

Seven ways a warming climate can kill the boreal forest

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With unmitigated climate change, Minnesota is likely to lose the boreal biome and ca 1/3 of our native species

Biome map of Minnesota by MNDOT

- Northern conifer (boreal) in NE MN
- Temperate forest (oak and maple), stripes from NW to SE
- Grasslands and savanna, solid beige in W and SW

1960-1980

1980-2000

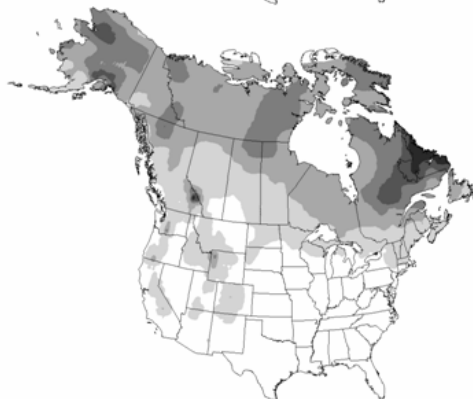
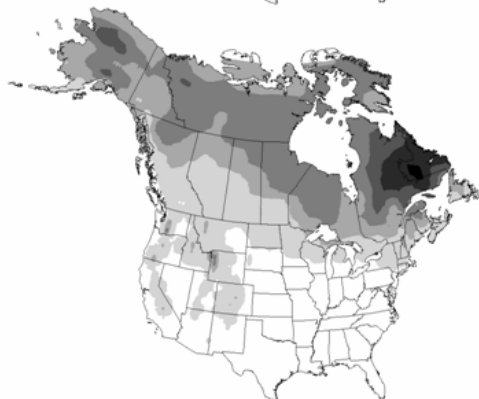
Snow cover and depth in North America: 1960-1980 compared with 1980-2000.

From, J.L. Dyer and T.L. Mote. 2006. Spatial variability and trends in observed snow depth over North America. *Geophysical Research Letters* 33: L16503.

Pentad 15
Mar 12-16



Pentad 20
Apr 6-10



Pentad 25
May 1-5



2 – 20 cm

40 – 60 cm

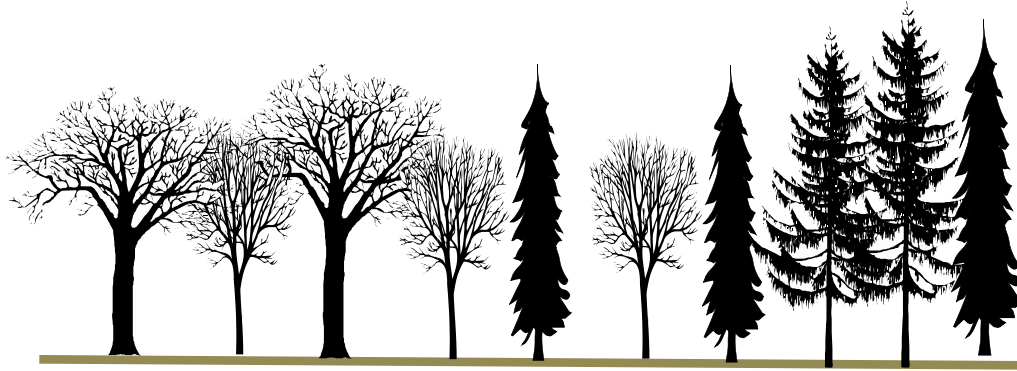
80 – 100 cm

20 – 40 cm

60 – 80 cm

> 100 cm

Local transitions in **warm** and **cool** summer climates



Temperate

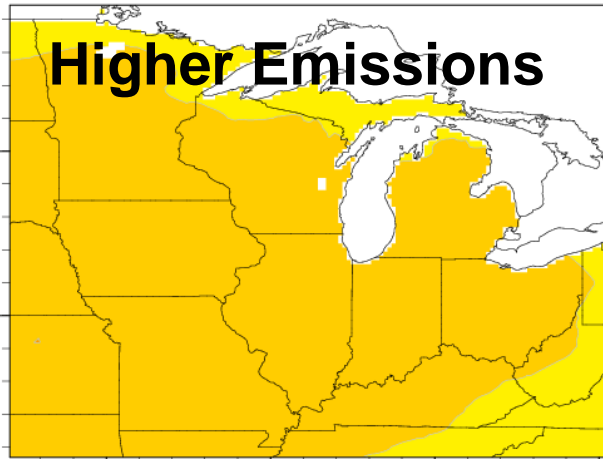
Boreal



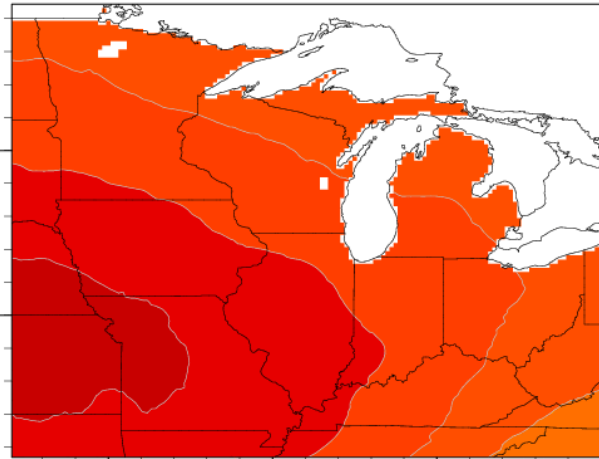
Temperate tree species are invading boreal forests, but have not had time to replace boreal species and it is not yet warm enough to kill boreal forest—therefore mixed forest or ecotone is becoming wider

Fisichelli, Frelich and Reich. 2014.
Ecography 37: 152-161. Photo, Duluth News Tribune

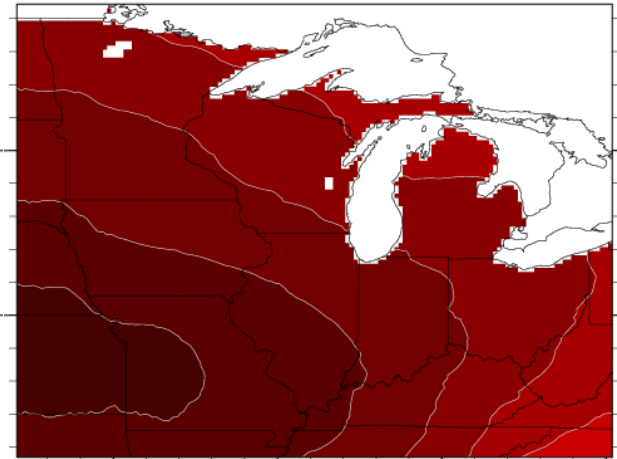
Change in summer (JJA) temperature



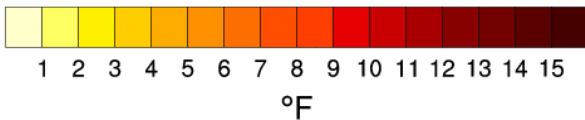
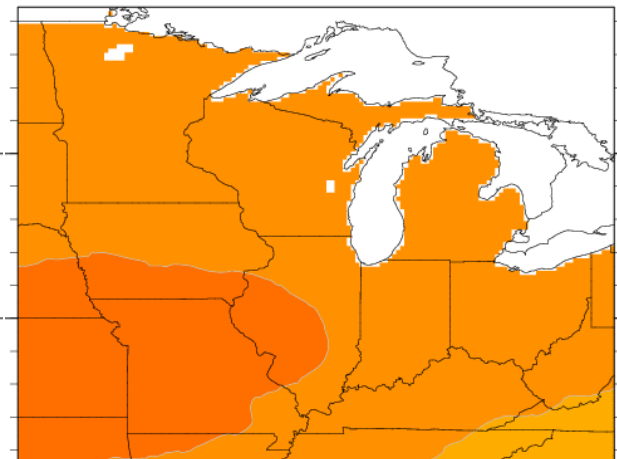
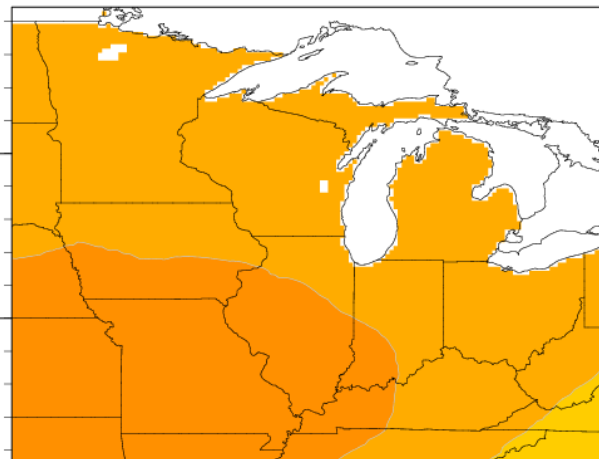
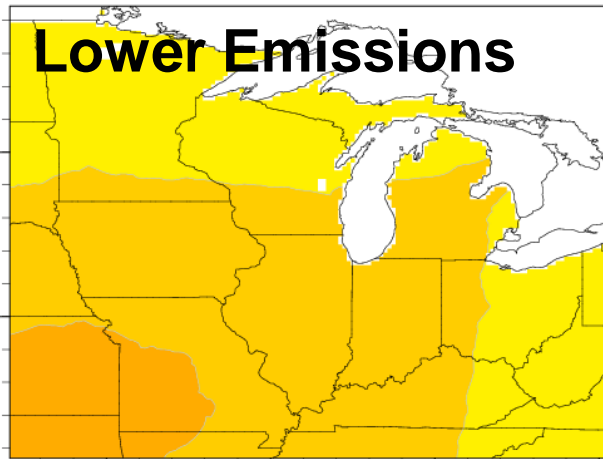
2010-2039



2040-2069



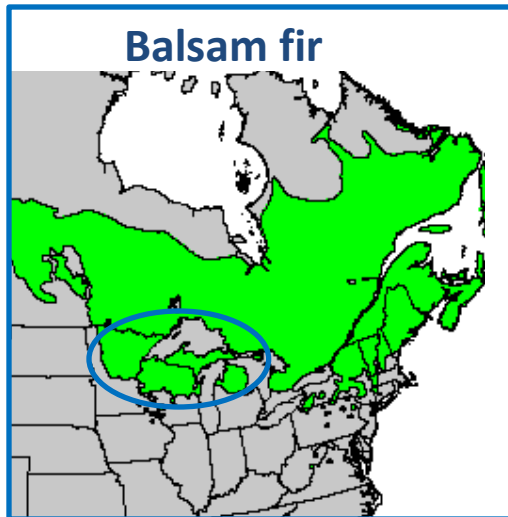
2070-2099



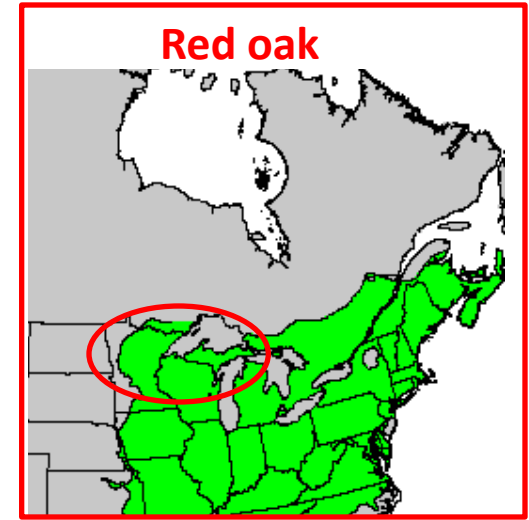
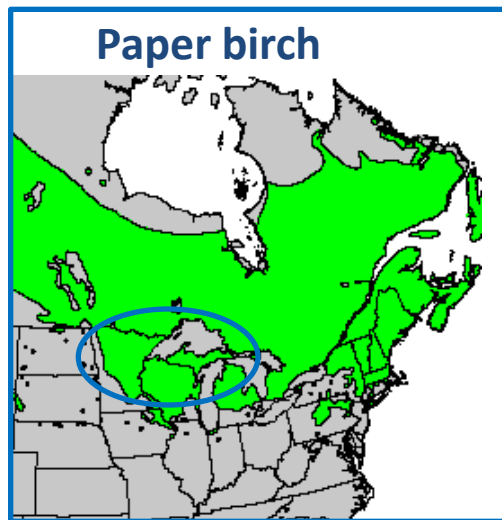
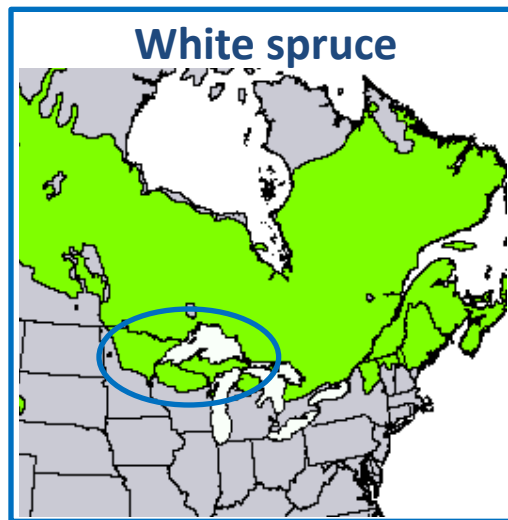
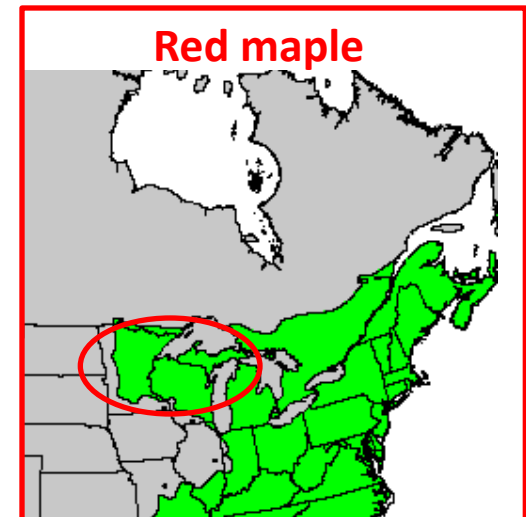
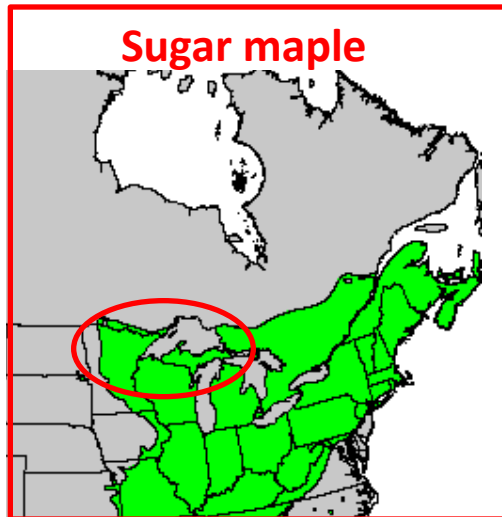
Slide: Don Wuebbles

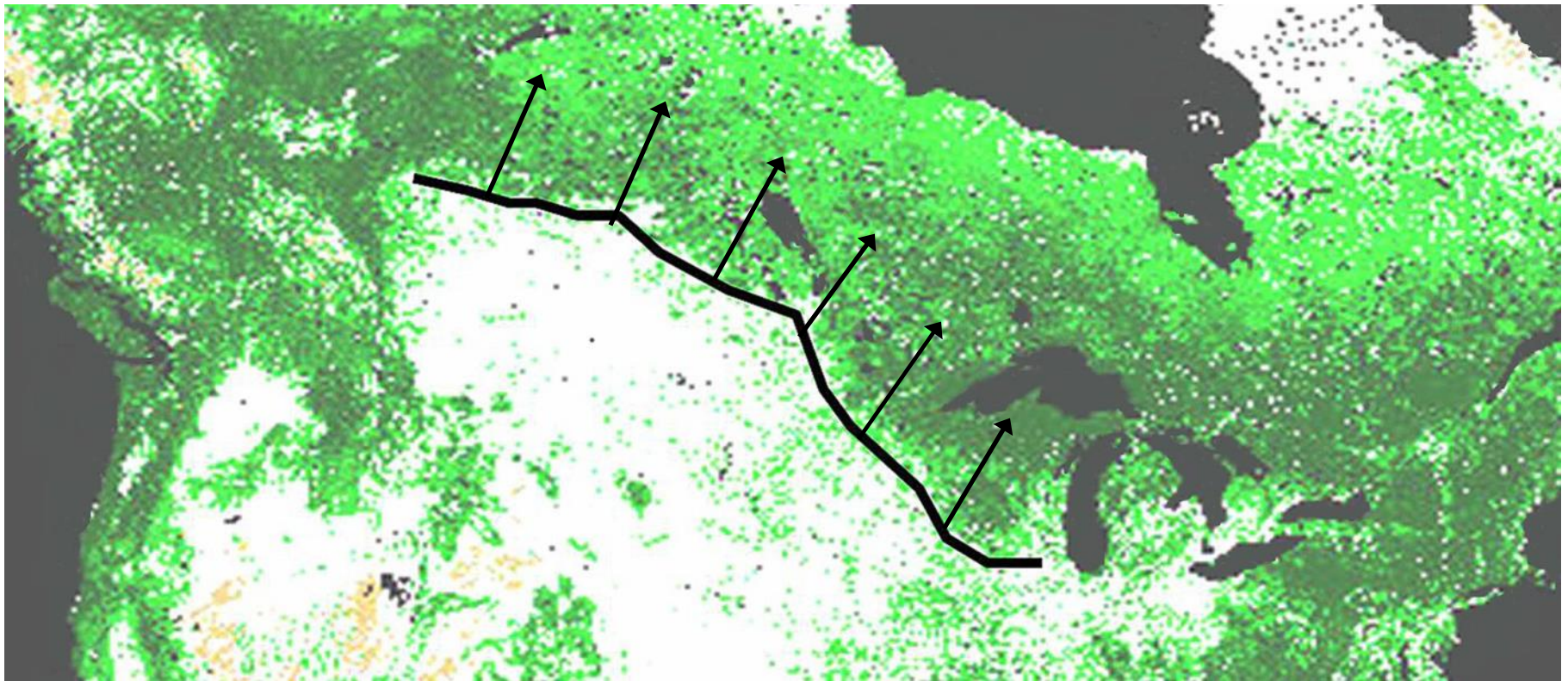
Range Distributions of Temperate and Boreal Species

Boreal Trees



Temperate Trees





Forest cover of central North America (green). Prairie-forest border (black line), and arrows showing the border moving 300 miles to the northeast by 2100 for a business as usual climate change scenario. Modified from Frelich and Reich 2010, *Frontiers in Ecology and the Environment*

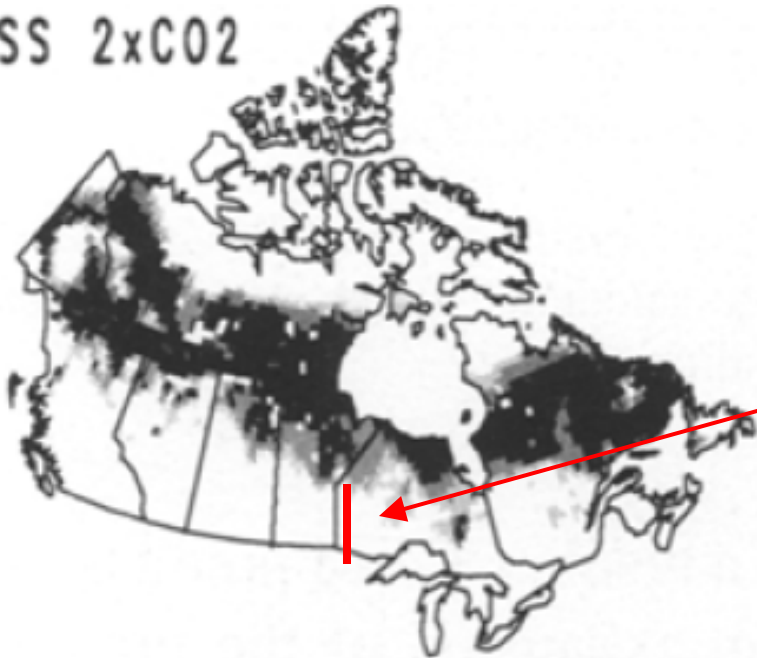
The BWCAW will be at the prairie-forest border!

OBSERVED

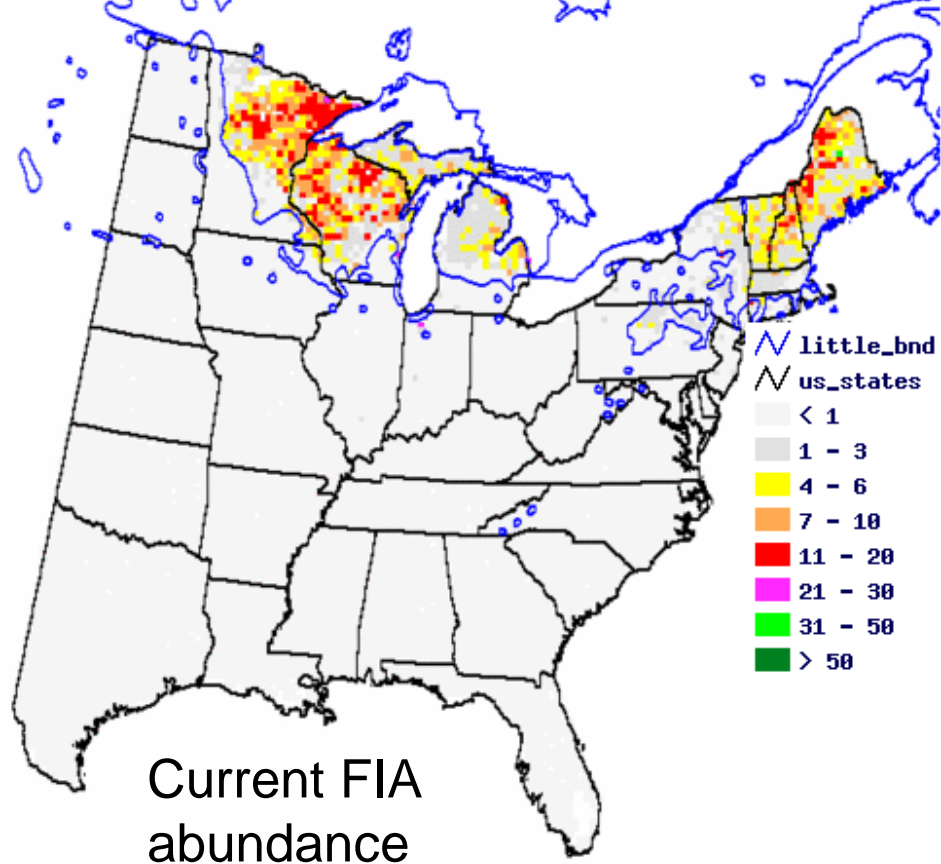


Current and simulated future range of black spruce, from Lenihan and Neilson 1995.

GISS 2xCO2



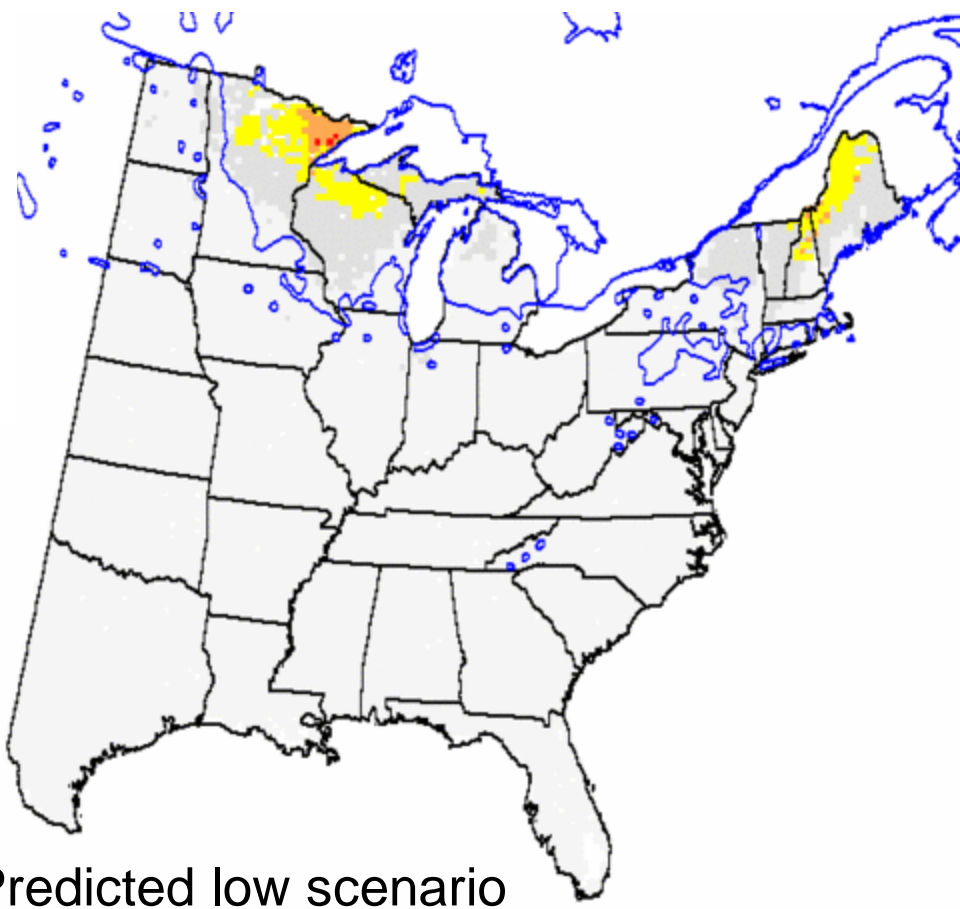
300 mile shift is equal to distance moved in ~ 2000 years in paleorecord



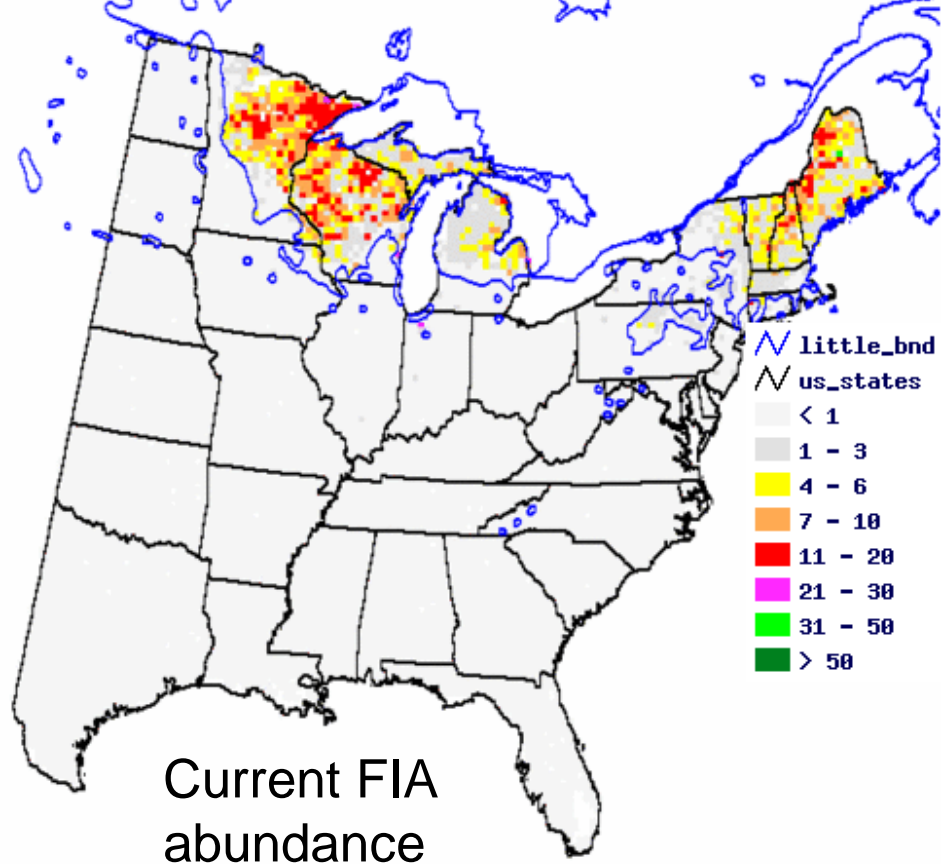
Current FIA abundance

Paper birch abundance: Current FIA compared to predictions for low emissions scenario

Source: USDA Climate and Tree Atlas



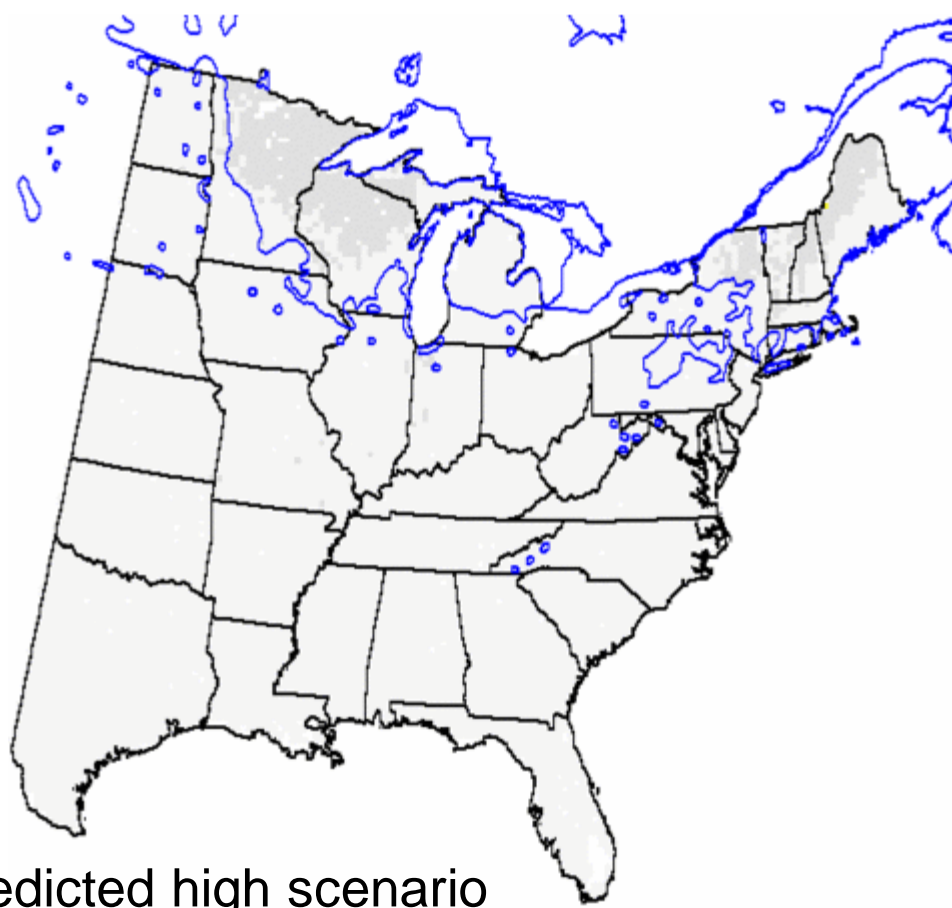
Predicted low scenario



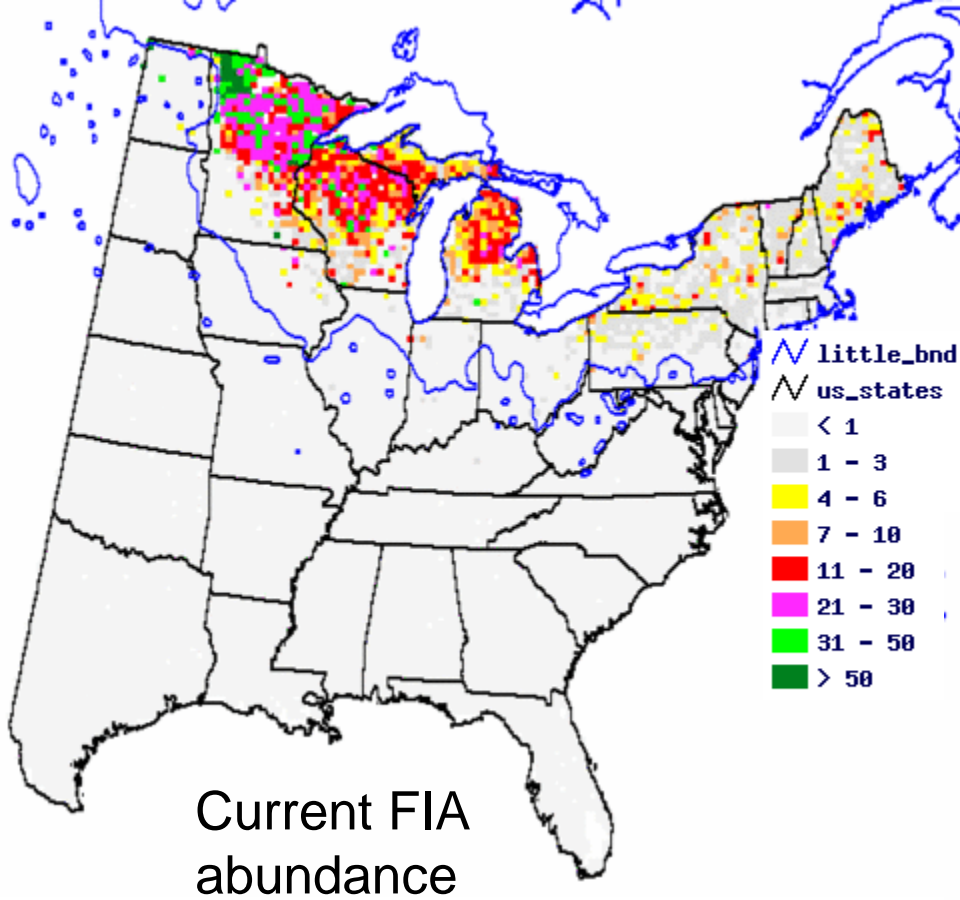
Current FIA abundance

Paper birch abundance: Current FIA compared to predictions for high emissions scenario

Source: USDA Climate and Tree Atlas



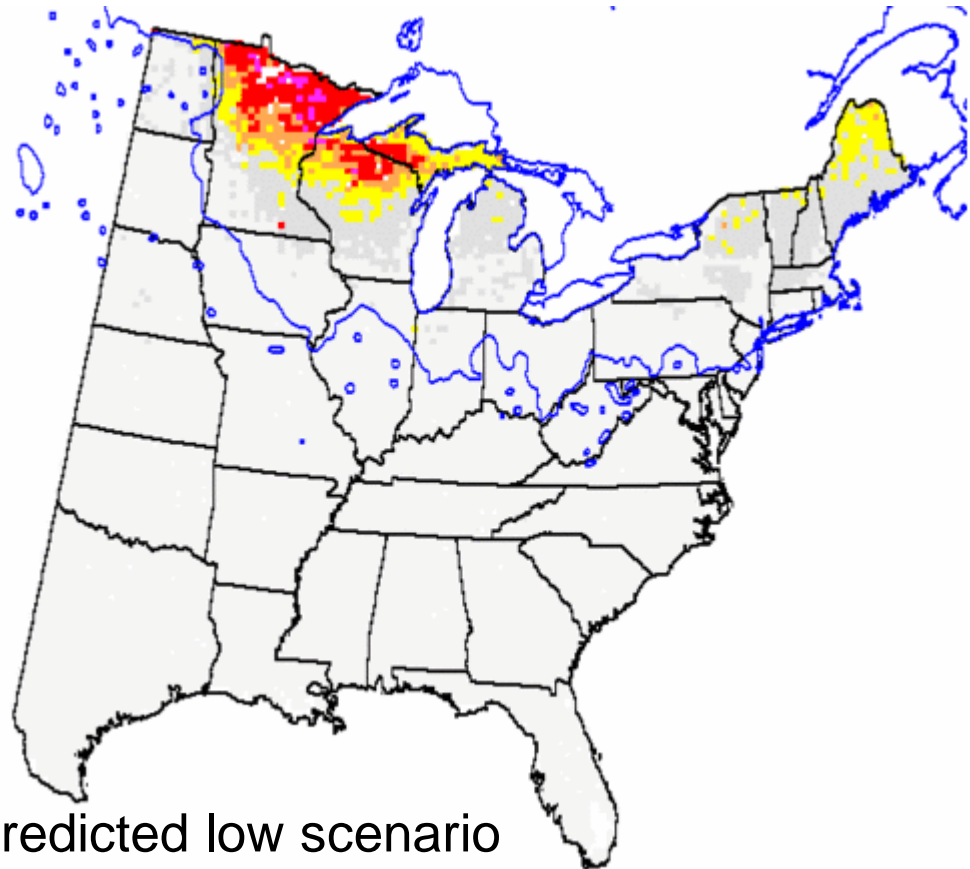
Predicted high scenario



Current FIA abundance

Quaking aspen abundance: Current FIA compared to predictions for low emissions scenario

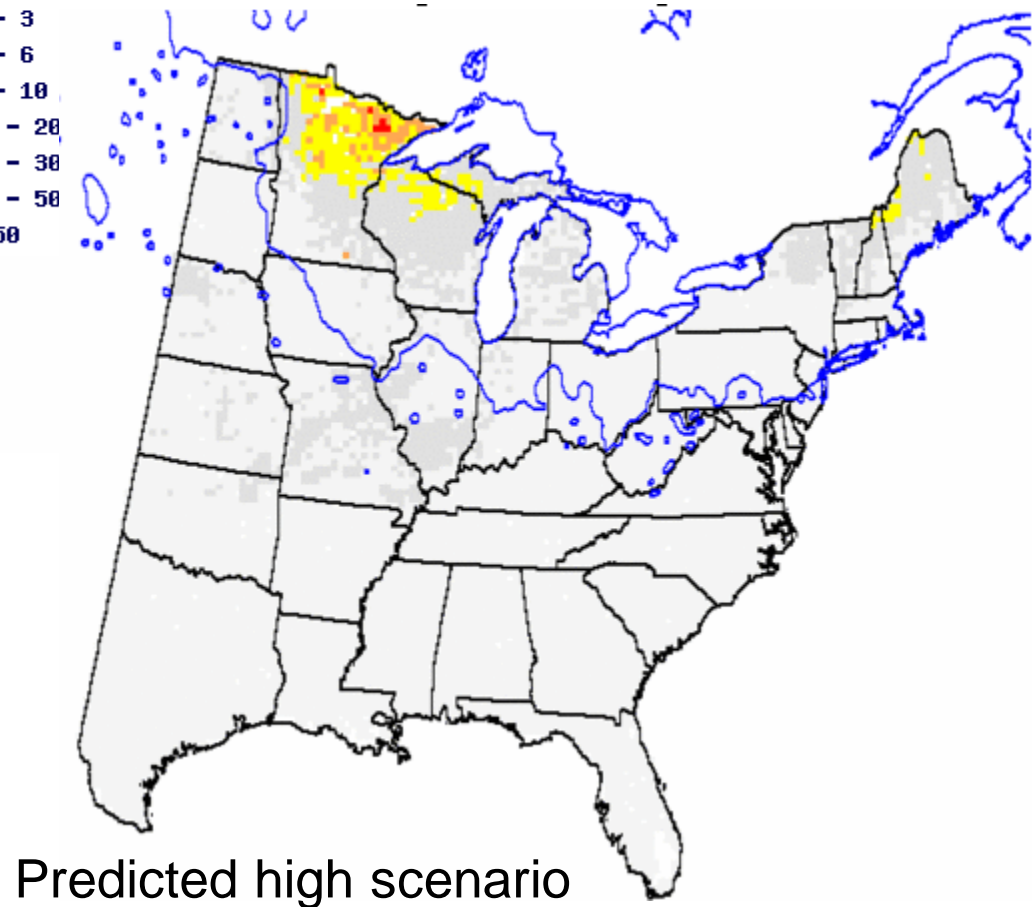
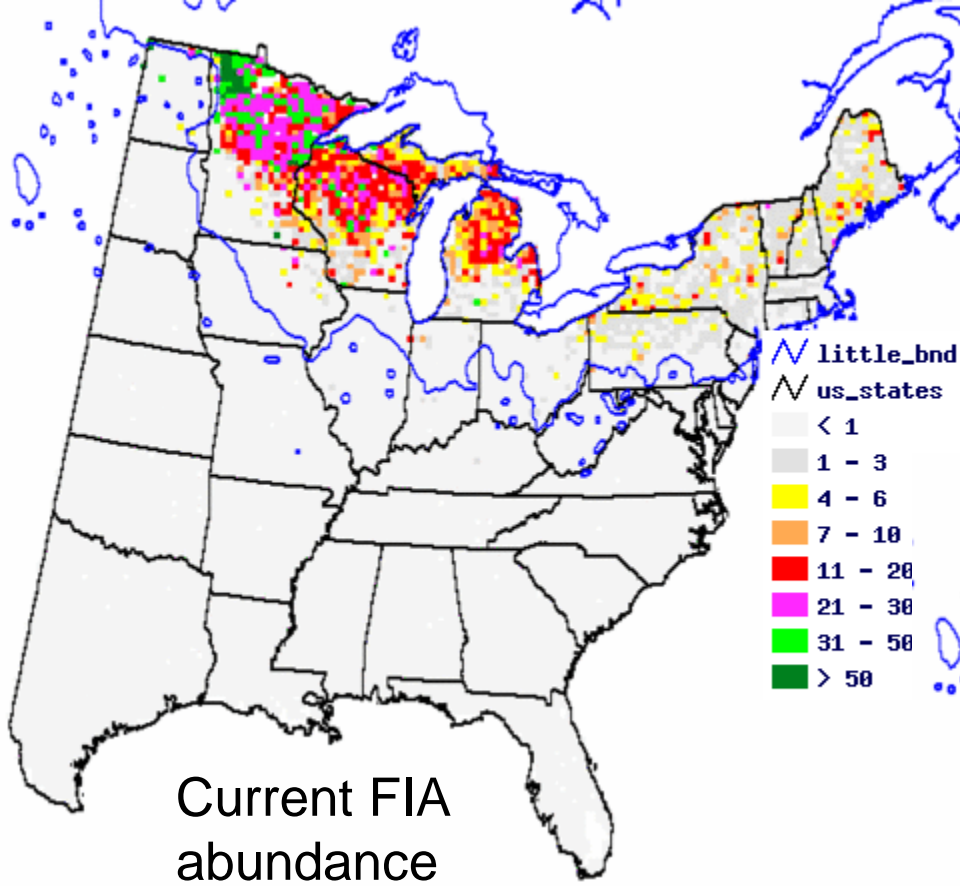
Source: USDA Climate and Tree Atlas

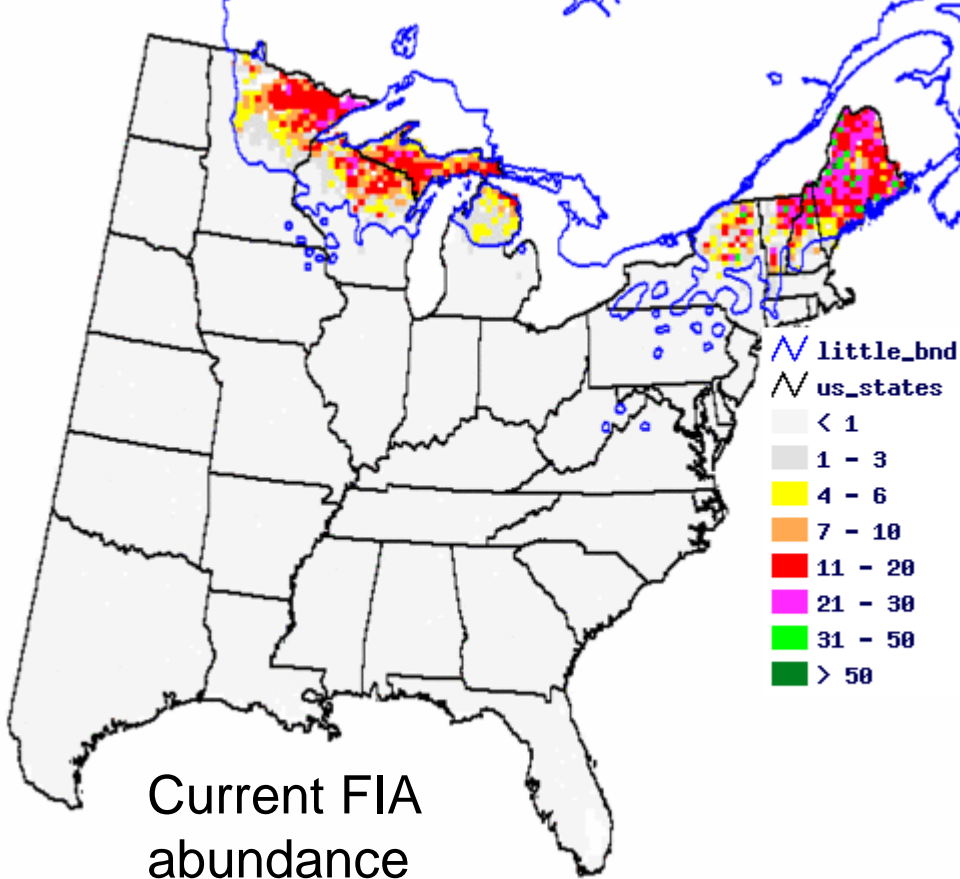


Predicted low scenario

Quaking aspen abundance: Current FIA compared to predictions for high emissions scenario

Source: USDA Climate and Tree Atlas

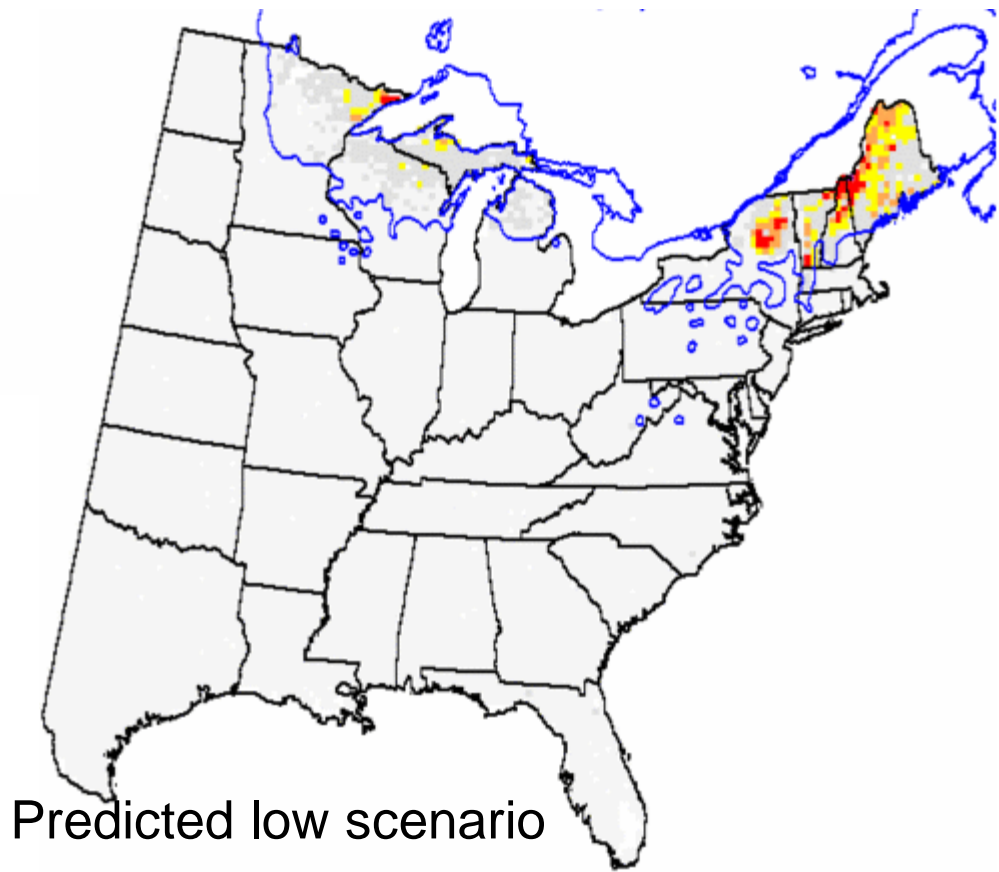




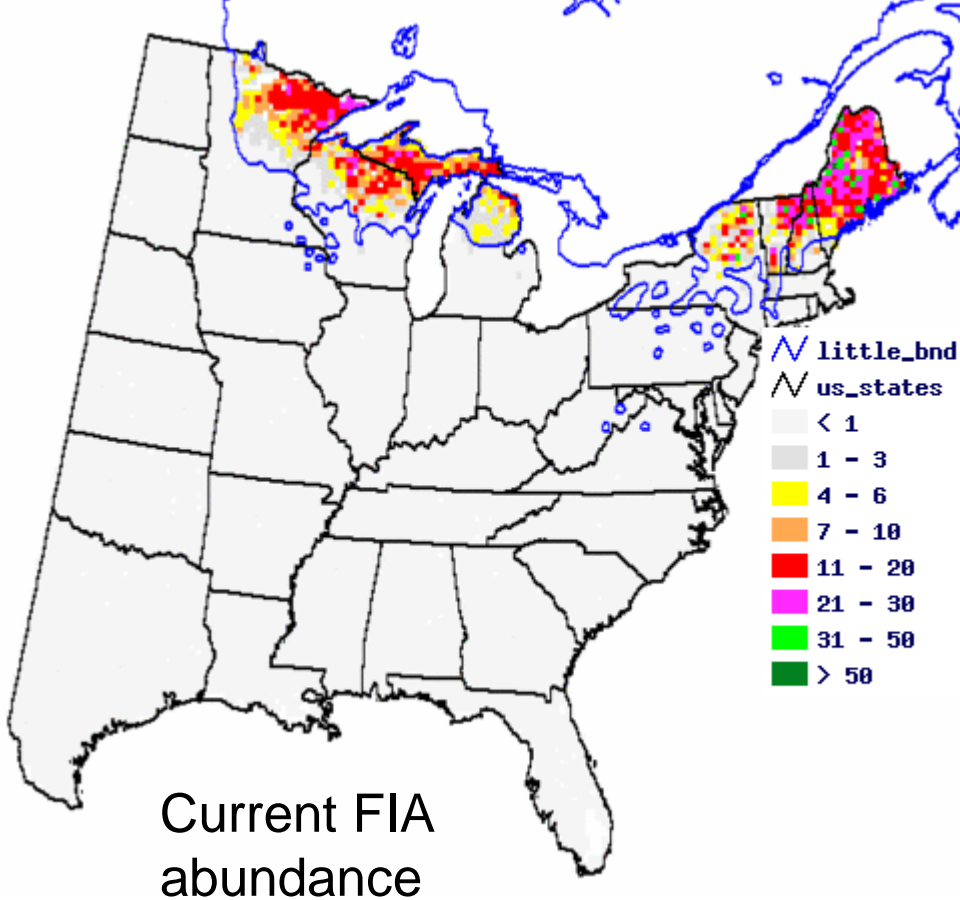
Current FIA abundance

Balsam fir abundance:
 Current FIA compared to
 predictions for low
 emissions scenario

Source: USDA Climate and Tree Atlas



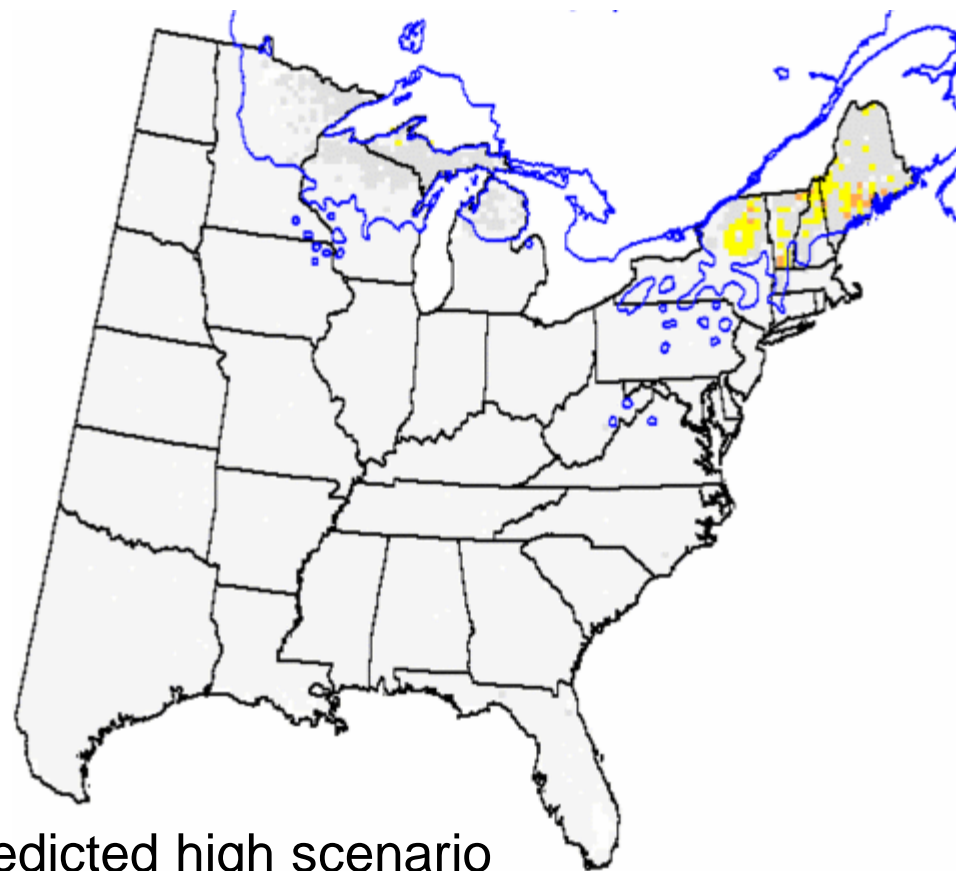
Predicted low scenario



Current FIA abundance

Balsam fir abundance:
 Current FIA compared to
 predictions for high
 emissions scenario

Source: USDA Climate and Tree Atlas



Predicted high scenario



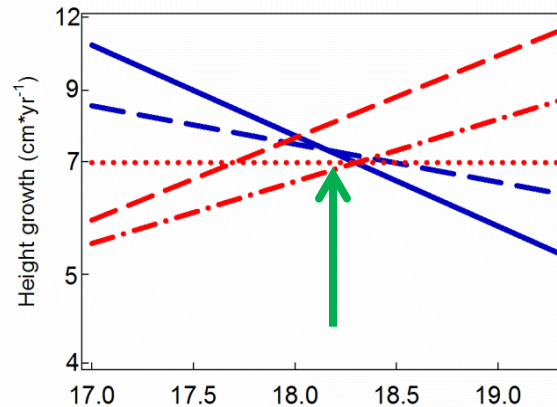
Boreal to temperate forest conversion mechanisms:

- Gap dynamics/gradual infiltration of temperate species
- Trophic cascade; delay followed by sudden change
- Wind/hail storms
- Wind + Fire
- Heat/drought stress
- Insect infestation (native and exotic) due to lack of extreme cold
- Phenological disturbance

Temperate sapling relative performance 'cooled' by deer.

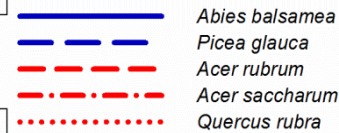
Fischelli, Frelich and Reich, 2012, *Global Change Biology* 18: 3455-3463.

(a) Low browse pressure

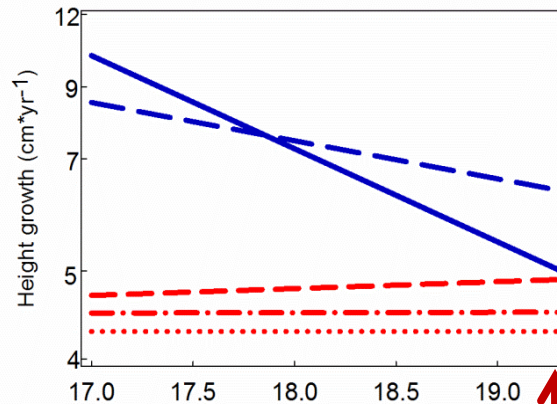


'Cross over' mean summer temperature for growth of maple and oak versus spruce and fir:

18.2 C with low deer

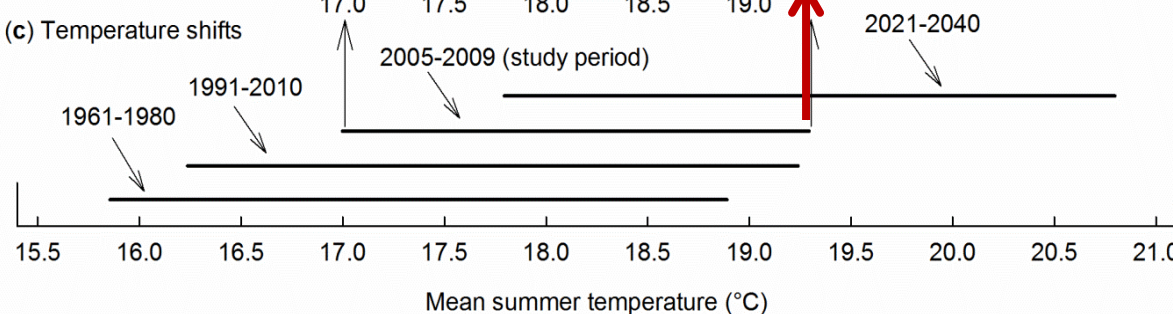


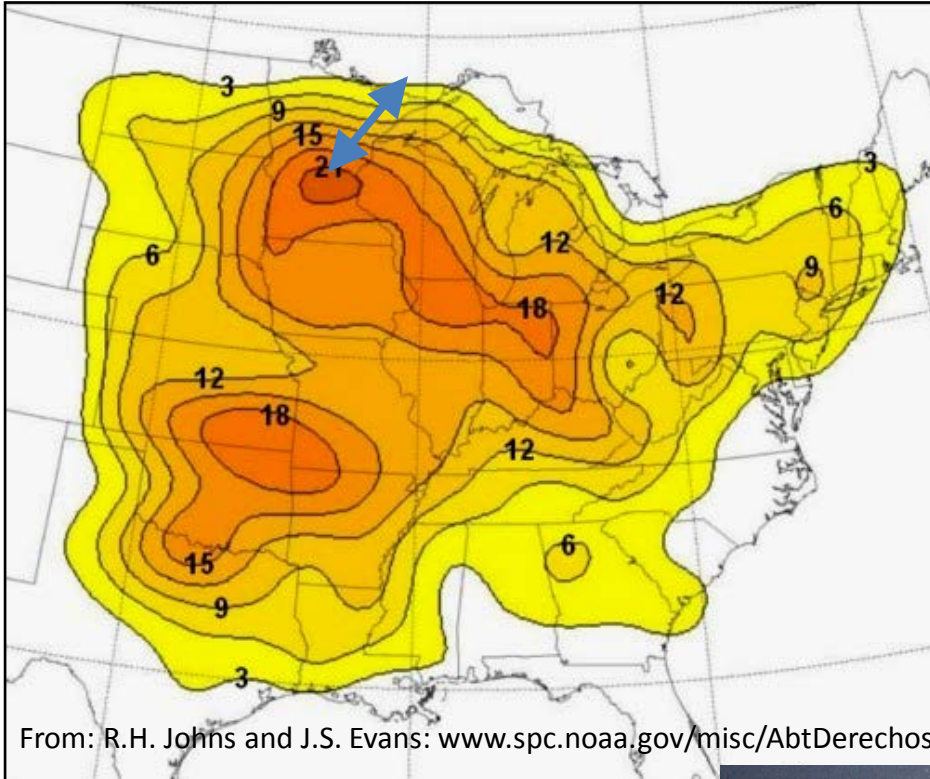
(b) High browse pressure



19.5 C with high deer

(c) Temperature shifts





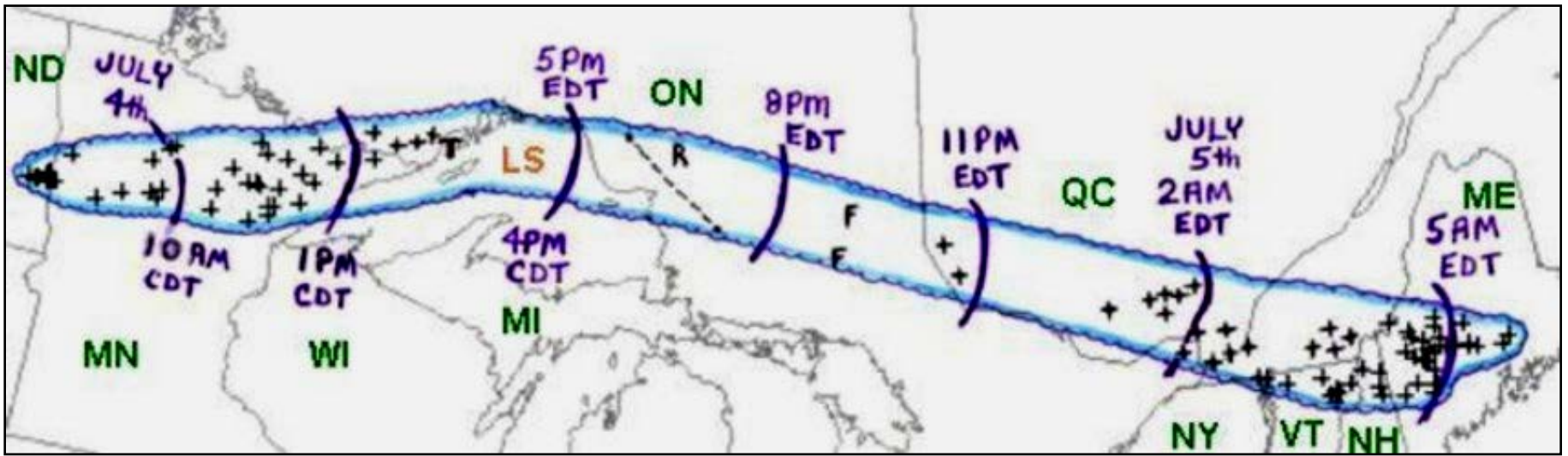
Derechos are severe thunderstorms that can level large swaths of boreal forest (10-1000s km²)

From: R.H. Johns and J.S. Evans: www.spc.noaa.gov/misc/AbtDerechos

Summer derecho frequency
(#observed in 22 years)

Robinwestenra.blogspot.com





From: R.H. Johns and J.S. Evans: www.spc.noaa.gov/misc/AbtDerechos

The BWCAW derecho,
 July 4, 1999: a combination
 bow echo and supercell
 derecho that crossed half
 of North America





Minneapolis Star Tribune

Before and after the 1999 blowdown





90,000 red maple seedlings and saplings km² followed by
a canopy levelling wind event equals:

Sudden transition from boreal to temperate forest by wind



Red pine bark stripped by hail during August 14, 2000 storm. Brule River State Forest, WIDNR.



Hail damage to pine from August 14, 2000 storm.
Brule River State Forest. WIDNR.

Wind plus fire = major forest transformation

Nick Fisichelli and Roy Rich, Cavity Lake Burn, Seagull Lake, July 2007.

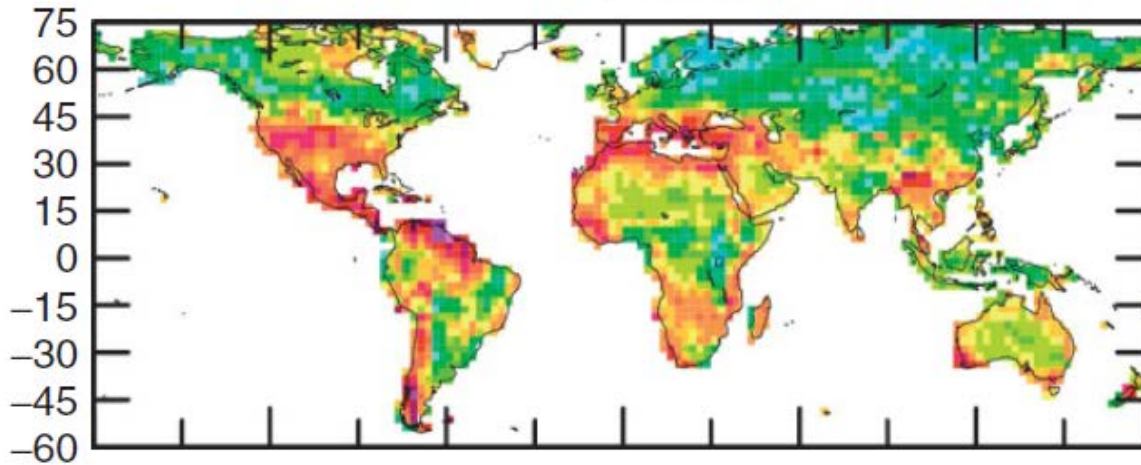
Photo: Dave Hansen, University of MN



Wind+fire should facilitate conversion to oaks in a warming climate

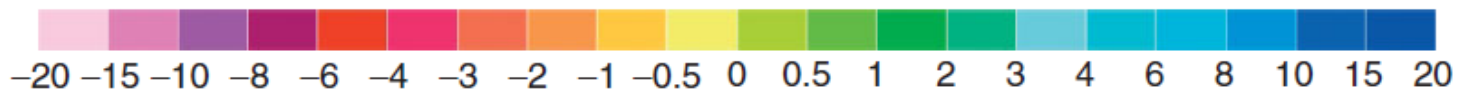
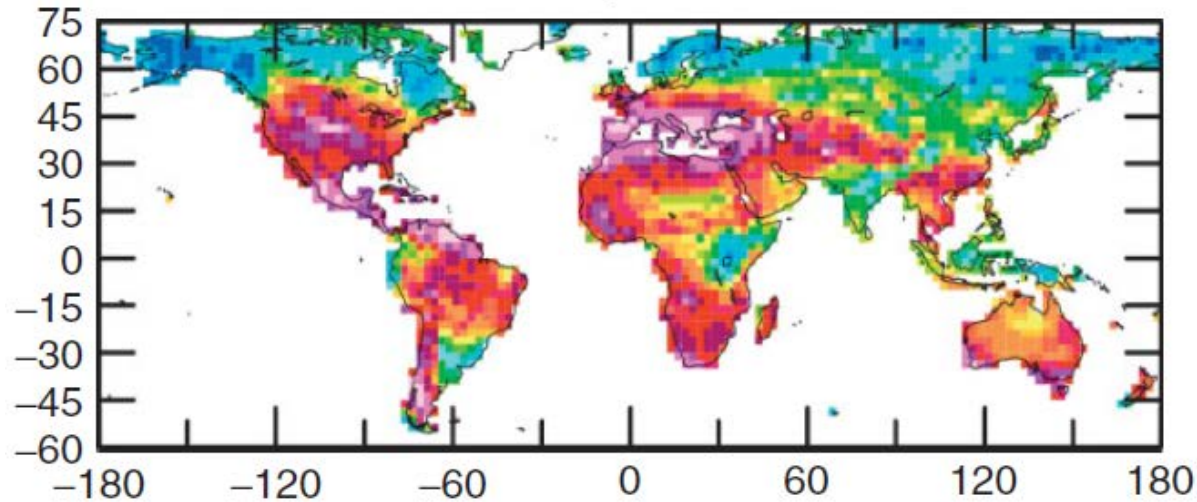
Comparing the 2060s with current

(c) SC-PDSI, 2000-2009



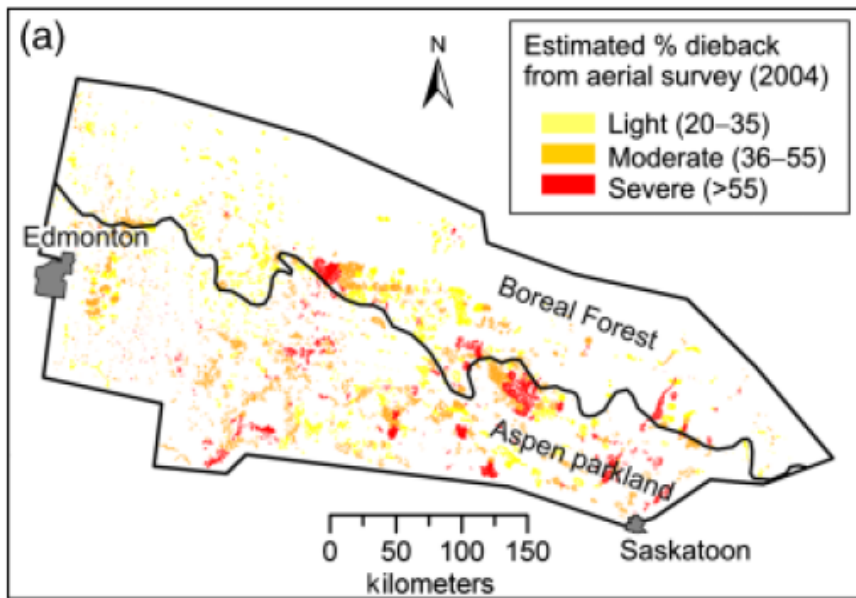
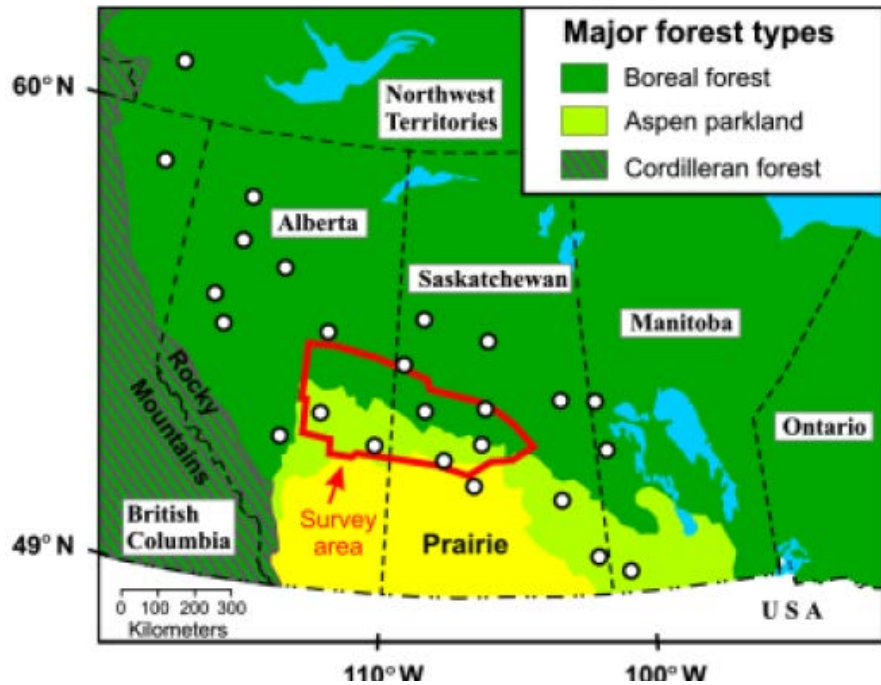
Dai, 2010, Drought under global warming,
Climate Change DOI: 10.1002/wcc.81

(e) SC-PDSI, 2060-2069



Massive mortality of aspen following severe drought along the southern edge of the Canadian boreal forest

MICHAEL MICHAELIAN, EDWARD H. HOGG, RONALD J. HALL and ERIC ARSENAULT
Natural Resources Canada, Canadian Forest Service, 5320-122 Street, Edmonton, AB, Canada T6H 3S5



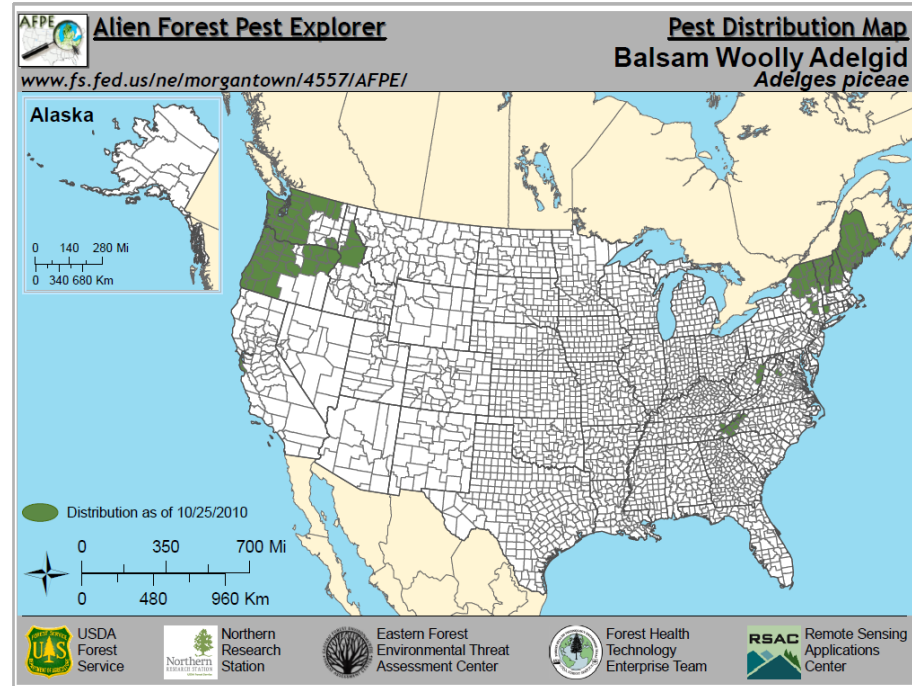
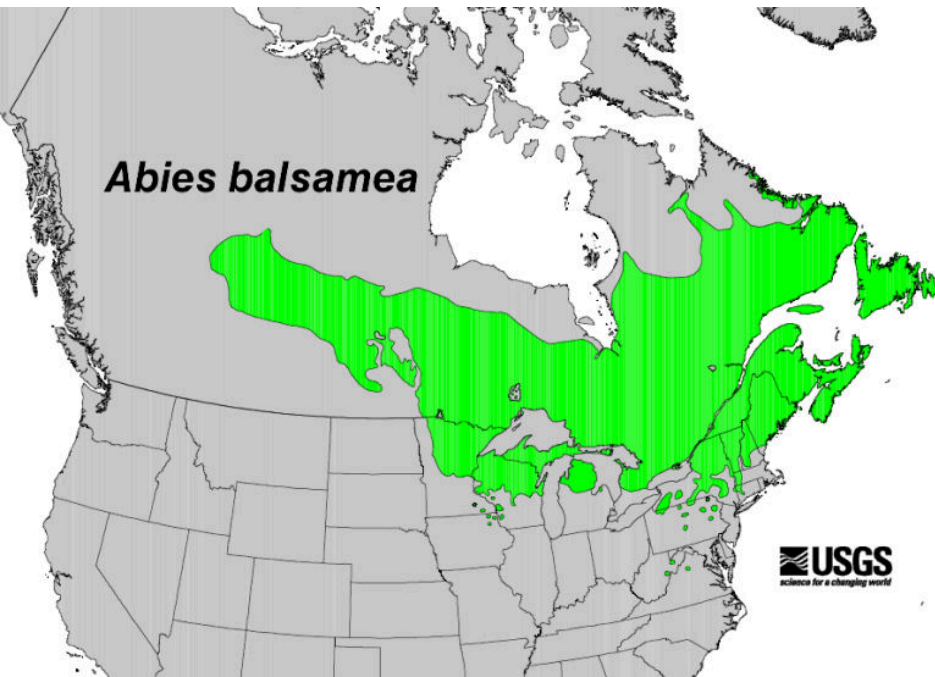


More drought = trees under stress and forest dieback
Should facilitate conversion to oaks and red maple

Native insects play a major role in forest change

Benign native insects can have outbreaks in a warmer climate. For example, mountain pine beetle in British Columbia—a native insect that caused massive tree mortality over 30 million acres of lodgepole pine forest, and could threaten jack pine in Minnesota





The Balsam woolly adelgid is in Maine and now has a route to get to MN—it just needs warmer winters

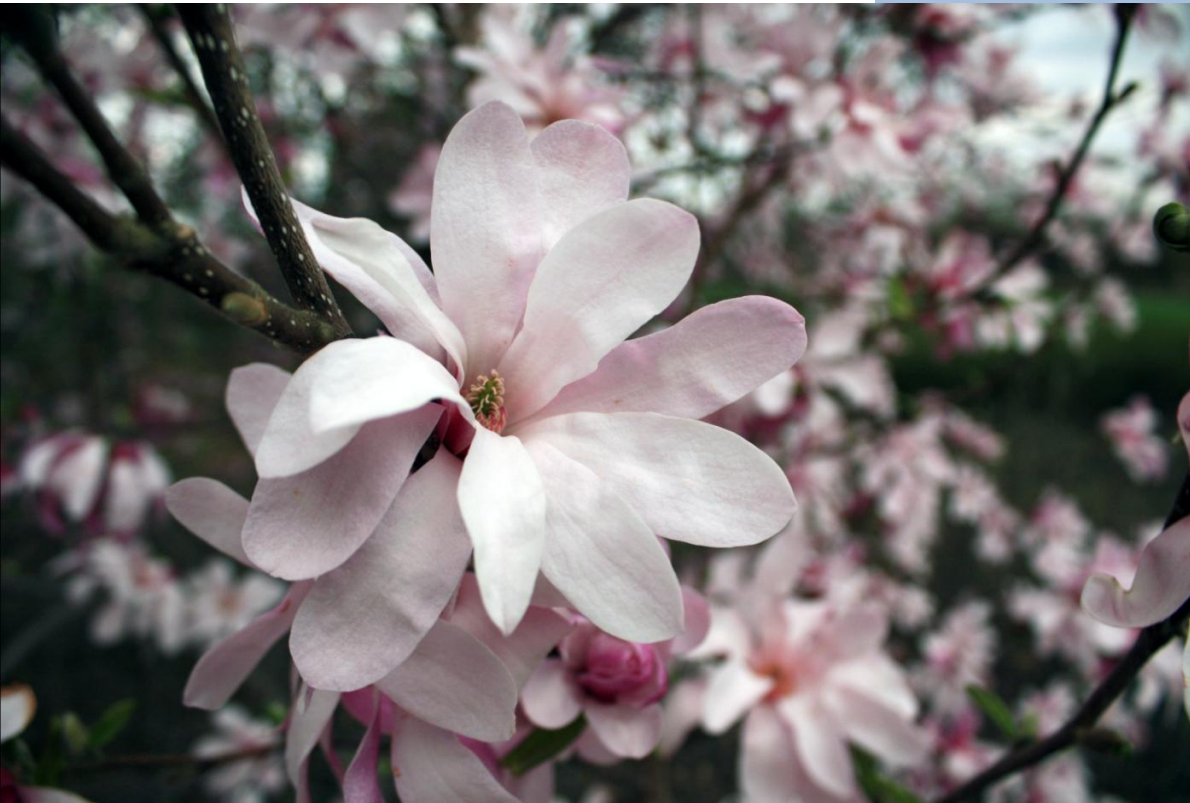
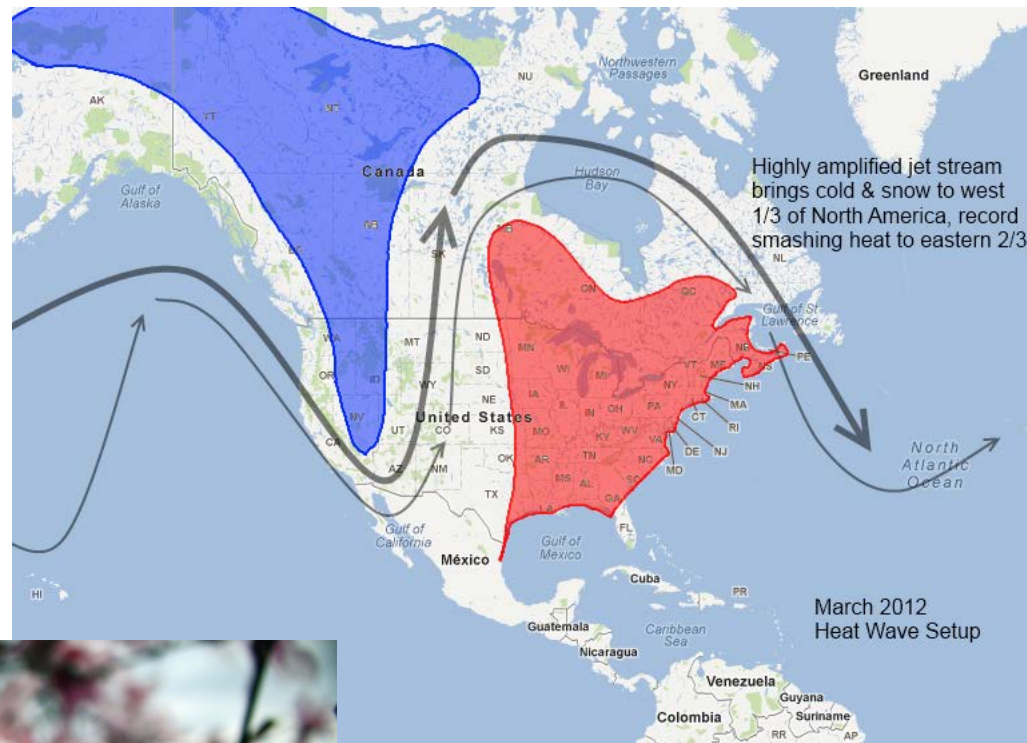
Global warming and cold/warm spells of weather:

- Warming is greater at the poles than equator
- Lesser temperature contrast between equator and poles
- Weaker westerlies
- More pronounced troughs and ridges in the jet stream
- More cold and warm temperature anomalies lasting several weeks



March 2012:

- 15,000 record highs in the U.S.
- Magnolias bloom in March in MN



Magnolia in bloom,
St.Paul Campus, March 27,
2012. Photo: Jenna Williams



Phenological disturbance

Browning of post-fire regeneration,
BWCAW, June 2012

Photo: Eli Anoszko

Winter browning of spruce
in Ontario, May 2012. Ontario
Ministry of Natural Resources





Boreal to temperate forest/savanna conversion mechanisms:

- Gap dynamics/gradual infiltration of temperate species
- Trophic cascade; delay followed by sudden change
- Wind/hail storms
- Wind + Fire
- Heat/drought stress
- Insect infestation (native and exotic) due to lack of extreme cold
- Phenological disturbance

All mechanisms operate on large tracts of land, only 1 is gradual

Photo, Eli Anoszko

Lots of redundancy; it's a matter of which mechanism operates first in a given location

At landscape/ecoregion scales a mosaic of conversion mechanisms and rates of change will occur



Forests of the BWCAW today



The BWCAW tomorrow. Gniess Outcrops Scientific and Natural Area, near Granite Falls MN (orange star)—an analog for the future BWCAW (blue star) in a warmer climate, with shallow rocky soils similar to the BWCAW. Photo: Minnesota River Basin Data Center

