Understanding the impacts of climate change on the Acadian Forest

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Natural Resources Canada

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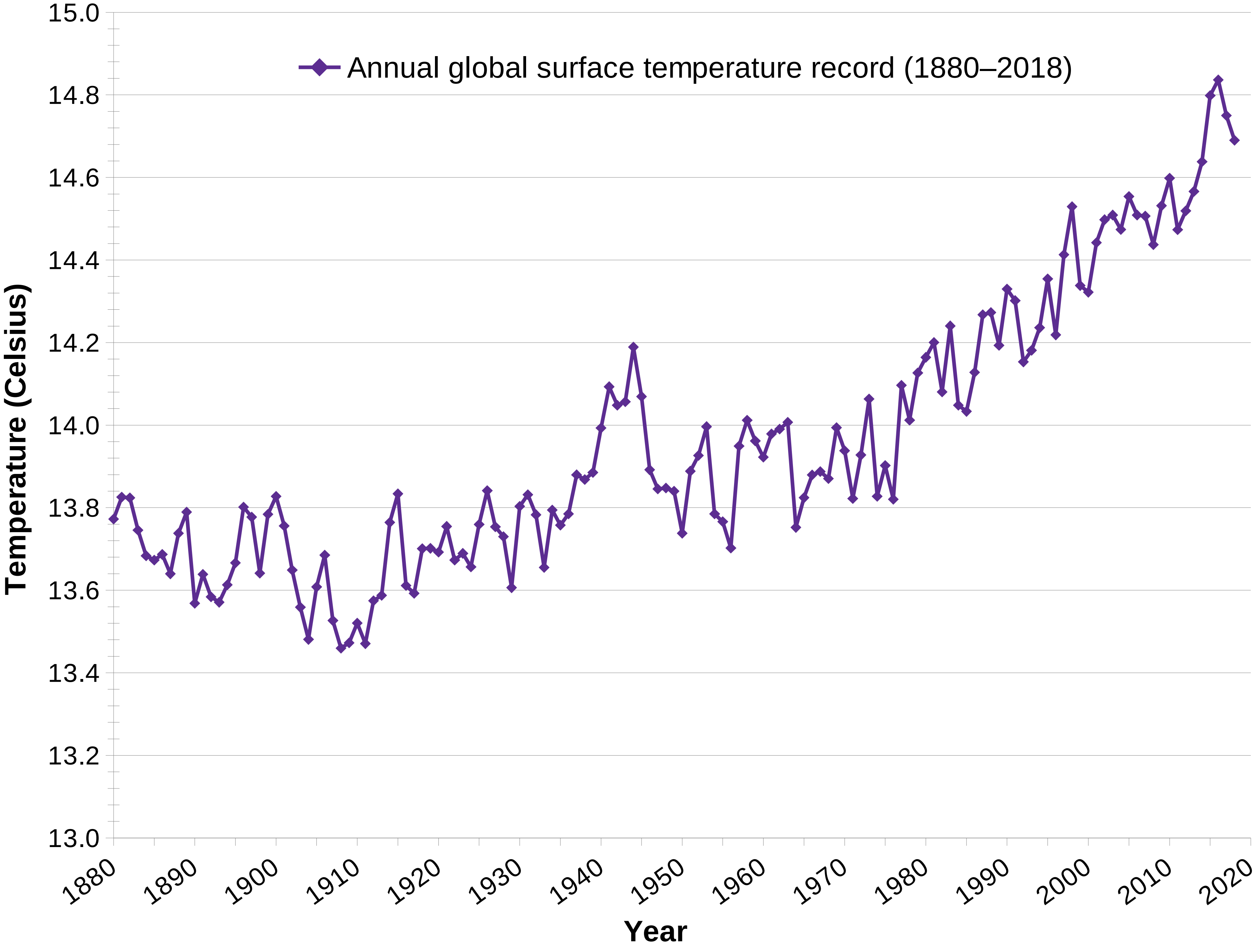
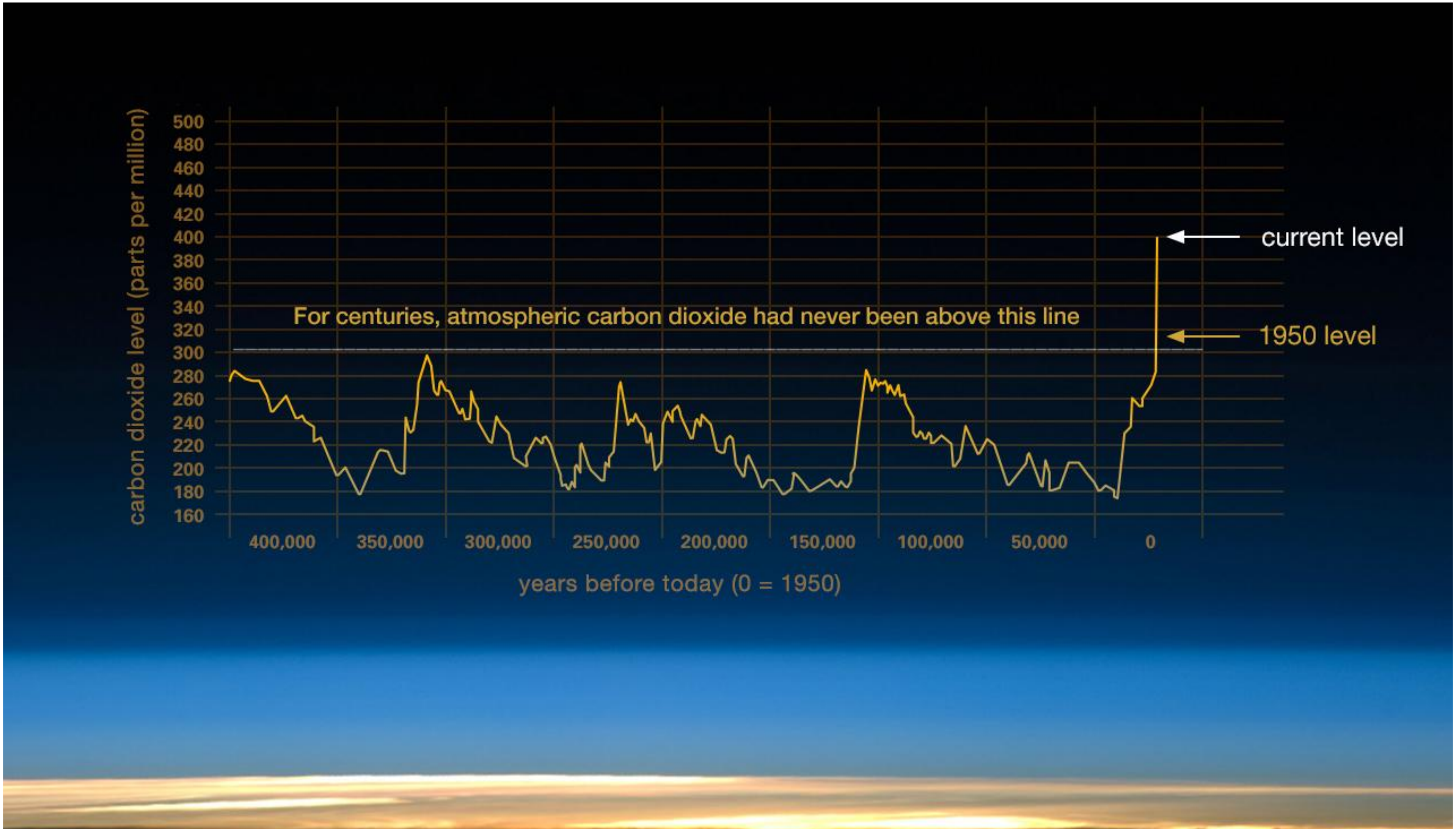
Today’s Agenda

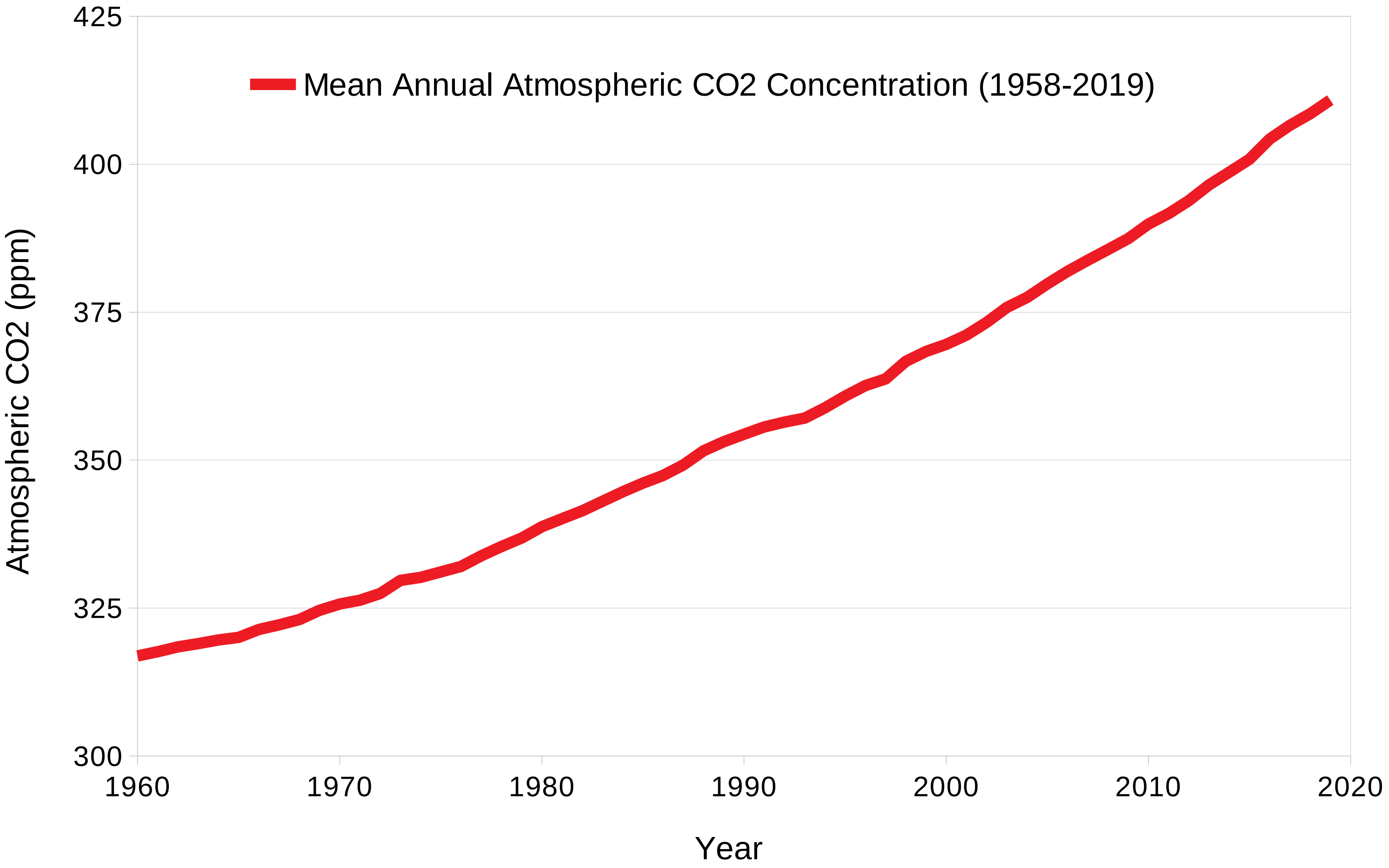
1. How much climate change
2. Impact on the Acadian Forest
3. Knowledge gaps
4. What can we do


Annual global surface temperature record (1880–2018)
Temperature (Celsius)
15.0
14.8
14.6
14.4
14.2
14.0
13.8
13.6
13.4
13.2
13.0
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Year

Atmospheric CO_2 highest in past 650,000 years

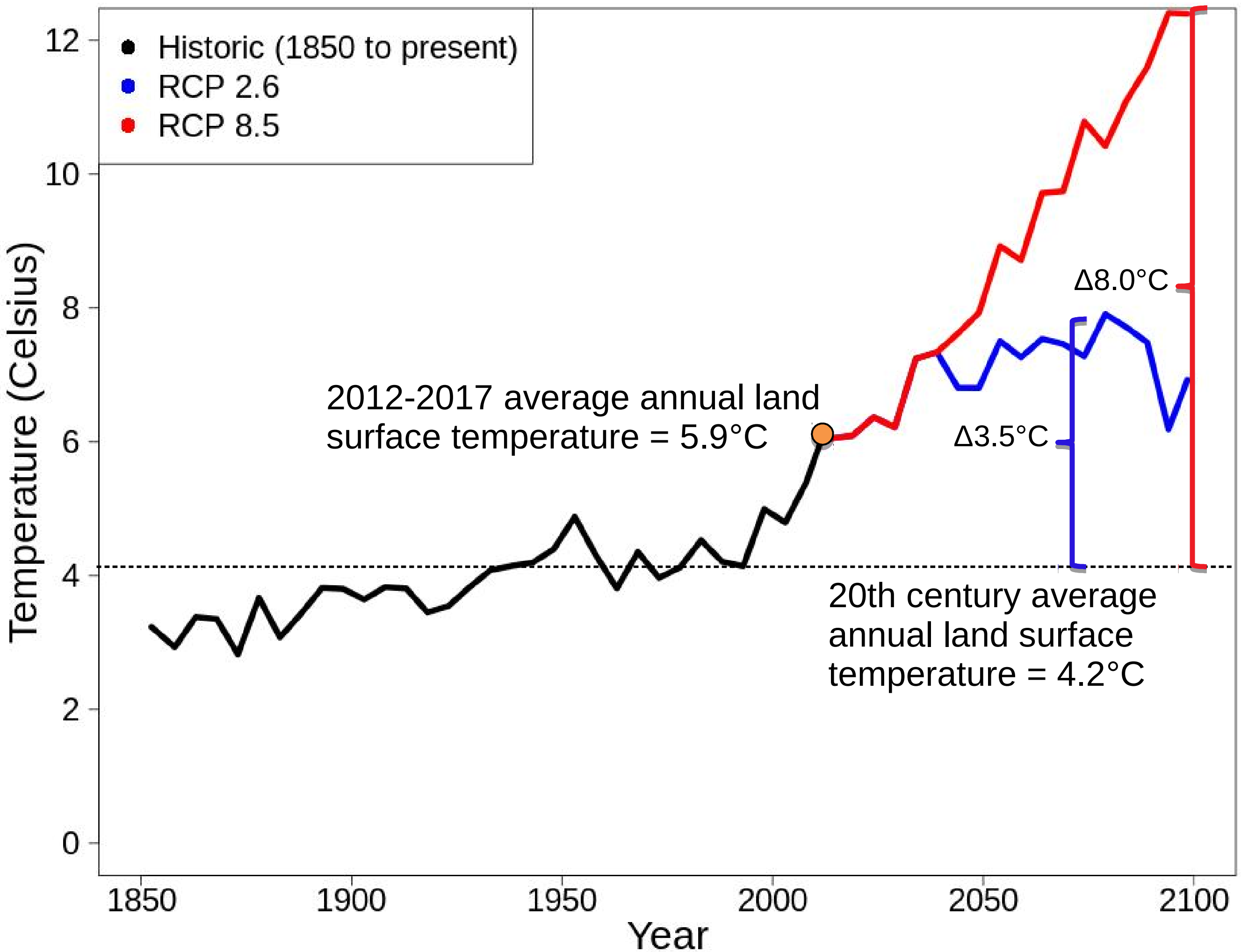


Source: NASA



Mean Annual Atmospheric CO2 Concentration (1958-2019)
Atmospheric CO2 (ppm)
425
400
375
350
325
300
1960
1970
1980
1990
2000
2010
2020
Year

Source: NASA

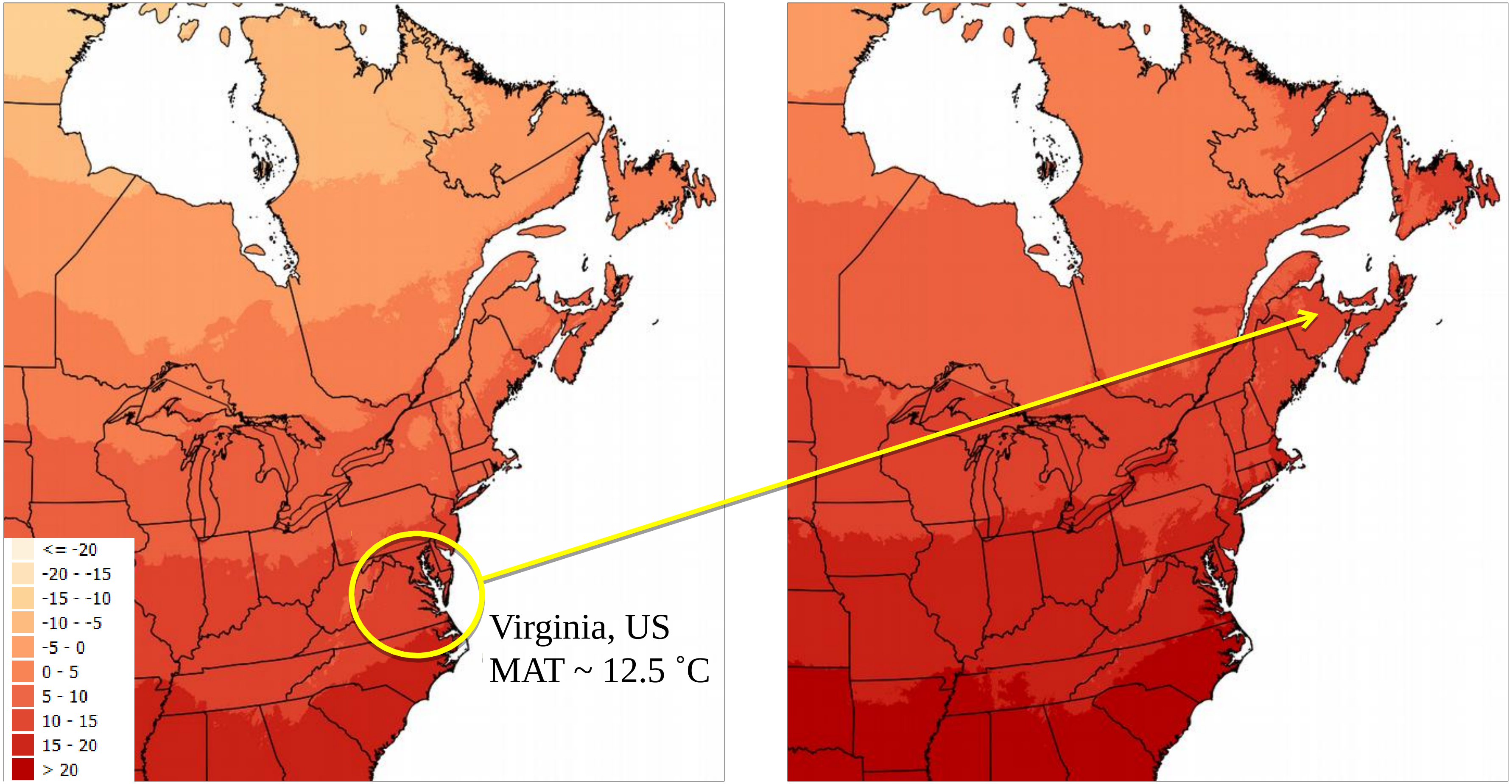


Sources:

Historic data: (berkeleyearth.org)

Projection data: (Natural Resources Canada)

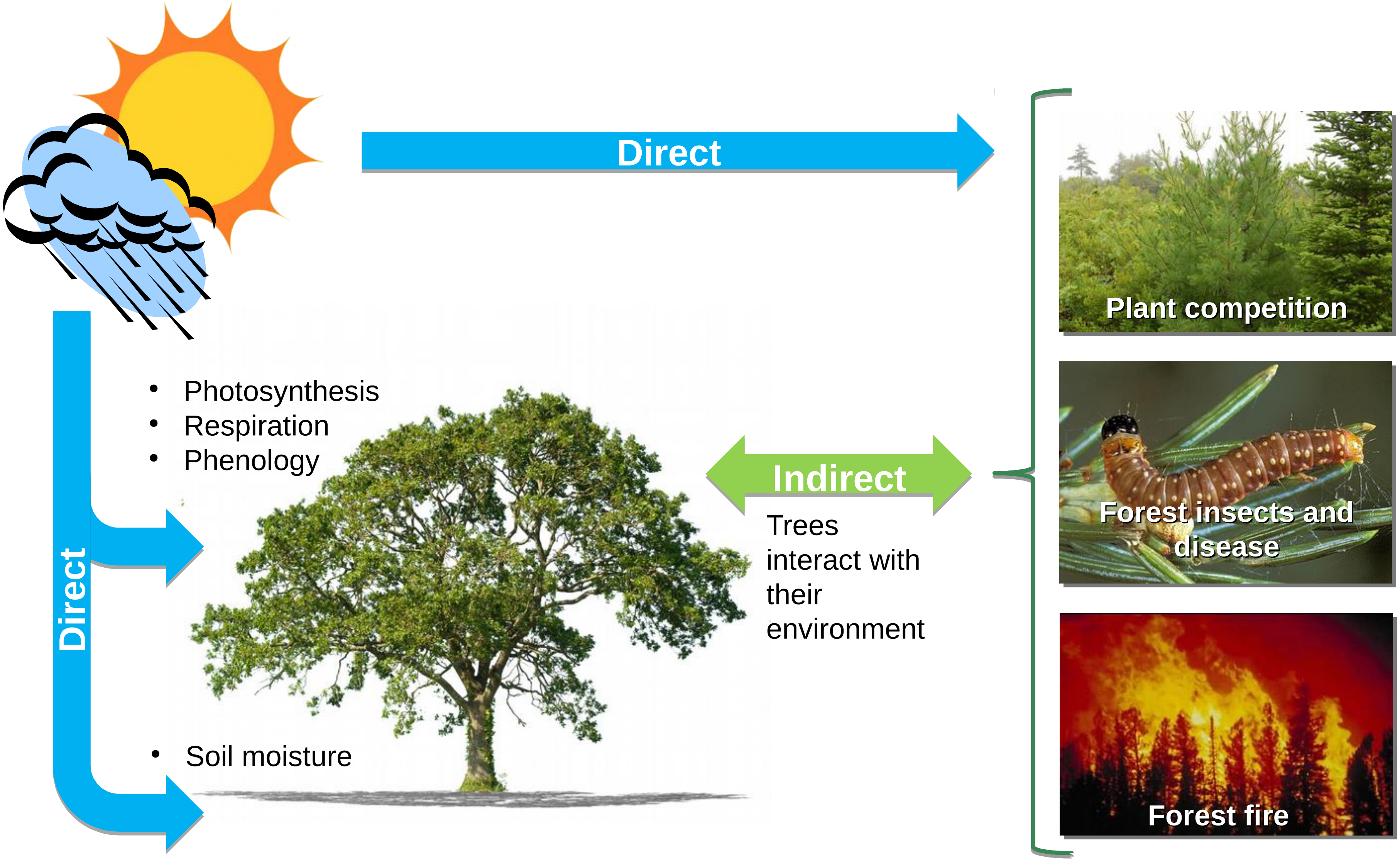
Mean Annual Temperature



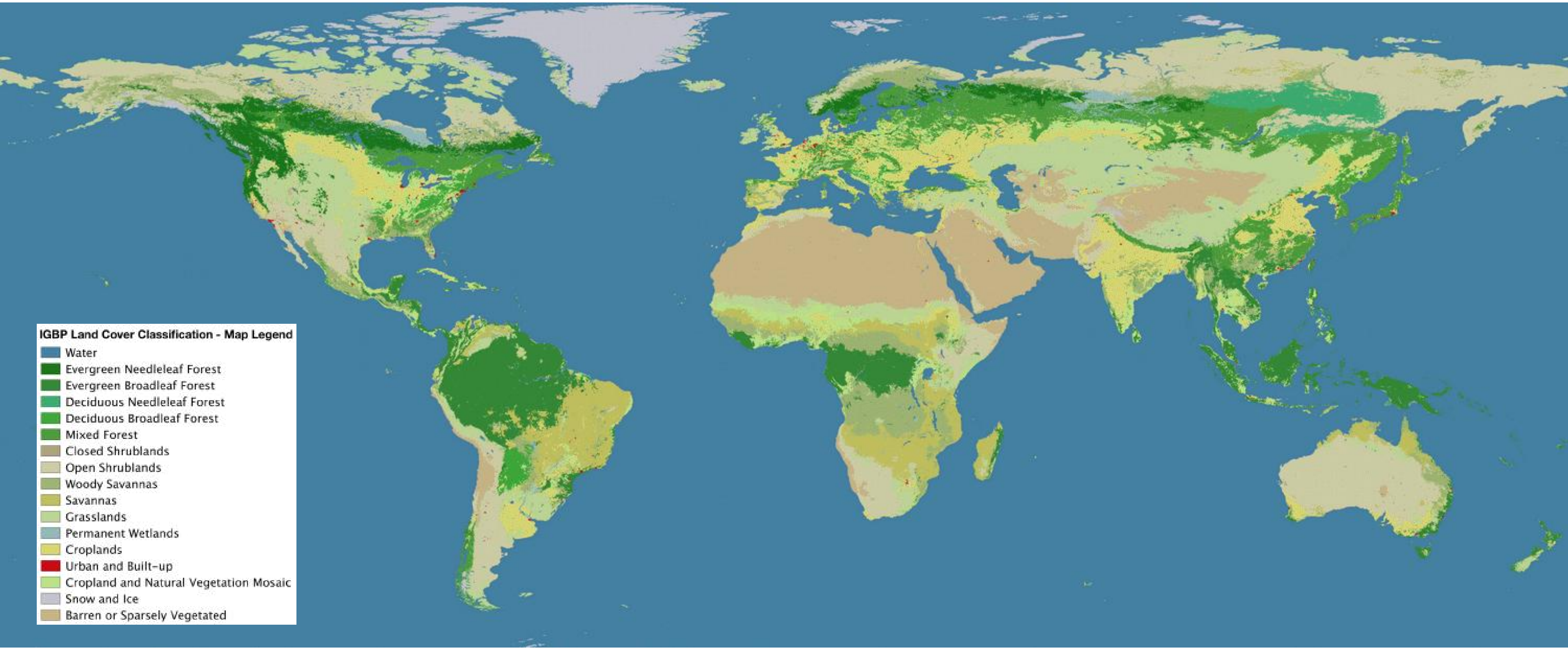
Current Climate

RCP 8.5 by end of 21st century

How will climate change affect our forest?



Climate controls global distribution of vegetation

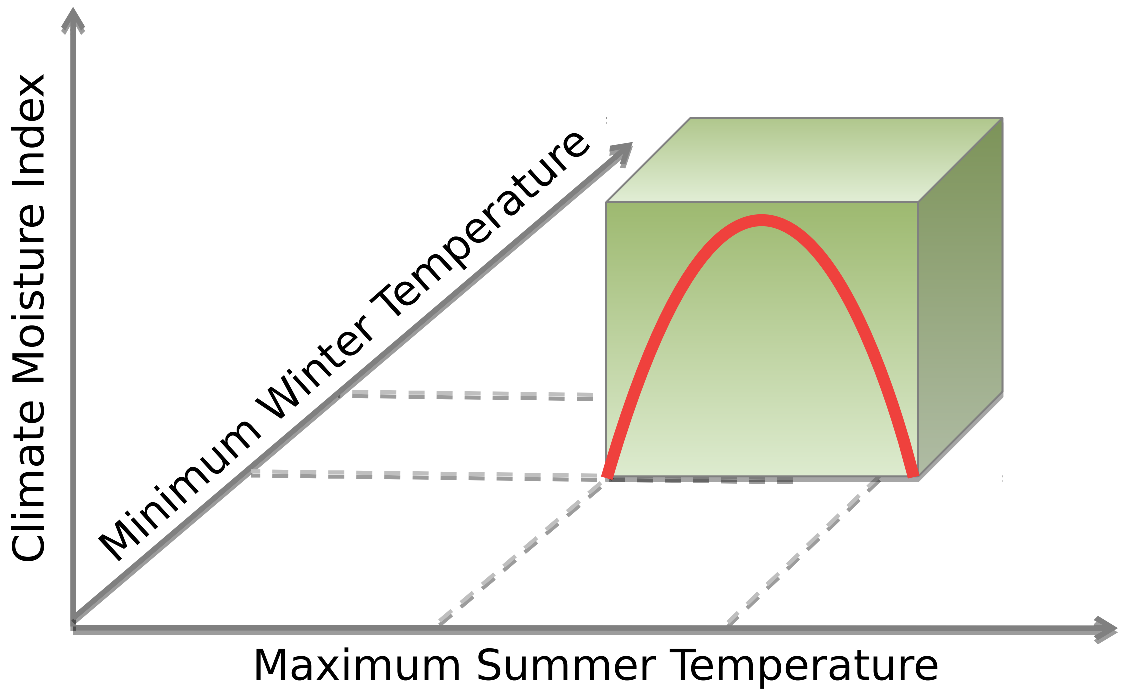


Environmental Niche Theory

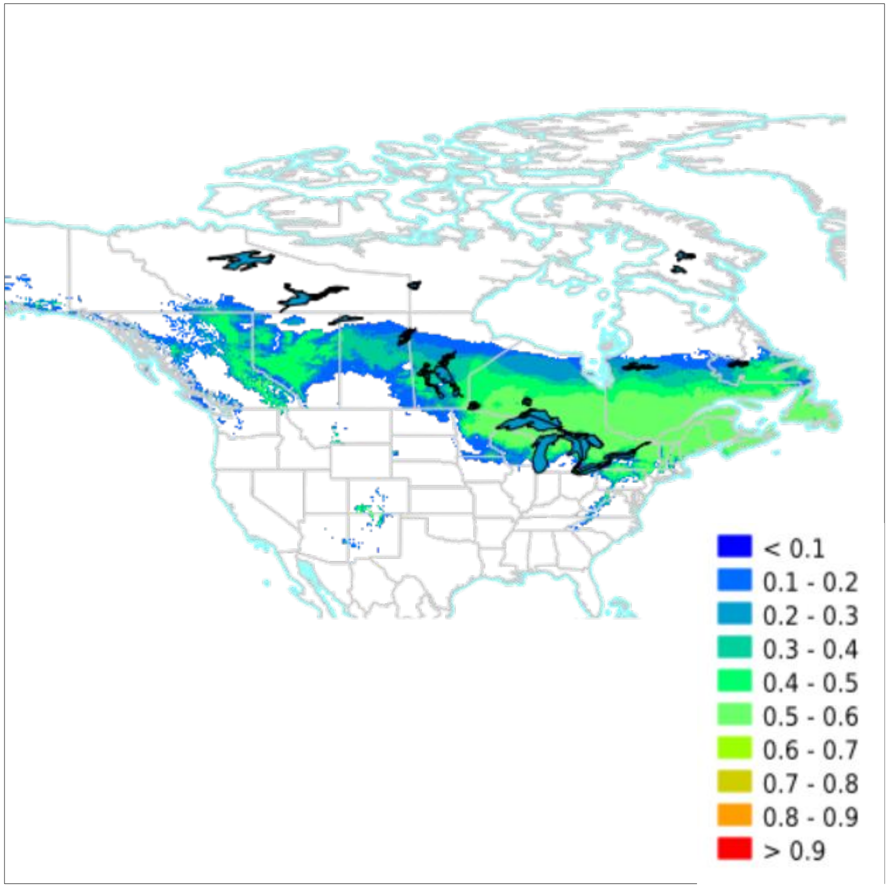
No species is adapted to all environments!

Environmental Niche: Sum total of a species' adaptations to its environment

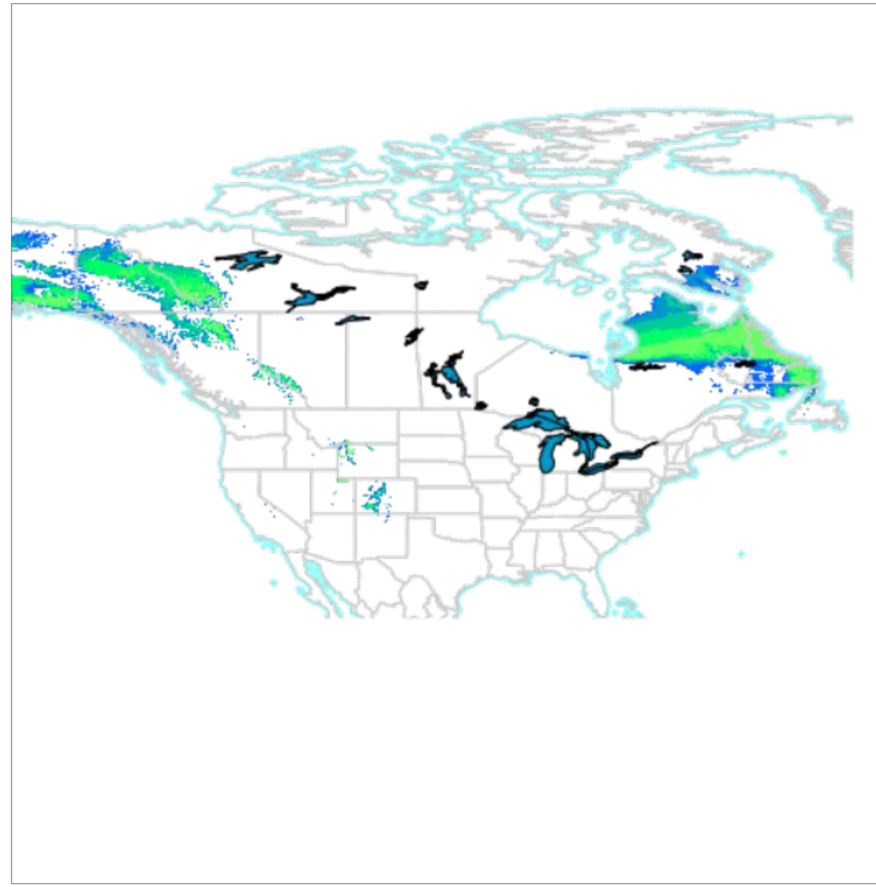
The niche is a multi-dimensional **Envelope** where each axis describes a species' response to an environmental factor that affects its **Performance** (growth, survival, and reproduction)



Balsam fir climate envelope



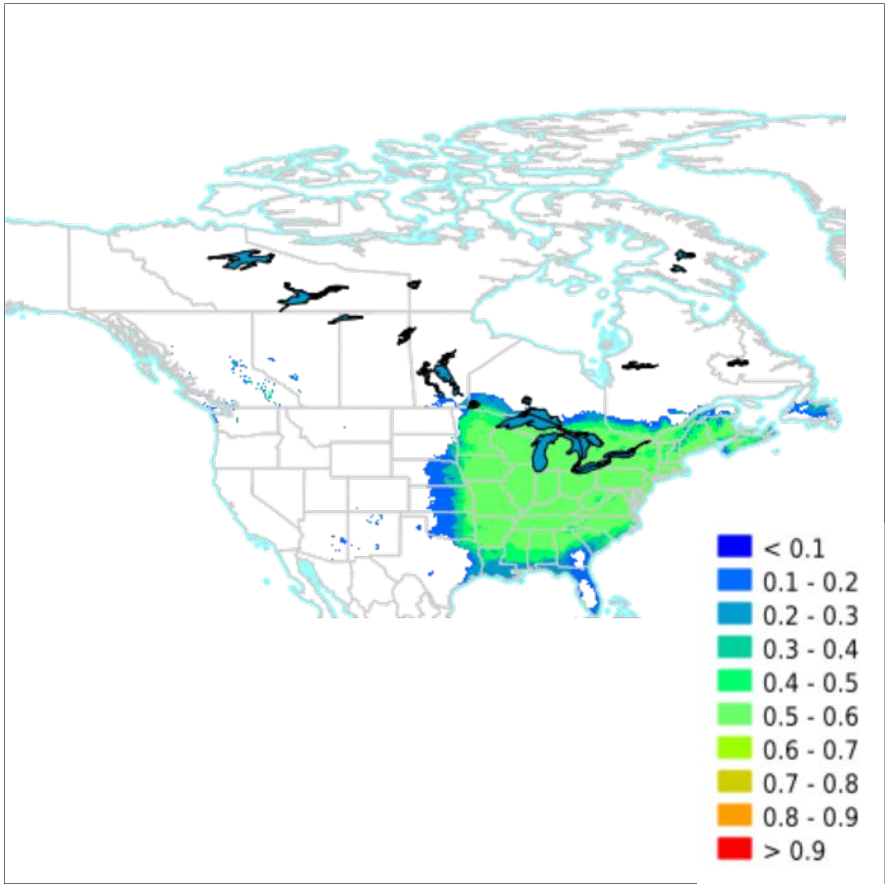
Current Climate Envelope



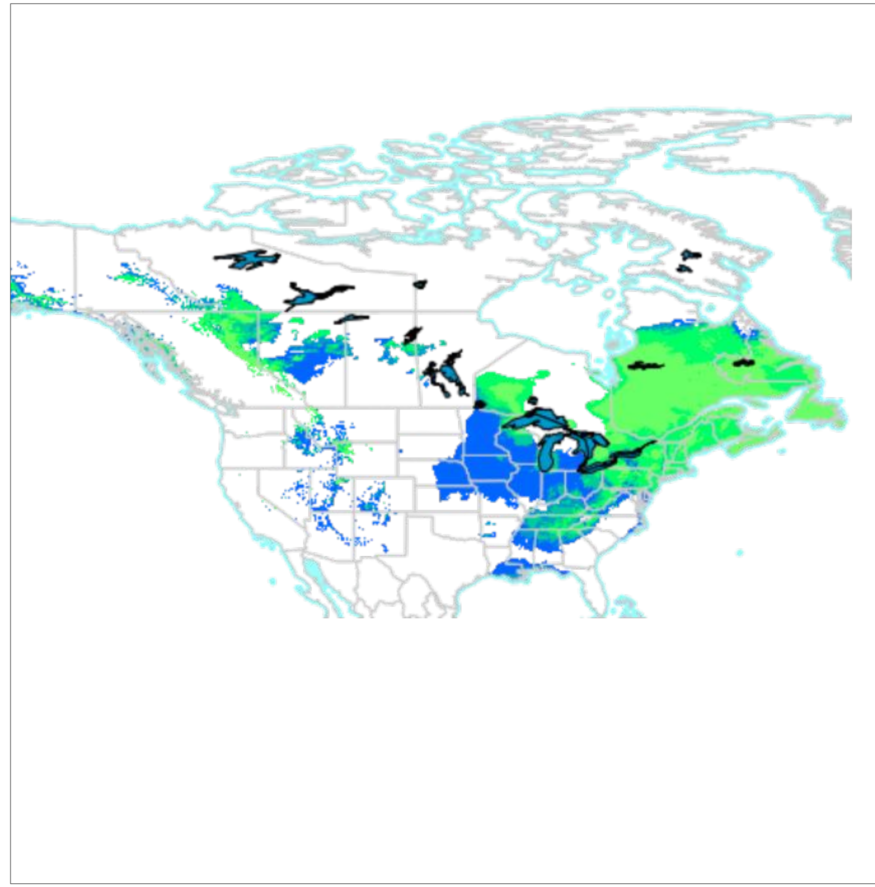
Projected Climate Envelope
Year 2100, RCP 8.5

Source: http://planthardiness.gc.ca/

Red oak climate envelope



Current Climate Envelope



Projected Climate Envelope
Year 2100, RCP 8.5

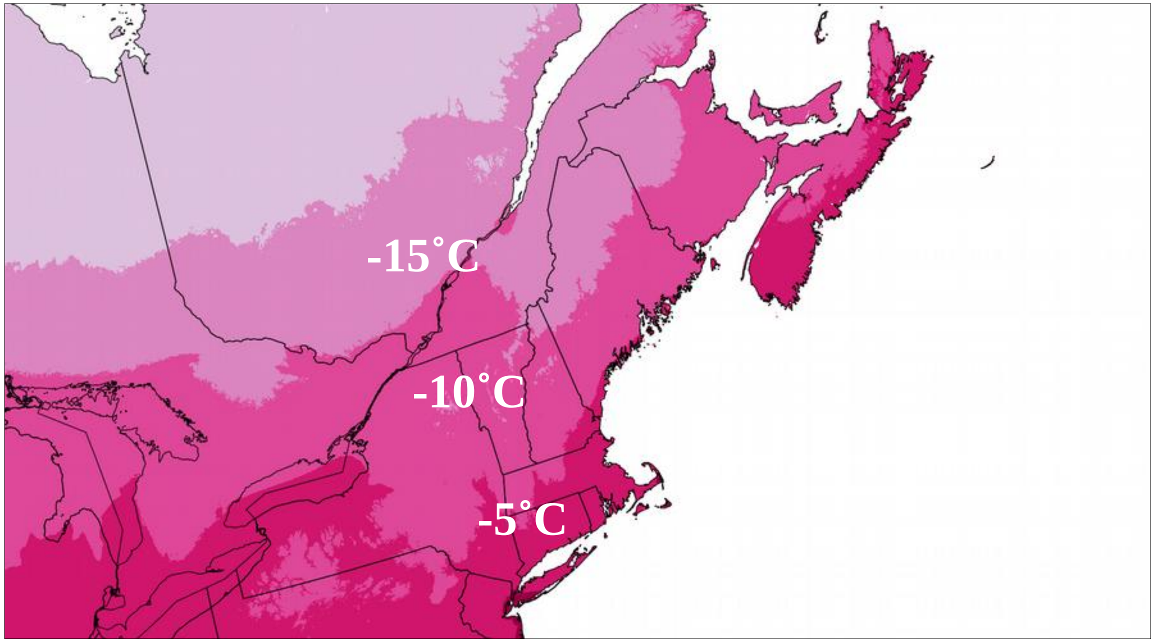
Source: http://planthardiness.gc.ca/

Indirect climate impacts

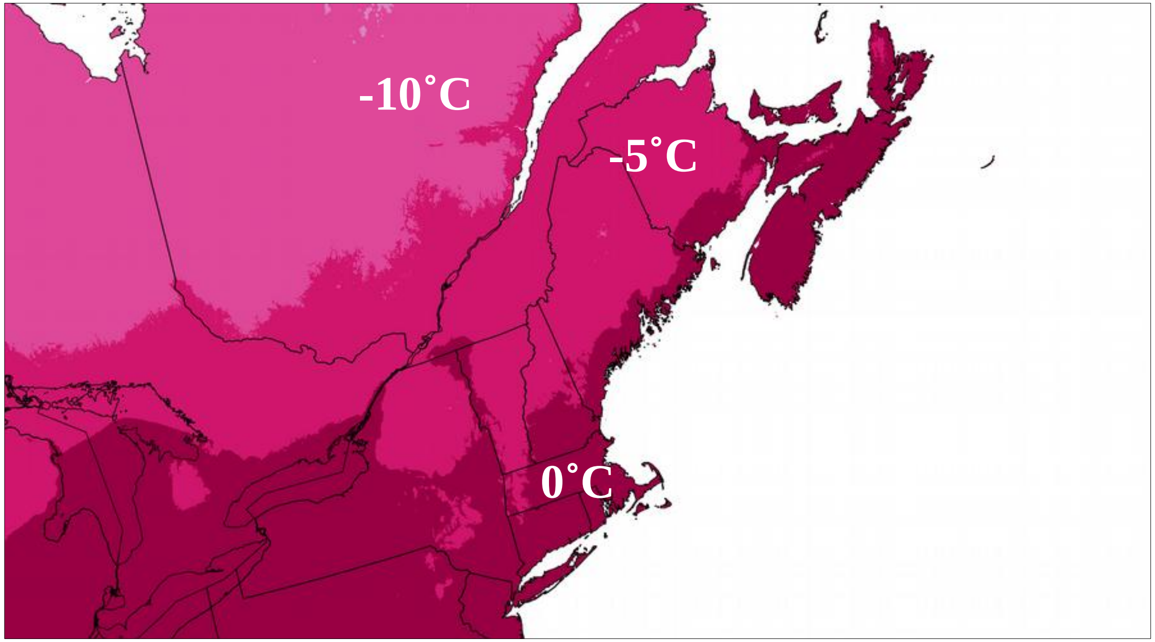
Hemlock Woolly Adelgid

- HWA (*Adelges tsugae*) introduced to Virginia, U.S. from Japan circa 1951
- Spread into New England states by 1980s; into southern Nova Scotia just recently
- Constrained by low winter temperatures (mean winter temp. of -5 ˚C, Paradis *et al.* 2008)
- Under RCP 8.5 it will expand its climatic range across all of Maritimes

Current Mean Winter Temperature

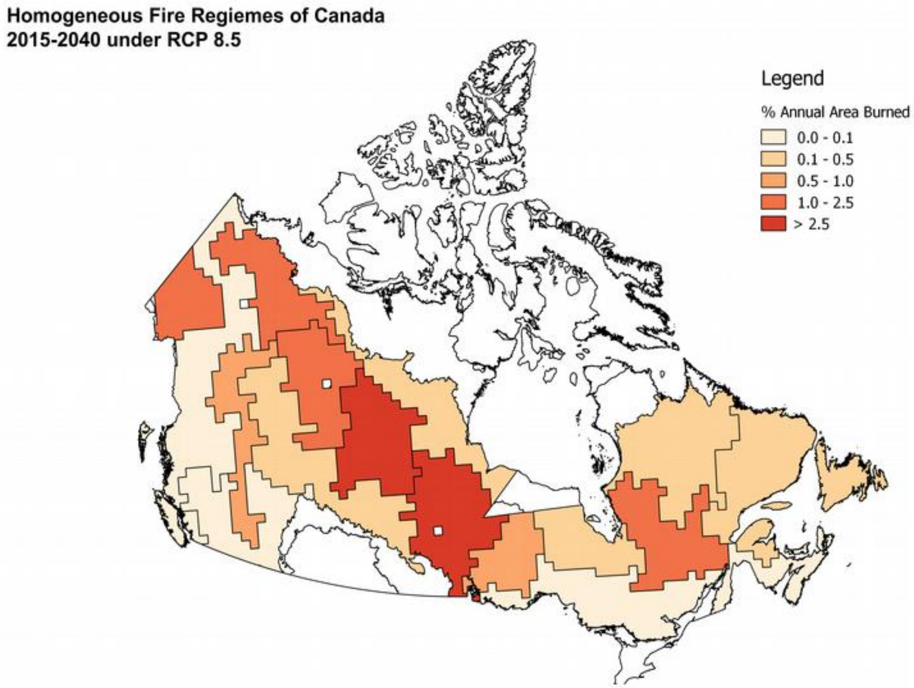


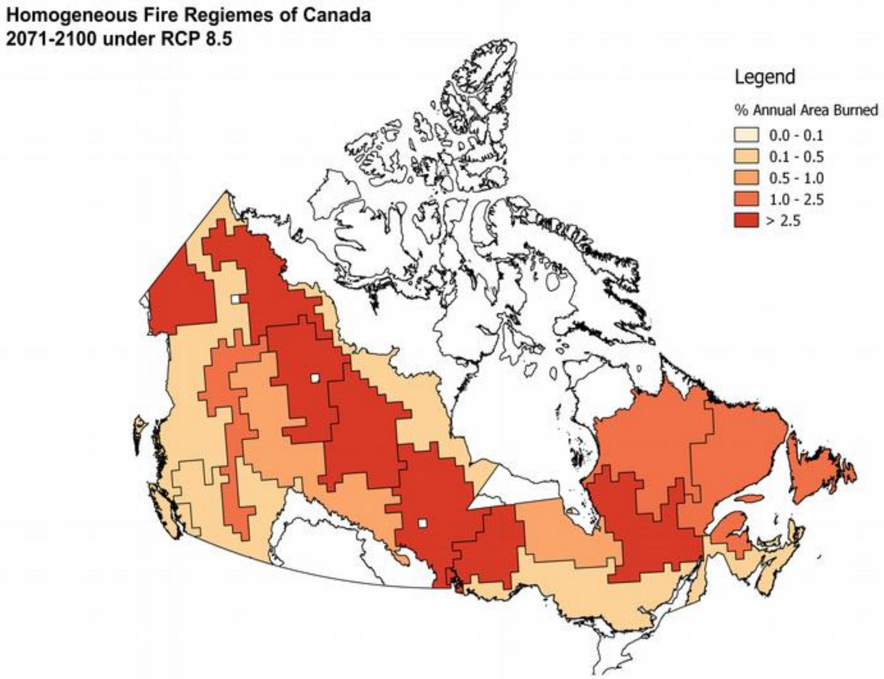
Mean Winter Temperature under RCP 8.5 by 2085



Indirect climate impacts

Wild Fire



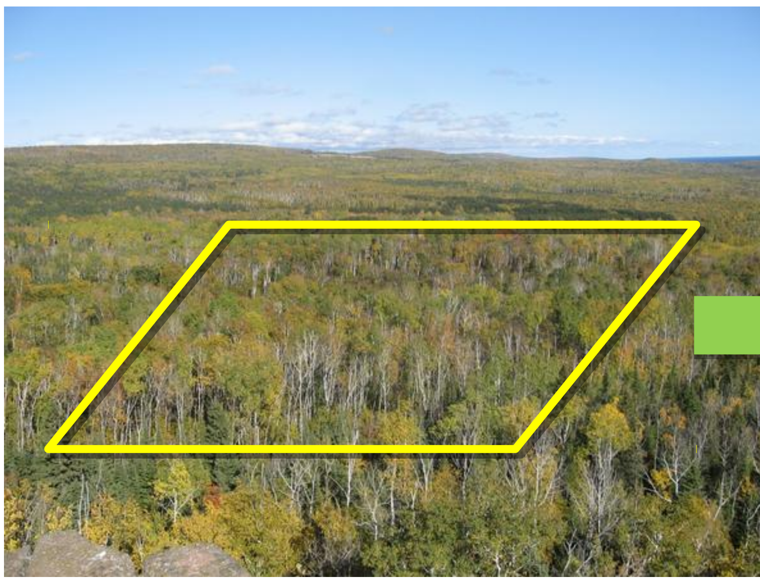


Source: Boulanger et al. (2013)

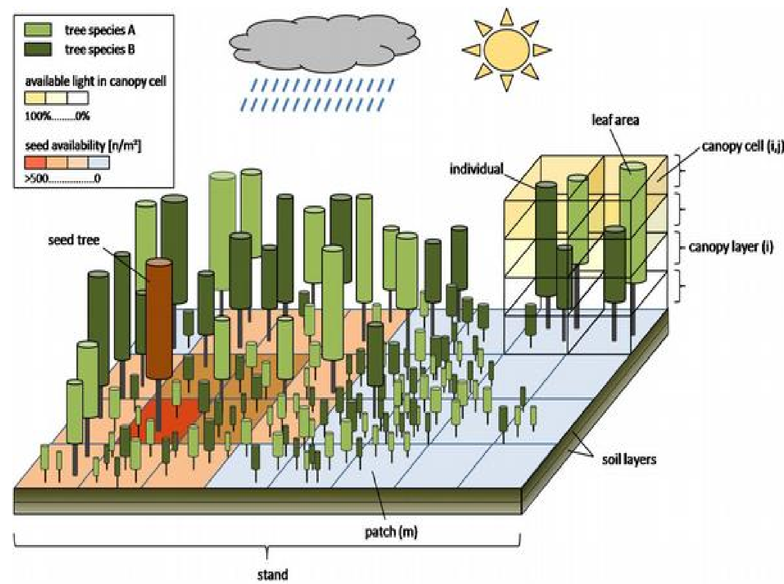
Bringing the pieces together

Forest Ecosystem Modeling

Computer models provide a framework for integrating our knowledge of how ecosystems function and allows us to make projections about how the system may respond to stimuli



Real Forest Ecosystem



Virtual Forest Ecosystem

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Rapid 21st century climate change projected to shift composition and growth of Canada's Acadian Forest Region

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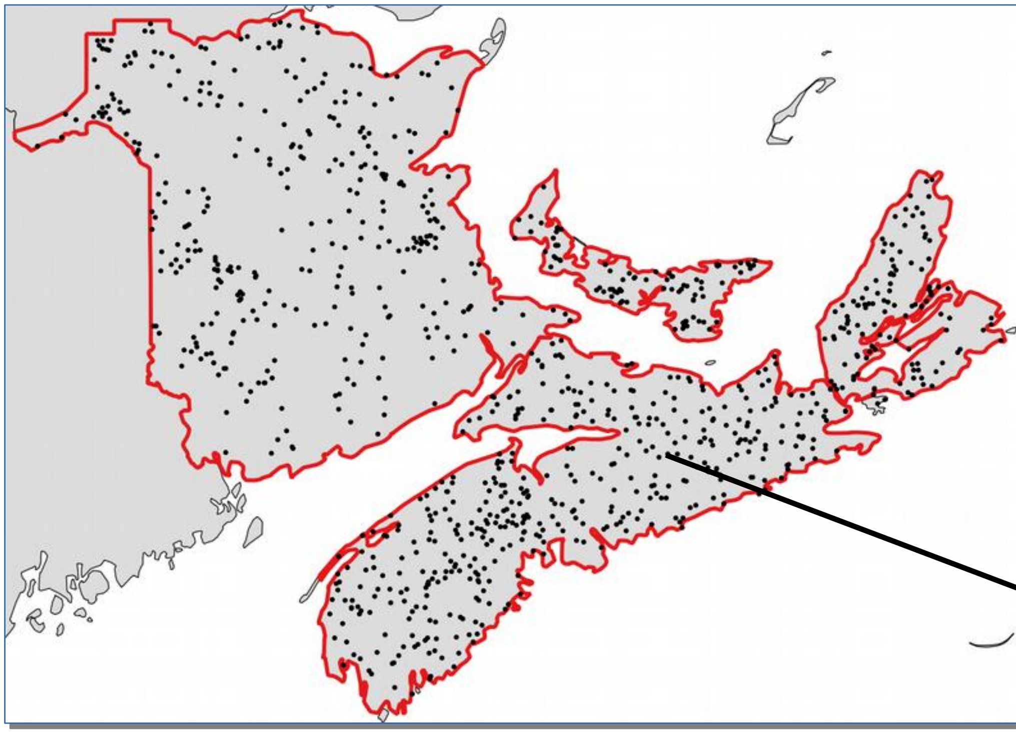
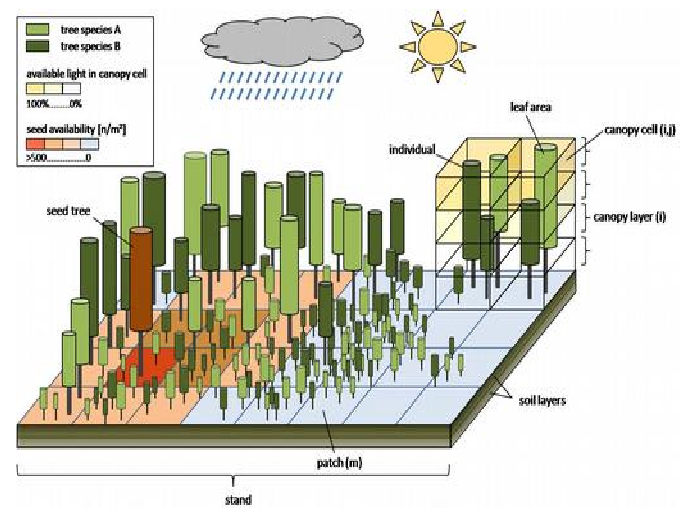
ABSTRACT

The impact of climate change on forests is expected to vary globally and regionally. Canada's Acadian Forest Region lies in the transition between the North American boreal and temperate forest biomes and may be particularly sensitive to changes in climate because many of its component species are currently at their southern or northern climatic range limits. Although some species may be lost, others may exhibit major productivity boosts—affecting the goods and services we derive from them. In this study, we use a well-established forest ecosystem simulation model, PICUS, to provide the first exploration of the impact of climate change on the composition and growth of the Acadian Forest Region for the period 2011 to 2100 under two radiative forcing scenarios, RCP 2.6 and RCP 8.5.

In the short term (2011–2040), little to no changes in forest composition or growth were projected under either forcing scenario compared with current forest conditions (simulated for 1981–2010 baseline climate); however, by mid-century, PICUS projected increasing departures from the baseline simulations in both composition and growth, with the greatest changes occurring under RCP 8.5 during the late 21st century (2071–2100). Our study indicates that under rapid 21st century warming, Canada's Acadian Forest Region will begin to lose its boreal character (i.e., "deborealize") as key tree species fail to regenerate and survive. Furthermore, increased growth and establishment by warm-adapted, temperate tree species may be unable to keep pace with the rapid loss of boreal species. This potential "lag effect" may lead to a temporary decrease in forest growth and wood supply during the late 21st century.

Modeling the Acadian Forest





Projections of forest composition
Results

Short-term (Today until year 2050)

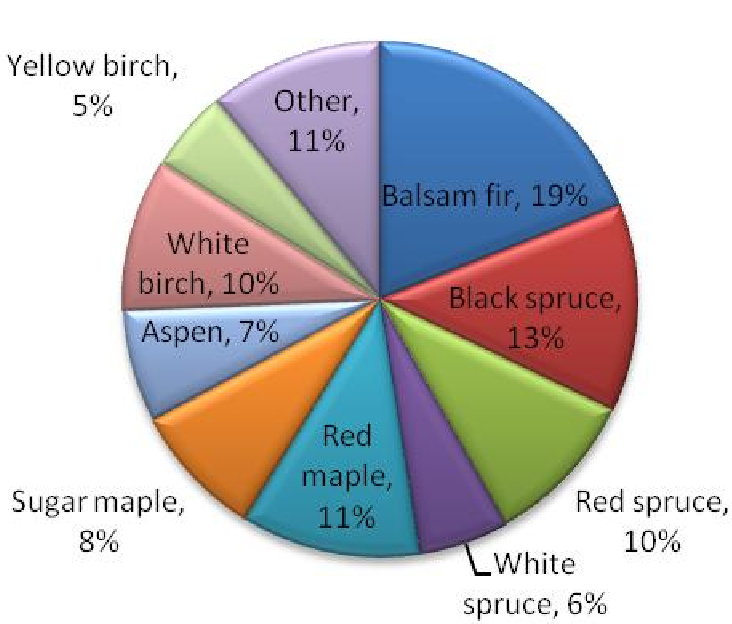
- Little to no change in forest composition under either RCP 2.6 or RCP 8.5

Long-term (year 2050 to 2100)

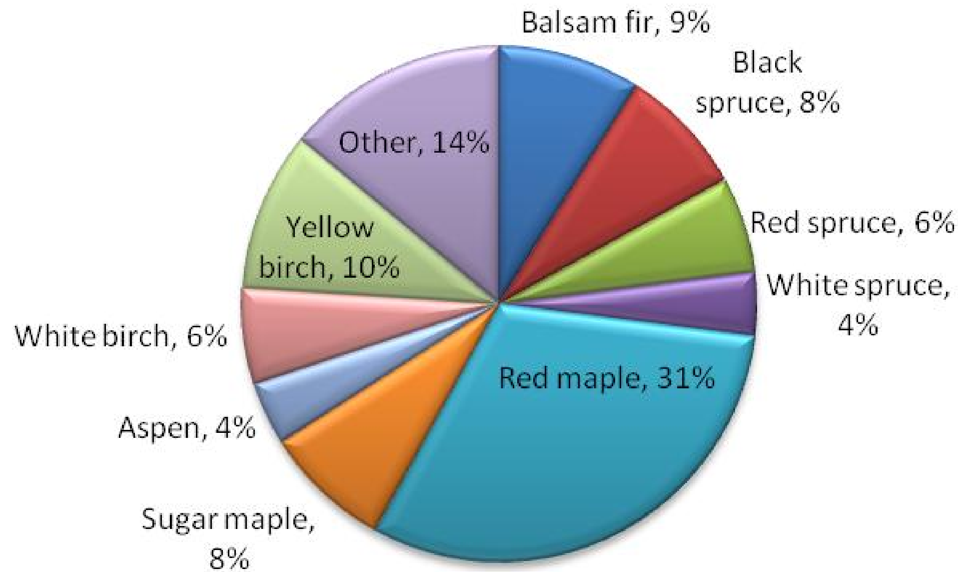
- No changes under RCP 2.6
- **Large changes under RCP 8.5**
  - Decline in cold adapted boreal species
  - Increase in warm adapted temperate species
  - Deborealization of the Acadian Forest

Projections of forest composition

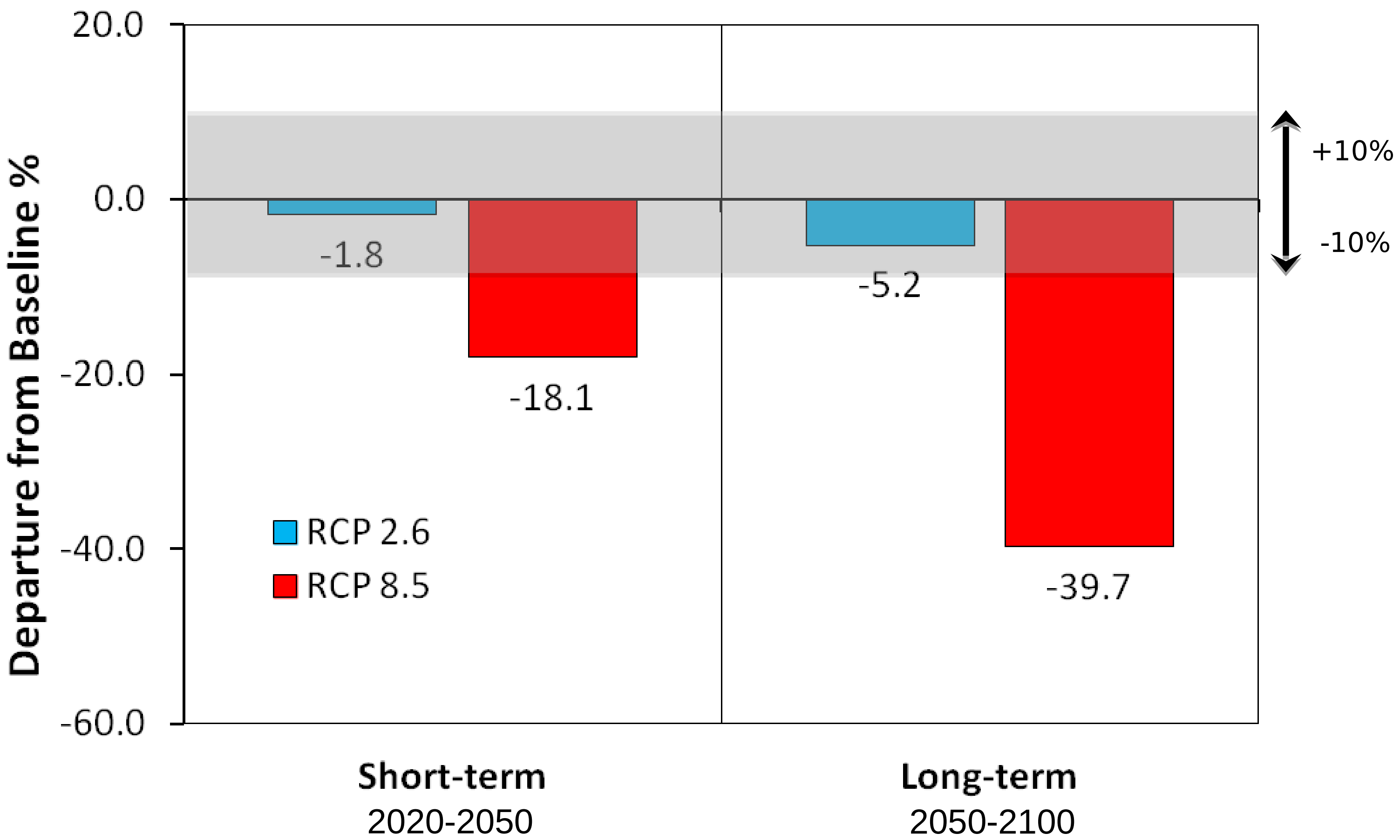
Current forest composition



Projected forest composition by 2100 under RCP 8.5



Projections of forest growth



Interpreting our model results

- Composition shifts driven by changes in "**interspecific competition**" **(implications for silviculture)**
- Growth decline driven by 1) direct climate effects and 2) a "**blocking mechanism**"
- Balsam fir and spruce are unlikely to disappear, but will become increasingly **maladapted**, rendering them less competitive

Comparing with other model results

Our results align with a growing number of other modeling studies

1) Bourque and Hassan 2008 (The Forestry Chronicle)
2) Rogers et al. 2016. (Global Change Biology)
3) Boulanger et al. 2017 (Landscape Ecology)

Table 4. Comparison of climate change resiliency projections from three research projects, for thirteen tree species, for 2011-2100. This estimate (*) likely underestimates the effects of beech bark disease in the region and (**) likely underestimates the overall abundance of sugar maple (see article for details).

Native Tree Species	FBR	Taylor *et al.*	Bourque & Hassan	Conclusion
American Basswood (*Tilia americana*)	Decline	-	-	
American Beech (*Fagus grandifolia*)	Prosper	Increase*	-	
American Mountain Ash (*Sorbus americana*)	Persevere	-	-	
Balsam Fir (*Abies balsamea*)	Decline	Decrease	Decline	**Decline**
Balsam Poplar (*Populus balsamifera*)	Persevere	-	-	
Black Ash (*Fraxinus nigra*)	Decline	-	-	
Black Cherry (*Prunus serotina*)	Prosper	-	-	
Black spruce (*Picea mariana*)	Decline	Decrease	-	**Decline?**
Black Willow (*Salix nigra*)	Decline	-	-	
Bur Oak (*Quercus macrocarpa*)	Persevere	-	-	
Butternut (*Juglans cinerea*)	Persevere	-	-	
Eastern Hemlock (*Tsuga canadensis*)	Persevere	Unclear	Persevere	**Persevere**
Eastern Larch (*Larix laricina*)	Persevere	Decrease	-	**Unclear**
Eastern White Cedar (*Thuja occidentalis*)	Persevere	Unclear	Decline	**Isolated patches?**
Grey Birch (*Betula populifolia*)	Decline	-	-	
Ironwood (*Ostrya virginiana*)	Proliferate	-	-	
Jack pine (*Pinus banksiana*)	Disappear	Decrease	-	**Decline?**
Large Toothed Aspen (*Populus grandidentata*)	Decline	-	-	
Mountain Maple (*Acer spicatum*)	Persevere	-	-	
Mountain paper Birch (*Betula cordifolia*)	Prosper	-	-	
Pin Cherry (*Prunus pensylvanica*)	Persevere	-	-	
Red Maple (*Acer rubrum*)	Proliferate	Increase	Proliferate	**Proliferate**
Red Oak (*Quercus rubra*)	Prosper	Increase	Proliferate	**Proliferate**
Red pine (*Pinus resinosa*)	Persevere	Decrease	Decline	**Decline**
Red spruce (*Picea rubens*)	Decline	Decrease	Persevere	**Isolated patches?**
Serviceberry (*Amelanchier canadensis*)	Persevere	-	-	
Silver Maple (*Acer saccharinum*)	Persevere	-	-	
Striped Maple (*Acer pensylvanicum*)	Persevere	-	-	
Sugar Maple (*Acer saccharum*)	Persevere	Decrease**	Persevere	**Persevere**
Trembling Aspen (*Populus tremuloides*)	Persevere	Decrease	-	**Unclear**
White Ash (*Fraxinus americana*)	Persevere	Increase	Proliferate	**Prosper**
White Birch (*Betula papyrifera*)	Decline	Decrease	Decline	**Decline**
White Elm (*Ulmus americana*)	Prosper	-	-	
White pine (*Pinus strobus*)	Prosper	Increase	Prosper	**Prosper**
White spruce (*Picea glauca*)	Decline	Decrease	Decline	**Decline**
Yellow Birch (*Betula alleghaniensis*)	Decline	Unclear	Persevere	**Isolated patches?**

Comparing with empirical studies

Growing number of empirical studies support our predicted changes

1) Evans and Brown 2017 (Environmental Reviews)
2) Fisichelli et al. 2014. (Ecography)
3) **Fei et al. 2017 "Divergence of species responses to climate change" (Science)**

Over the last 30 years

- **76% of species shifted west**
- **62% of species shifted north**
- **Greater shifts in saplings than adults**
- **Shifts correlated with climate shifts**
- **Different shifts depending on phylogeny**
  - **81% angiosperms shifted west**
  - **71% of gymnosperms shifted north**

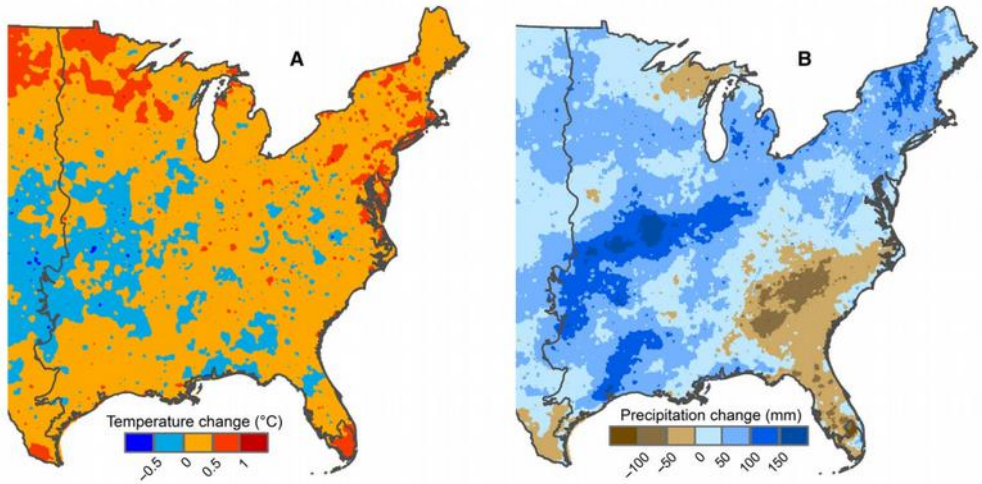


Fig. 1. Changes in temperature and precipitation across the eastern United States. (**A**) Changes in MAT and (**B**) TAP between the recent past (1951–1980) and the study period (1981–2014).

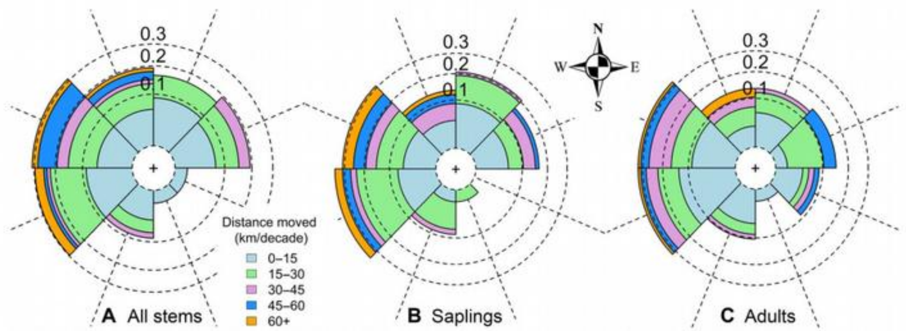
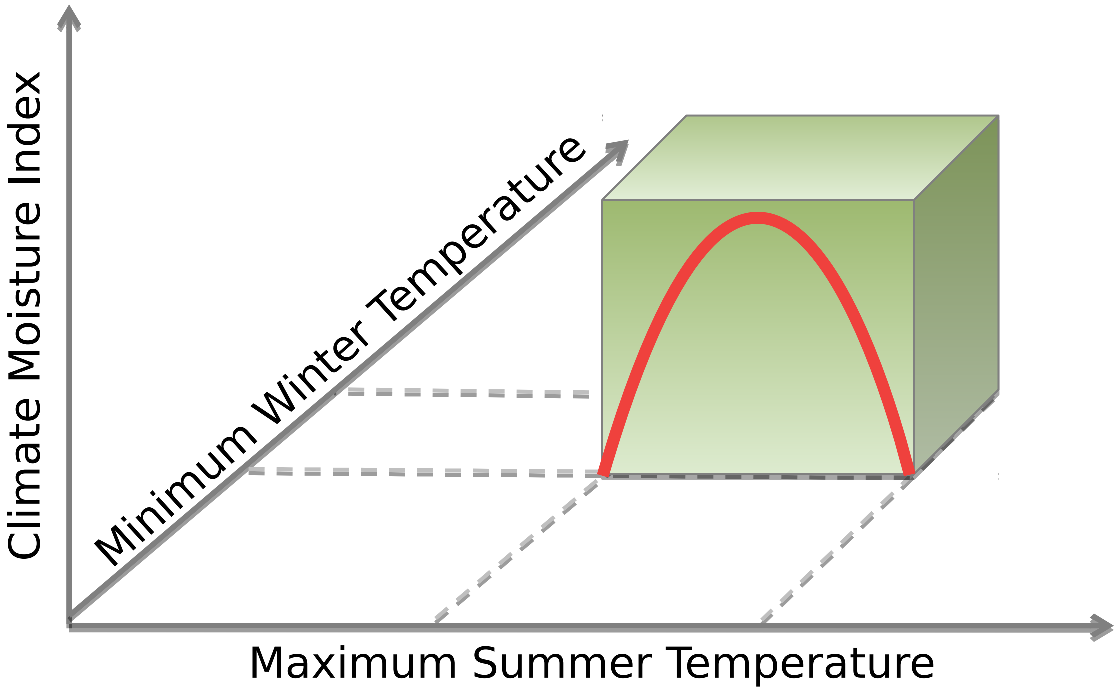


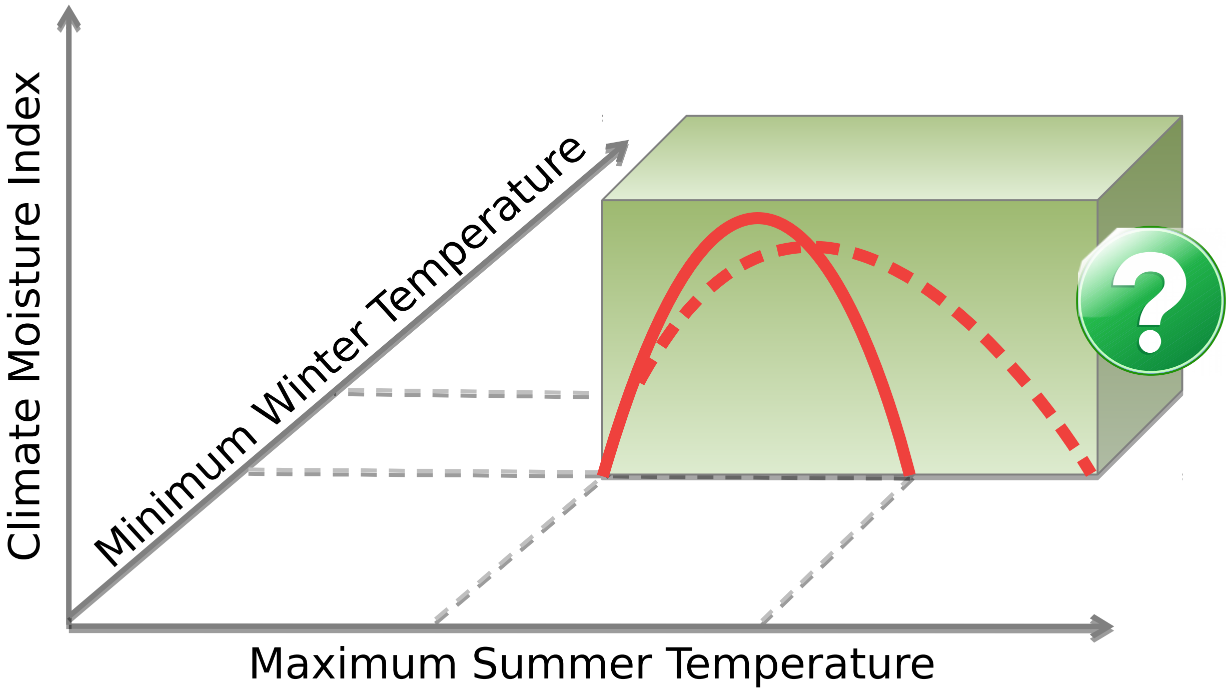
Fig. 2. Rose diagrams depicting the direction and distance of abundance shifts for 86 species. Spatial shift of species abundance for (**A**) all stems, (**B**) saplings, and (**C**) adult trees between two inventory periods (1980s and 2010s). Color represents the different distance categories, and wedge width represents the proportion of species in each direction-distance category.

Take it with a grain of salt...

Environmental Niche Theory



Environmental niche limits poorly understood



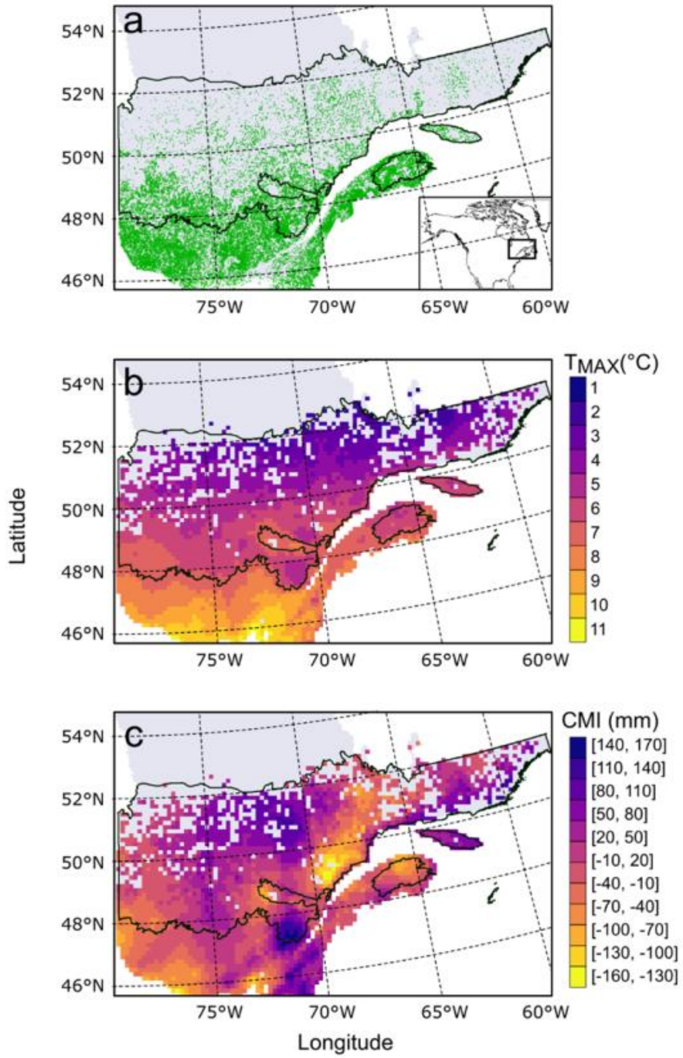
Recent research on climatic limits

D’Orangeville et al. (2018) Beneficial effects of climate warming on boreal tree growth may be transitory. **Nature Communications**

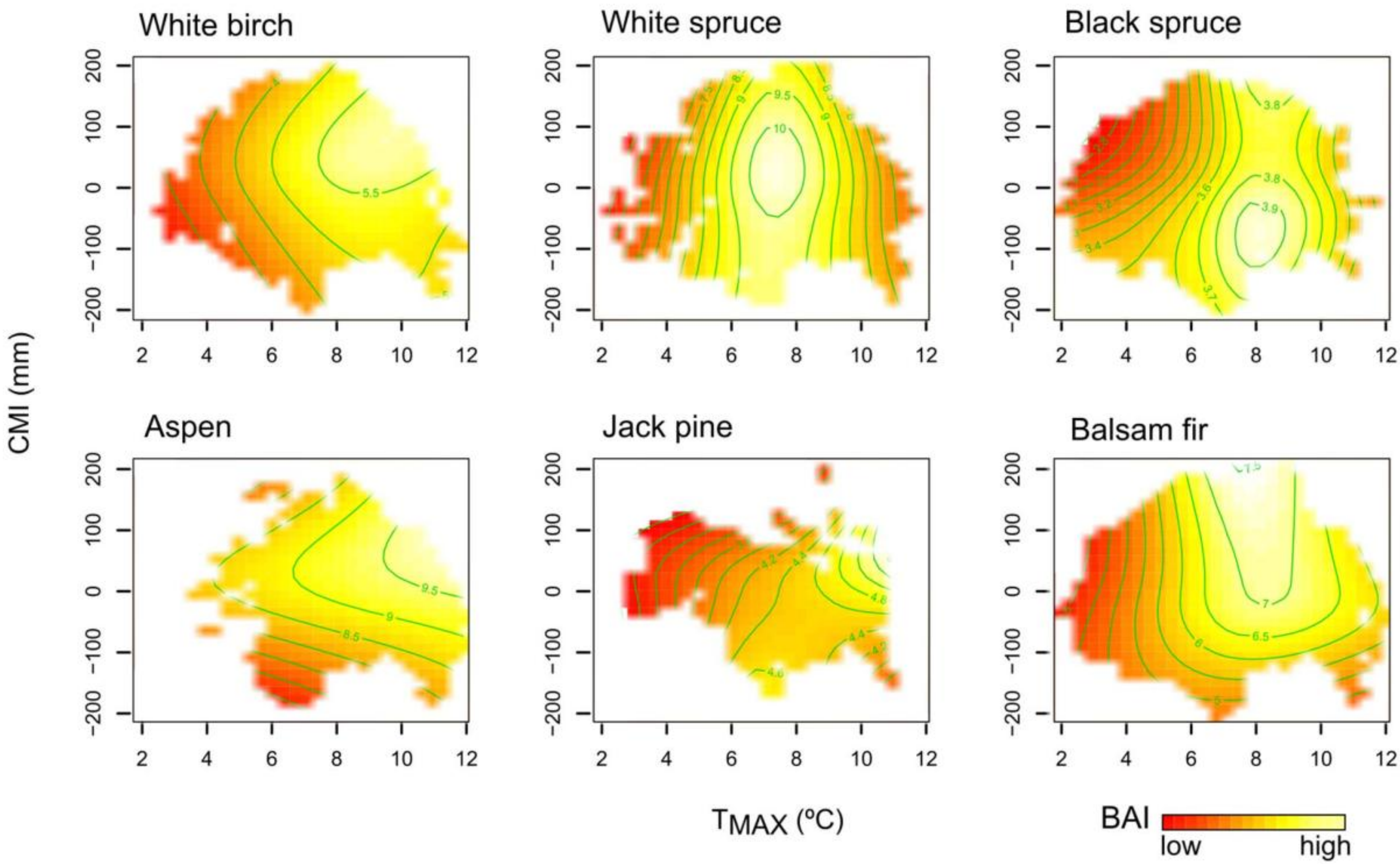
A tree-ring collection of 270 000 trees for the six most abundant boreal tree species across 96,000 boreal and temperate stands (**a**)

An 11°C annual temperature gradient (**b**)

A 330-mm growing season moisture gradient (**c**)



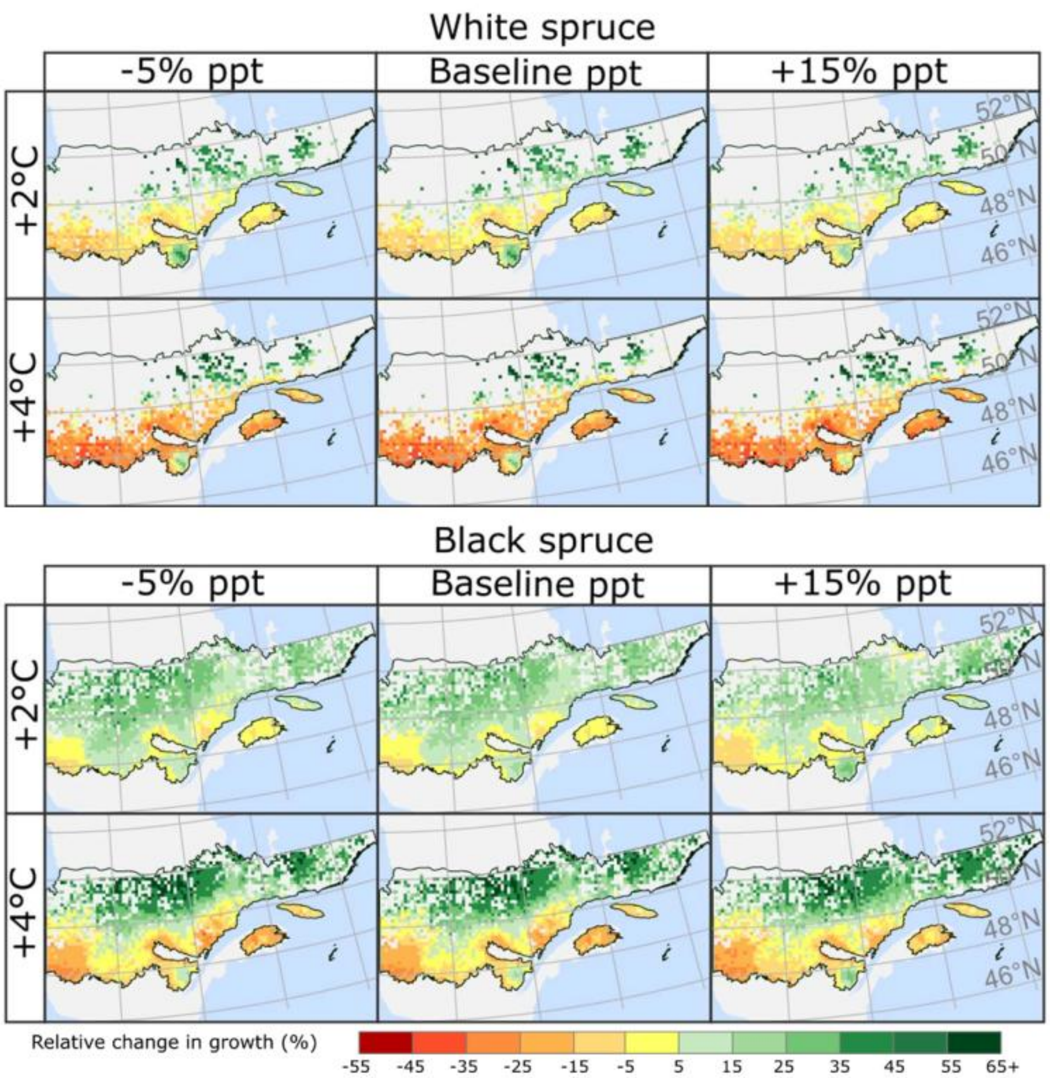
Temperature-moisture interactions



Spruce

White spruce
- Severe declines across most of its range
- Low sensitivity to precipitation
- High sensitivity to warming

Black spruce
- Large gains north of 50°N
- Moderate declines in southern trees.
- Low sensitivity to precipitation



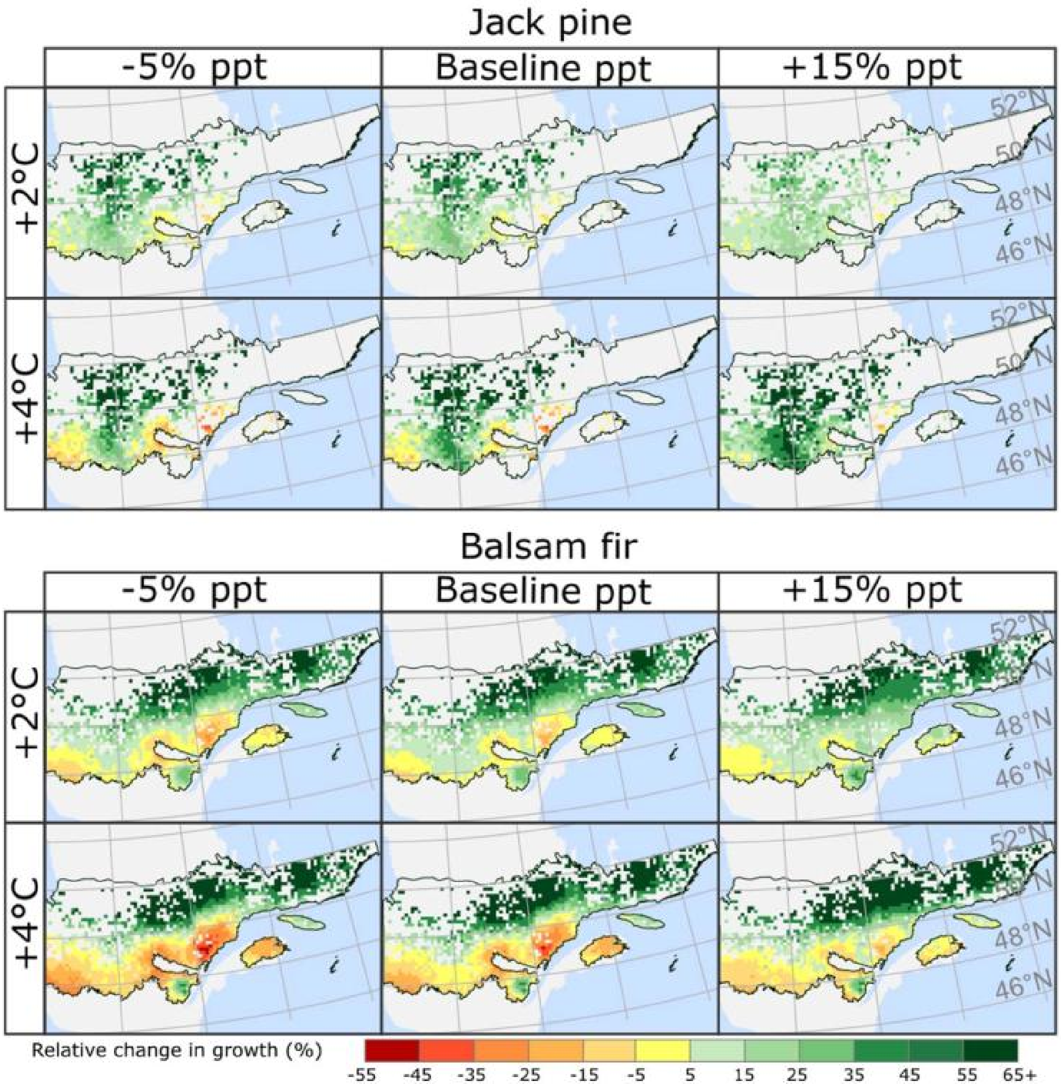
Jack pine and balsam fir

Jack pine

- Large gains across its range
- Precipitation effect depends on warming

Balsam fir

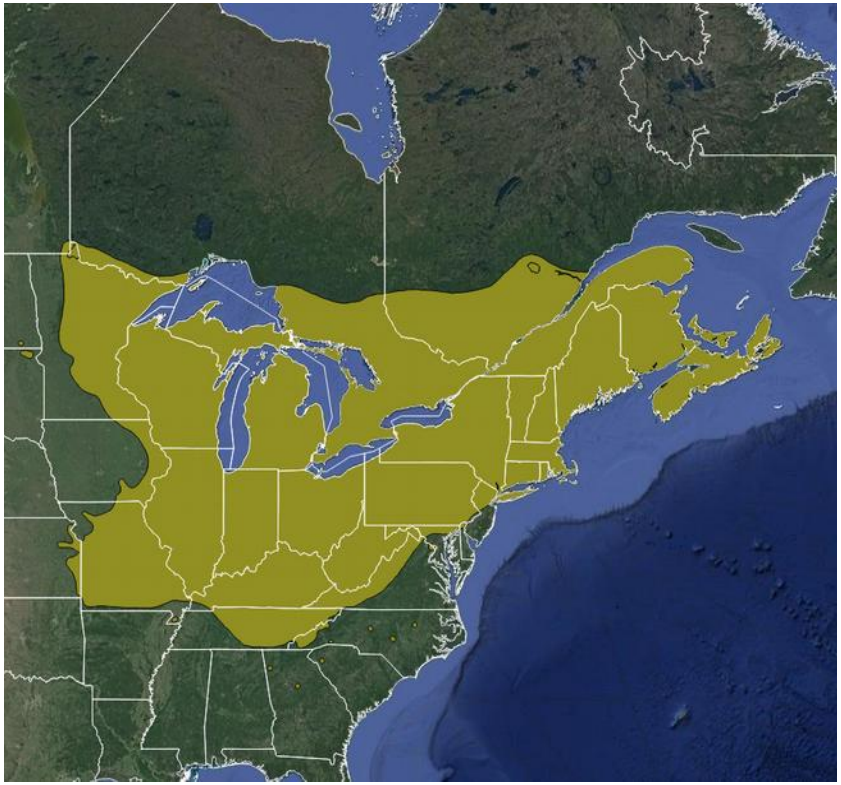
- Large gains north of 50°N
- Large declines in southern trees.
- High sensitivity to precipitation



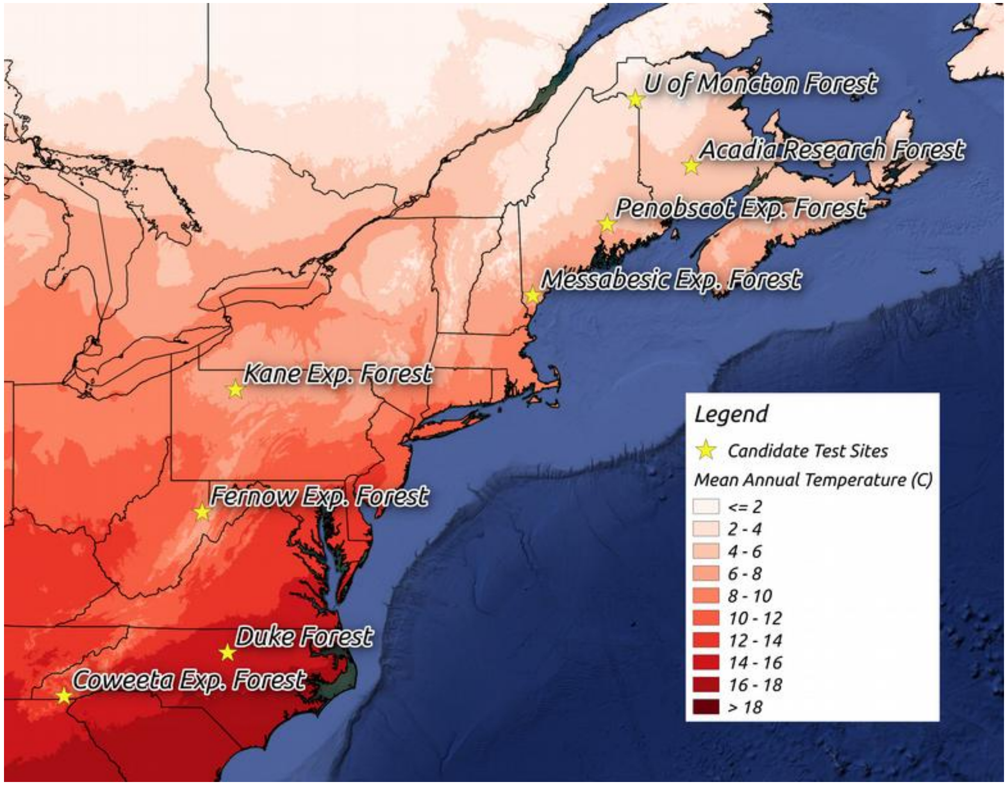
Future research on climatic limits

Three new studies (NRCan / UNB / NBDERD)

Study# 1
Range-wide PSPs



Study# 2
Latitudinal Transect



Future research on climatic limits

Study# 3
Greenhouse Experiments

Implications for Maritime forestry sector

Wood supply and product mix

RCP 2.6

- Minimal changes expected
- Low impact on forestry sector

RCP 8.5

- Changes in composition (product mix)
- Decline in overall forest growth
- Implications on wood supply after 2050

Unlikely humanity will keep global warming within RCP 2.6 range and society must prepare for unavoidable climate change impacts

So what can we do?

Mitigation

- Reduce greenhouse gas emissions
- Pro carbon forestry

Adaptation

- Assisted Migration
- Adaptive silviculture
- Alternative forest products

Measurement

- Monitoring programs
- Experiments and field studies
- Improve forecasting ability (i.e., improve models)

Thanks for your time

Questions?