Interactions of climate, vegetation, and fire during the Holocene: Insights from Alaska

Philip Higuera

Assistant Professor

University of Idaho

College of Natural Resources

National Science Foundation

National Park Service

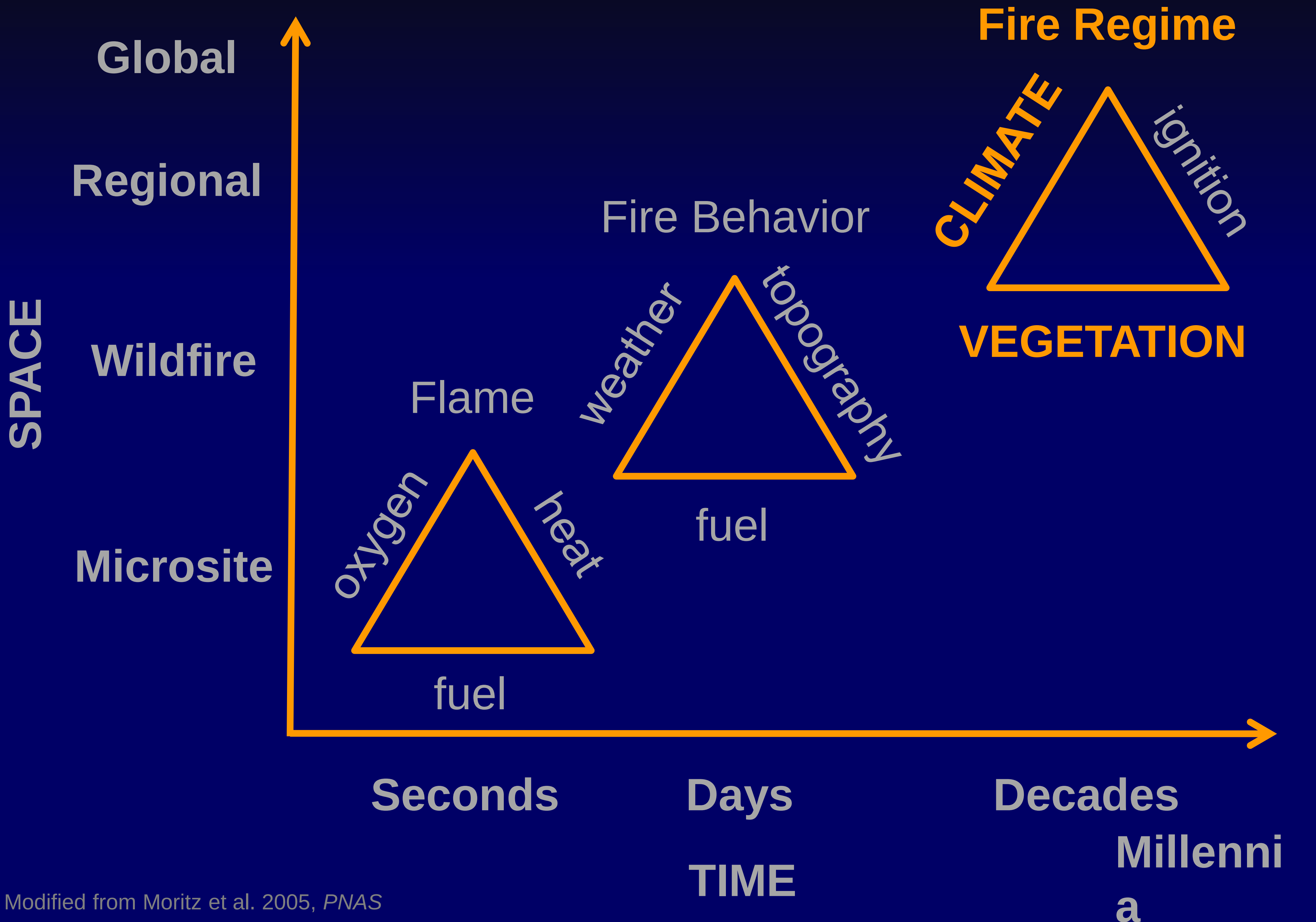
Joint Fire Science Program

Research Supporting Sound Decisions

"As a result of climate change, we are in essence conducting a global experiment such that future wildland fire activity is highly uncertain." ***– Flannigan et al. 2009***

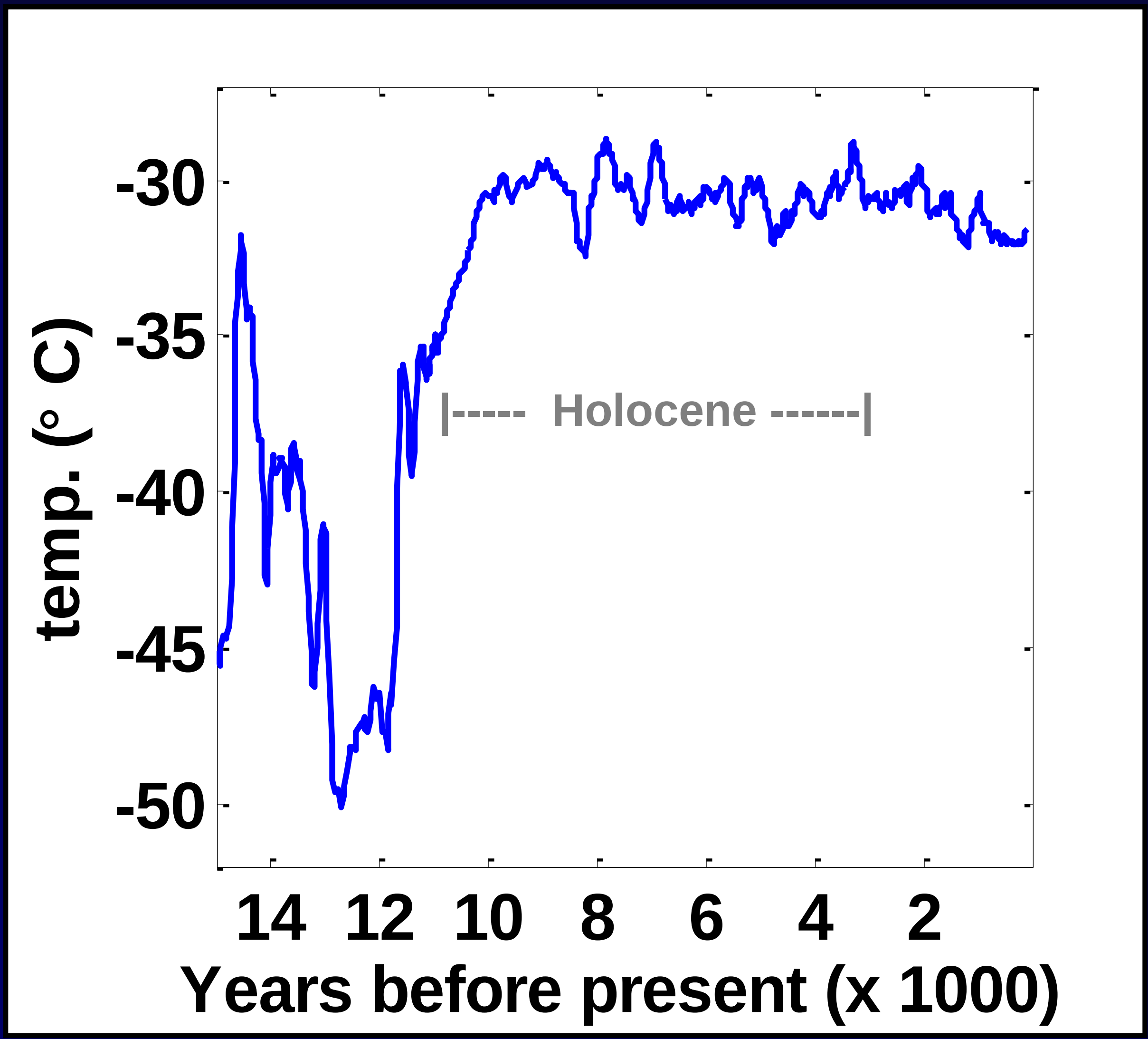
Yukon Flats, Alaska

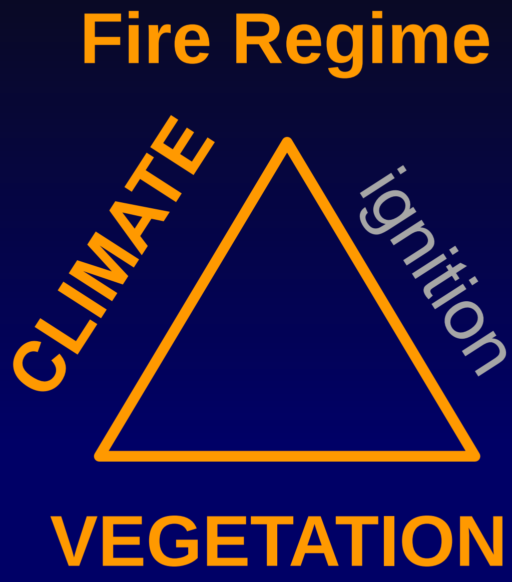
Conceptual Framework



Modified from Moritz et al. 2005, *PNAS*

Conceptual Framework

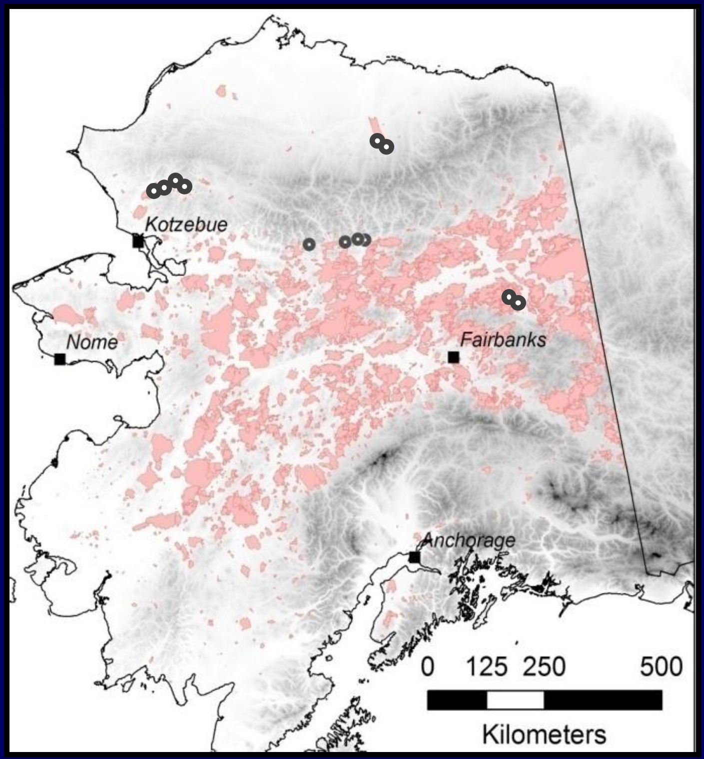




Overview

1. Climate-vegetation-fire interactions

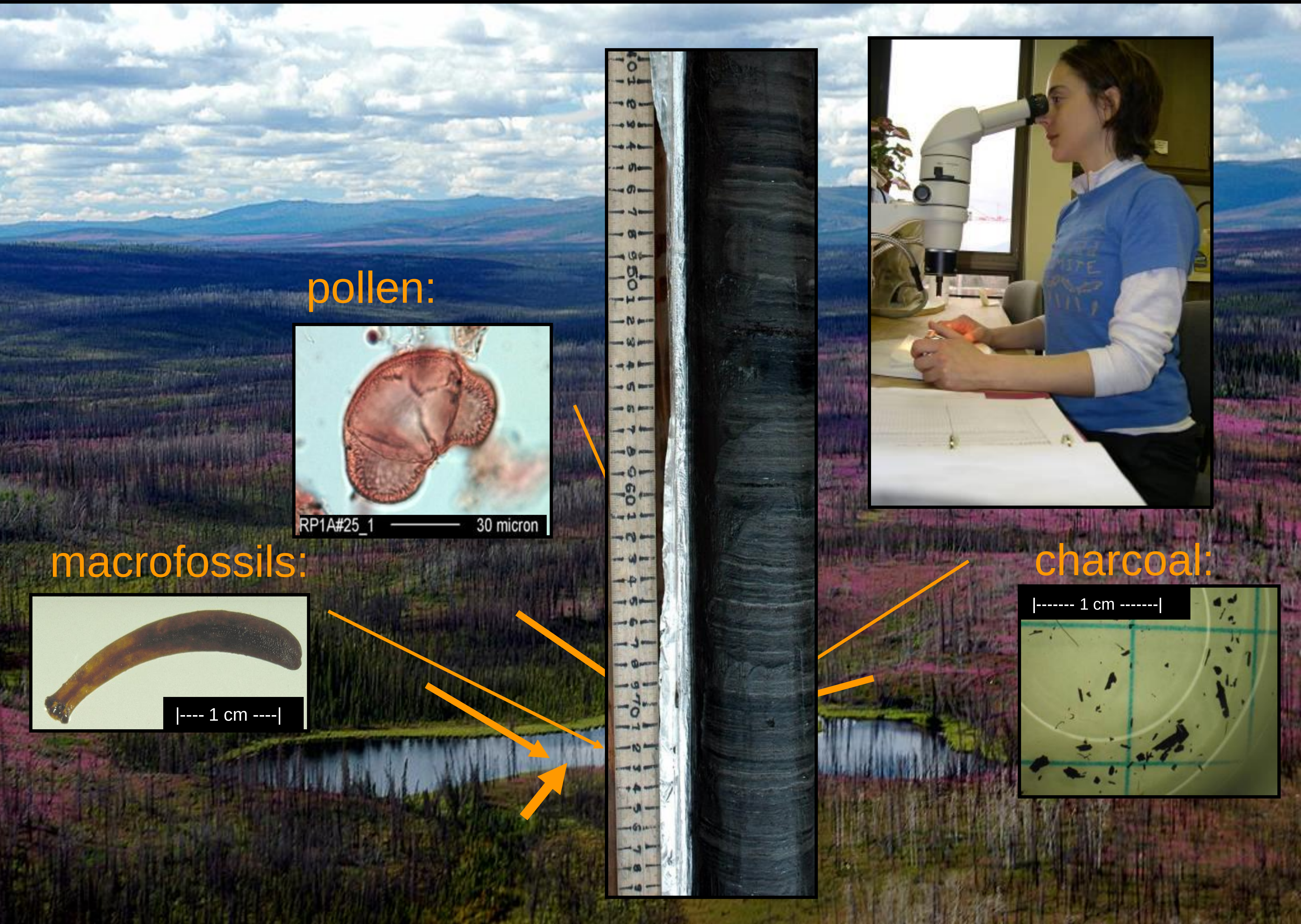
- Reconstructing fire history
- Insights from Alaska
- Context for ongoing change



2. Conceptual challenges

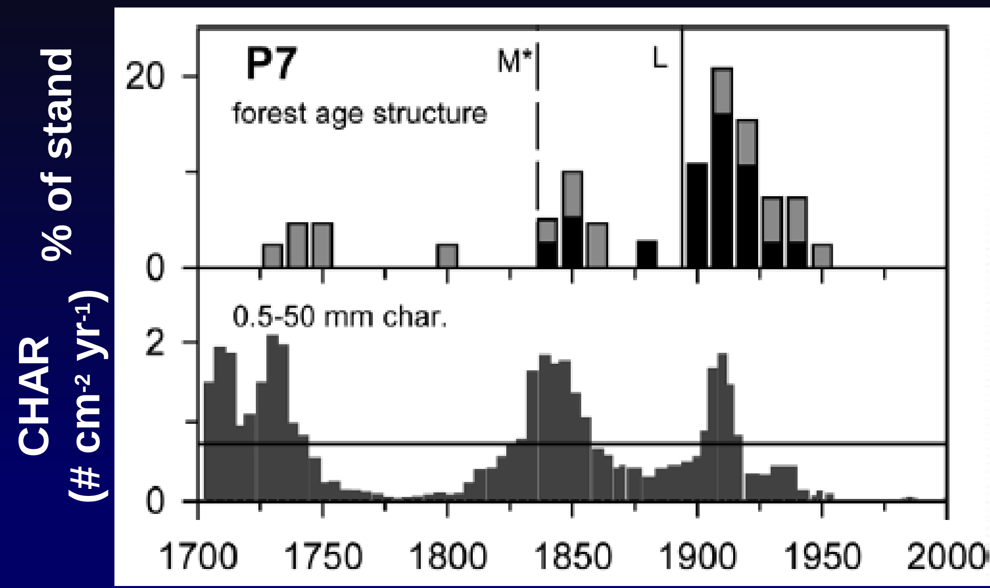
- Defining regimes and detecting change

Reconstructing the past



Fire history from continuous sediment records

Empirical support:



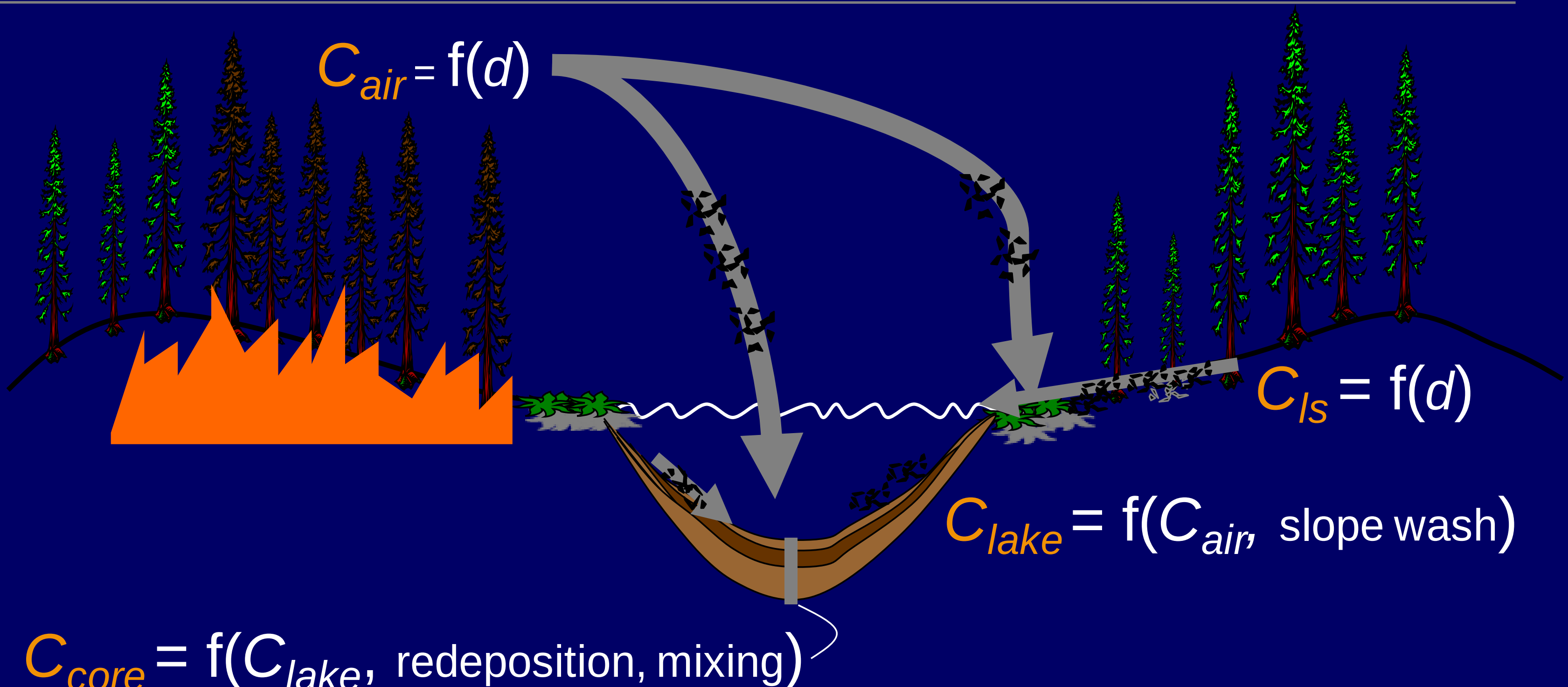
Stand age & fire scars

Charcoal accumulation

Year AD

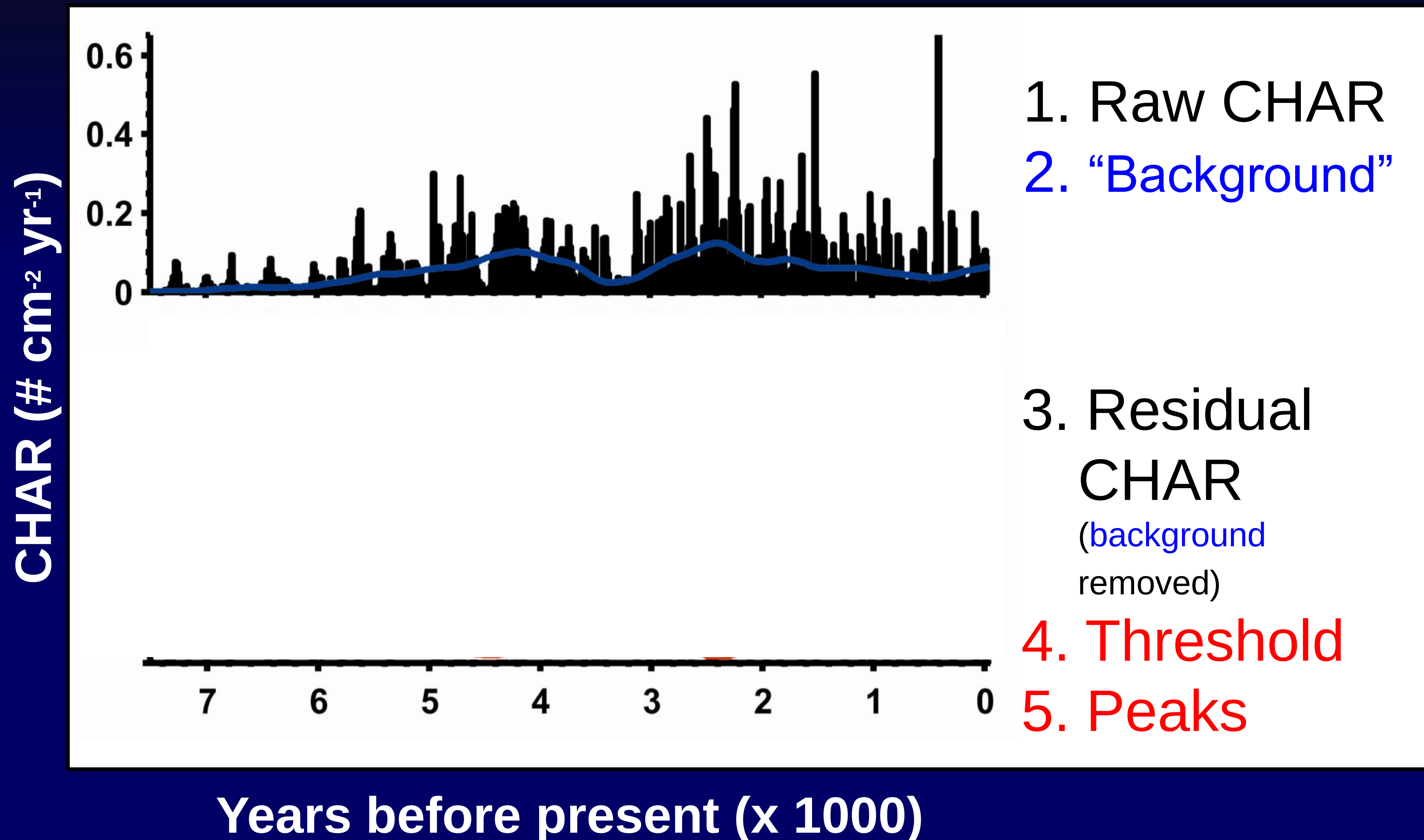
Higuera et al. 2005

Theoretical support:



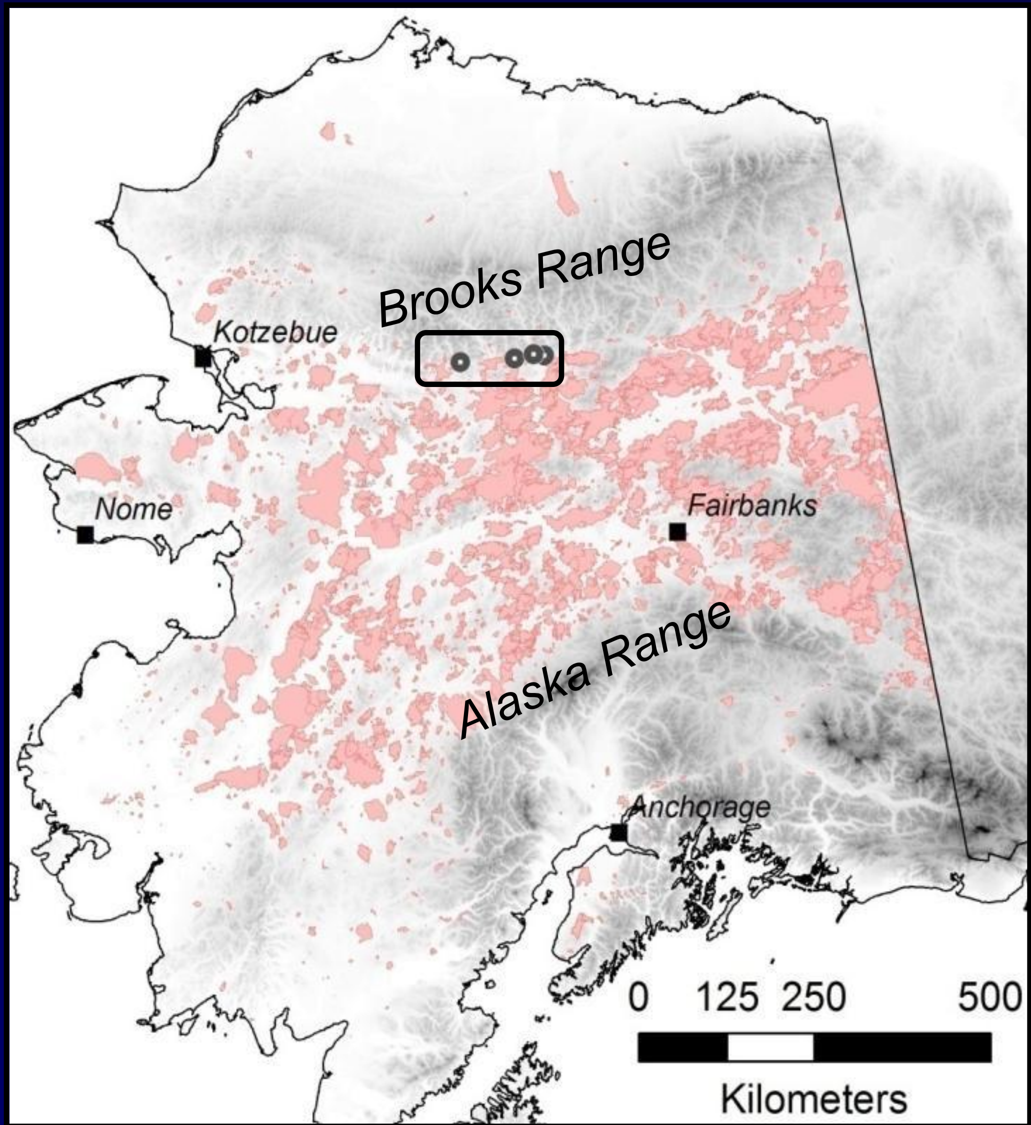
Higuera et al. 2007; Peters and Higuera, 2007

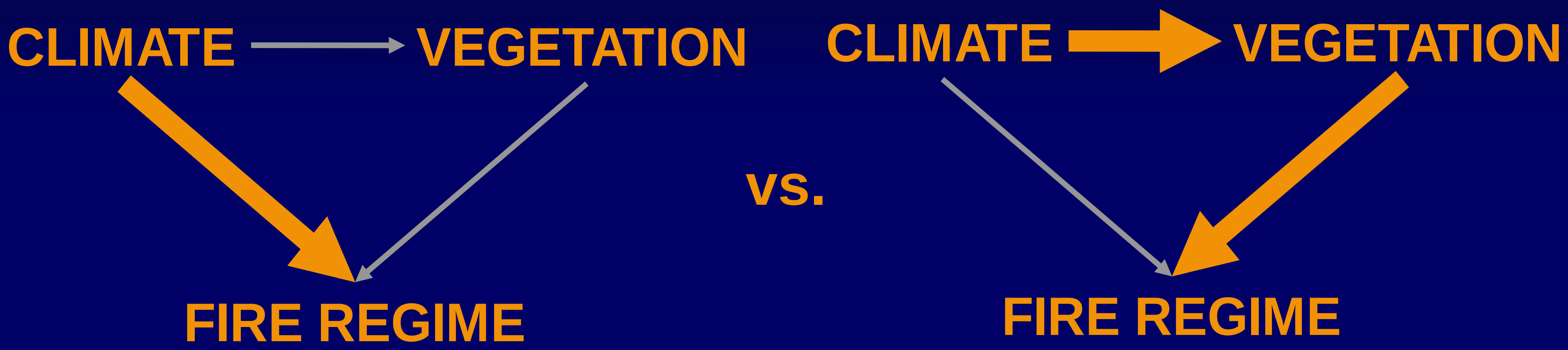
Fire history from continuous sediment records

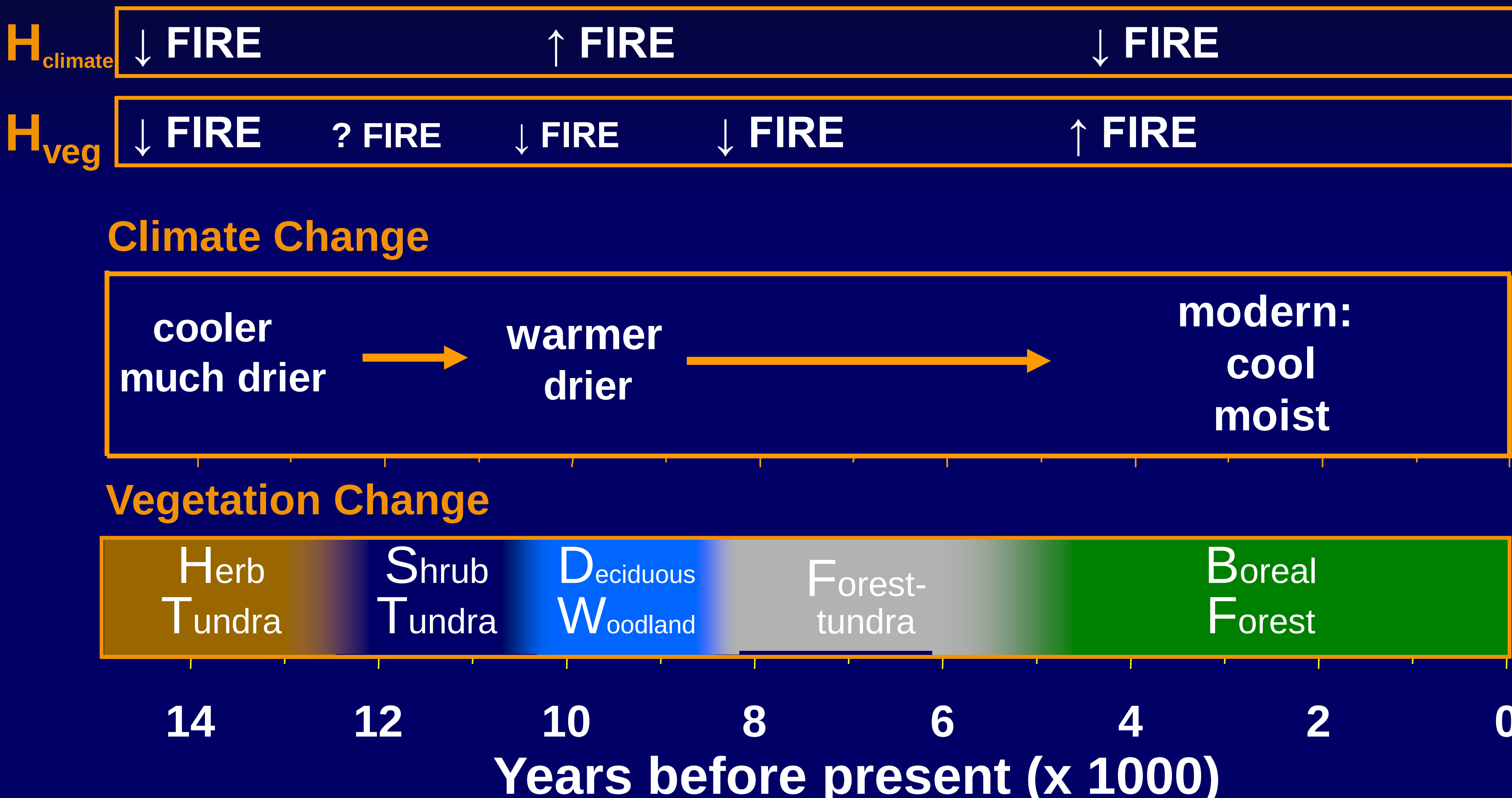


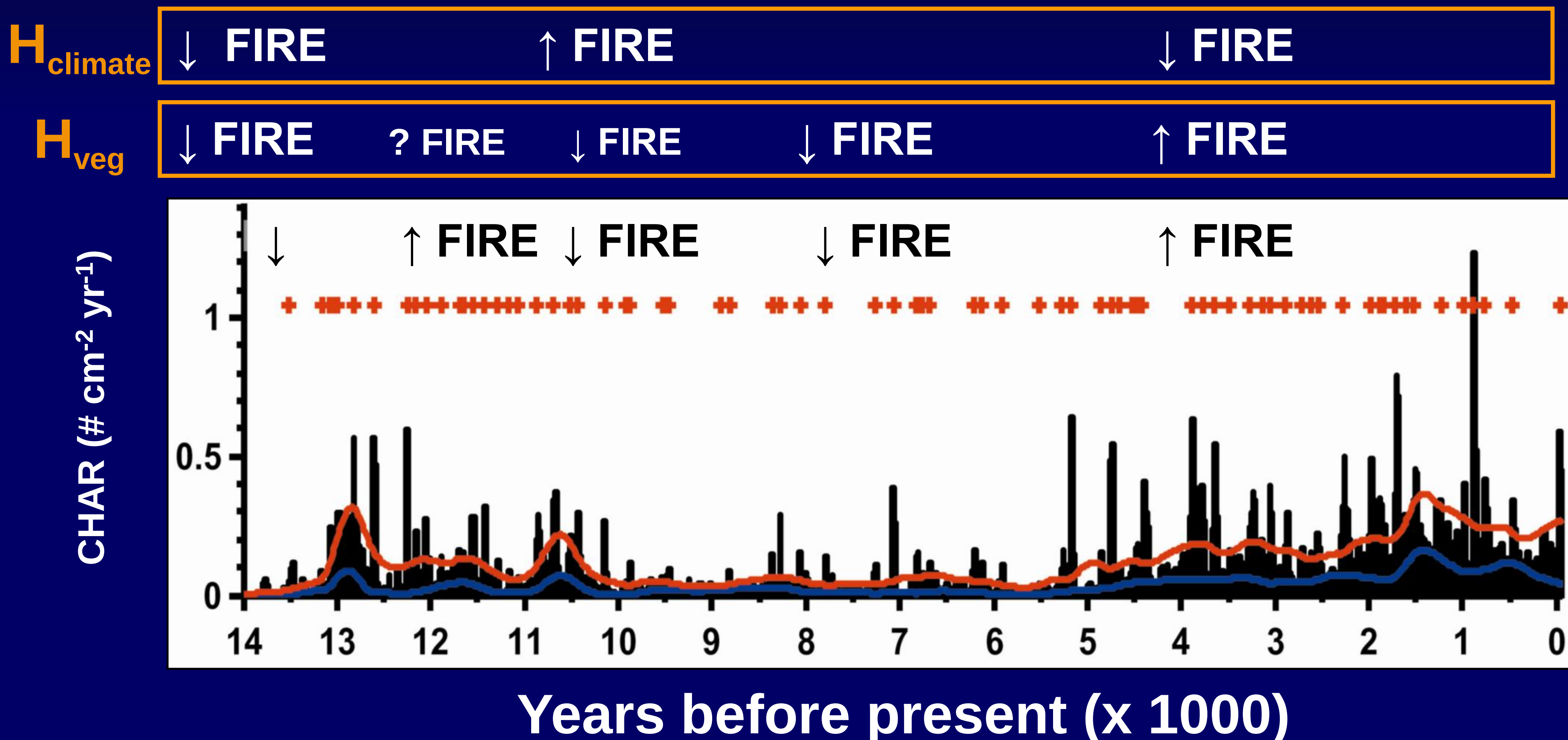
Vegetation mediates the impacts of climate change on fire regimes

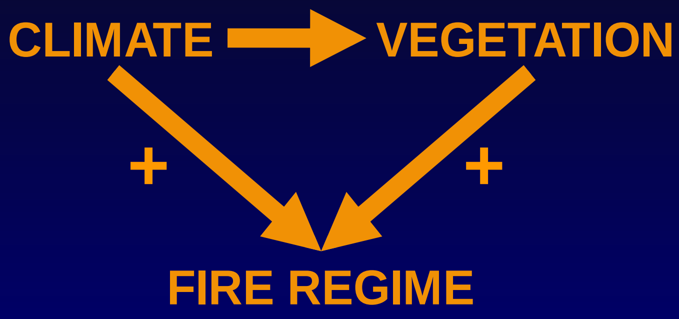
P. Higuera, L. Brubaker, P. M. Anderson, T. Brown, F. S. Hu

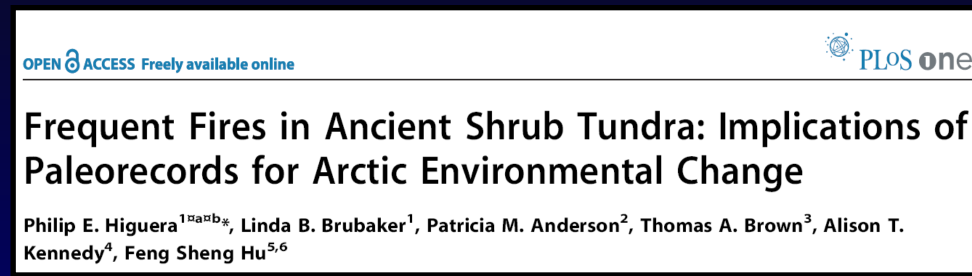



CLIMATE
VEGETATION
FIRE REGIME
vs.
CLIMATE
VEGETATION
FIRE REGIME


H climate
↓ FIRE
↑ FIRE
↓ FIRE
H veg
↓ FIRE
? FIRE
↓ FIRE
↓ FIRE
↑ FIRE
Climate Change
cooler
much drier
warmer
drier
modern:
cool
moist
Vegetation Change
Herb
Tundra
Shrub
Tundra
Deciduous
Woodland
Forest-
tundra
Boreal
Forest
14
12
10
8
6
4
2
0
Years before present (x 1000)


H climate
↓ FIRE
↑ FIRE
↓ FIRE
H veg
↓ FIRE
? FIRE
↓ FIRE
↓ FIRE
↑ FIRE
↓
↑ FIRE
↓ FIRE
↓ FIRE
↑ FIRE
CHAR (# cm-2 yr-1)
1
0.5
0
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Years before present (x 1000)

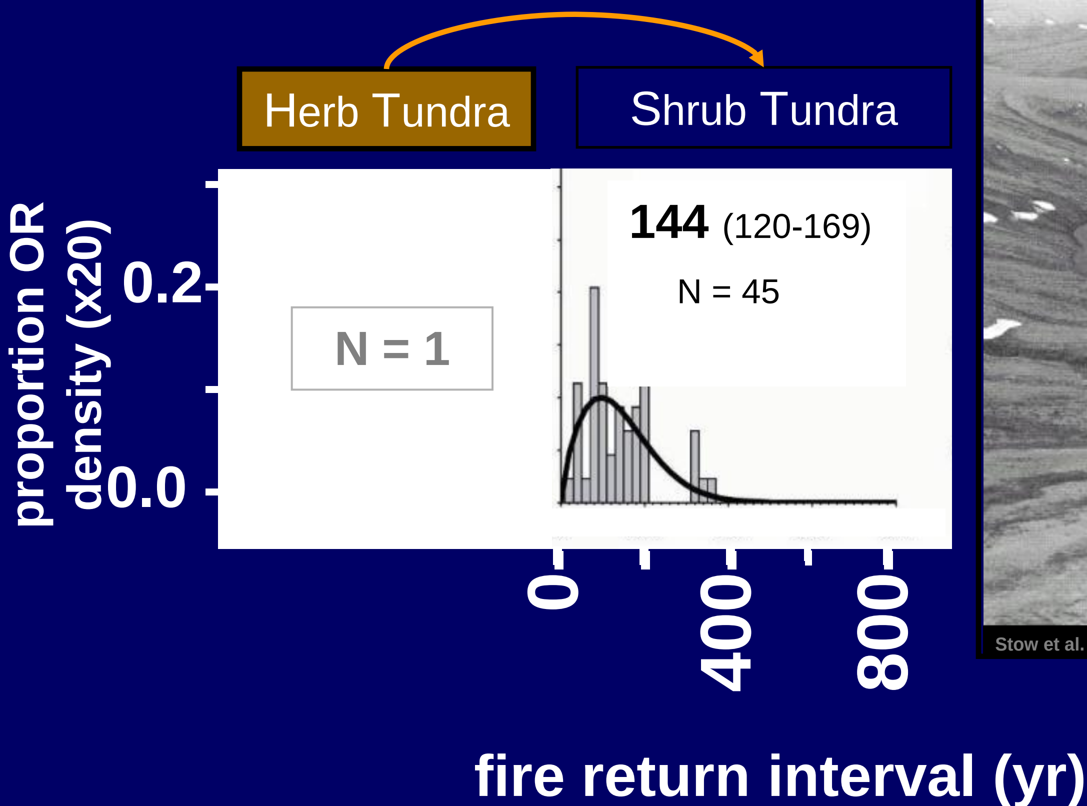


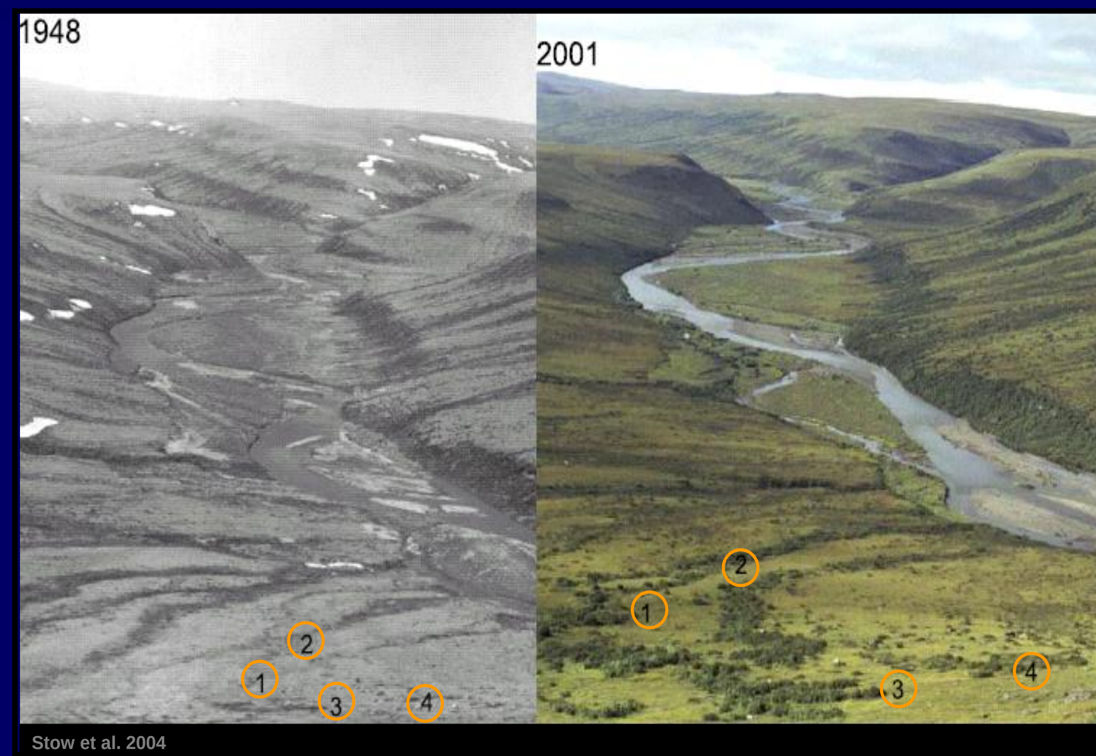


OPEN ACCESS Freely available online
PLoS one

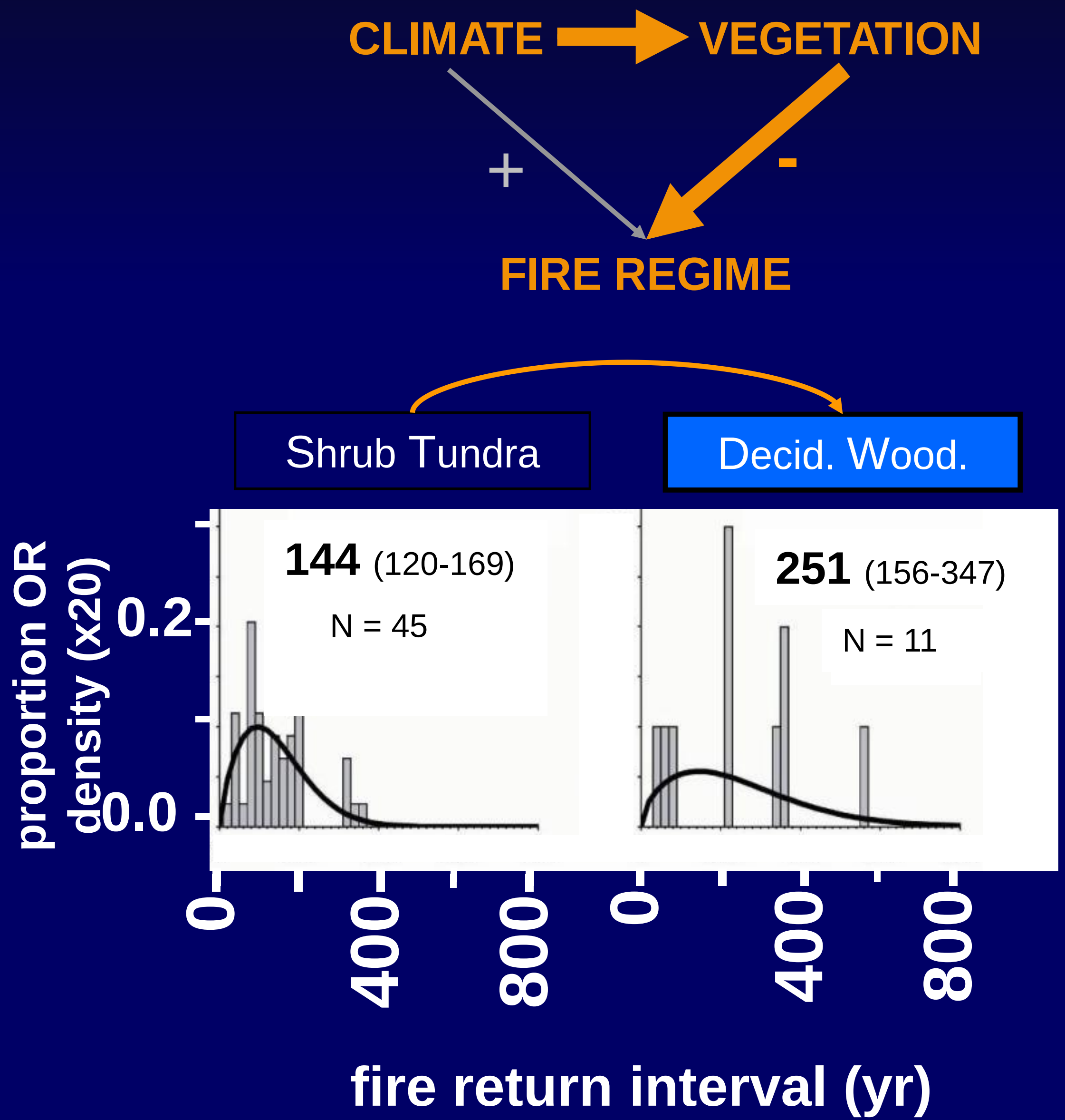
Frequent Fires in Ancient Shrub Tundra: Implications of Paleorecords for Arctic Environmental Change

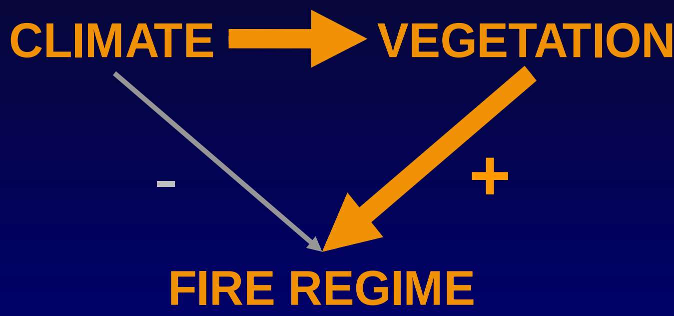
Philip E. Higuera[1¤a¤b*], Linda B. Brubaker[1], Patricia M. Anderson[2], Thomas A. Brown[3], Alison T. Kennedy[4], Feng Sheng Hu[5,6]

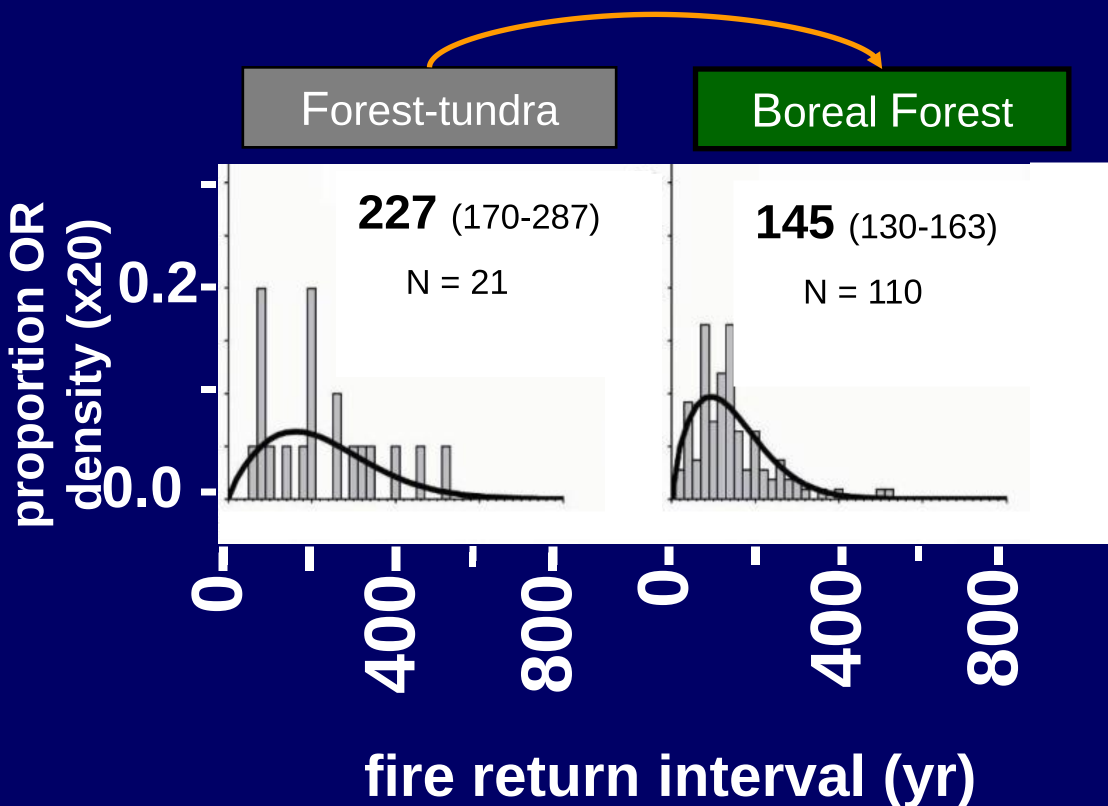




Higuera et al., 2008, *PLoS ONE*; Higuera et al. 2009 *Ecological Monographs*; Also: Tinner et al. 2008, *Ecology*.


CLIMATE
VEGETATION
+
-
FIRE REGIME
Shrub Tundra
Decid. Wood.
144 (120-169)
N = 45
251 (156-347)
N = 11
proportion OR density (x20)
0.2
0.0
0
400
800
0
400
800
fire return interval (yr)

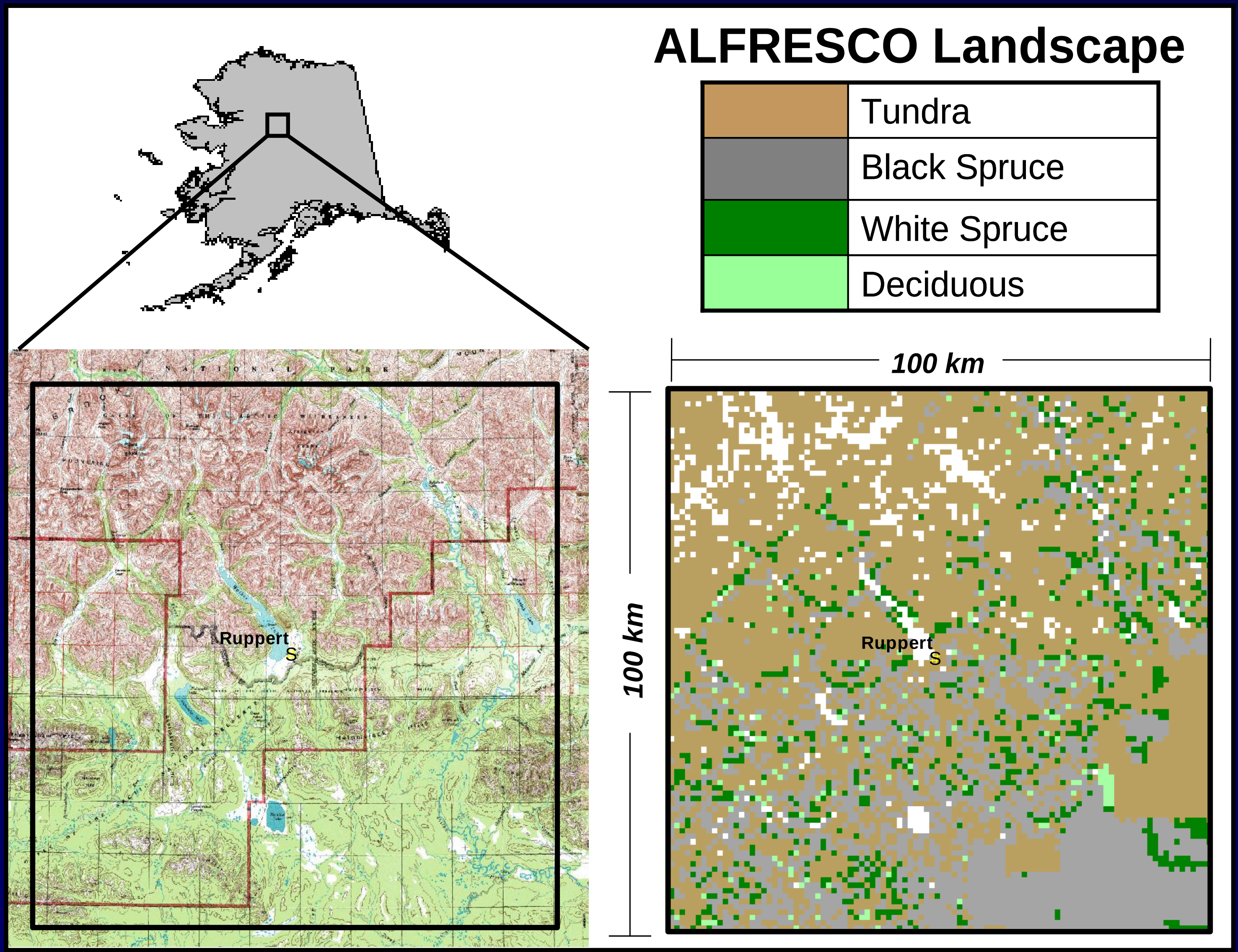




Higuera et al. 2009 *Ecological Monographs*; Also: Lynch et al. 2002

Modeling climate-veg.-fire interactions:

fire = f(*climate*, *vegetation*)



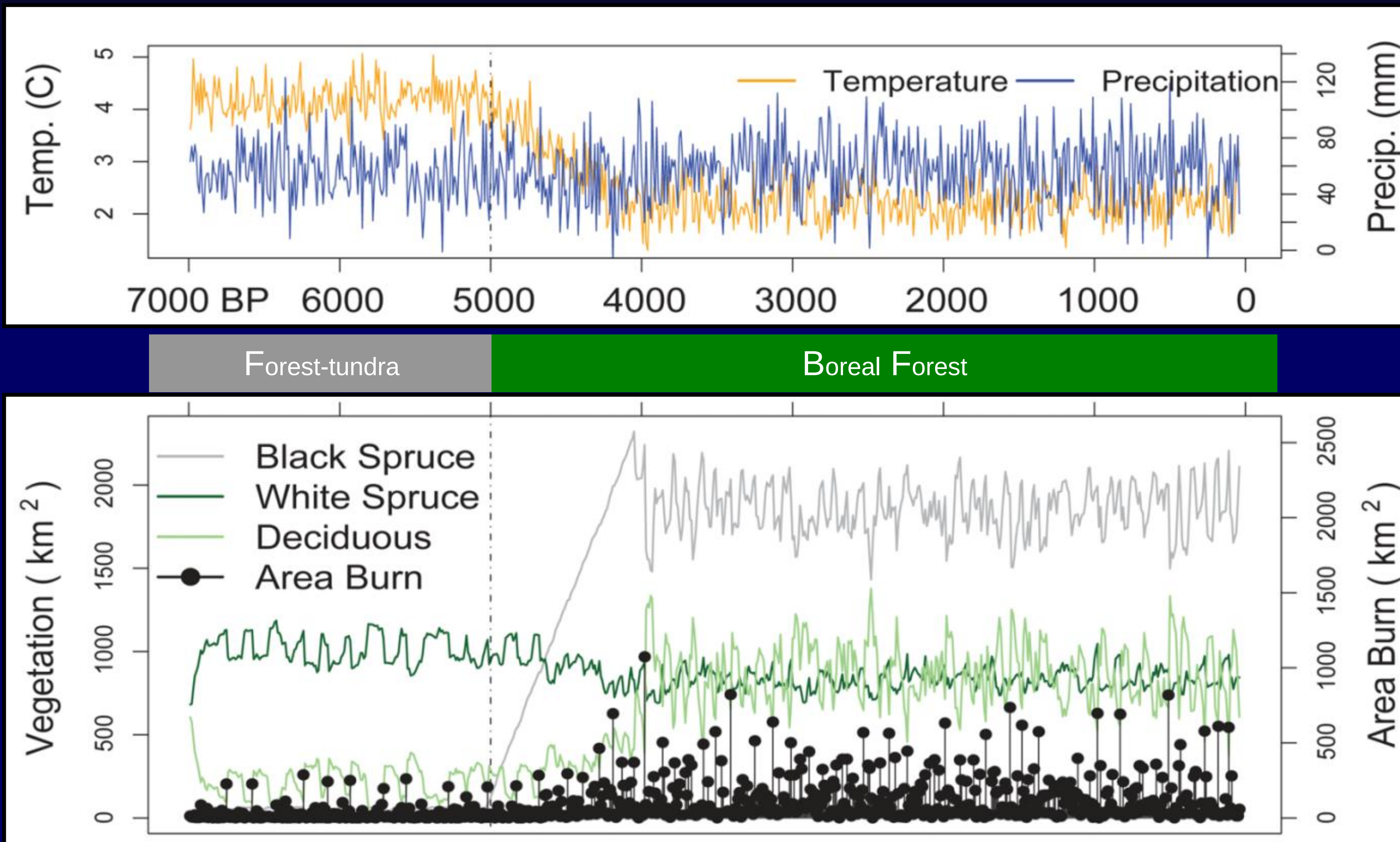
e.g. Rupp, T. S. et al. 2000. *Landscape Ecology*

Brubaker, Higuera, Rupp, Olson, Anderson, and Hu. 2009. *Ecology*

Veg. and climate change required for data-model match

climate

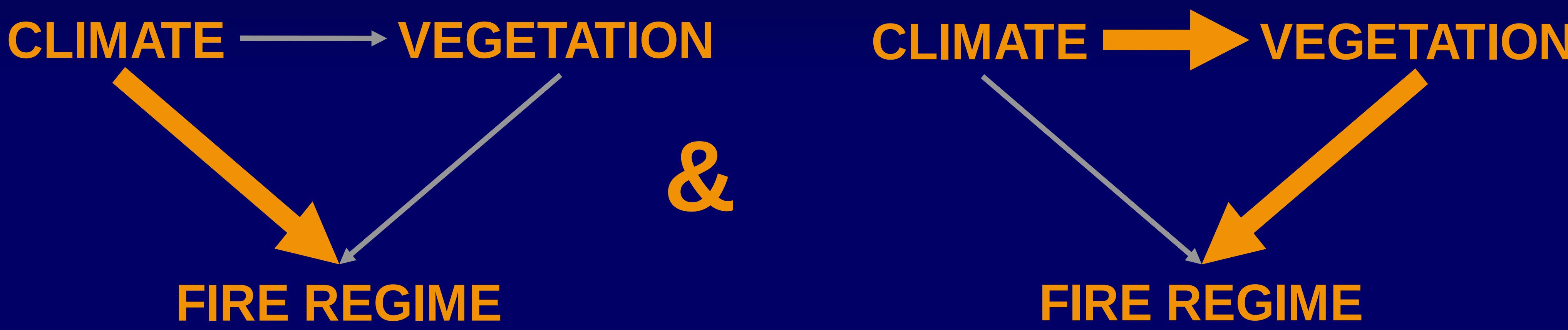
veg. & fire



Simulated years before present

Brubaker, Higuera, Rupp, Olson, Anderson, and Hu. 2009. *Ecology*

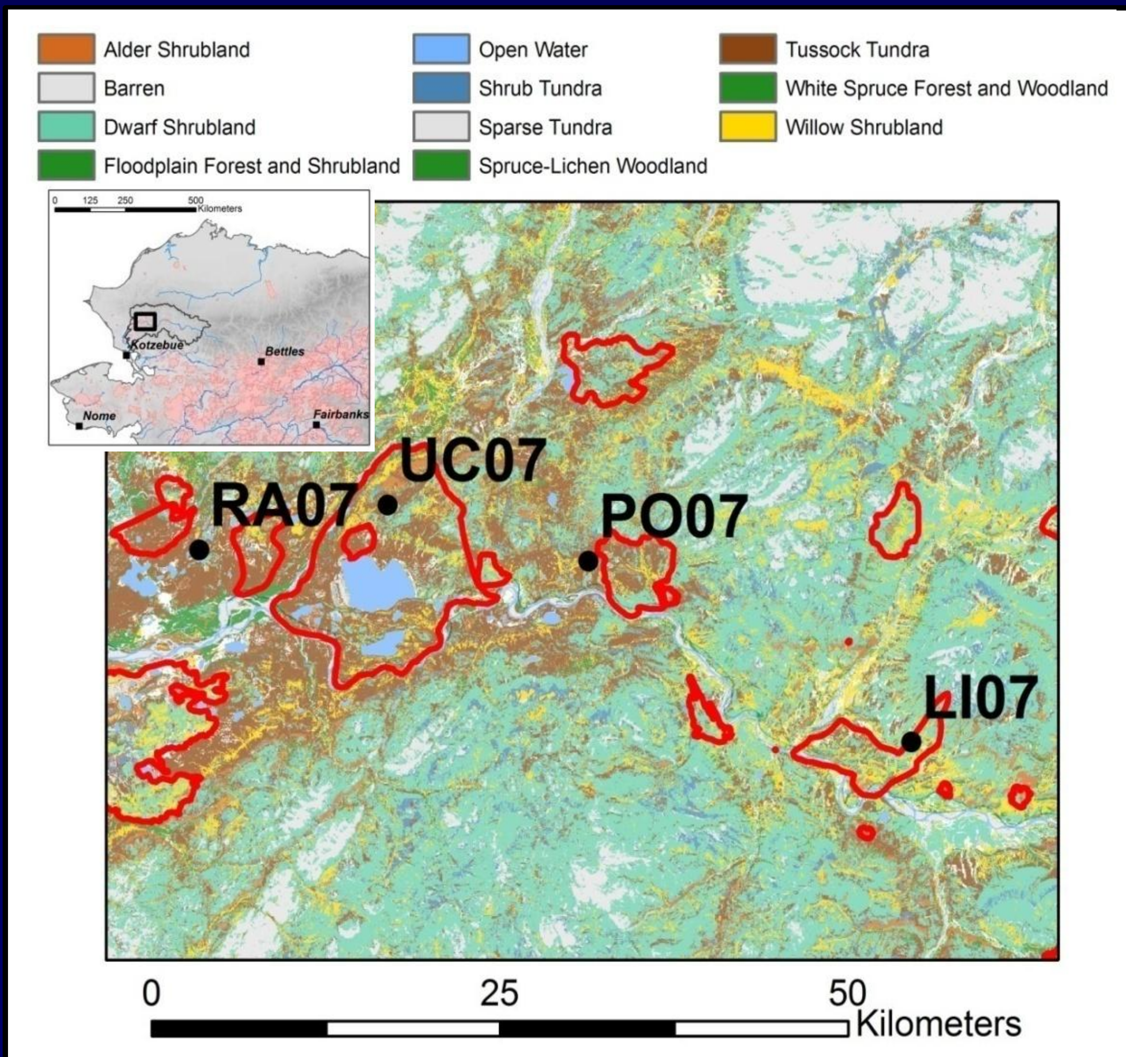
As in the past, future fire regimes determined by:



- ***If fire is limited more by the abundance and/or continuity of fuels, then vegetation change can be more important than climate change.***

Locally-mediated response of tundra vegetation and fire regimes to late-Holocene climate change

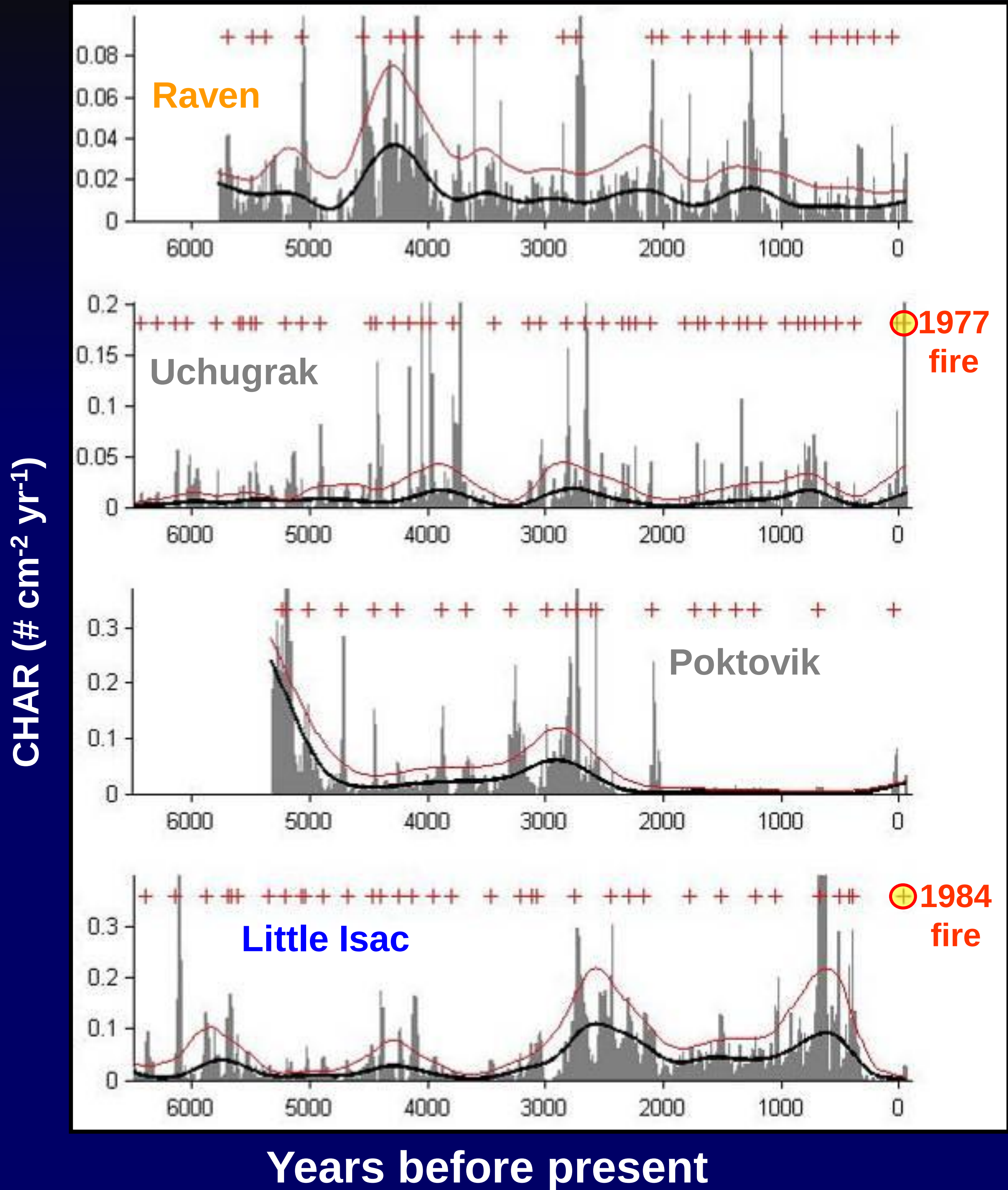
P. Higuera, M. Chipman, J. Allen, M. Urban, F. S. Hu

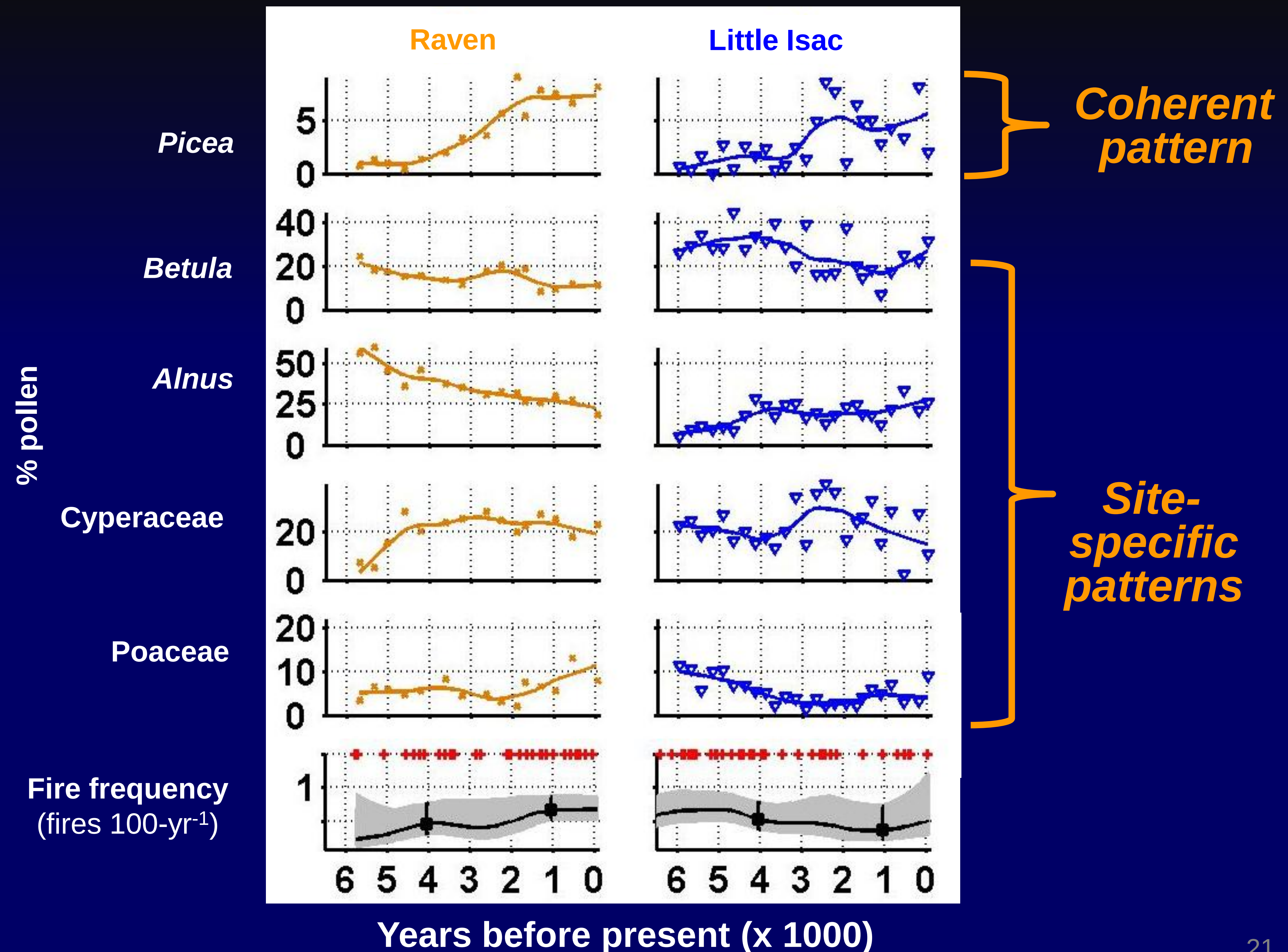


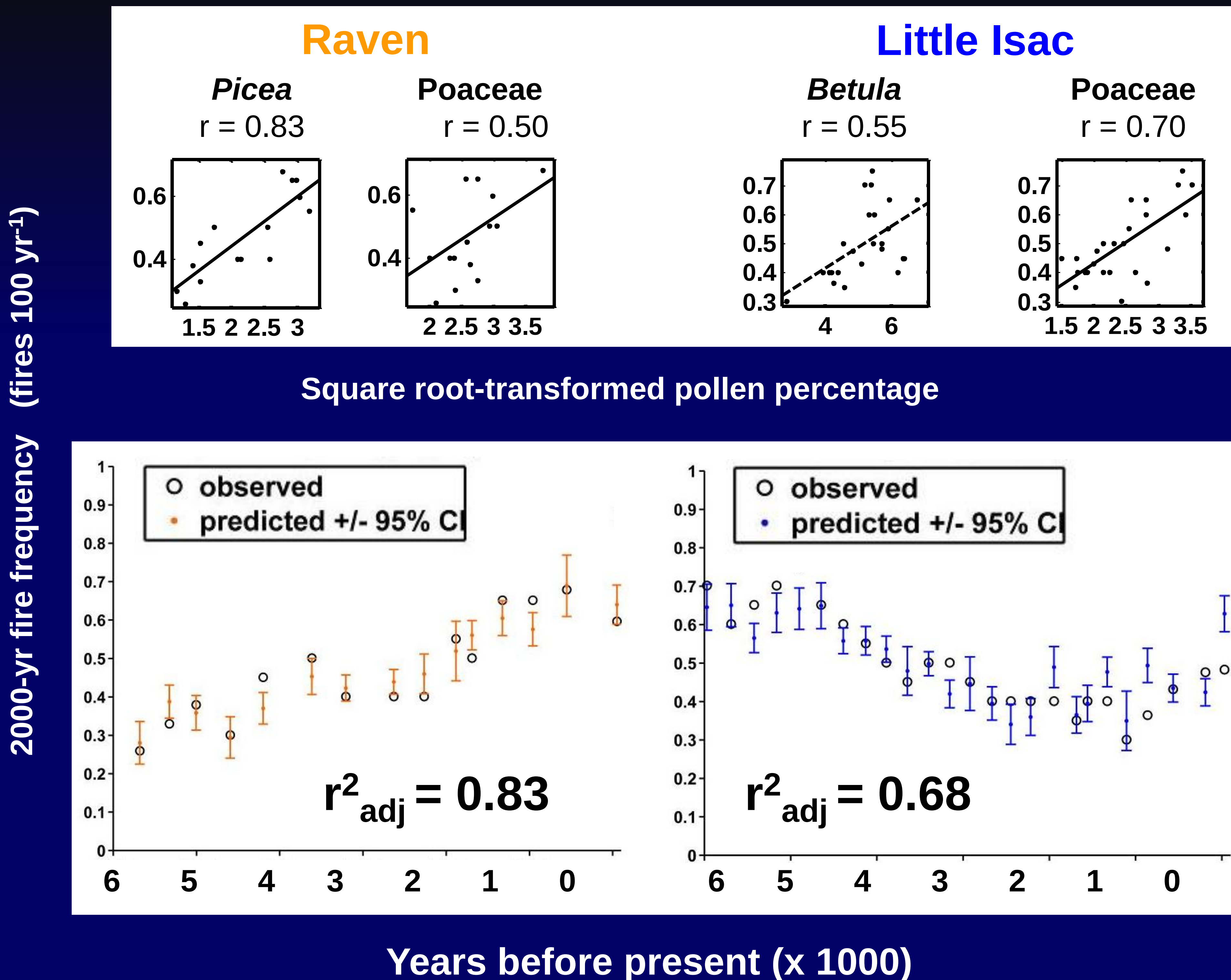
Raven Lake

Tundra burns

- Recent large fires detected

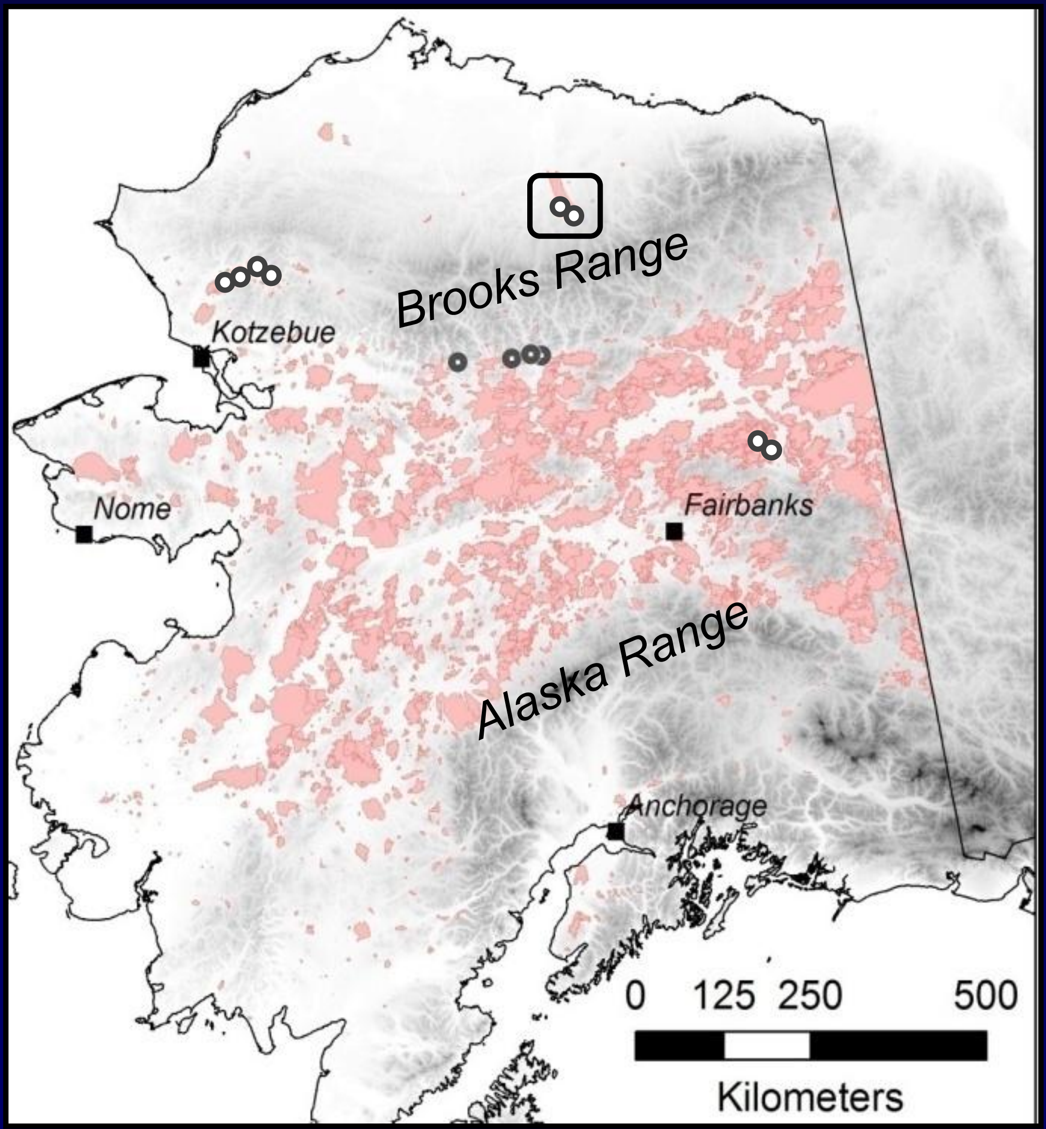



Raven
Little Isac
Coherent pattern
Site-specific patterns
Picea
Betula
Alnus
Cyperaceae
Poaceae
Fire frequency
(fires 100-yr-1)
% pollen
5
0
40
20
0
50
25
0
20
0
20
10
0
1
6 5 4 3 2 1 0
6 5 4 3 2 1 0
Years before present (x 1000)



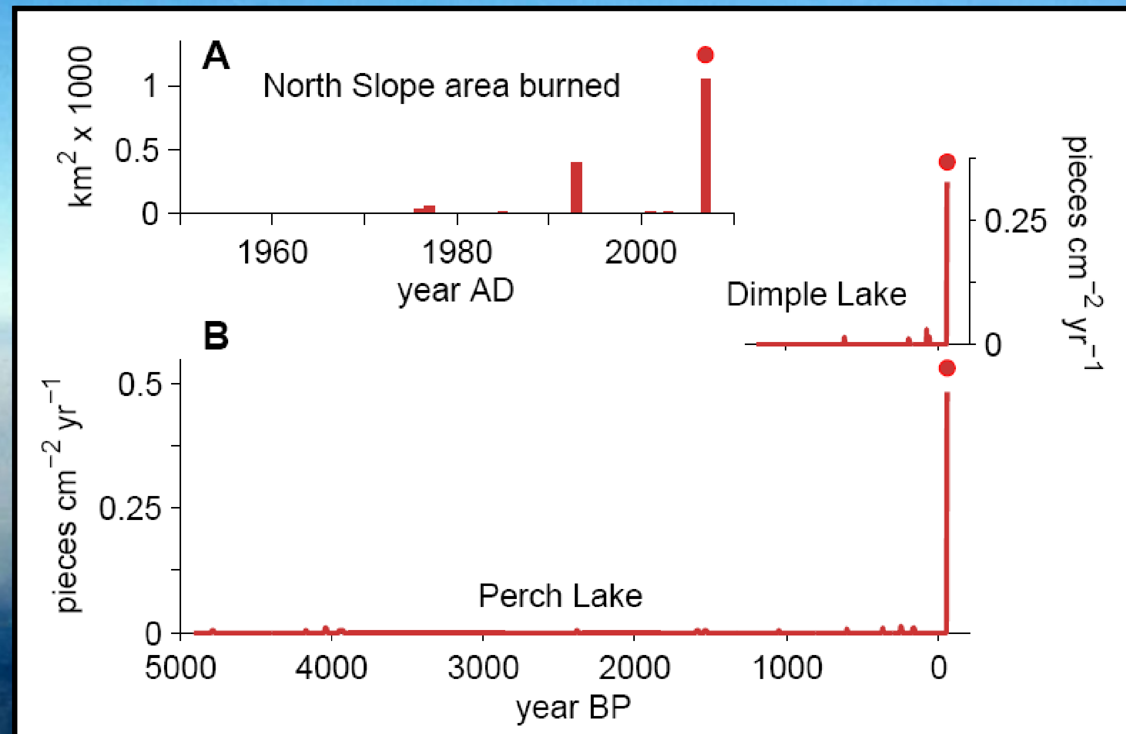
Raven
Little Isac
Picea
r = 0.83
Poaceae
r = 0.50
Betula
r = 0.55
Poaceae
r = 0.70
Square root-transformed pollen percentage
2000-yr fire frequency (fires 100 yr-1)
observed
predicted +/- 95% CI
r2adj = 0.83
r2adj = 0.68
Years before present (x 1000)

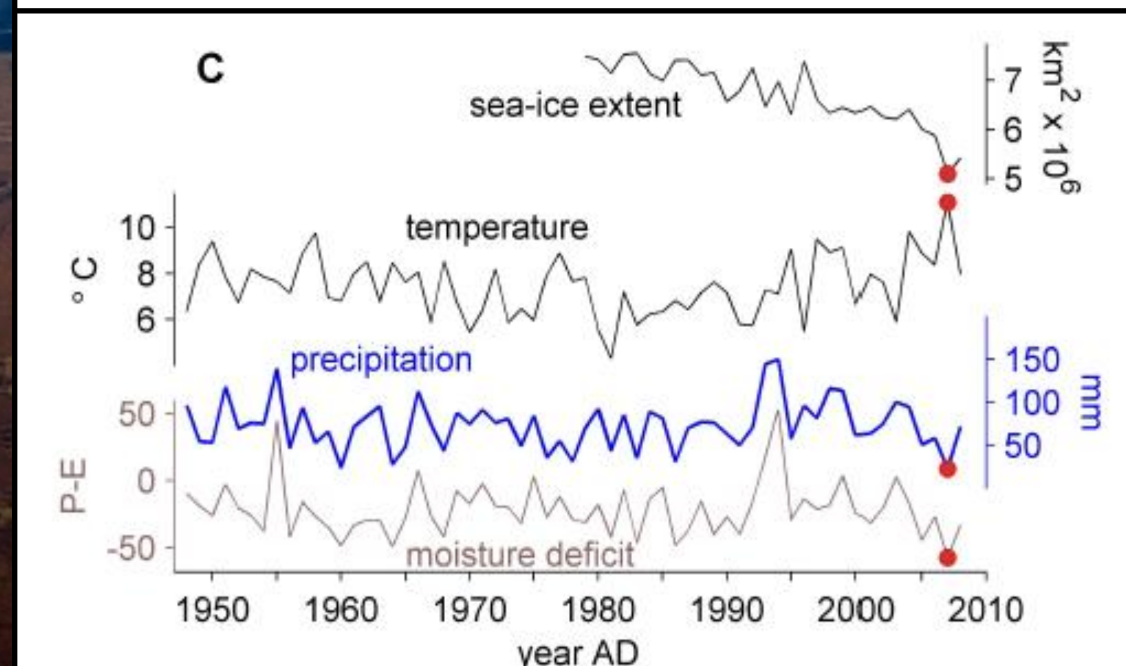
Context for ongoing change



Unprecedented Tundra Burning During Extreme Sea-Ice Retreat

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



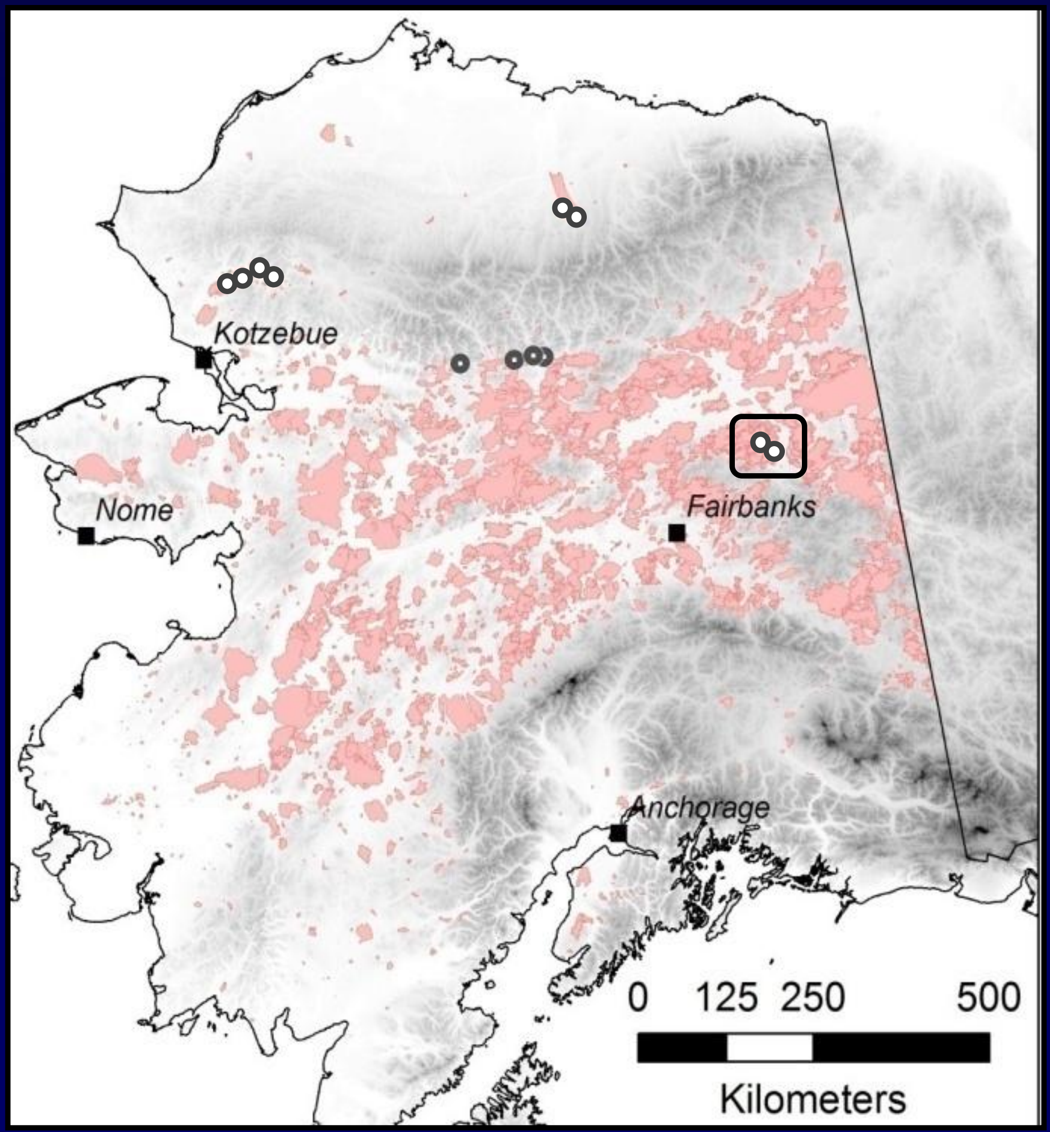


Hu, Higuera, et al., In revision.

Photo: Dale Woitas, AFS, BLM

Data-model comparisons suggest increased burning since 1860, Yukon Flats

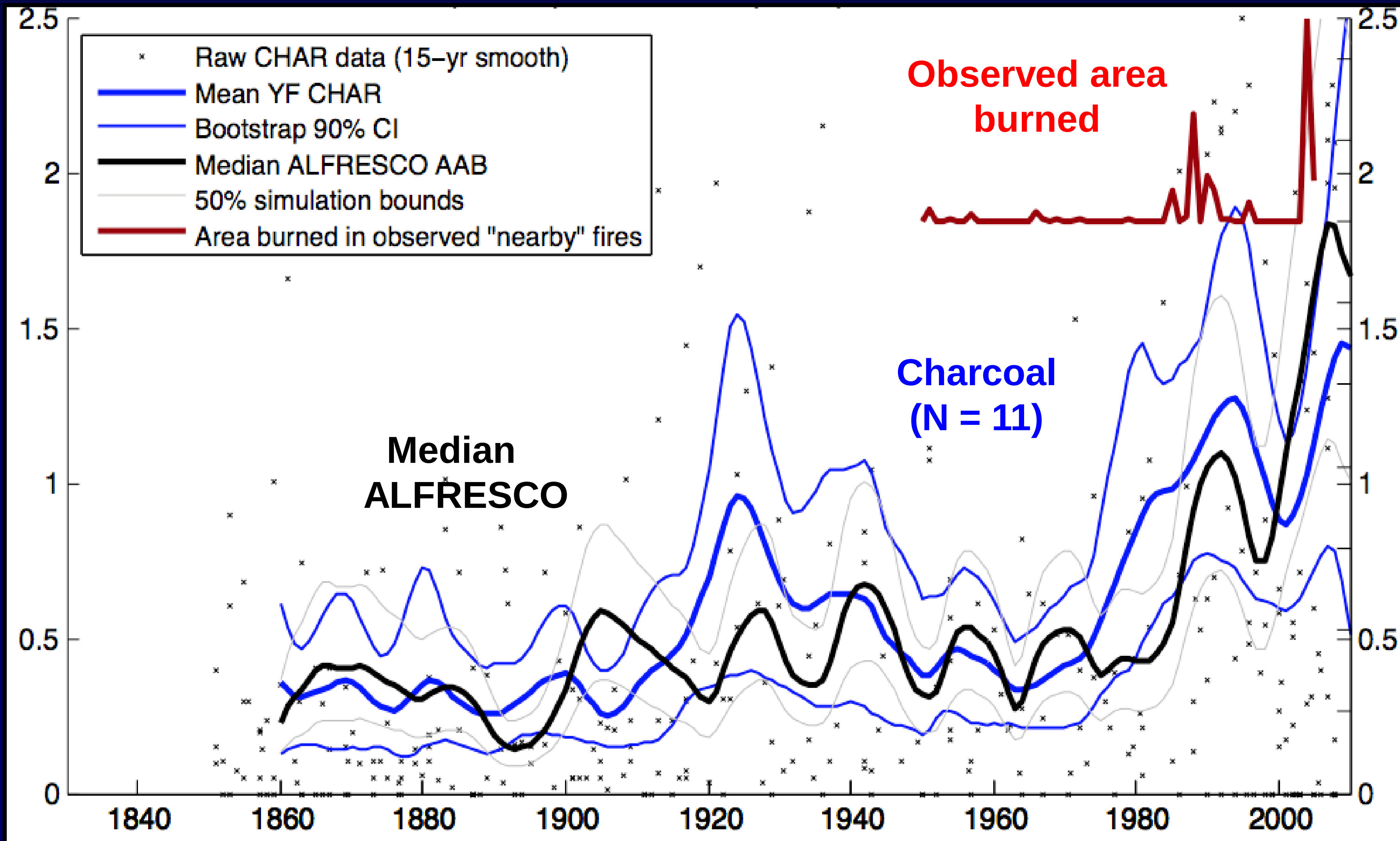
Ryan Kelly, S. Rupp, M. Olson, P. Higuera, F. S. Hu



Data-model comparisons suggest increased burning since 1860, Yukon Flats

Ryan Kelly, S. Rupp, M. Olson, P. Higuera, F. S. Hu

Standardized CHAR



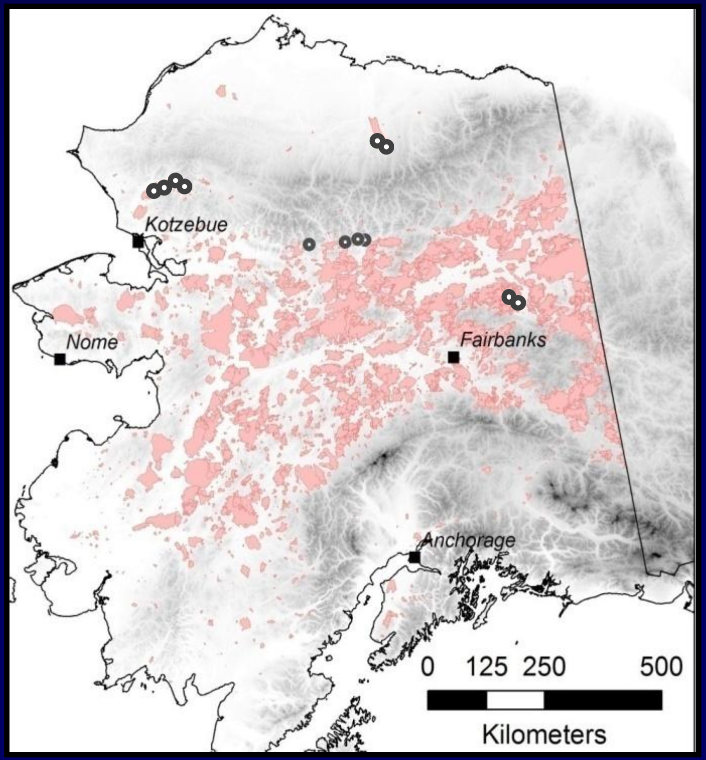
Standardized ALFRESCO area burned

Year CE

Overview

1. Climate-vegetation-fire interactions

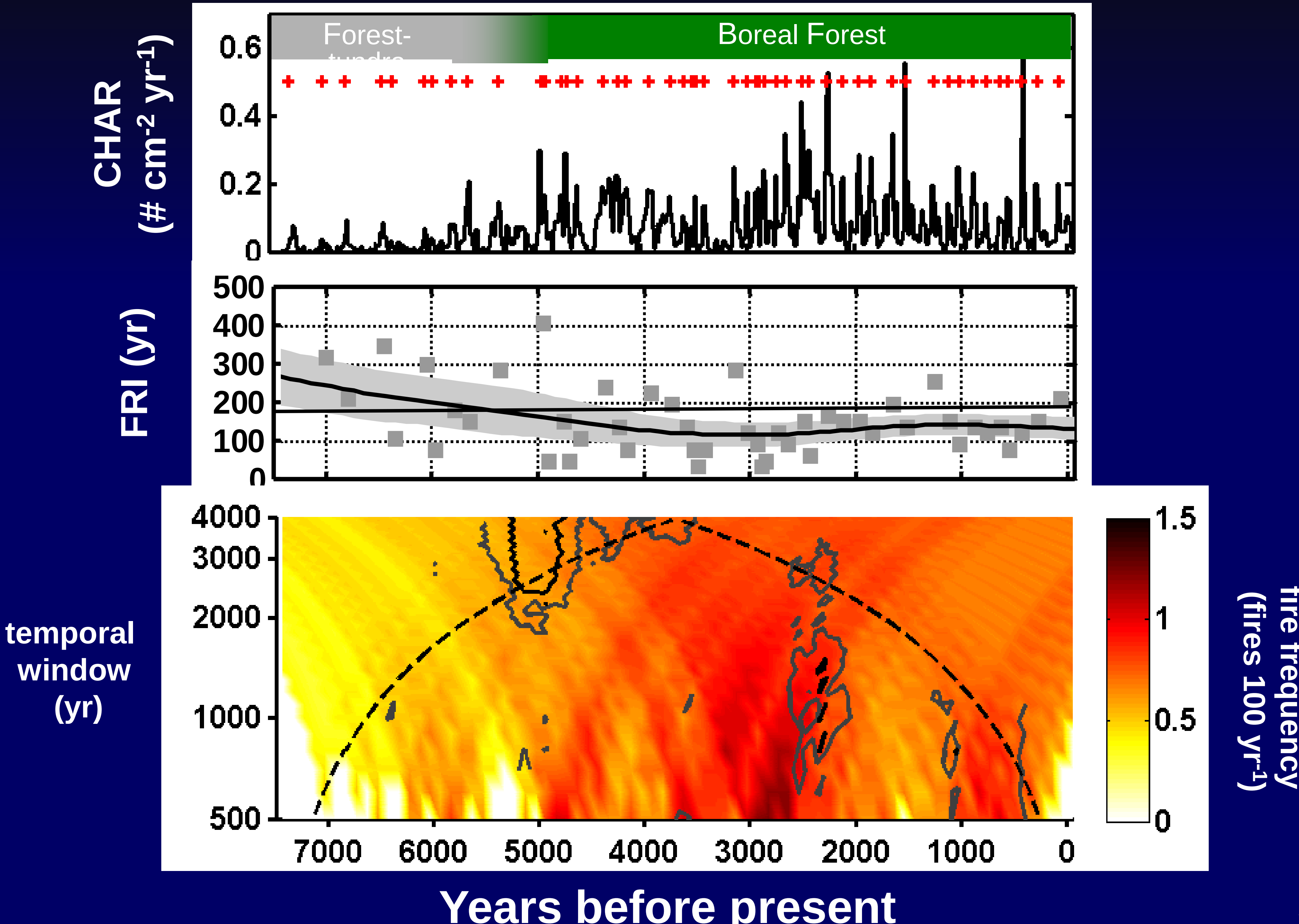
- Reconstructing fire history
- Insights from Alaska
- Context for ongoing change



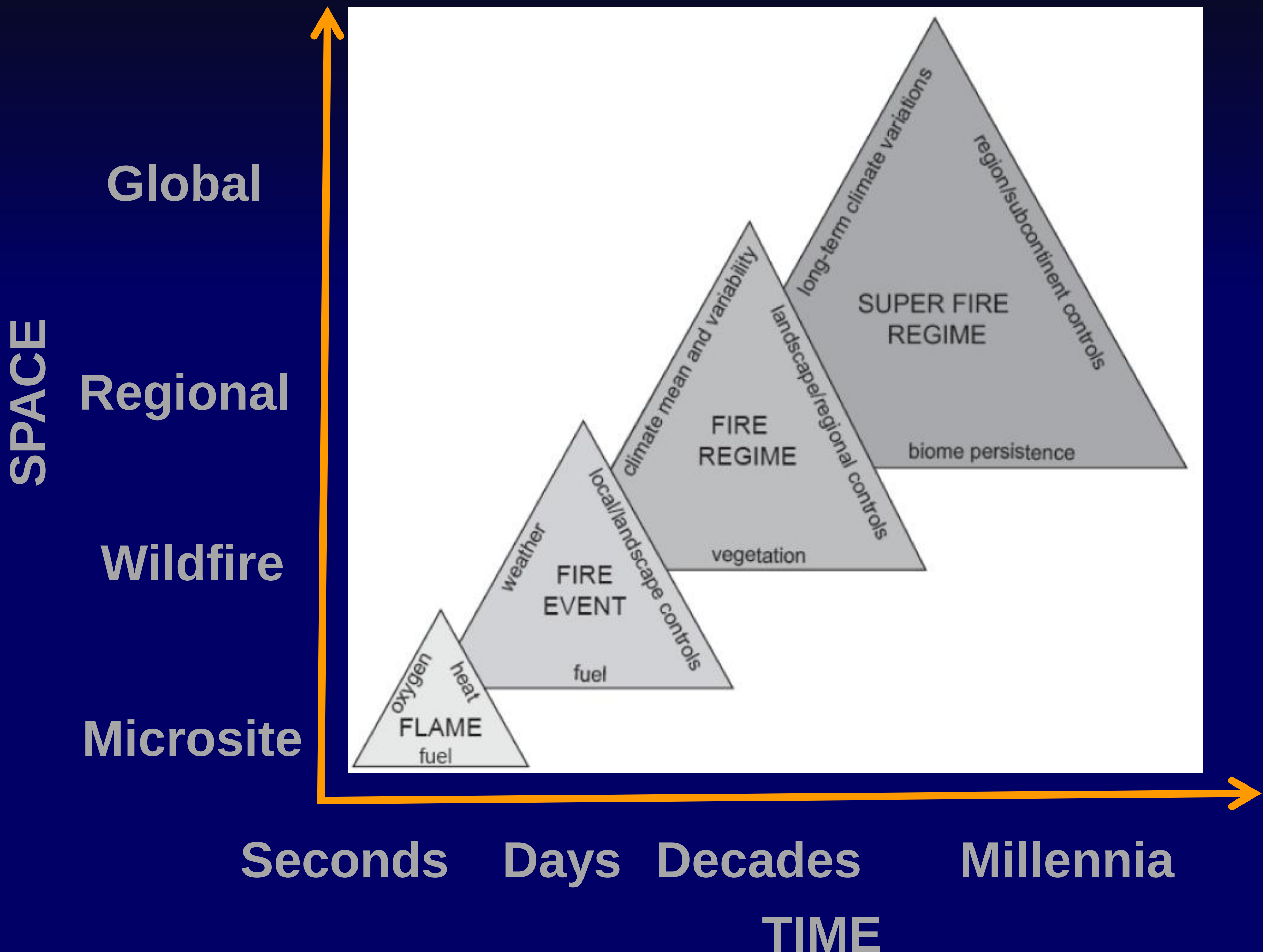
2. Conceptual challenges

- Defining regimes and detecting change

Temporal scale of fire regimes



Temporal scale of fire regimes



Modified from Whitlock, Higuera, et al. 2010; *The Open Ecology Journal*

Acknowledgments

Collaborators:

- Jennifer Allen, NPS
- Pat Anderson, U of WA
- Tom Brown, LLNL
- Linda Brubaker, U of WA
- Melissa Chipman, U of IL
- Ryan Kelly, U of IL
- Feng Sheng Hu, U of IL
- Scott Rupp, U of AK
- Mike Urban, U of IL

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Research Supporting Sound Decisions
www.firescience.gov

National Park Service
U.S. Department of the Interior

University of Idaho
College of Natural Resources

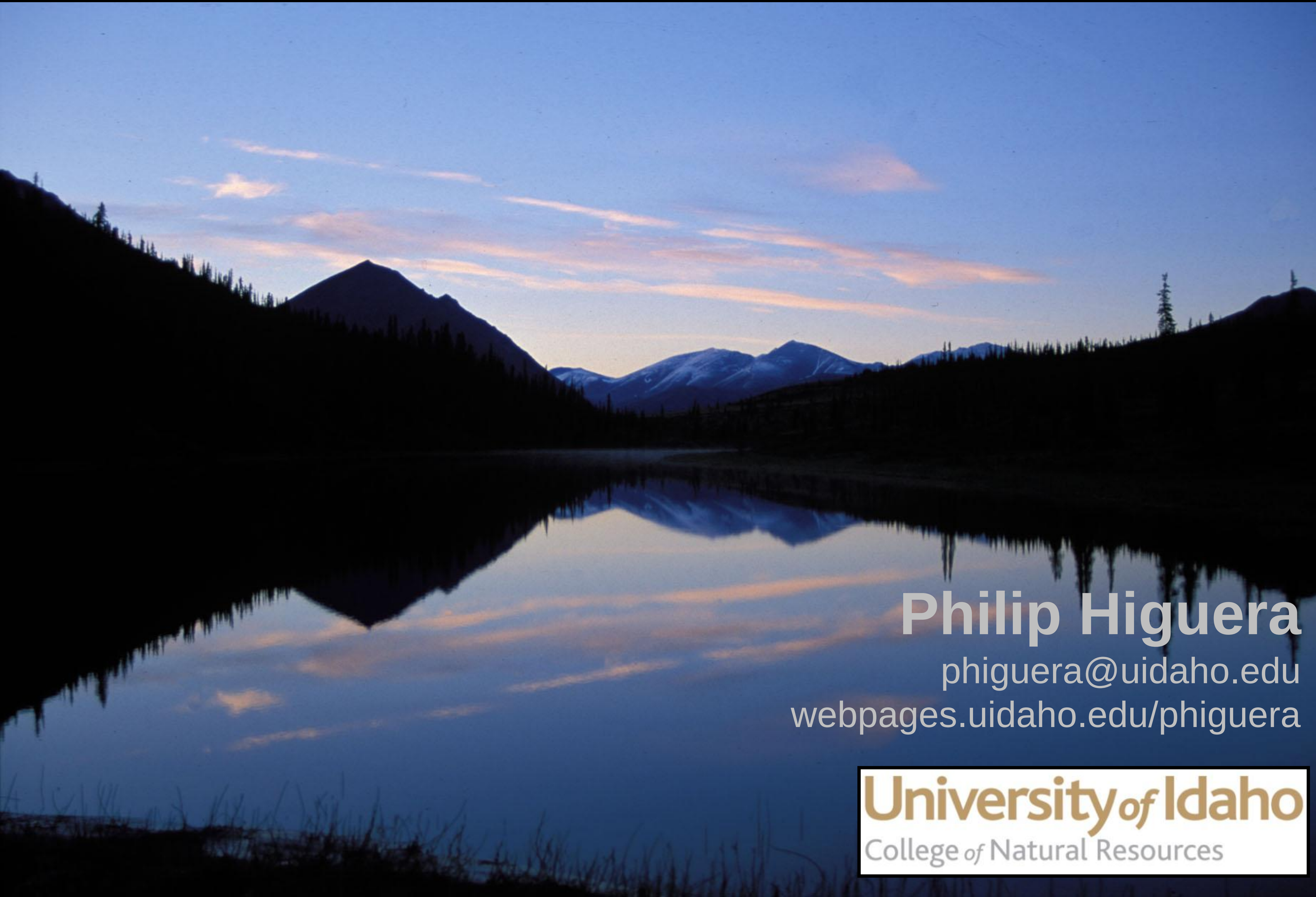
UNIVERSITY of WASHINGTON

MONTANA STATE UNIVERSITY
Mountains & Minds

Field and Lab Assistance:

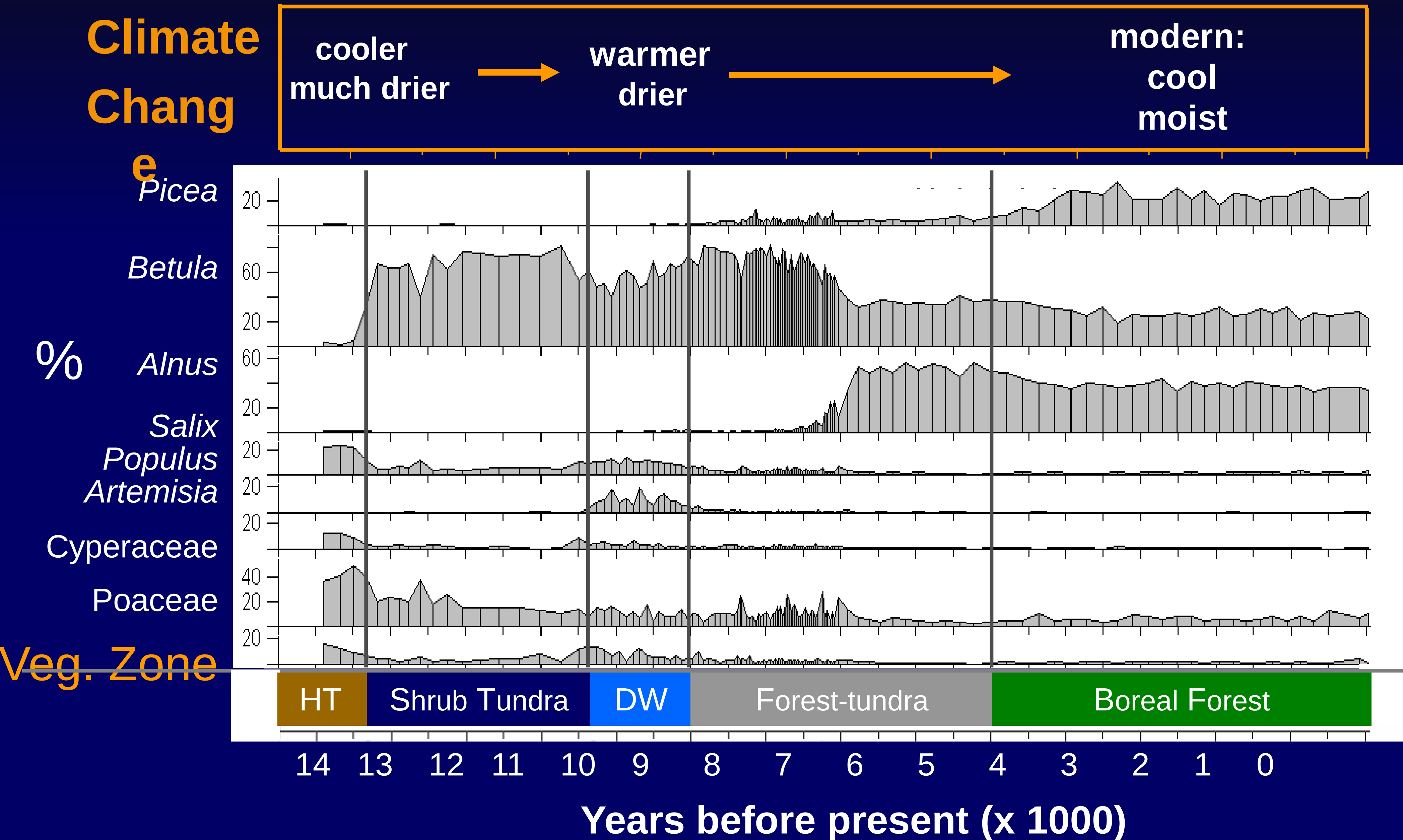
- Claire Adam
- Melissa Chipman
- Ben Clegg
- Jennifer Leach
- Amy Lilienthal
- John Mauro
- NPS personnel
- Kate Shick
- Jason Smith
- Emily Spaulding

Questions?

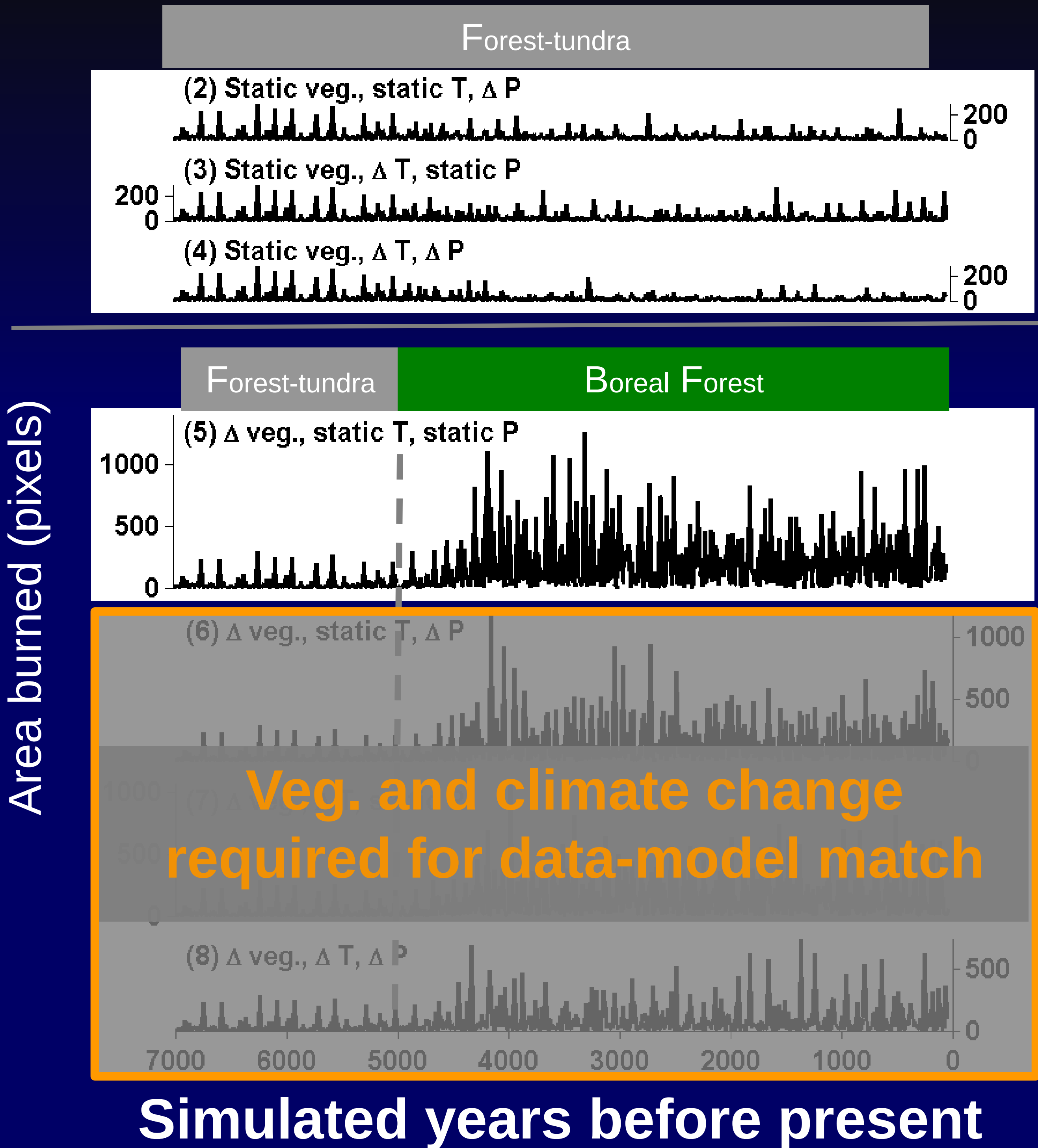


Footprint Lake, Brooks Range, 1 am

		RA	UC	PO	LI
		r	r	r	r
Taxa-specific correlations	Picea	***0.83***	--	--	***-0.57***
	Betula	***-0.75***	-0.22	0.58	0.55
	Alnus	***-0.73***	--	--	***-0.56***
	Salix	***0.38***	0.29	--	--
	Cyperaceae	--	0.45	-0.63	--
	Poaceae	***0.50***	--	--	0.70
	Artemesia	***0.66***	--	--	--
	Ericaceae	--	-0.27	0.43	--
Multi-taxa model	Model r^2_{adj}	**0.832**	**0.165**	**0.544**	**0.676**
	Model p_{adj}	**0.002**	**0.009**	**0.002**	**0.004**
	P_{dw}	**0.052**	**0.799**	**0.024**	**0.169**
	$Window_{max\ cor}$	**2000 yr**	**750 yr**	**1000 yr**	**2000 yr**



Climate: Anderson and Brubaker, 1993,1994. Vegetation: Higuera et al. 2009, *Ecological Monographs*



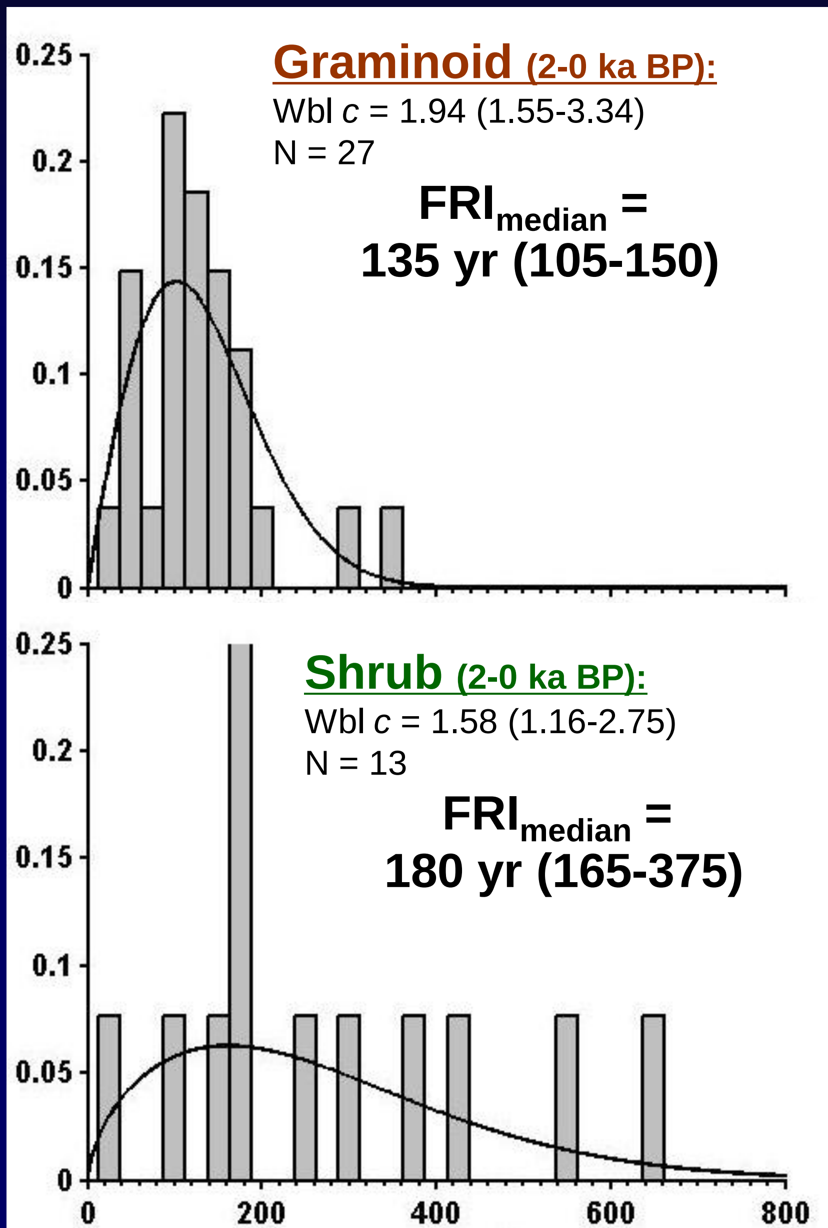
Δ climate

Δ climate &/or Δ vegetation

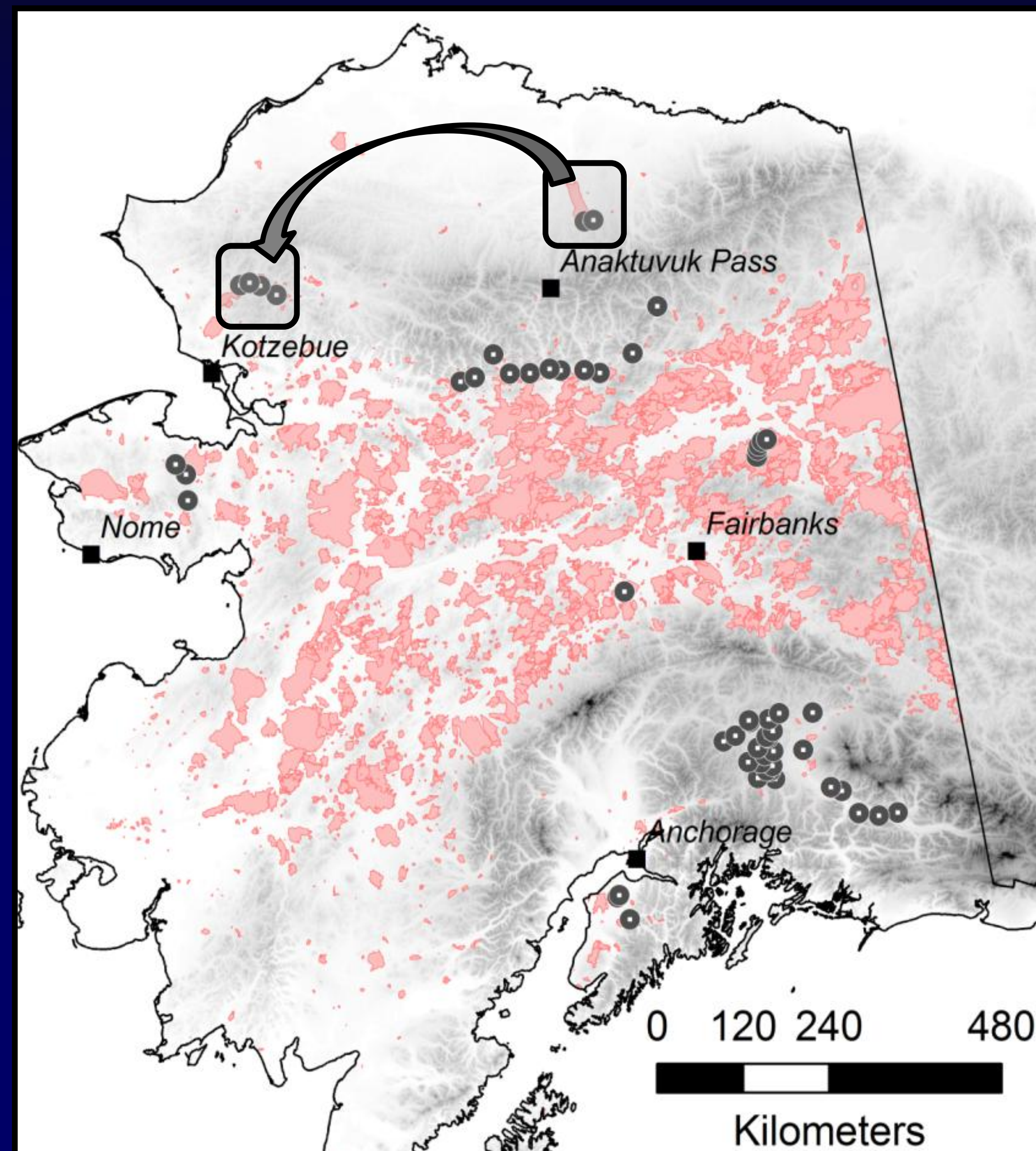
Brubaker, Higuera, Rupp, Olson, Anderson, and Hu. 2009. *Ecology*

But tundra does burn…frequently

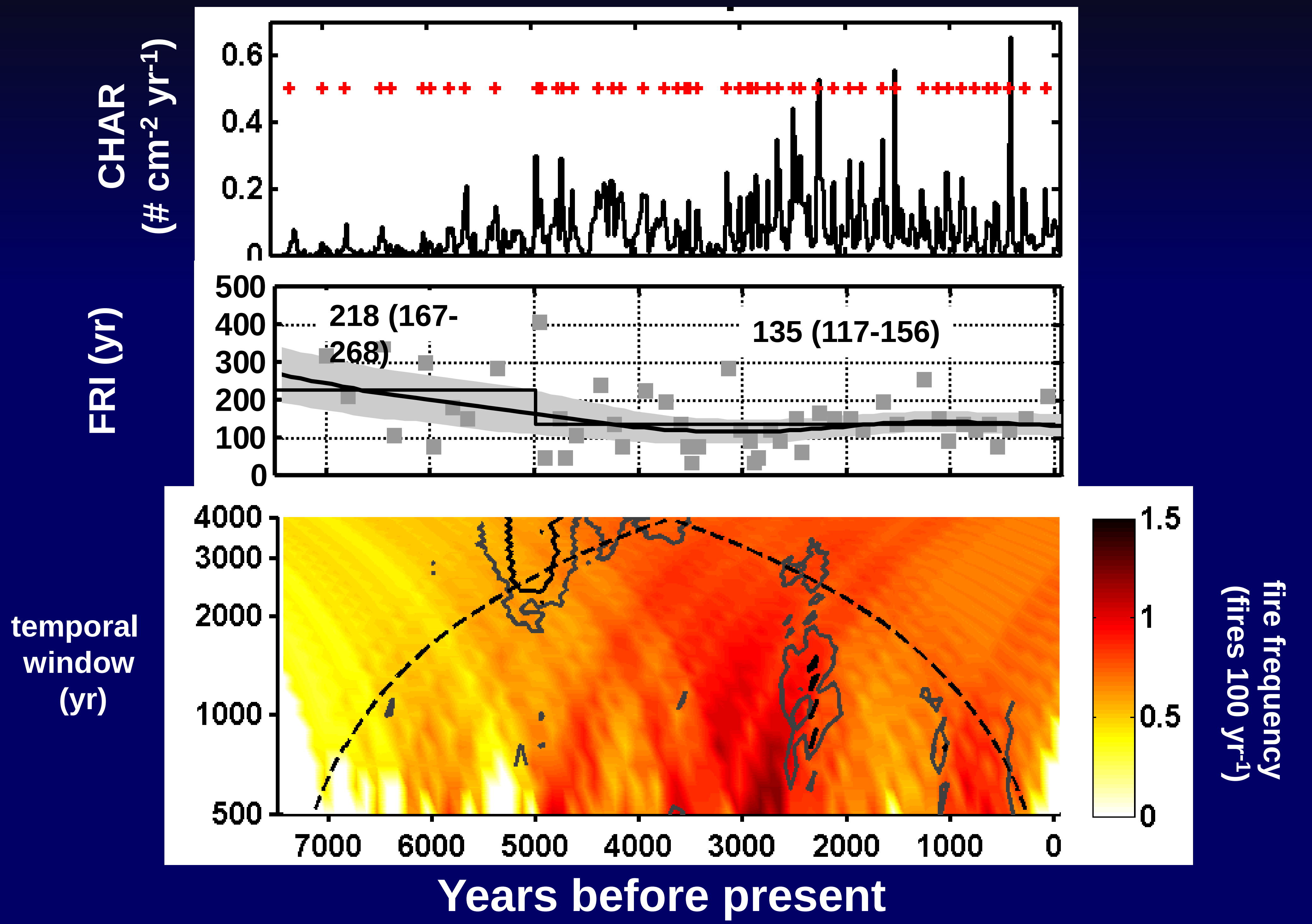
density OR proportion (x20)

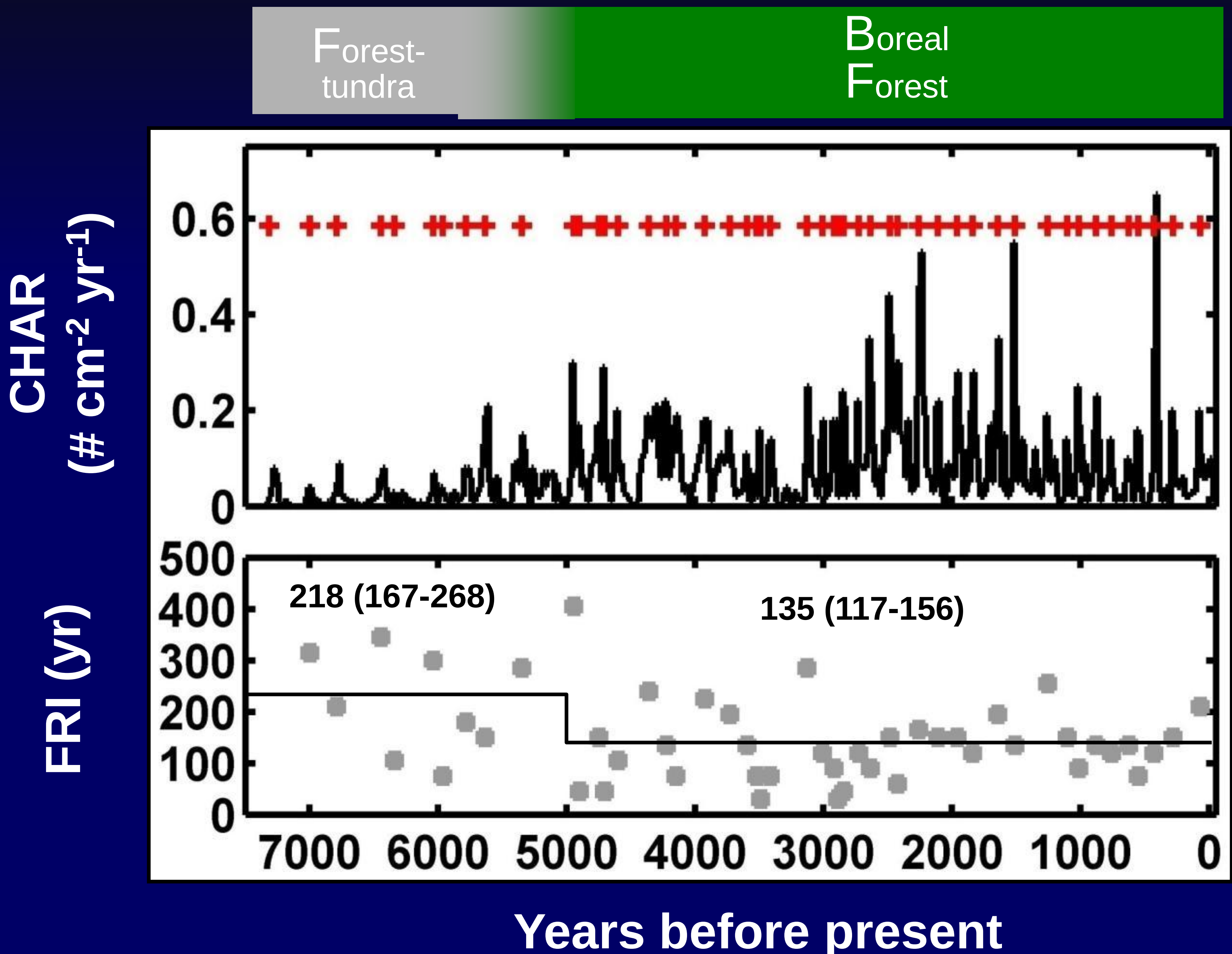


FRI (yr)



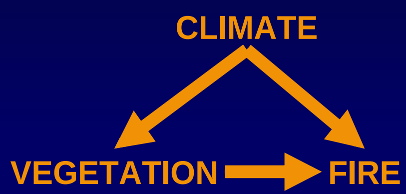
Temporal scale of fire regimes

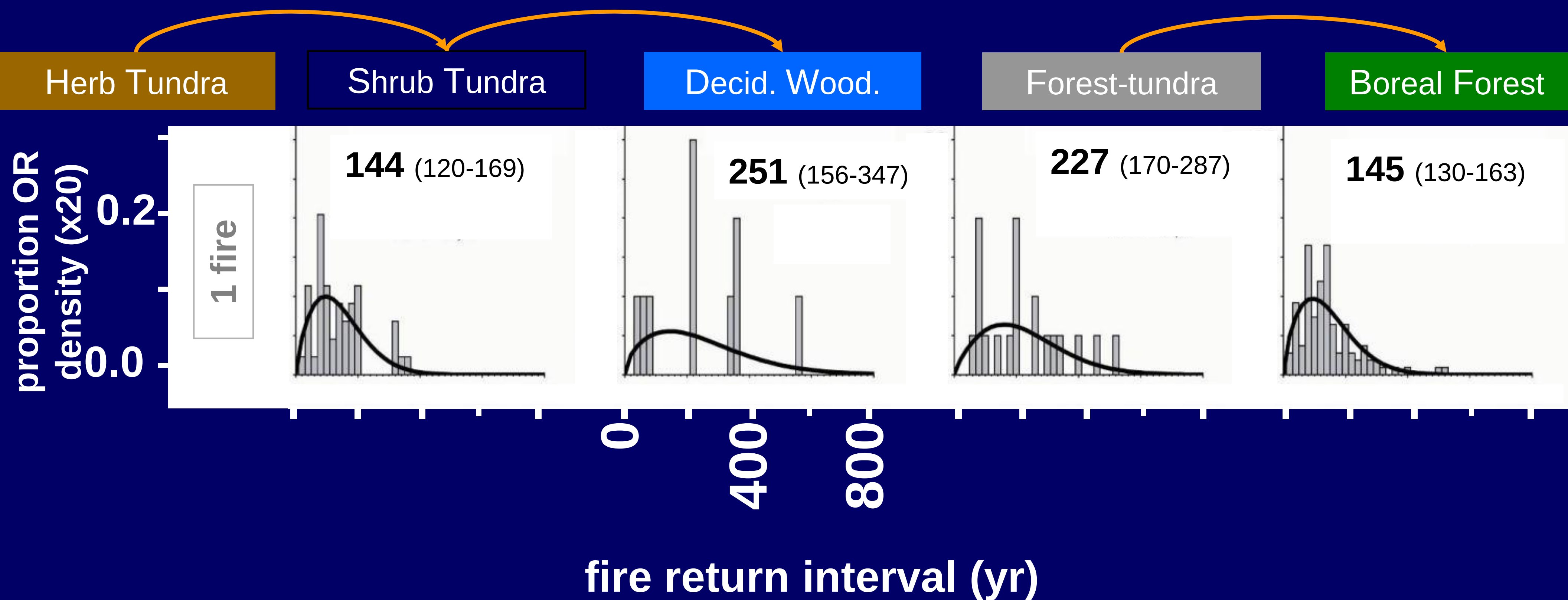




Forest-
tundra
Boreal
Forest
CHAR
(# cm-2 yr-1)
0.6
0.4
0.2
0
FRI (yr)
500
400
300
200
100
0
218 (167-268)
135 (117-156)
7000
6000
5000
4000
3000
2000
1000
0
Years before present


Vegetation mediates the impacts of climate change on fire regimes.





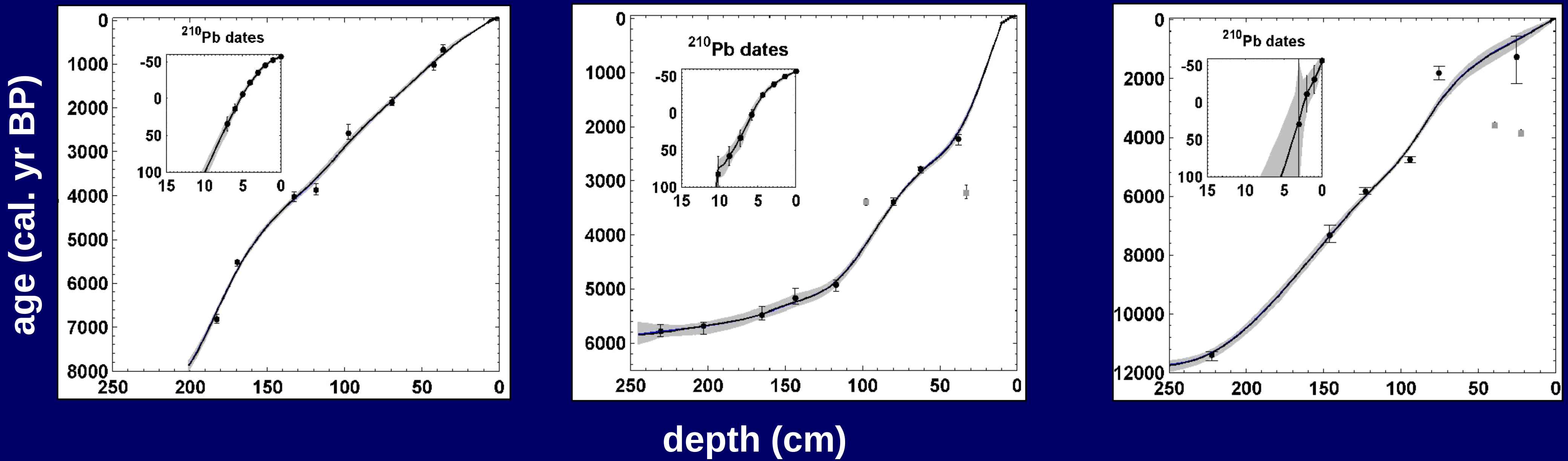
IV. Noatak Fire History

Age Models

Uchugrak Lake

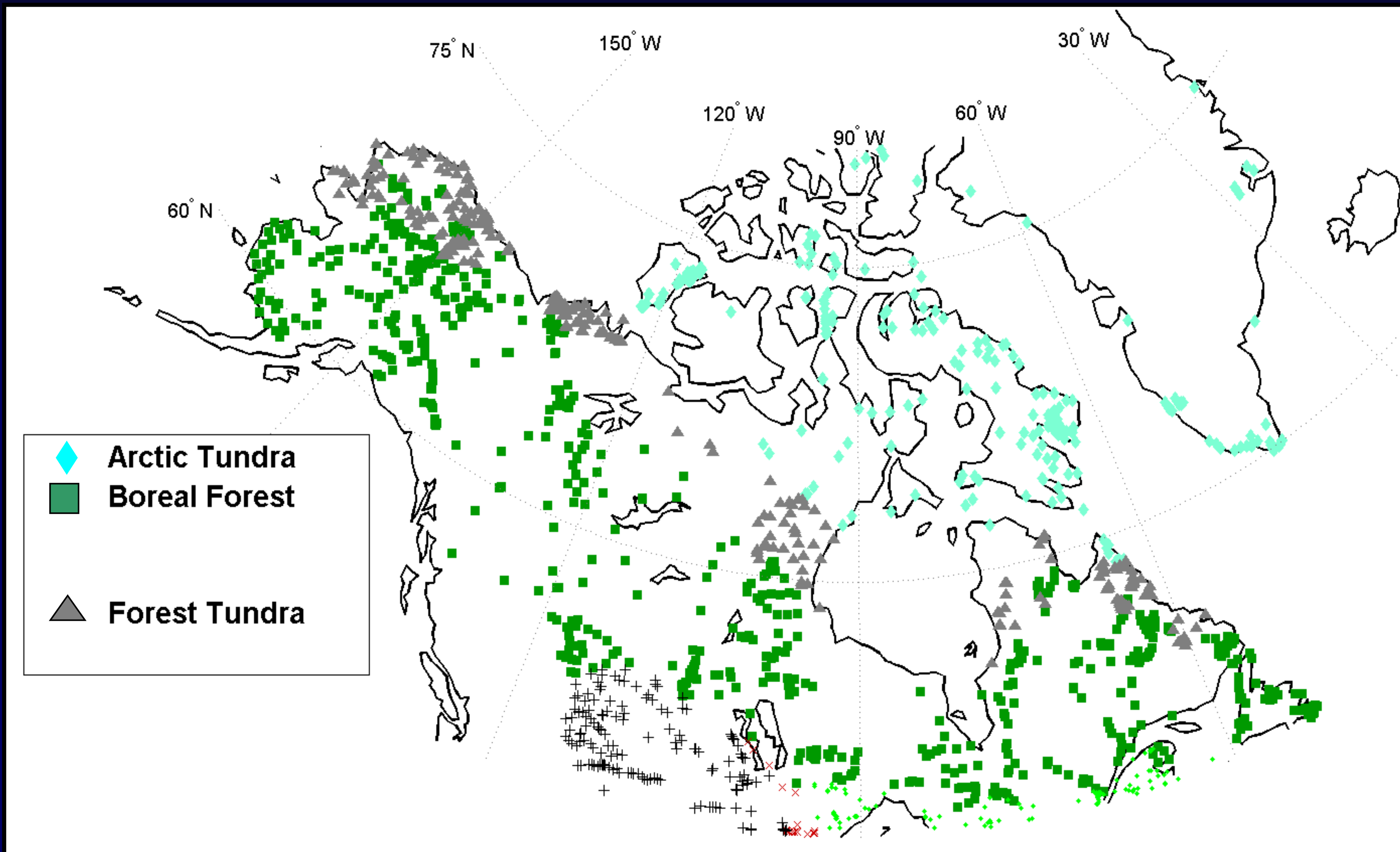
Poktovik Lake

Little Isac Lake



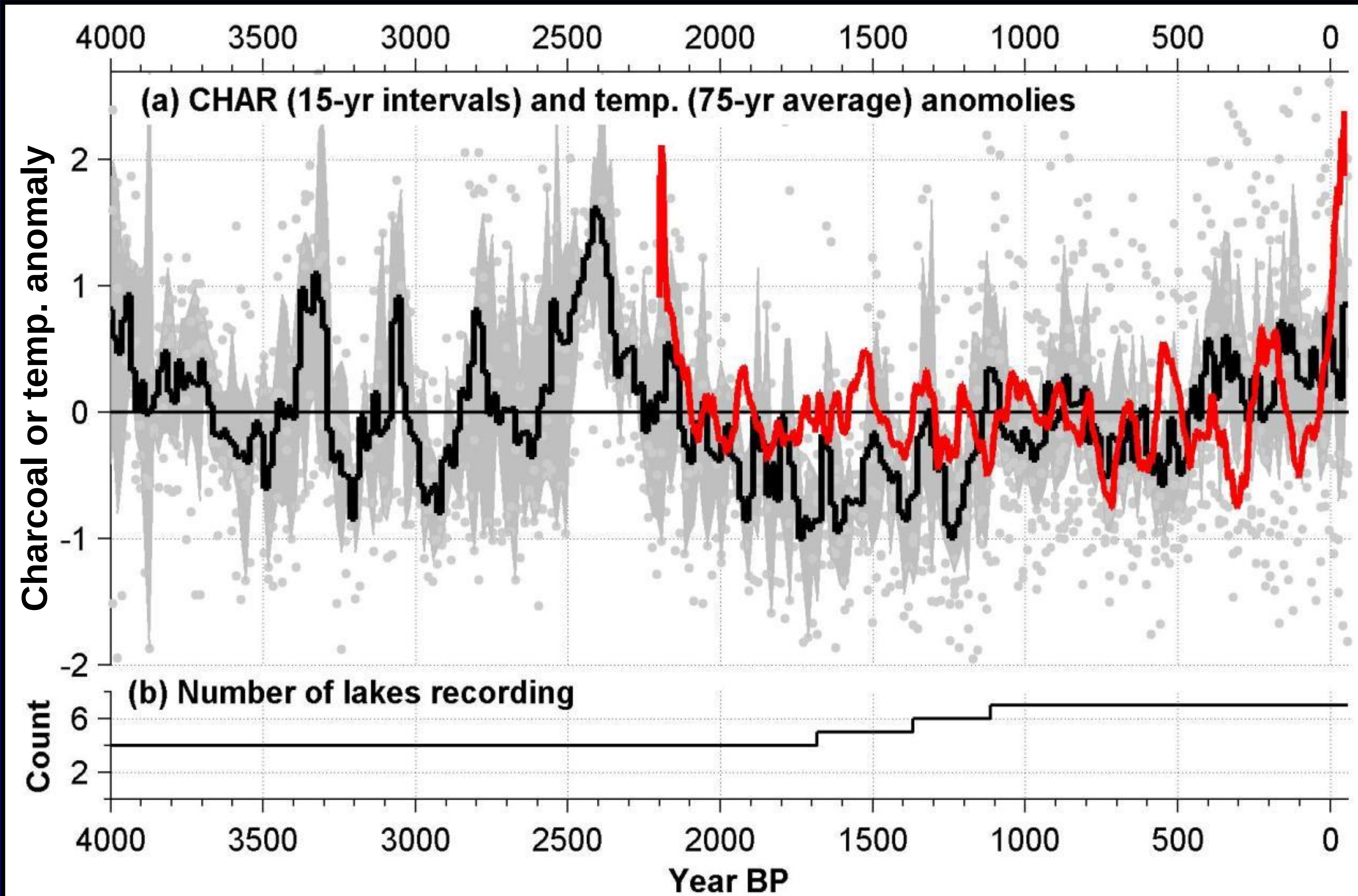
Q2: Late glacial and Holocene Fire Hx Methods

- Interpreting pollen data via modern analogs



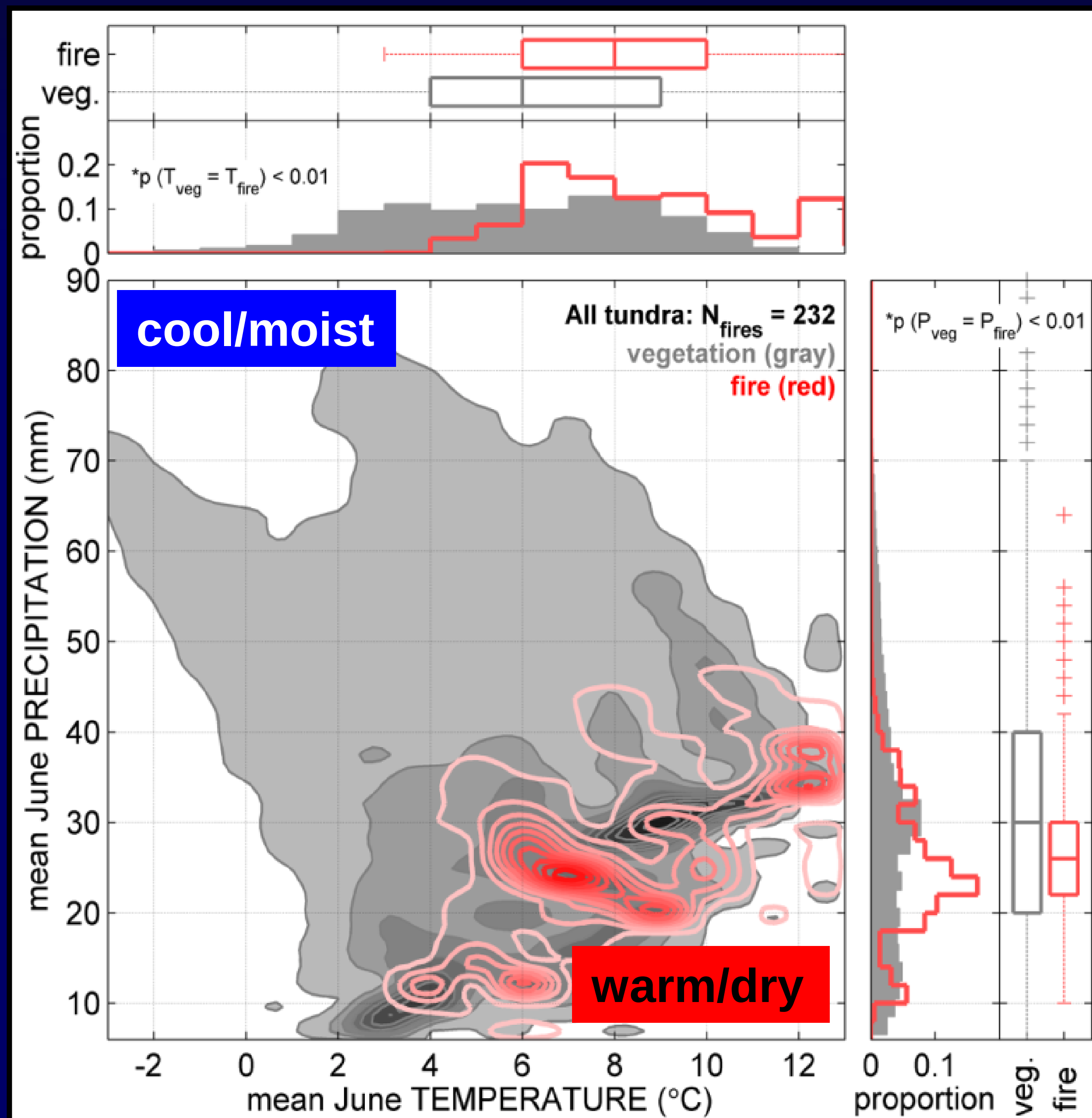
- What is the probability that fossil sample *X* is similar to modern sample modern sample *Y*?

Decadal- to centennial- scale controls



Temperature recon. by Salzer and Kipfmueller 2005.

Tundra Fire Regimes

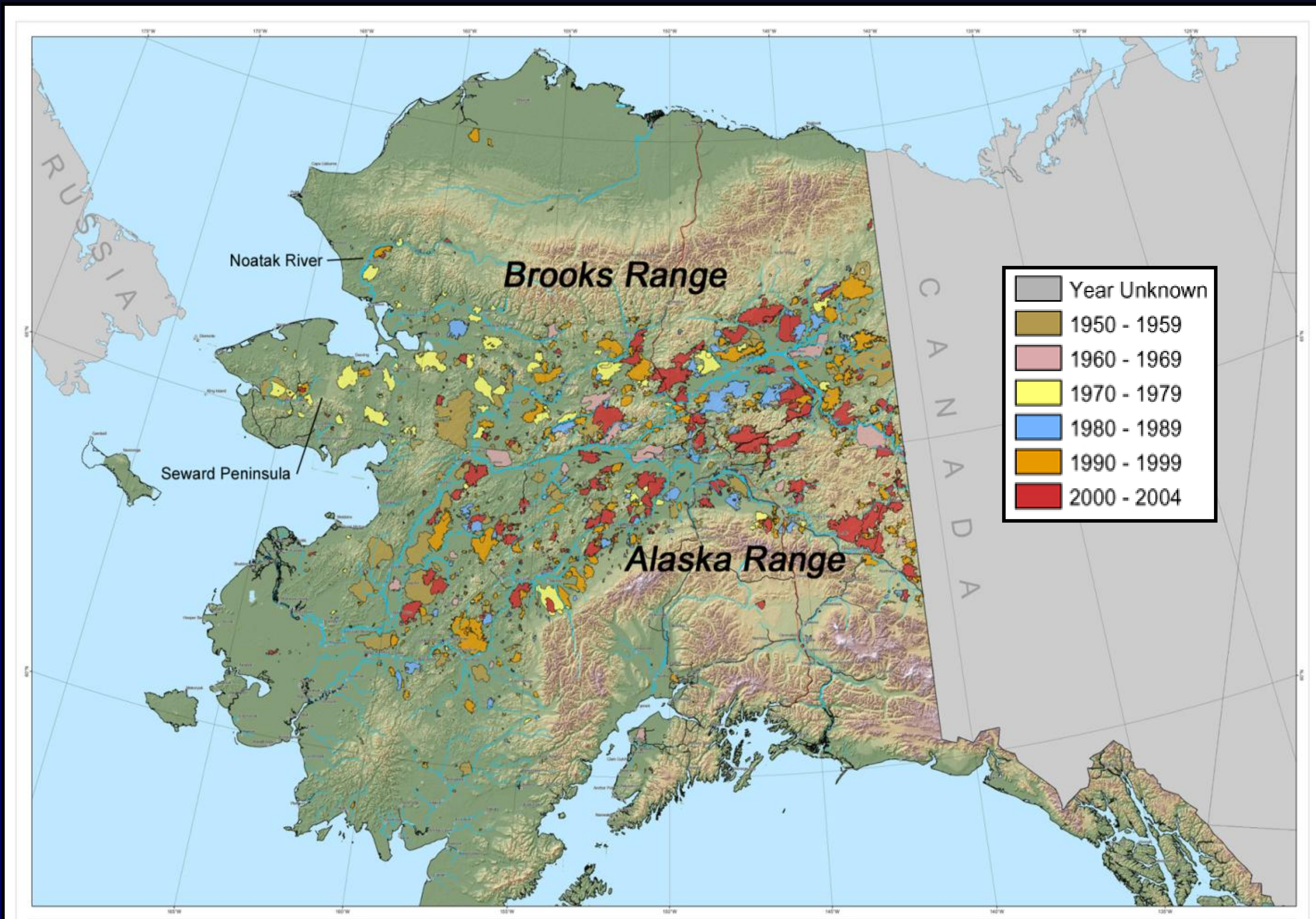


mean June PRECIP. (mm)

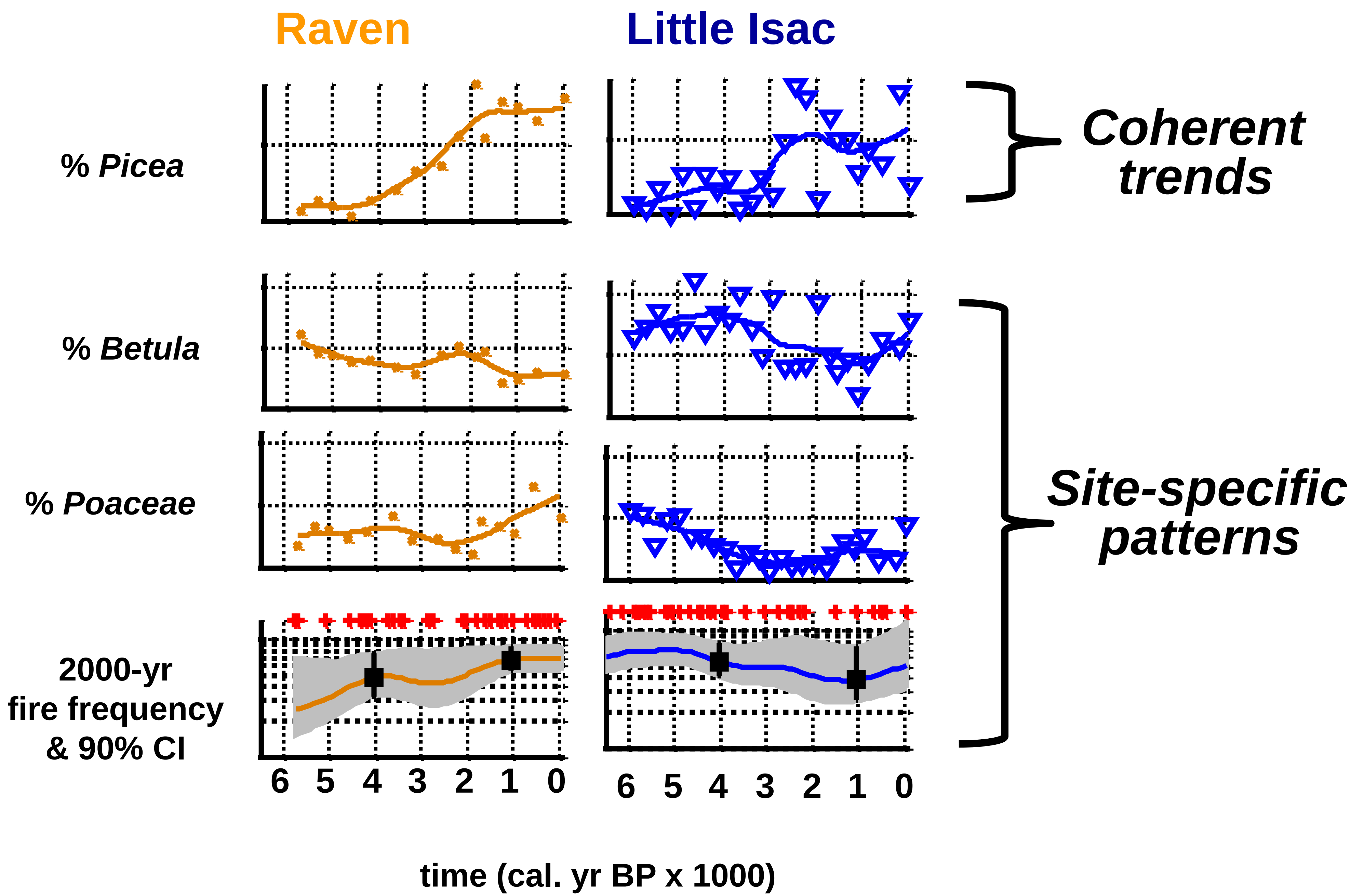
mean June TEMP. (°C)

Higuera et al. 2008. PLoS ONE

Modern Fire Regimes



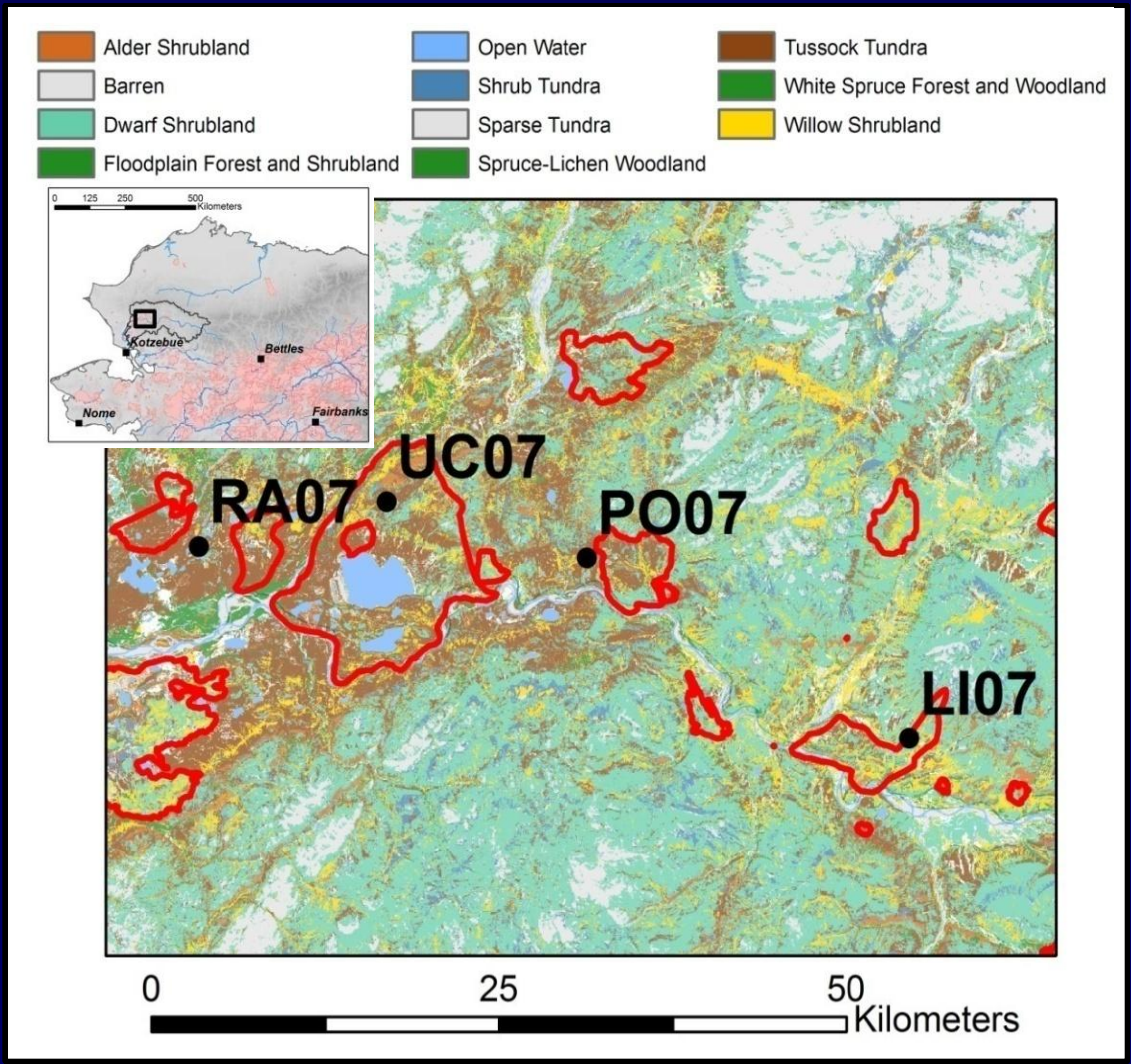
BLM, Alaska Fire Service

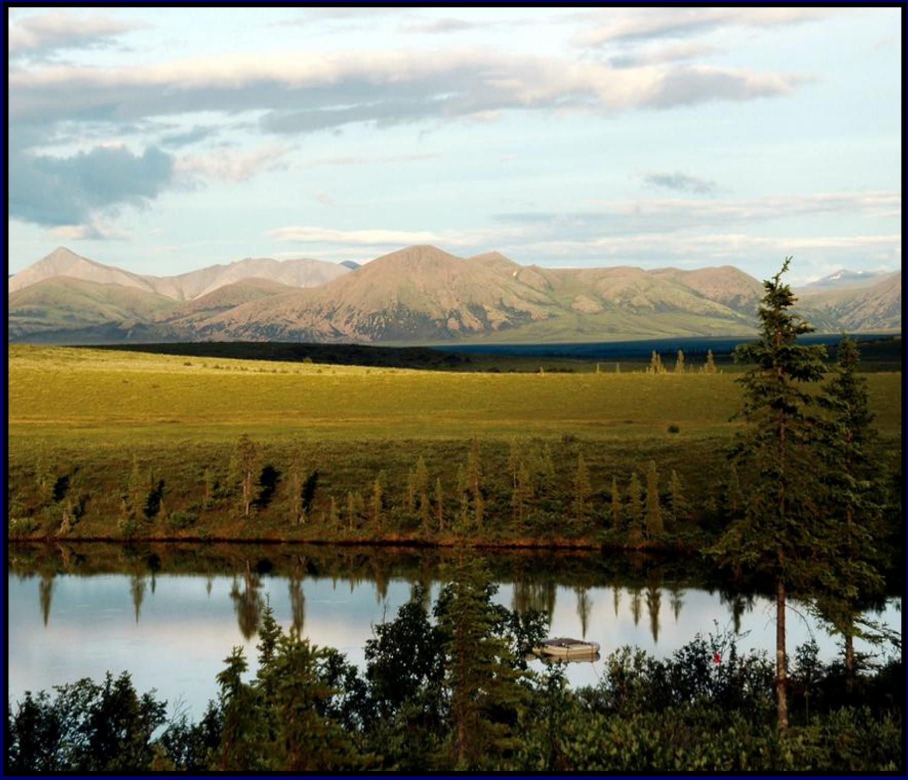


Raven
Little Isac
% Picea
% Betula
% Poaceae
2000-yr
fire frequency
& 90% CI
6 5 4 3 2 1 0
6 5 4 3 2 1 0
time (cal. yr BP x 1000)
Coherent
trends
Site-specific
patterns

Western Brooks Range, Alaskan tundra

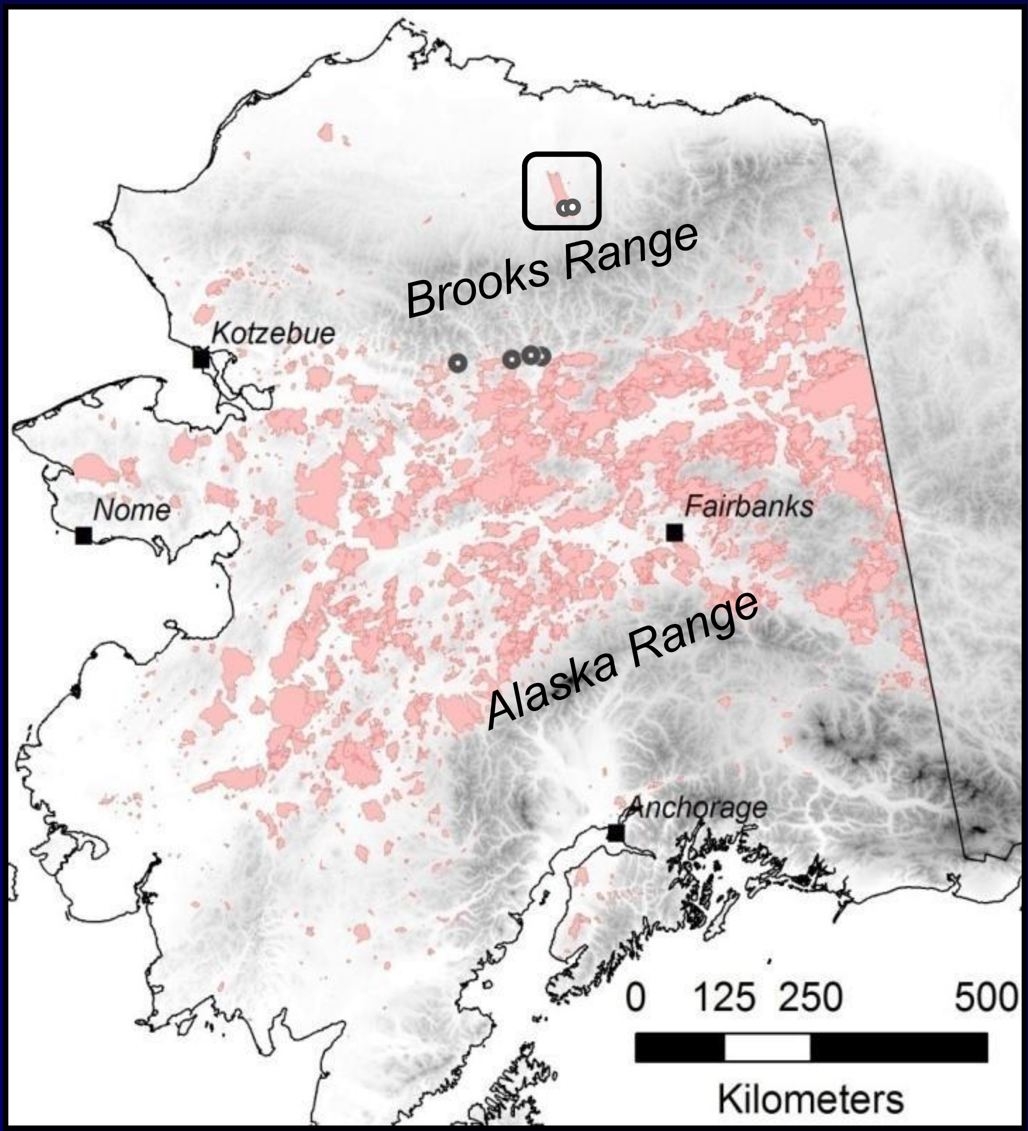
Locally-mediated response to climate change





Raven Lake

Context for ongoing change



Climate Change and Fire Regimes

Vegetation mediates the impacts of climate change on fire regimes