

Tundra fire regimes of Alaska: the Holocene perspective



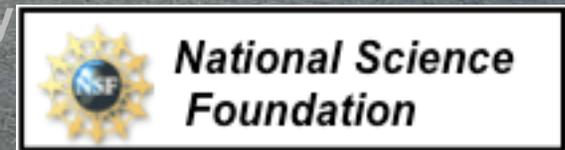
Philip Higuera U. of Idaho, College of Natural Resources, phiguera@uidaho.edu

Melissa Chipman U. of Illinois, Dep. of Plant Biology

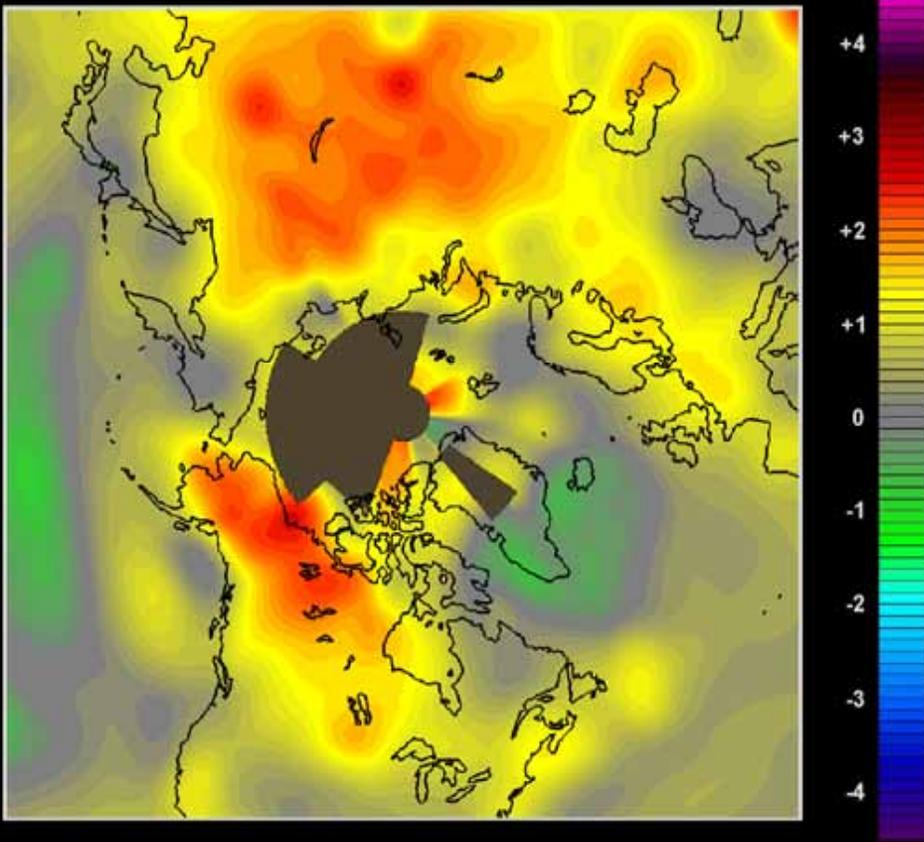
Jennifer Allen National Park Service

Scott Rupp U. of Alaska

Mike Urban, Feng Sheng Hu U. of Illinois



Surface air temperature change : 1954 - 2003
annual - °C



Shrub expansion:

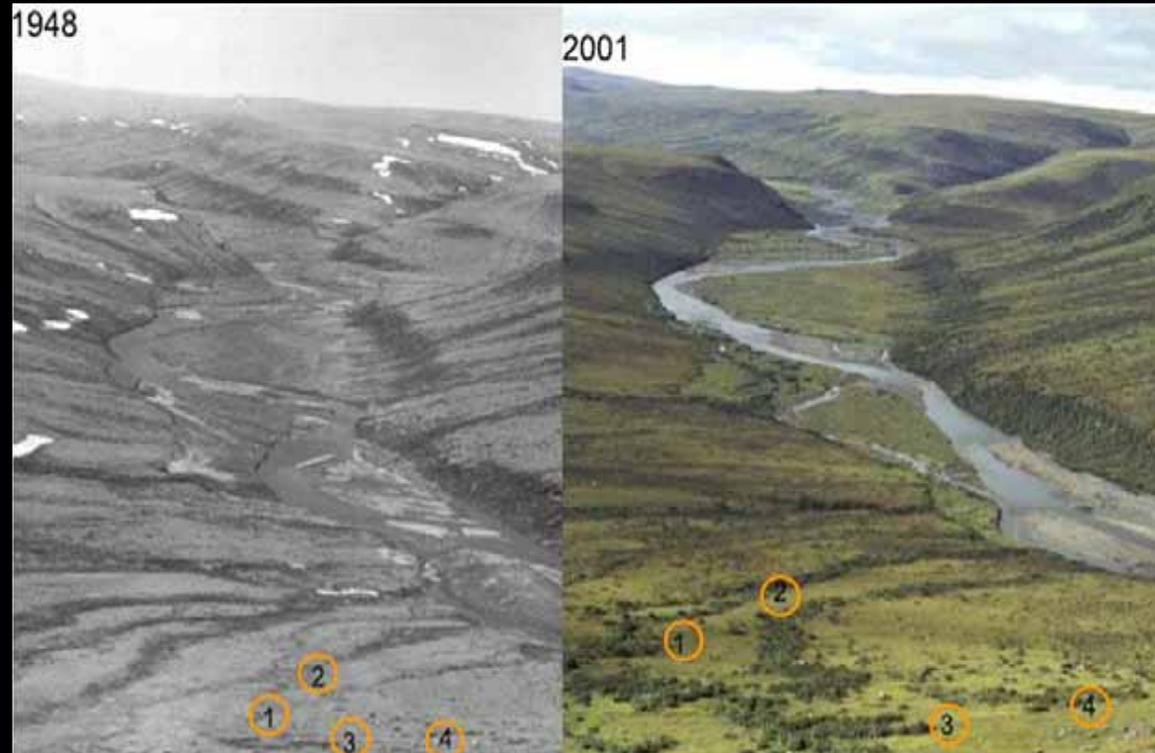
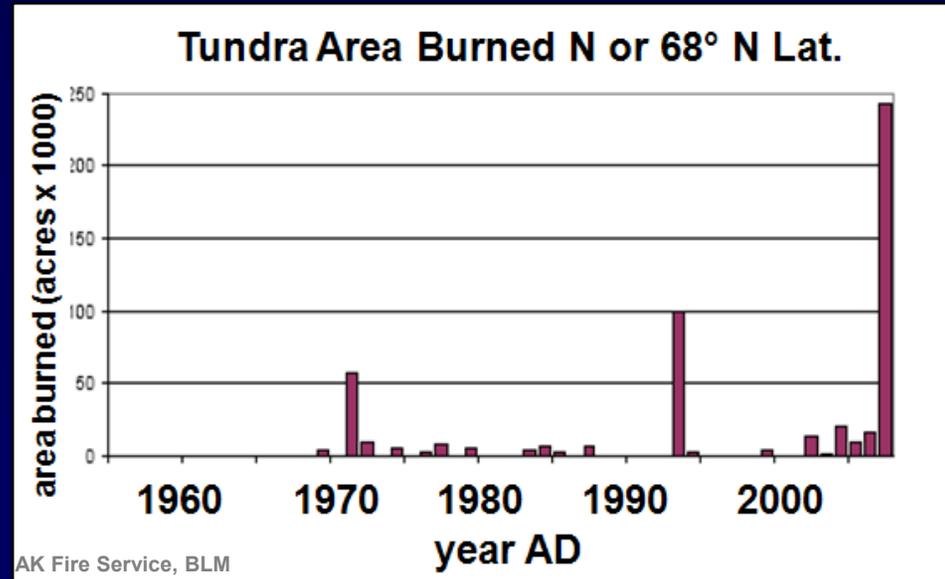


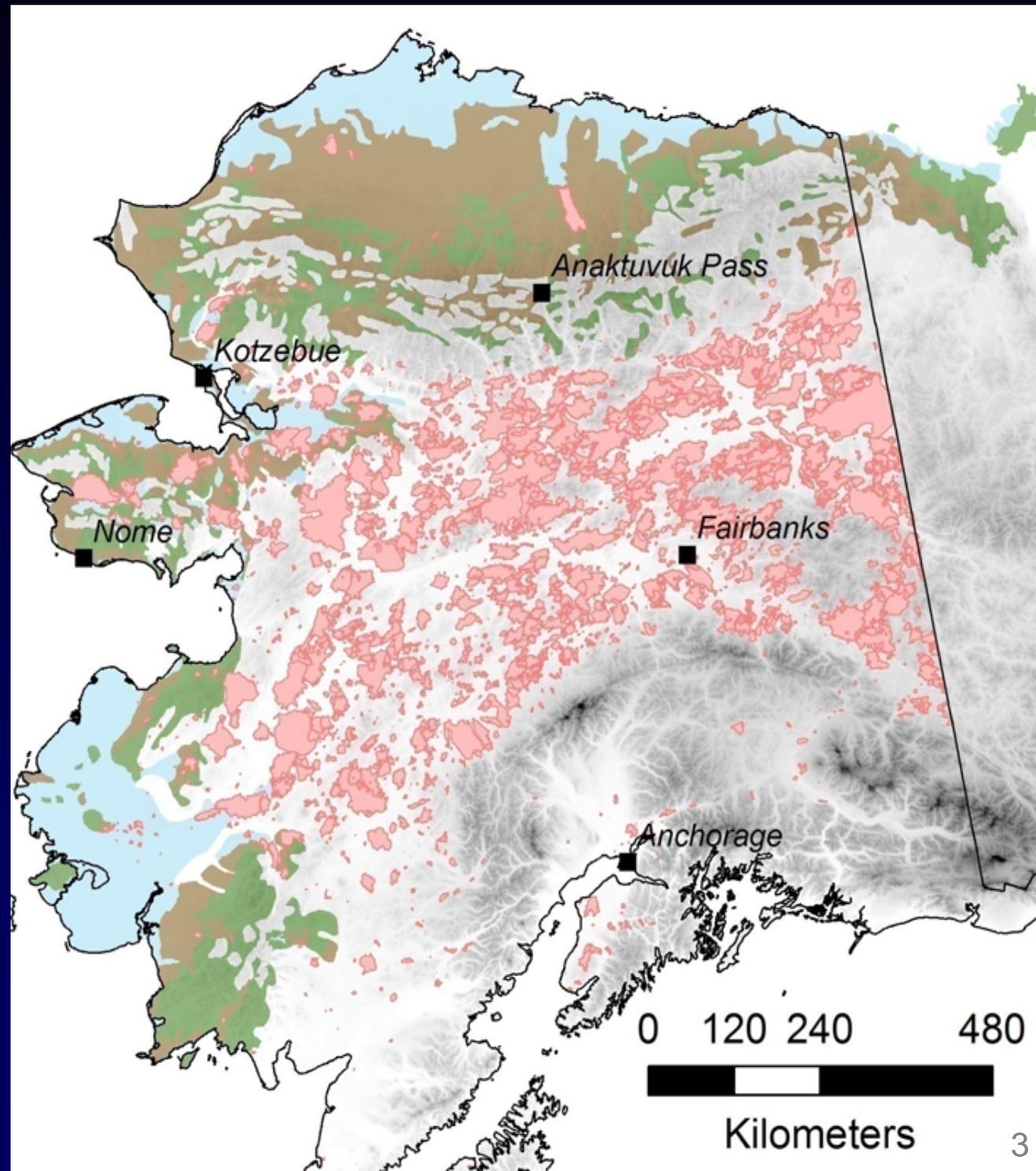
Fig. 4. from Stow *et al.* 2004. Remote sensing of vegetation and land-cover change in arctic tundra ecosystems.

- Will tundra area burned increase?

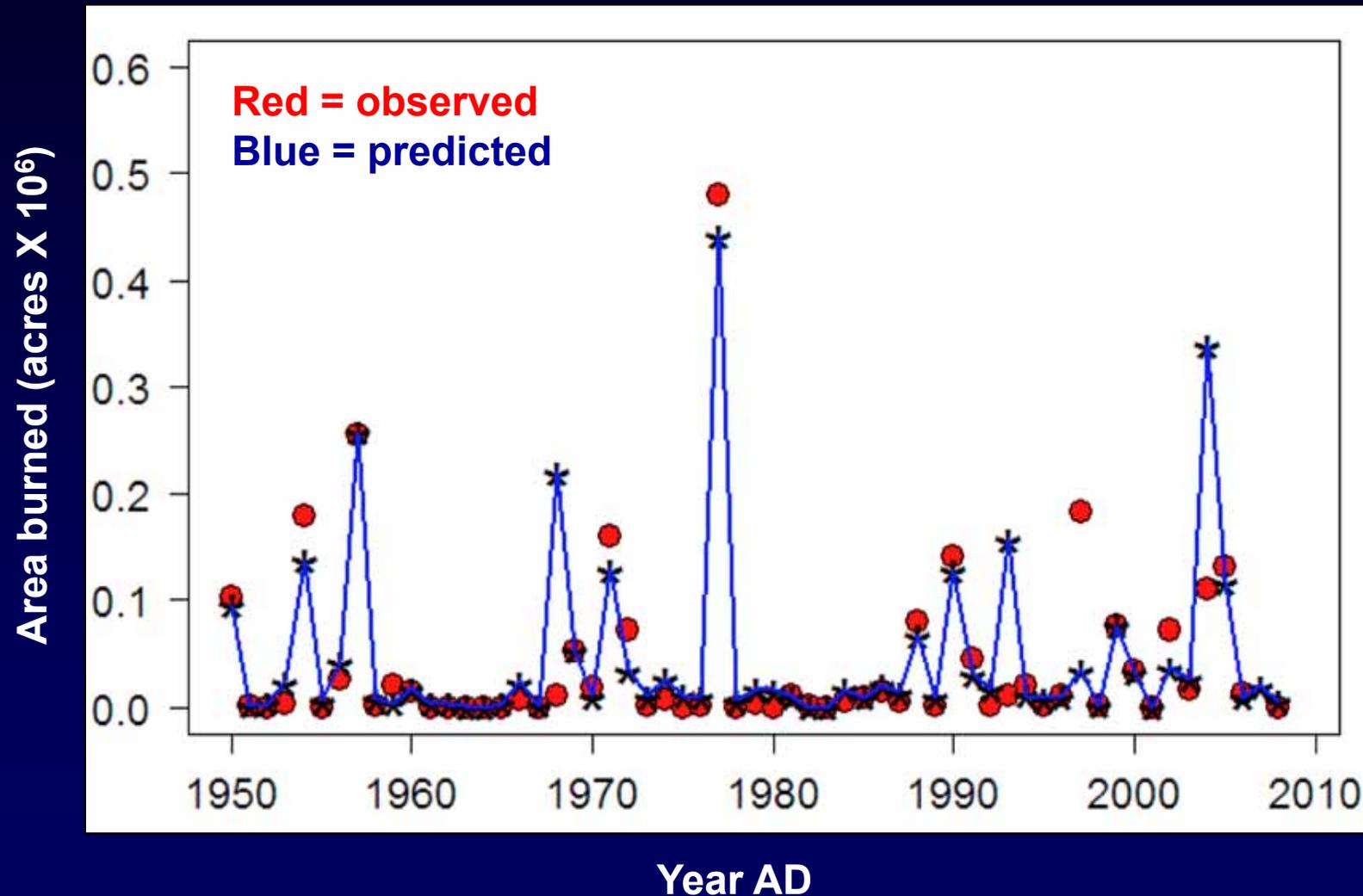


AK Fire Service, BLM

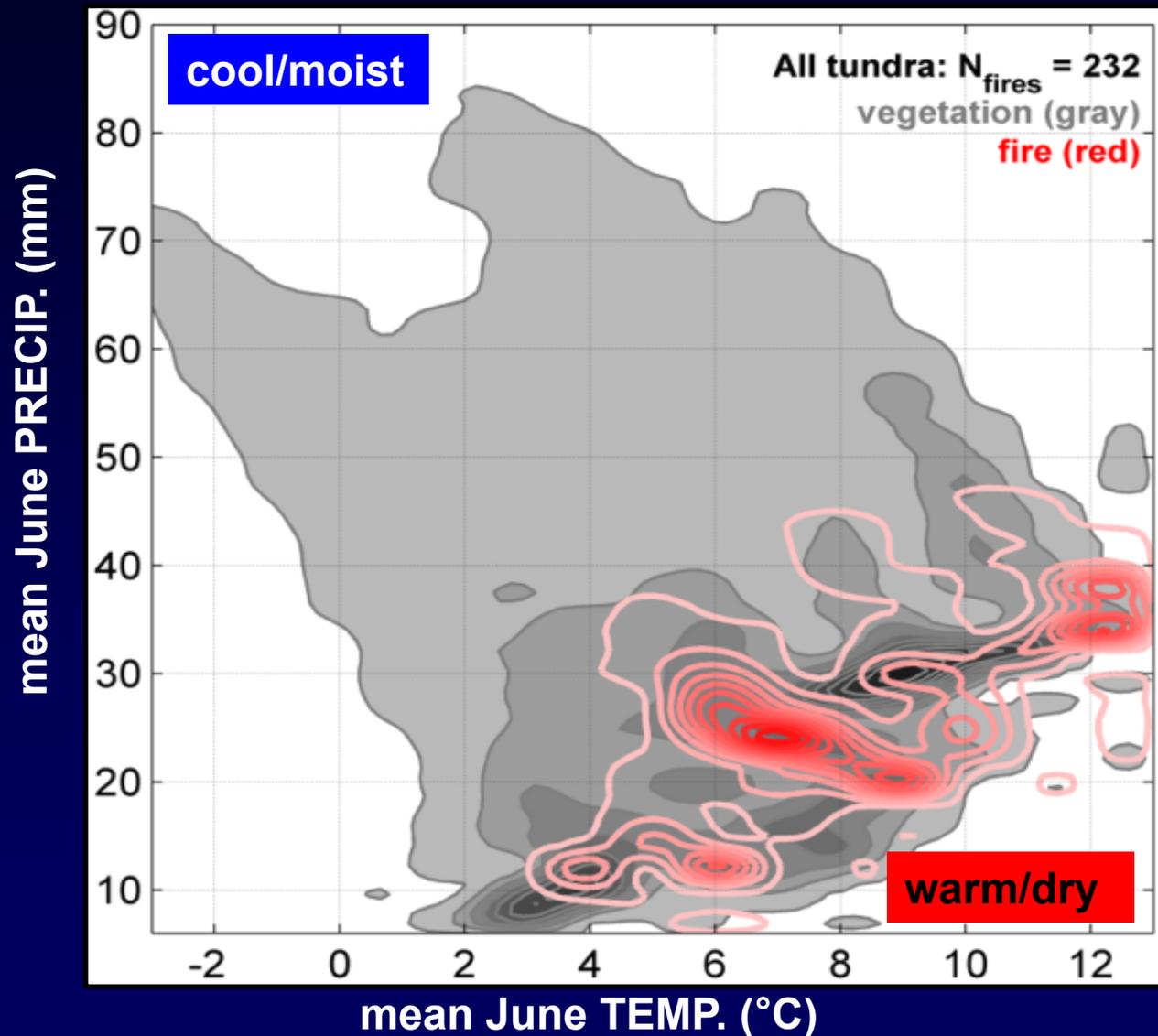
- $\approx 90\%$ area burned in boreal forest
- > 1.8 million ha burned in tundra
- 1500 citations: “boreal forest + fire”
- 151 citations: “tundra + fire”



- **Inter-annual variability explained by August temperature and precipitation (fire weather)**



- Tundra fires occur in “warm/dry” climate space



Paleo Evidence of Frequent Tundra Fires

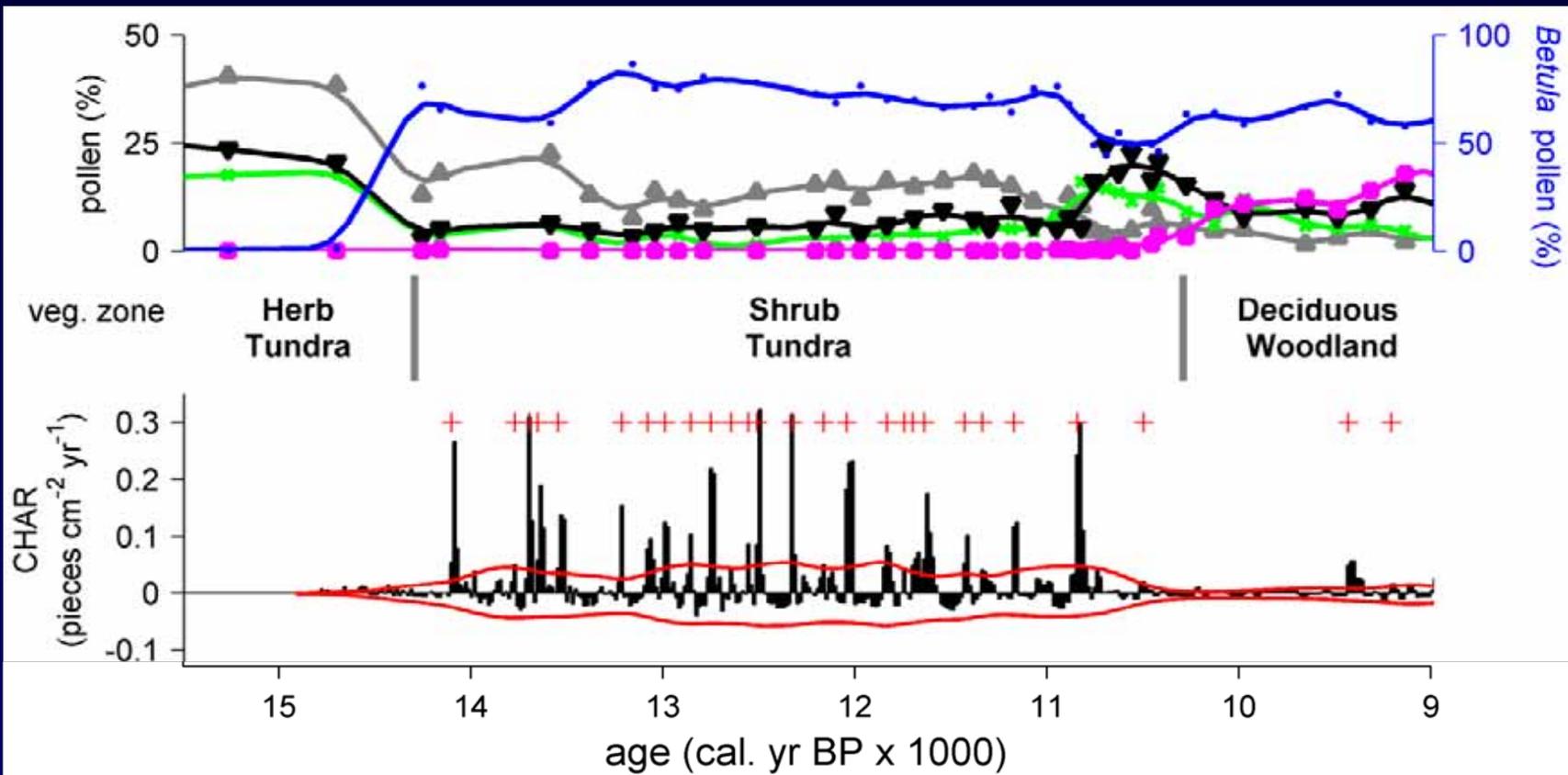
- Tundra fire frequencies could increase with shrub abundance and climatic drying

OPEN ACCESS Freely available online

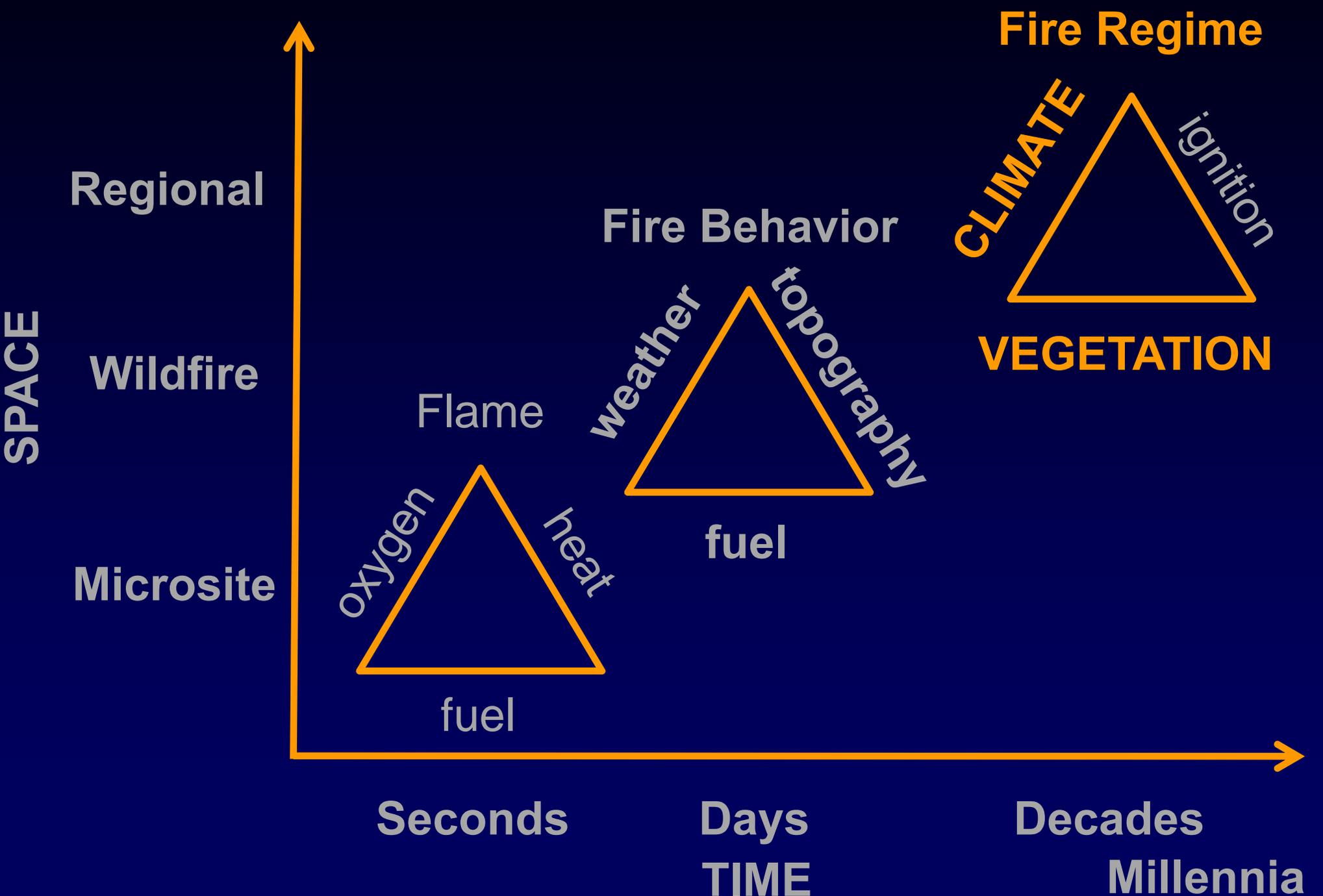
PLoS one

Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change

Philip E. Higuera^{1,2,3,4,5}, Linda B. Brubaker¹, Patricia M. Anderson², Thomas A. Brown³, Alison T. Kennedy⁴, Feng Sheng Hu^{3,6}



Conceptual Framework

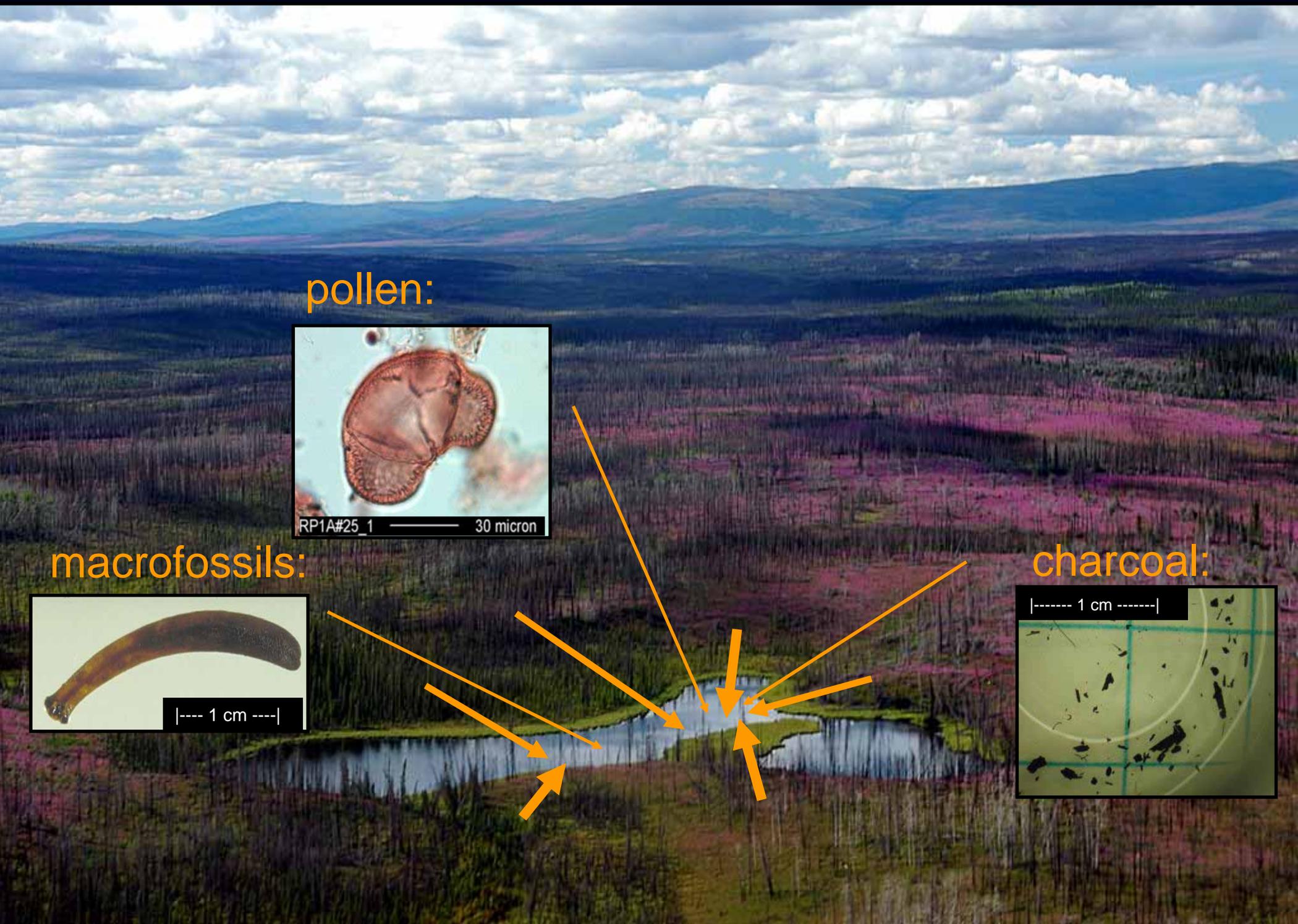


Modified from Moritz et al. 2005, PNAS

Reconstructing the past



Reconstructing the past



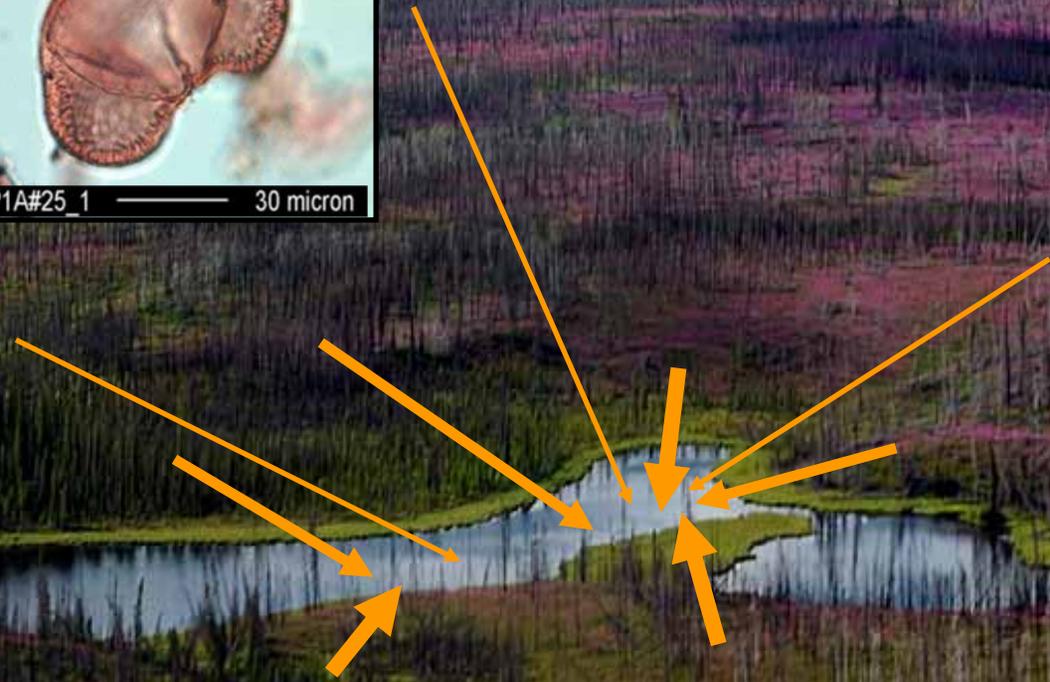
pollen:



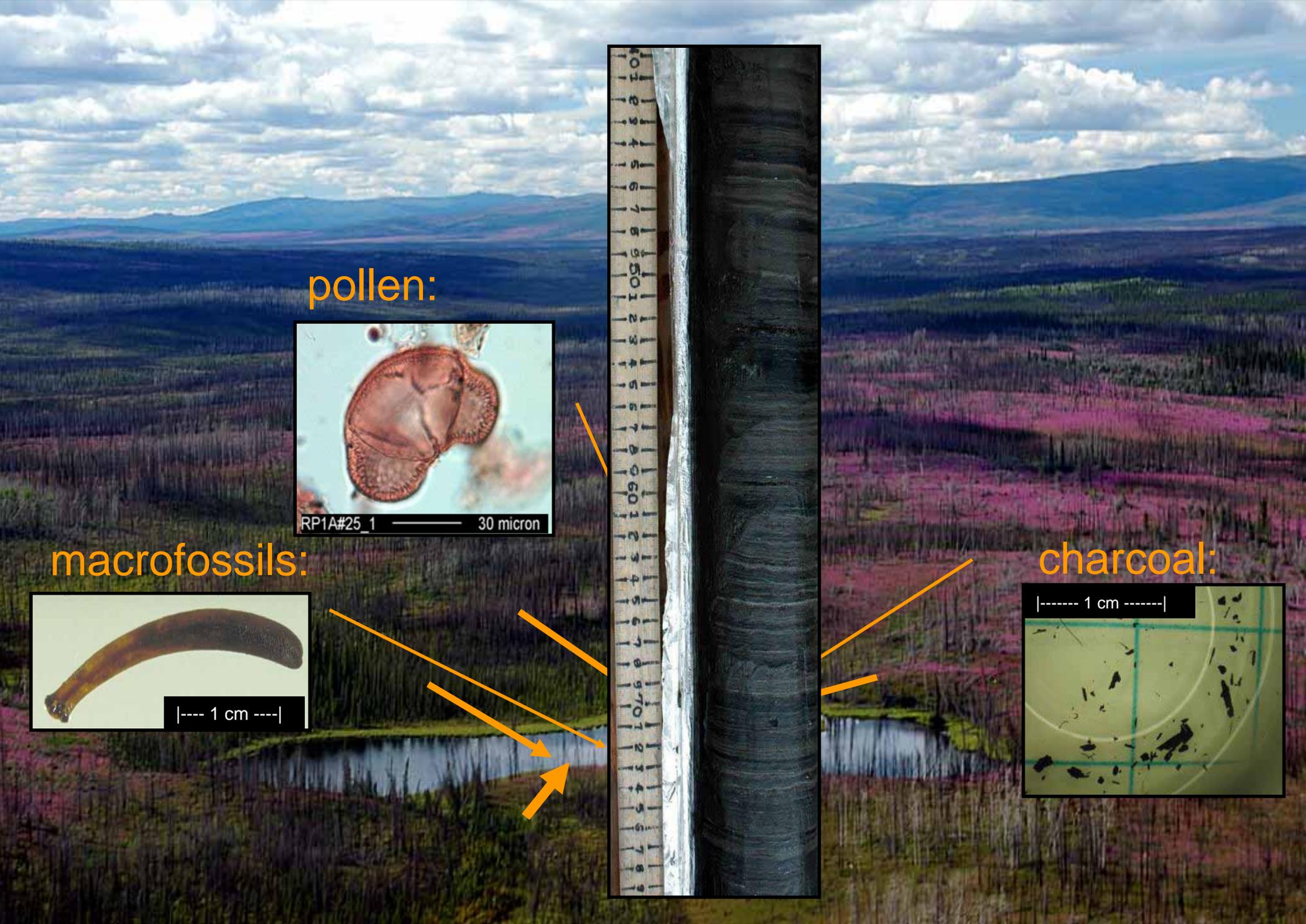
macrofossils:



charcoal:



Reconstructing the past



pollen:



macrofossils:



charcoal:



Reconstructing the past

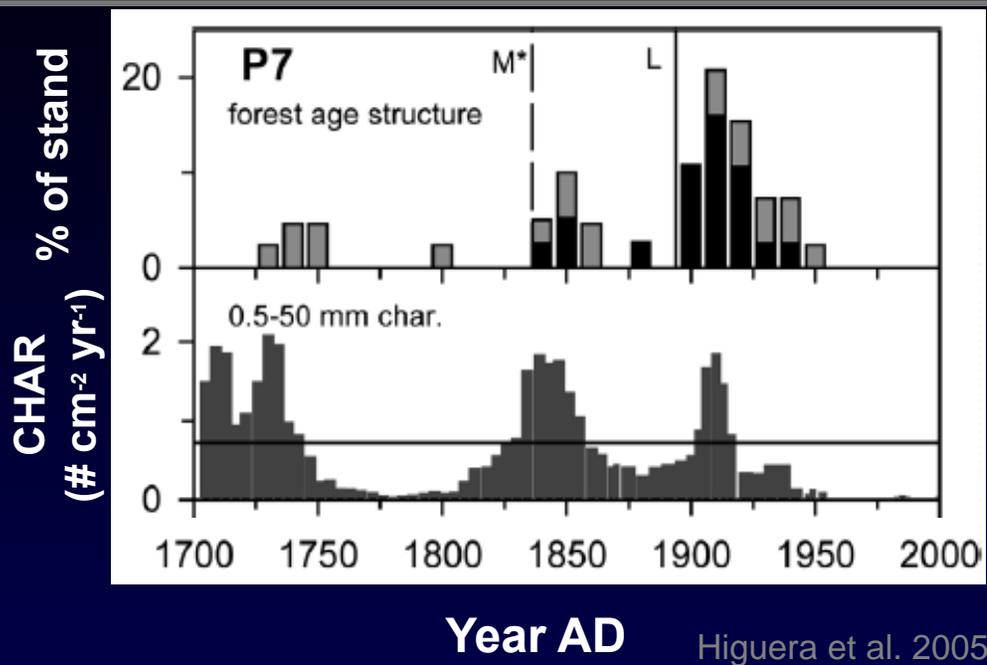


Reconstructing the past



Fire history from continuous sediment records

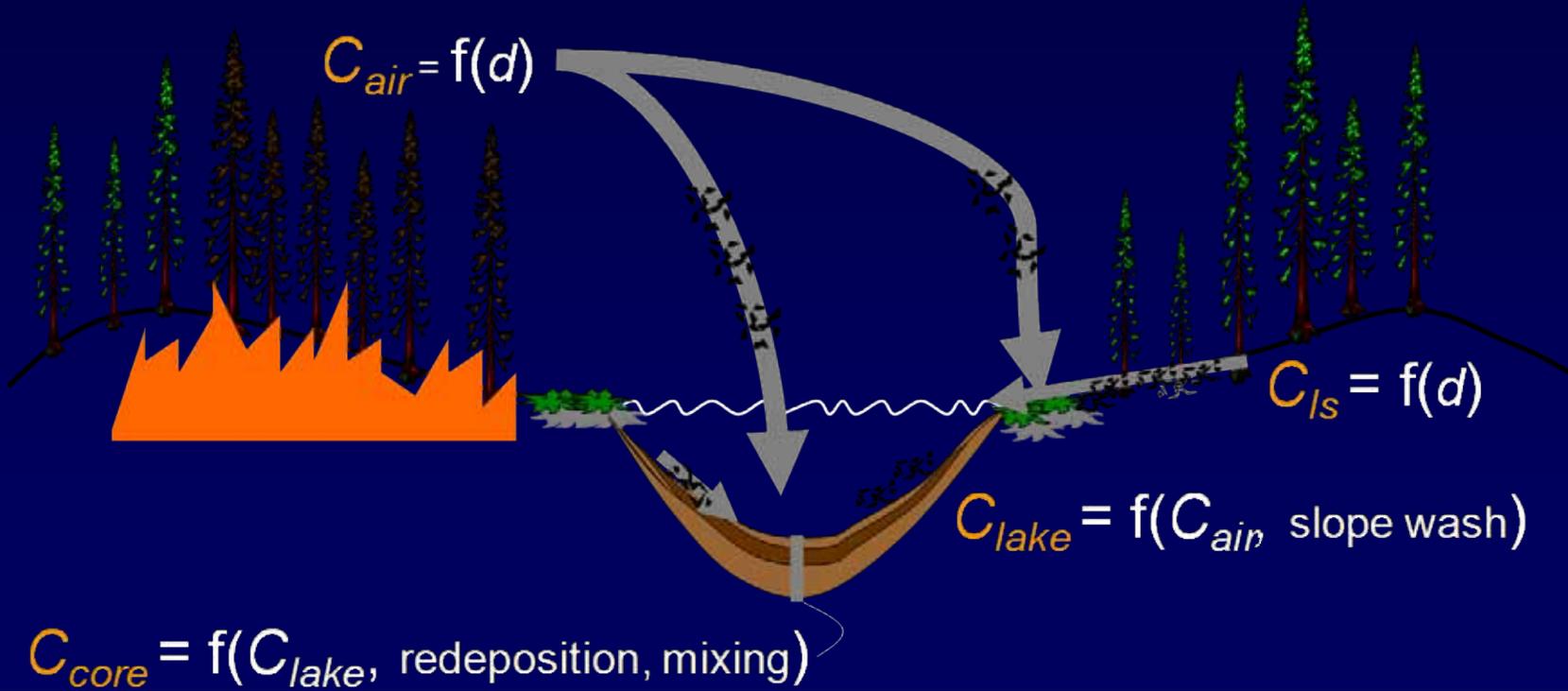
Empirical support:



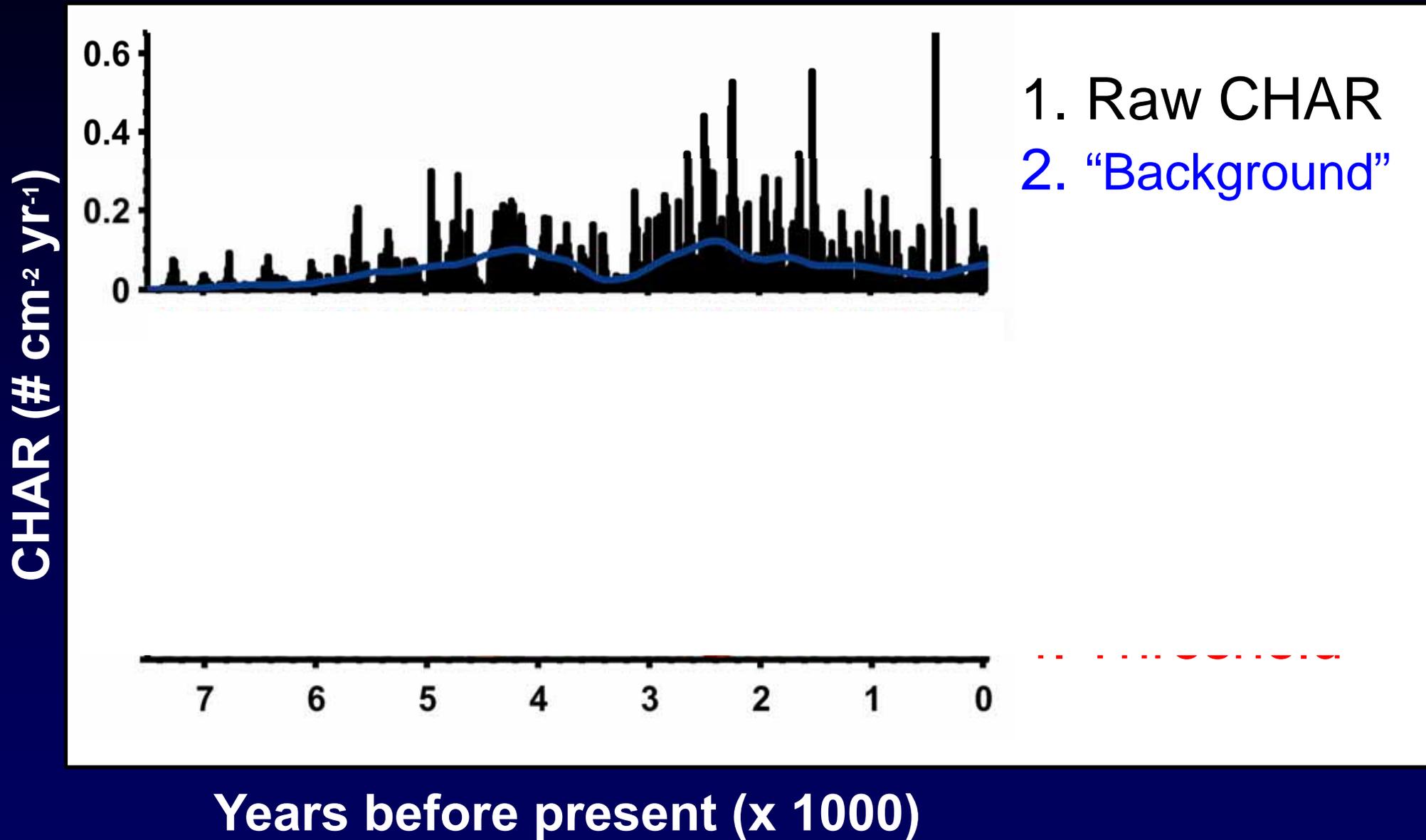
Stand age & fire scars

Charcoal accumulation

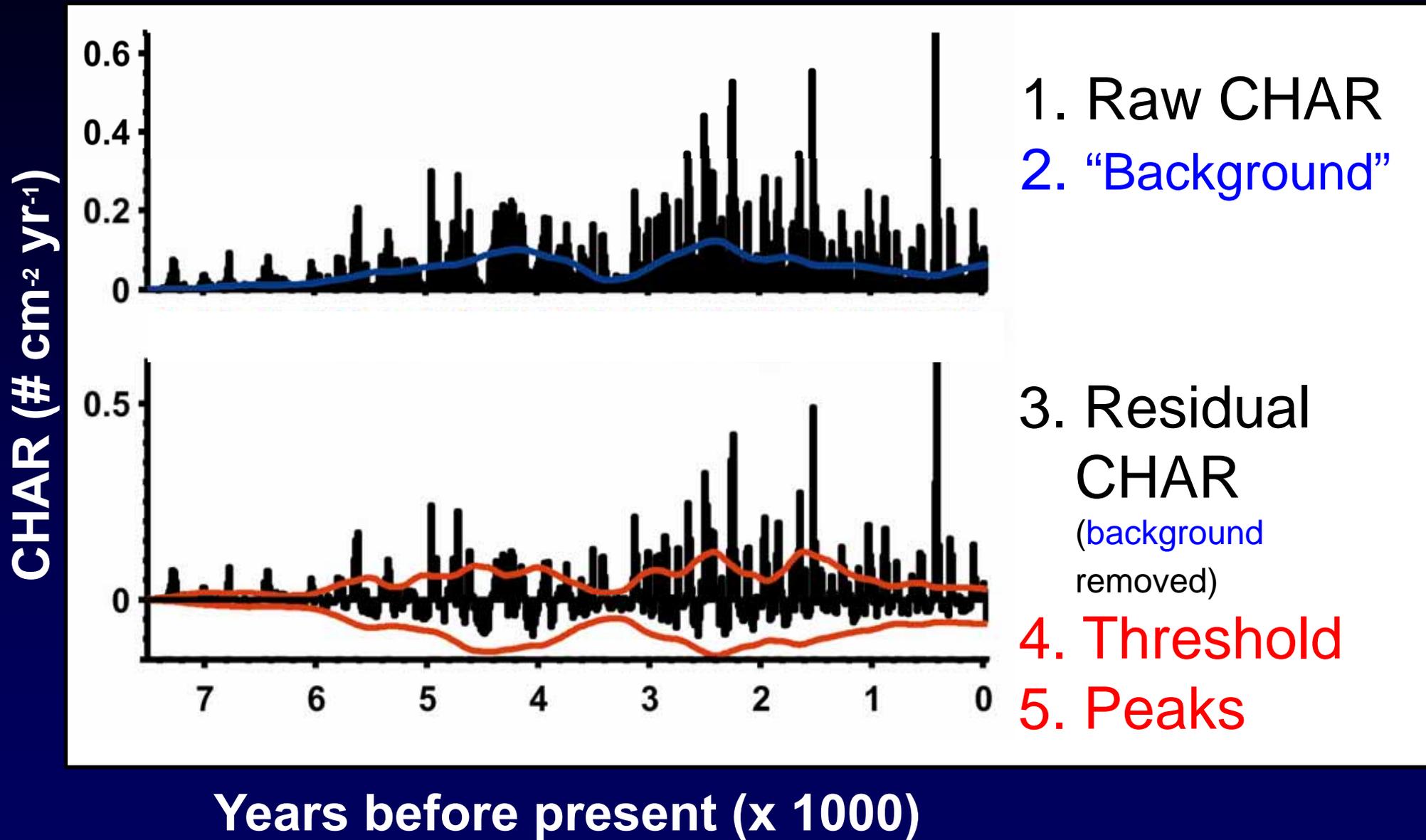
Theoretical support:



Fire history from continuous sediment records

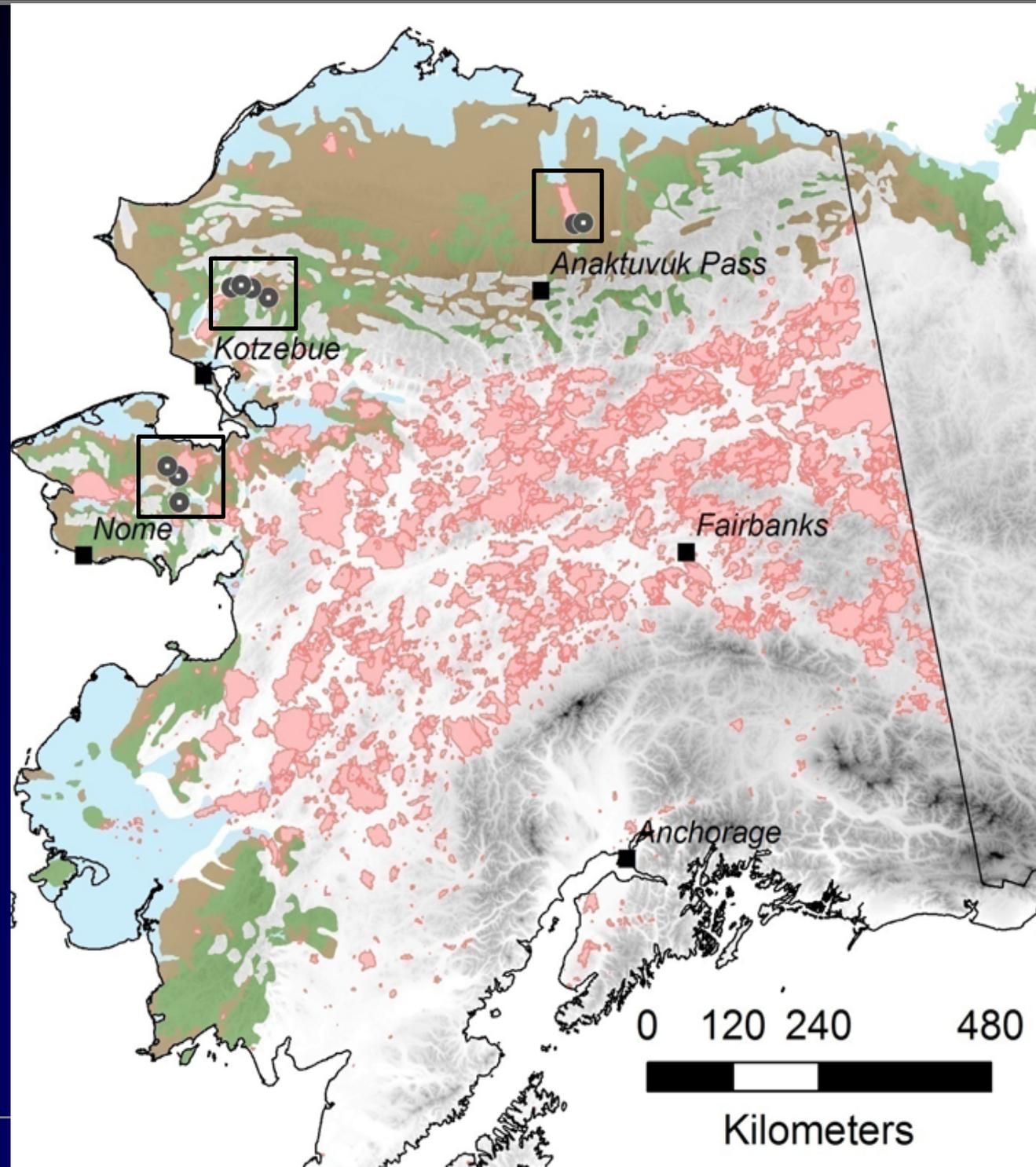


Fire history from continuous sediment records



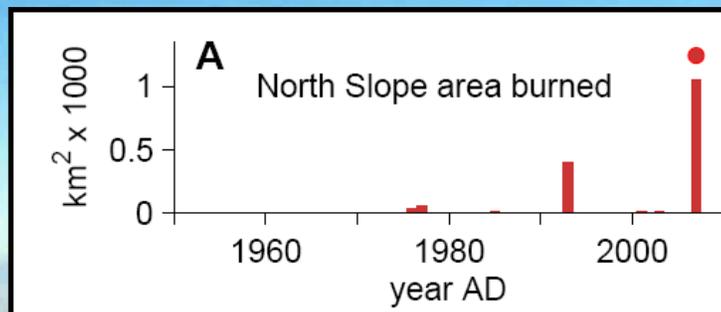
Holocene records of tundra fires

- Anaktuvuk River Fire
- Noatak NP
- Bering Land Bridge NP



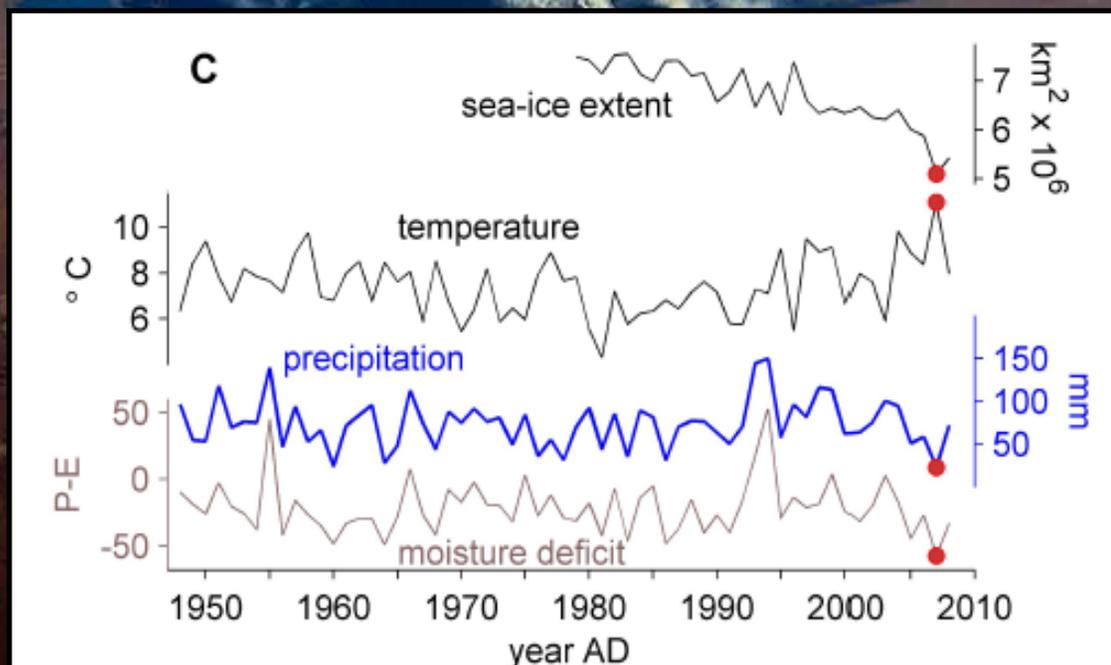
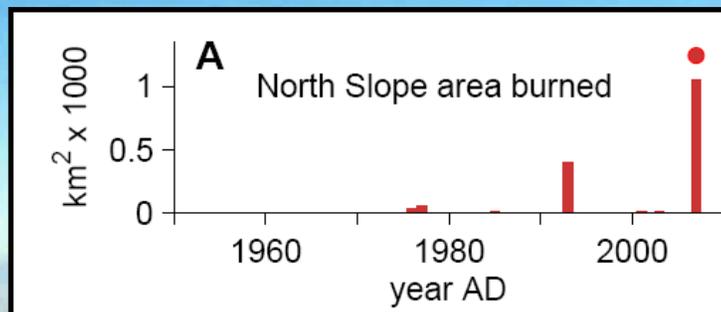
Unprecedented Tundra Burning and Possible Linkages to Extreme Sea-Ice Retreat

F. S. Hu, P.E. Higuera,
J. E. Walsh, W. L. Chapman,
L. B. Brubaker, M. L. Chipman



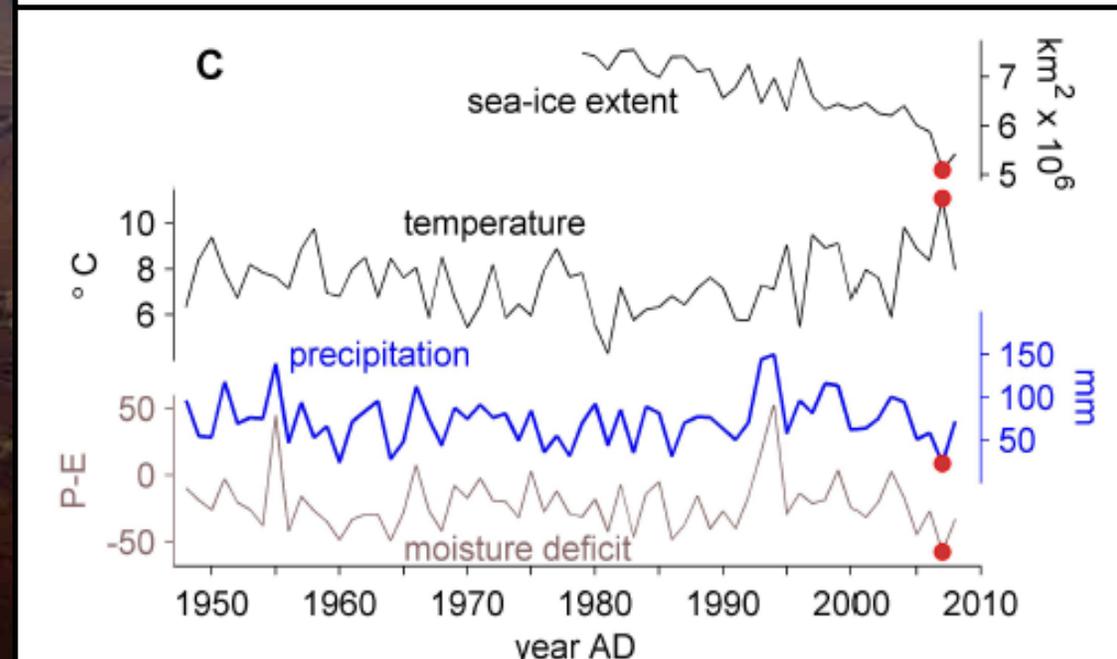
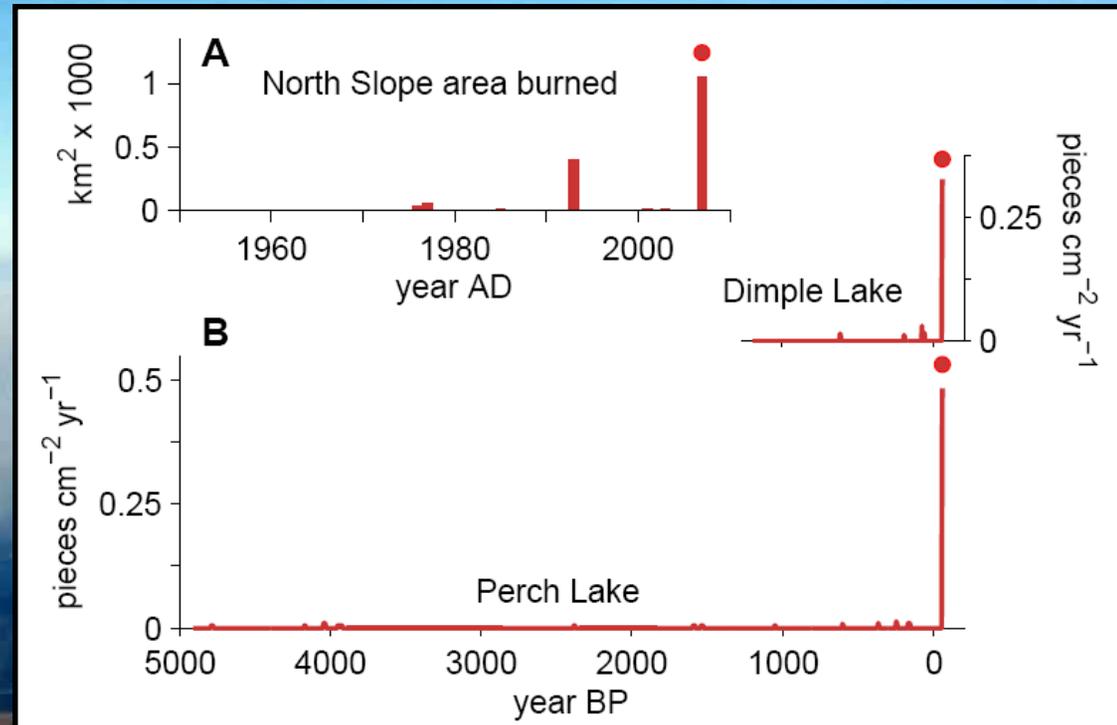
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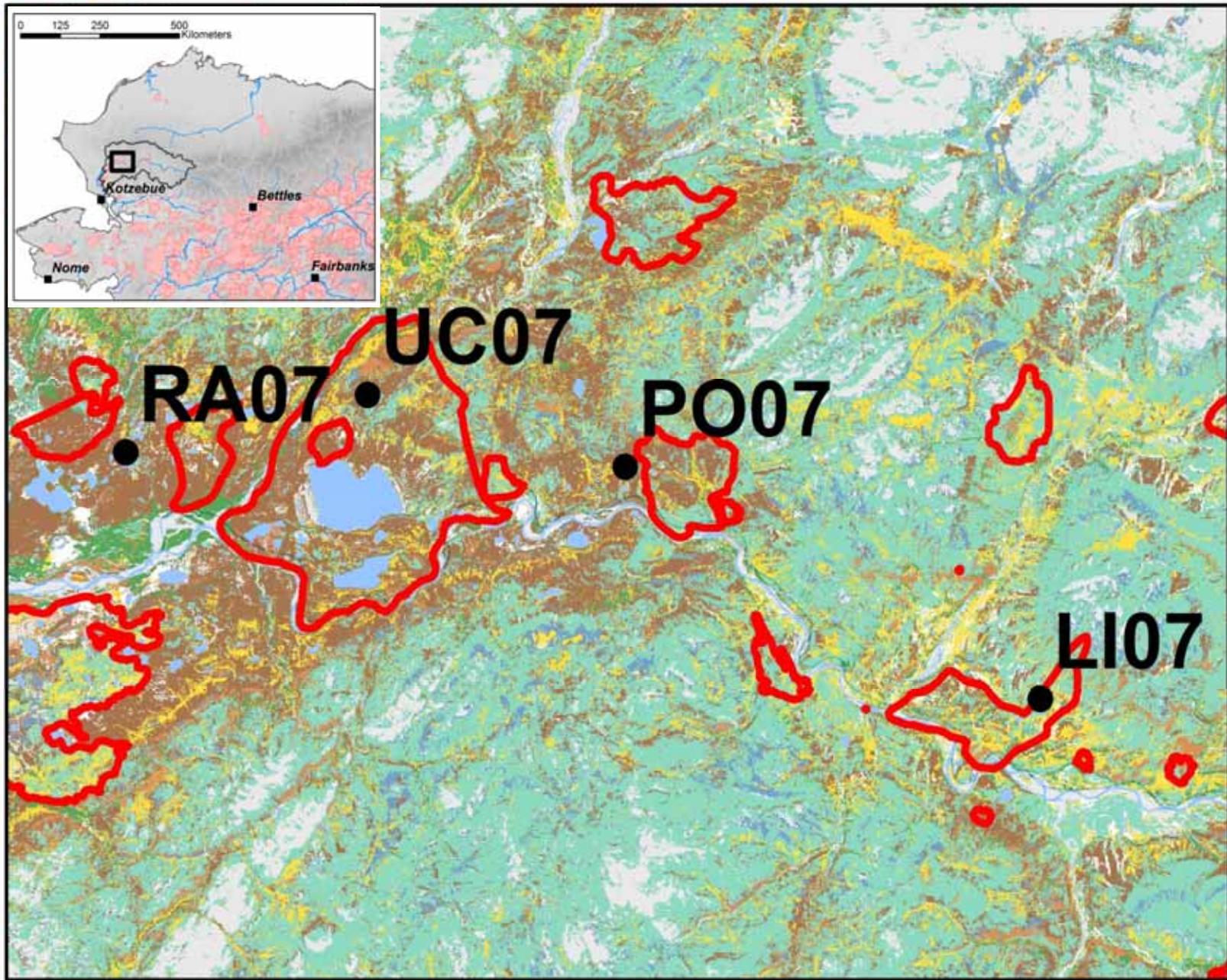
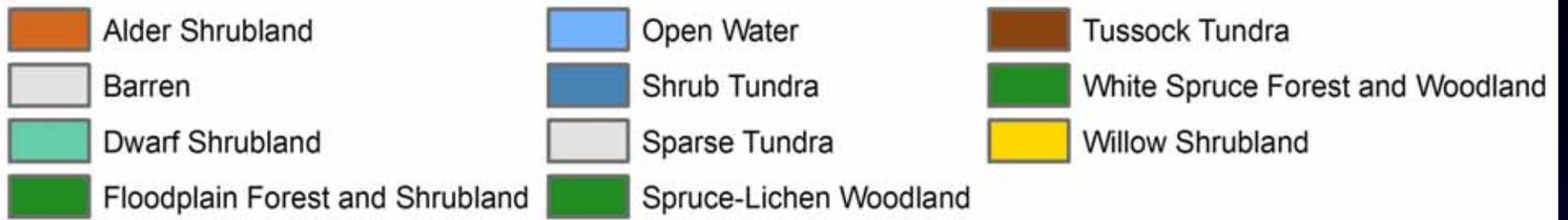
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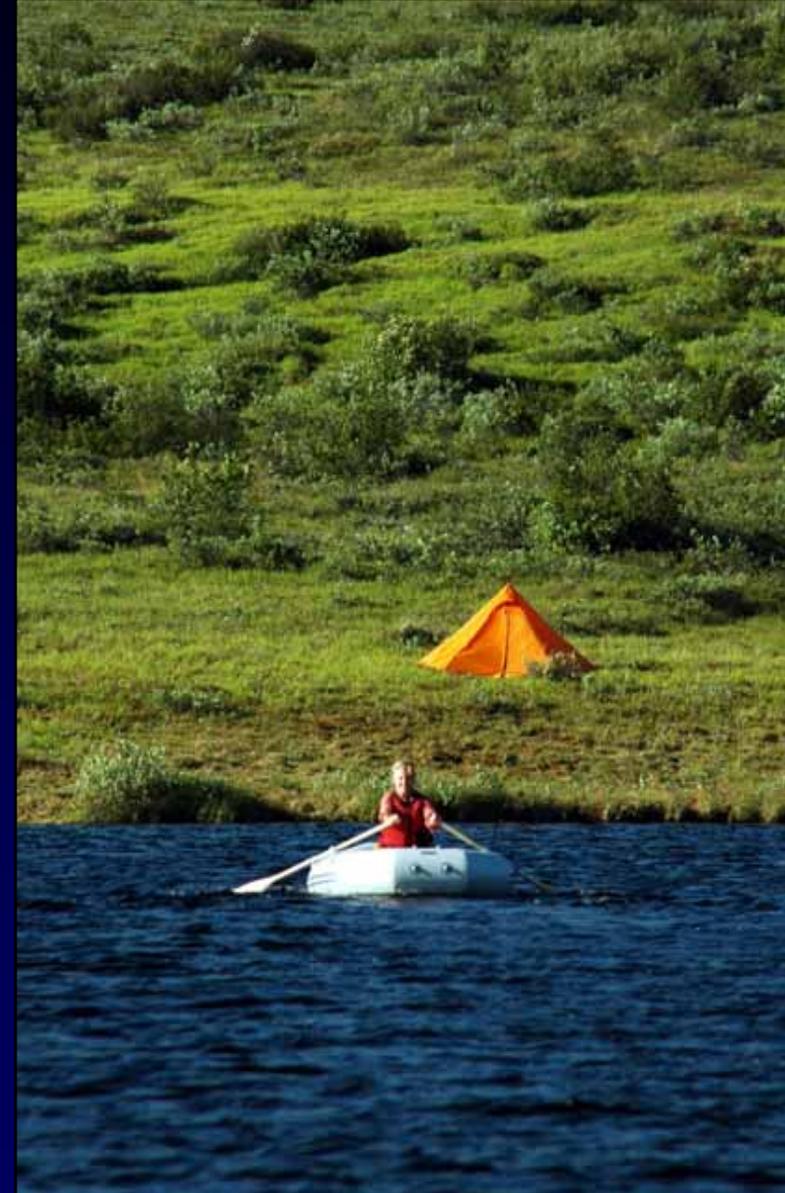


- 1. Quantify tundra fire history over the past 6000 years**
- 2. Infer climate-vegetation-fire relationships from pollen and independent paleoclimatic records**
- 3. Inform ecosystem model (ALFRESCO) for assessing fire and fuels hazards in tundra under future climate / veg.**

Noatak Study Area



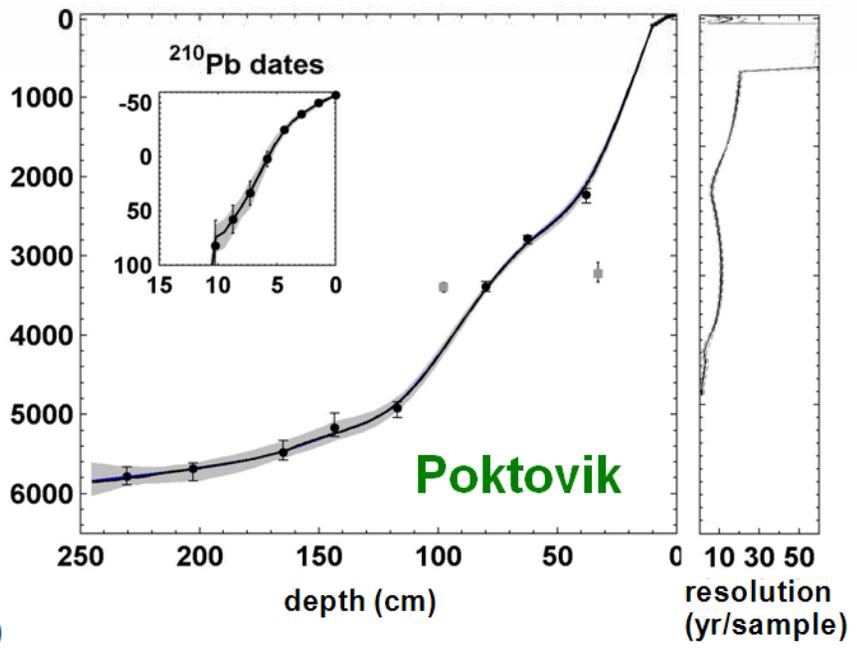
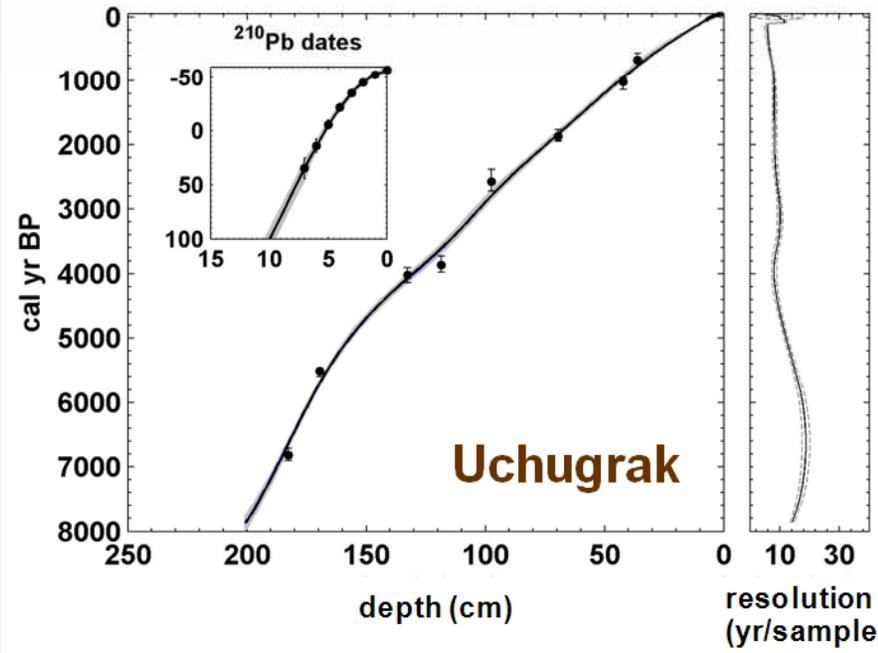
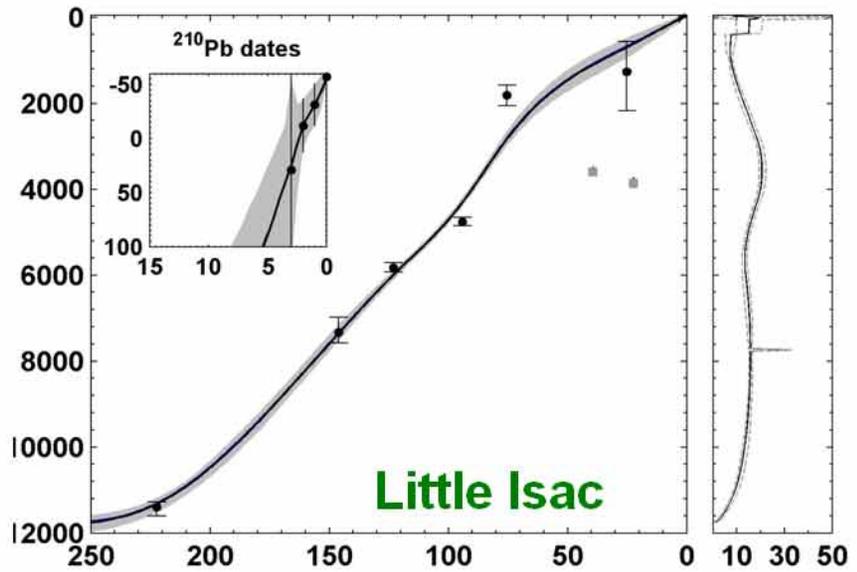
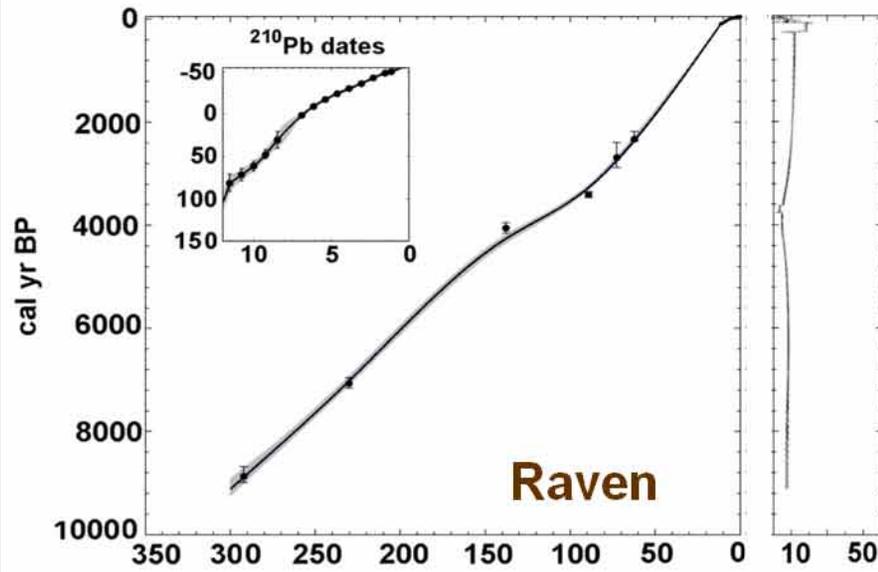
Graminoid Tundra:
Cyperaceae , Poaceae, dwarf shrubs



Shrub Tundra:
Betula, Alnus, Salix

Age Models

age (cal. yr BP)



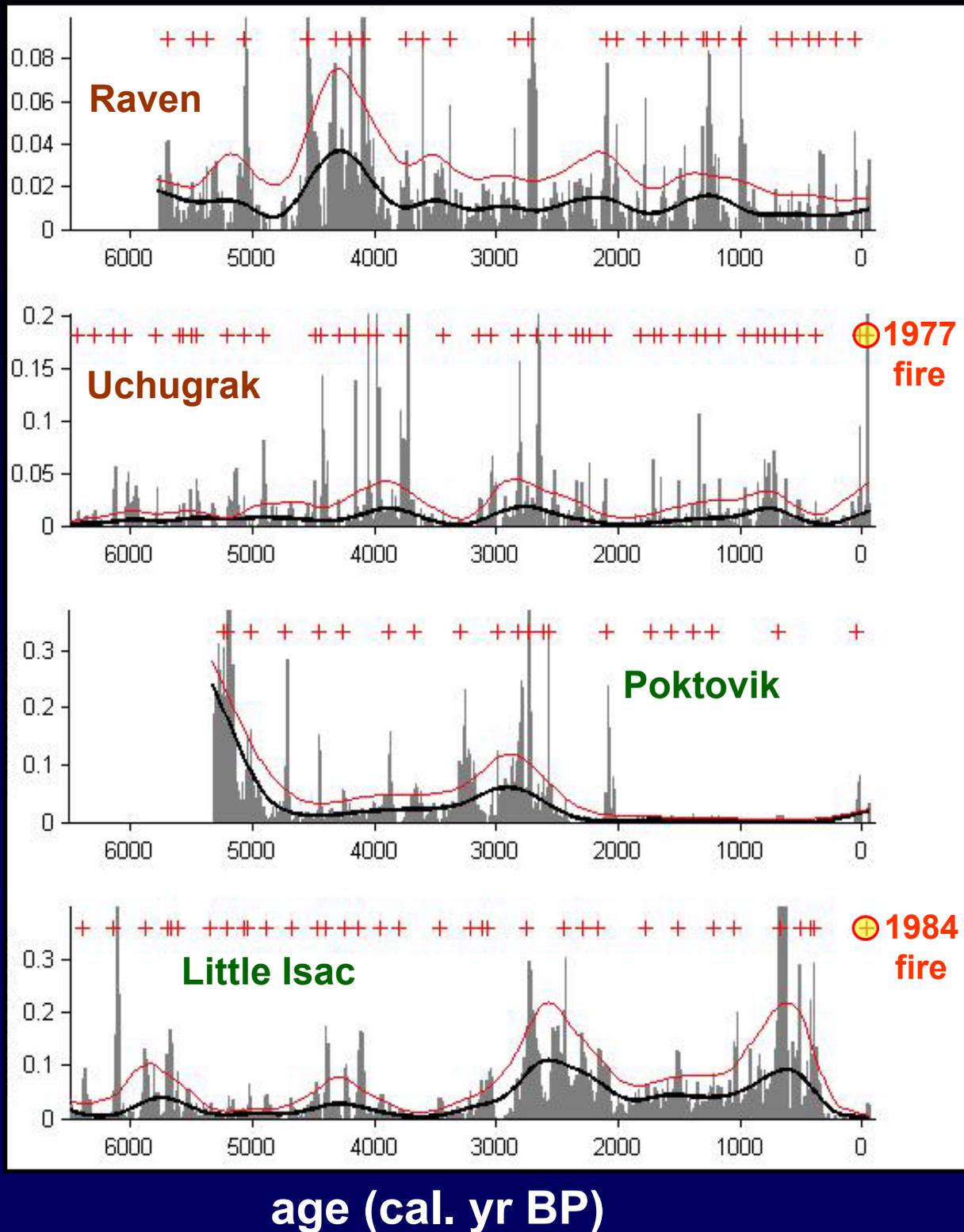
• ^{14}C or ^{210}Pb date, 95% CI — cubic spline interpolant, 95% CI ■ excluded date, 95% CI*

depth (cm)

Peak Identification

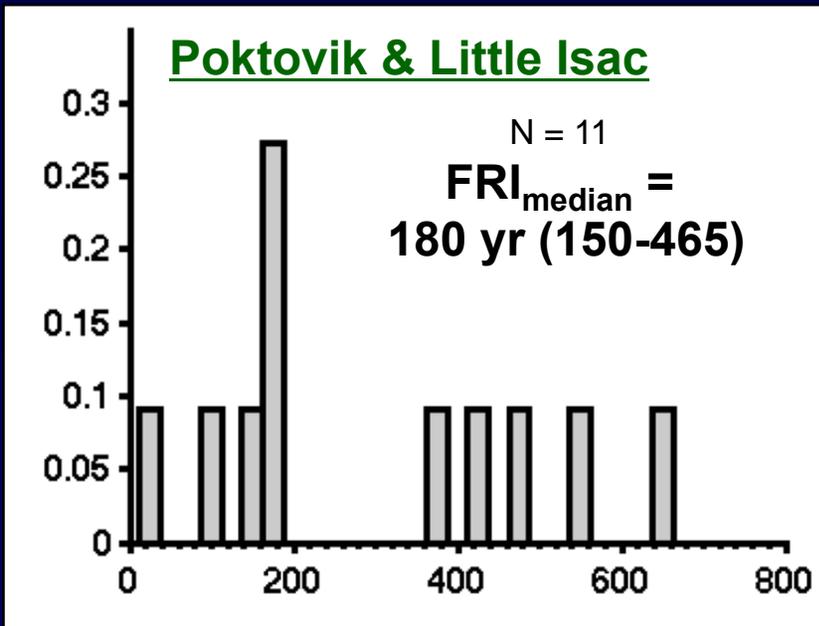
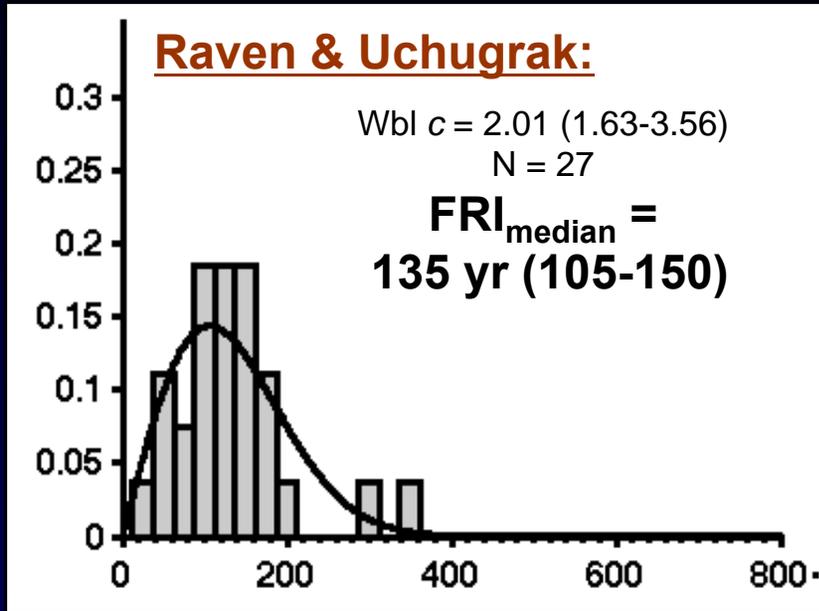
1. Tundra burns

- Records appropriate for peak identification
- Recent large fires detected



2. Location matters

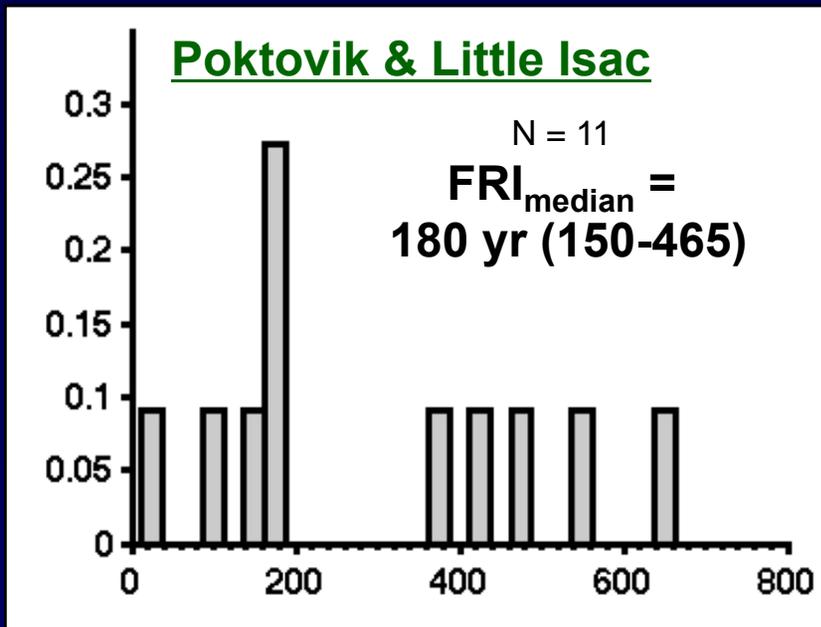
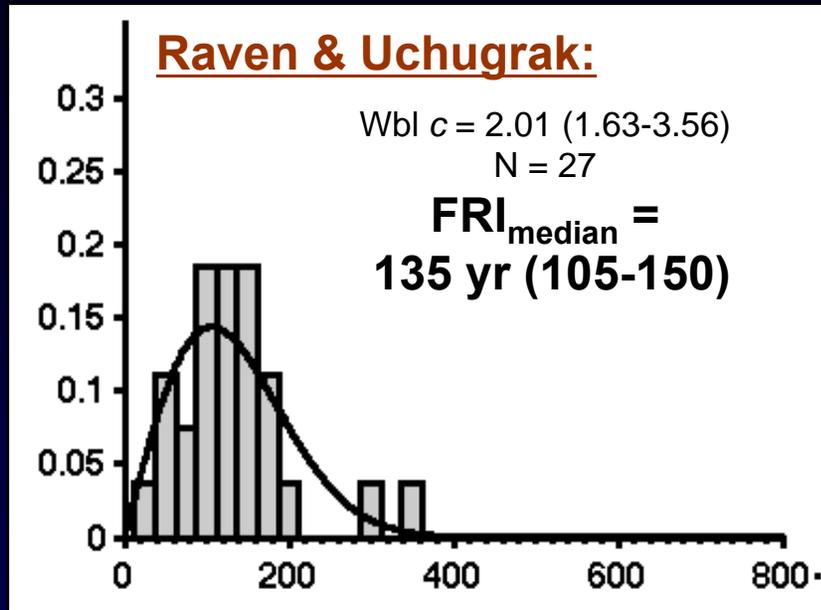
density OR proportion (x25)



FRI (yr)

Fire return intervals since 2000 yr BP

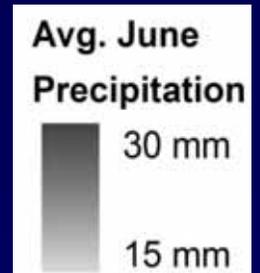
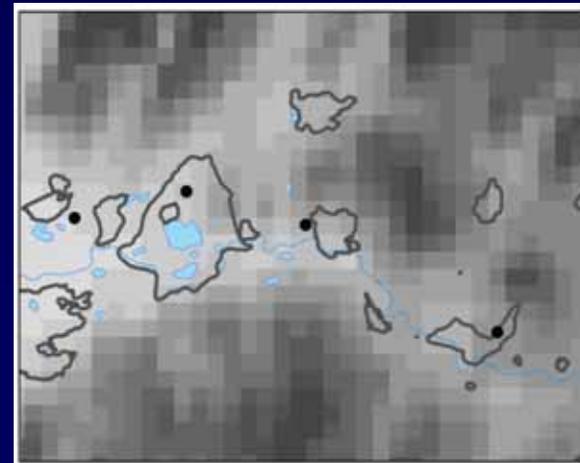
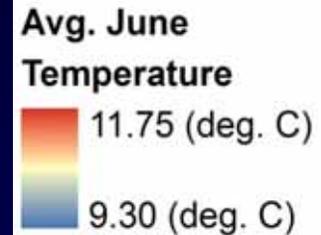
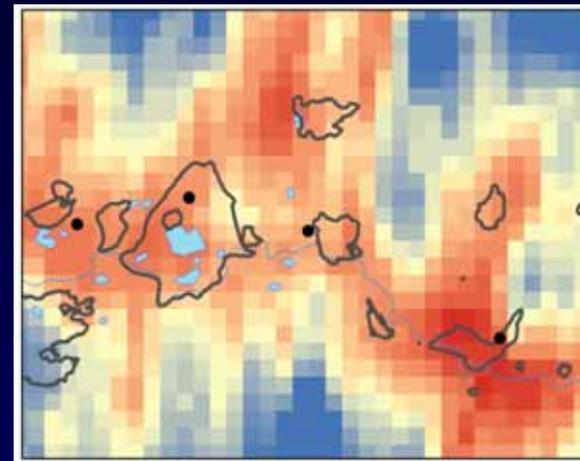
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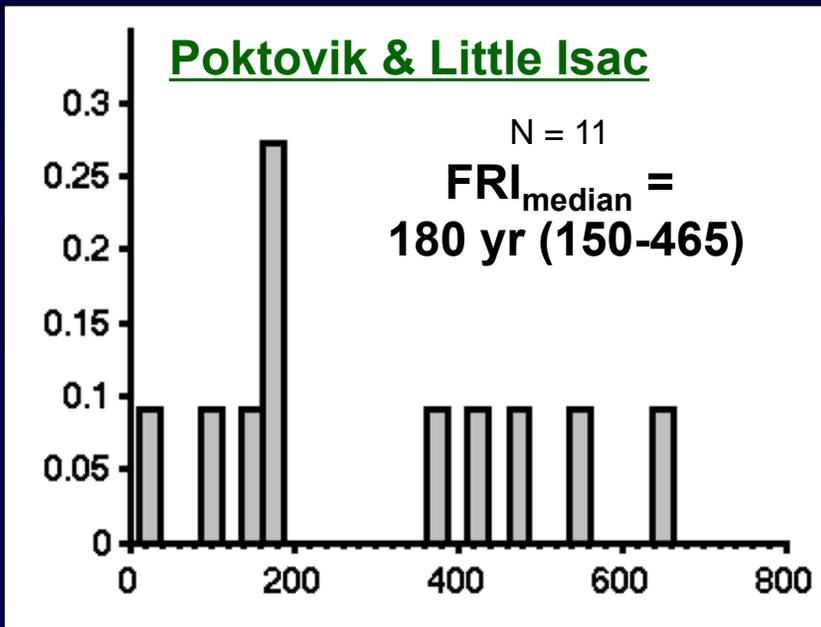
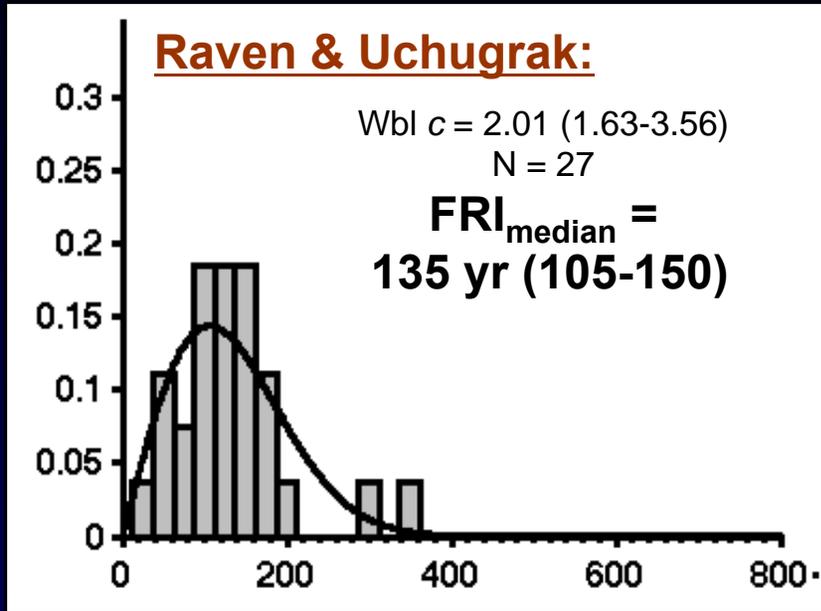
FRI (yr)

2. Location matters:

- climate



density OR proportion (x25)



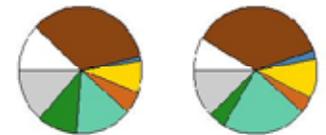
FRI (yr)

2. Location matters:

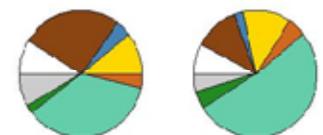
- climate + vegetation



RA, UC:



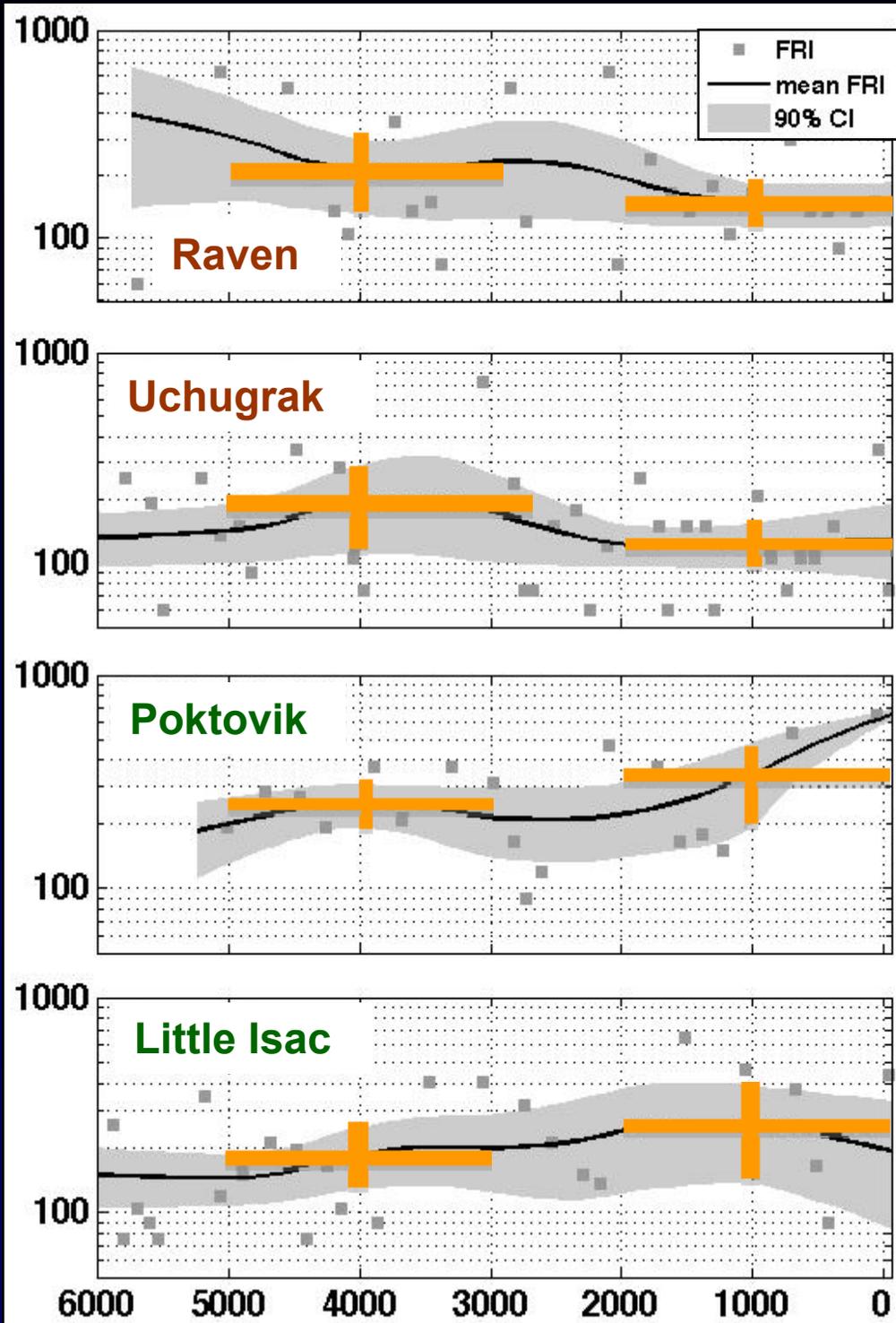
PO, LI:



fewer fires →

FRI (yr)

← more fires



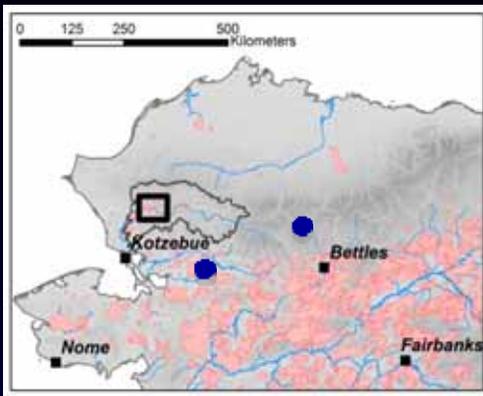
age (cal yr BP)

3. FRIs vary through time

- At individual sites
- Between sites

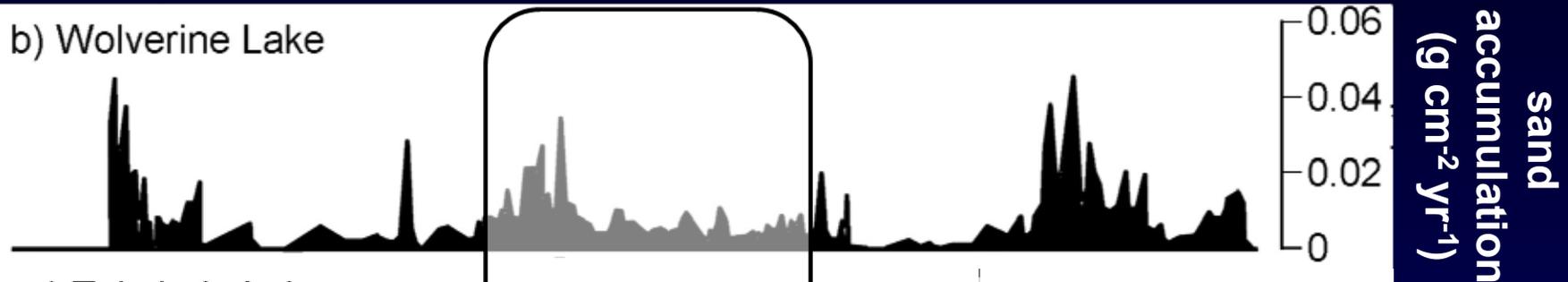
site	4000 yr BP	1000 yr BP
RA	210	140
UC	195	130
PI	250	340
LI	180	260

Holocene effective moisture



125 km

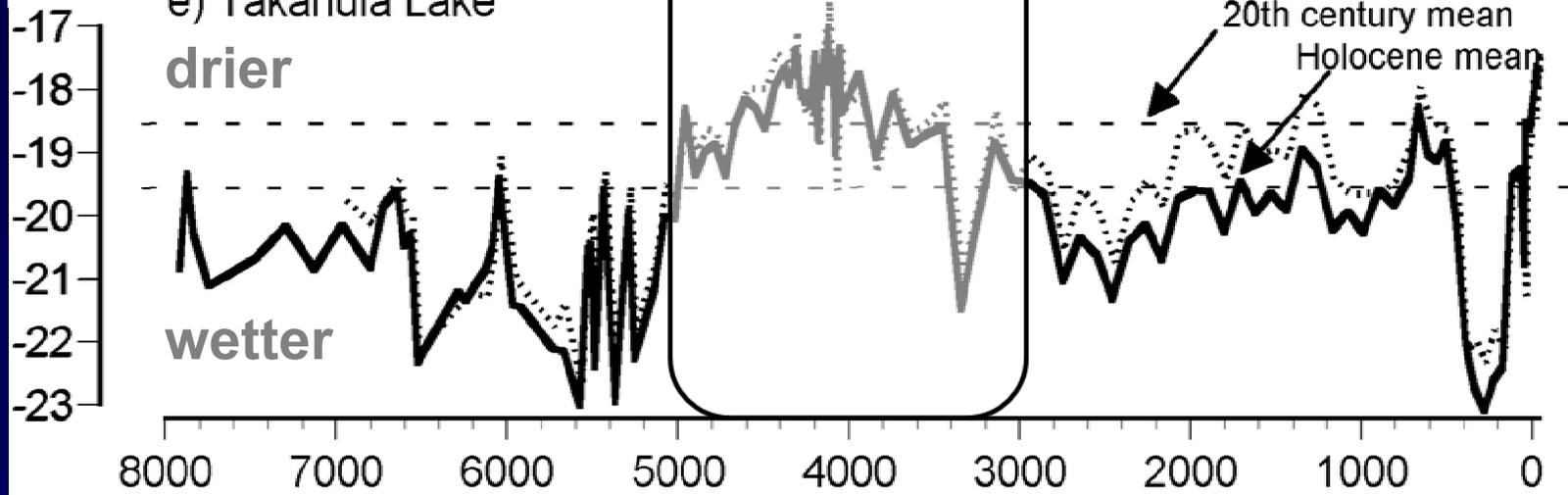
b) Wolverine Lake



sand
accumulation
(g cm⁻² yr⁻¹)

e) Takahula Lake

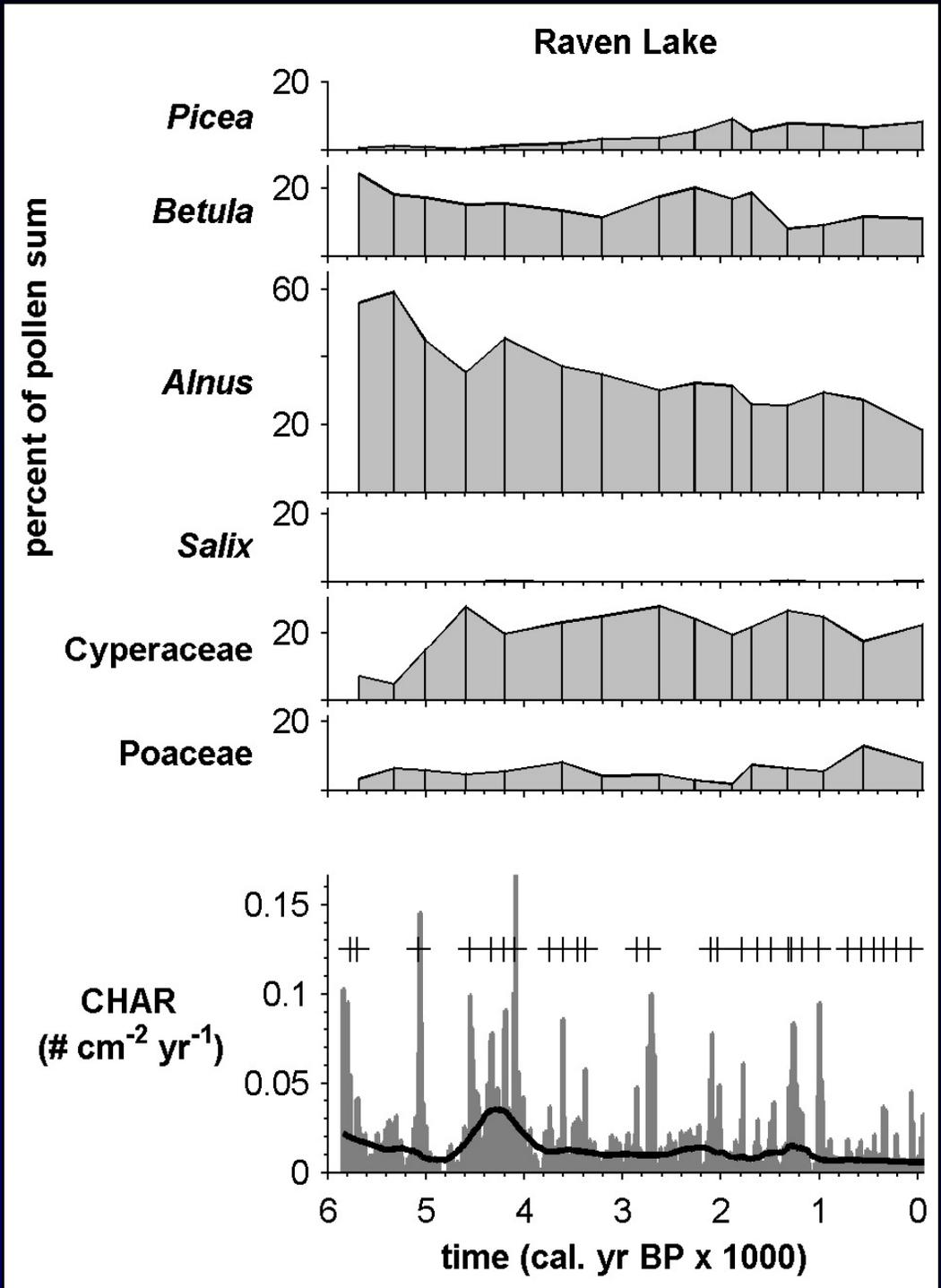
$\delta^{18}\text{O}$ (‰ V-PDB)



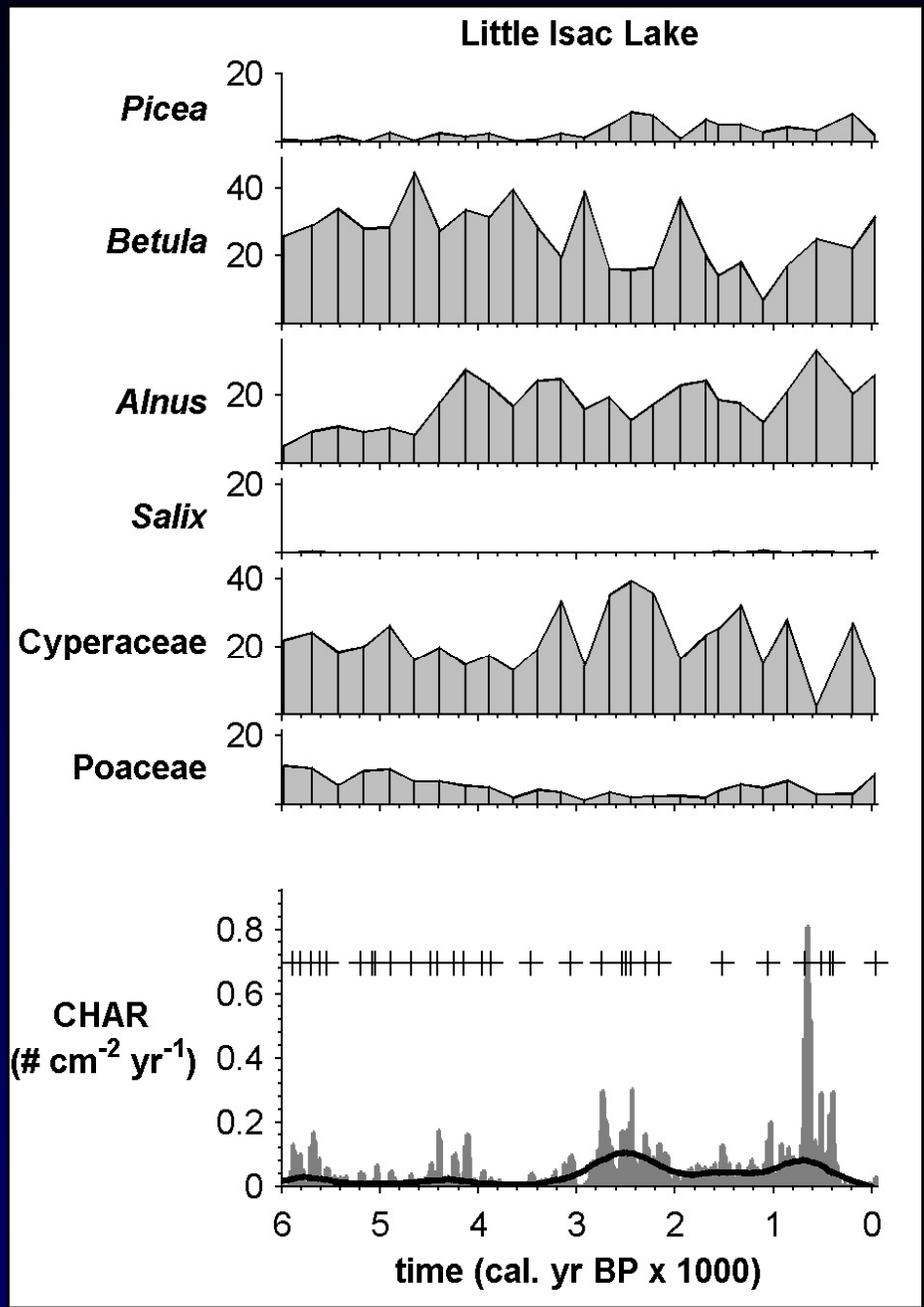
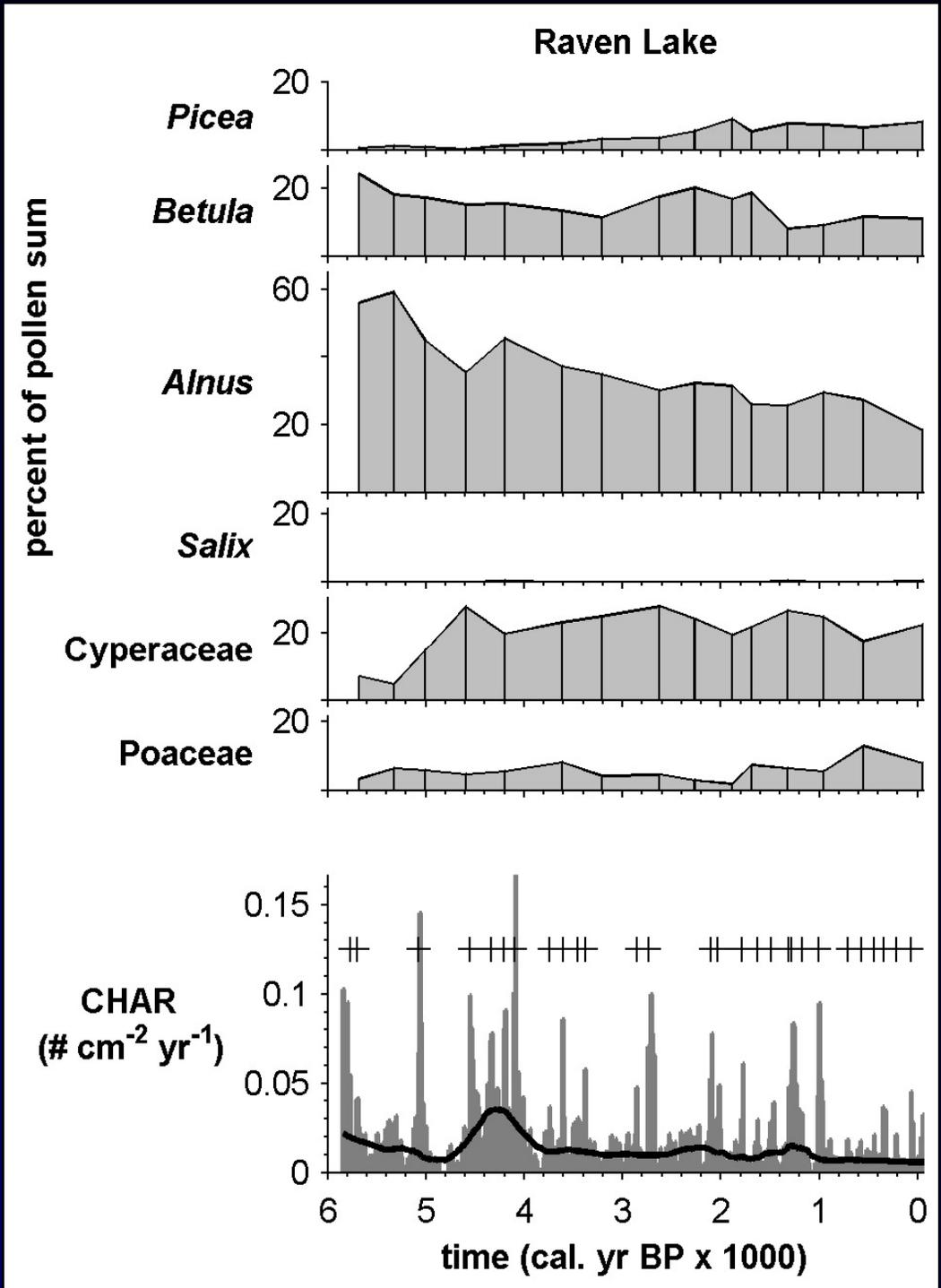
300 km

age (cal. yr BP)

Holocene vegetation change



Holocene vegetation change



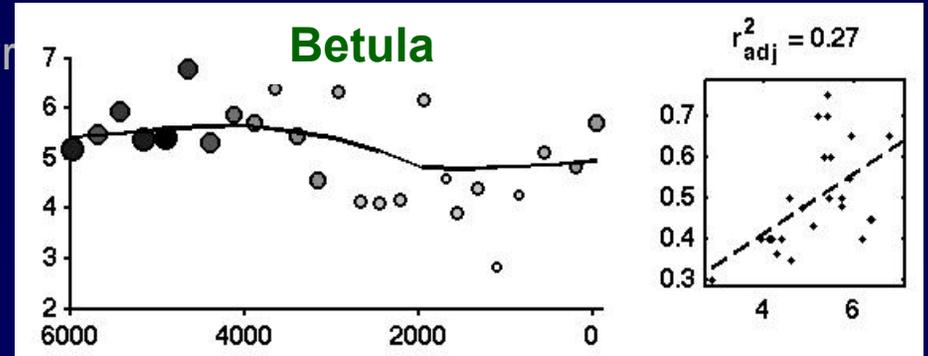
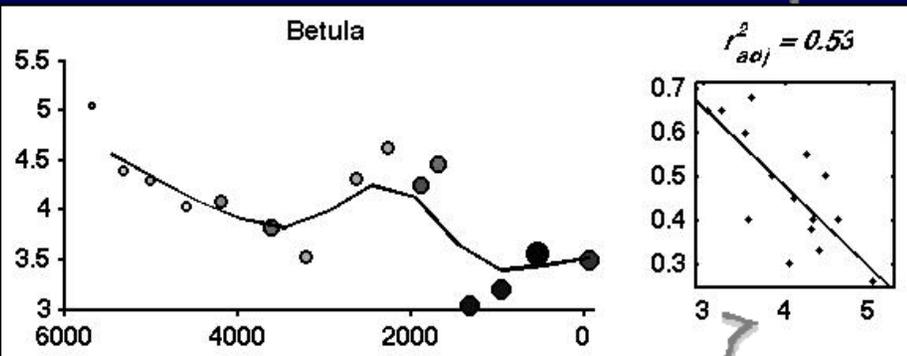
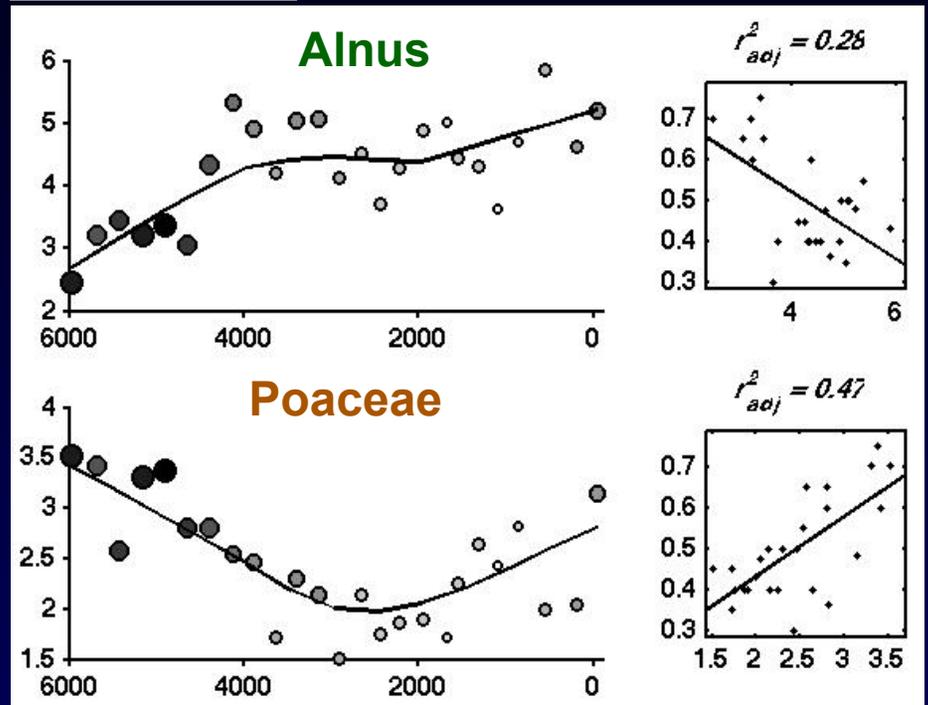
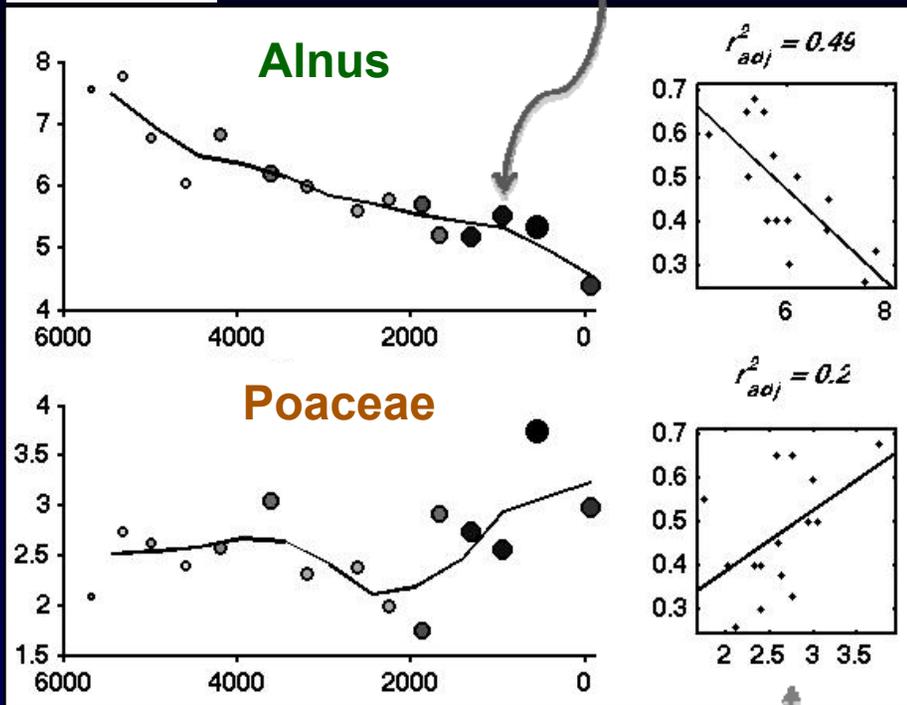
4. Fire frequency varies with vegetation

Raven

bubble size = 2000-yr fire frequency

Little Isac

sqrt. transform % pollen

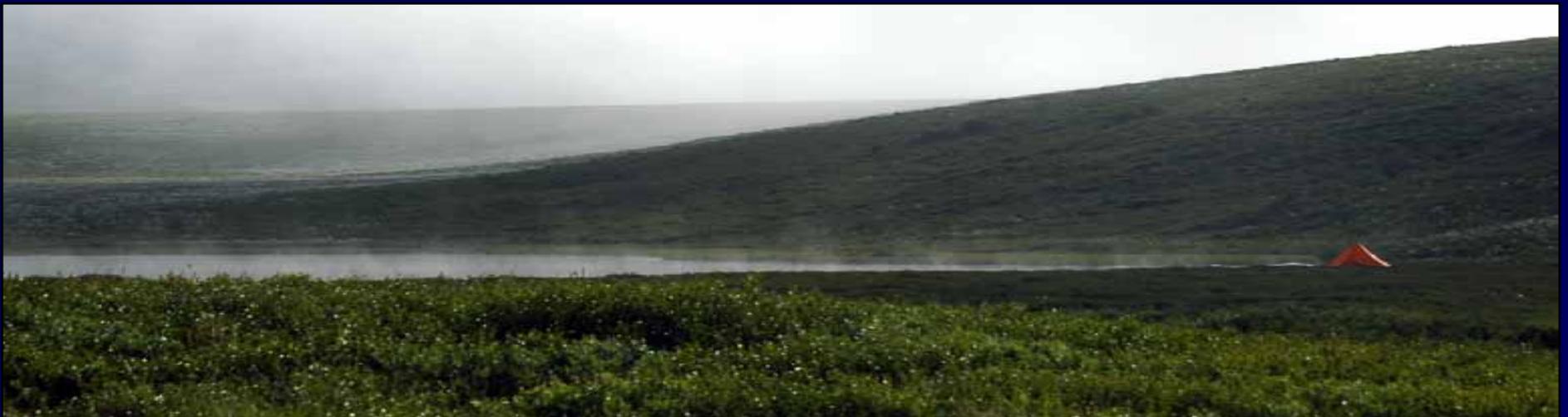


age (cal. yr BP)

2000-yr fire frequency (fires 100-yr⁻¹)
as function of pollen

Summary

- 1. Modern geographic variability reflected in late Holocene fire history**
- 2. Fire frequencies varied through time: climate, vegetation, and local factors**
- 3. Tundra fire regimes are sensitive to environmental change**



Acknowledgements and Questions

Funding: Joint Fire Science Program and the National Park Service.



Joint Fire Science Program

Research Supporting Sound Decisions

www.firescience.gov



Field Assistance: Denali National Park fire personnel

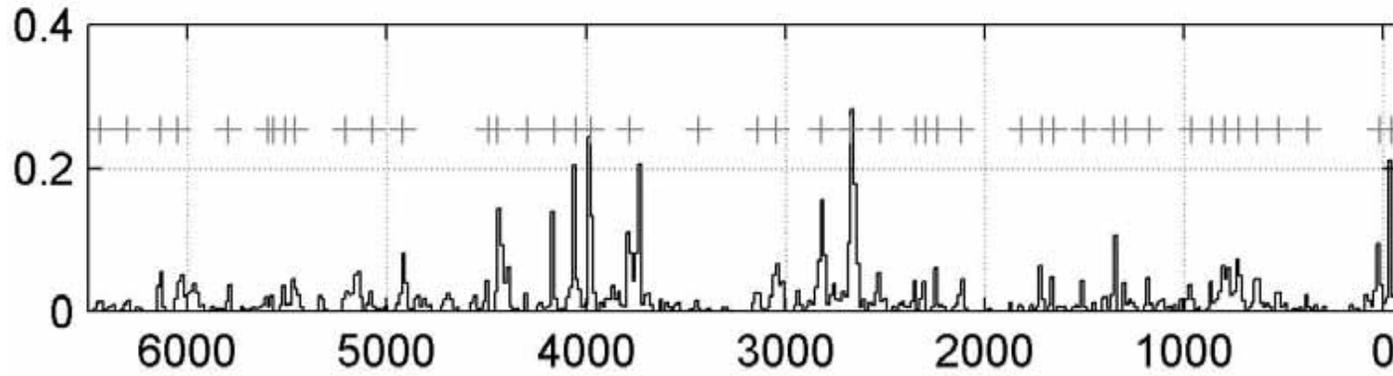
Lab Assistance: Triet Vuong and Jennifer Schwarz



Poktovik Lake, 11:30 pm, June 19th

Temporal Scales of Change

CHAR (# cm⁻² yr⁻¹)



Uchugrak Lake

