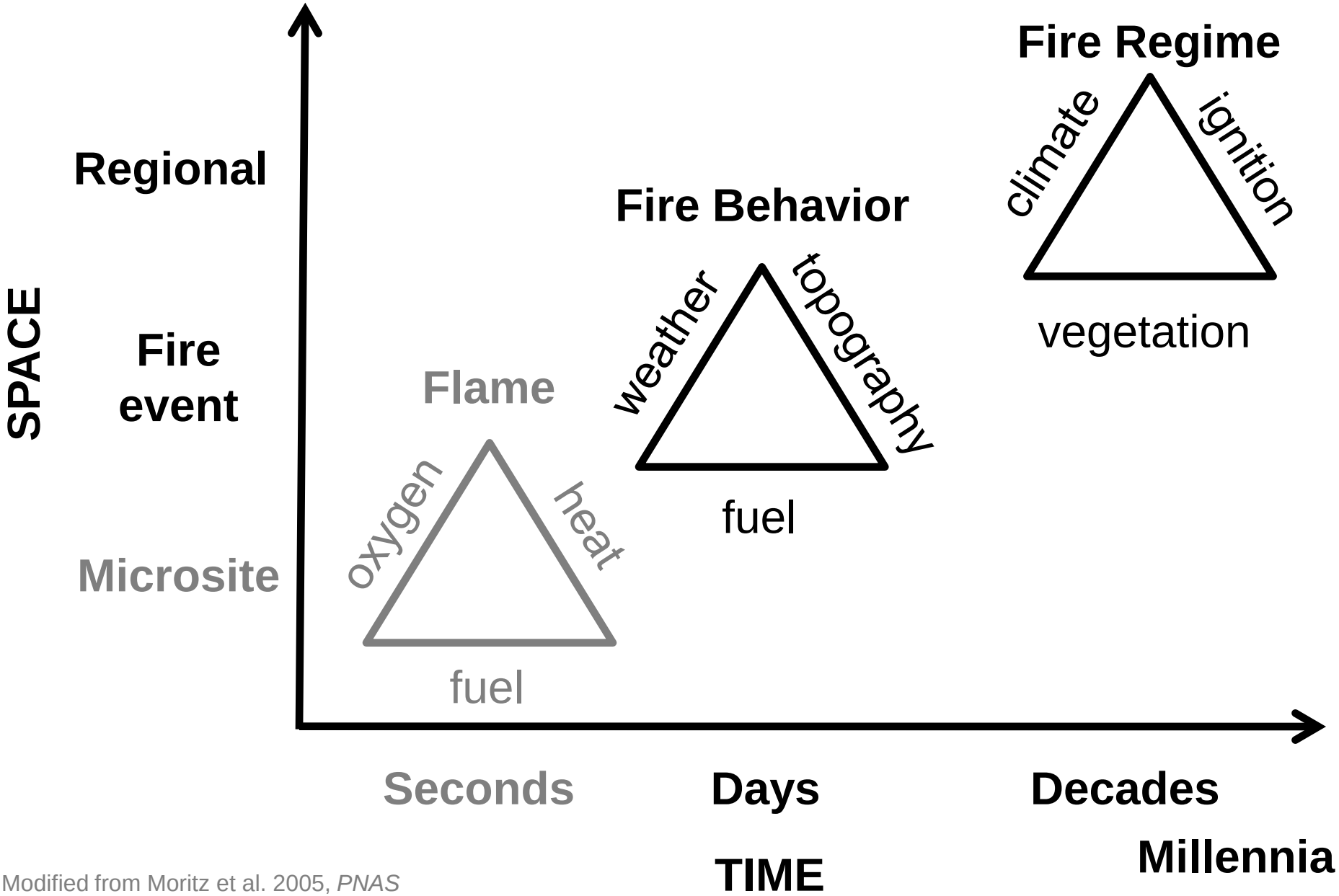
Questions?



Philip Higuera
phiguera@uidaho.edu
www.uidaho.edu/cnr/paleoecologylab
University of Idaho
College of Natural Resources

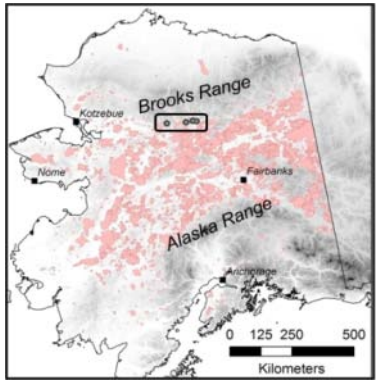
Footprint Lake, Brooks Range, 1 am.

Framework for controls of burning

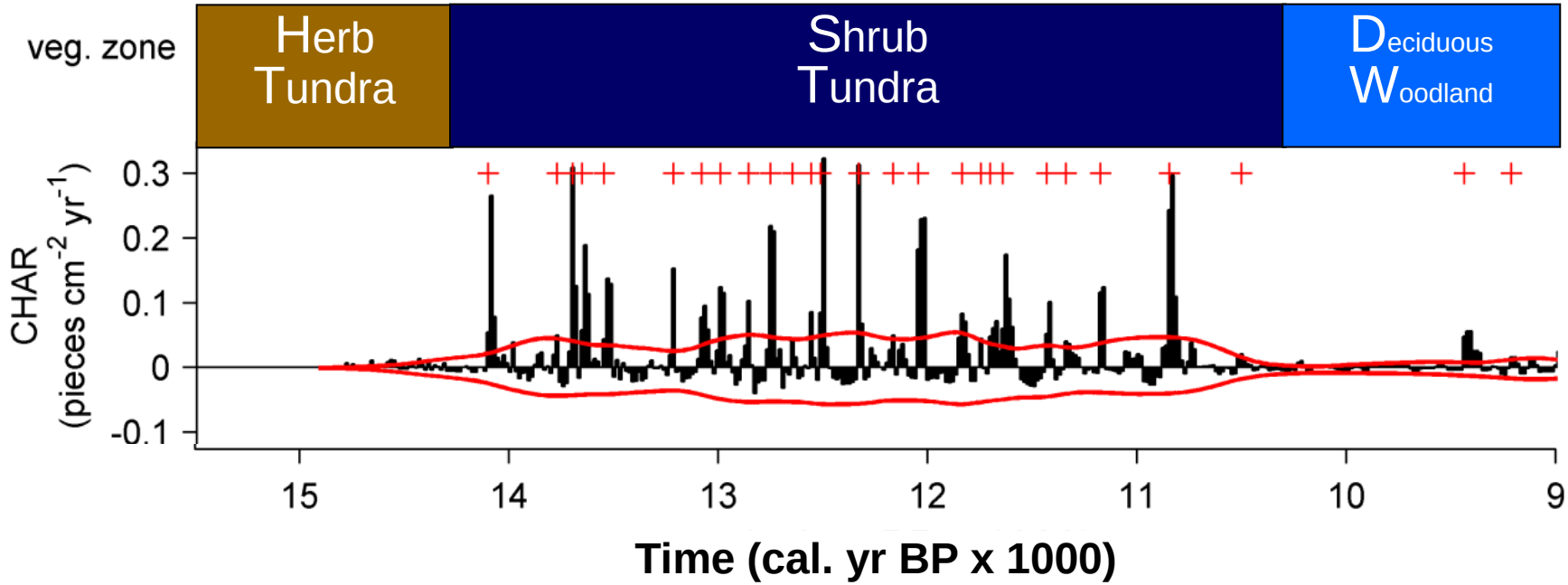


Modified from Moritz et al. 2005, *PNAS*

Vegetation and fire correlated over millennial time scales



Long-term trend toward warmer climate →

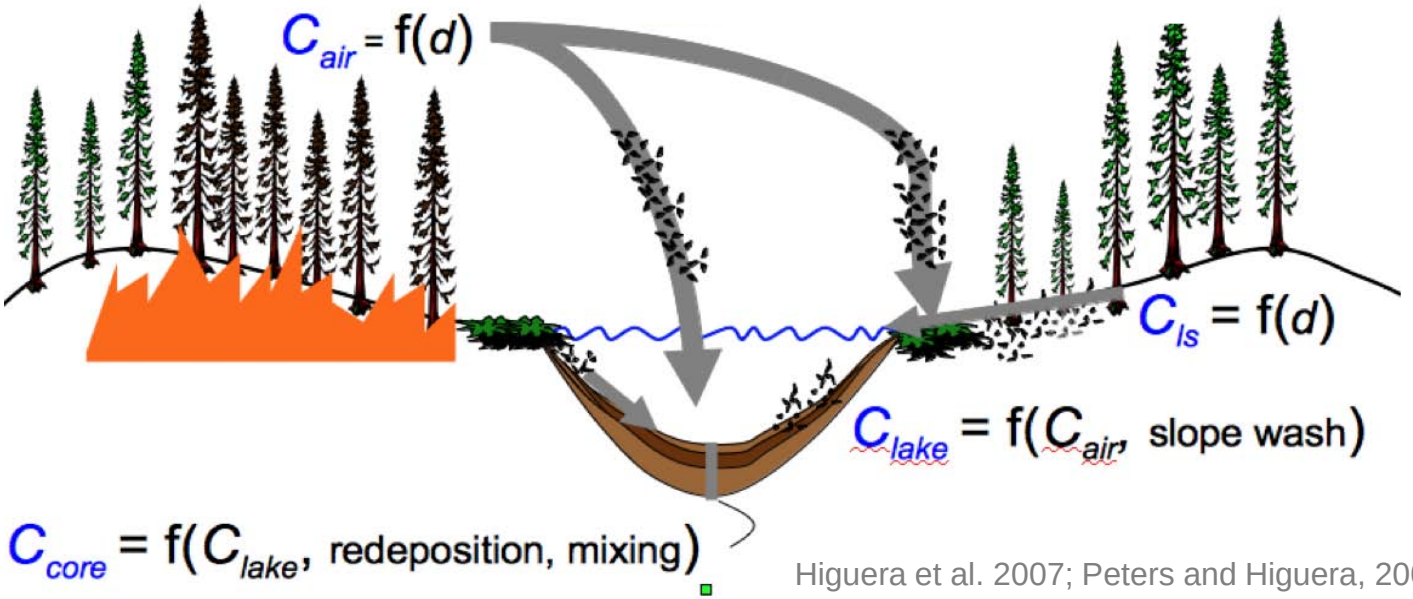


Higuera et al. 2008, *PLoS ONE* 3: e0001744

Higuera et al. 2009. Brooks Range Fire History. *Ecological Monographs* 79: 201-219.

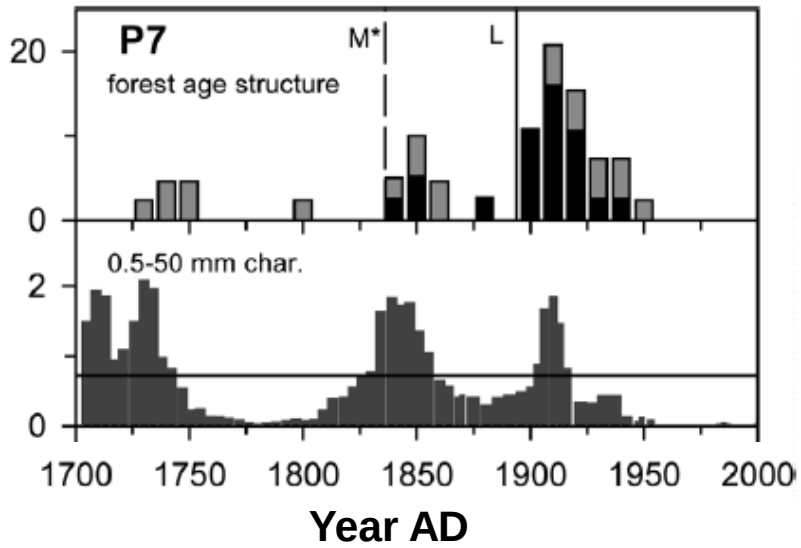
Fire history from continuous sediment records

Theoretical / modeling:



Higuera et al. 2007; Peters and Higuera, 2007; Higuera et al. 2010; Kelly, Higuera, et al., 2011.

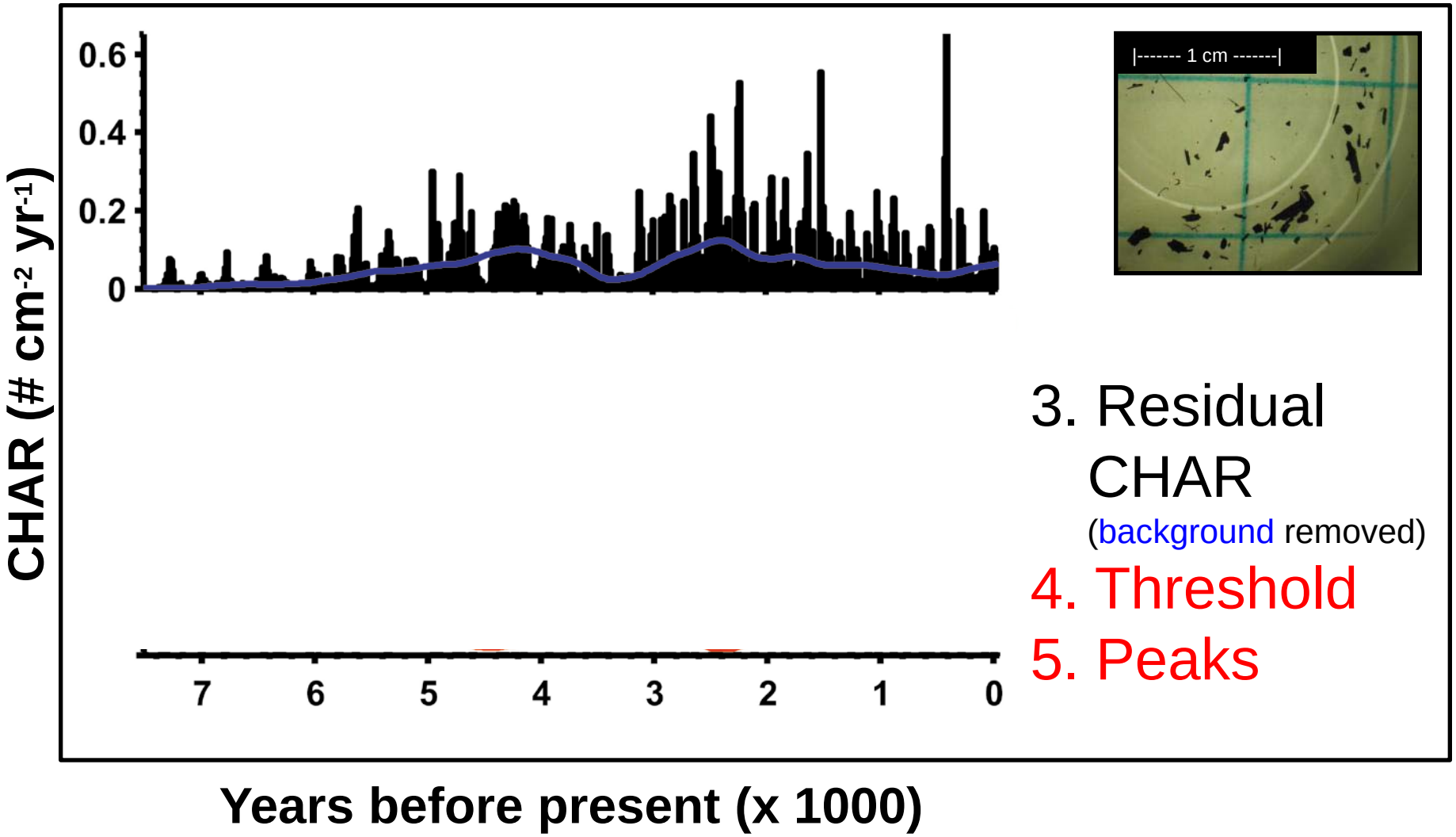
Empirical tests:



Stand age & fire scars

Charcoal accumulation

Higuera et al. 2005
Higuera et al. 2011


CHAR (# cm-2 yr-1)
0.6
0.4
0.2
0
7
6
5
4
3
2
1
0
Years before present (x 1000)
|------- 1 cm -------|
3. Residual CHAR
(background removed)
4. Threshold
5. Peaks