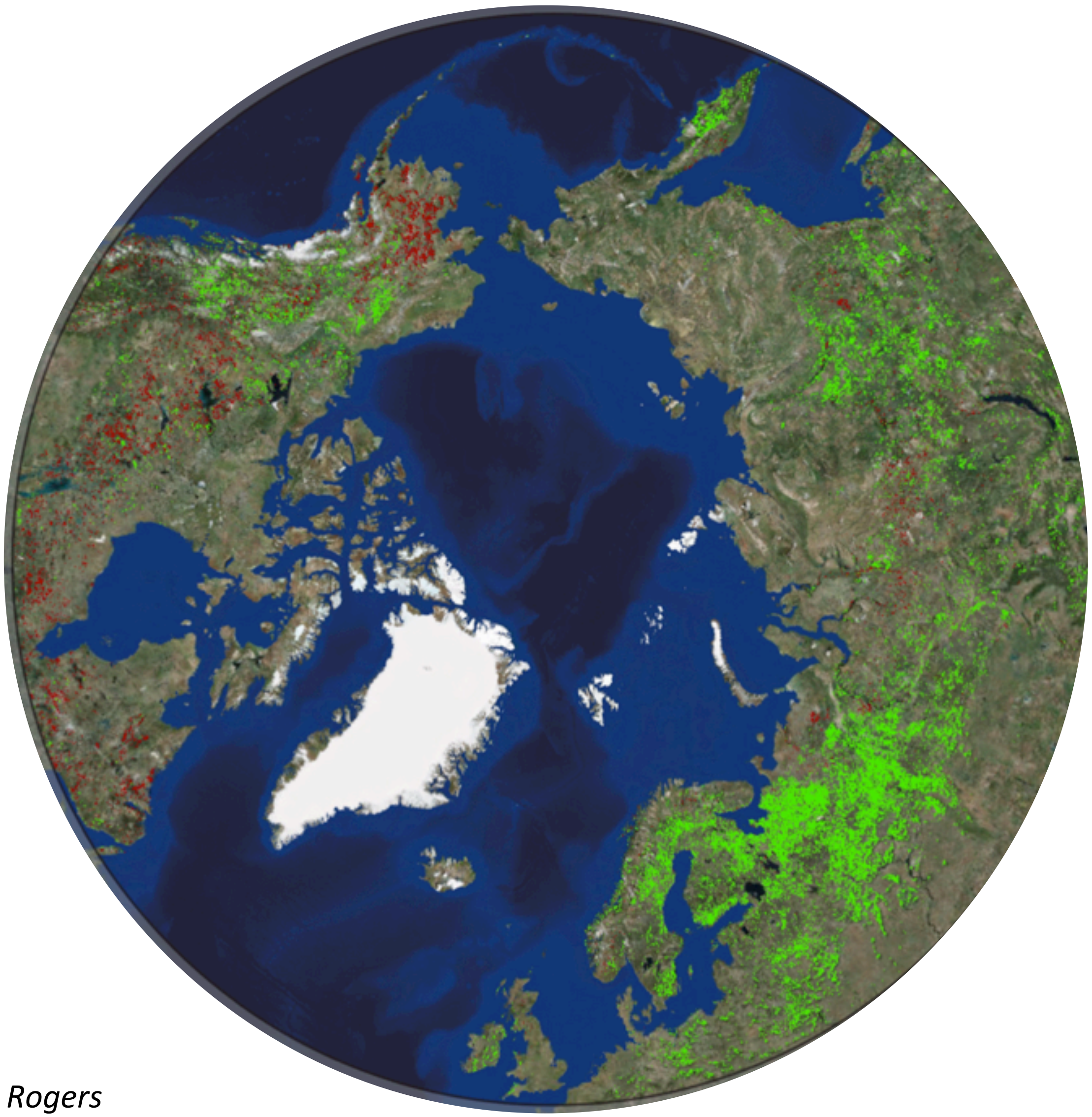
Mapping, Monitoring and Modeling Changes in the North American Boreal Biome

Scott Goetz
(and collaborators)

NORTHERN ARIZONA UNIVERSITY

Bonanza Creek LTER
Annual Symposium
April 2018



Goetz & Rogers

from Appenzeller "The New North" article in Science (Aug 2015)

Greening & Browning of "The New North"

AVHRR GIMMS 3G
Growing Season
NDVI Trends

8 km res
1982 – 2014

In some Boreal forest areas satellite observed productivity declines with warming & drying (drought / high VPD)

Significant ($p<0.05$)
Greening & Browning trends
in areas with >20% tree cover

ECOLOGY LETTERS

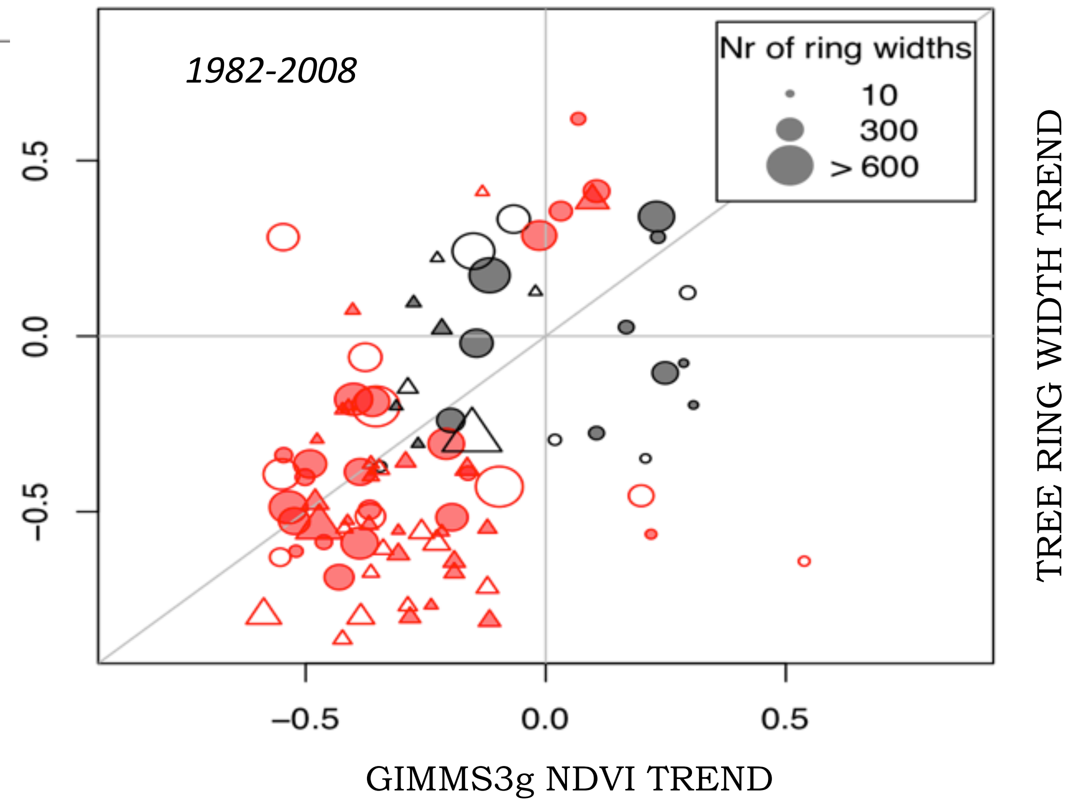
Ecology Letters, (2011) **14**: 373–379 doi: 10.1111/j.1461-0248.2011.01598.x

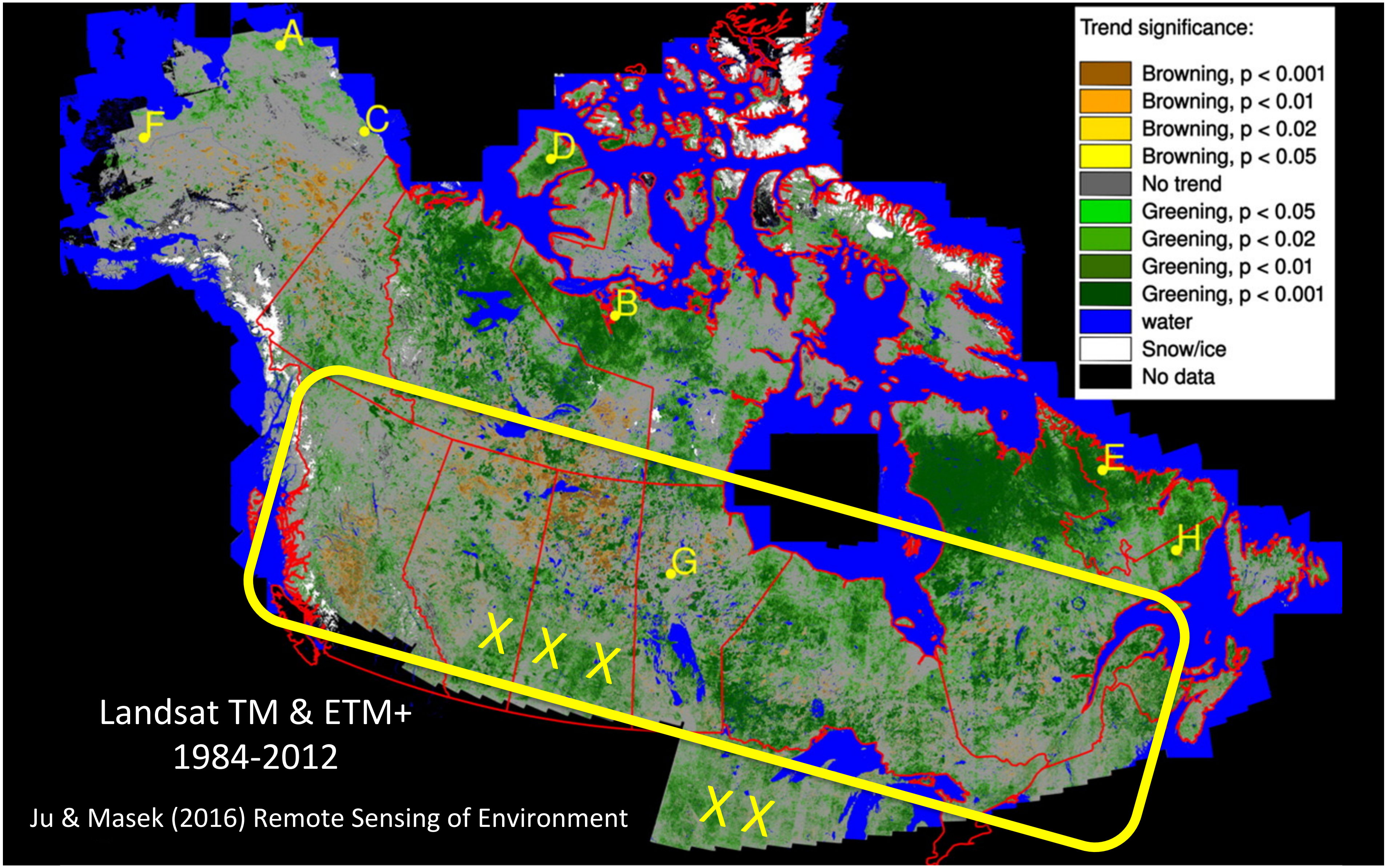
LETTER

Changes in forest productivity across Alaska consistent with biome shift

Pieter S. A. Beck,[1]* Glenn P. Juday,[2] Claire Alix,[3] Valerie A. Barber,[2] Stephen E. Winslow,[2] Emily E. Sousa,[2] Patricia Heiser,[2] James D. Herriges[4] and Scott J. Goetz[1]

- *Circles represent white spruce & triangles black spruce stands.*
- *Open symbols are locations where fire disturbance (burning and regrowth after 1950) took place.*
- *Red indicates where the series trend was significantly different from zero (0.05).*




Trend significance:
Browning, p < 0.001
Browning, p < 0.01
Browning, p < 0.02
Browning, p < 0.05
No trend
Greening, p < 0.05
Greening, p < 0.02
Greening, p < 0.01
Greening, p < 0.001
water
Snow/ice
No data
A
B
C
D
E
F
G
H
Landsat TM & ETM+
1984-2012
Ju & Masek (2016) Remote Sensing of Environment

PNAS 2016

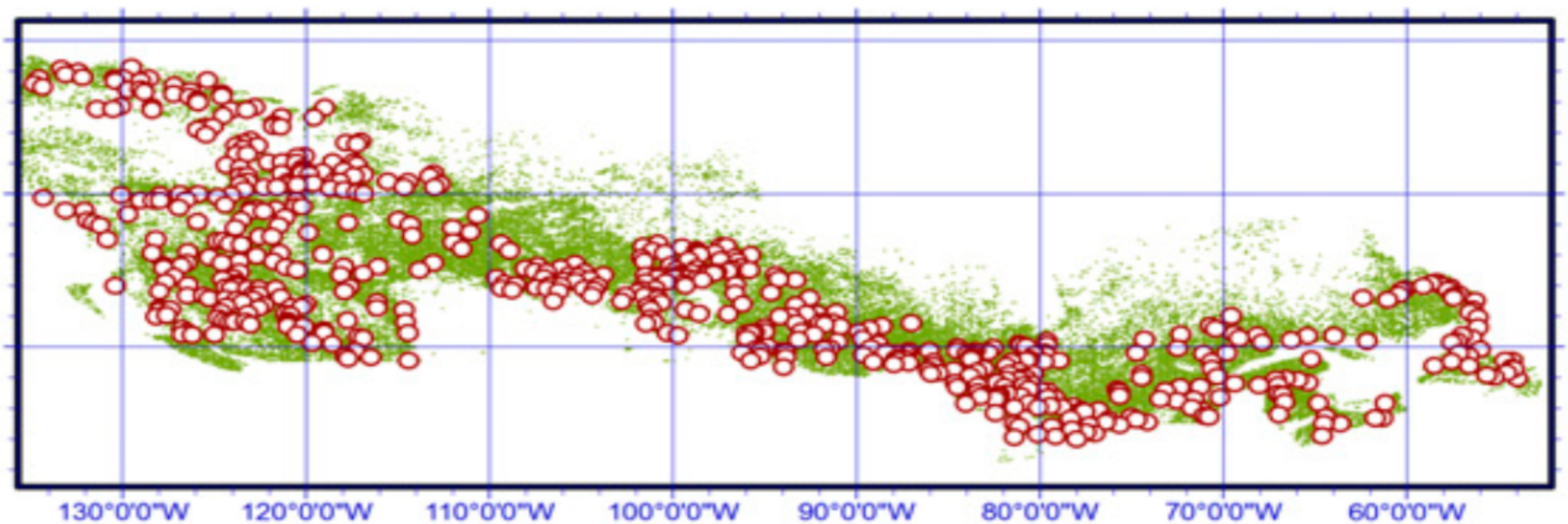
No growth stimulation of Canada's boreal forest under half-century of combined warming and CO_2 fertilization

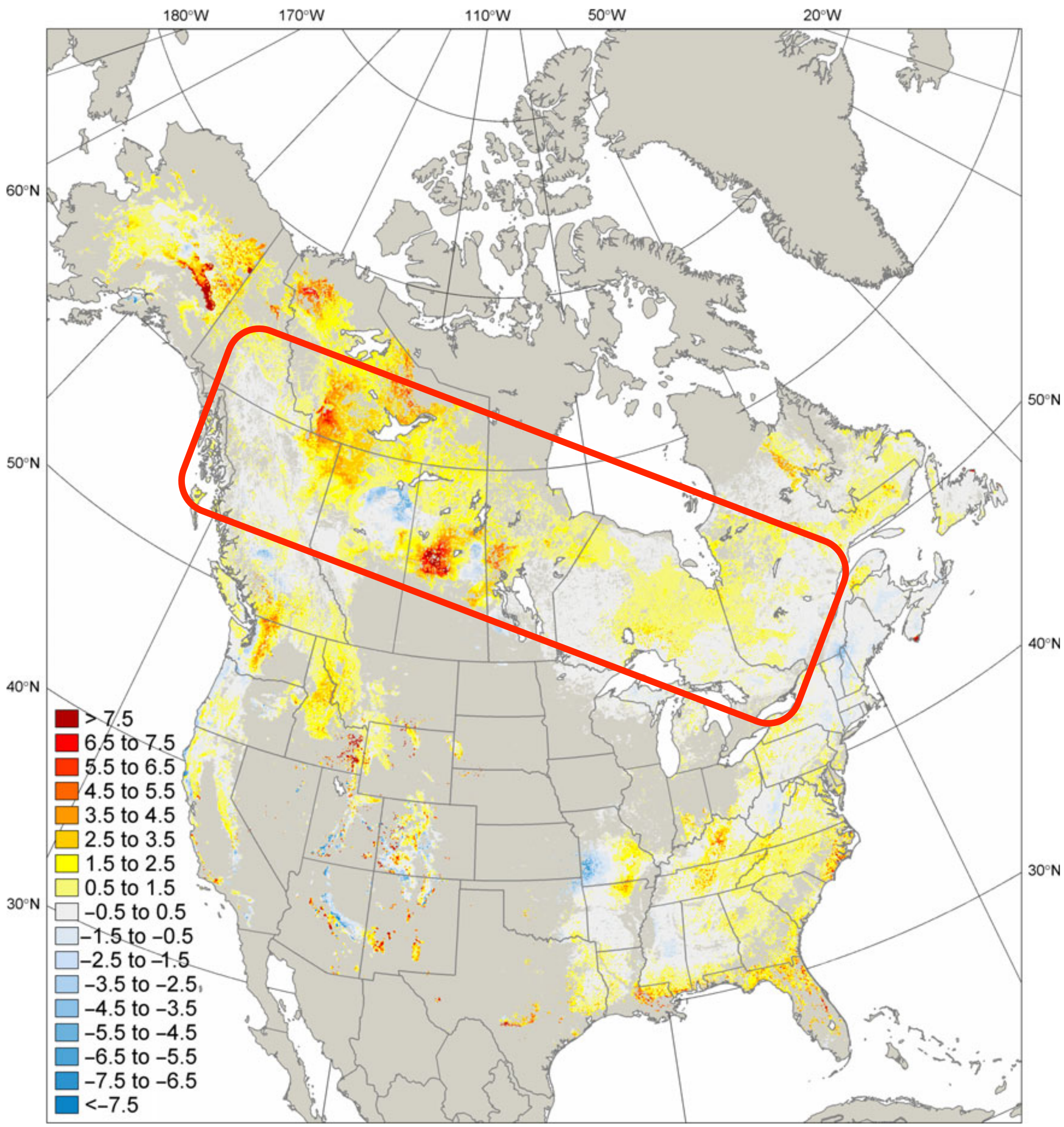
Martin P. Girardin[a,1], Olivier Bouriaud[b,2], Edward H. Hogg[b], Werner Kurz[c], Niklaus E. Zimmermann[d,e], Juha M. Metsaranta[b], Rogier de Jong[f], David C. Frank[d,g], Jan Esper[h], Ulf Büntgen[d,i], Xiao Jing Guo[a], and Jagtar Bhatti[b]

[a]Laurentian Forestry Centre, Canadian Forest Service, Natural Resources Canada, Quebec, QC, Canada G1V 4C7; [b]Northern Forestry Centre, Canadian Forest Service, Natural Resources Canada, Edmonton, AB, Canada T6H 3S5; [c]Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, Victoria, BC, Canada V8Z 1M5; [d]Landscape Dynamics, Swiss Federal Institute for Forest, Snow and Landscape Research, CH-8903 Birmensdorf, Switzerland; [e]Department of Environmental Systems Sciences, Swiss Federal Institute of Technology, CH-8092 Zurich, Switzerland; [f]Remote Sensing Laboratories, University of Zurich, CH-8057 Zurich, Switzerland; [g]Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ 85721; [h]Department of Geography, Johannes Gutenberg University, 55099 Mainz, Germany; and [i]Oeschger Centre for Climate Change Research, 3012 Bern, Switzerland

Edited by Christopher B. Field, Carnegie Institution of Washington, Stanford, CA, and approved November 7, 2016 (received for review June 22, 2016)

Some areas of the NA boreal forest biome are not greening, but browning (declining in productivity)





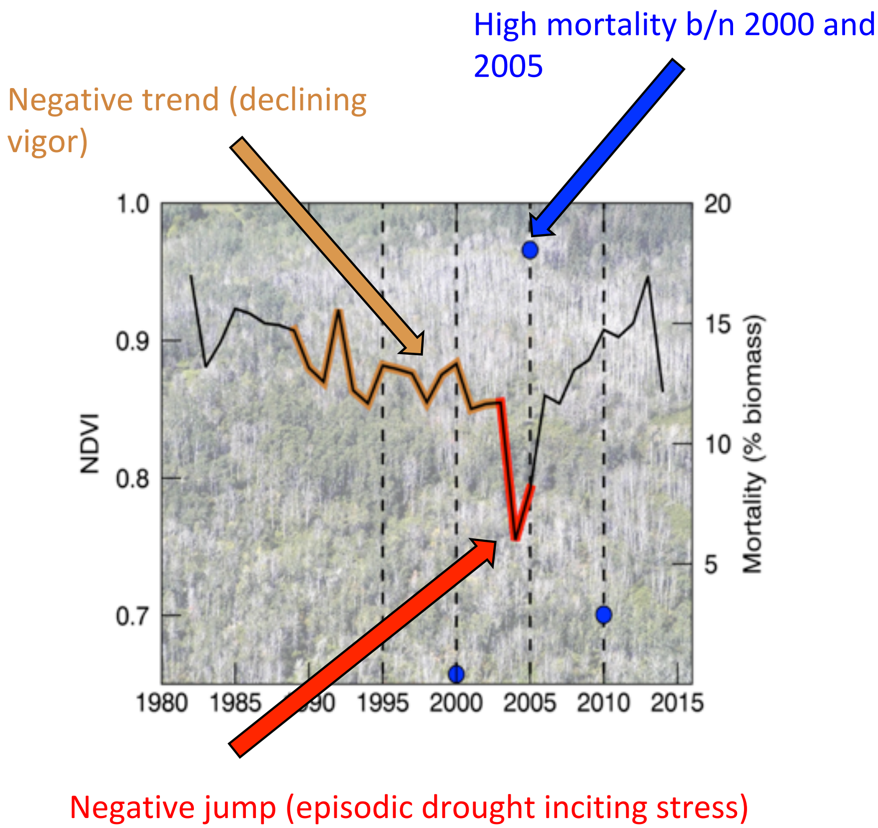
Change in annual probability of mortality (% year) 1951–2014

Inferred from the slope of OLS regression fit to the annual time series of gridded predictions
(8.1 million mmts of change at 46,000 plots)

Hember et al. 2016 GCB

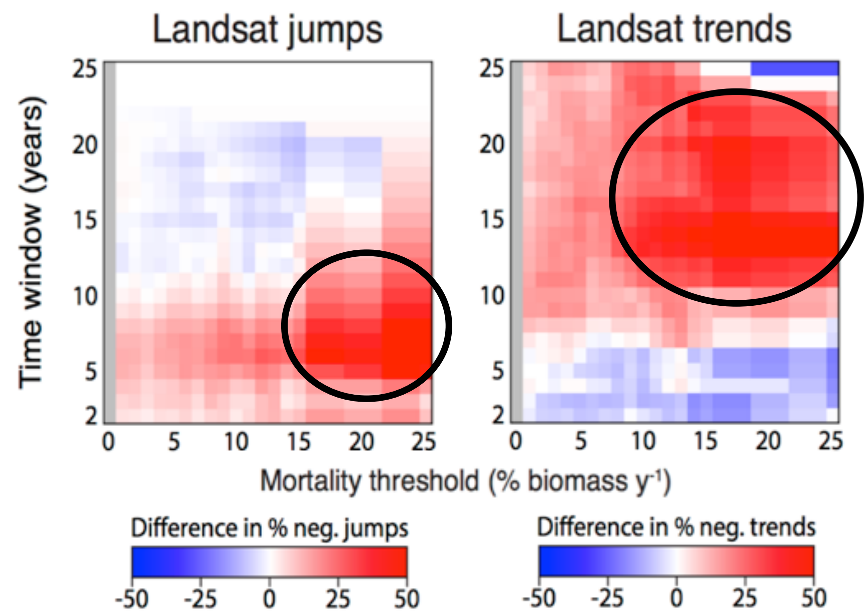
"Temporal variability in the mortality predictions across North America was strongly shaped by extreme droughts in 1981, 1988, 1998, 2006, 2007 and 2012"

Detecting precursors of tree mortality in boreal North America using multi-scale satellite data



Rogers et al. (2018) *Global Change Biology*

"Early warning" metrics common at high mortality levels and relatively long time windows before death

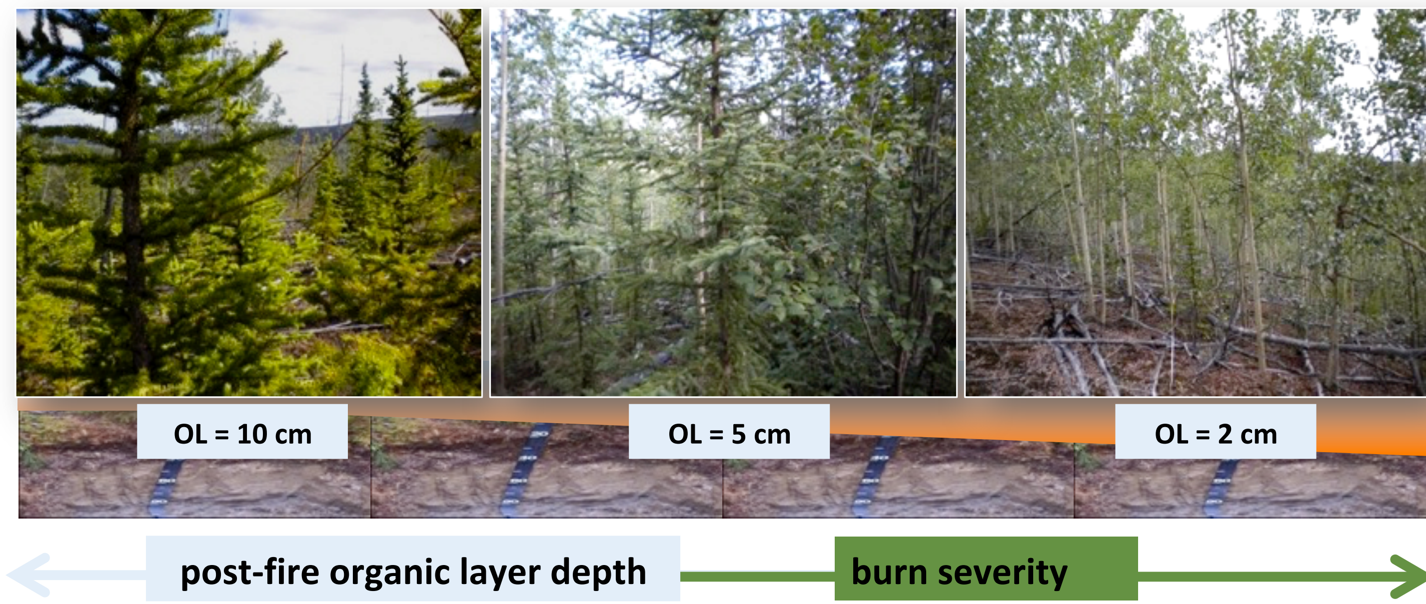


Results are broadly consistent across forest inventories, tree species, early warning metrics, and satellite sensors (Landsat, MODIS, and AVHRR)

Ongoing work to integrate thousands more field plots across Canada and develop forecasting models that combine NDVI and climate predictors

The composition of boreal forest post-fire depends on the severity of burning

Greater burn severity results in more deciduous tree cover –
composition changes persist for decades

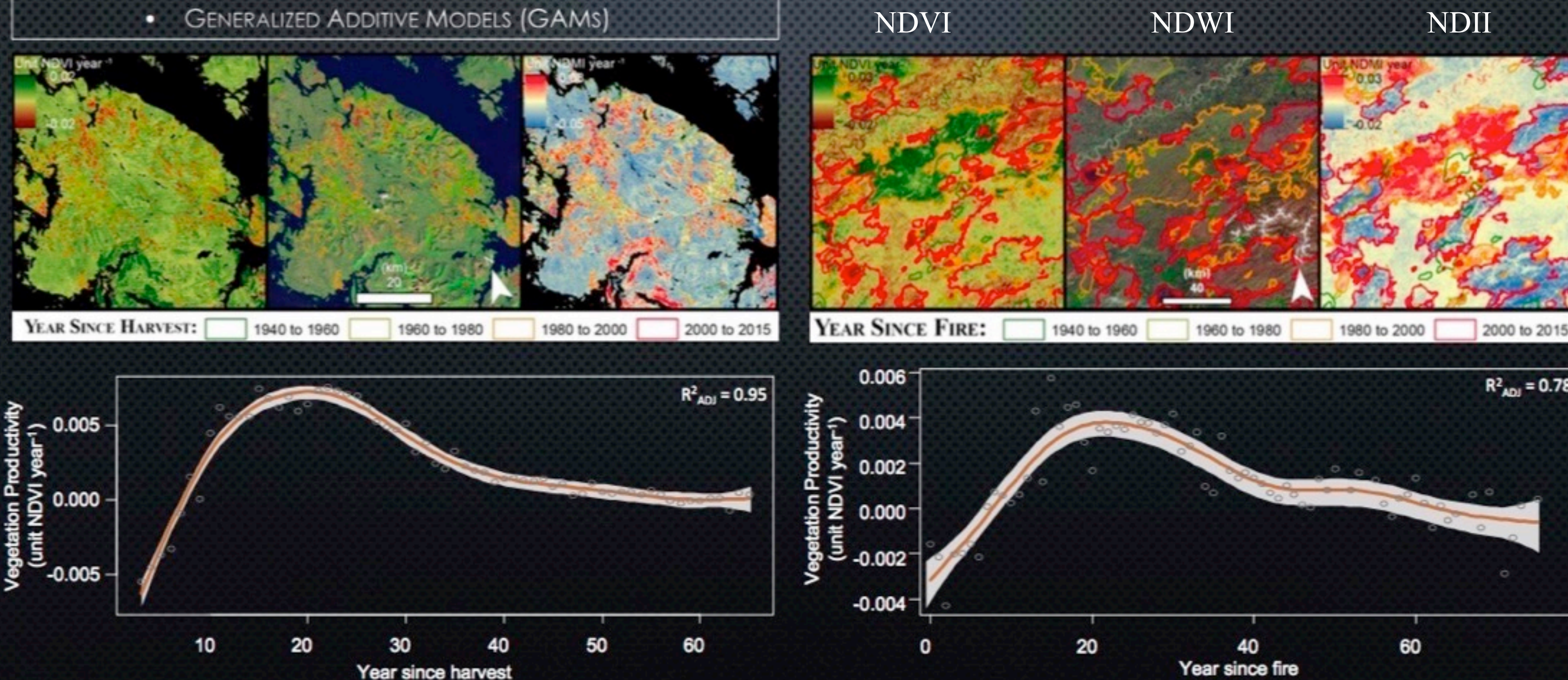


Several decades of research on this topic – remote sensing brought to bear in past two decades.

Ongoing projects documenting aspects & implications of boreal post-fire succession

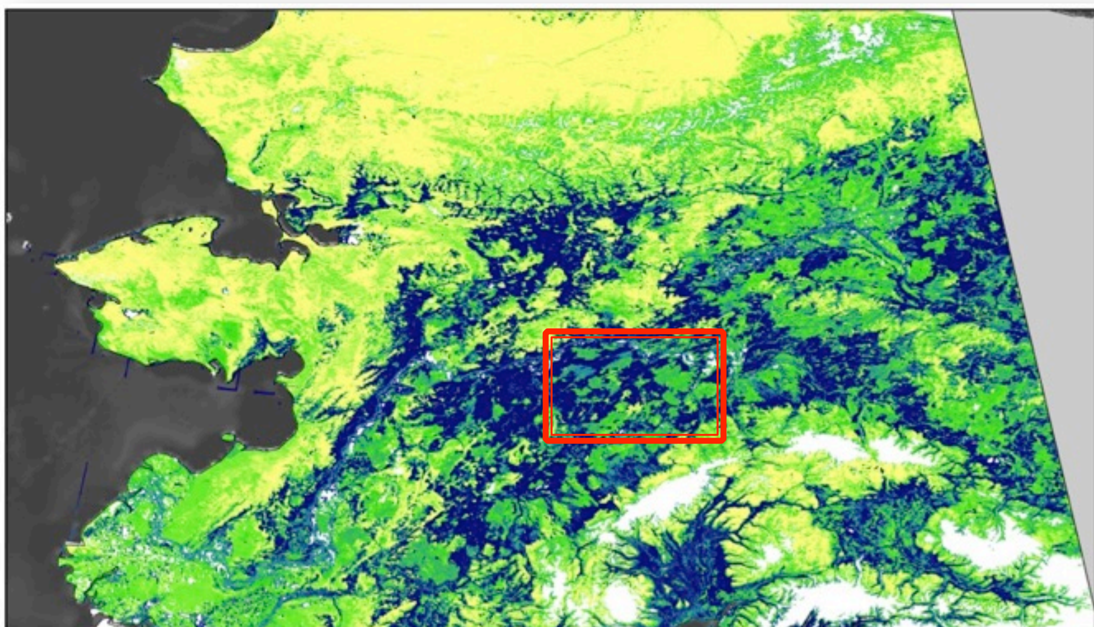
ATTRIBUTION OF CHANGING SPECTRAL INDICES

- CHRONOSEQUENCE:
  - WILDFIRE, HARVESTING, AND INSECT DAMAGE
    - GENERALIZED ADDITIVE MODELS (GAMS)

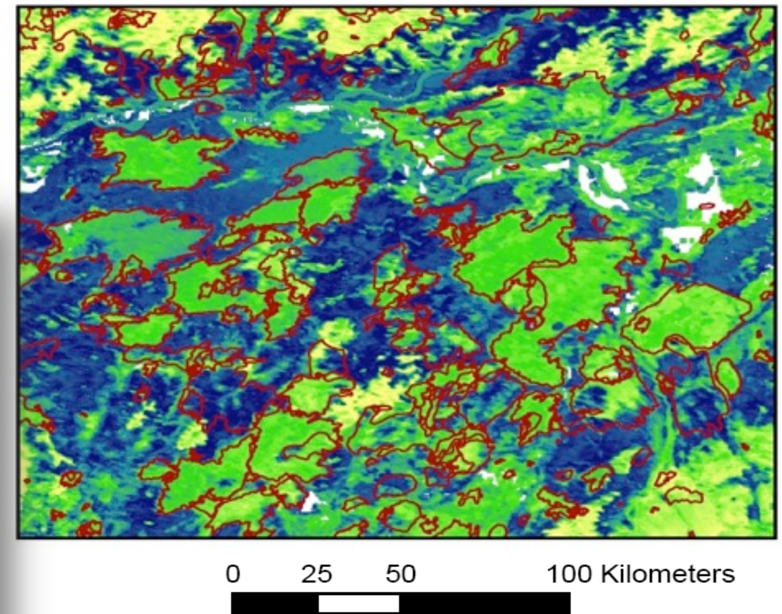


Pastick et al. Global Change Biology, in press.

Severe Fire Disturbance Changes Boreal Composition altering Energy, Carbon & Water cycles



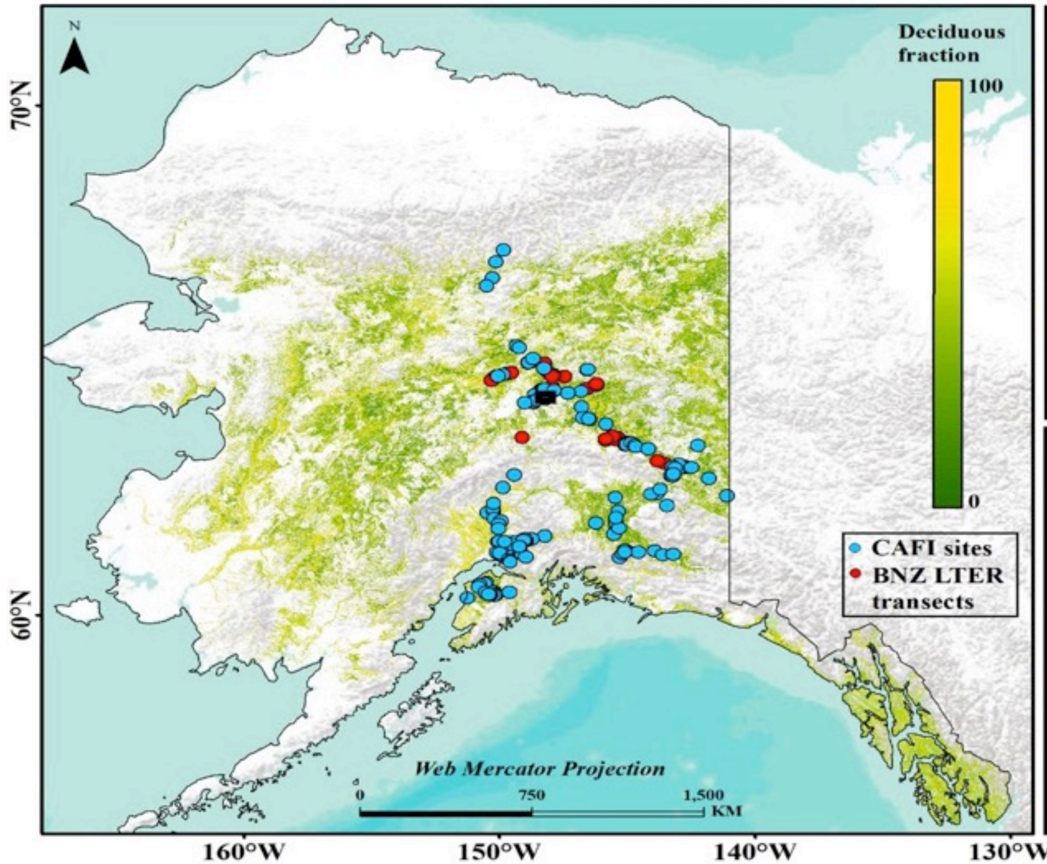
Linked Energy, Carbon & Water exchanges with the atmosphere



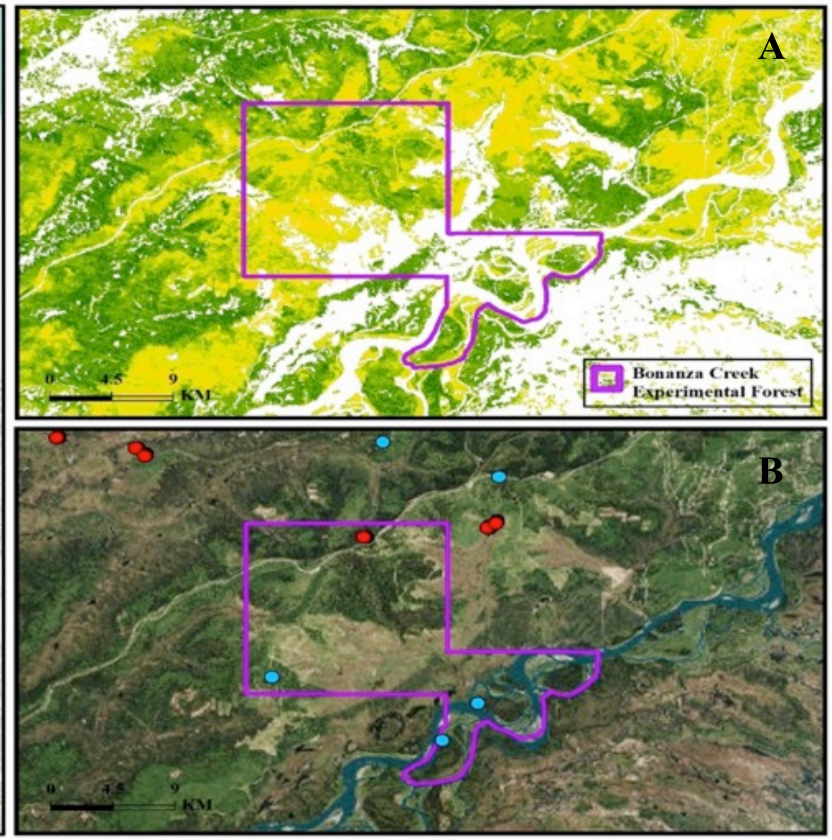
Beck et al. 2011 GCB

Landsat-based deciduous fraction mapping of Alaska and the ABoVE Domain

DF is important for energy partitioning, carbon & nutrient dynamics, and climate feedbacks



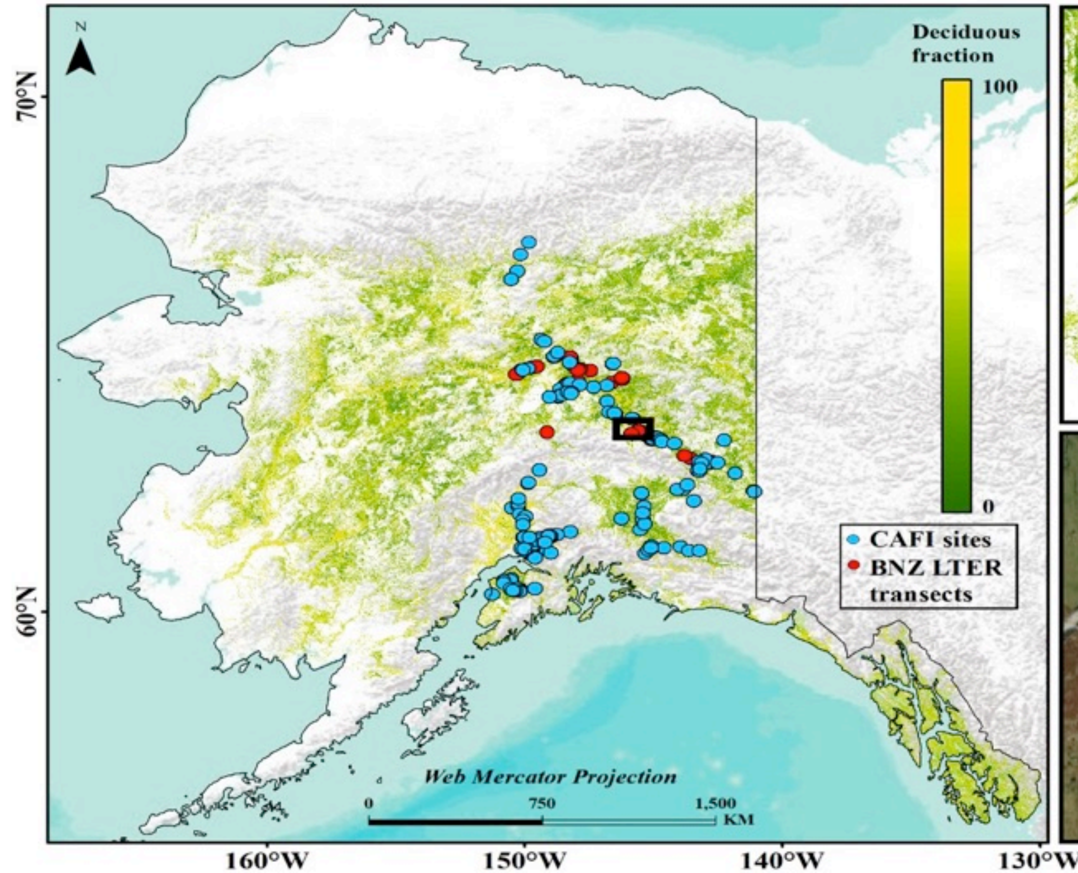
DF map of Alaska (year 2010) and location of field plots from Cooperative Alaska Forest Inventory and Bonanza Creek LTER regional site network .



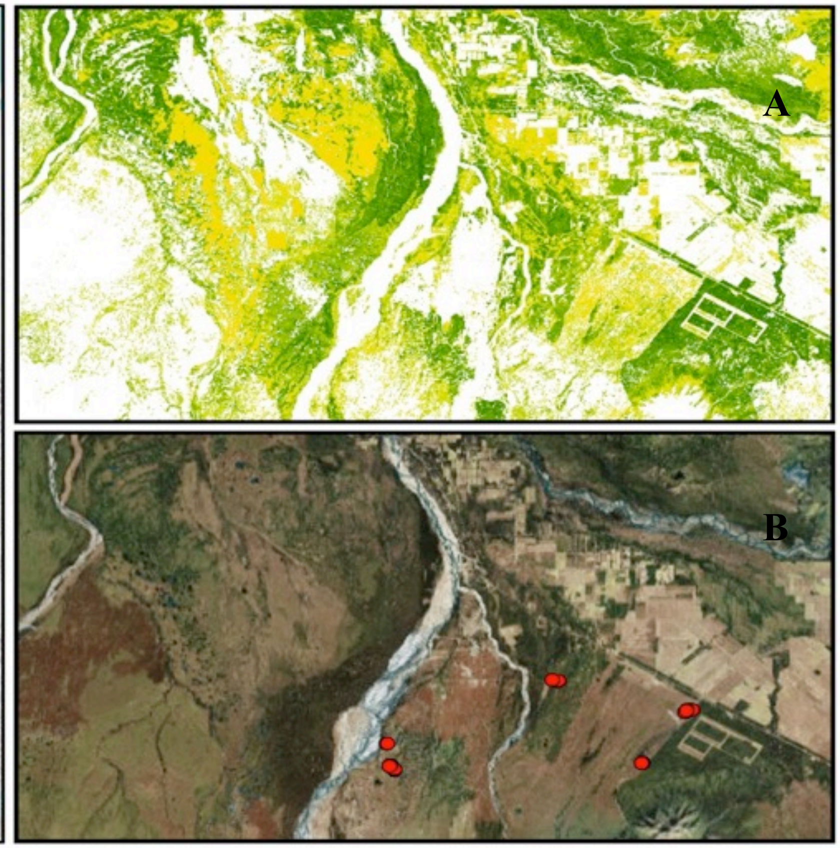
Panels A (deciduous fraction) & B (high resolution imagery) are centered on Bonanza Creek Experimental Forest.

Landsat-based deciduous fraction mapping of Alaska and the ABoVE Domain

DF is important for energy partitioning, carbon & nutrient dynamics, and climate feedbacks



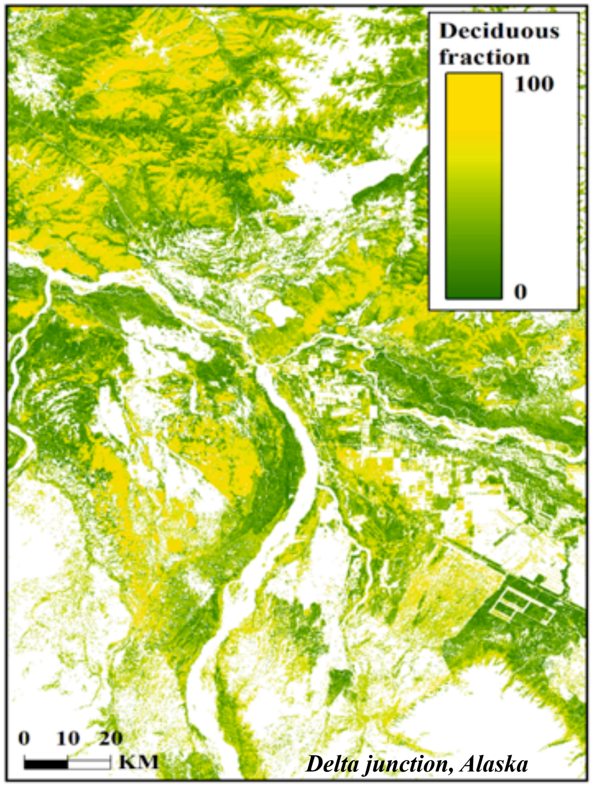
DF map of Alaska (year 2010) and location of field plots from CAFI and Bonanza Creek LTER regional site network .



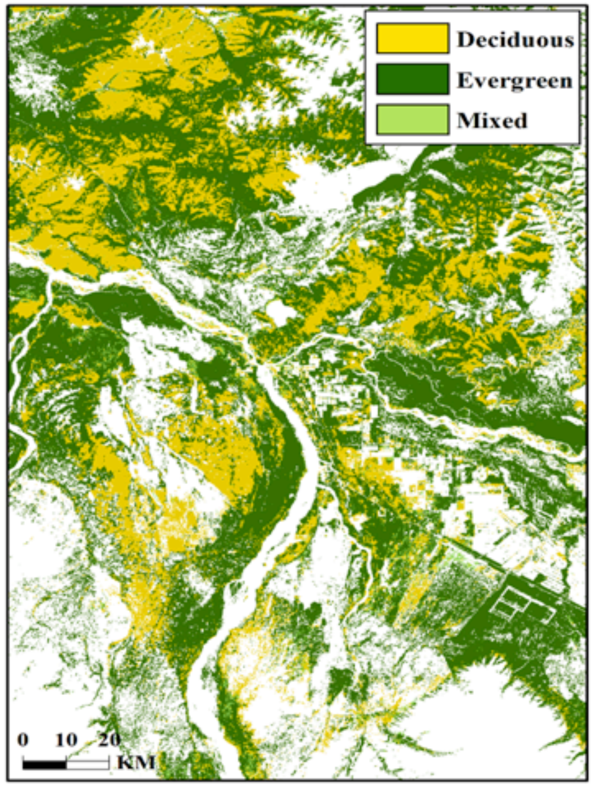
Comparison of DF map (A) with high resolution imagery (B) shows good agreement with observed forest cover

Massey, Goetz, Rogers, Mack et al. (forthcoming)

Landsat-derived deciduous fraction map comparison with USGS NLCD 2011



Alaska deciduous fraction 2010

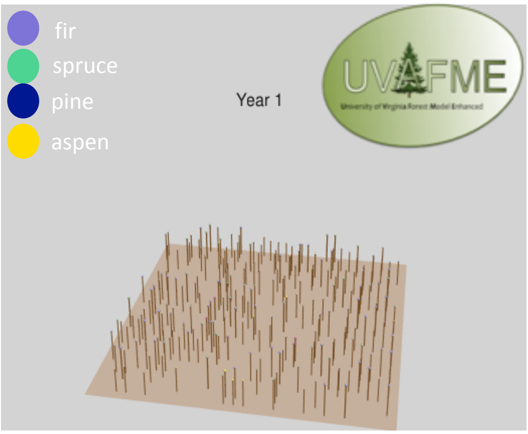


USGS NLCD 2011

High resolution imagery (ESRI 2013)

High resolution imagery indicates we are mapping deciduous cover better than NLCD, in addition to capturing the more continuous nature of forest composition.

Individual tree-based modeling in interior Alaska



University of Virginia Forest Model Enhanced

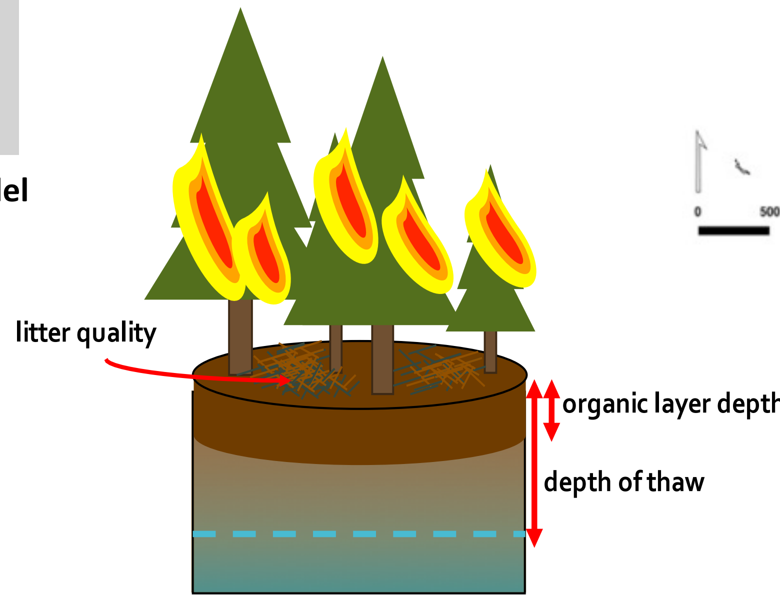
UVAFME – individual tree- based model that simulates tree growth and response to external factors & tree-tree competition (Yan & Shugart 2005; Foster et al. 2017)

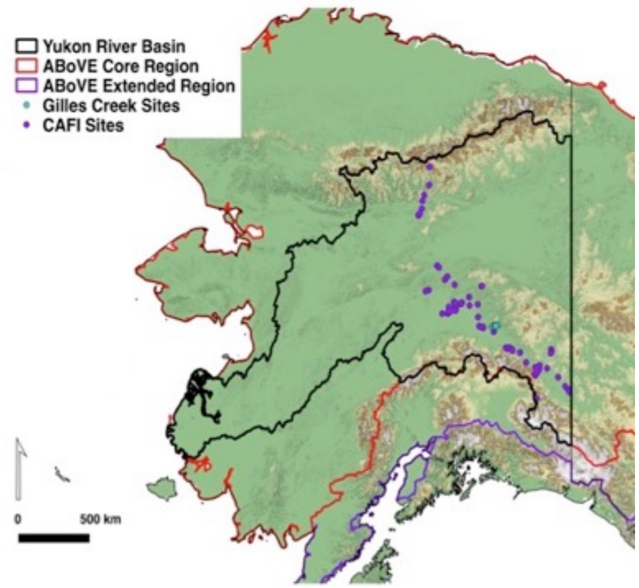
ABoVE Project Goetz-03

Foster et al. (forthcoming)

Updates to UVAFME

- Simulation of **permafrost depth**
- Update of **litter and nutrient** modules
- Incorporation of **fuels tracking** and **fire consumption of litter & humus, improved post-fire regrowth**

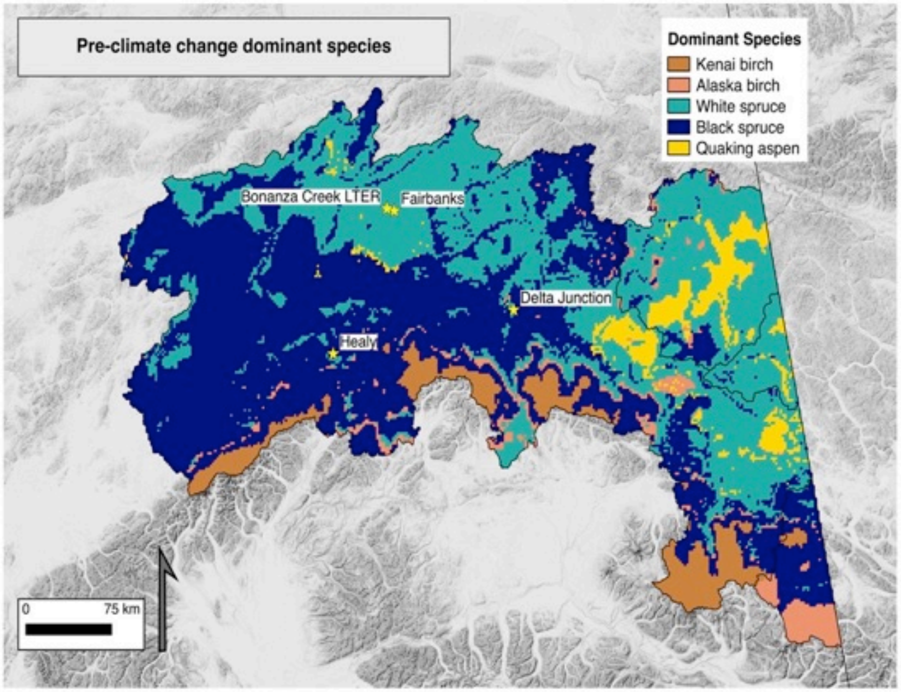


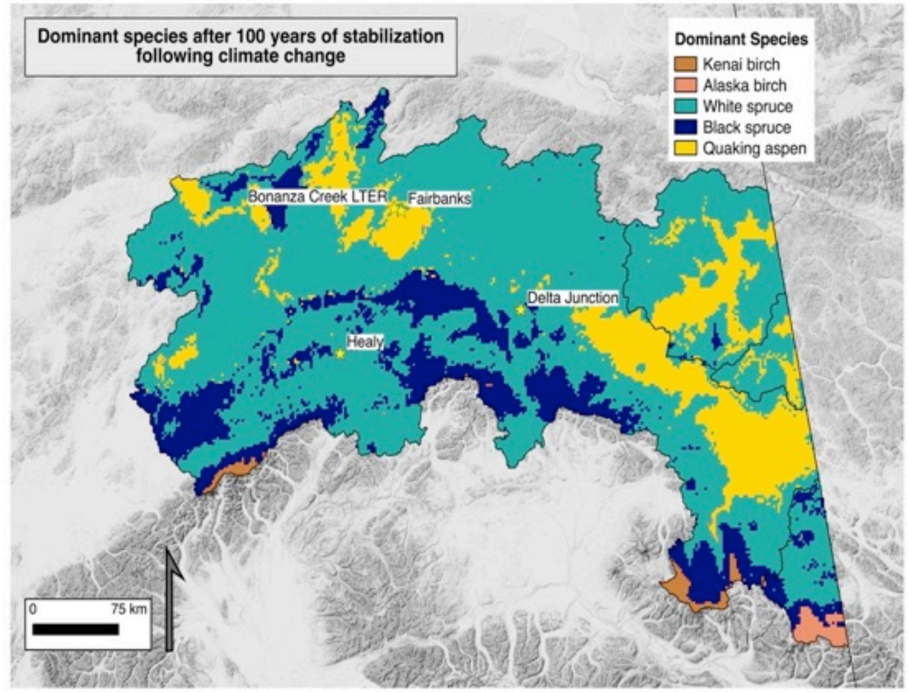


Alaskan Modeling

- 77 CAFI sites
- 30 black spruce/white spruce sites near Gilles Creek
- Wall-to-wall simulations across Yukon River Basin (2km resolution ~ 131,000 sites)

Dominant species in the Tanana: pre-climate change and after 100 years of stabilization following climate change (RCP 8.5)

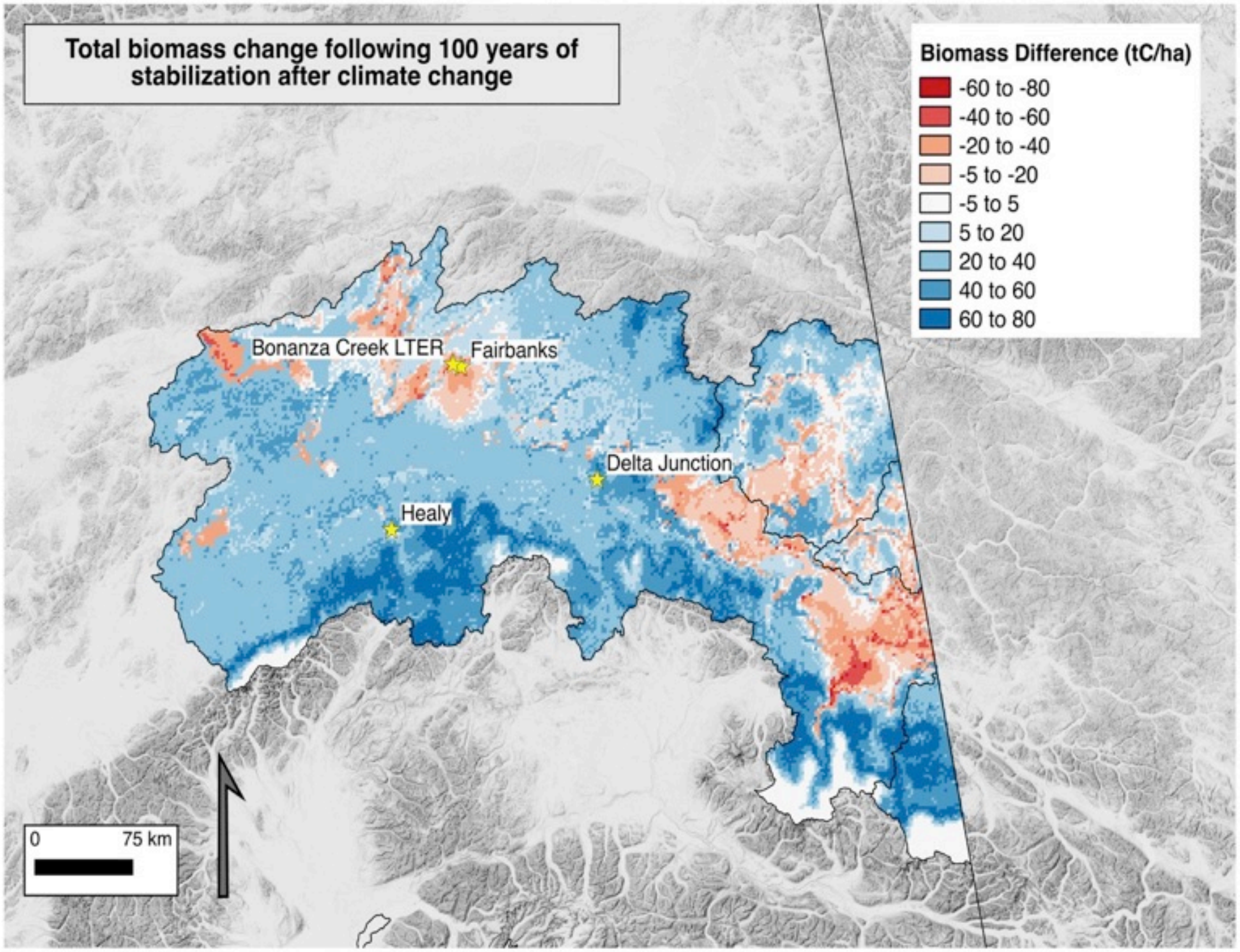




Climate change was initiated at mature forest state (400 years from bare ground initiation) – **year 2006**

Climate change consisted of 94 years of changing monthly temperature and precipitation (in this scenario both increased) from **2006 to 2100**

Comparisons to pre-climate change conditions were taken from year 600 of simulations **(i.e. year 2206)**



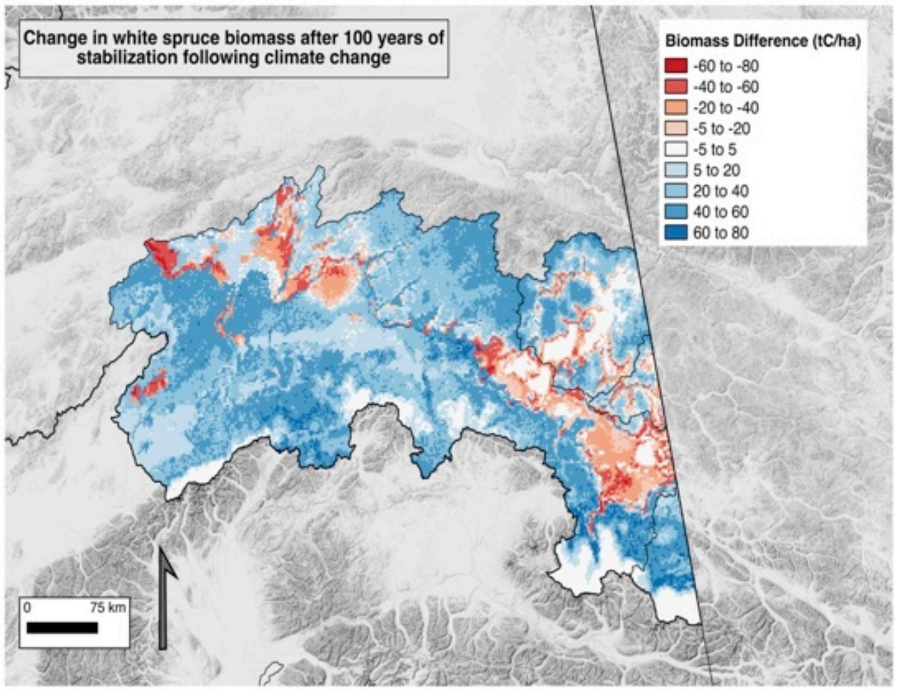
ABoVE Project Goetz-03; *Foster et al. (forthcoming)*

Climate change was initiated at mature forest state (400 years from bare ground initiation) – **year 2000**

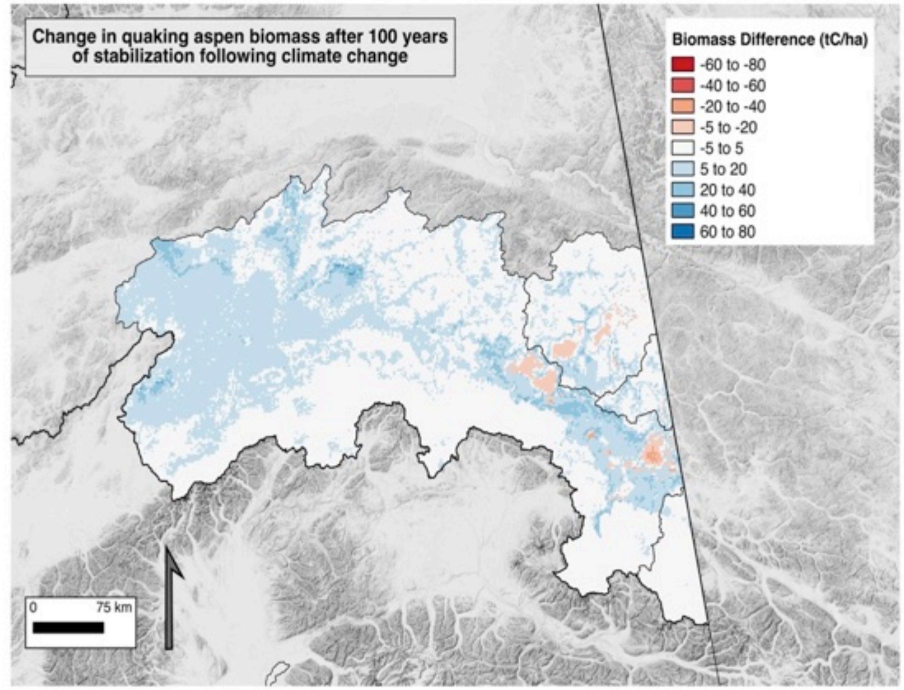
Climate change consisted of 94 years of changing monthly temperature and precipitation (in this scenario both increased) **from 2006 to 2100**

Comparisons to pre-climate change conditions were taken from year 600 of simulations **(i.e. year 2206)**

White spruce and black spruce biomass change (from historical/pre-climate change) after 100 years of stabilization following climate change (RCP 8.5)



White spruce



Quaking aspen

Climate change was initiated at mature forest state (400 years from bare ground initiation) – **year 2006**

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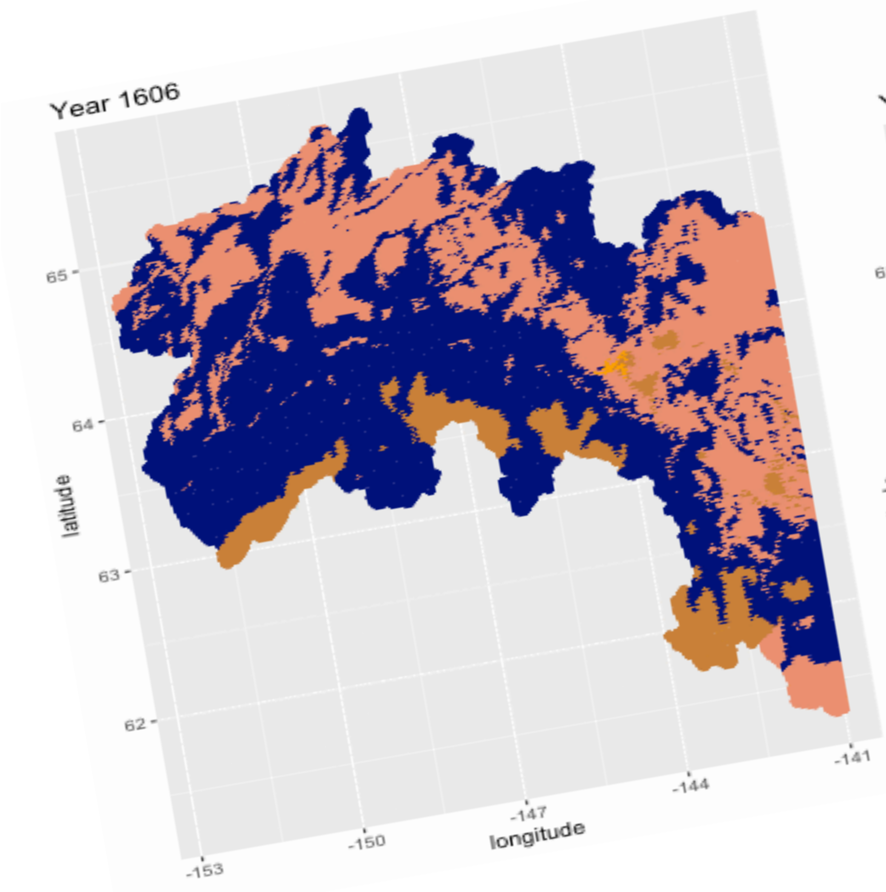
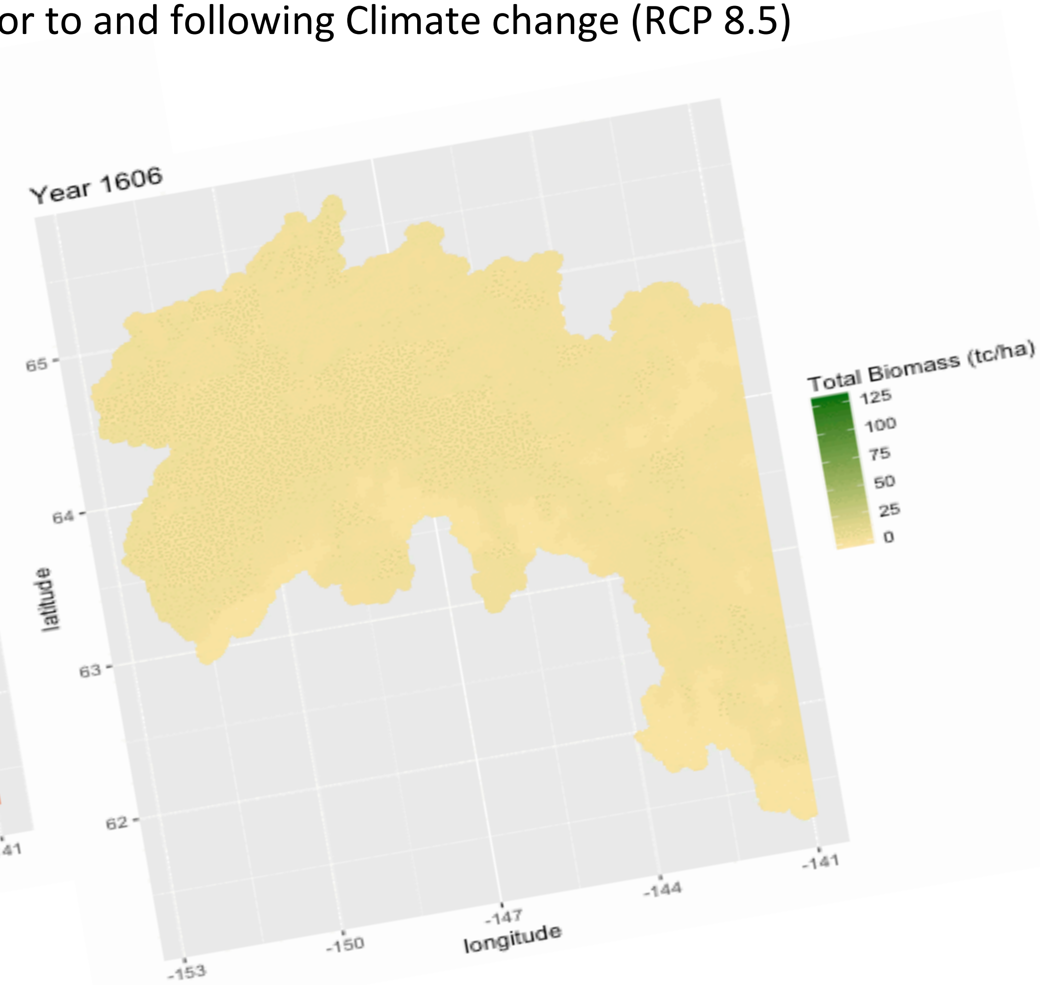
Comparisons to pre-climate change conditions were taken from year 600 of simulations **(year 2206)**

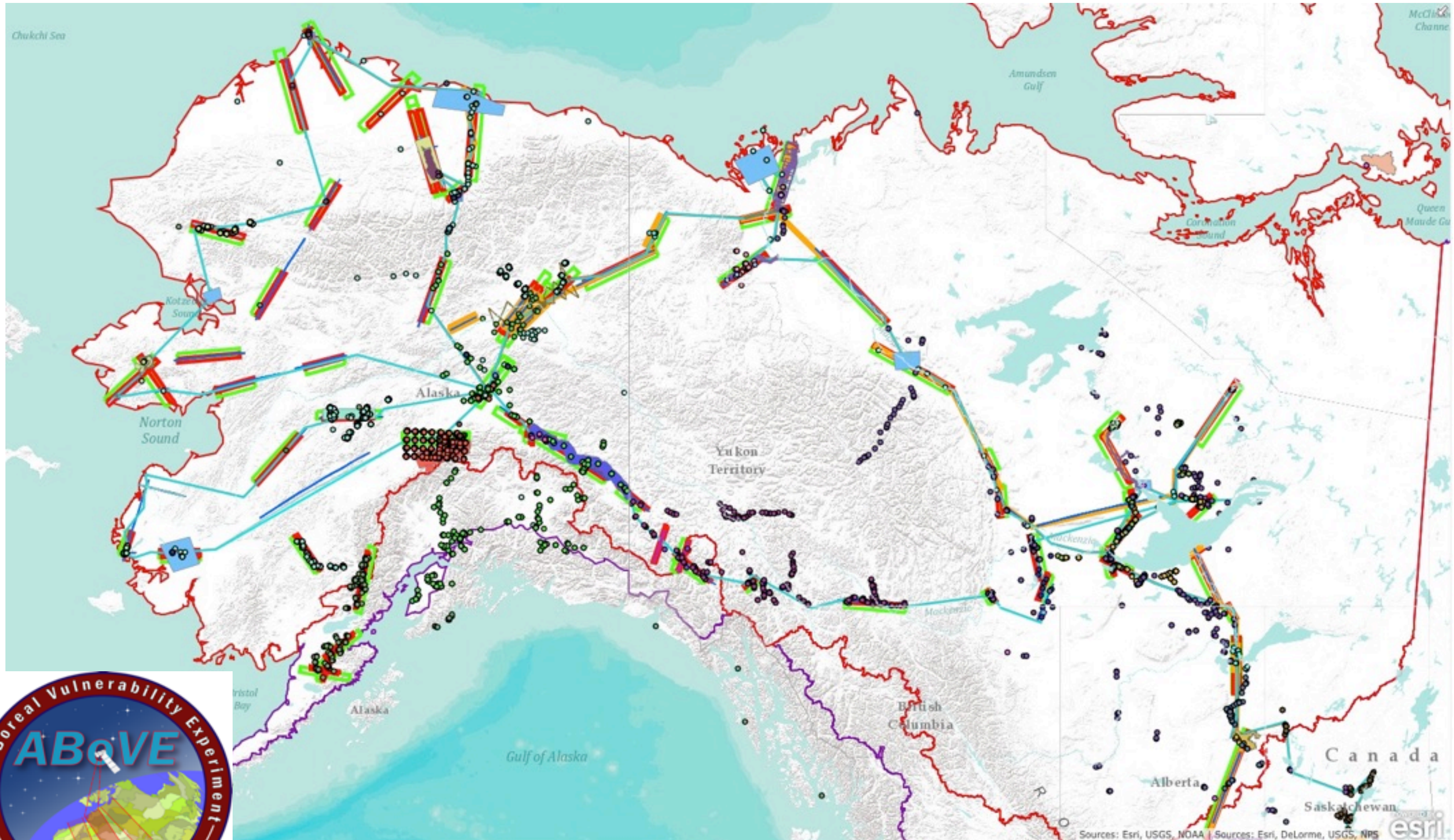
Composition and Biomass changes prior to and following Climate change (RCP 8.5)





Species equilibrate for 400 years; Climate changes across years 400-495; Species re-equilibrate years 495-600

Coordinated Field measurements and Airborne Acquisitions



For details visit above.nasa.gov/airborne.html