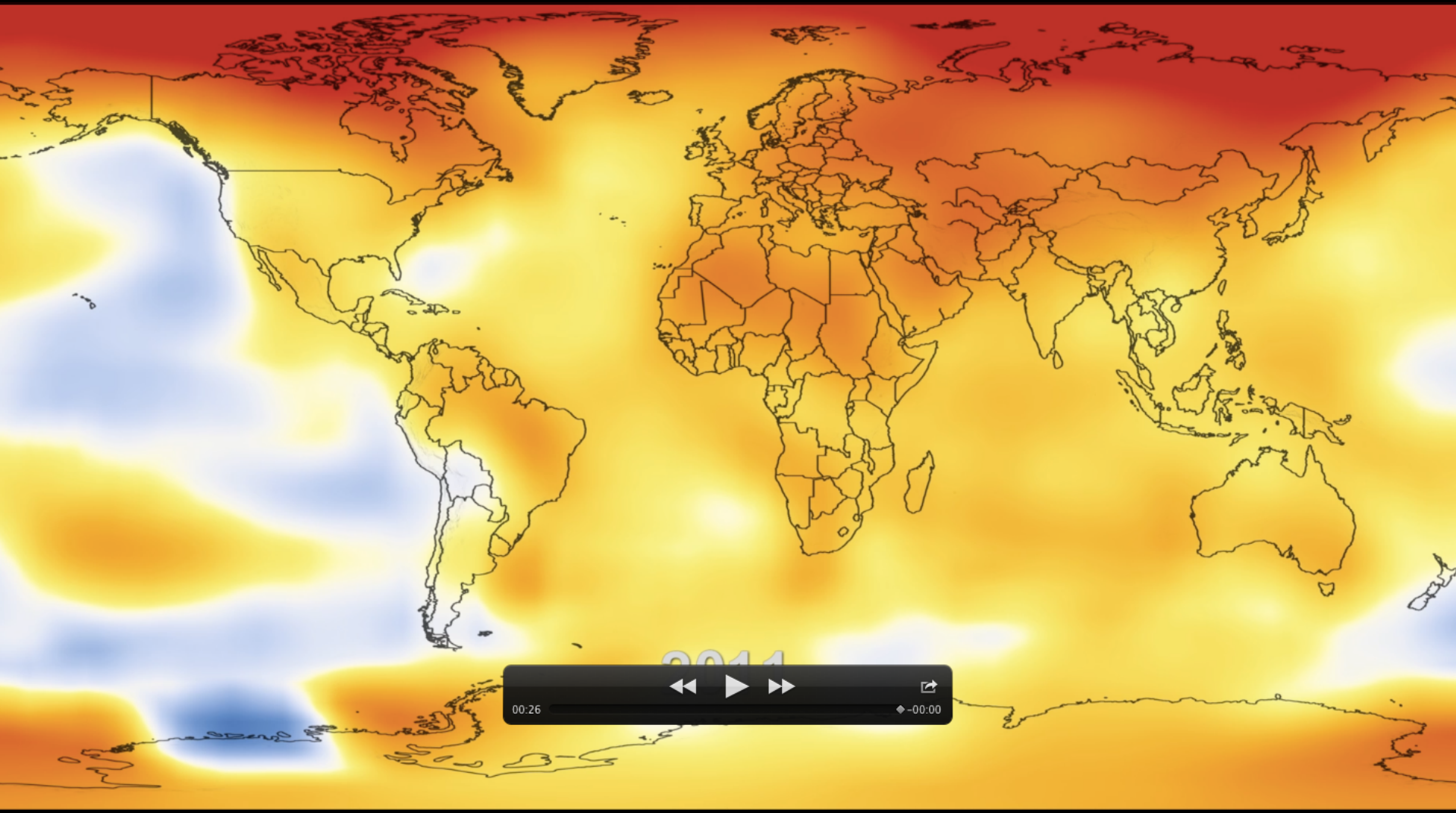
High latitude systems: Synthesis of what we know, don't know, and need to know, pre-ABoVE

SCOTT GOETZ
NASA Terrestrial Ecology meeting
LA JOLLA, CA
MAY 2013

THE WOODS HOLE RESEARCH CENTER

We know: Climate warming & arctic amplification



2011 mean Ta -vs- longer-term 1881-2011 mean

Goddard Institute for Space Studies (GISS)

Permafrost Carbon Feedback to Climate

Need to know: What is the **magnitude**, **timing**, and **form** of the permafrost carbon release to the atmosphere in a warmer world?

Cumulative C Emissions: 1850-2005 (2012)

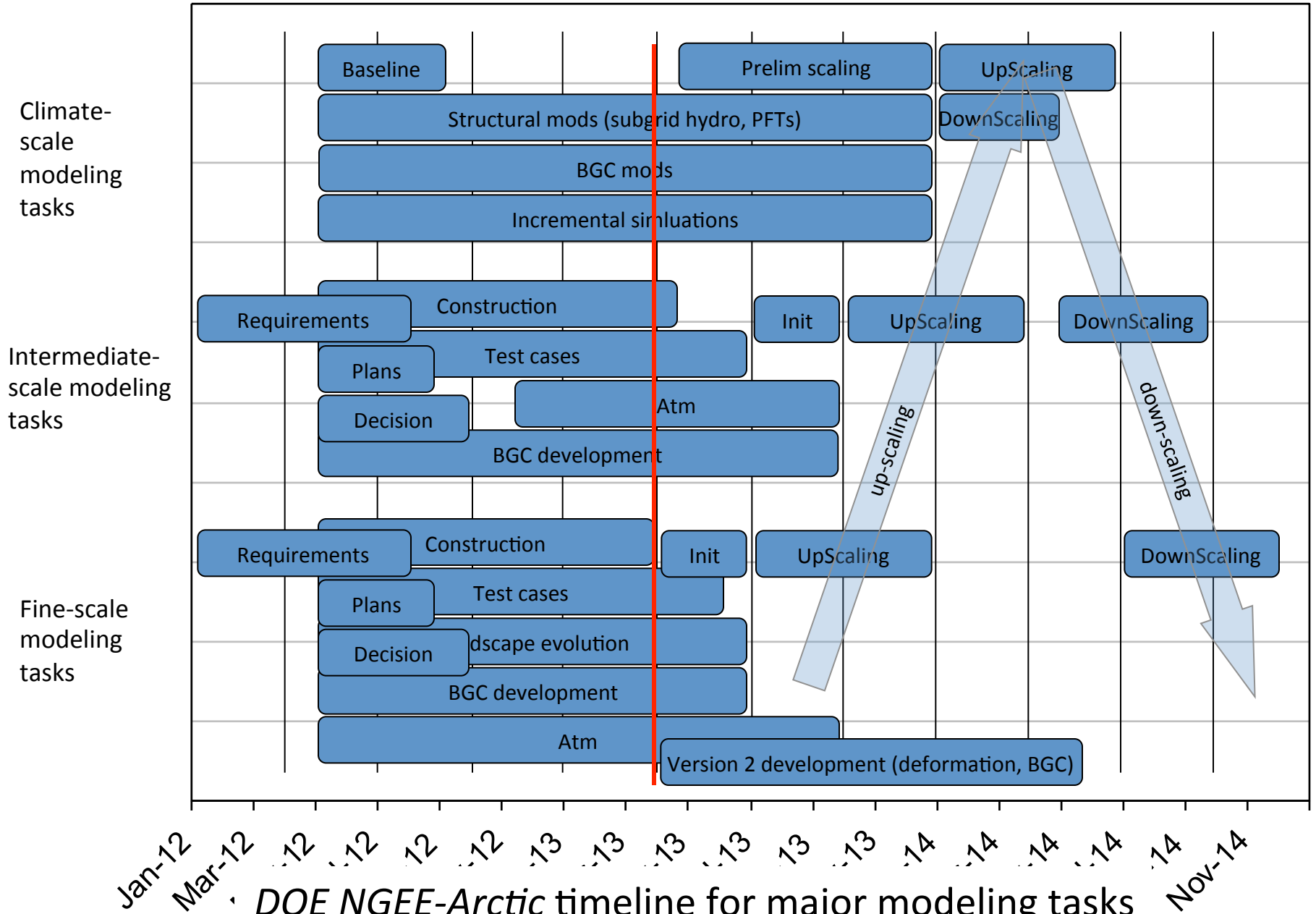
Fossil Fuel Emissions	365 Pg
Land Use Change	151 Pg

Future (2100) Permafrost Zone C Emissions?

7-11% Loss?	120-195 Pg
Expert Survey (Schuur 2013)	(162-288 Pg CO_2-C_{eq})

Ted Schuur & Permafrost RCN

Know: Permafrost is not well represented in Earth System Models

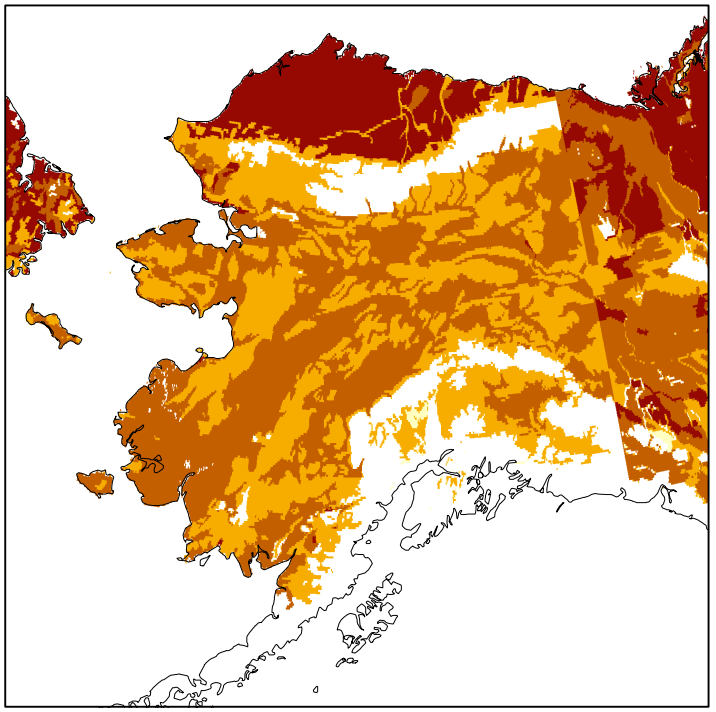


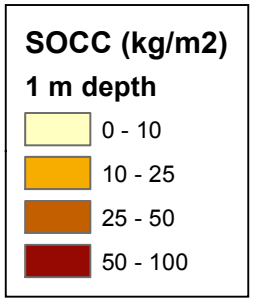
DOE NGEE-Arctic timeline for major modeling tasks

Know: knowledge of permafrost properties over large areas is poor but critically important for magnitude & timing of carbon release

Permafrost extent

Soil carbon in permafrost region

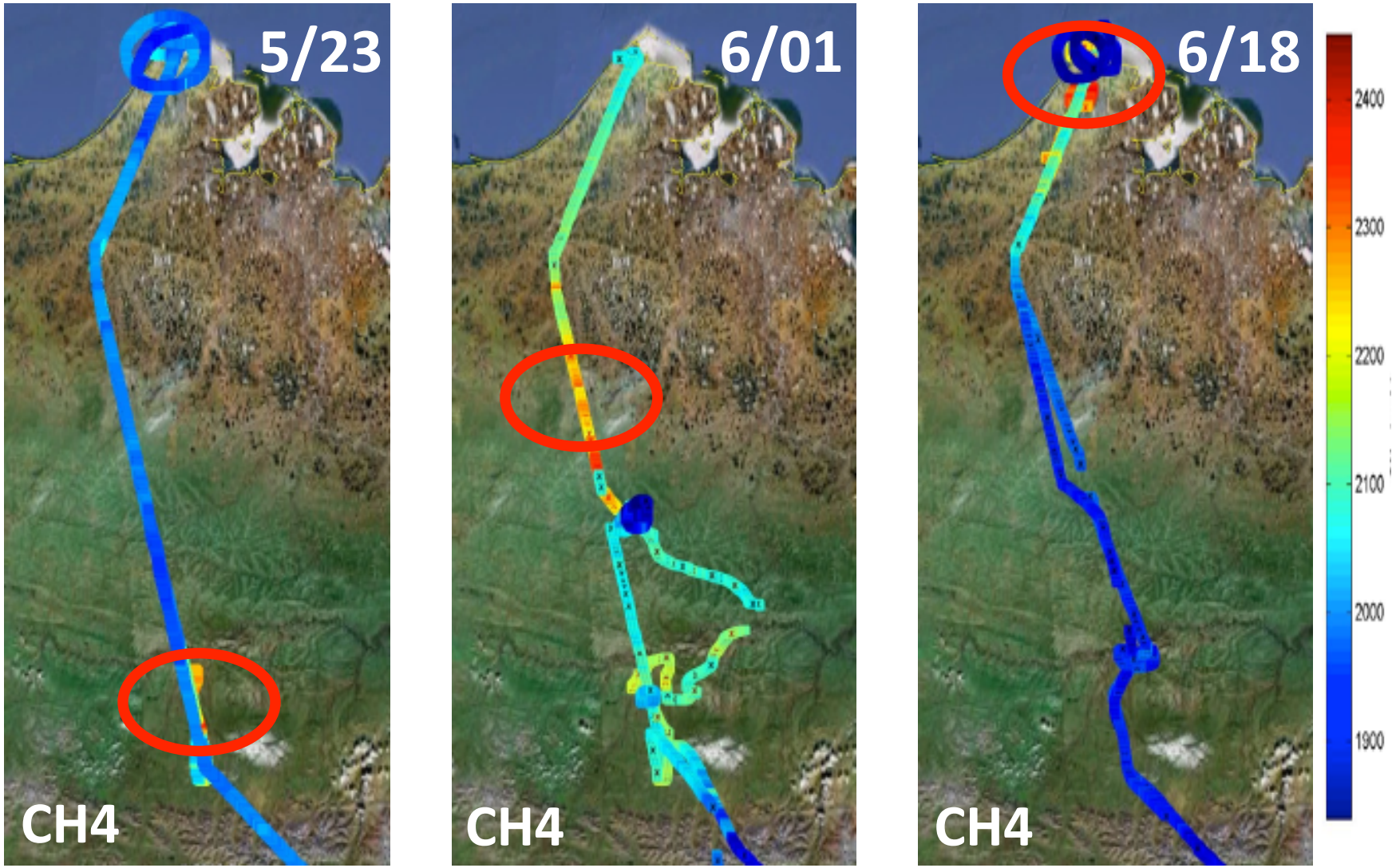




Hugelius et al. (2013)

Tremendous heterogeneity within these classes

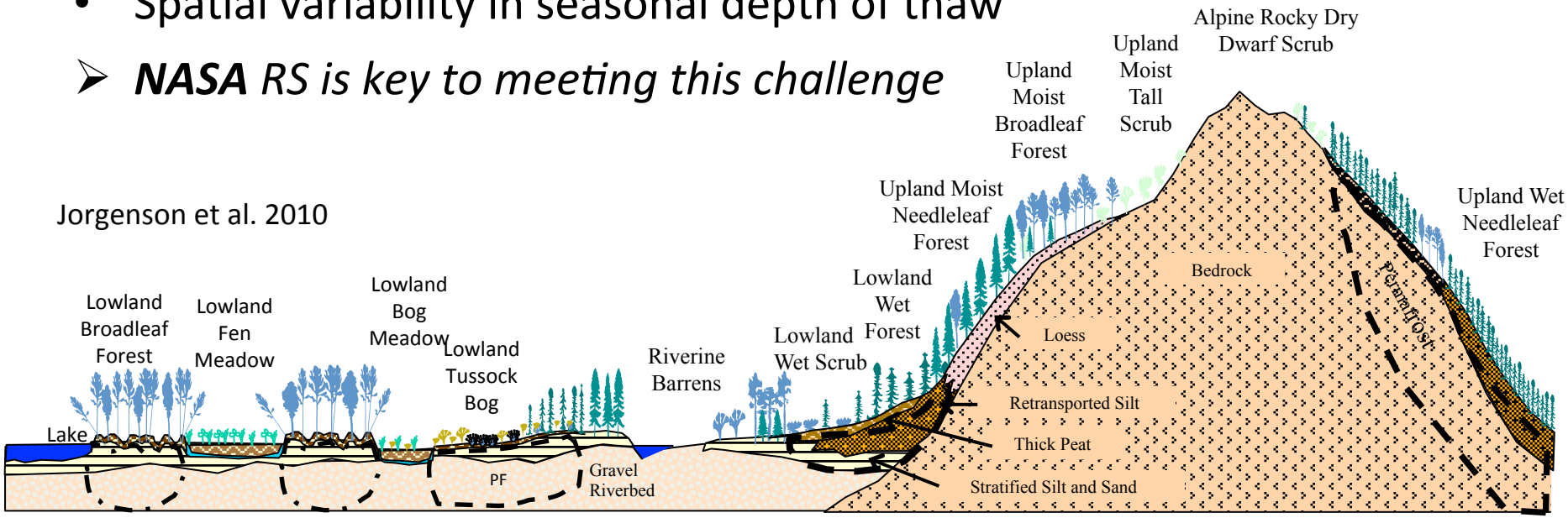
CARVE observations of methane bursts as Spring thaw moves across the North Slope



Need to be able to link this variability to surface & subsurface properties

Need to know: How do permafrost landscape properties vary at relatively fine scale (10-100m) across the landscape?

- Not just presence but also substrate properties (e.g. soil moisture & texture, ice content & morphology)
- Vegetation cover & density, surface hydrology & other properties
- Snow cover, seasonality & properties (e.g. SWE)
- Freeze-Thaw state & seasonal variability
- Spatial variability in seasonal depth of thaw
- ➢ ***NASA*** *RS is key to meeting this challenge*



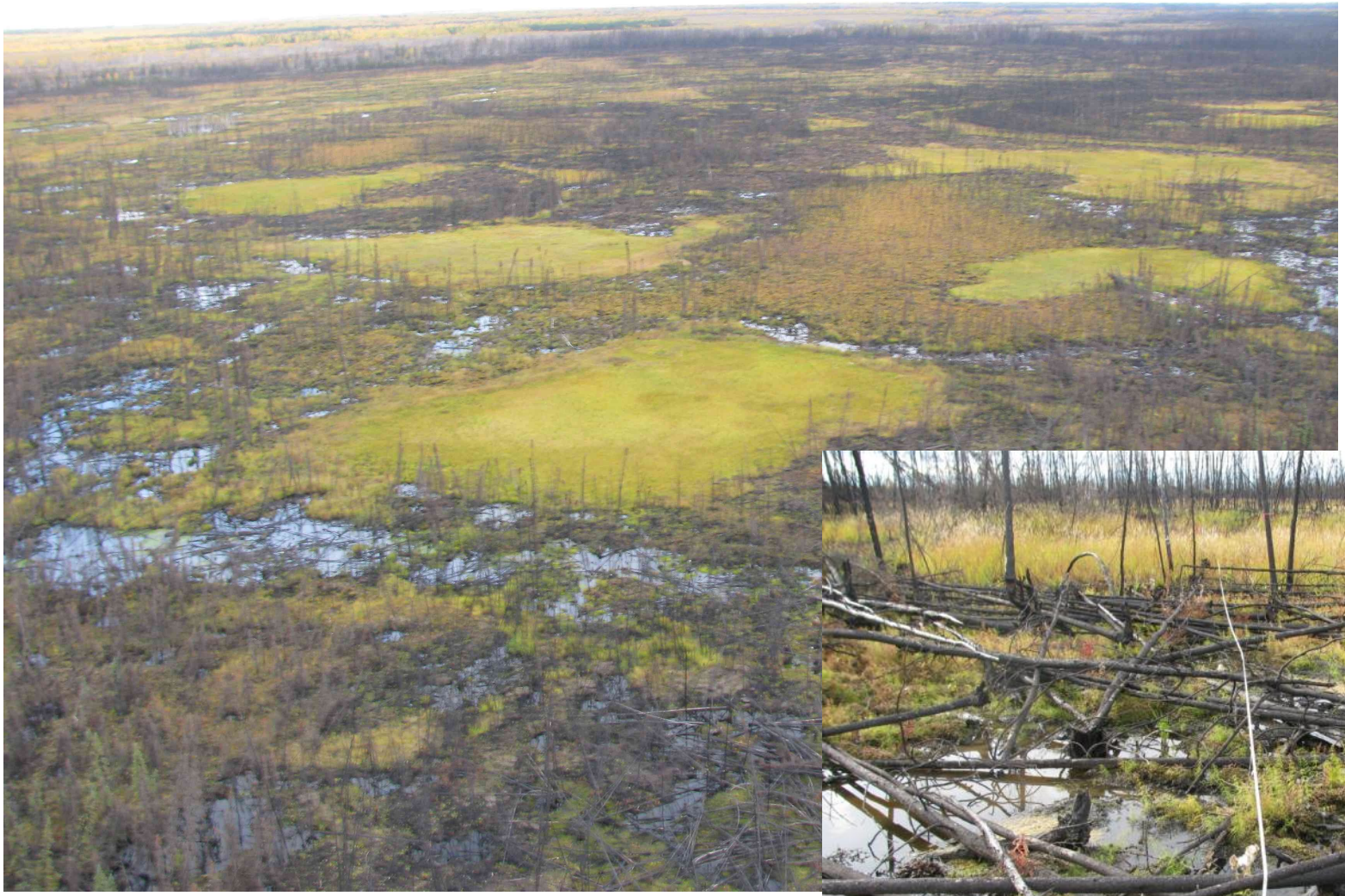
Opportunities to Use Remote Sensing in Understanding Permafrost Ecosystems: A Workshop

National Academy of Sciences

In formulation stage

Planned for 8-9 Oct 2013
Location TBD

Need to know: How does fire disturbance alter active layer / depth of thaw and how does this change in the years post-disturbance?



2010 Fire on Tanana Flats, AK

Photos by Torre Jorgenson

Need to know: How can we work this information into meaningful spatial models of subsurface temperature & thaw depth?

***Know*:** like Freeze-Thaw, these do not scale linearly with spatial resolution

Romanovsky & Marchenko

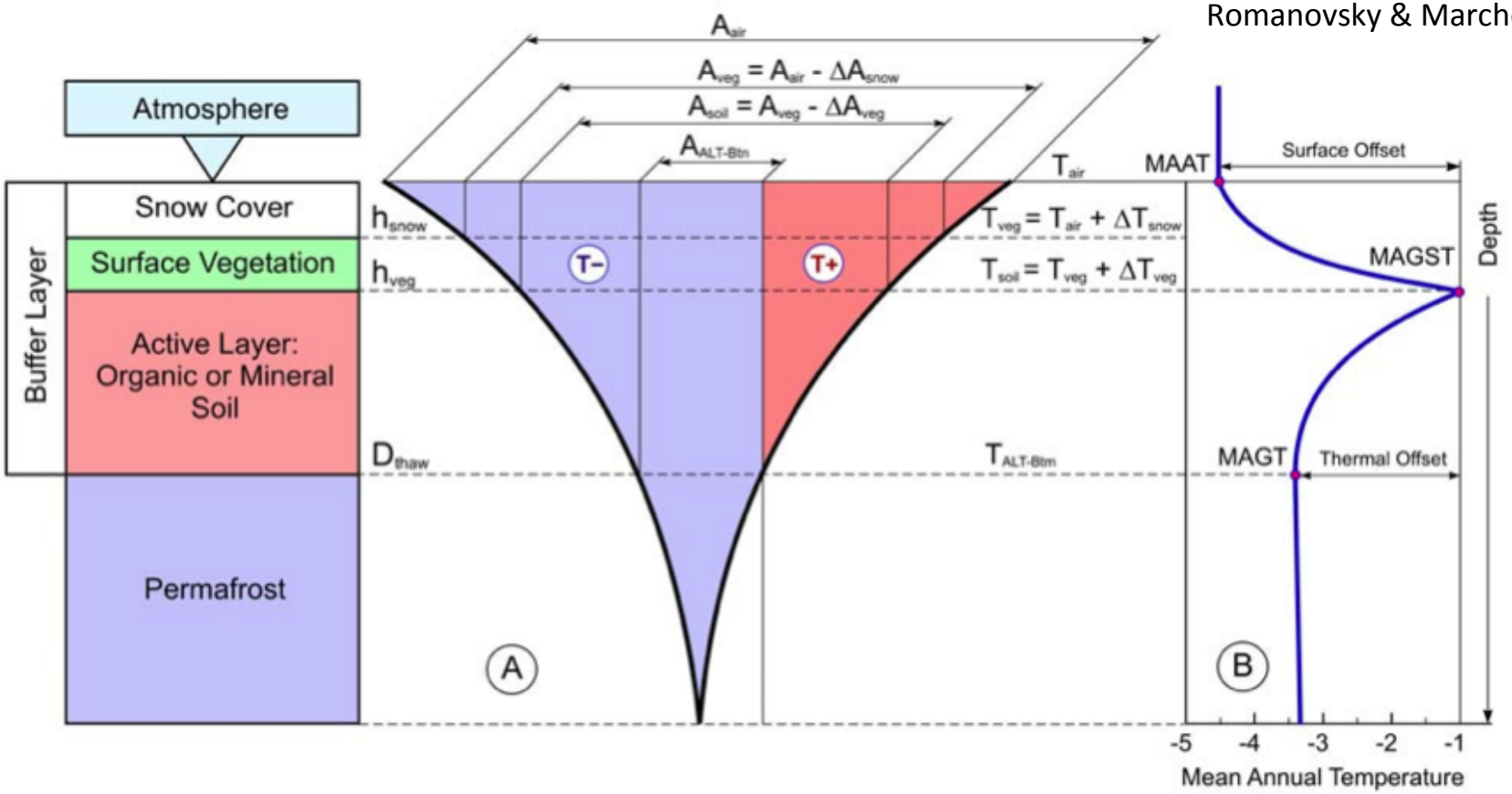
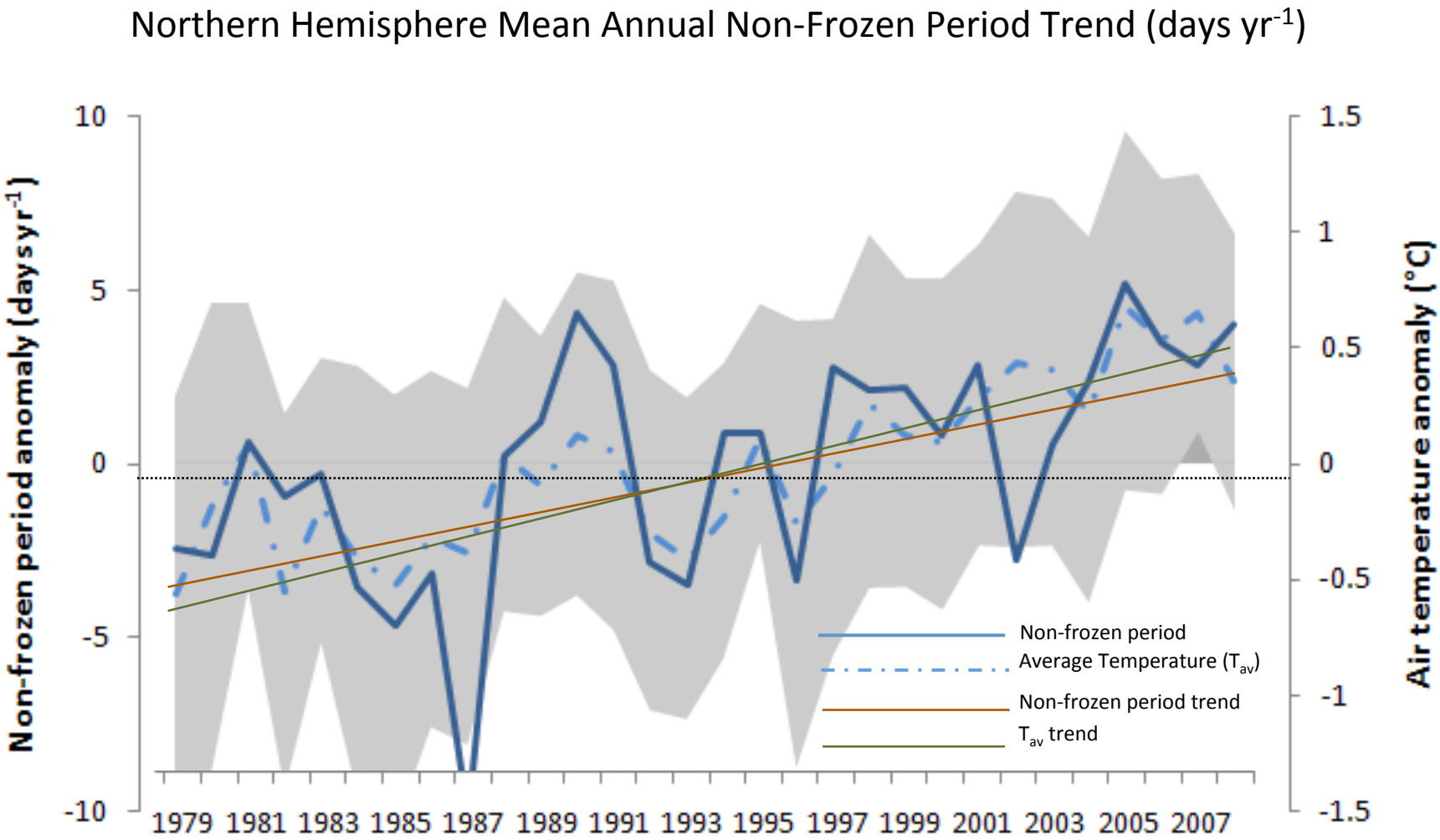
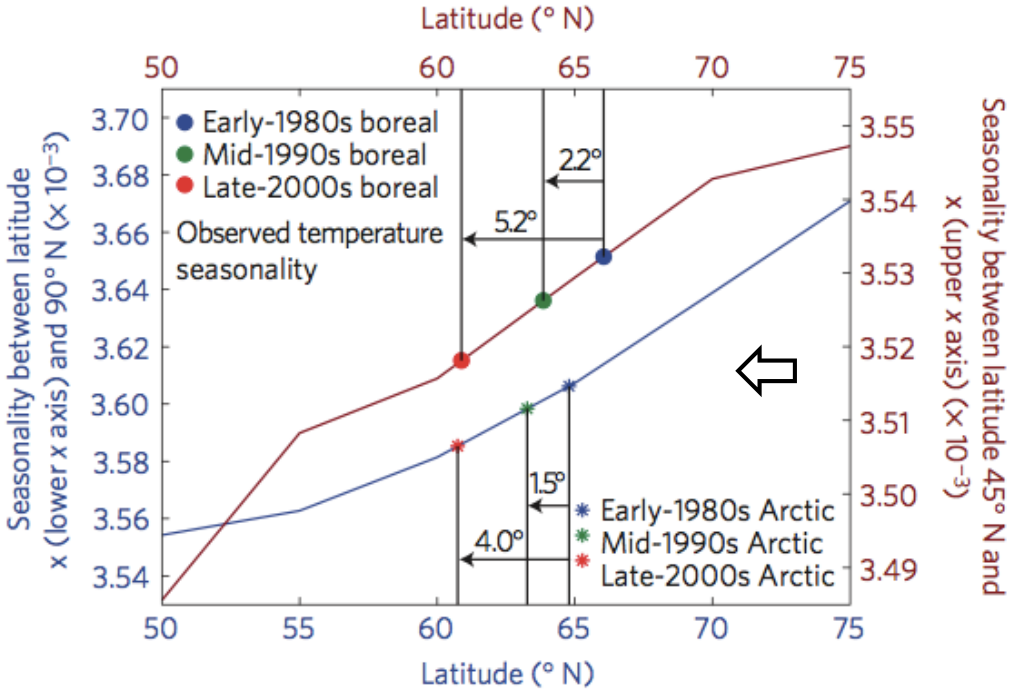


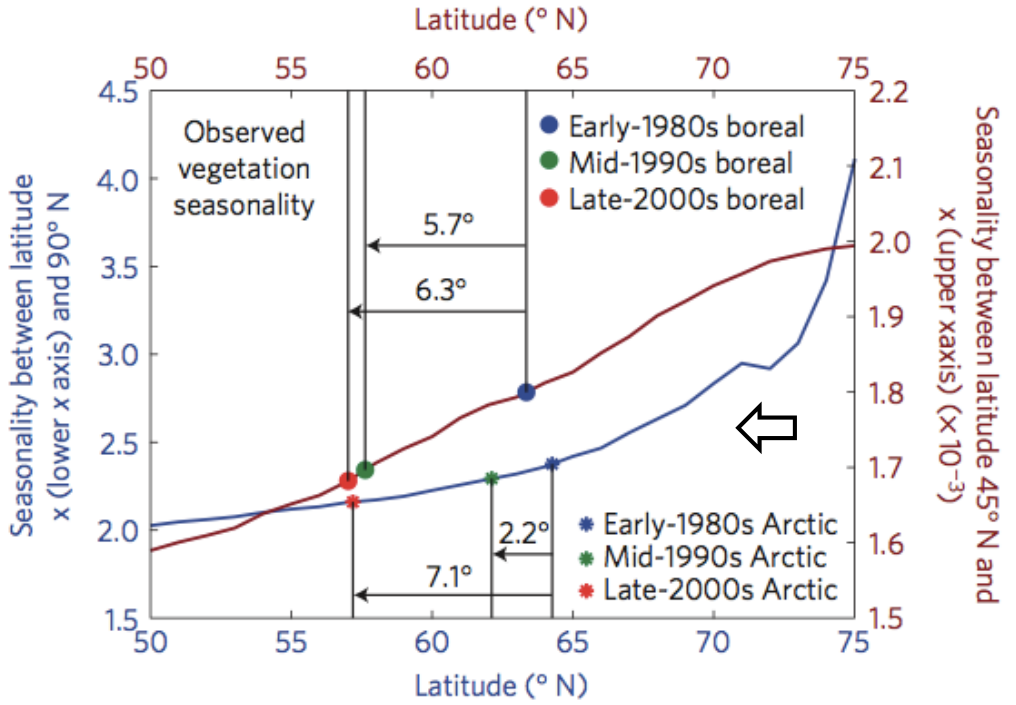
Figure 1. The GIPL-1 model conceptual diagram (A) and schematic profile of mean annual temperature through the lower atmosphere, active layer and upper permafrost (B).

Know: Satellite microwave detection of northern hemisphere non-frozen season shows increasing trend



Kim, Kimball et al. 2011. *Remote Sensing of Environment*.



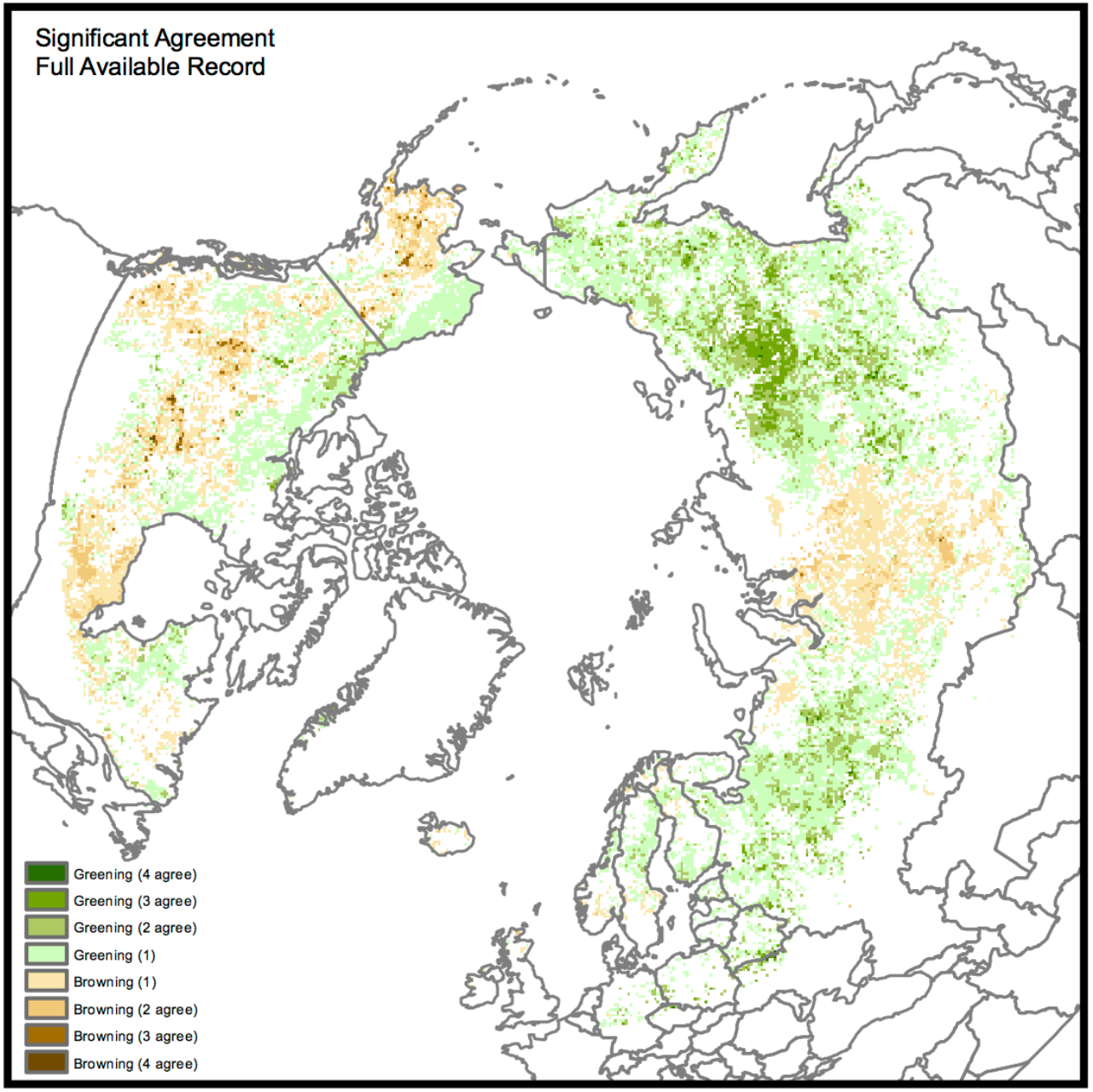


Know: Temperature & vegetation seasonality is shifting HNLs towards more southerly status

Temperature Seasonality through time

Vegetation Seasonality

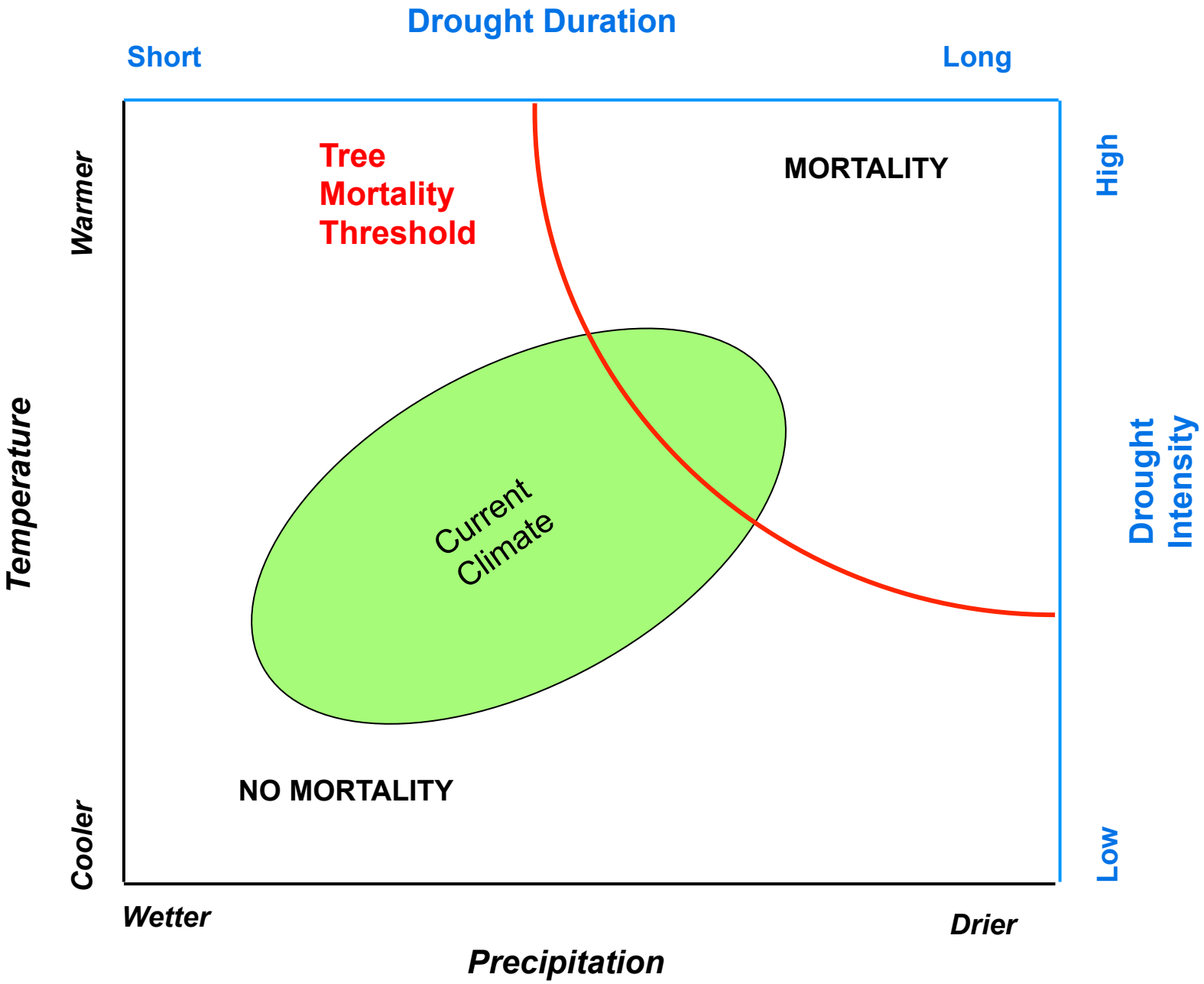
Xu, Myneni & 19 others 2013



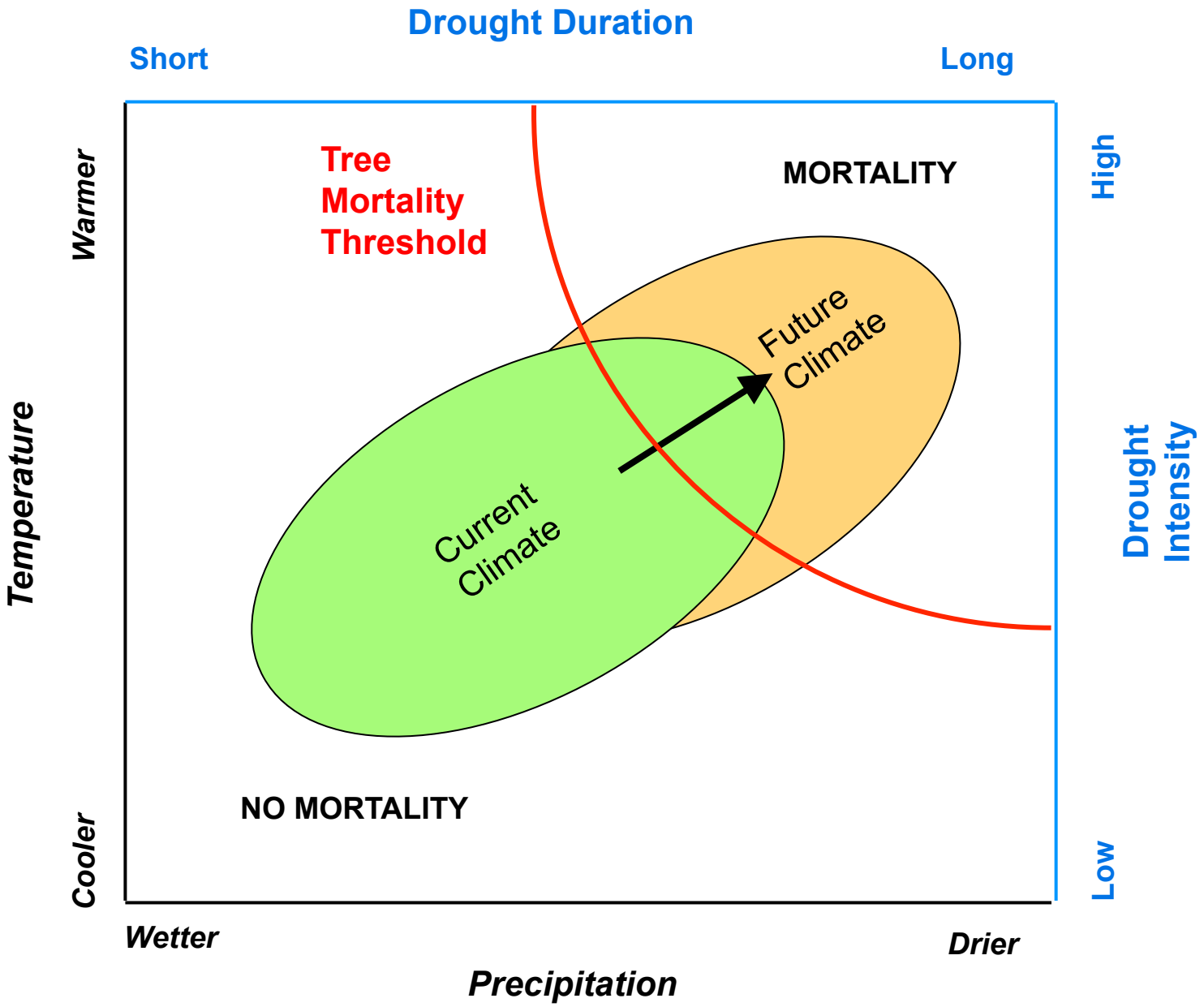
Know: satellite observed productivity trends vary with warming as well as drying (drought / high VPD).

These are coupled

NDVI Products
GIMMS 3g
SeaWiFS
MODIS (NBAR)
SPOT (VEG NBAR)



Allen et al – 2010



Allen et al – 2010

Recent work supports drought influence on boreal productivity & mortality

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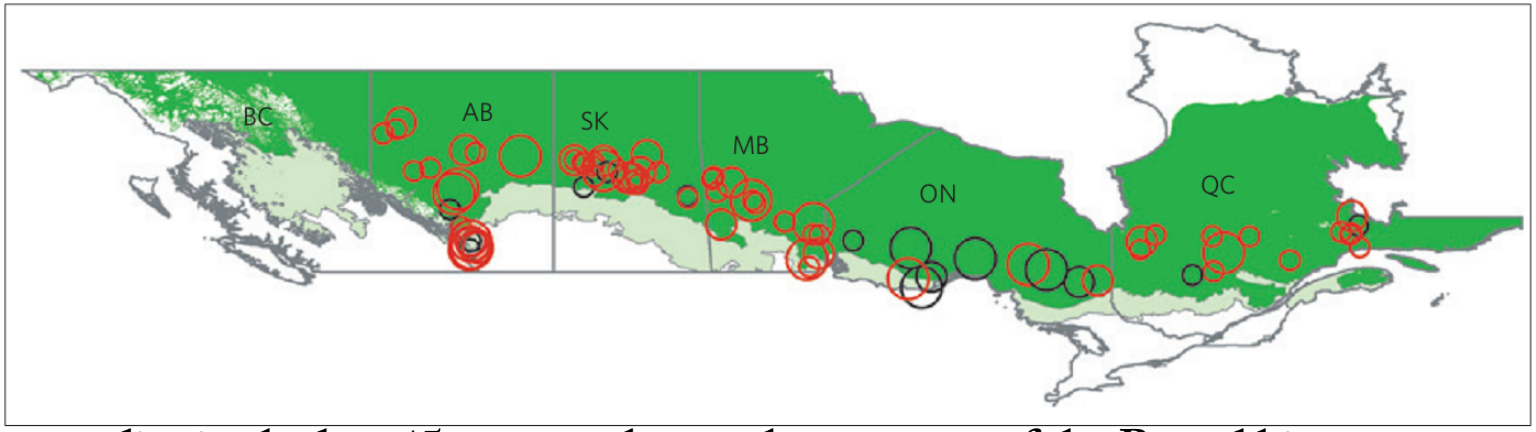
PNAS

Ma *et al.* 2012 Proceedings of the National Academy of Sciences of the United States of America

Regional drought-induced reduction in the biomass carbon sink of Canada's boreal forests

Zhihai Ma[a,1], Changhui Peng[a,b,1,2], Qiuan Zhu[b], Huai Chen[b], Guirui Yu[c], Weizhong Li[b], Xiaolu Zhou[a], Weifeng Wang[a], and Wenhua Zhang[a]

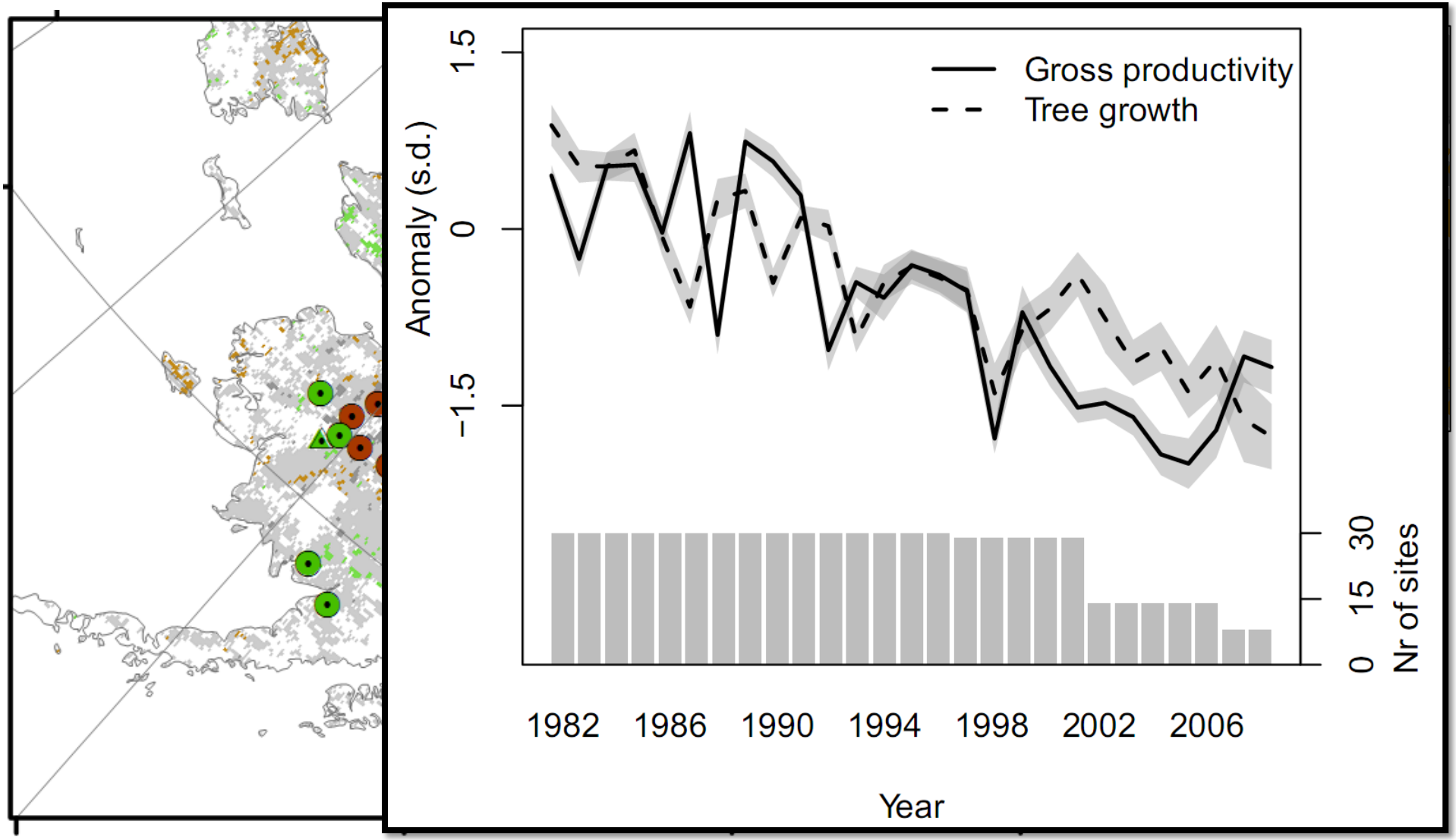
LETTERS Peng *et al.* 2011 NATURE CLIMATE CHANGE DOI: 10.1038/NCLIMATE1293



Tree mortality in the last 45 years at the southern extent of the Boreal biome.

Increasing: ○ Decreasing: ○

Know: Tree ring data support evidence for satellite observed productivity declines



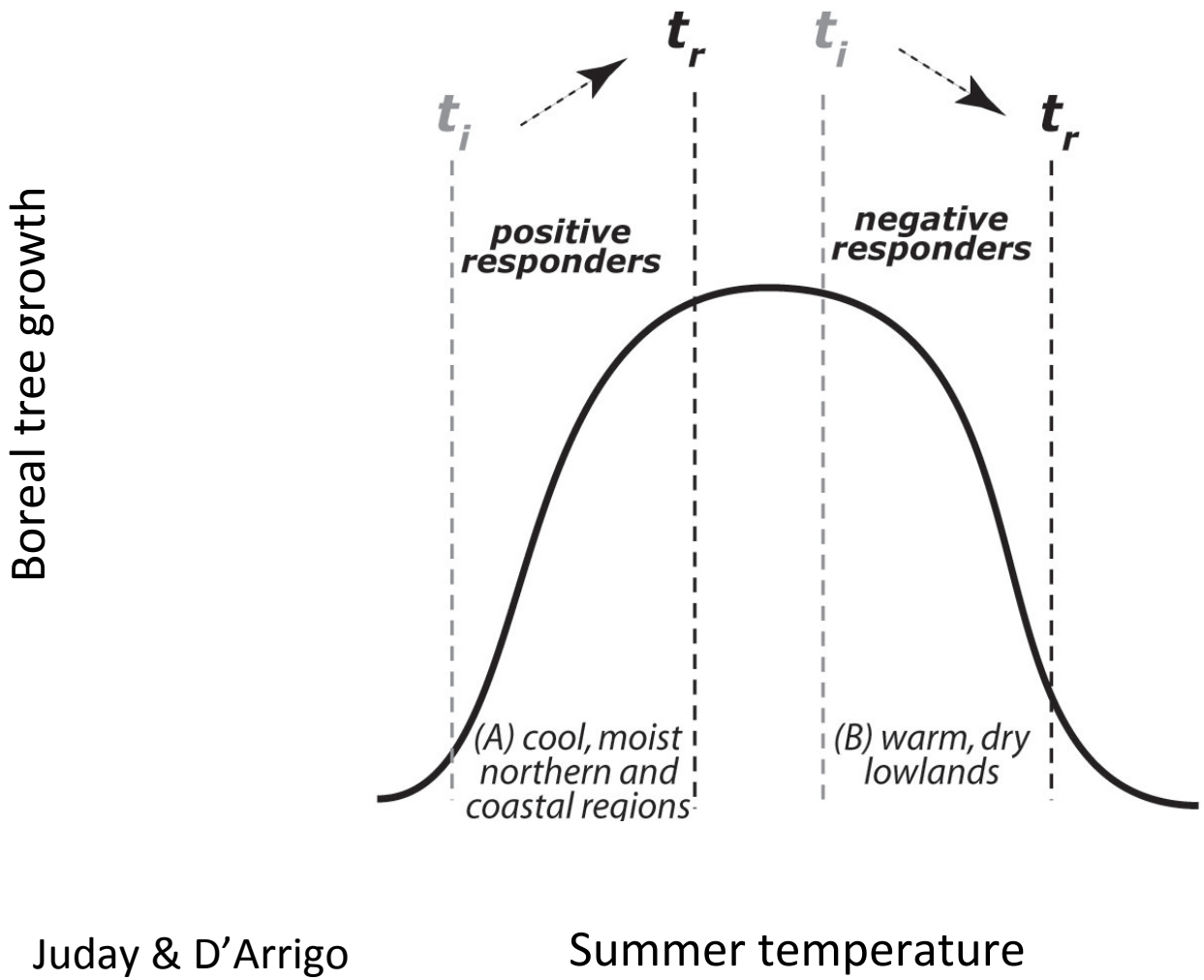
Spruce growth and gross productivity (Prs) 1982-2008

Decreasing

Increasing

Beck et al., *Ecology Letters* 2011

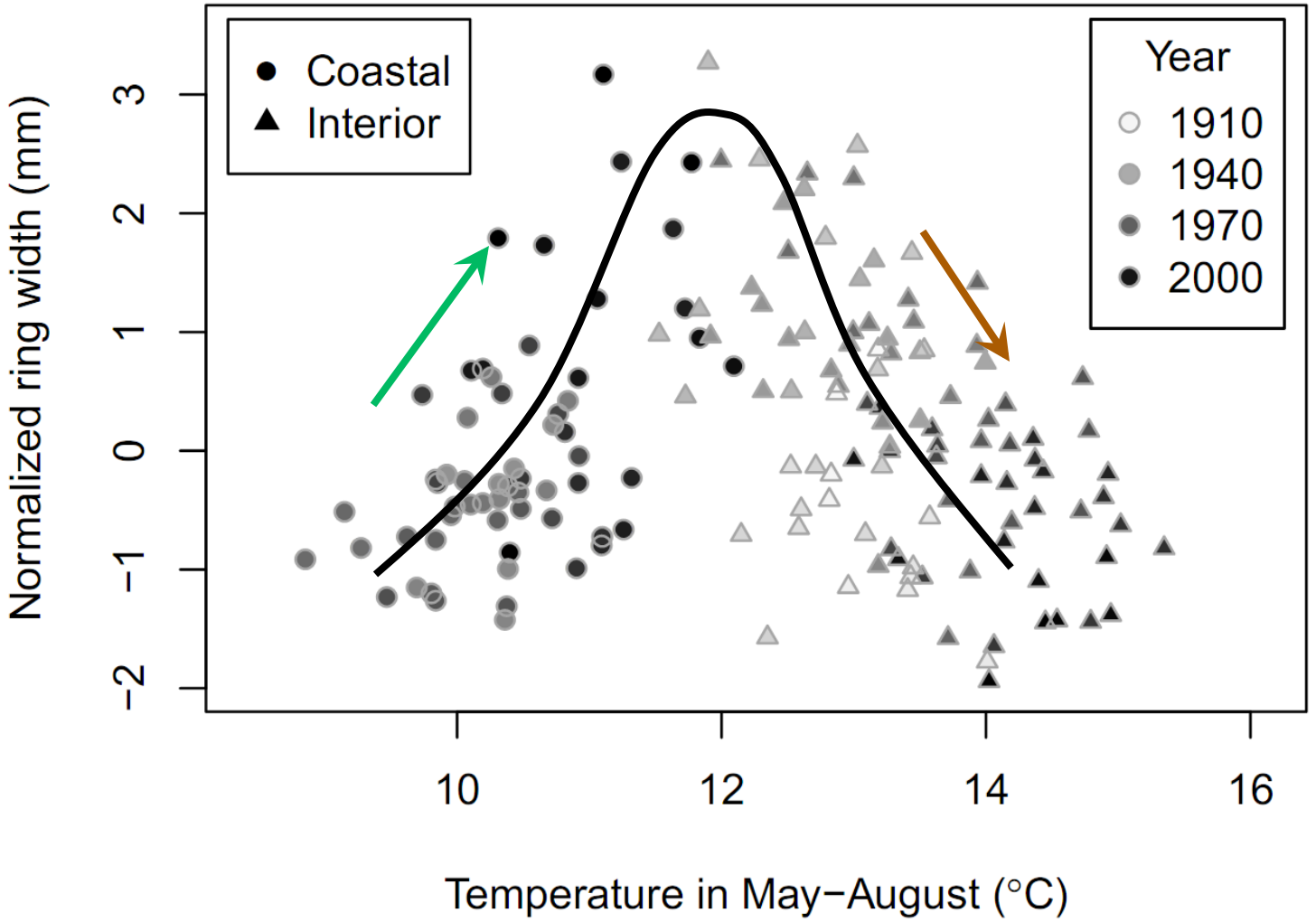
Need to know: is a "biome shift" being captured in tree ring & satellite data records?



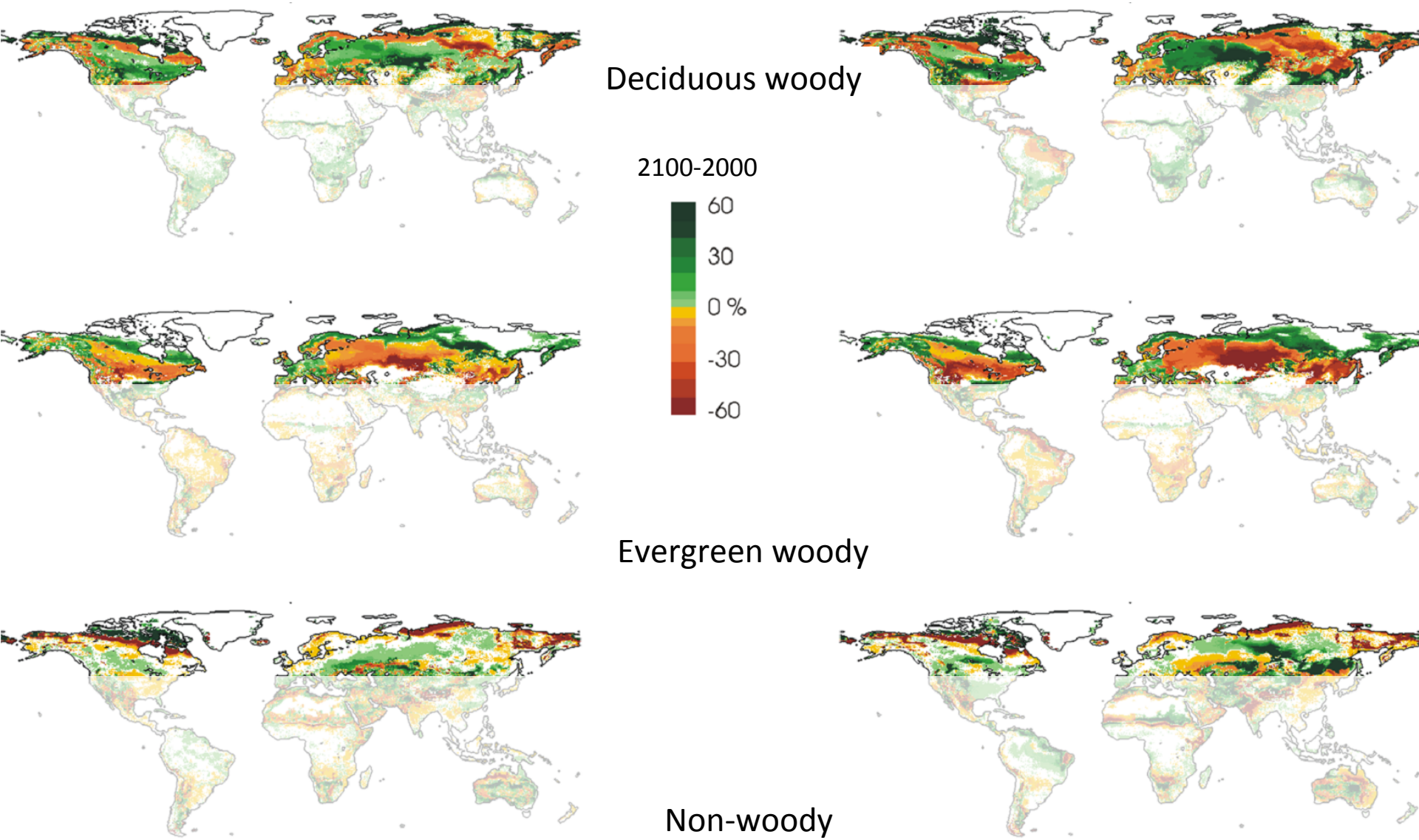
Juday & D'Arrigo

Know: Alaska tree ring & satellite observations are consistent with a biome shift

Cooler coastal zone greening with warming whereas interior browning



Global vegetation models predict 21st century 'biome shift'



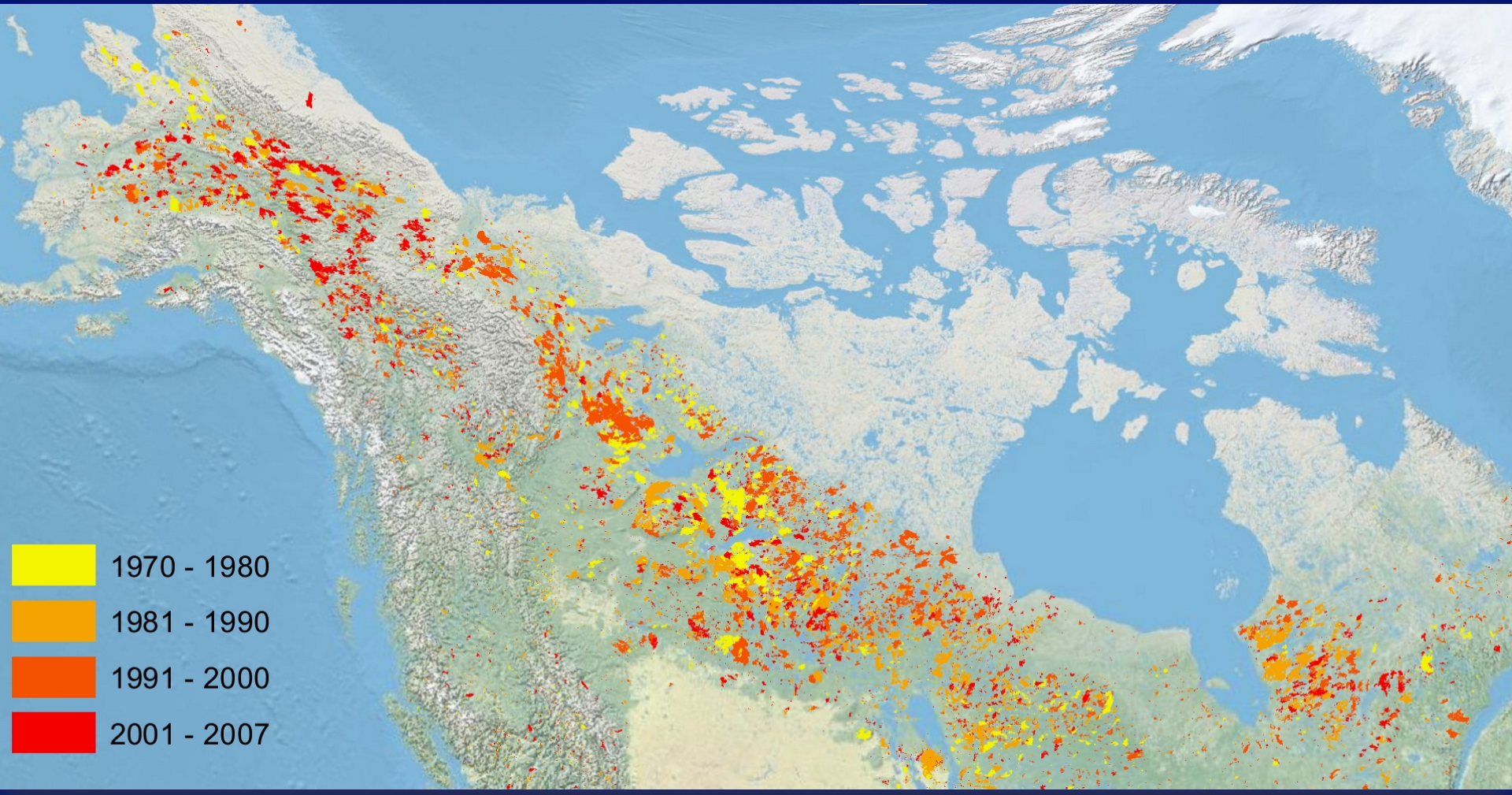
SRES B1 emissions scenario

SRES A2 emissions scenario

Lucht et al. 2006

Know: drought decreases productivity but also intensifies the fire regime.

Need to know: will fire disturbance accelerate a biome shift?



Boreal fire is common, widespread and increasingly intense (greater burn severity)

Kasischke & Turetsky 2006 GRL – Turetsky et al. 2011 Nature Geoscience

Know: more severe fires burn organic soil, increase depth of thaw & change composition of regrowth

burn severity

post-fire organic layer depth

OL = 10 cm

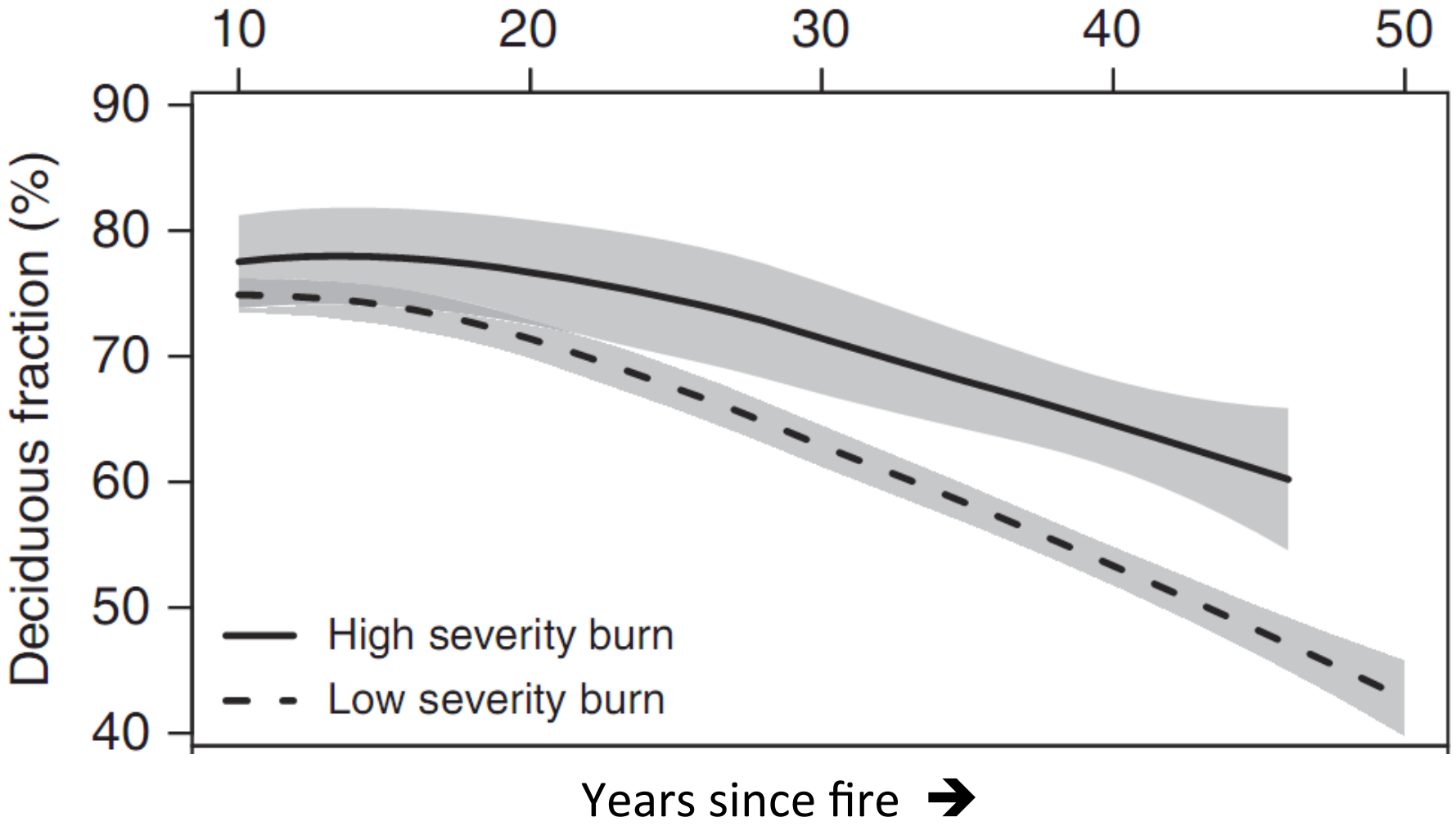
OL = 5 cm

OL = 2 cm

Johnstone *et al.* 2010 Glob Change Biol.
Kasischke *et al.* 2010 CJFR and Kasischke & Hoy 2012 GCB
Turetsky *et al.* 2010 Nature GeoSci.
Barrett *et al.* 2011 Ecol. Appl.; Alexander *et al*. 2012a,b

1983 Minto Flats Burn
Interior Alaska
Alexander and Mack

Know: larger later-season fires, indicative of more severe burning, show successional trajectory shift (captured by MODIS)

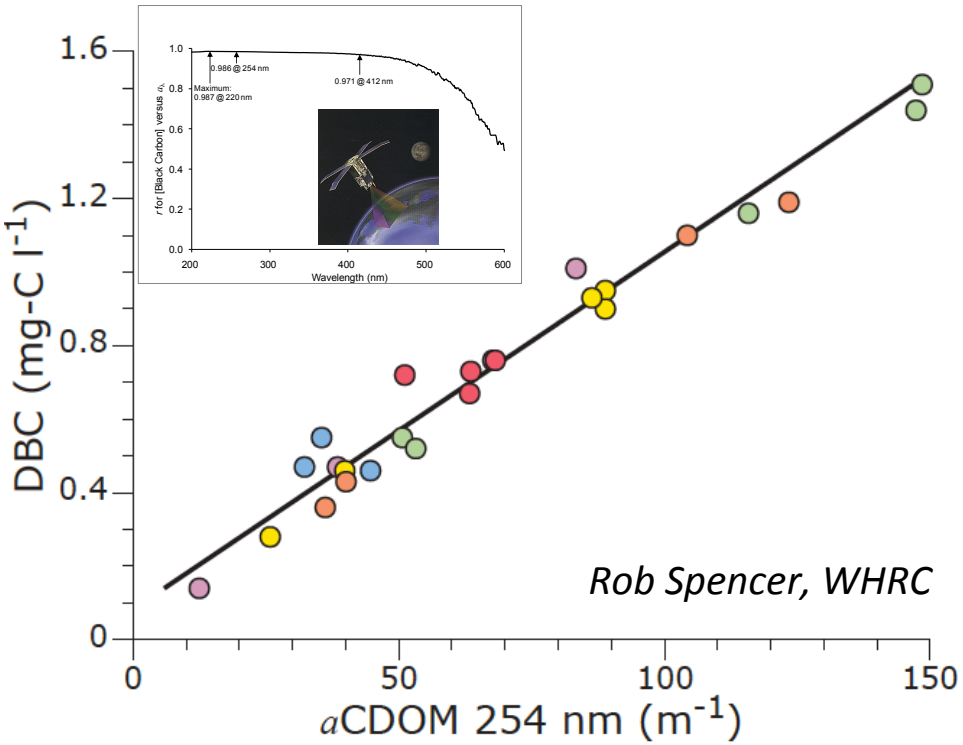


Beck et al. (2011) *Global Change Biology*

Know: river measurements & RS observations capture record of fire disturbance in river carbon chemistry

Arctic Great Rivers Observatory

Black carbon versus color (CDOM)



Absorption is similar out to ~440nm

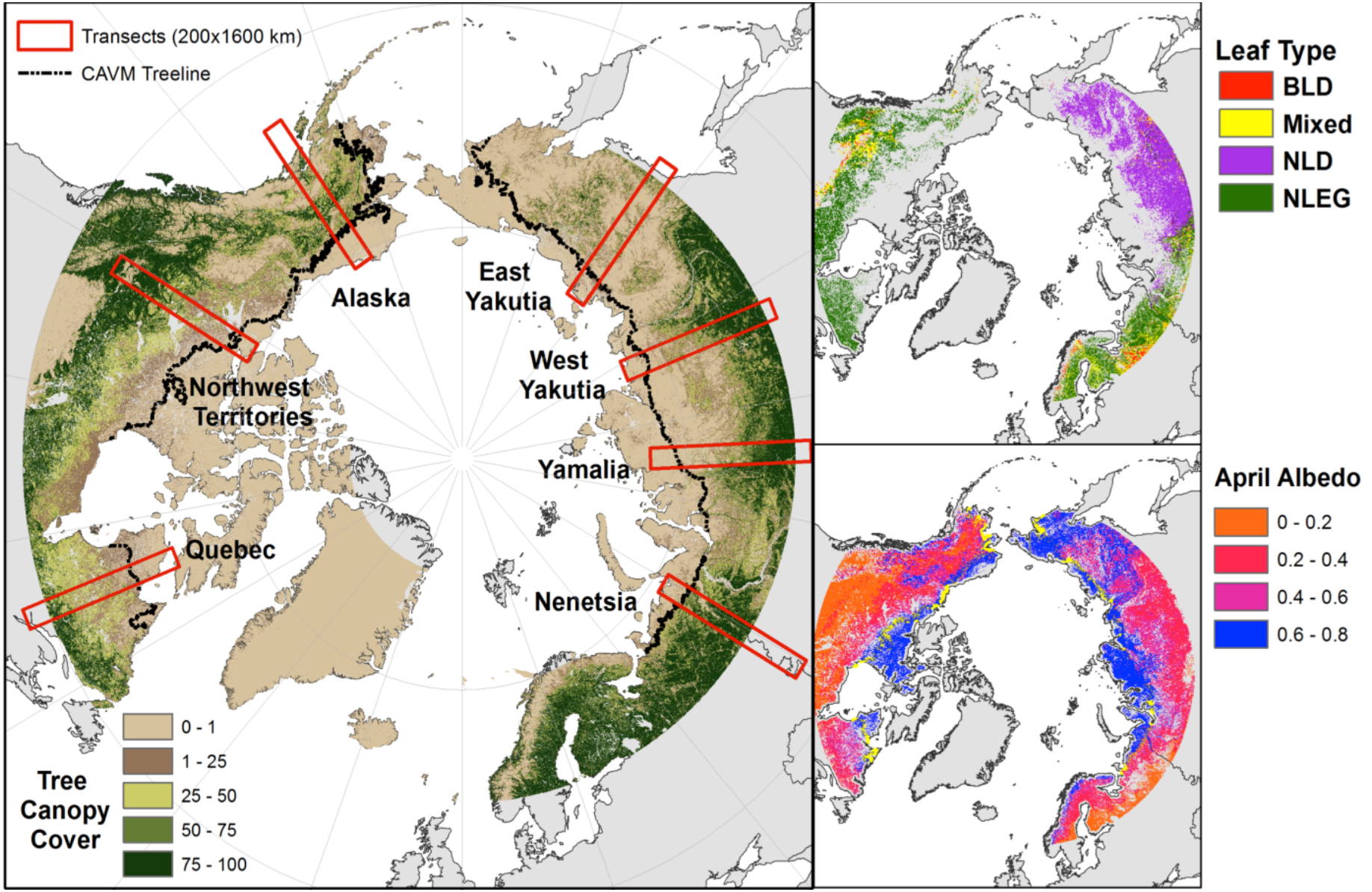
Need to know: the extent to which fire-produced condensed aromatic carbon is exported into rivers and the ocean and, by absorbing light, warms & enhances photochemical processes (compounded by declining sea ice)

Need to know: The influence of insect disturbance on nutrient & carbon budgets

Spruce budworm & aspen caterpillar defoliation in NE Alberta

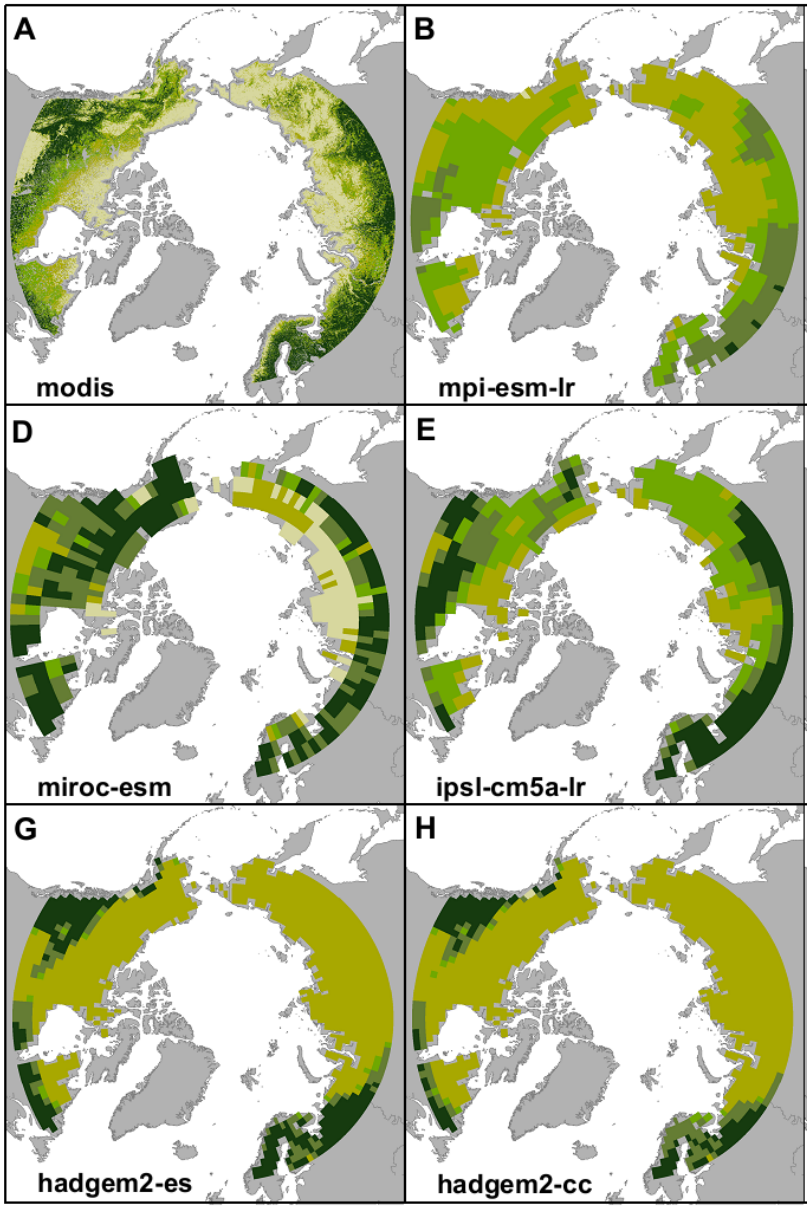
Photo by Ted Hogg

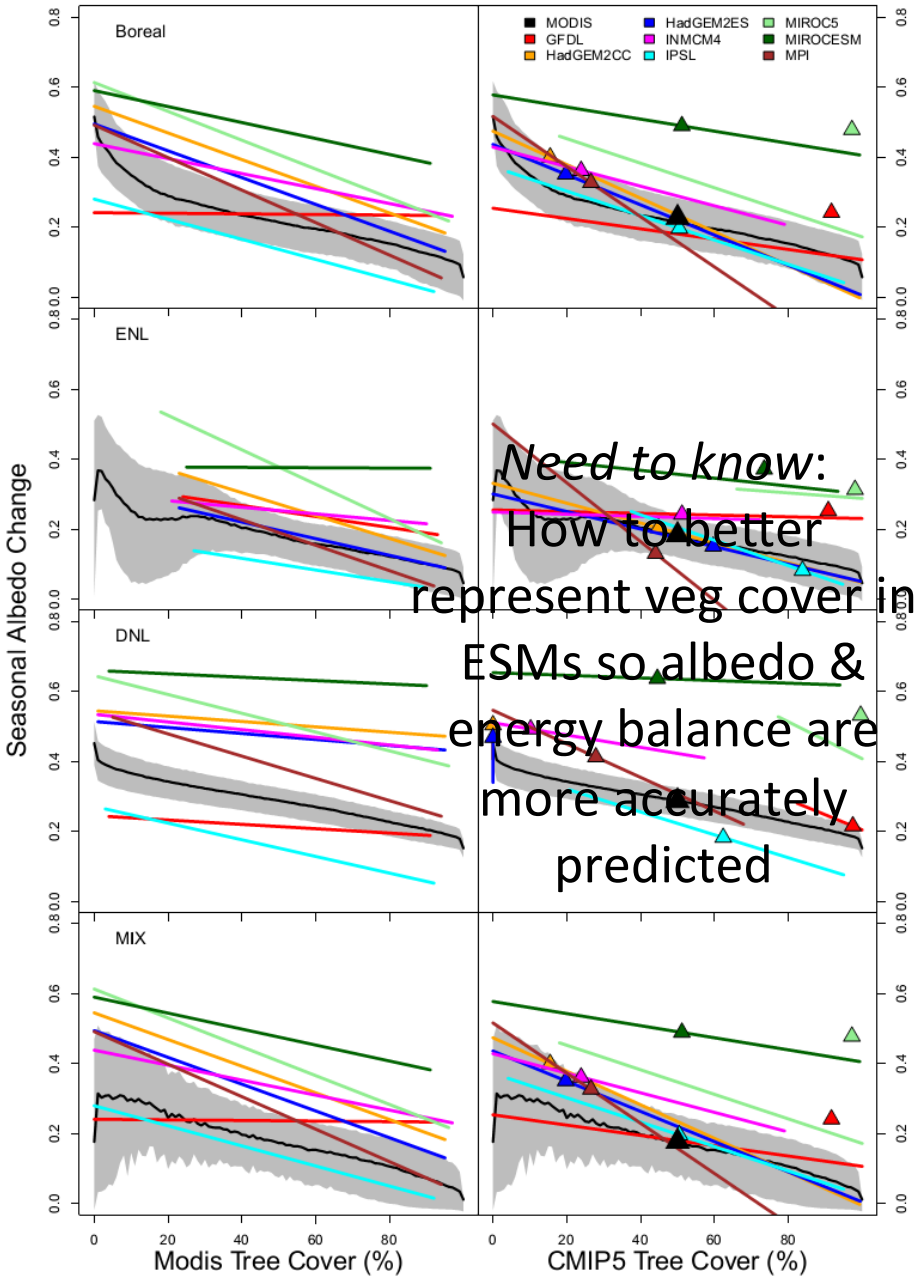
Know: vegetation & the boreal – tundra transition is not well represented in Earth System Models



MODIS Tree Cover & Albedo

Loranty et al. (submitted)





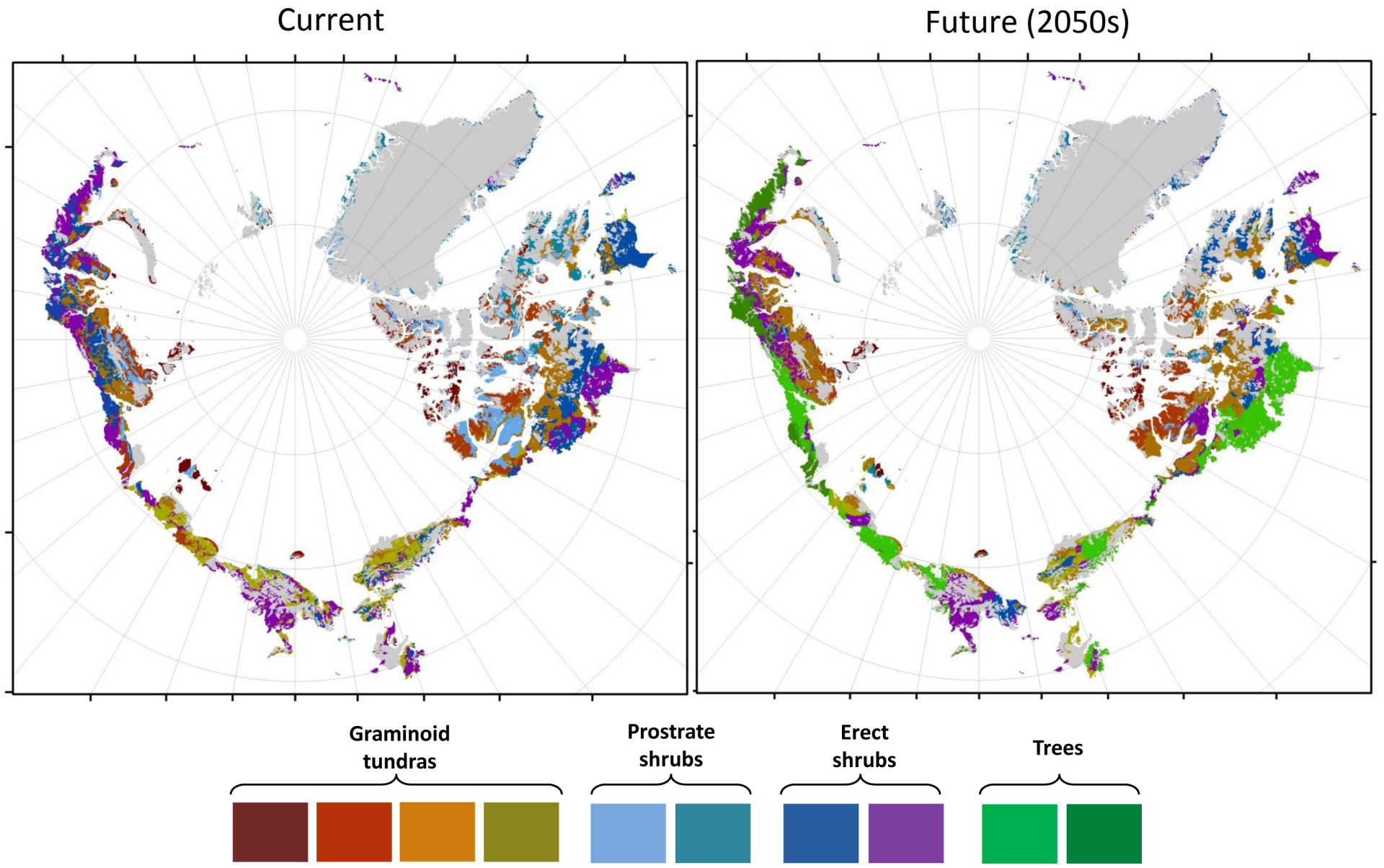
Need to know: How to better represent veg cover in ESMs so albedo & energy balance are more accurately predicted

The Woods Hole Research Center

NSF

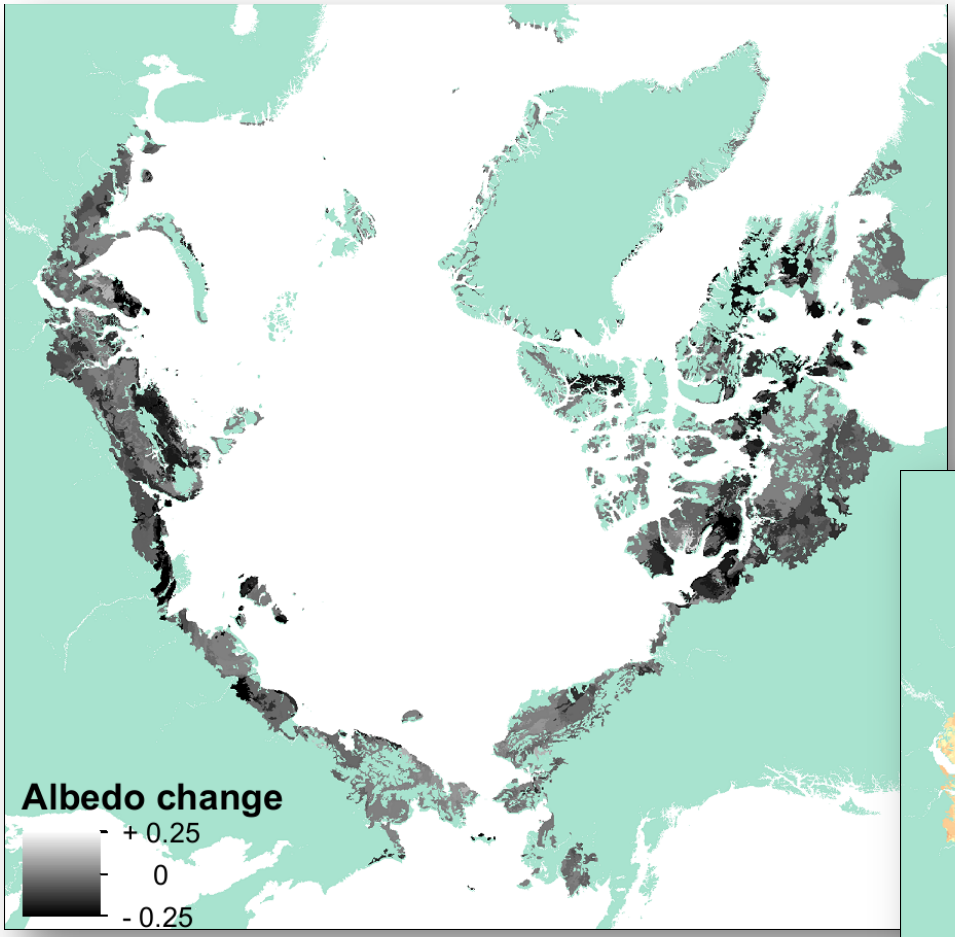
UCI University of California, Irvine

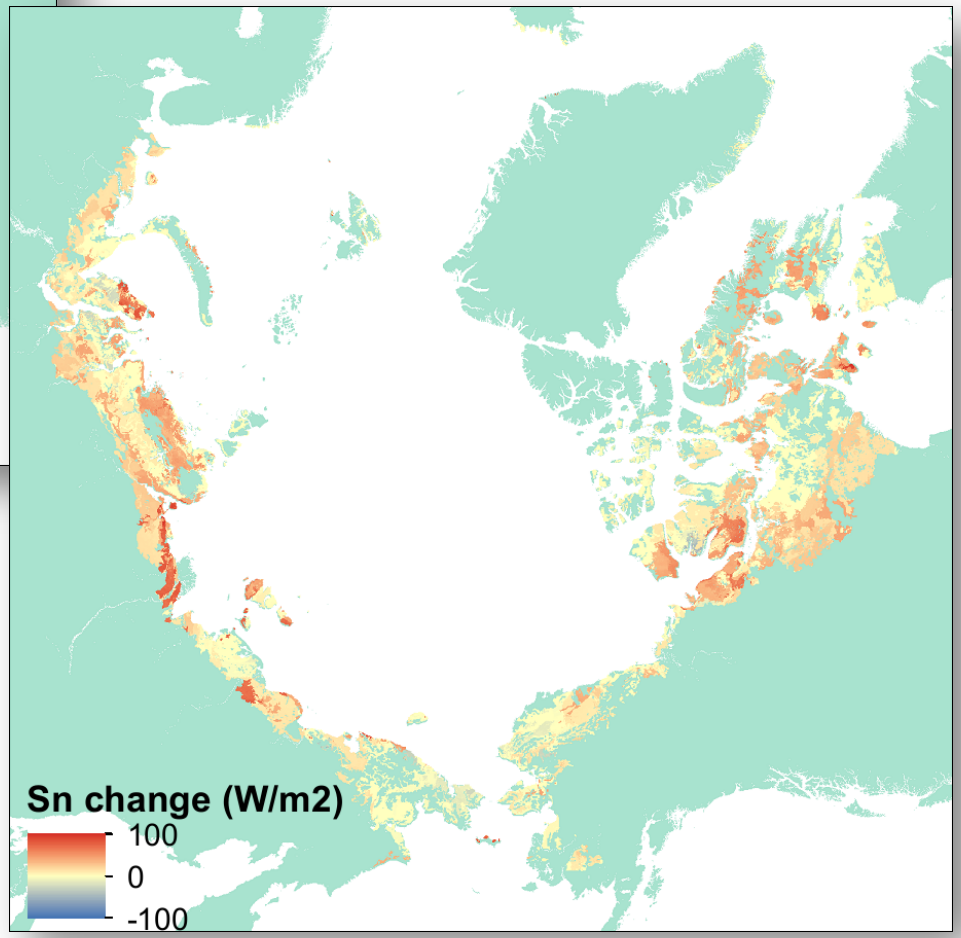
Know: the future distribution of arctic vegetation will change substantially



Pearson et al. 2013. Nature Climate Change

Need to know: How will future vegetation distribution alter albedo, energy balance, nutrient & carbon budgets?





Albedo & net solar radiation change under ~2050 vegetation compared to present.

Goetz et al., unpublished

Need to know: How will the "human dimension" play out?
Impacts –vs– responses & adaptation

Photos by Bruce Forbes

Need to know: How will wildlife & biodiversity will be affected by climate & vegetation change?

The Arctic will become greener within decades as rising temperatures leads to an increase in plant life

- **Rising temperatures will lead to an increase in trees and shrubs in the Arctic**
- **Wooded areas in the Arctic could increase by 50 per cent in a few decades**
- **Research shows that this dramatic greening will also accelerate climate warming**

By JAYMI MCCANN

PUBLISHED: 13:22 EST, 31 March 2013 | **UPDATED:** 13:22 EST, 31 March 2013

The Arctic will turn green due to rising temperatures within decades, warns a new study.

The study forecasts that rising temperatures will lead to a massive 'greening' - increase in trees and shrubs - in the Arctic.

Scientists have revealed new models projecting that wooded areas in the Arctic could increase as much as 50 per cent over the next few decades.

Exploring: The Arctic could soon become greener as temperatures warm and lead to an increase in trees and shrubs

Know: we have a communications & public outreach challenge

Arctic Region Could Soon Become Much Greener

April 1, 2013

Image Credit: pr2is / Shutterstock


Arctic-Boreal Vulnerability Experiment
ABoVE