Could climate change turn Minnesota into the new Kansas?

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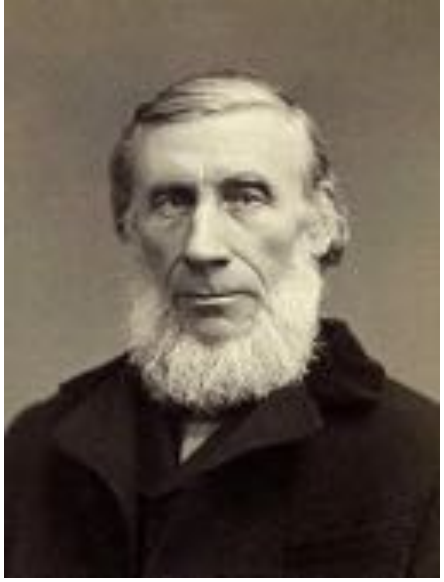
UNIVERSITY OF MINNESOTA

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

Fourier—discovered that greenhouse gases exist—1820s

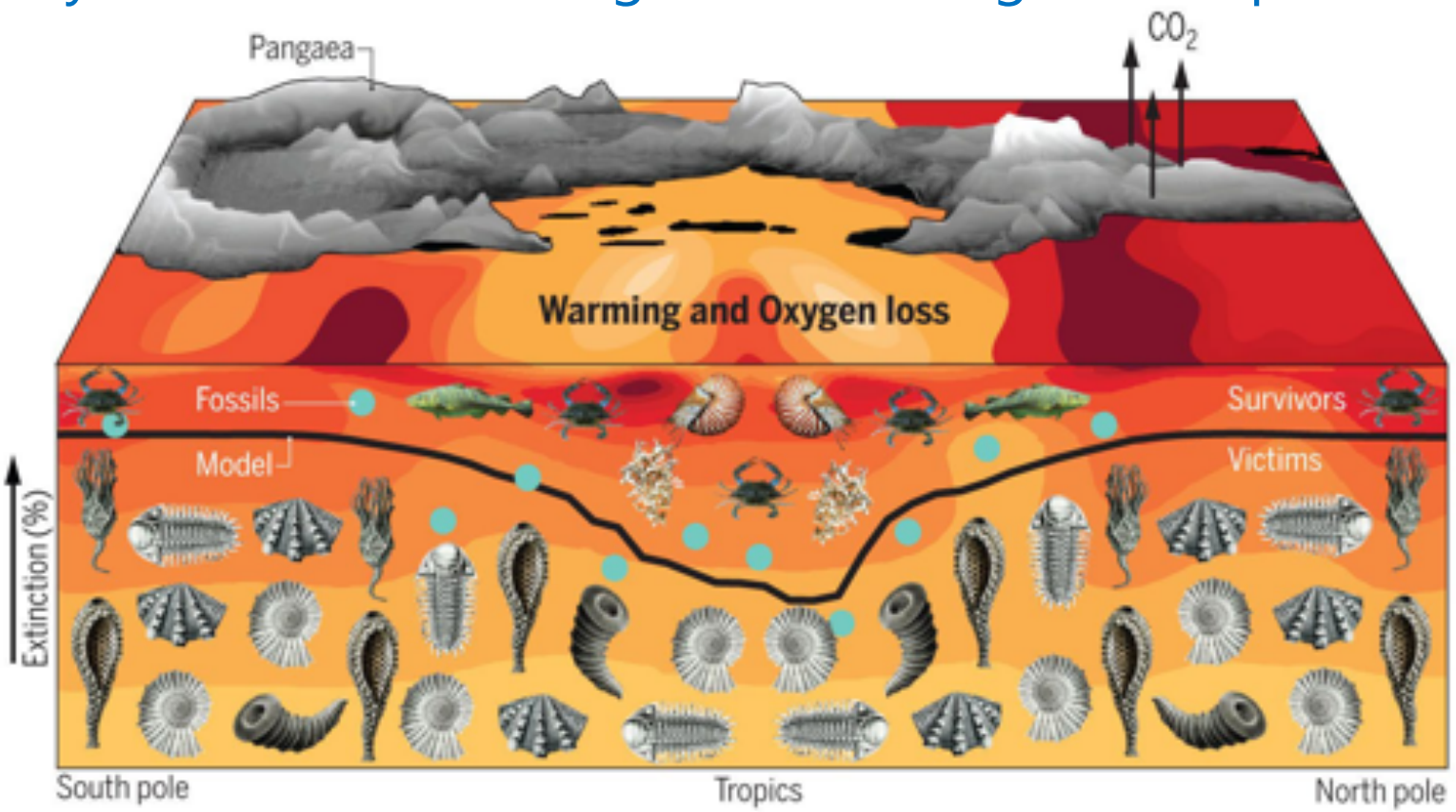


Tyndall—proposed that CO_2 played a role in climate—1860s

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

Why do scientists think global warming is so important?



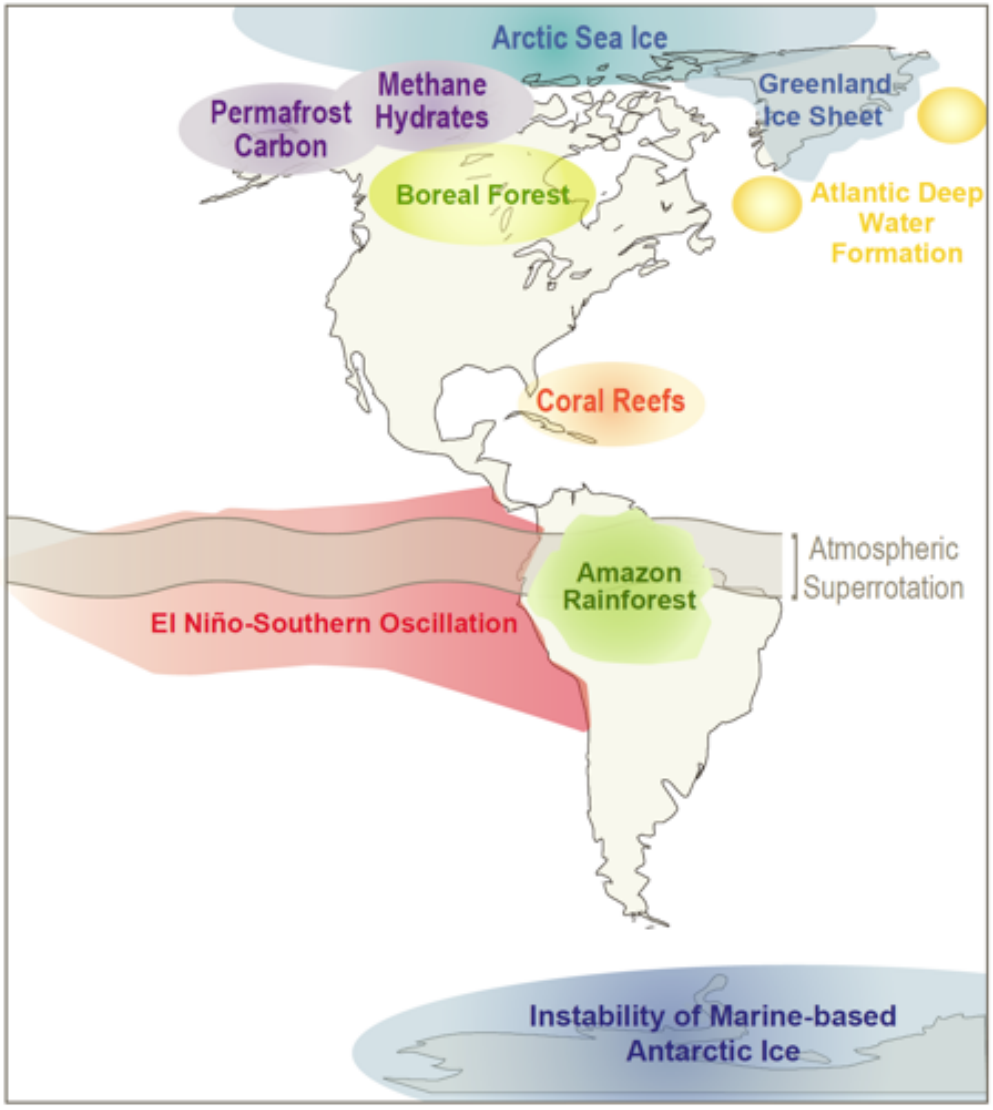
The largest mass extinction in Earth's history—the End Permian Extinction—was caused by an episode of global warming due to rising CO_2 levels from volcanoes and resulting ocean acidification and loss of oxygen

Image Credit: Justin Penn and Curtis Deutsch/University of Washington

A low CO_2 emissions scenario minimizes the chances of surprises or tipping points in the Earth's climate:

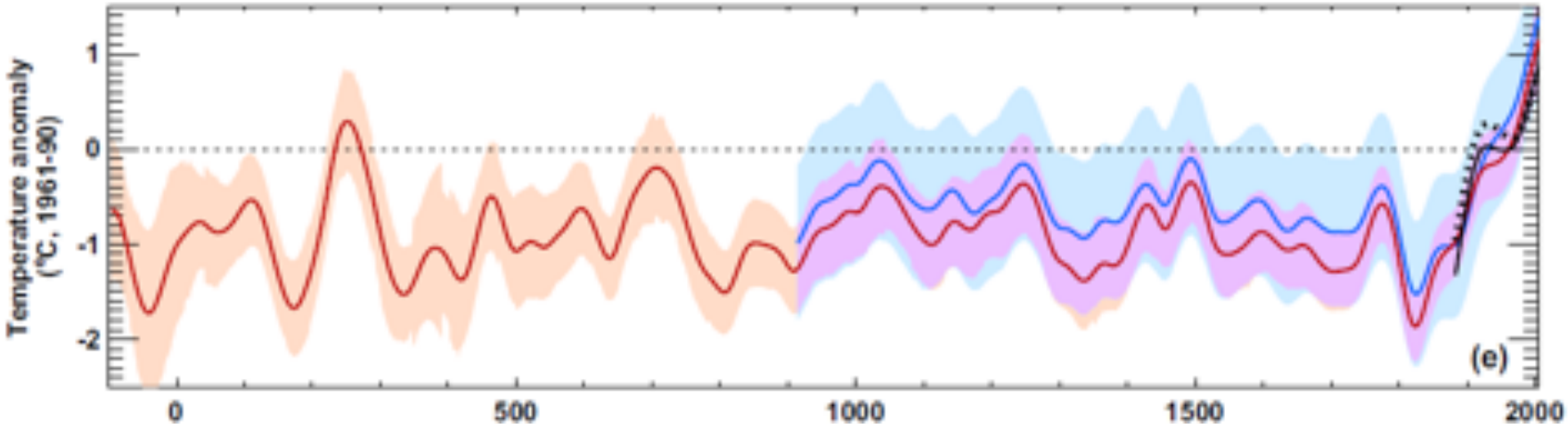
- Arctic amplification
- Boreal or Amazon forest loss
- Equatorial superrotation
- Stratocumulus cloud breakup

Is there a scenario that stops at 4 °C warming?
Or do all of those scenarios lead to a 'hothouse' Earth 8 to 12 °C warmer?



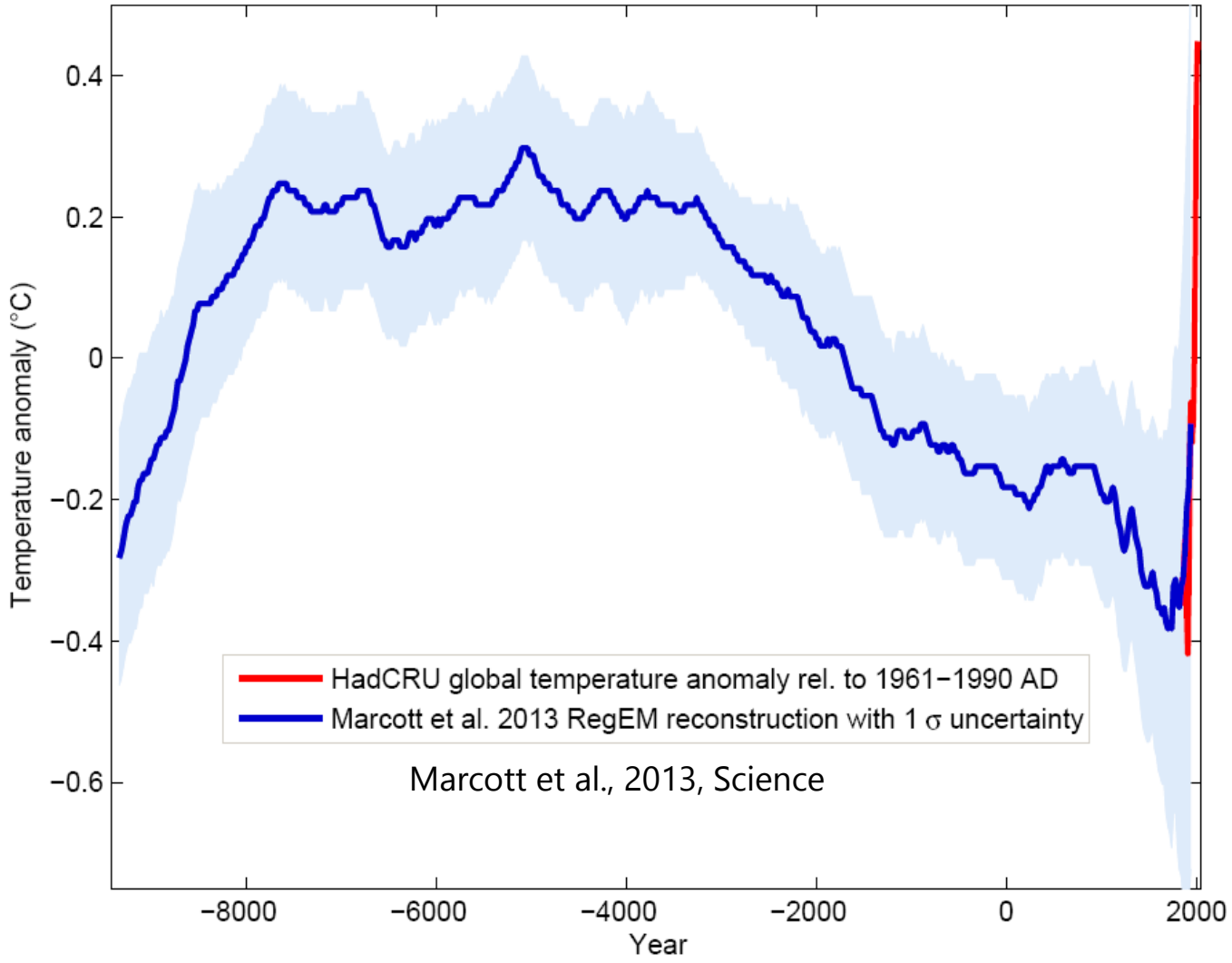
Kopp et al. 2017. *Climate Science Special Report, Chapter 15*
Schneider et al. 2019 *Nature Geoscience*

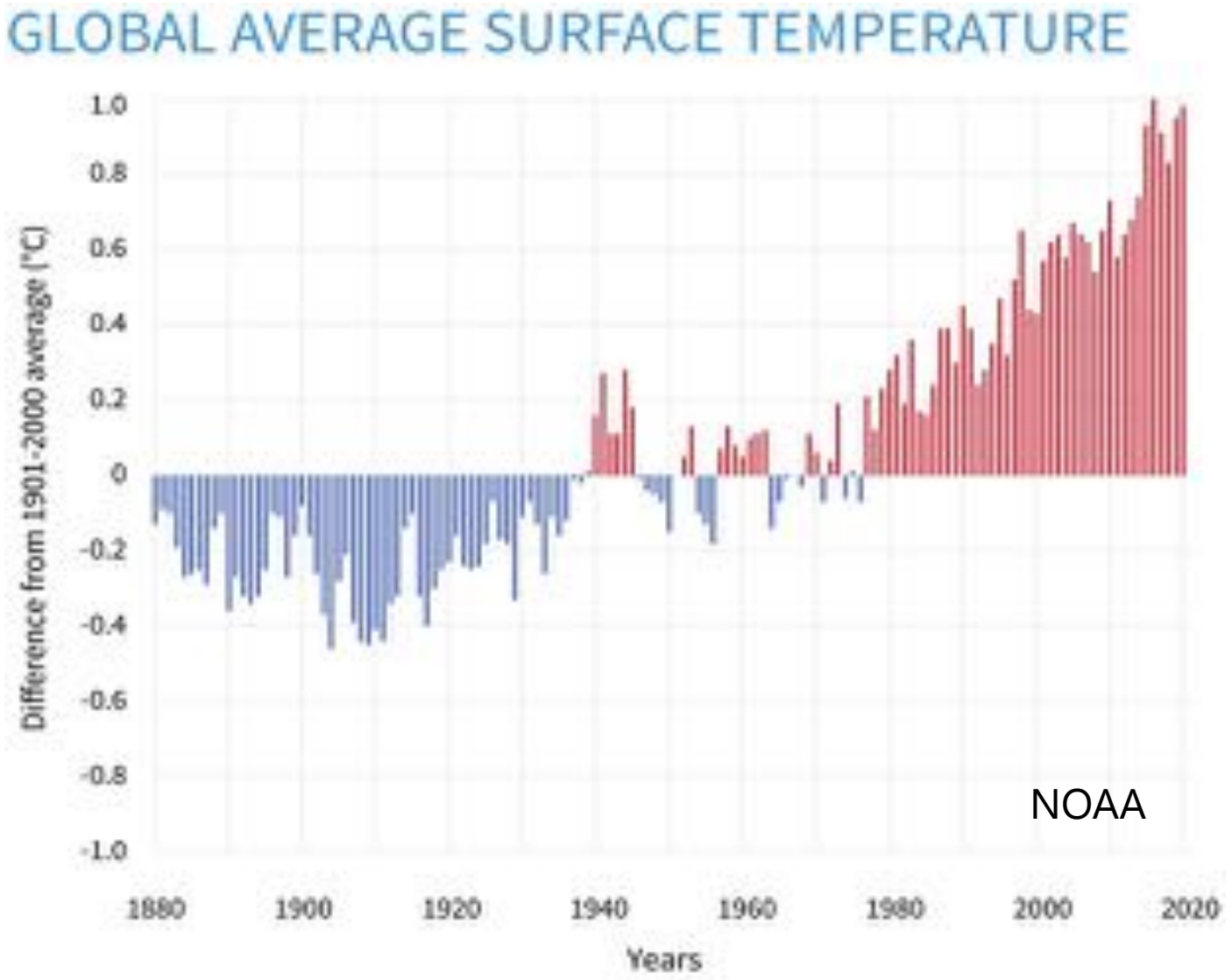
Tree-ring analysis of June-July and August mean temperature from the Yamalia and northern Ural Region, Russia Briffa et al. 2013



Photos: Russiatrek.org, Yamelta.ru

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

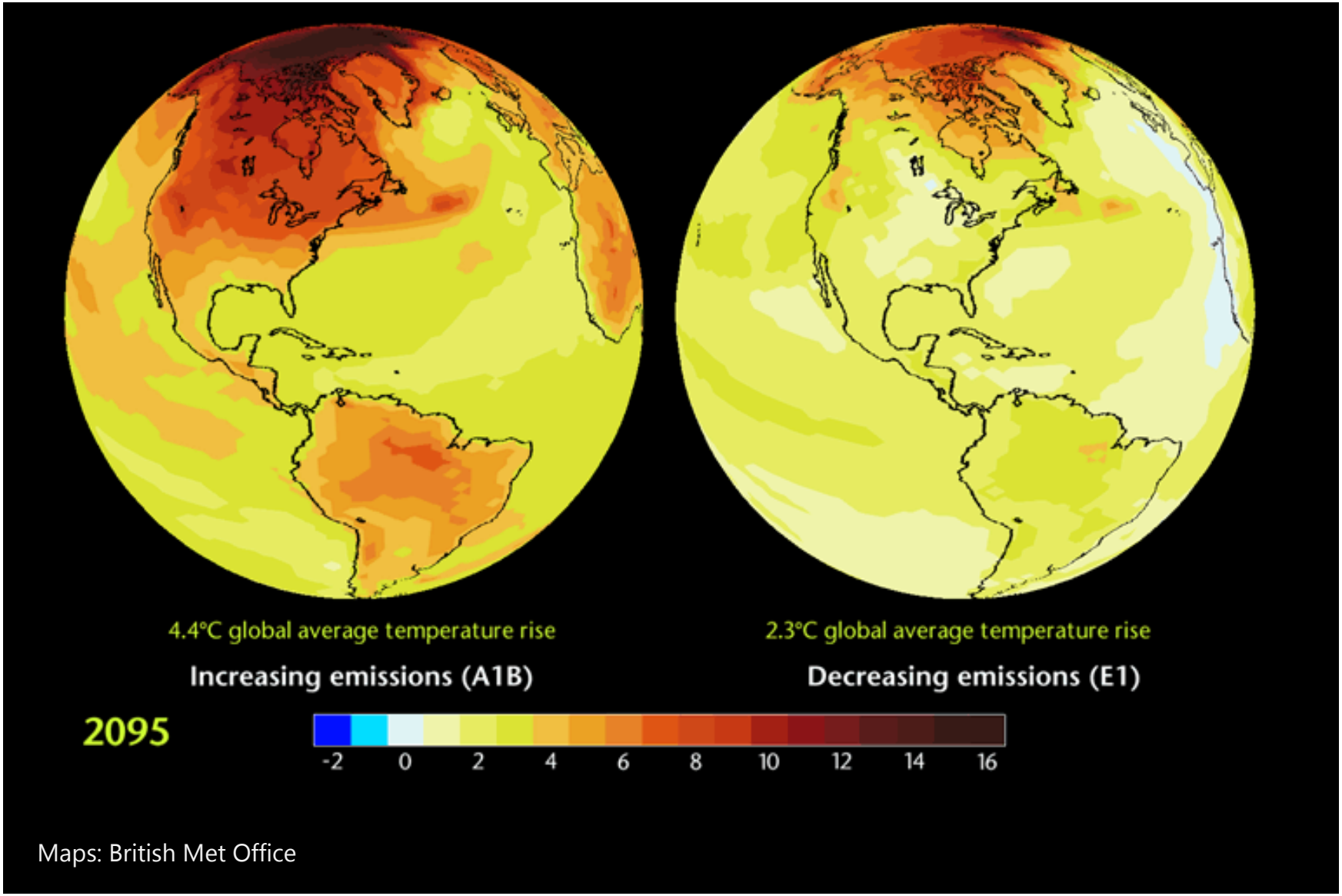




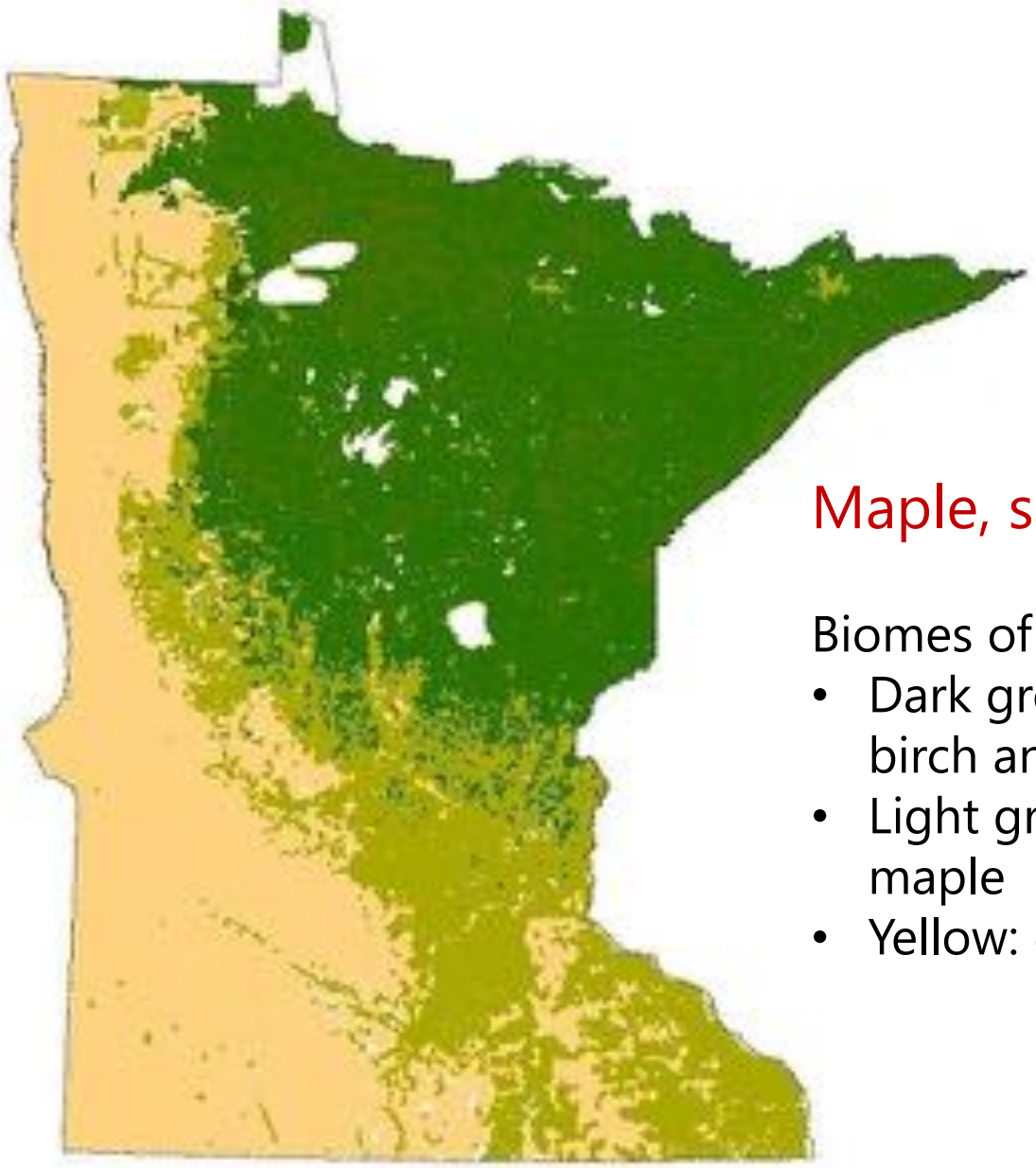
Increase of 1.8 °F reverses 5000-year natural cooling trend

CO_2 currently at 413 ppm–highest in 3 million years

Alternative futures for high and low greenhouse gas emissions scenarios



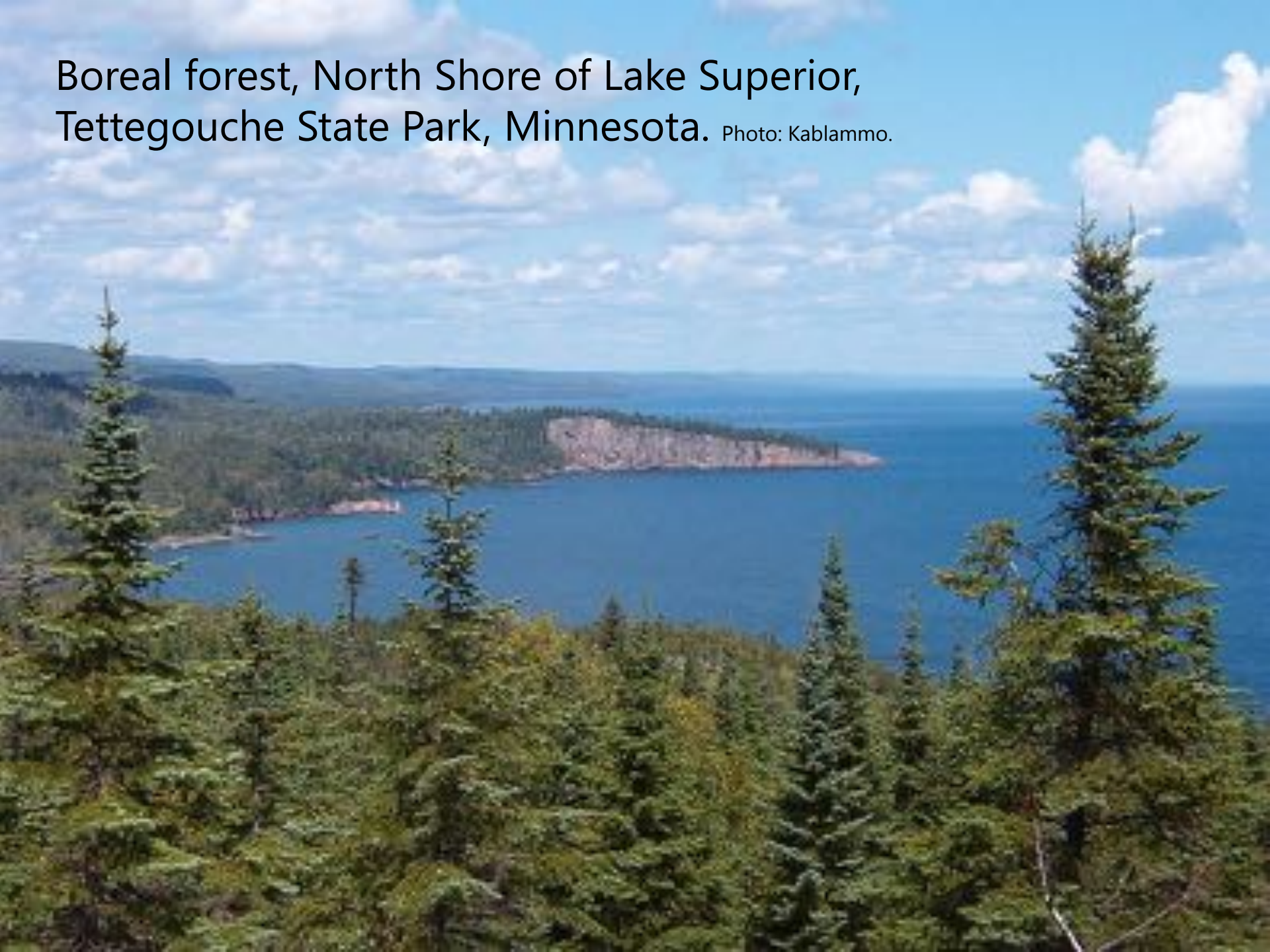
Maps: British Met Office



Maple, spruce, or savanna?

Biomes of Minnesota:

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

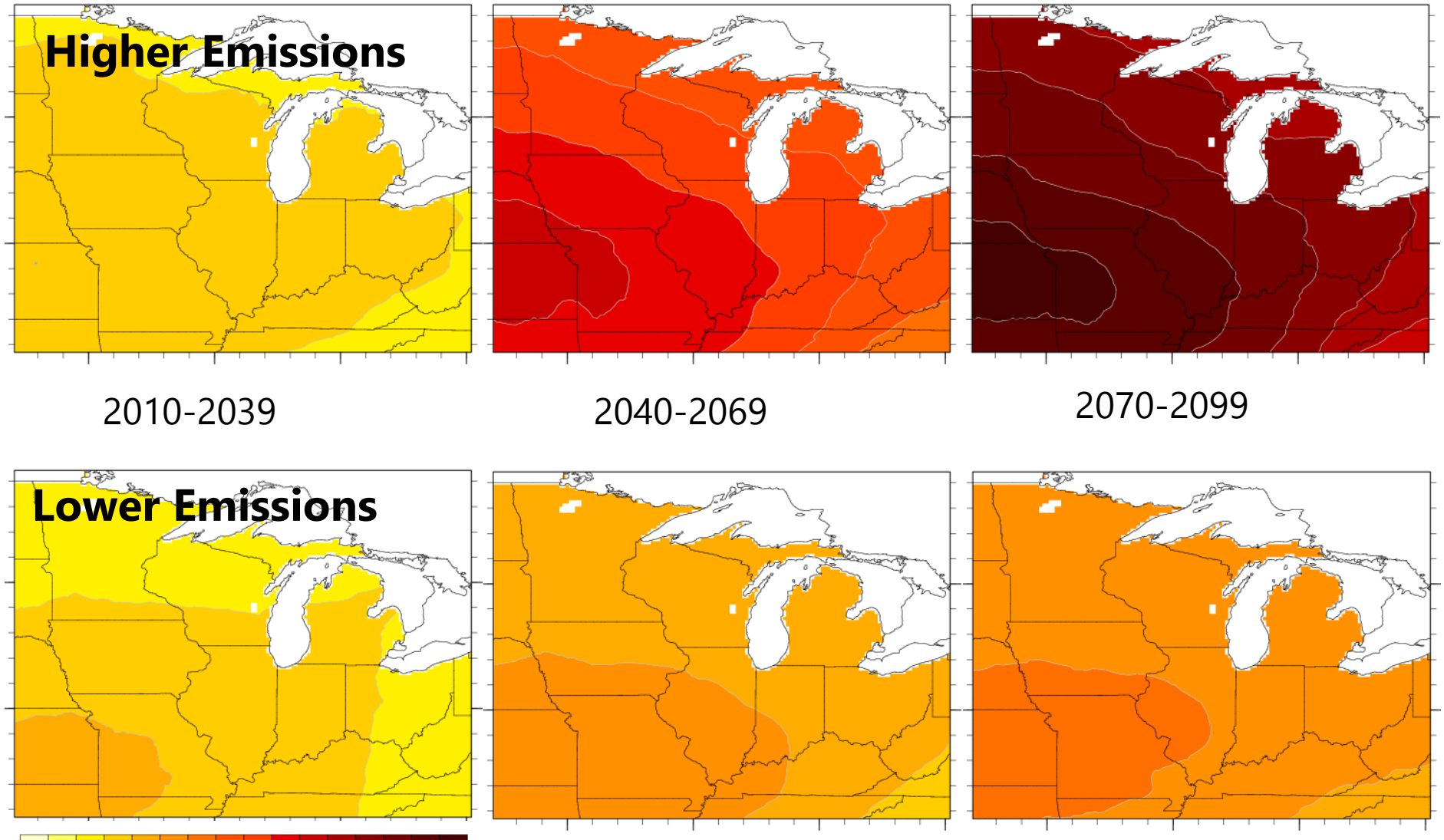


Boreal forest, North Shore of Lake Superior, Tettegouche State Park, Minnesota. Photo: Kablammo.


A sugar maple, basswood and red oak forest
in the Cannon River Wilderness, SE MN

Prairie landscape, Mound Spring Prairie, MN
(photo Dave Hansen, UMN)

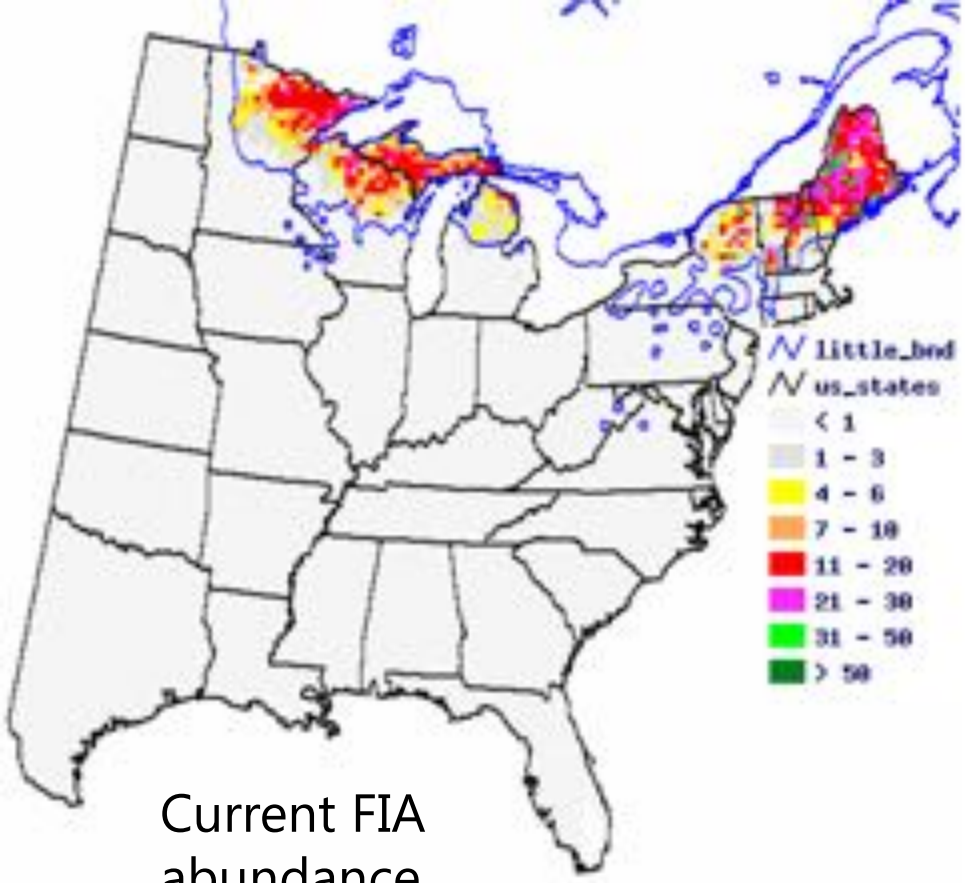
Change in summer (JJA) temperature



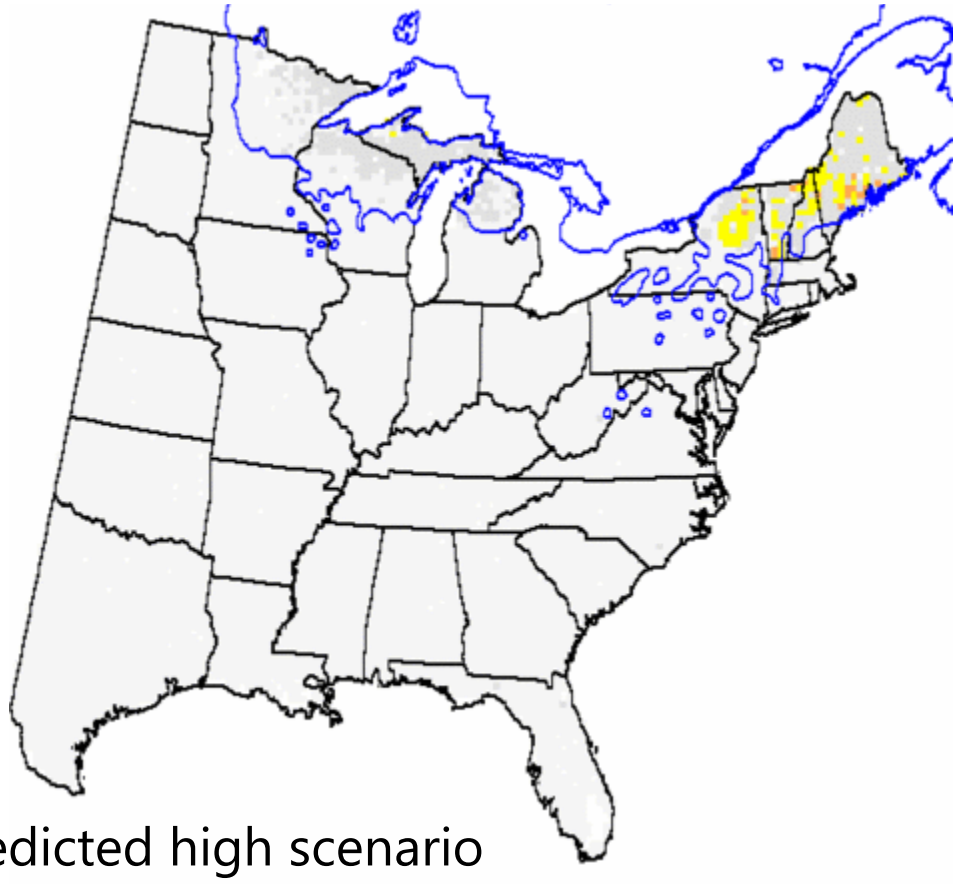
Slide: Don Wuebbles

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

Source: USDA Climate and Tree Atlas



Current FIA abundance



Predicted high scenario

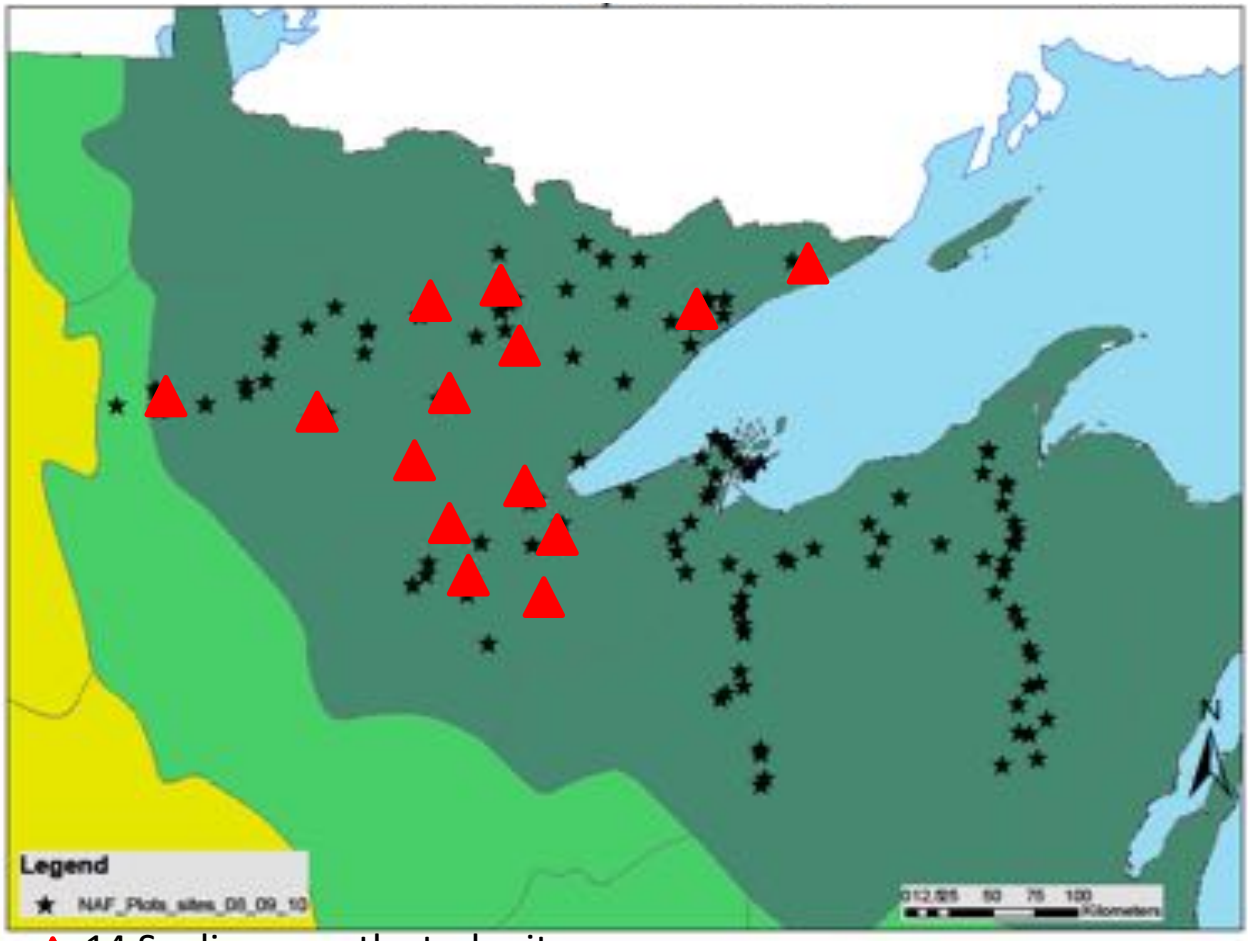
Similar results for

- Black spruce
- White spruce
- Paper birch

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

Temperate species: bur oak, red oak, basswood, sugar maple, red maple, yellow birch

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.

Growth measurements of boreal and temperate saplings

5 species

Balsam fir
(*Abies balsamea*)

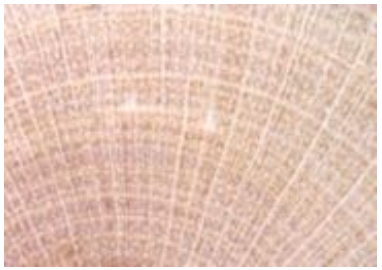
White spruce
(*Picea glauca*)

Red maple
(*Acer rubrum*)

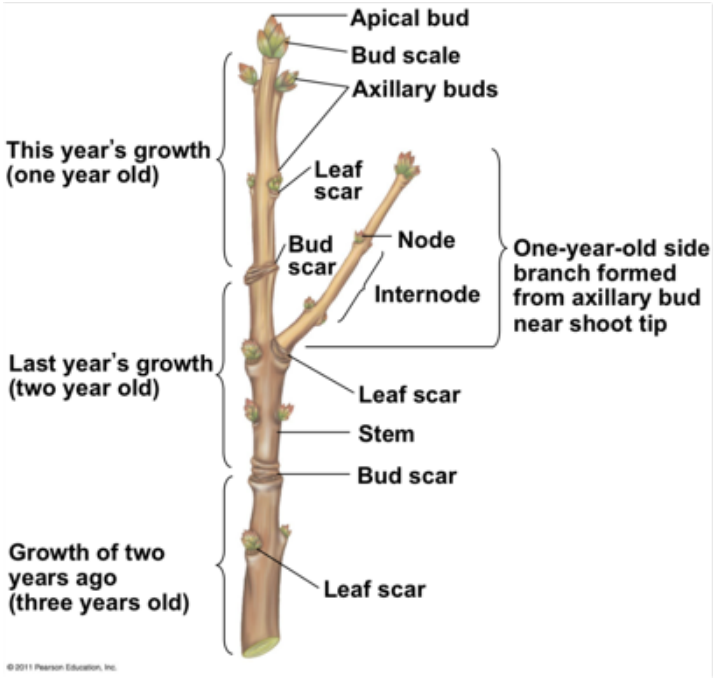
Sugar maple
(*Acer saccharum*)

Red oak
(*Quercus rubra*)

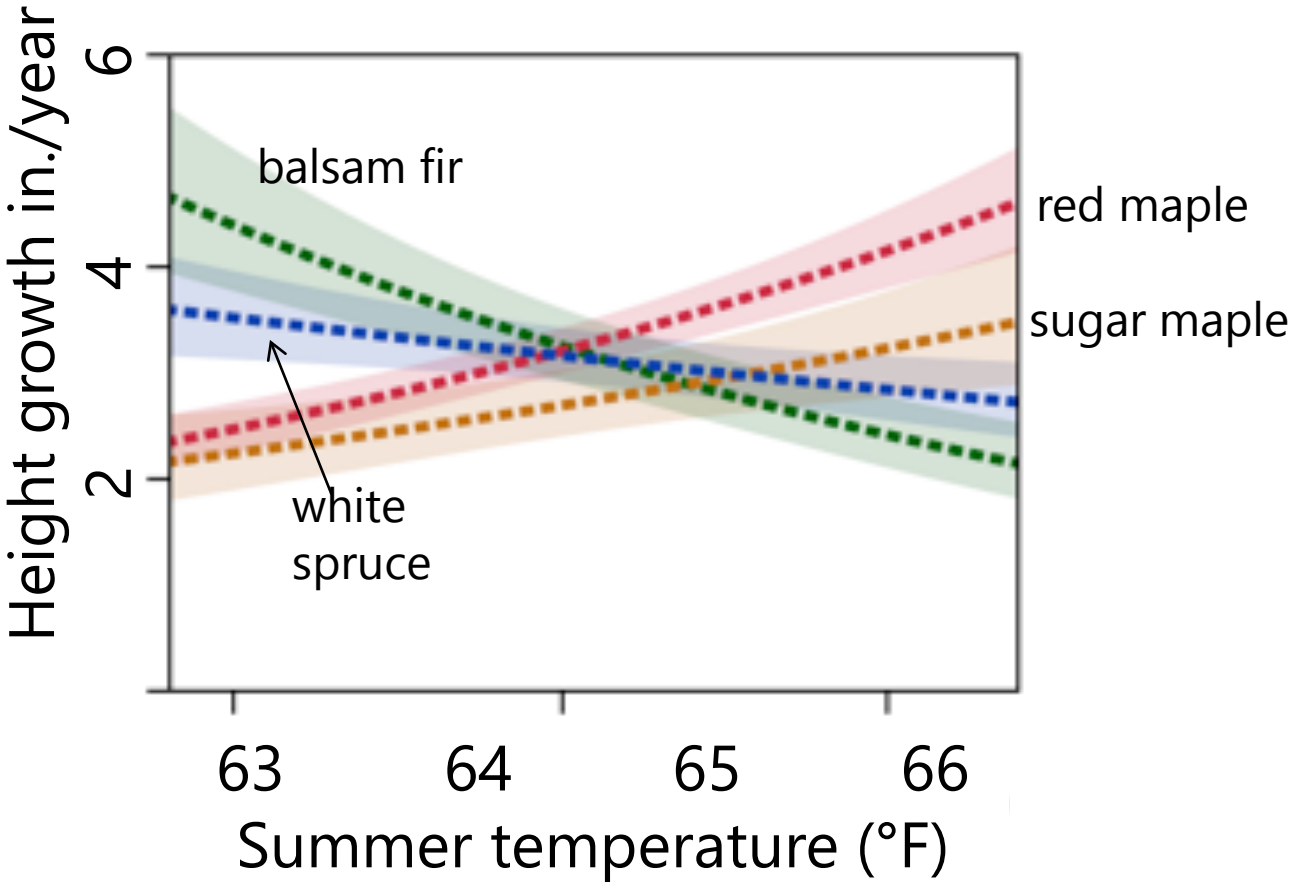
Radial Growth



Height Growth



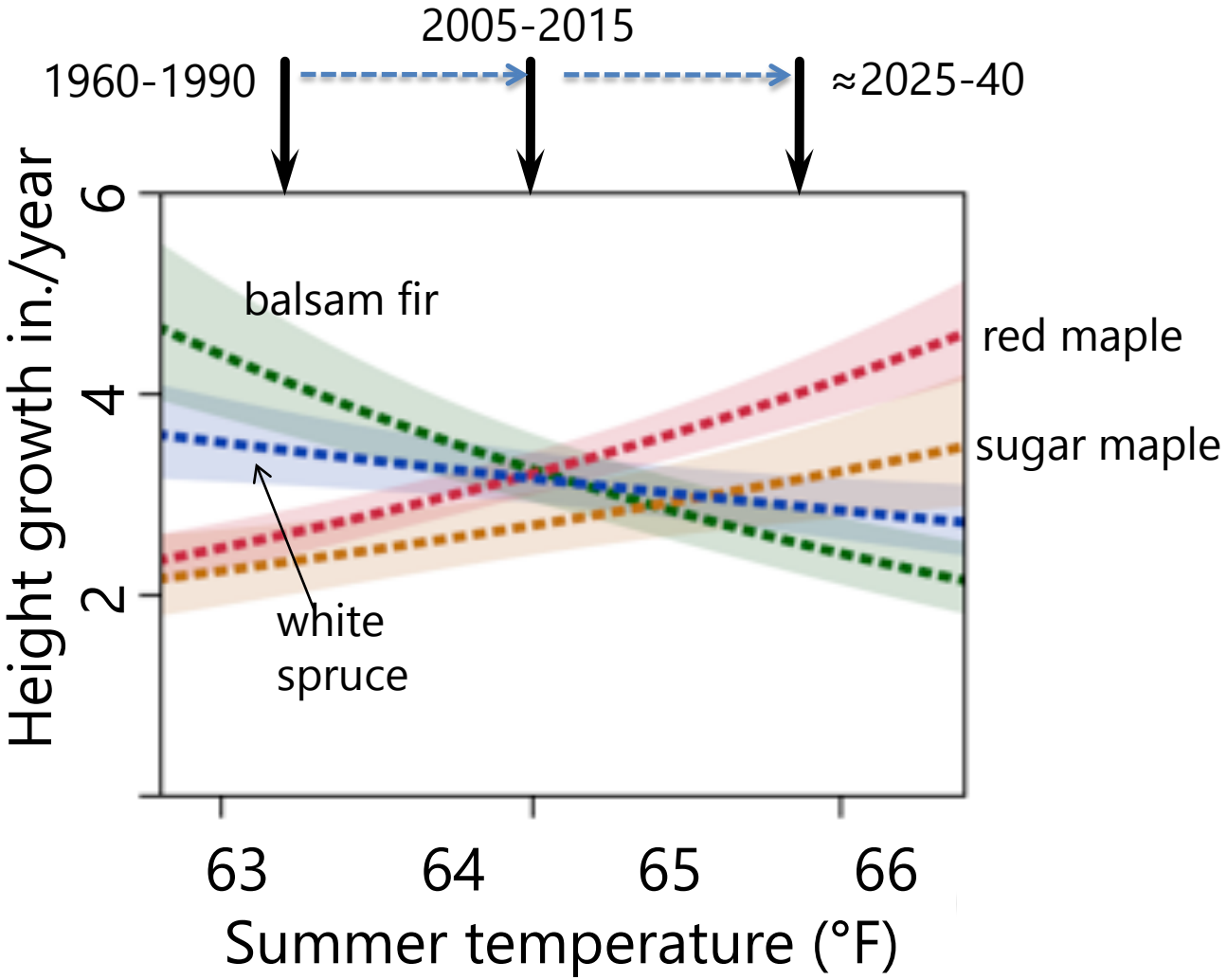
Crossover point between temperate and boreal sapling growth is 64-65 degrees



≈1,700 trees, northern Minnesota

Fisichelli, Reich, Frelich (2012)

Regional mean summer temperature

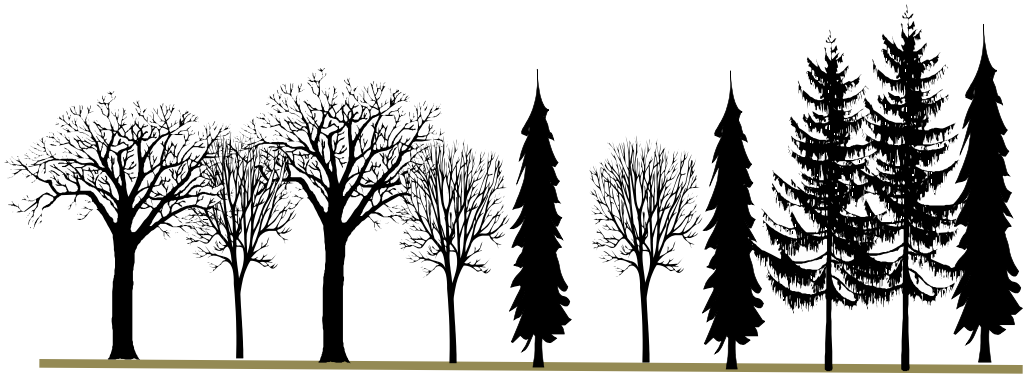


≈1,700 trees, northern Minnesota

Fisichelli, Reich, Frelich (2012)

Sugar maple and balsam fir,
Duck Bay, Newport State Park
Summer 2016

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

Minneapolis Star Tribune

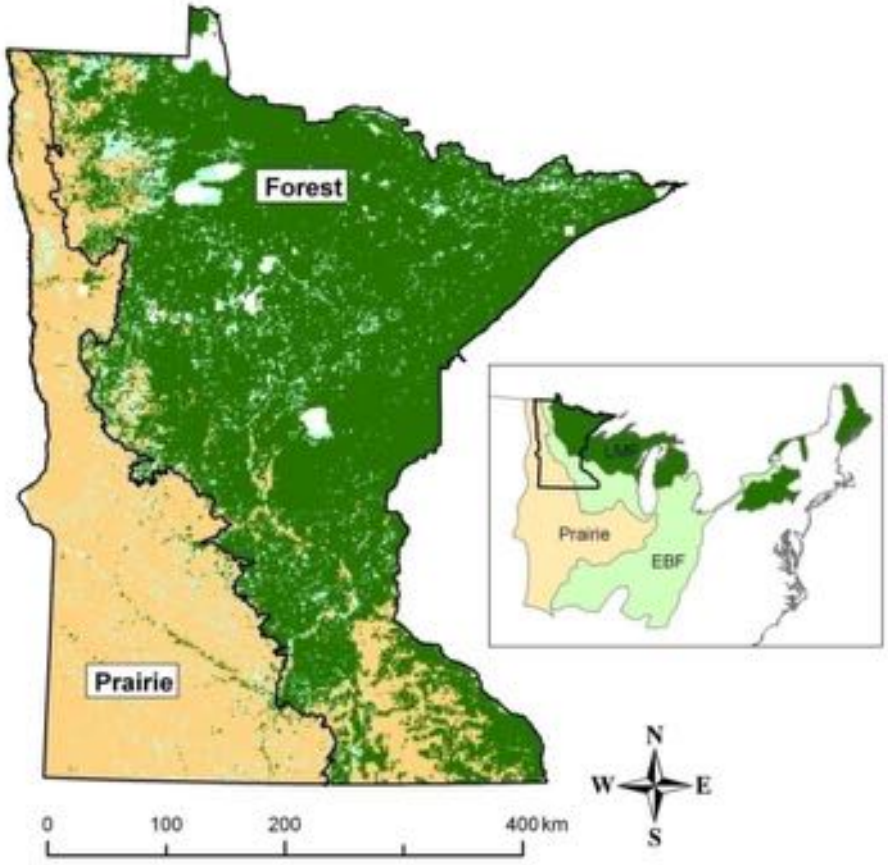
Before and after the 1999 blowdown

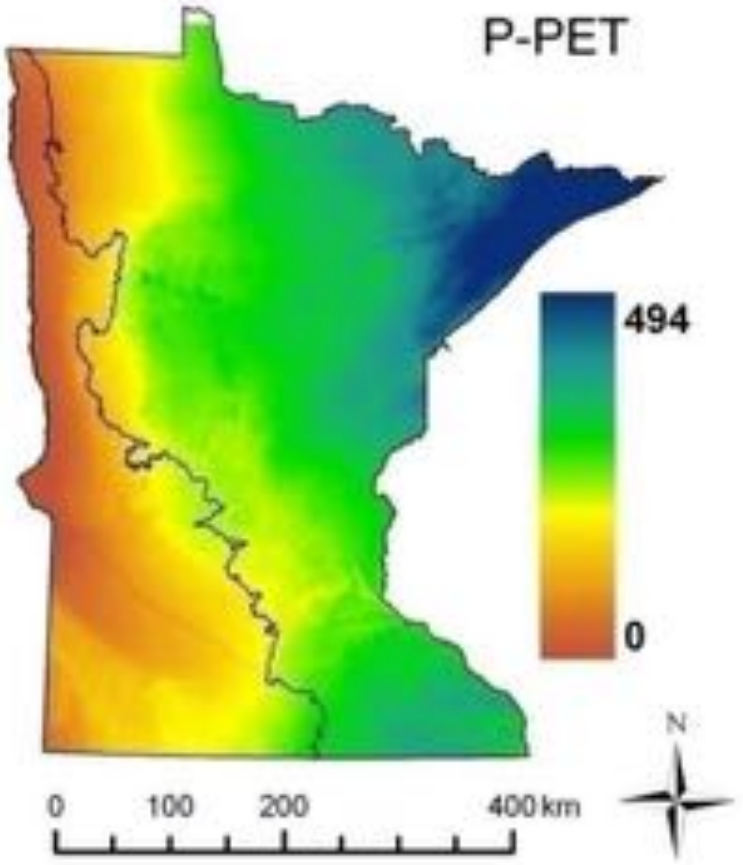
Understory invasion by temperate saplings followed by wind =

Instant conversion from boreal to temperate forest

The Prairie-forest border of Minnesota:

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





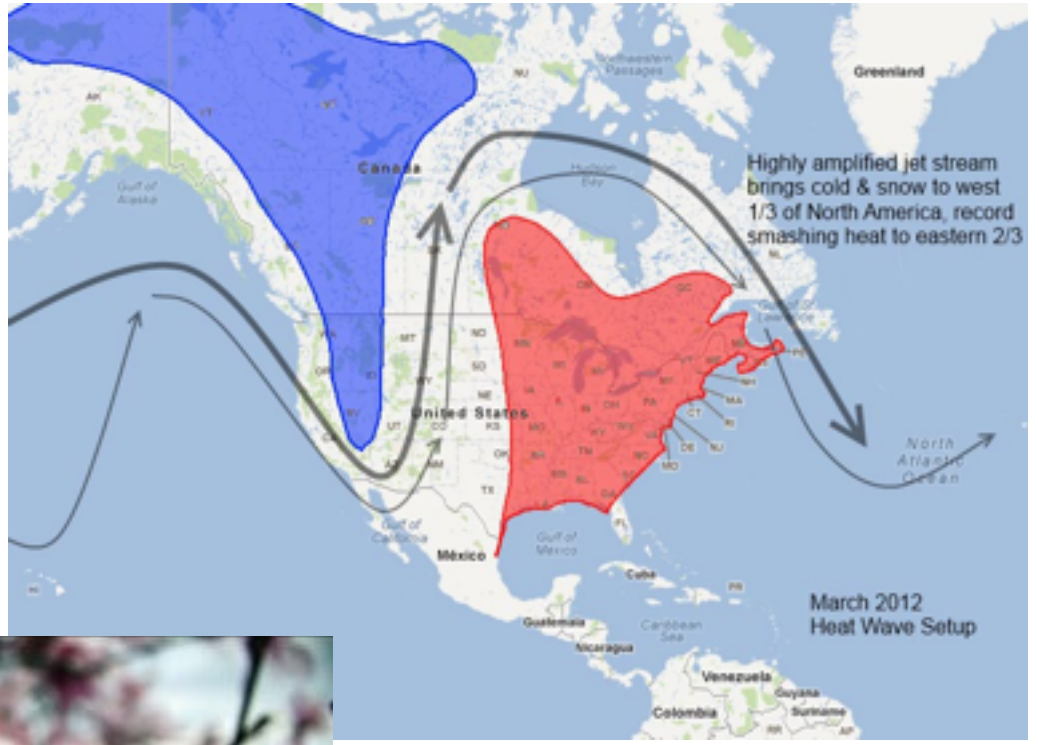
From: Danz, Reich, Frelich and Niemi, 2011, *Ecography* 34: 402-414;
Danz, Frelich, Reich and Niemi, 2013, *Journal of Vegetation Science*, 24: 1129-1140

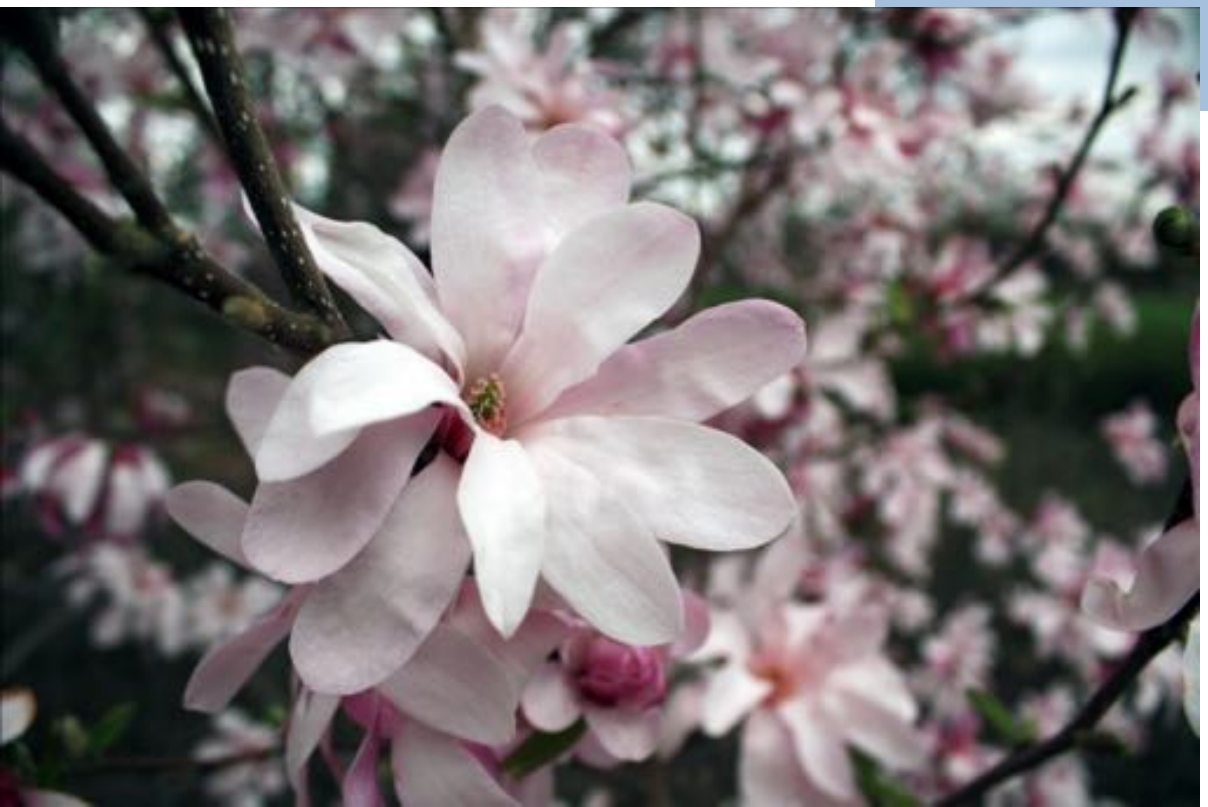
Photos above and below: Dave Hansen

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

March 2012:

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





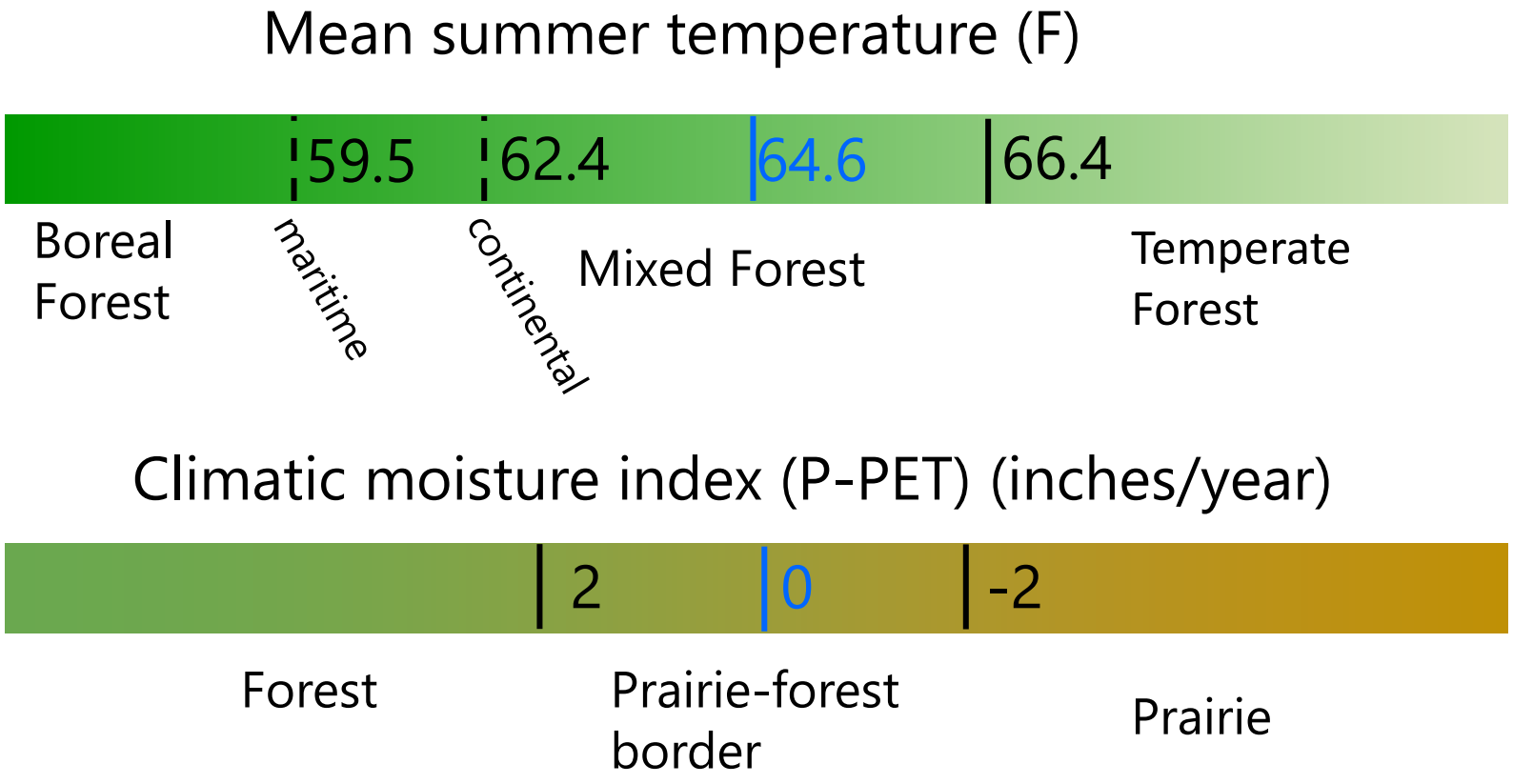
Magnolia in bloom, St.Paul Campus, March 27, 2012. Photo: Jenna Williams

Phenological disturbance

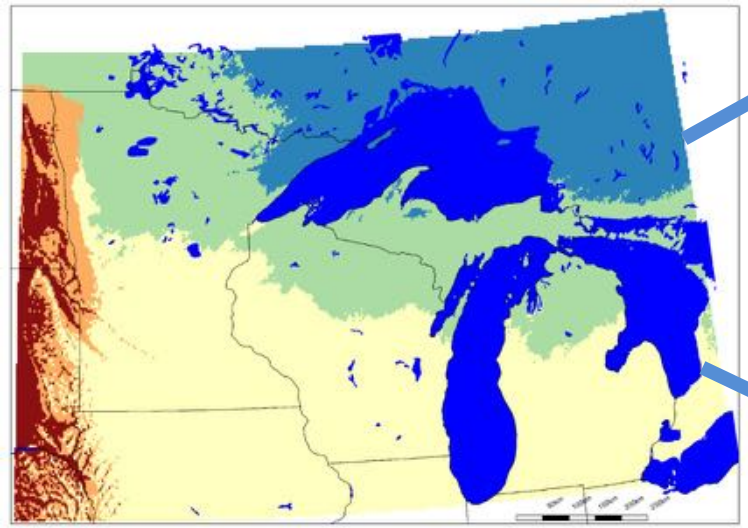
Browning of post-fire regeneration, BWCAW, June 2012
Photo: Eli Anoszko

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

Biome climate envelopes

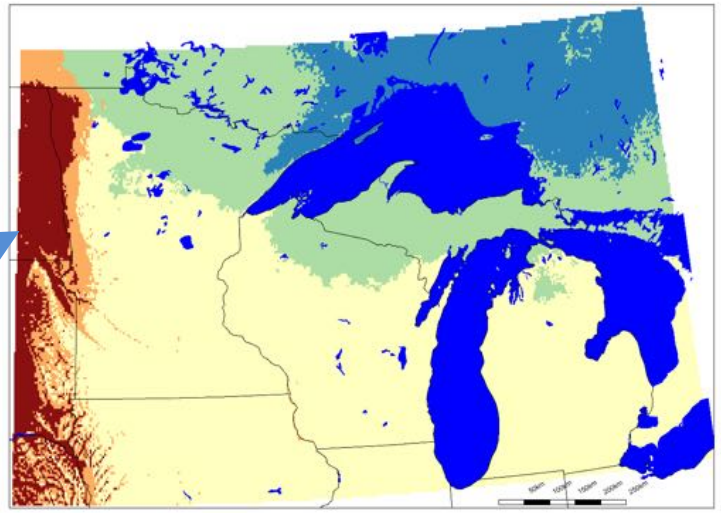


Future biome distribution in MN depends on choices made now for high or low CO_2 emission scenarios



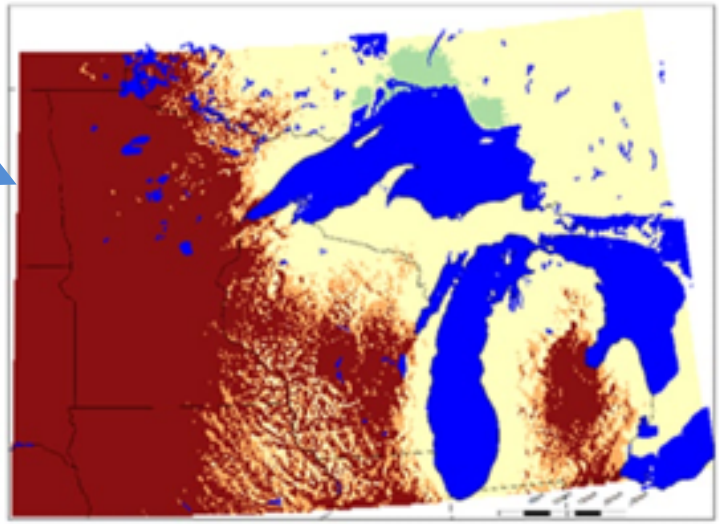
Current

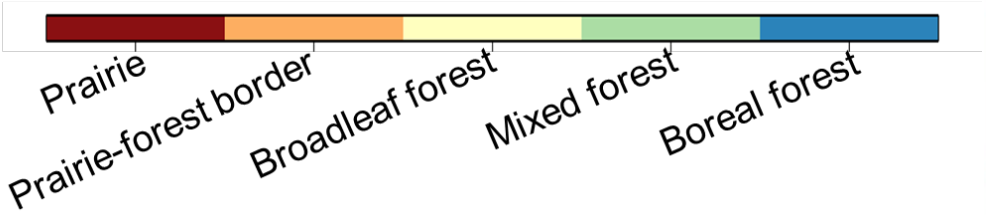
Low



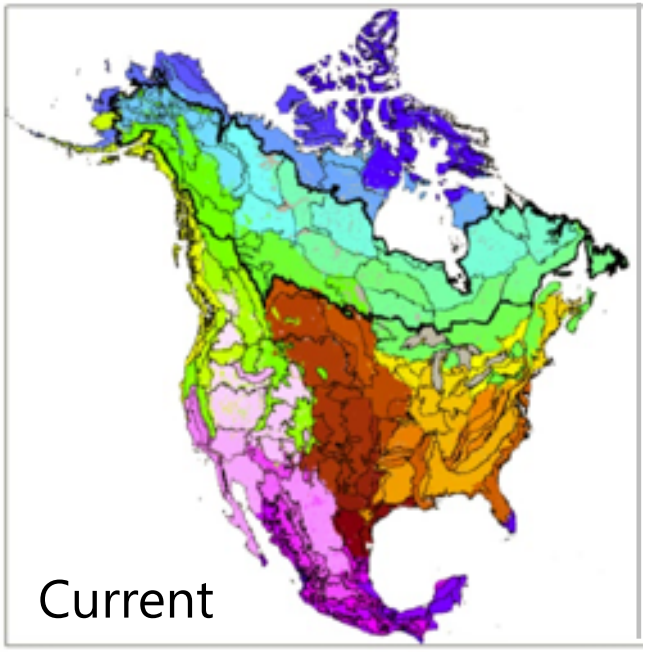
Future-2070

High





After Toot, Frelich, Butler and Reich. 2020. Forests, http://dx.doi.org/10.3390/f11091015s



Biome analysis:

Brown: grasslands

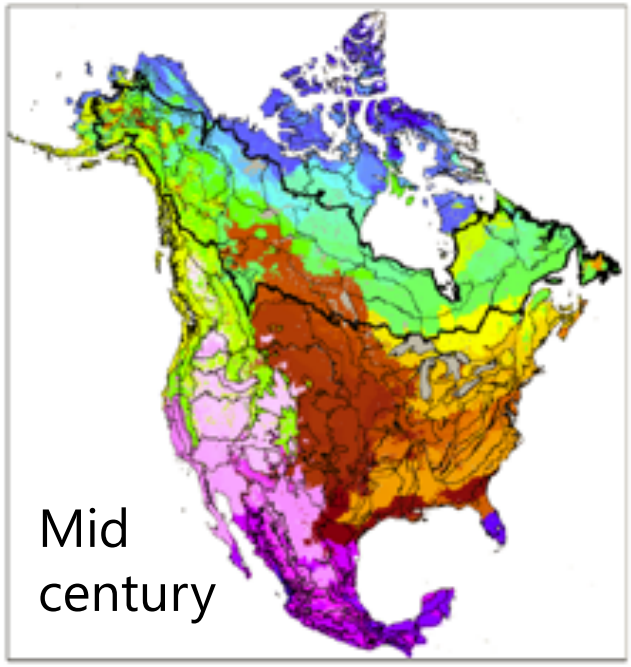
Orange/yellow: temperate forest

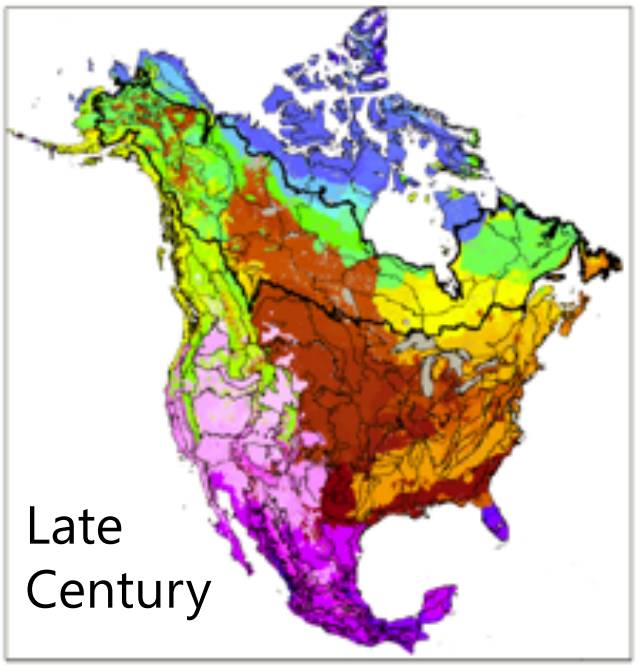
Green/light blue: Boreal forest

Light green: montane forests

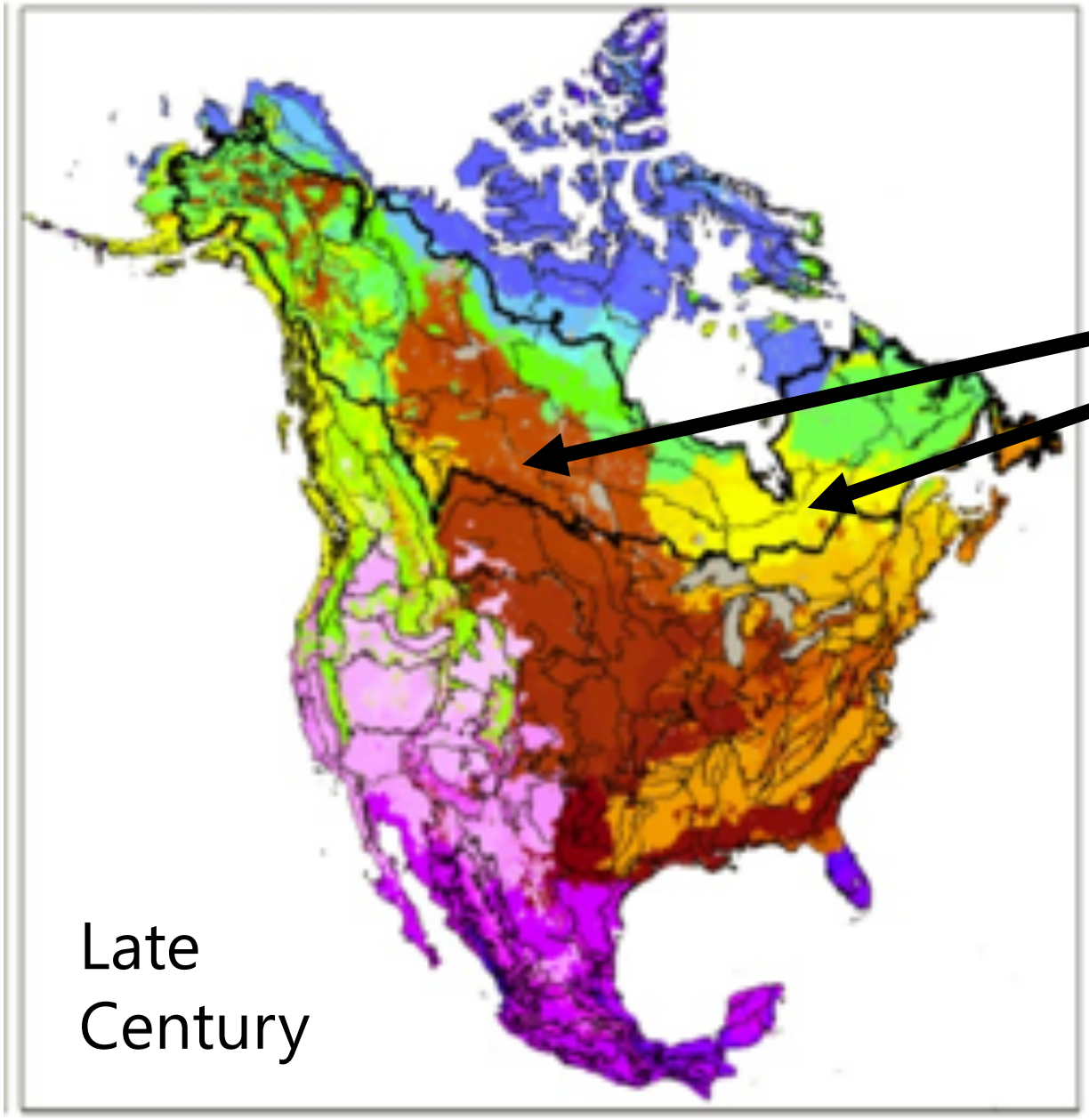
Dark blue: tundra

Pink/magenta: desert





Source: Diana Stralberg
Based on random forest analysis of 26 bioclimatic variables and an ensemble of 15 CMIP5 GCMs, RCP 8.5



Expected conversion of huge boreal forest expanses to:

- grasslands
- temperate forest

Climate analog:

Minnesota's Boundary Waters Canoe Area Wilderness today (blue star) and by end of the 21st Century (orange star)

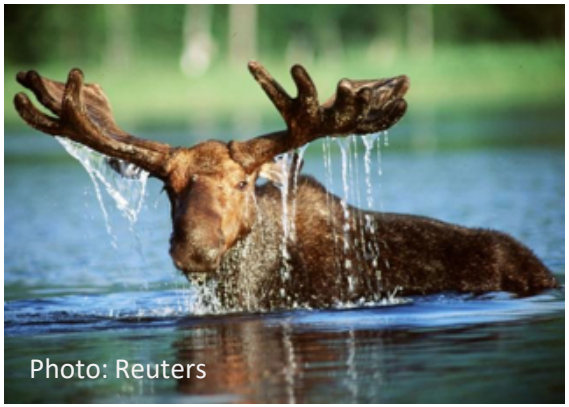
Boreal forest, Boundary Waters Canoe Area Wilderness, MN. Photo, Eli Anoszko

Lake and rocky island scenery, Gneiss Outcrops Natural Area
(photo Dave Hansen, UMN)

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

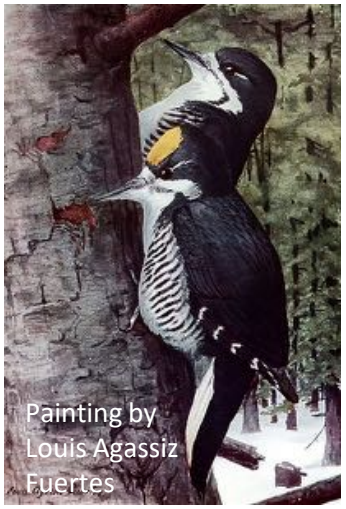
Lynx

Bobcat



Moose

Deer



Black Backed Woodpecker

Red-Bellied Woodpecker

Lee E. Frelich,
Gerald Niemi
and ten Minnesota
botanical artists

https://store.bookbaby.com/book/art-on-the-edge-of-the-boreal-forest1

Kathleen Franzen
Blackburnian Warbler, *Setophaga fusca (formerly Dendroica fusca)*
Watercolor
Mat opening: 9.5"w x 7.5"h
(White spruce, Pine)

Tamarack
Mary Ann O'Malley

Alternative futures based on choices made today:

Duncan Lake, BWCAW, in the future, with currently existing boreal forest reflected in the water. Digital image by David Luke.

Steve Windels, Ron Moen
Ryan Toot, Peter Reich,
Ethan Butler
Bruce and Ruth Dayton
Darby and Geri Nelson