Climate change and forests: maple, spruce or savanna?

Lee E. Frelich
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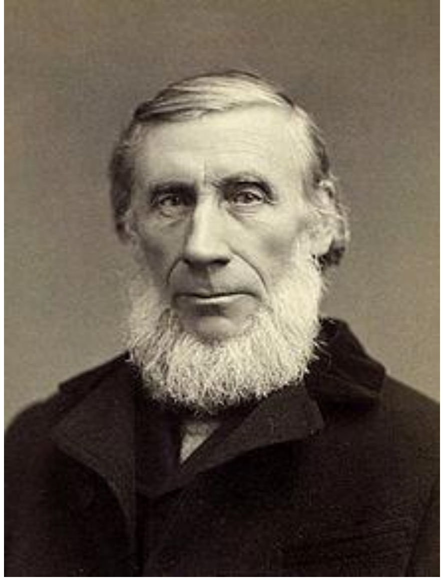
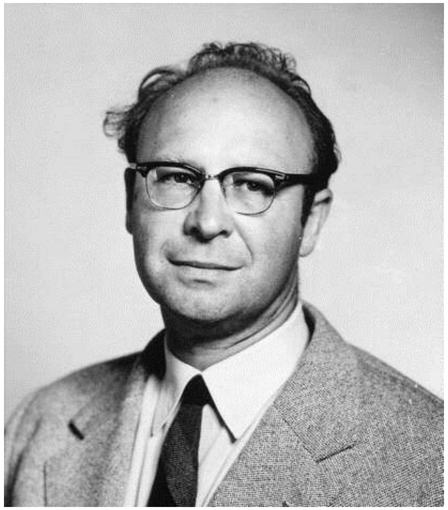
University of Minnesota



Fourier—discovered CO_2 is a greenhouse Gas—1820s

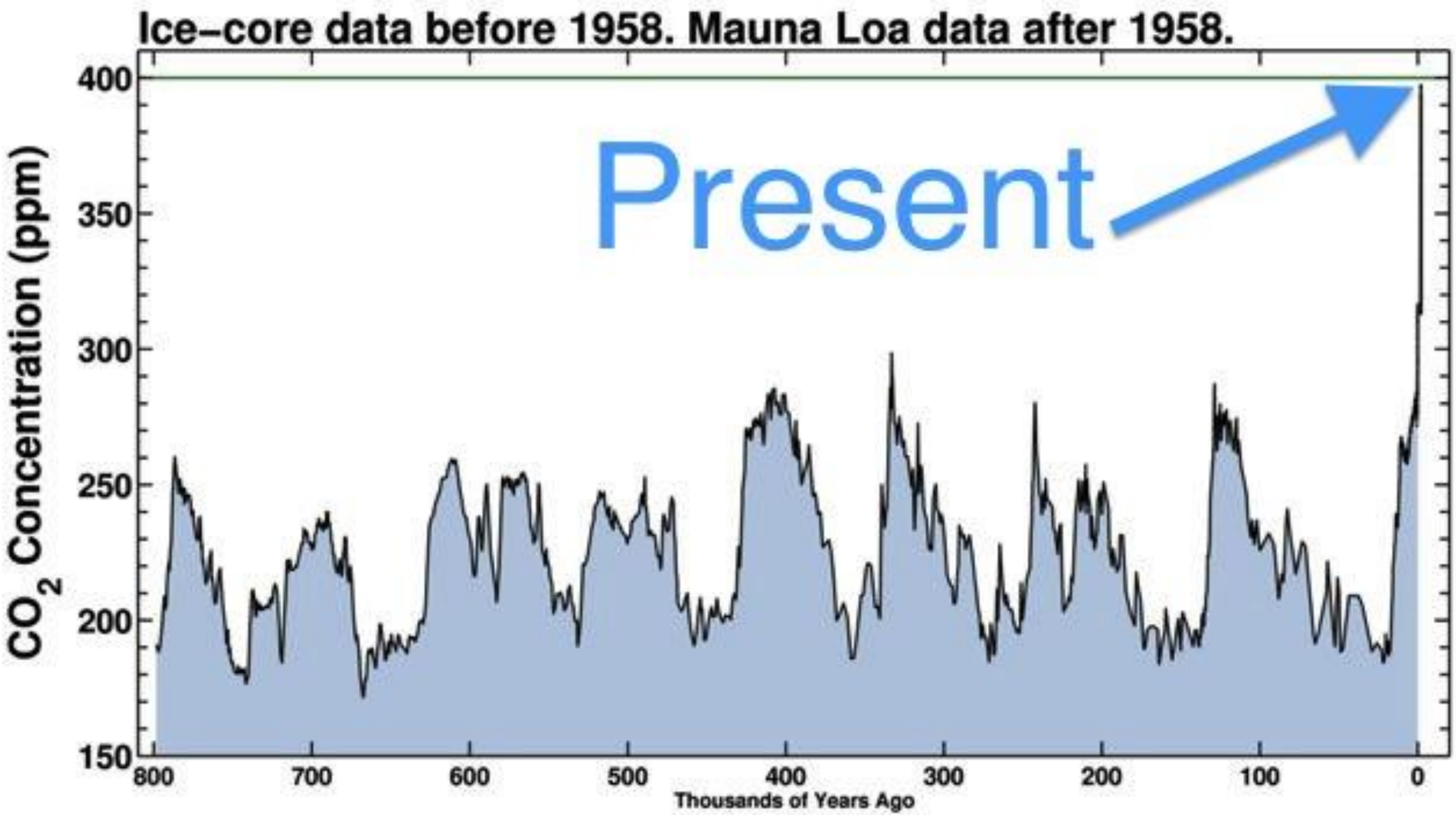
Tyndall—showed that CO_2 played a role in climate—1860s

Arrhenius—1st projections of mean temp for Earth for 2x CO_2—1896



Suess—proved that excess CO_2 in the atmosphere came from fossil fuels—1950s

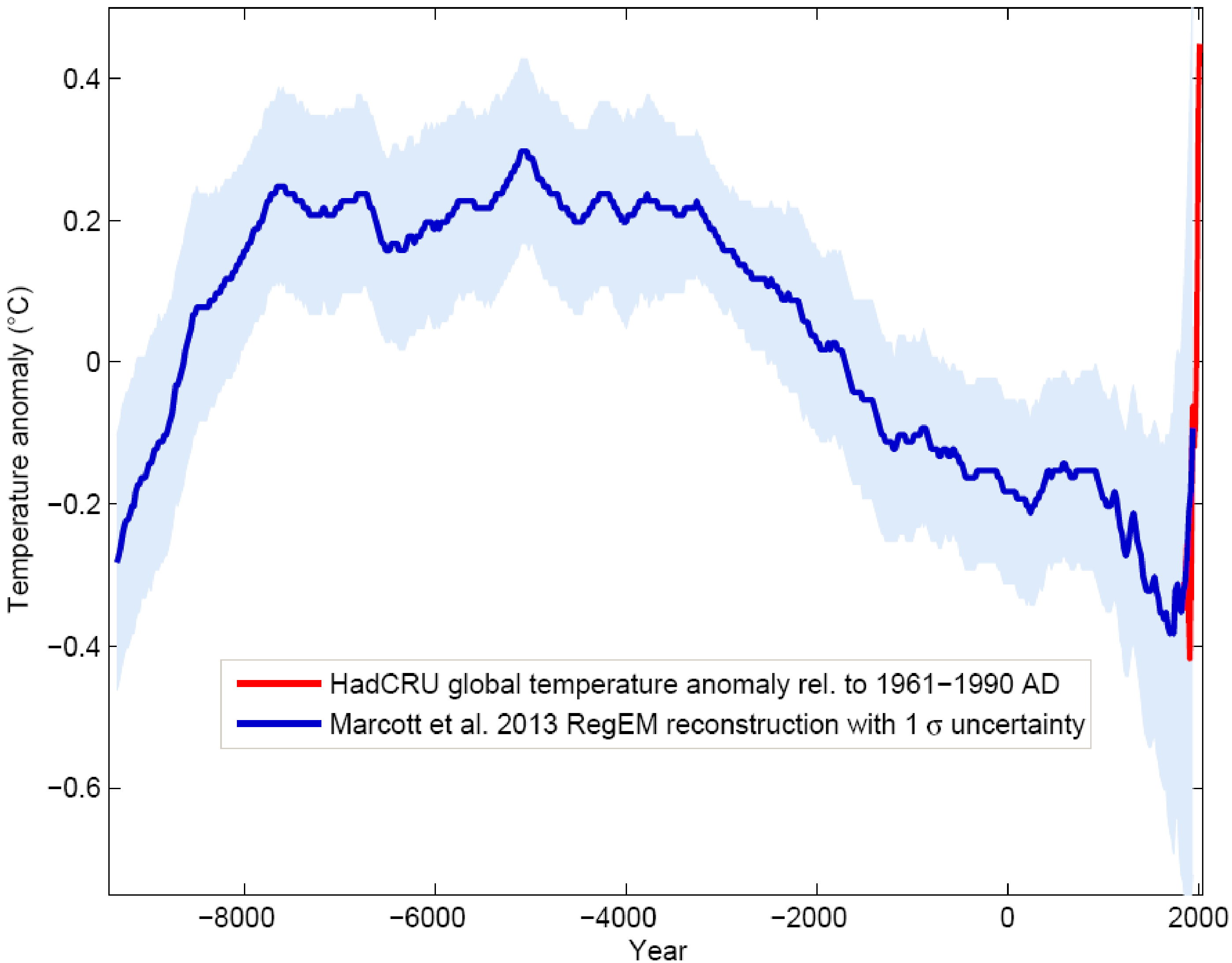
We have a massive 200-year body of scientific evidence on climate
Climate responds to the laws of physics, not people's opinions or beliefs



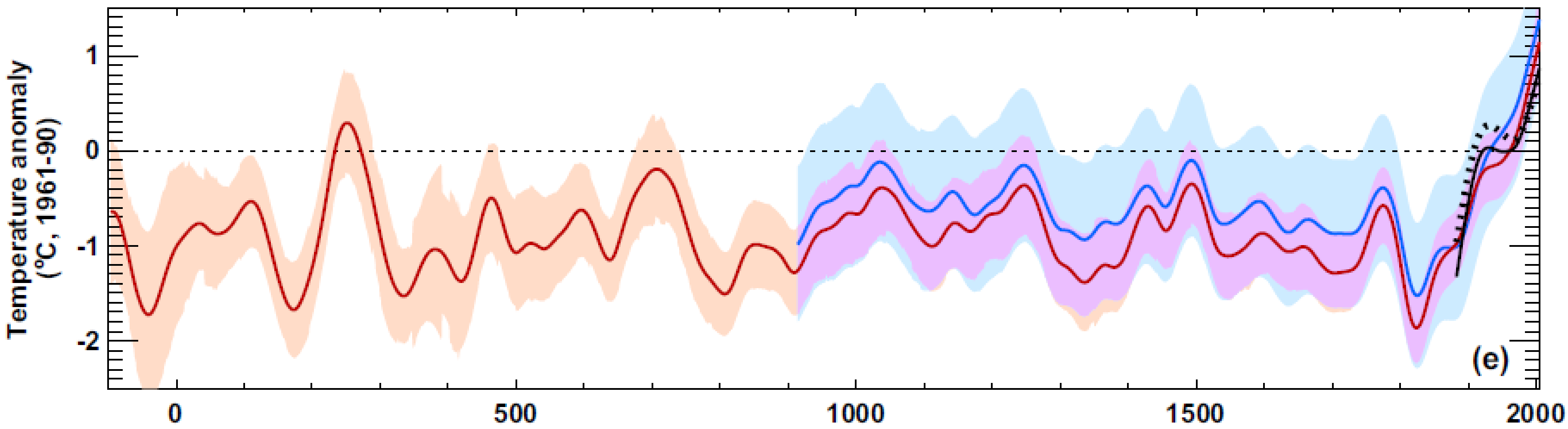
800,000 years of CO2, Scripps Institute of Oceanography

Climate change during the 20-21st Centuries is a reversal of a 5000 year natural trend towards a cooler climate.

Marcott et al., 2013, Science.



Tree-ring analysis of June-July and August mean temperature from the Yamalia and northern Ural Region, Russia



Quaternary Science Reviews 72 (2013) 83–107

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Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

ELSEVIER

Reassessing the evidence for tree-growth and inferred temperature change during the Common Era in Yamalia, northwest Siberia☆

CrossMark

Keith R. Briffa [a,*], Thomas M. Melvin [a], Timothy J. Osborn [a], Rashit M. Hantemirov [b], Alexander V. Kirdyanov [c], Valeriy S. Mazepa [b], Stepan G. Shiyatov [b], Jan Esper [d]

[a] *Climatic Research Unit, School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK*
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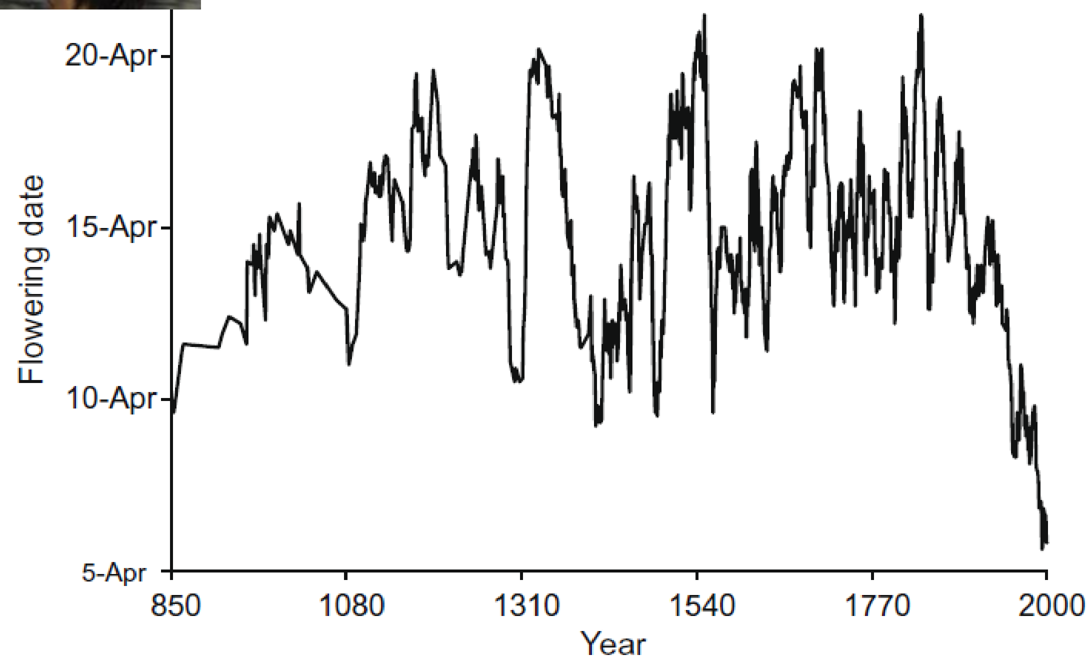
[d] *Department of Geography, Johannes Gutenberg-University, 55099 Mainz, Germany*

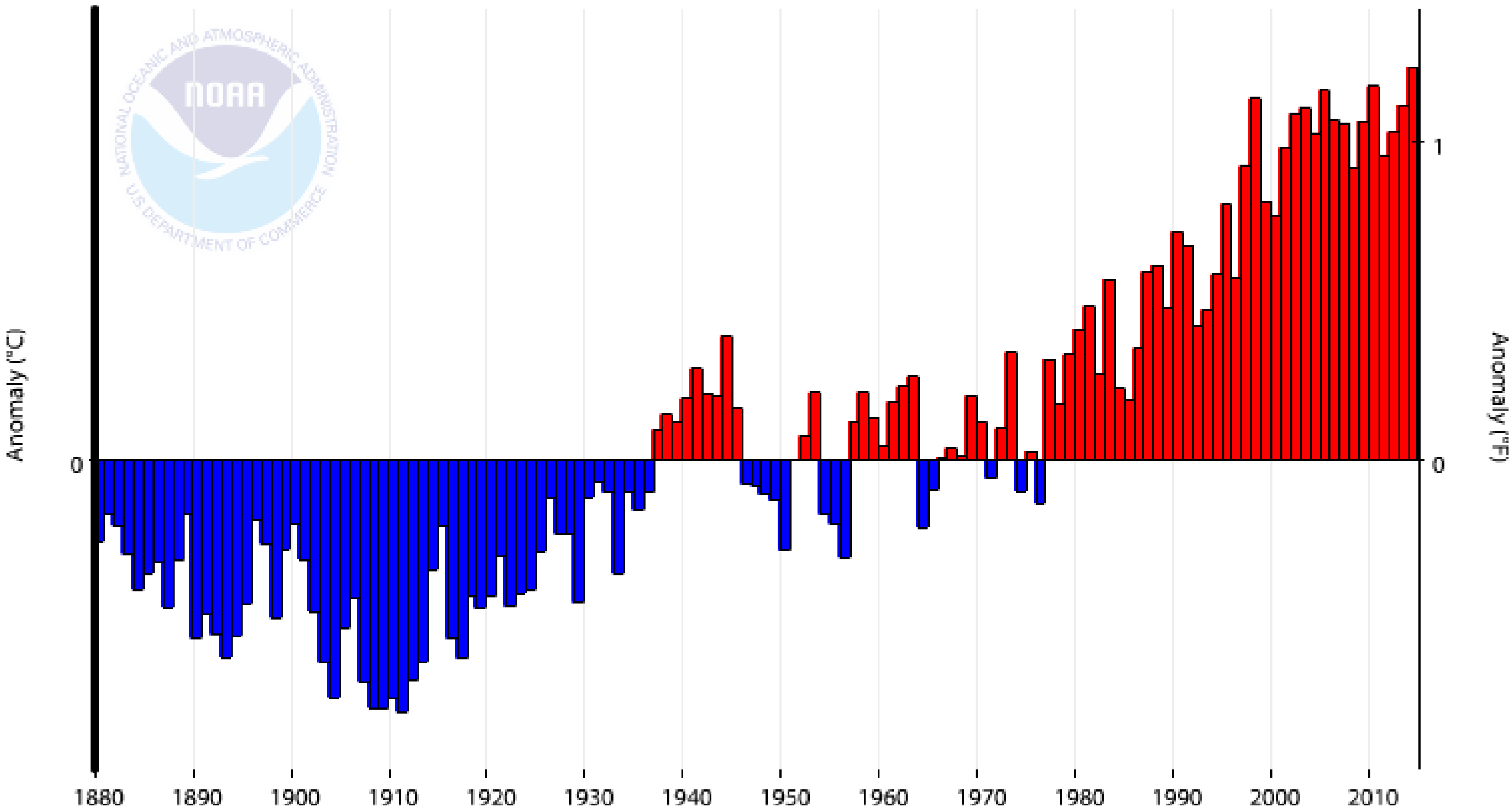
Court records of cherry blossom time

Dates of cherry blossoming in Kyoto. 3.3 ^{o}C warming in recent times, 1.1 from urban heat island and 2.2 from regional climate warming

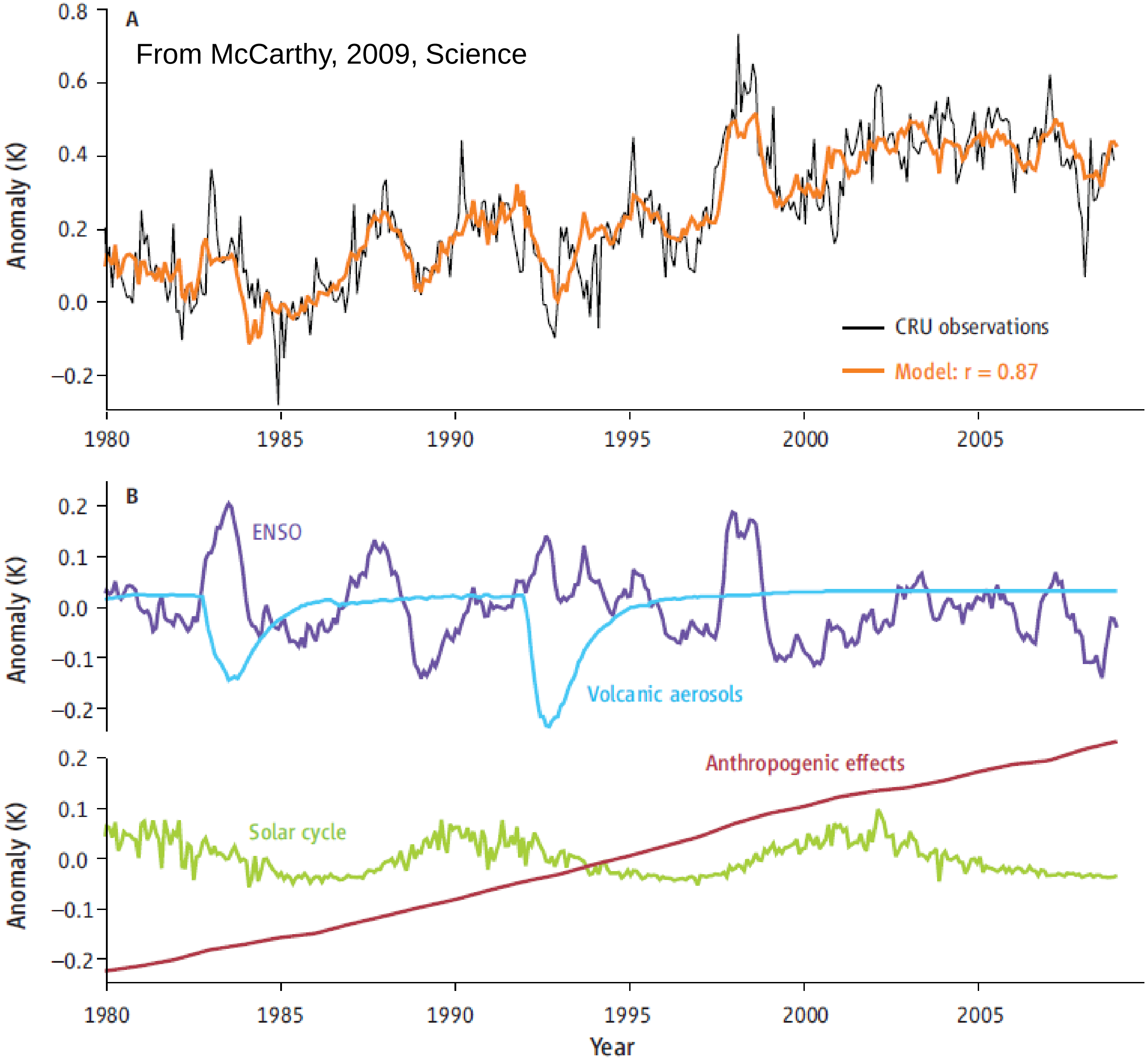
From Primack et al 2009
Biological Conservation 142.

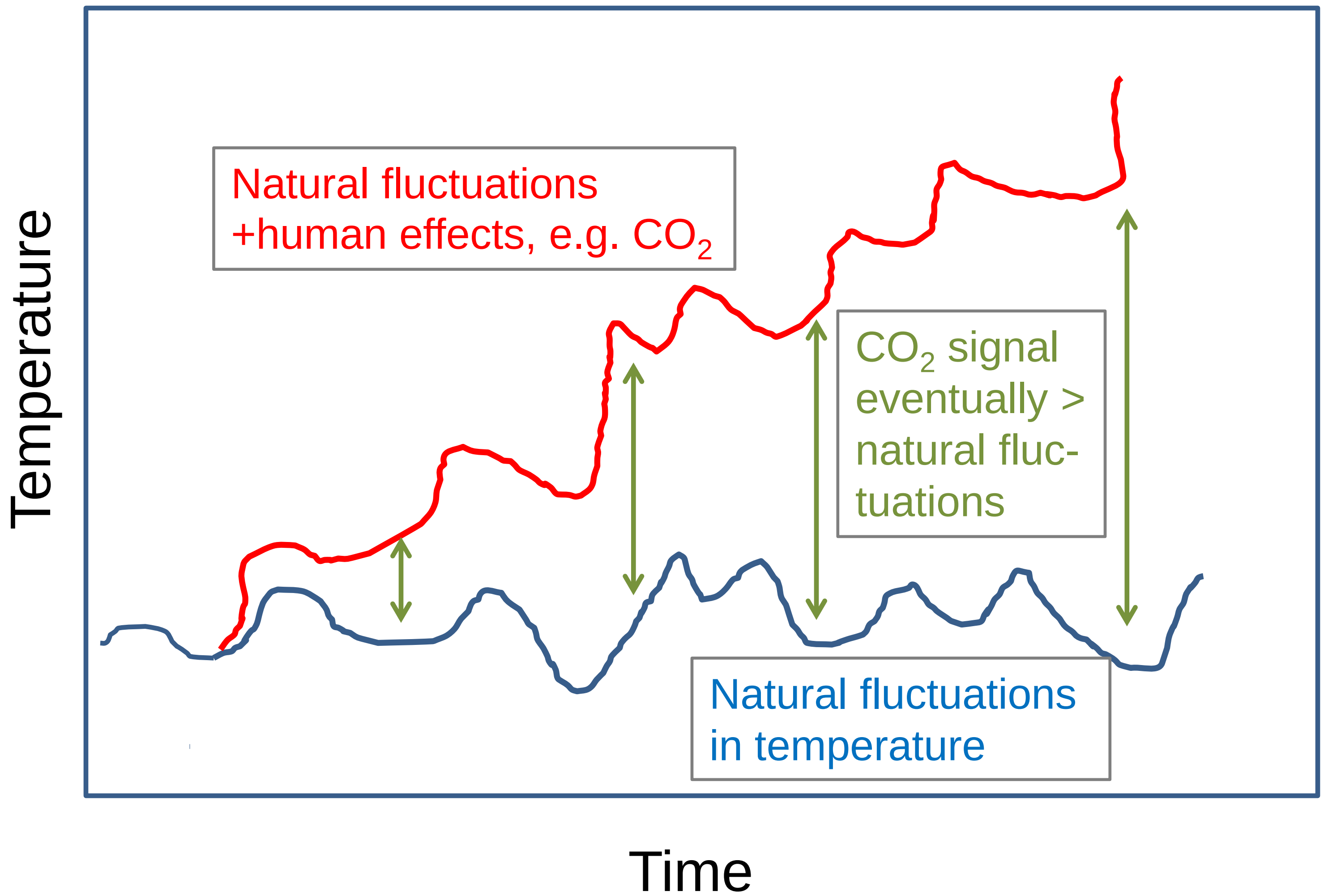


Global Land and Ocean Temperature Anomalies, January-December



Modeling of temperature (1980-2010) shows how natural and human influences work together to explain the recent upward temperature trend.

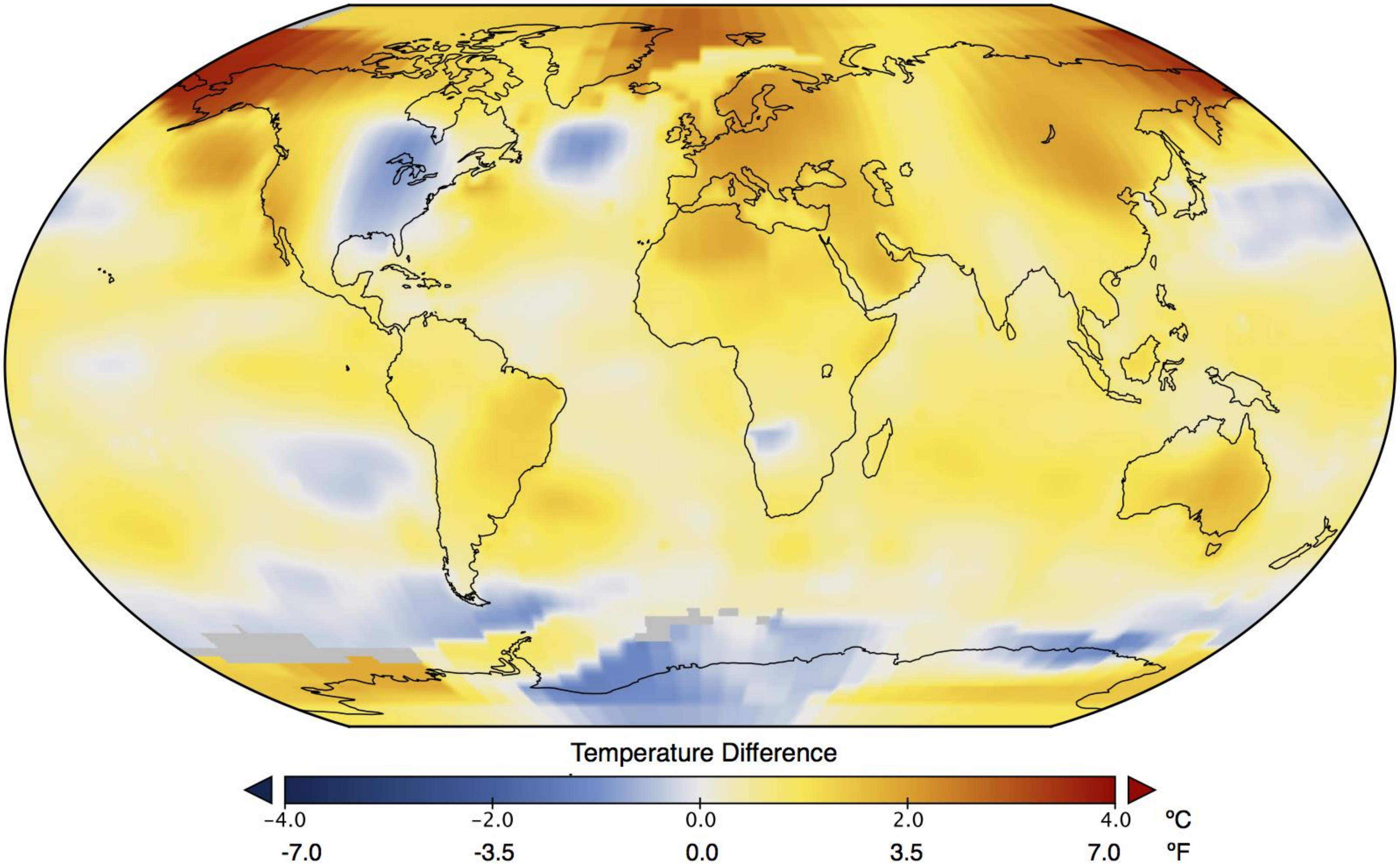




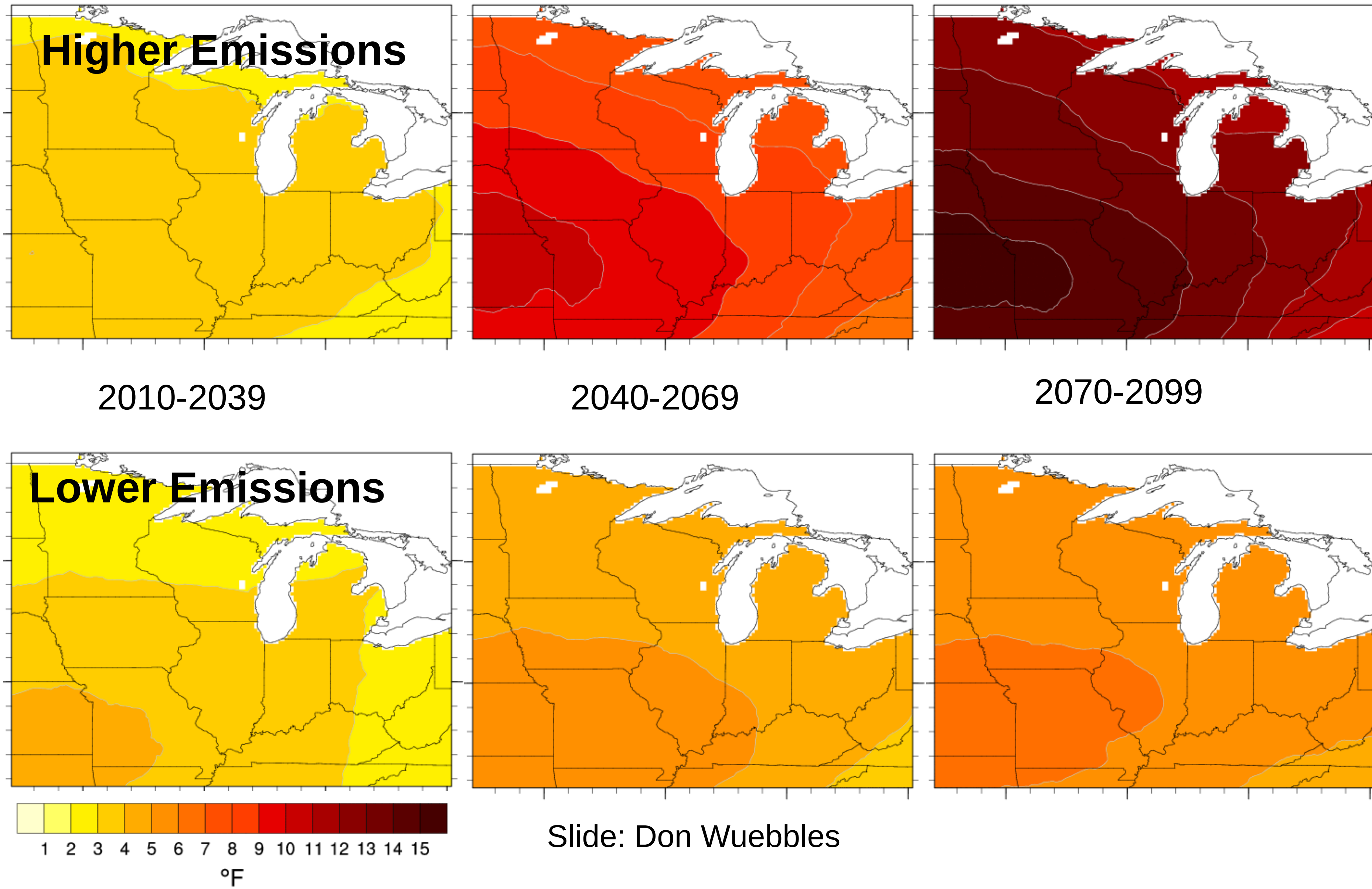
Natural fluctuations
+human effects, e.g. CO2
CO2 signal eventually > natural fluc-tuations
Natural fluctuations in temperature
Temperature
Time

NASA GISS 2014 Global Temperatures

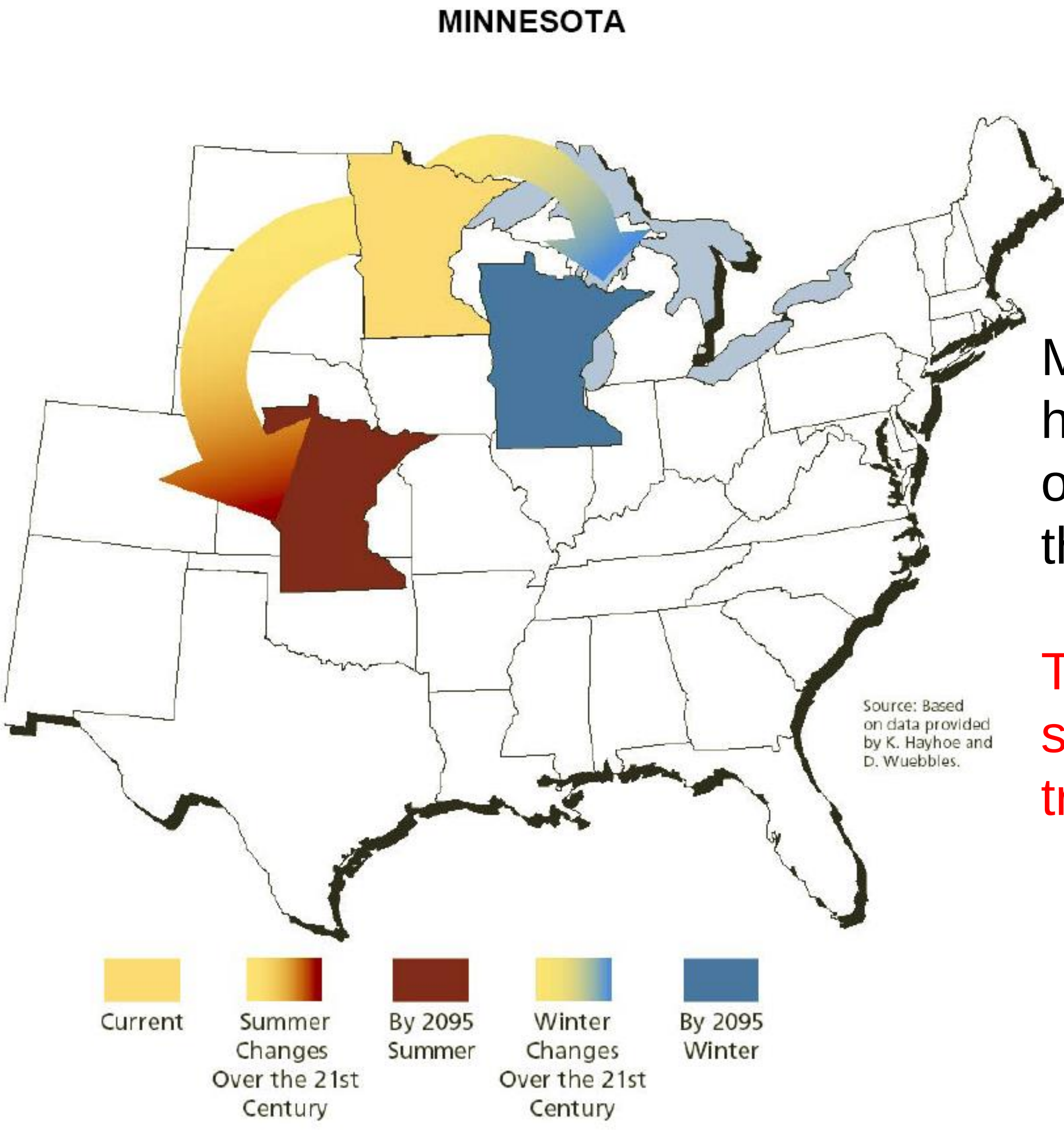
with respect to 1951–1980



Change in summer (JJA) temperature



Slide: Don Wuebbles



Minnesota will likely have the summer climate of NB and KS by the end of the century.

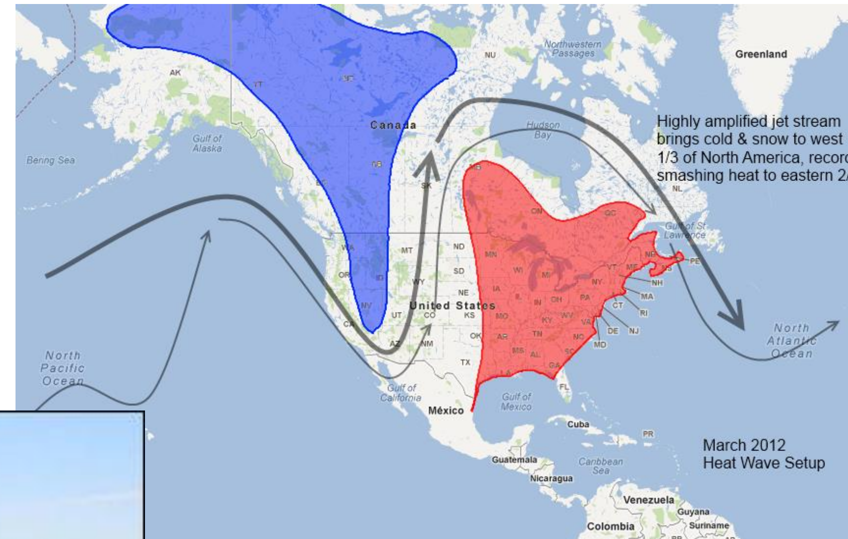
This will cause northward range shifts of ca 300 miles for most tree species

Global warming and phenology:

- 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, extreme early spring, with temperatures equal to projections for 2090

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

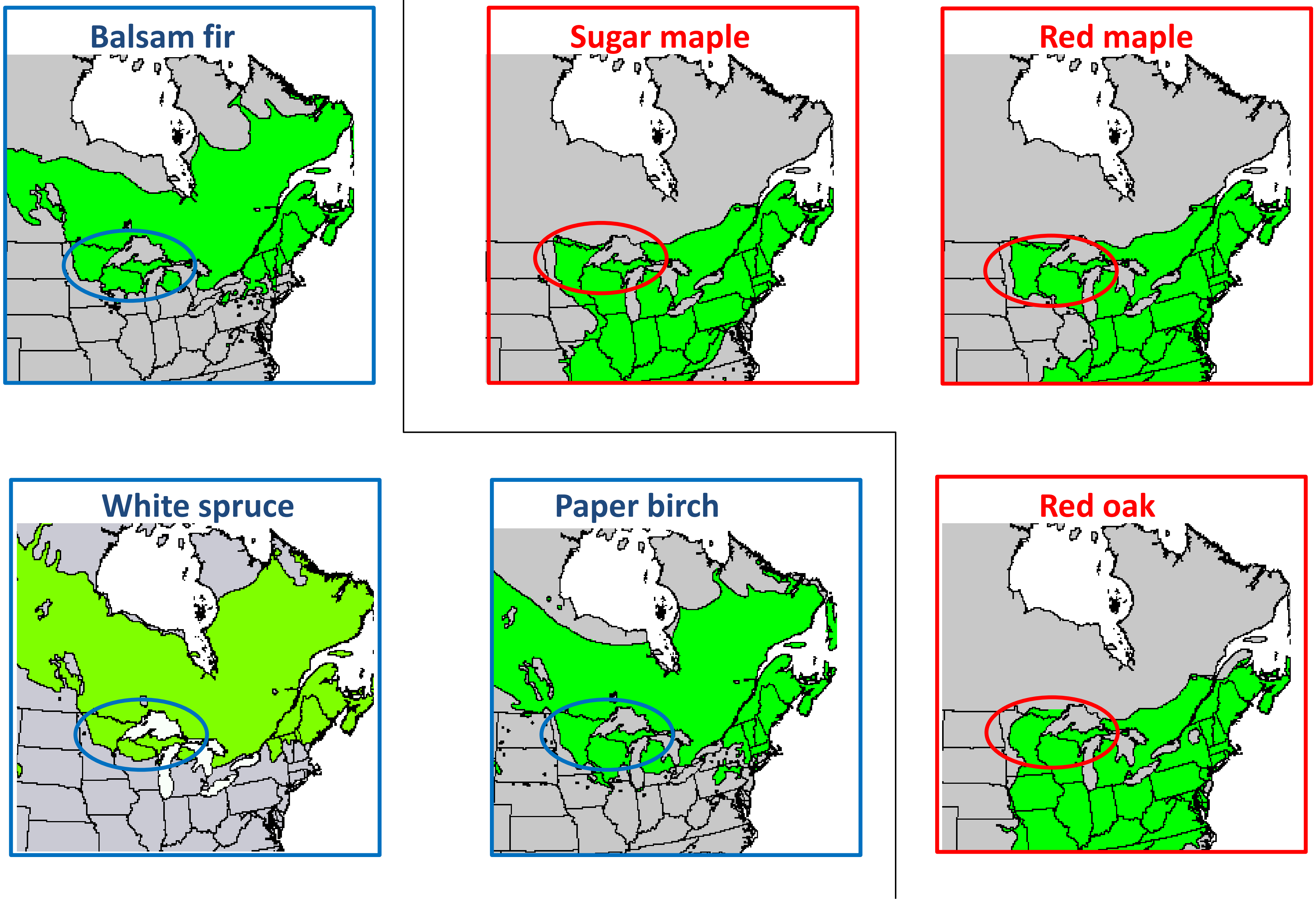


Winter browning of spruce in Ontario, May 2012. Ontario Ministry of Natural Resources

Range Distributions of Temperate and Boreal Species

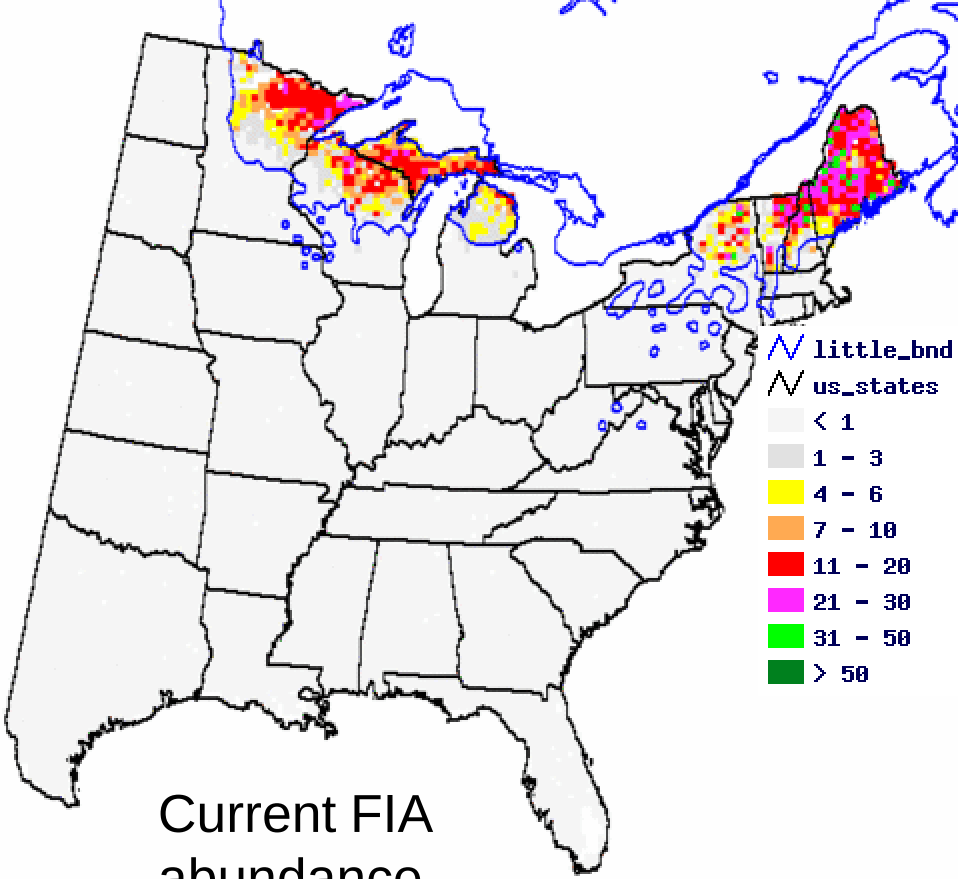
Boreal Trees

Temperate Trees

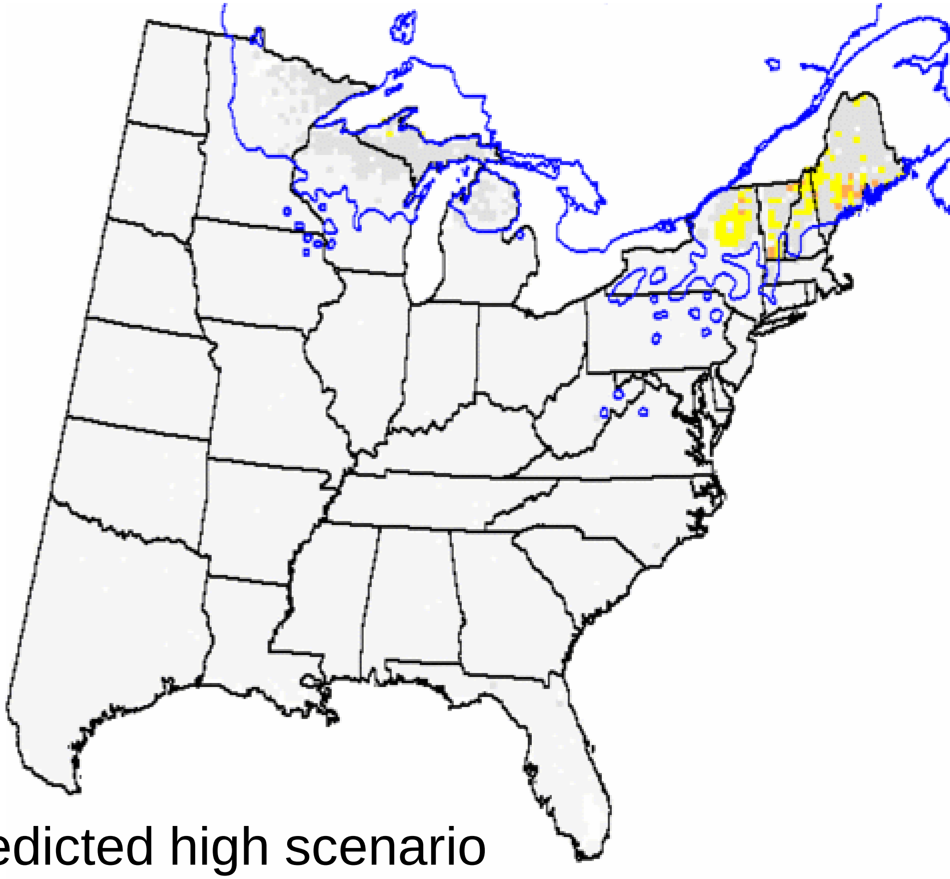


Balsam fir abundance: Current FIA compared to predictions for high emissions scenario

Source: USDA Climate and Tree Atlas



Current FIA abundance



Predicted high scenario

Nick Danz—Prairie forest Border. UW-Superior

Chaina Bapikee—Sugar maple abundance across a regional climate gradient. Kristi Nigul

Recent PhD graduates—climate change

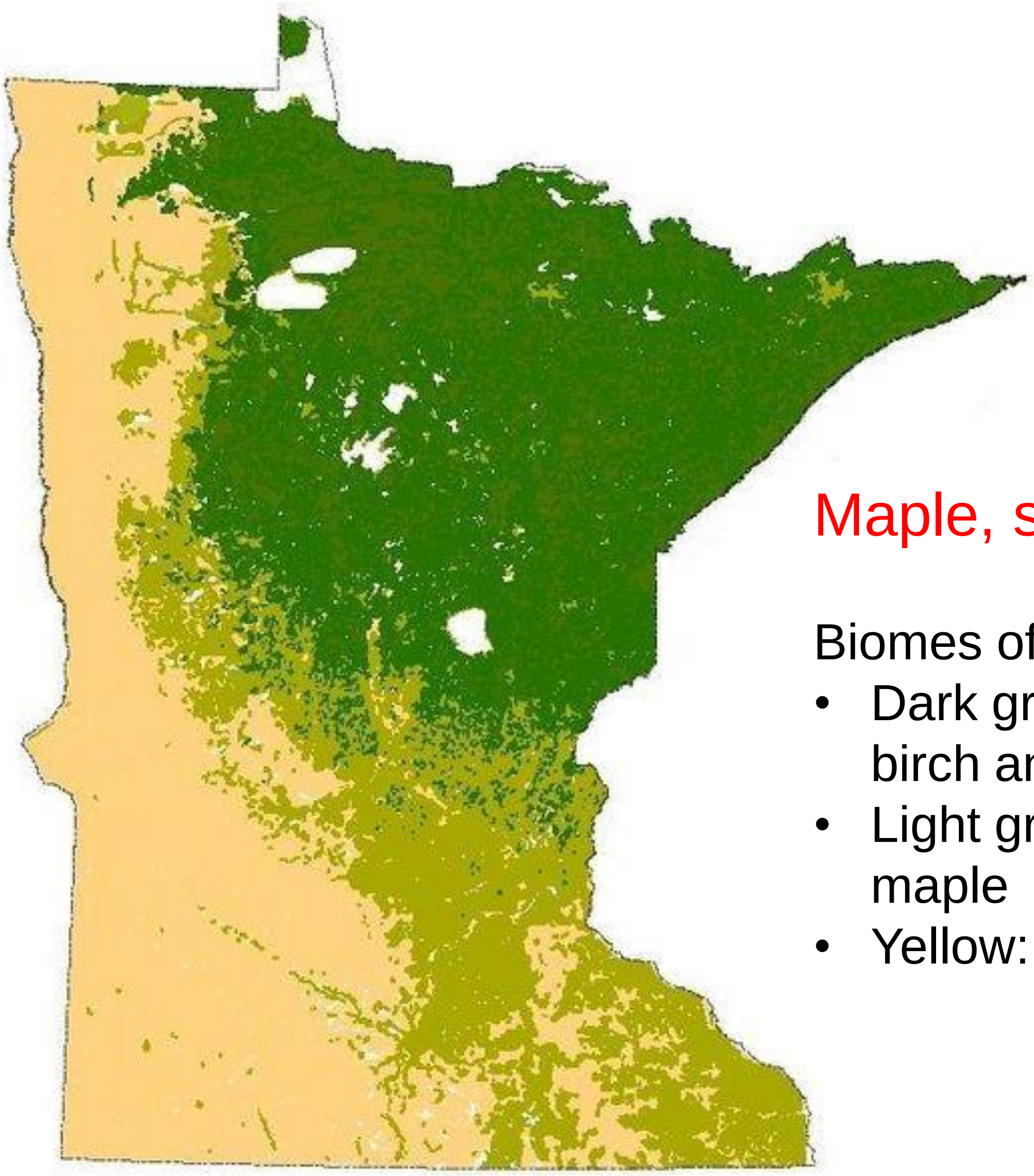
Roy Rich (left)—Large-scale wind and forests

Nick Fisichelli (right)—Mesic boreal-temperate transition. Dave Hansen.

Dave Chaffin—Temperature patterns across the landscape; invasion of temperate tree species into the boreal forest

Eli Anoszko—Combined wind and fire effects on boreal forests in a changing climate

Current PhD students—climate change



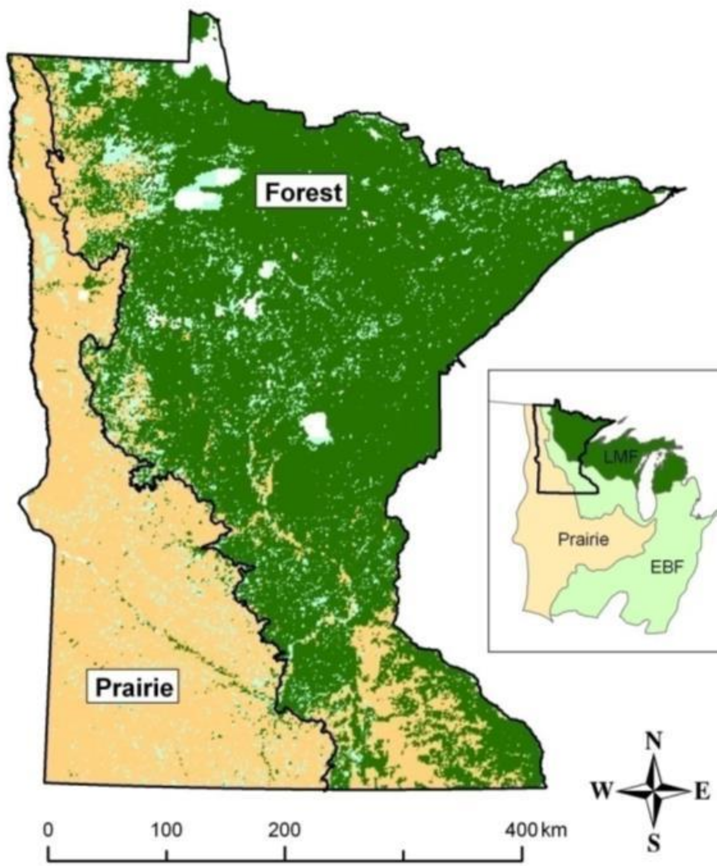
Maple, spruce, or savanna?

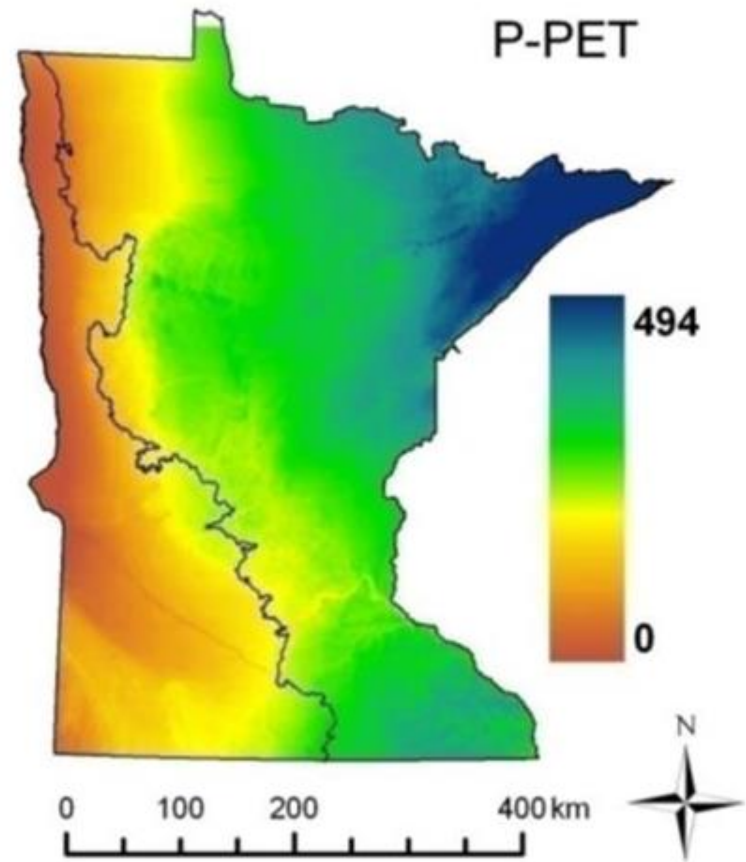
Biomes of Minnesota:

- Dark green, boreal conifers with birch and aspen
- Light green, deciduous oak and maple
- Yellow: grassland

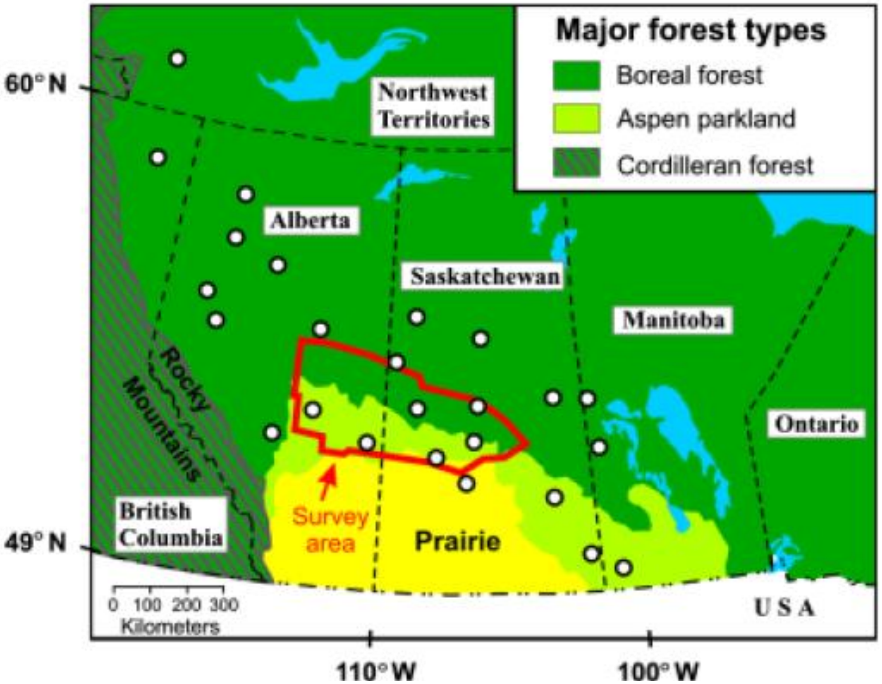
The Prairie-forest border of Minnesota:

- Precipitation – Evapotranspiration was most important factor
- Transition from grass to forest was abrupt across a gradual climate gradient





From: Danz, Reich, Frelich and Niemi, 2011, *Ecography* 34: 402-414;
Danz, Frelich, Reich and Niemi, 2013, *Journal of Vegetation Science*, 24: 1129-1140



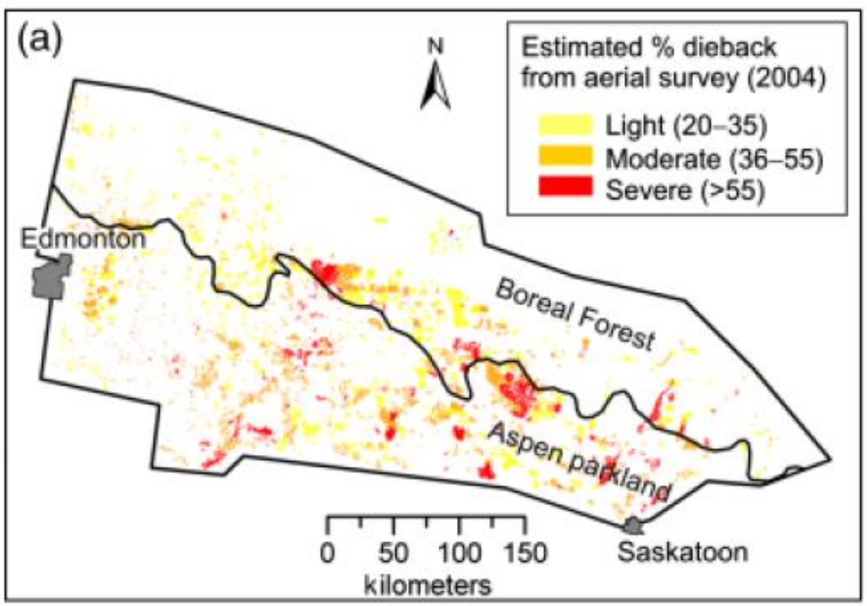
Global Change Biology

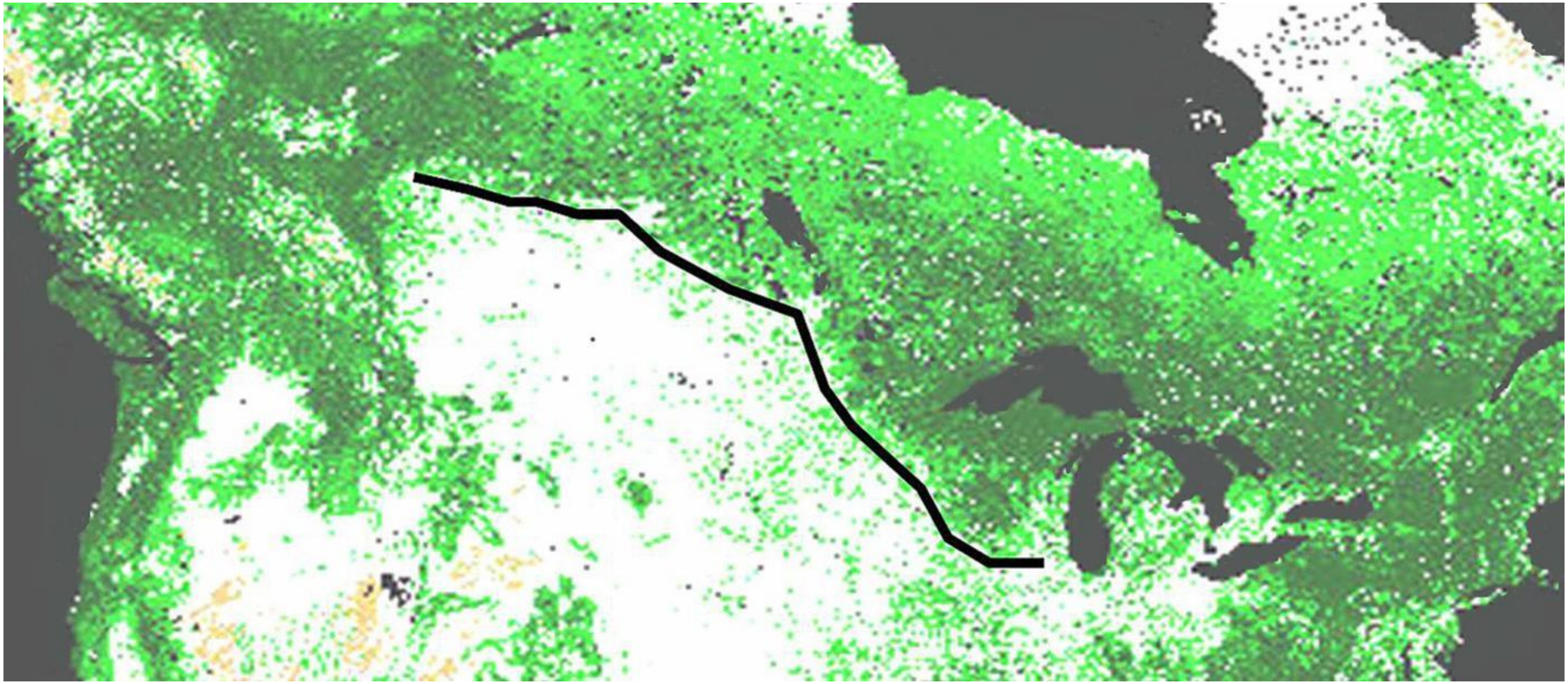
Global Change Biology (2011) **17**, 2084–2094, doi: 10.1111/j.1365-2486.2010.02357.x

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





Forest cover of central North America (green). DeFries, R., M. Hansen, J.R.G. Townshend, A.C. Janetos, and T.R. Loveland (2000), 1 Kilometer Tree Cover Continuous Fields, 1.0, Department of Geography, University of Maryland, College Park, Maryland, 1992-1993.

It is possible that the prairie-forest-border will move 300 miles to the north and east by 2100, deforesting an area 2X the size of CA. The BWCAW will be at the prairie-forest border!

Drought, insect infestation, wind and fire will accompany climate change

Photos above and below: Dave Hansen

War of the worms

What turns a humble friend of the soil into an environmental menace? Jessica Marshall investigates

DEEP IN the woods of Minnesota, an army of environmental do-gooders has gone bad. Very bad. Seemingly hell-bent on wrecking the forest floor, it is wiping out plants and wild flowers and leaving only hard, bare soil in its wake. If someone doesn't find a way to stop them, the forests of the Midwest will be doomed.

A similar sorry tale is being told all over the world, but the identity of the culprit will come as something of a surprise. Of all the creatures capable of destroying ecosystems and wiping out species, it is perhaps the least likely. It's the ecological equivalent of a gentle but murderous granny: it is the earthworm.

Earthworms have a reputation as environmental good-guys, churning and enriching the earth as they munch their way through soil and leaf litter. The trouble is that Minnesota shouldn't have any worms. Nor should anywhere else in the US and Canada north of a line that runs roughly west from Boston – at least not since the end of the last ice age 10,000 years ago. These worms are invaders who hitched a ride with goods and settlers from Europe three centuries ago, and are now brought in as fishing bait.

In Minnesota the worms have a clear run at worm-free zones, but elsewhere in the world, worm wars are being fought between native species and exotic intruders. In the Carpathian Mountains of Romania, several species of native earthworms are being displaced by hardier invaders from other parts of Europe, probably brought in inadvertently through agriculture or deforestation. In the UK, native earthworms, including one of the species that's causing trouble in Minnesota, are under threat from two foreign flatworms, *Arthurdendyus triangulatus* from New Zealand and the Australian *Australoplana sanguinea*, which inject enzymes into their prey before eating them alive.

www.newscientist.com

Global warming or Global worming?

Earthworms are ecosystem engineers that alter soil structure, reduce water and nutrient availability, with large reductions in tree growth rate.

They also warm the soil!

Direct effects of earthworm invasion

- Removal of organic horizon
- Compaction of mineral soil
- Disturbance of soil

Indirect effects

- Alteration of seedbed conditions
- More runoff, drier soils
- Lower nutrient availability

Cascading effects on plant community

- Drought stress
- Changing growth rates and alteration of competitive relationships
- Mortality of plant populations
- Lower native plant species richness

Continued cascading effects

- Water quality
- Wildlife and insect habitat
- Facilitation of invasive plant species
- Plant animal interactions

Earthworm-free sites

Photos: Paul Ojanen, George Schlaghamersky

Heavily infested sites with sedge lawn (above) and bare soil (below).

Photos: Paul Ojanen

1990

Deer and drought causing failure of sugar maple reproduction. Example: Sylvania Wilderness from 1990 to 2006

From Salk, Frelich, Sugita, Calcote, Ferrari and Montgomery. 2011. *Forest Ecology and Management* 261: 1998-2006.

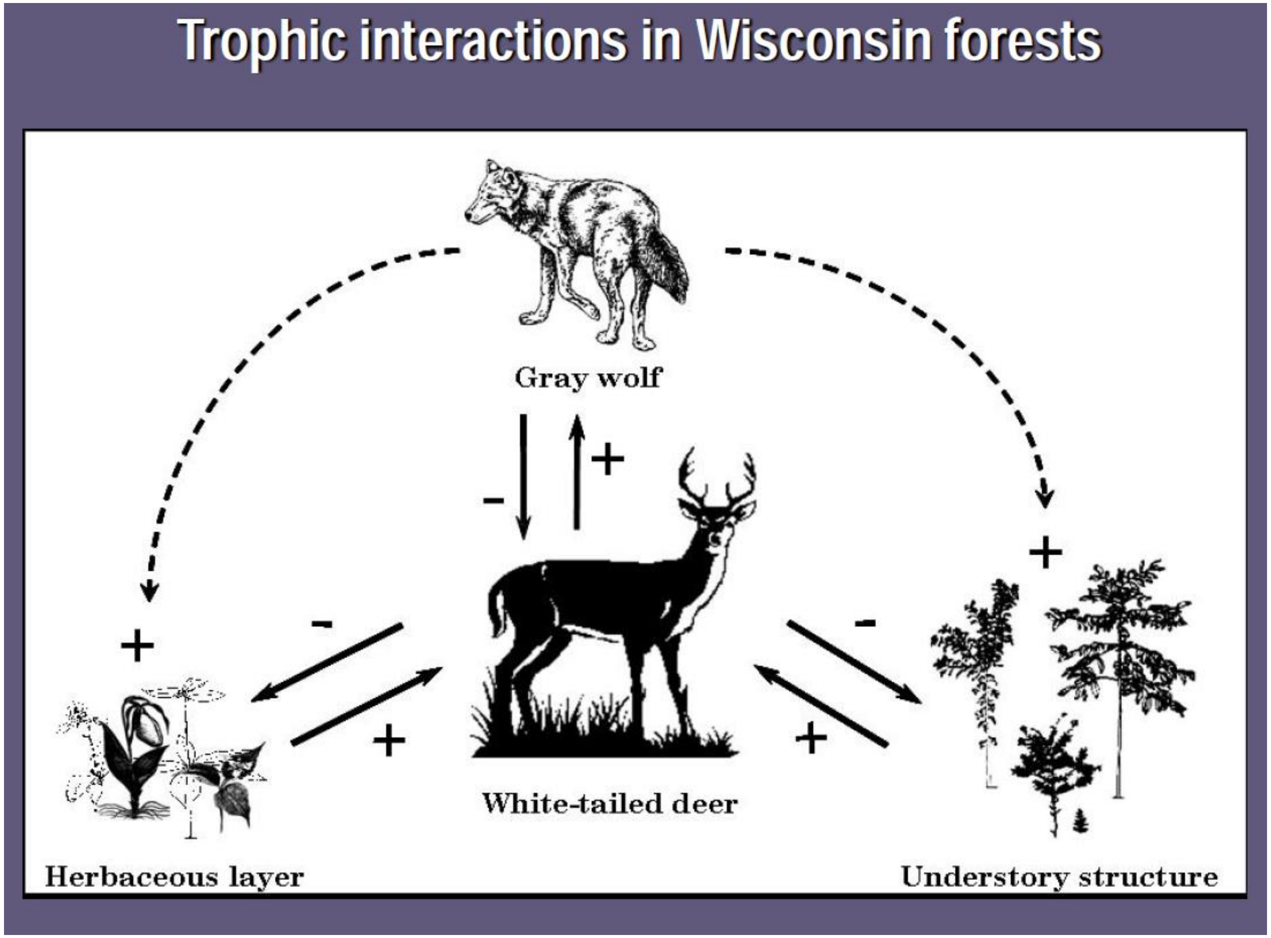
2006

100 YEARS Journal of Ecology British Ecological Society

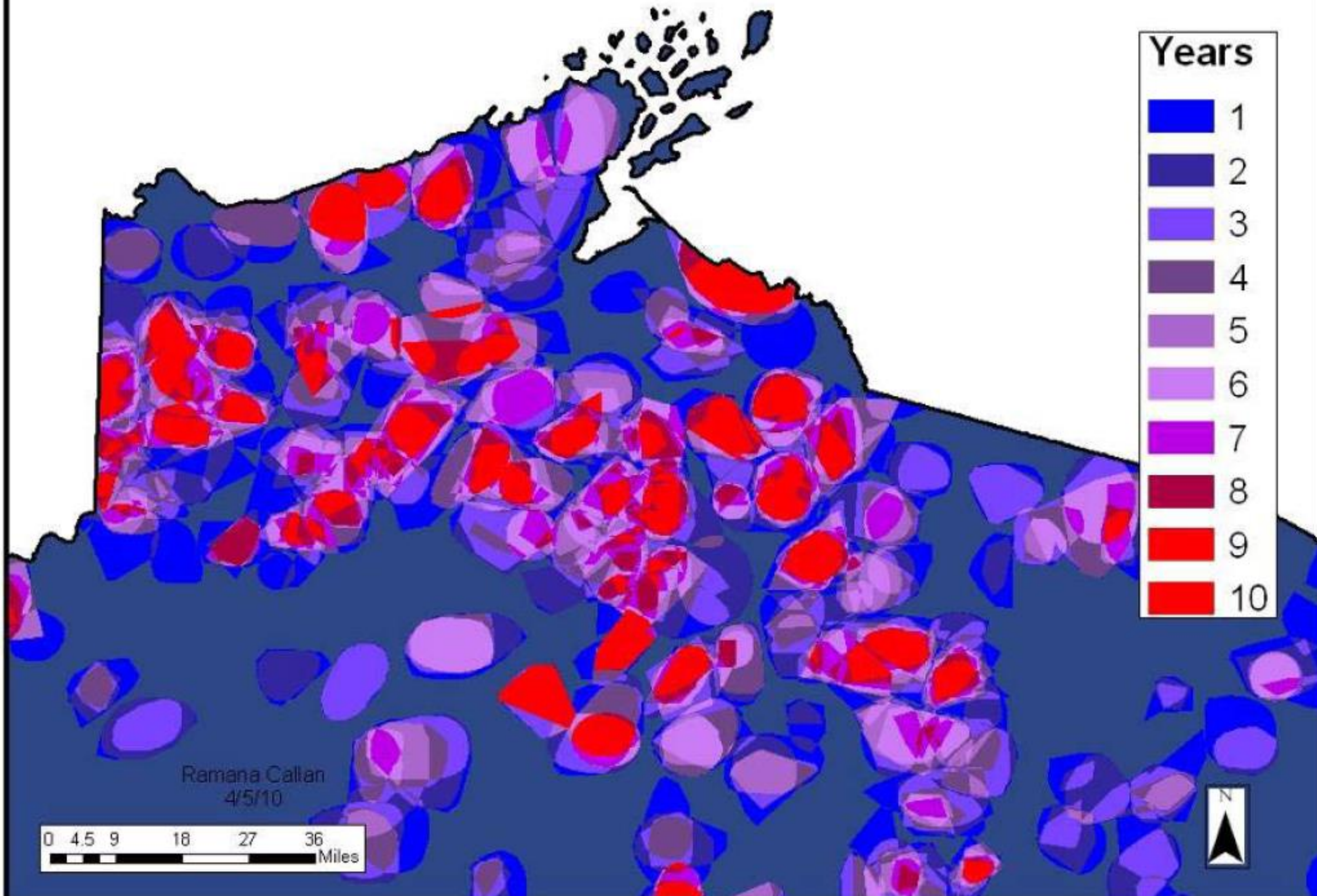
Journal of Ecology 2013, **101**, 837–845 doi: 10.1111/1365-2745.12095

Recolonizing wolves trigger a trophic cascade in Wisconsin (USA)

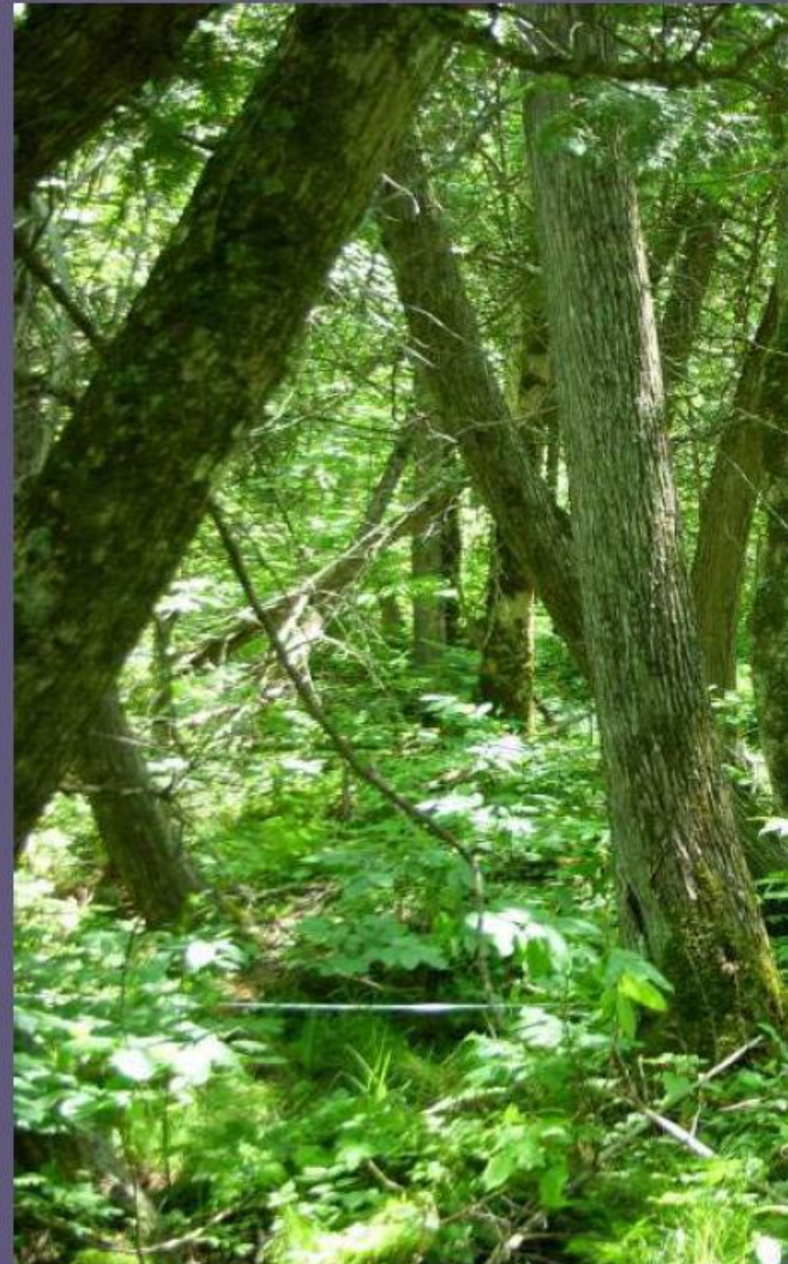
Ramana Callan[1]*, Nathan P. Nibbelink[2], Thomas P. Rooney[3], Jane E. Wiedenhoeft[4] and Adrian P. Wydeven[4]



Landscape Mosaic of Potential Wolf Impact (WI)

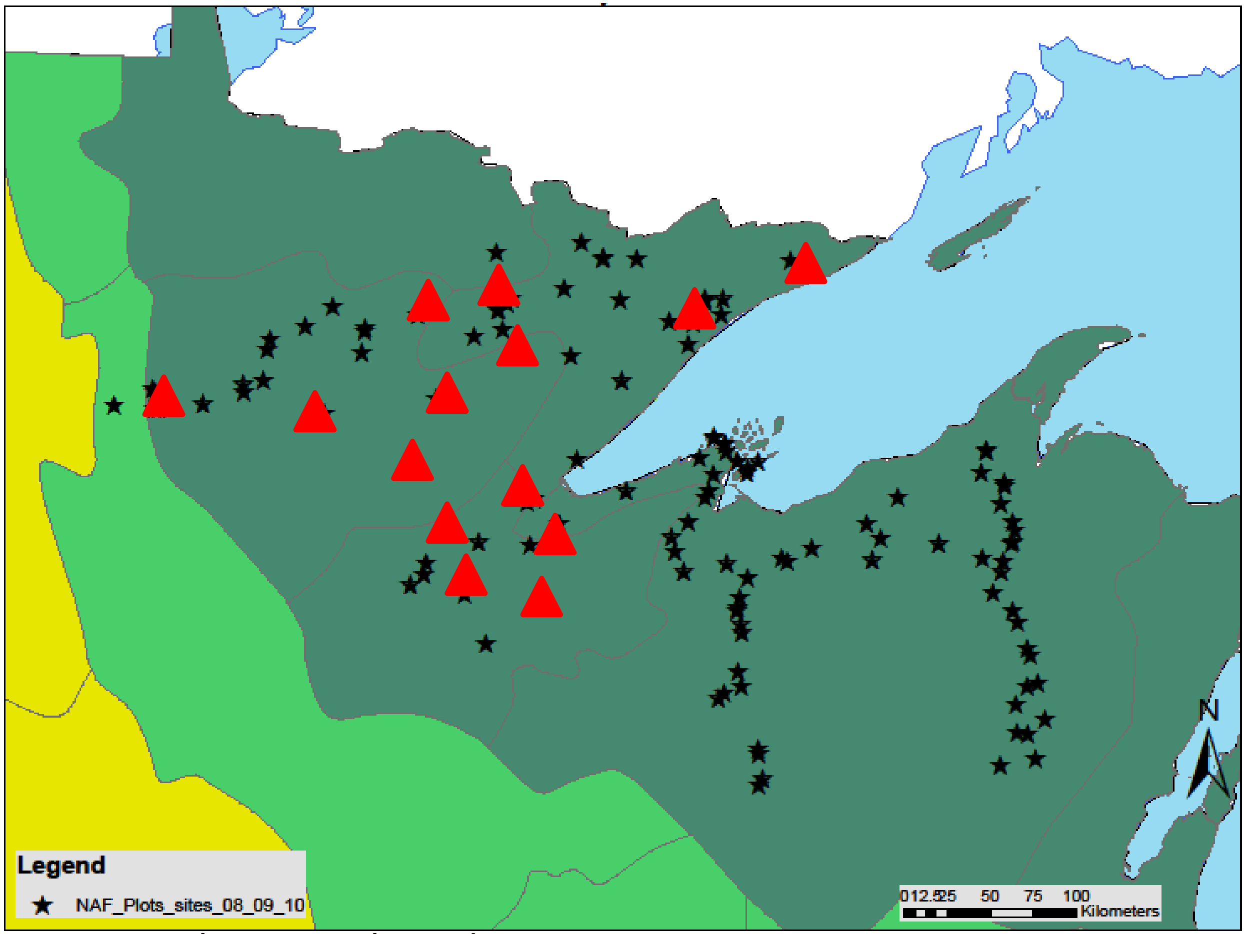


Low wolf impact area



High wolf impact area

Boreal (spruce-fir-) interactions with temperate (maple-oak-basswood) forests

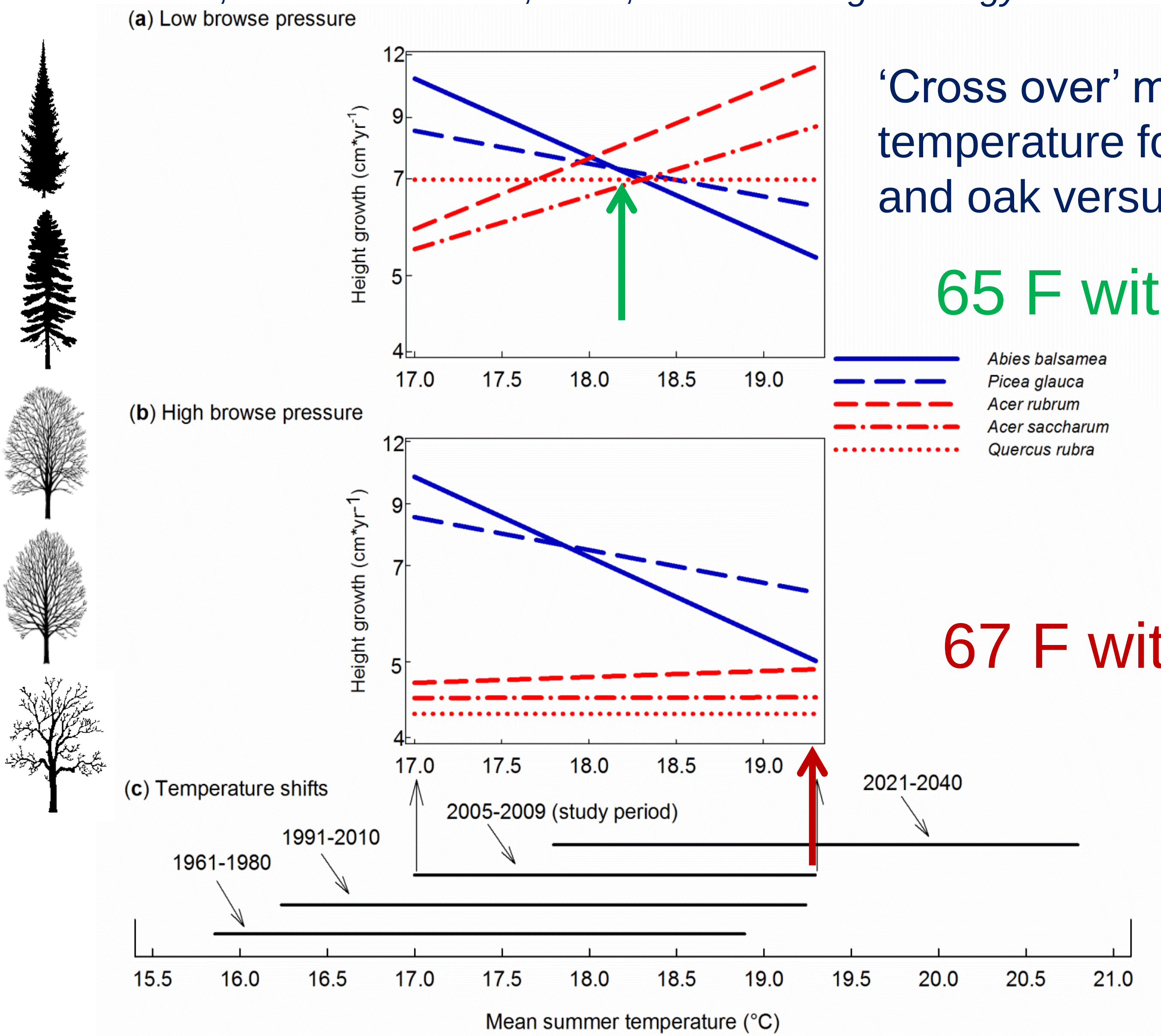


14 Sapling growth study sites

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

Temperate sapling relative performance ‘cooled’ by deer.

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

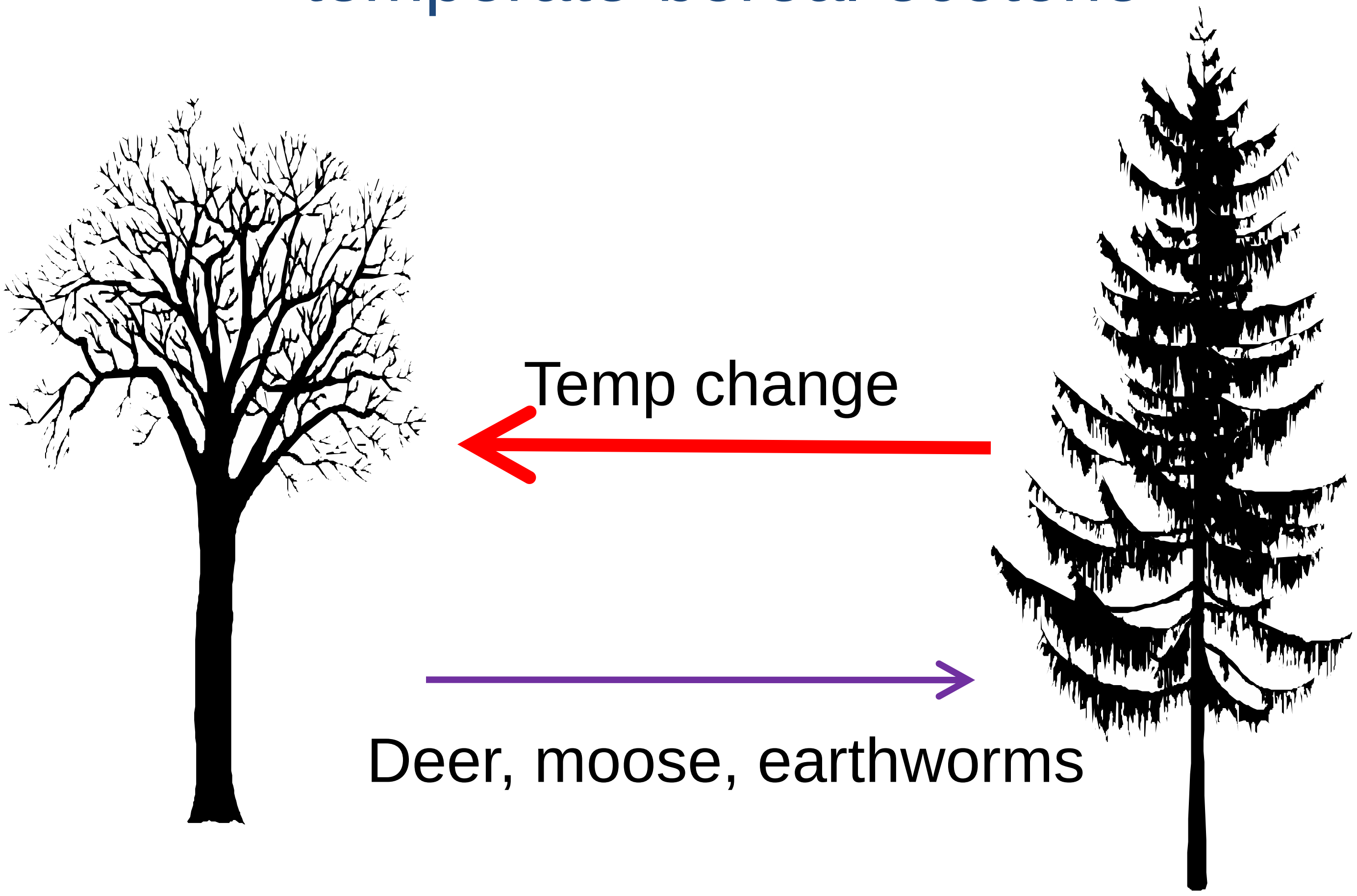


‘Cross over’ mean summer temperature for growth of maple and oak versus spruce and fir:

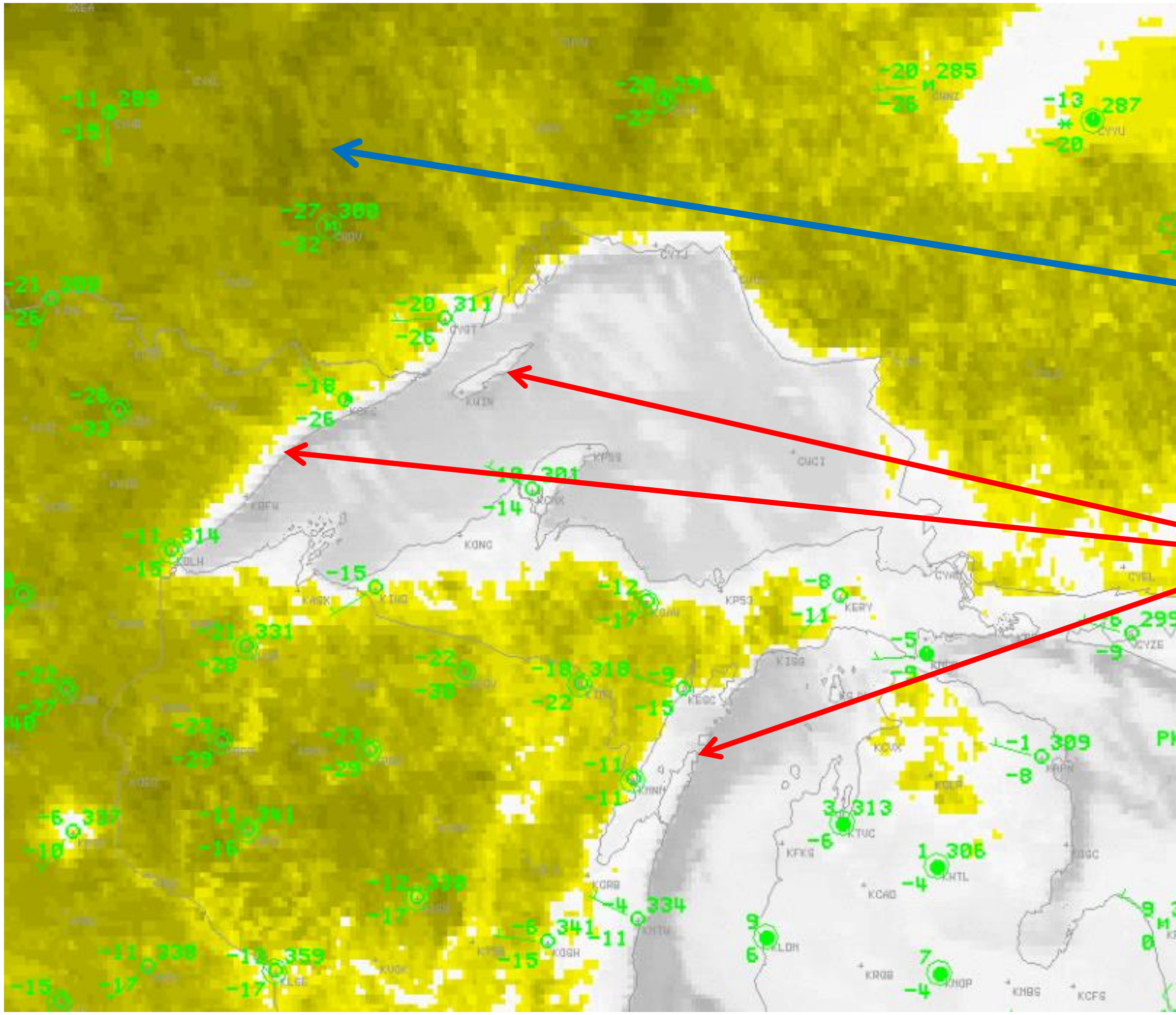
65 F with low deer

67 F with high deer

Sugar maple versus spruce in the temperate-boreal ecotone



Temperature pushing harder than opposing forces



Boreal forest can be kept free of temperate species by extreme winter cold (<-42 C), deep supercooling limit for cambium of maple and oak (winter boreal)

Or

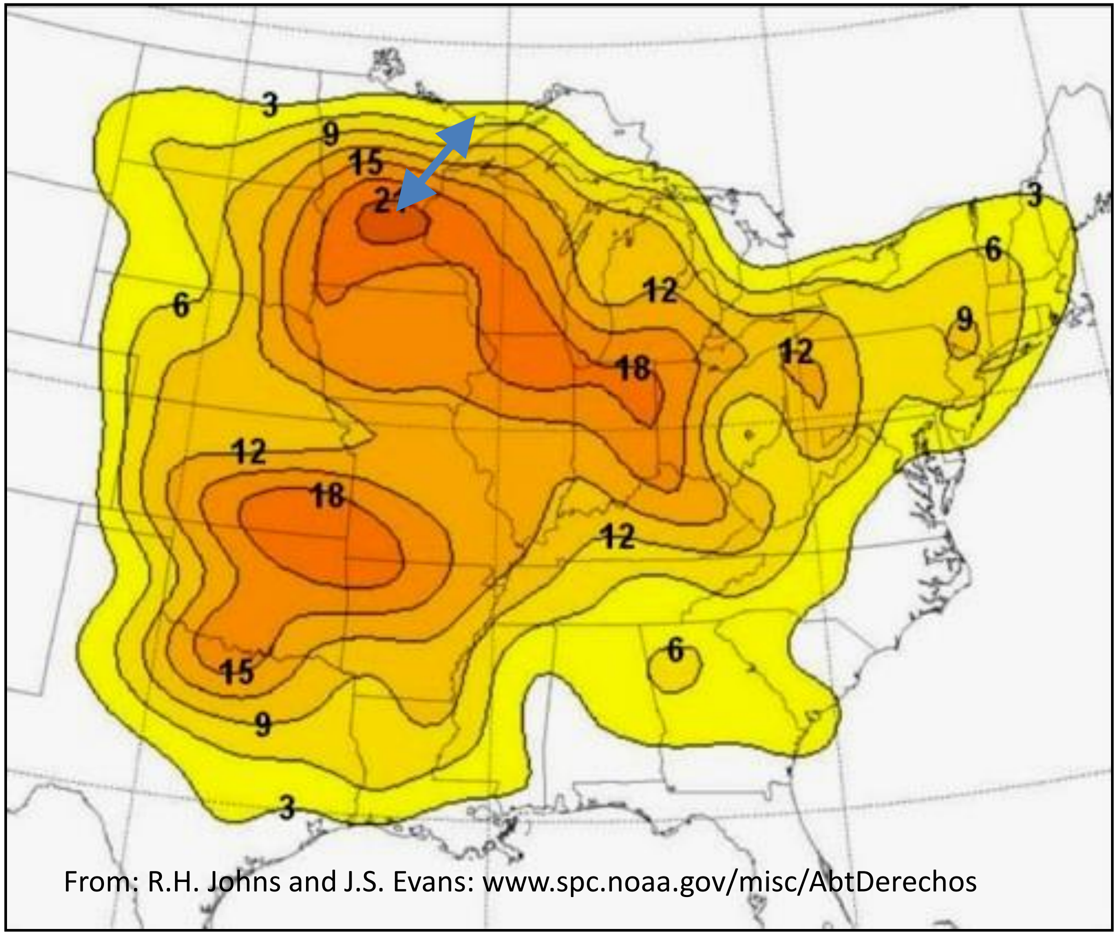
Summers too cool/short for temperate species to compete with boreal species (summer boreal)

(Or both)

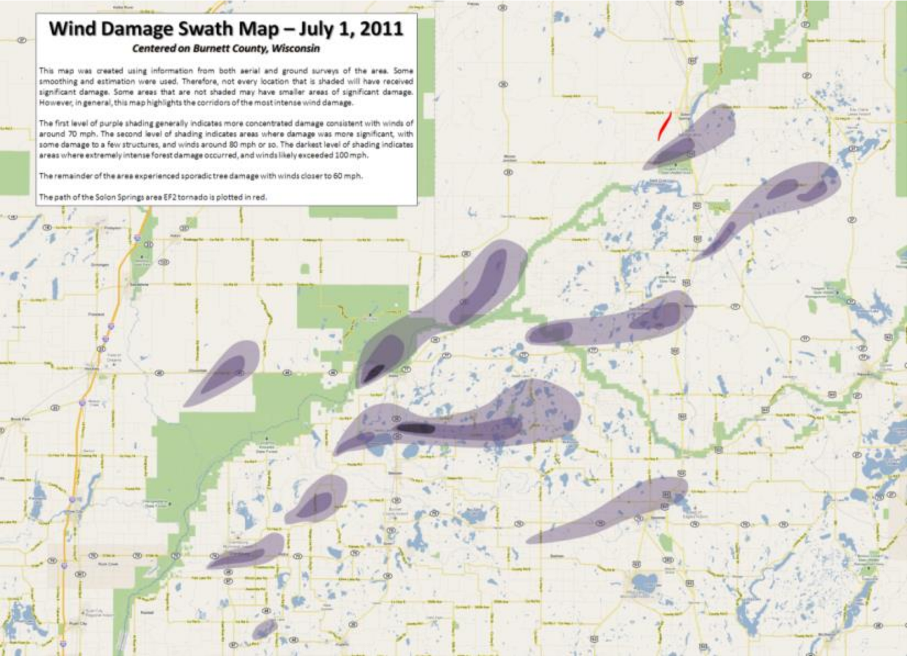
NWS Grand Rapids, MI, night time infrared image, Feb 11, 2014

Temperate forest invasion in the BWCAW: Red oak in boreal forest understory (upper right); Red maple replacing black spruce and birch-spruce forest (Upper left and lower left, respectively). Photos: Lee Frelich, Dave Hansen

Summer derecho frequency (#observed in 22 years)



Modeling potential for future severe storm frequency can be difficult—can 'climate migration' be useful? There is a 7-fold increase from the boreal forest to southern MN



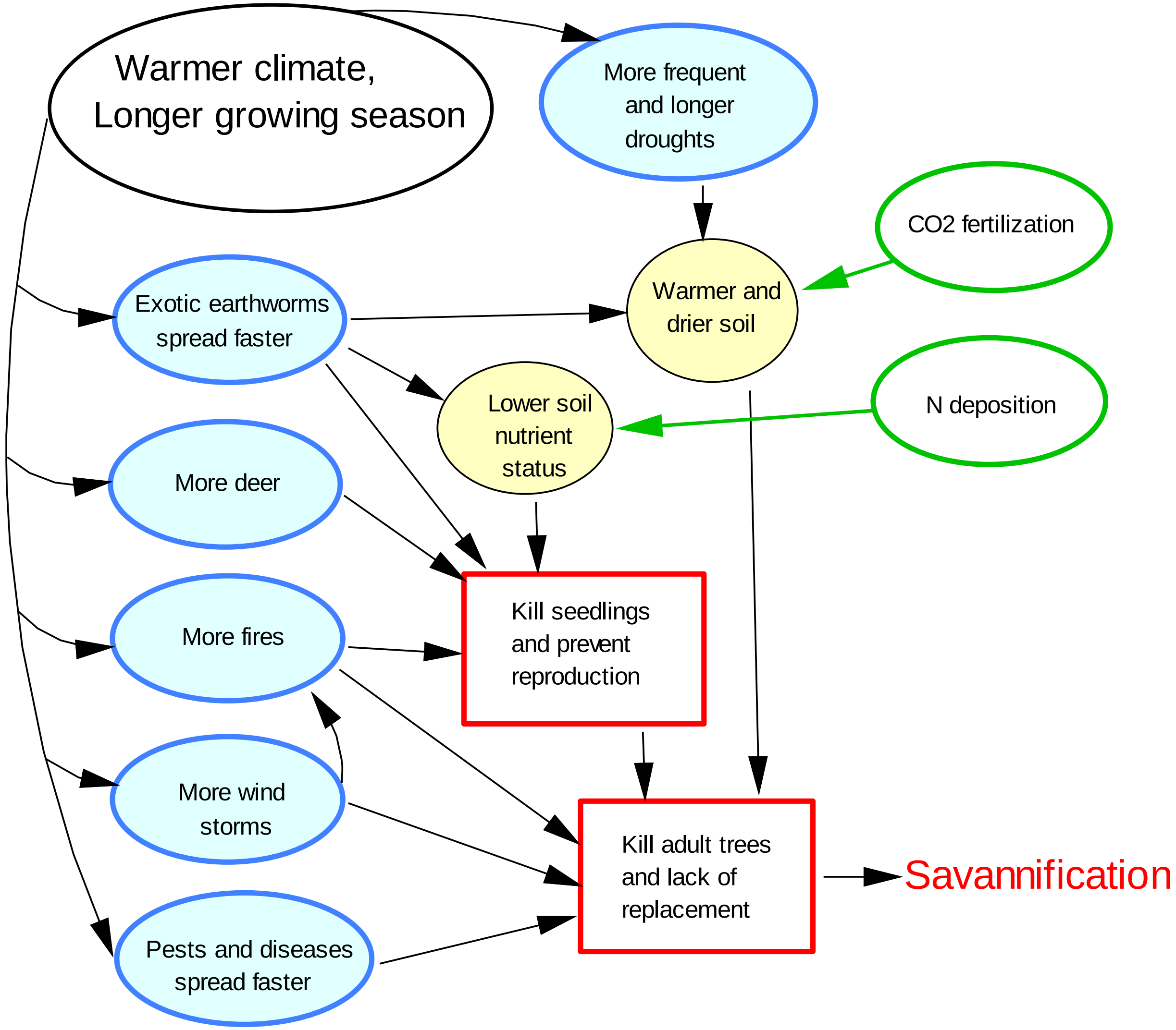
90,000 red maple seedlings/saplings km^2 followed by a canopy levelling wind event equals:

transition from boreal to temperate forest

NWS

Multiple factors working to reinforce climate change at the prairie-forest border

Frelich and Reich, *Frontiers in Ecology and the Environment* 8: 371-378.



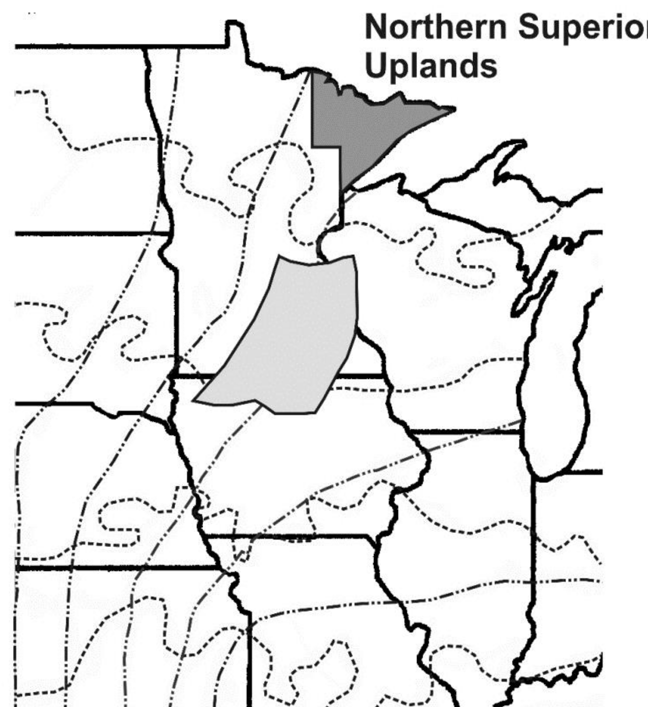

Forests of northern
MN today

Voyageurs NP

Lynx, photo Ron Moen

Future analogs for the BWCAW:

The Kandiyohi Elm Forest (orange star) and Gniess Outcrops Natural Area (blue star)



From: Galatowitsch, Frelich, and Phillips-Mao, *Biological Conservation 142:* 2012-2022

The Kandiyohi fossil elm forest: rock, red and American elm,
A blueprint for future forests on deep soils in northern MN, WI, MI, in a more droughty climate
Photo: Mark Stennes

Boreal species black spruce, white spruce, balsam fir, jack pine, red pine, quaking aspen and paper birch

Tree species present include elms, bur oak, basswood bitternut hickory, hackberry and Kentucky coffee tree

Gniess outcrops natural area, an analog for the future BWCAW on rocky, nutrient poor soils. Photos: Minnesota River Basin Data Center, NPS

Biome map of Minnesota by MNDOT

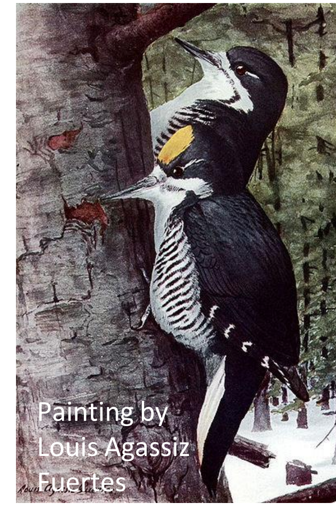
Boreal (spruce-fir-jack pine) forests of the north will be replaced by:

- Red maple now & other hardwoods later on deeper soils
- Oak savanna on shallow or sandy soils
- Minnesota is likely to lose the boreal biome and ca 1/3 of our native species

Some examples of potential changes in northern Minnesota wildlife with a warmer climate

Photo: Ron Moen


Photo: Reuters


Painting by Louis Agassiz Fuertes

Lynx

Moose

Black Backed Woodpecker

Red-Bellied Woodpecker

Bobcat

Deer

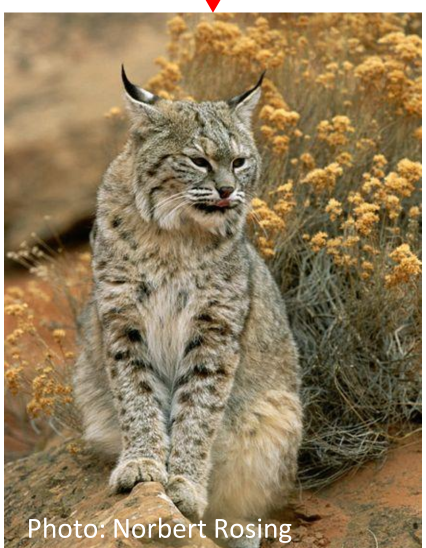
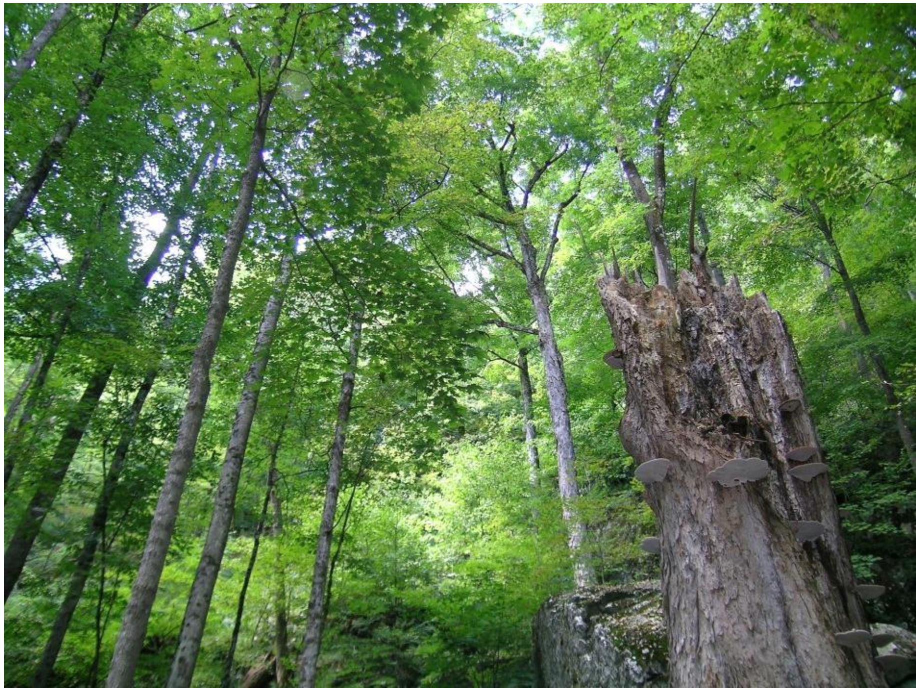


Photo: Norbert Rosing


Photo: David Augustine

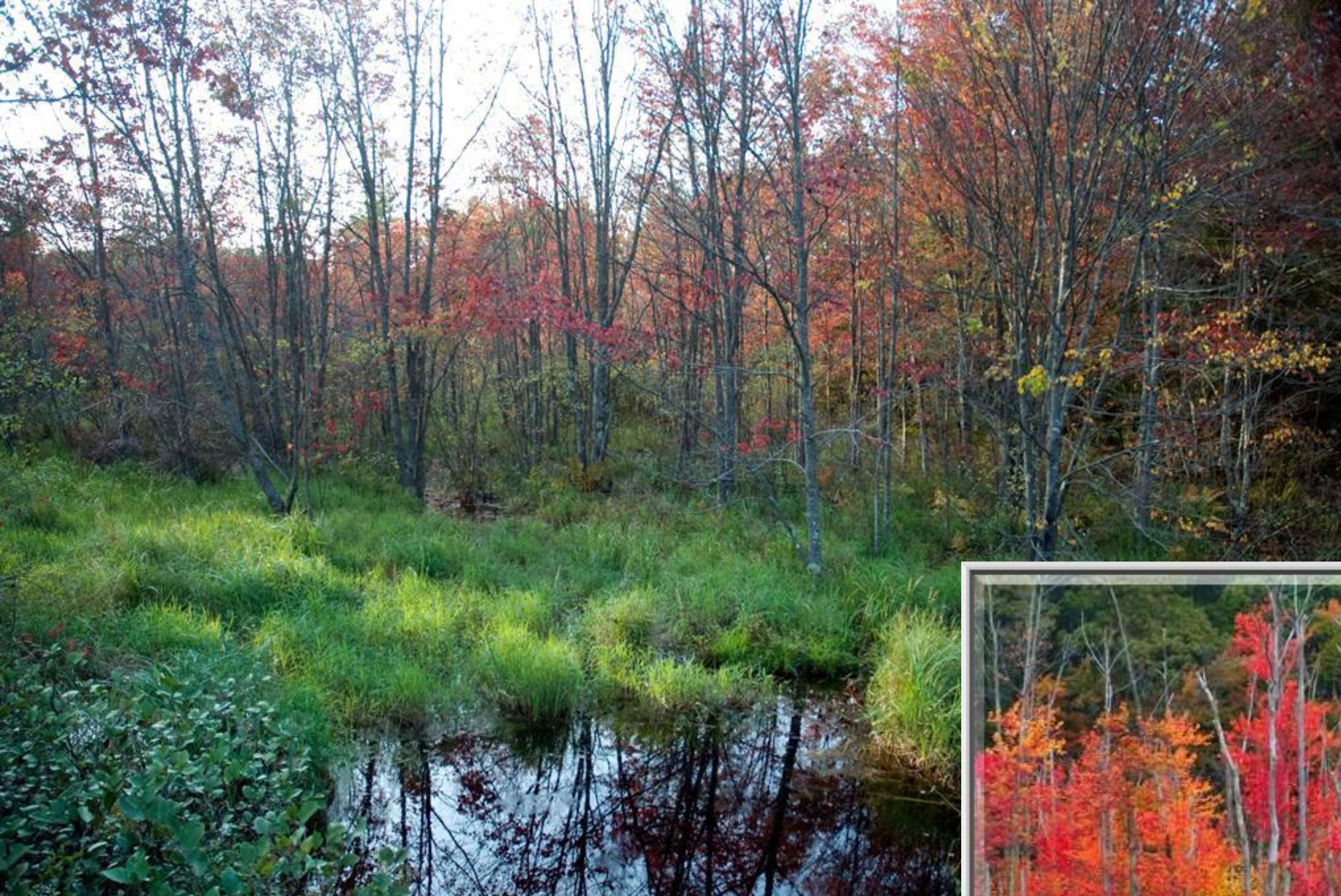

Photo: Ken Thomas

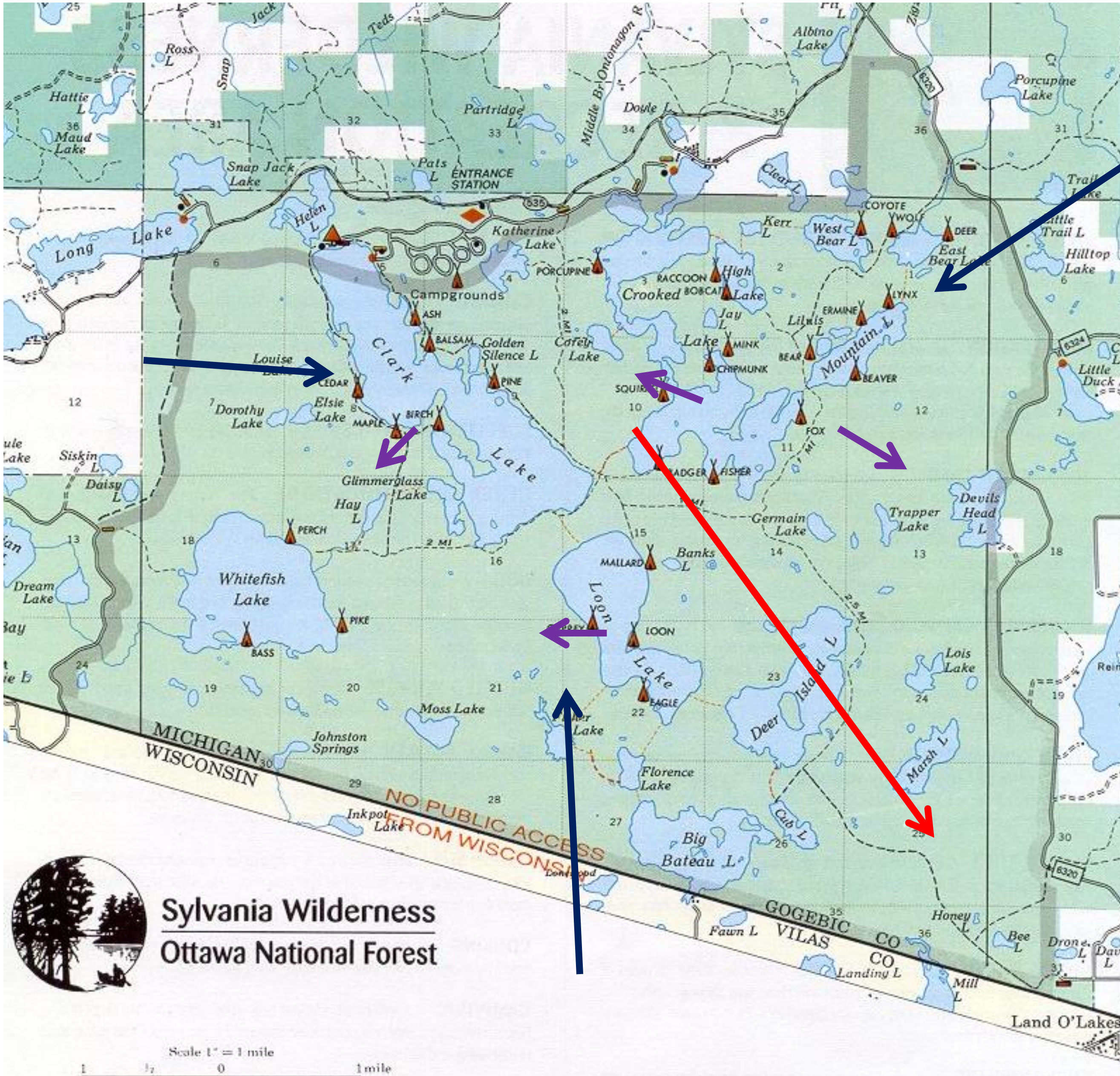
Sylvania today



Future analogs for Sylvania

And Sylvania tomorrow

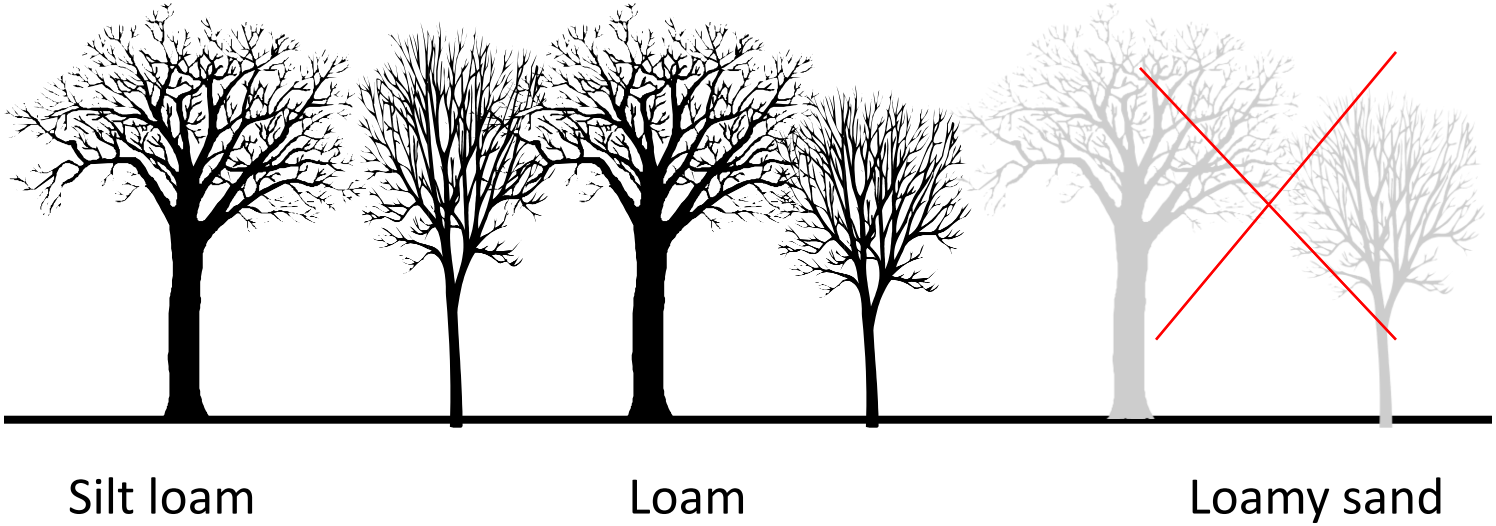



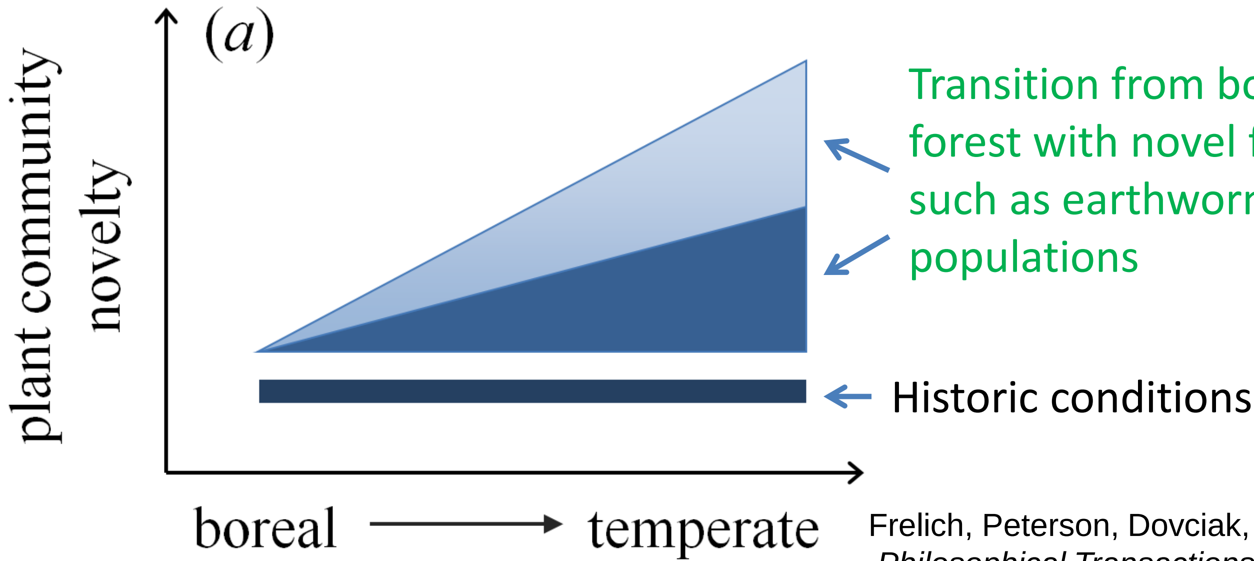
Sandy soil

Winter influx of deer

Rapidly spreading Earthworm infestation

Expect mesic northern hardwood forest species to contract their niche even in the interior of the forest biome—future sugar maple forests will be different than the historic ones we are used to





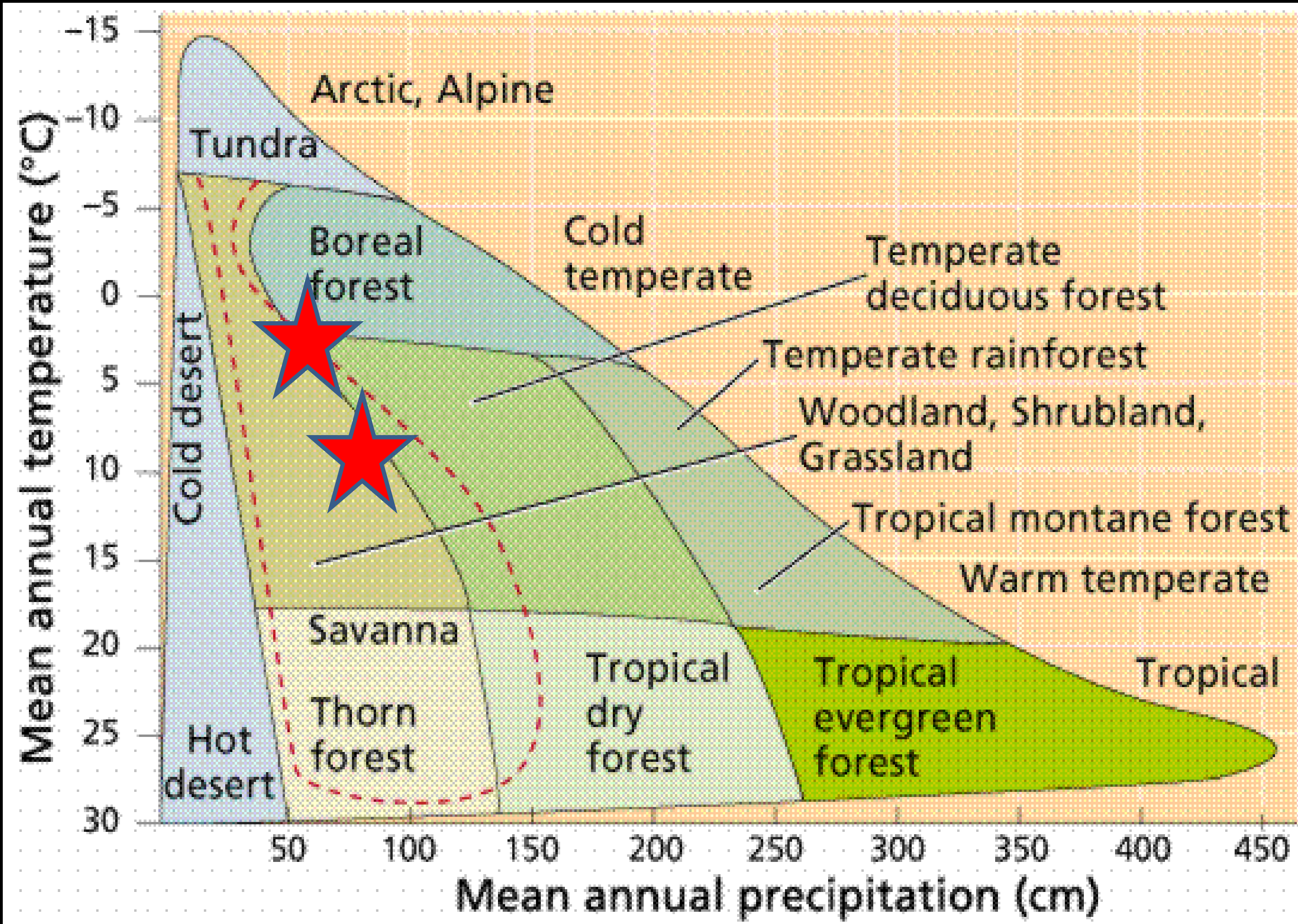
Frelich, Peterson, Dovciak, Reich, Vucetich and Eisenhauer, 2012
Philosophical Transactions of the Royal Society 367: 2955-2961.

Past sugar maple forests (left), and future mixed hardwoods (right)

Future of the northern hardwood and boreal transition zone:

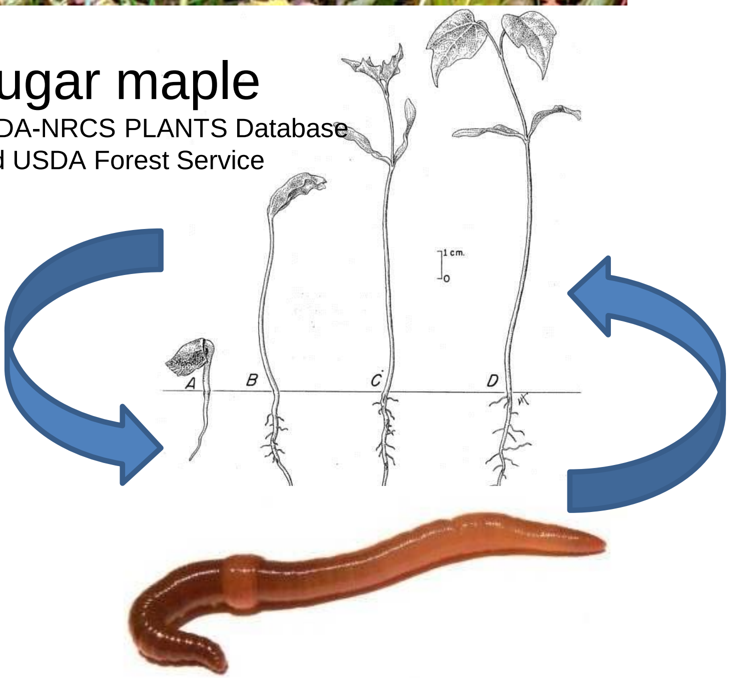
- Worms and drought will work against sugar maple
- Oaks will be favored by climate, fire and worms
- Deer will work against oak, but modified by wolves
- Boreal element of the landscape will likely disappear
- Oak-red maple, basswood, elm mixture likely in forests, some savannas on sandy soils

Photos: Kalev Jogiste



Arctic, Alpine
Tundra
Boreal forest
Cold temperate
Temperate deciduous forest
Temperate rainforest
Woodland, Shrubland, Grassland
Tropical montane forest
Warm temperate
Cold desert
Savanna
Thorn forest
Hot desert
Tropical dry forest
Tropical evergreen forest
Tropical
Mean annual temperature (°C)
Mean annual precipitation (cm)
−15
−10
−5
0
5
10
15
20
25
30
50
100
150
200
250
300
350
400
450

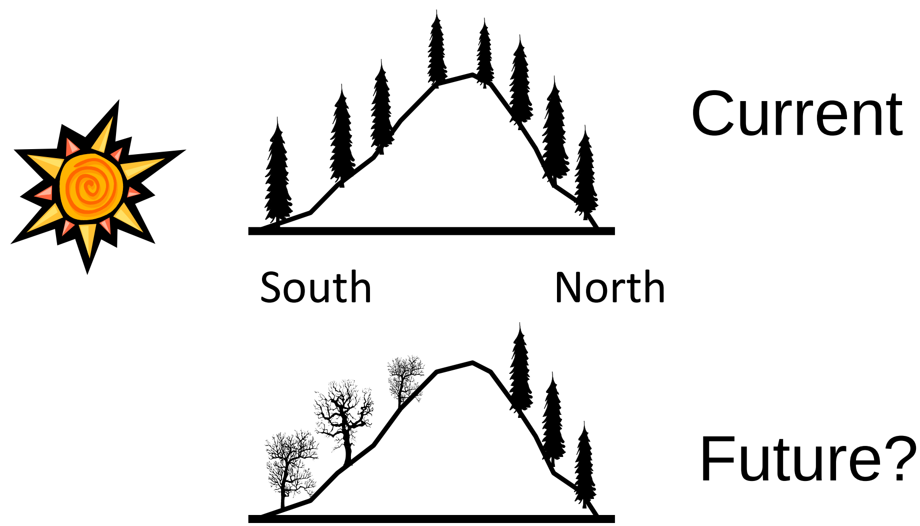
Sugar maple
USDA-NRCS PLANTS Database
And USDA Forest Service



Forest plants buffeted from above and below

Warming climate will change the forest through complex food web and migration processes

These effects will be uneven across the landscape



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