Changing Climate, Changing Forests

impacts of climate change on forests of the Northeastern US and Eastern Canada

Lindsey Rustad[1], John Campbell[1], Roger Cox[2], Marc DeBlois[3], Jeffrey Dukes[4], Thomas Huntington[5], Alison Magill[6], Jacqueline Mohan[7], Nicholas Rodenhouse[8], Andrew Richardson[6], Mark Watson[9] and Norman Willard[10],

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Climate Change and *NE Forests 2100*

- Climate has changed over the past 100 yrs
- Computer models project more change
- Need to understand implica

- *NE Forests 2100* is a coalitio
  Canadian scientists brought
  1. synthesize existing researc
     of climate change impacts
     northeastern NA, and
  2. make this information avai

A growing body of evidence…

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What makes ***NE Forests 2100*** unique is…its focus on forests!

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NE Forests 2100: A Synthesis of Climate Change Impacts on Forests of the Northeastern US and Eastern Canada

Changing Climate, Changing Forests:
impacts of climate change in the Northeastern United States and Eastern Canada

A Report of the NE Forests 2100 Project

Forest Service GTR

Questions posed

1. How is the Climate of the Northeast Changing?
2. How is the Water Cycle of the Northeast Responding to Climate Change?
3. How are Northeast Forests Responding to Climate Change?
4. How is Biogeochemical Cycling in Northeast Forests Changing with Climate Change?
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6. How are Nuisance Species of Northeast Forests Responding to Climate Change?

Conclusions and Implications for Policy: Mitigating and Adapting to Climate Change in Northeast Forests

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Conclusions and Implications for Policy: Mitigating and Adapting to Climate Change in Northeast Forests

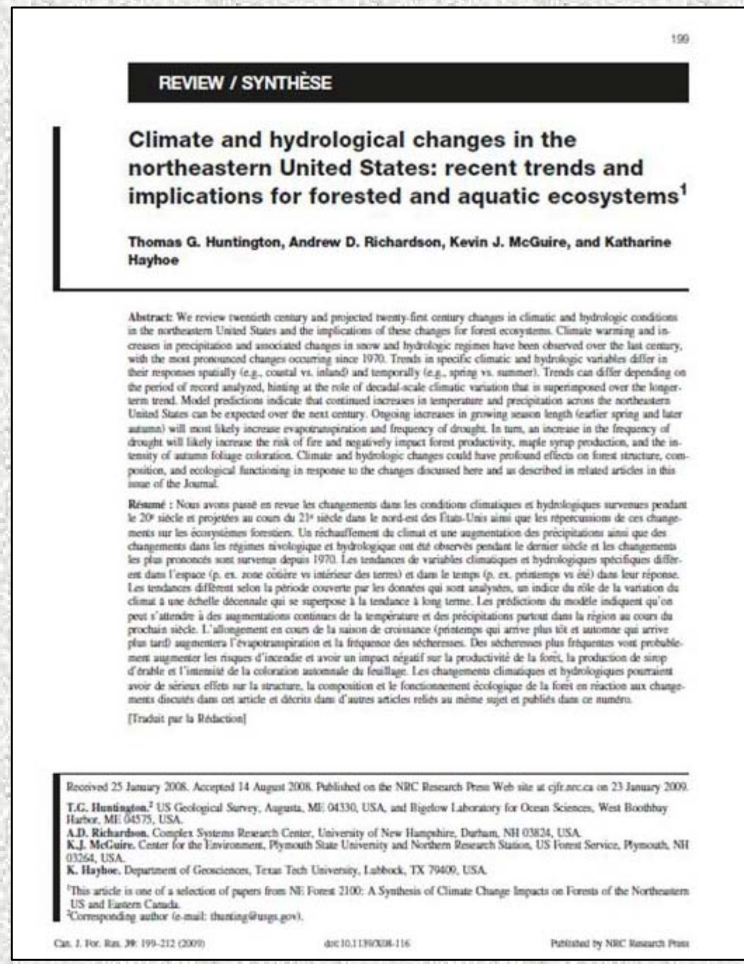
Approach

- First Principals
- Observed Changes
- Future Projections
- Implications

How are Climate and Hydrology in the Northeast Changing?

Authors

- Tom Huntington (USGS)
- Andrew Richardson (Harvard University)
- Kevin McGuire (Virginia Tech)
- Katharine Hayhoe (Texas Tech)



REVIEW / SYNTHÈSE

Climate and hydrological changes in the northeastern United States: recent trends and implications for forested and aquatic ecosystems[1]

Thomas G. Huntington, Andrew D. Richardson, Kevin J. McGuire, and Katharine Hayhoe

Abstract: We review twentieth century and projected twenty-first century changes in climatic and hydrologic conditions in the northeastern United States and the implications of these changes for forest ecosystems. Climate warming and increases in precipitation and associated changes in snow and hydrologic regimes have been observed over the last century, with the most pronounced changes occurring since 1970. Trends in specific climatic and hydrologic variables differ in their responses spatially (e.g., coastal vs. inland) and temporally (e.g., spring vs. summer). Trends can differ depending on the period of record analyzed, hinting at the role of decadal-scale climatic variation that is superimposed over the longer-term trend. Model predictions indicate that continued increases in temperature and precipitation across the northeastern United States can be expected over the next century. Ongoing increases in growing season length (earlier spring and later autumn) will most likely increase evapotranspiration and frequency of drought. In turn, an increase in the frequency of drought will likely increase the risk of fire and negatively impact forest productivity, maple syrup production, and the intensity of autumn foliage coloration. Climate and hydrologic changes could have profound effects on forest structure, composition, and ecological functioning in response to the changes discussed here and as described in related articles in this issue of the Journal.

Résumé : Nous avons passé en revue les changements dans les conditions climatiques et hydrologiques survenues pendant le 20e siècle et projetées au cours du 21e siècle dans le nord-est des États-Unis ainsi que les répercussions de ces changements sur les écosystèmes forestiers. Un réchauffement du climat et une augmentation des précipitations ainsi que des changements dans les régimes nivologique et hydrologique ont été observés pendant le dernier siècle et les changements les plus prononcés sont survenus depuis 1970. Les tendances de variables climatiques et hydrologiques spécifiques diffèrent dans l'espace (p. ex. zone côtière vs intérieur des terres) et dans le temps (p. ex. printemps vs été) dans leur réponse. Les tendances diffèrent selon la période couverte par les données qui sont analysées, un indice du rôle de la variation du climat à une échelle décennale qui se superpose à la tendance à long terme. Les prédictions du modèle indiquent qu'on peut s'attendre à des augmentations continues de la température et des précipitations partout dans la région au cours du prochain siècle. L'allongement en cours de la saison de croissance (printemps qui arrive plus tôt et automne qui arrive plus tard) augmentera l'évapotranspiration et la fréquence des sécheresses. Des sécheresses plus fréquentes vont probablement augmenter les risques d'incendie et avoir un impact négatif sur la productivité de la forêt, la production de sirop d'érable et l'intensité de la coloration automnale du feuillage. Les changements climatiques et hydrologiques pourraient avoir de sérieux effets sur la structure, la composition et le fonctionnement écologique de la forêt en réaction aux changements discutés dans cet article et décrits dans d'autres articles reliés au même sujet et publiés dans ce numéro.

[Traduit par la Rédaction]

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[1]This article is one of a selection of papers from NE Forest 2100: A Synthesis of Climate Change Impacts on Forests of the Northeastern US and Eastern Canada.
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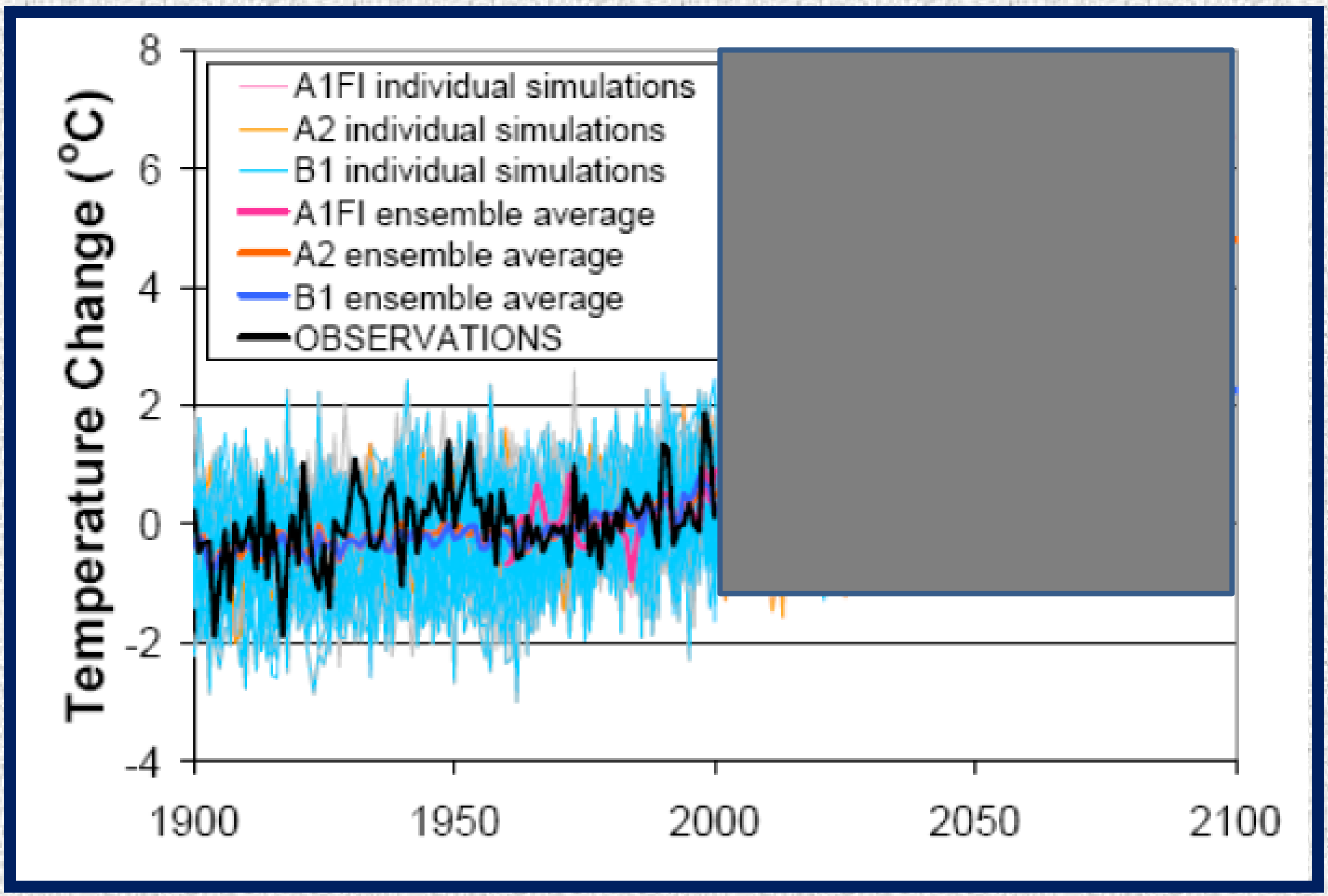
Observed Changes: Temperature

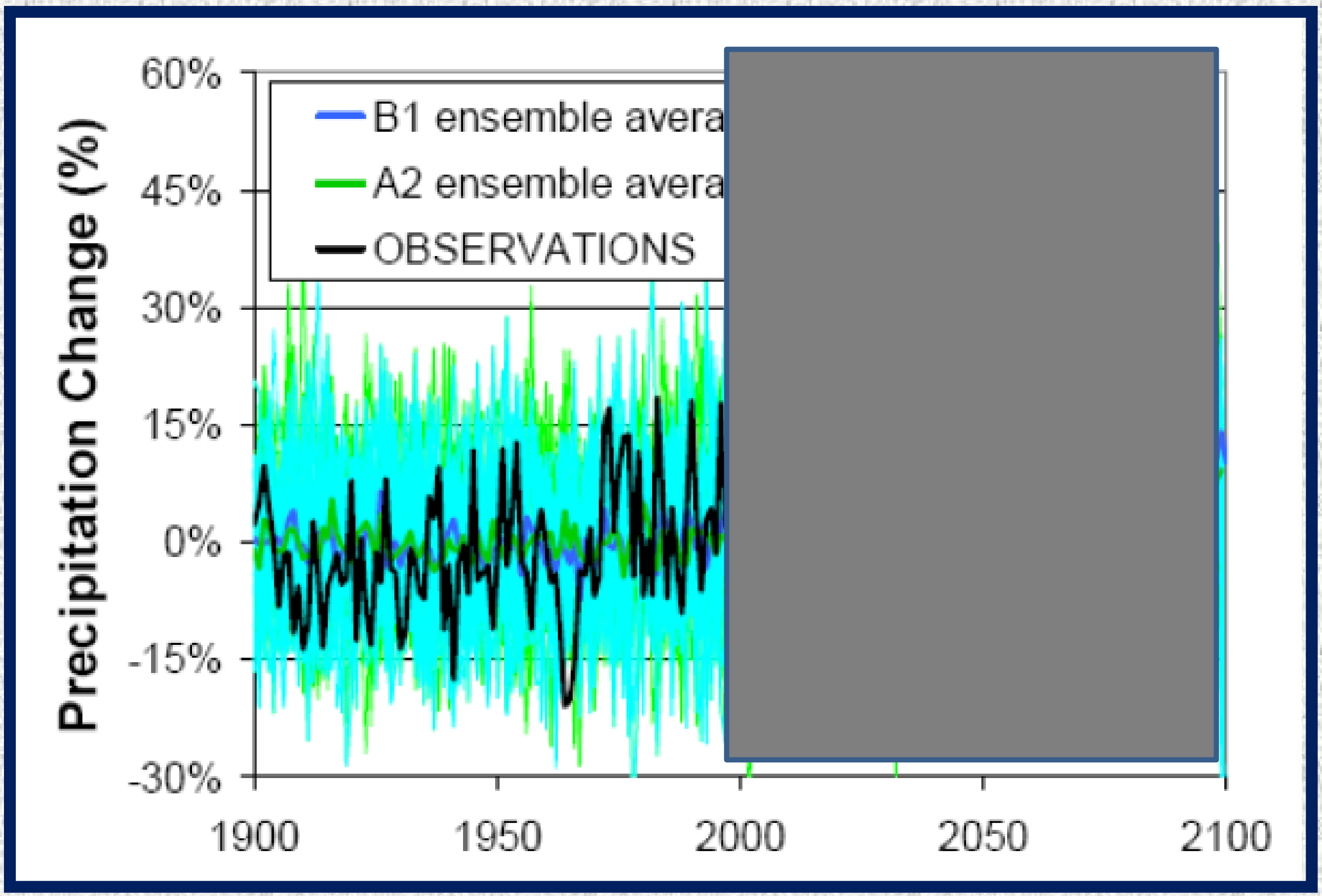


- **Surface air temperatures have warmed by ~<u>0.8°C</u> over the last century.**

Observed Changes: Temperature

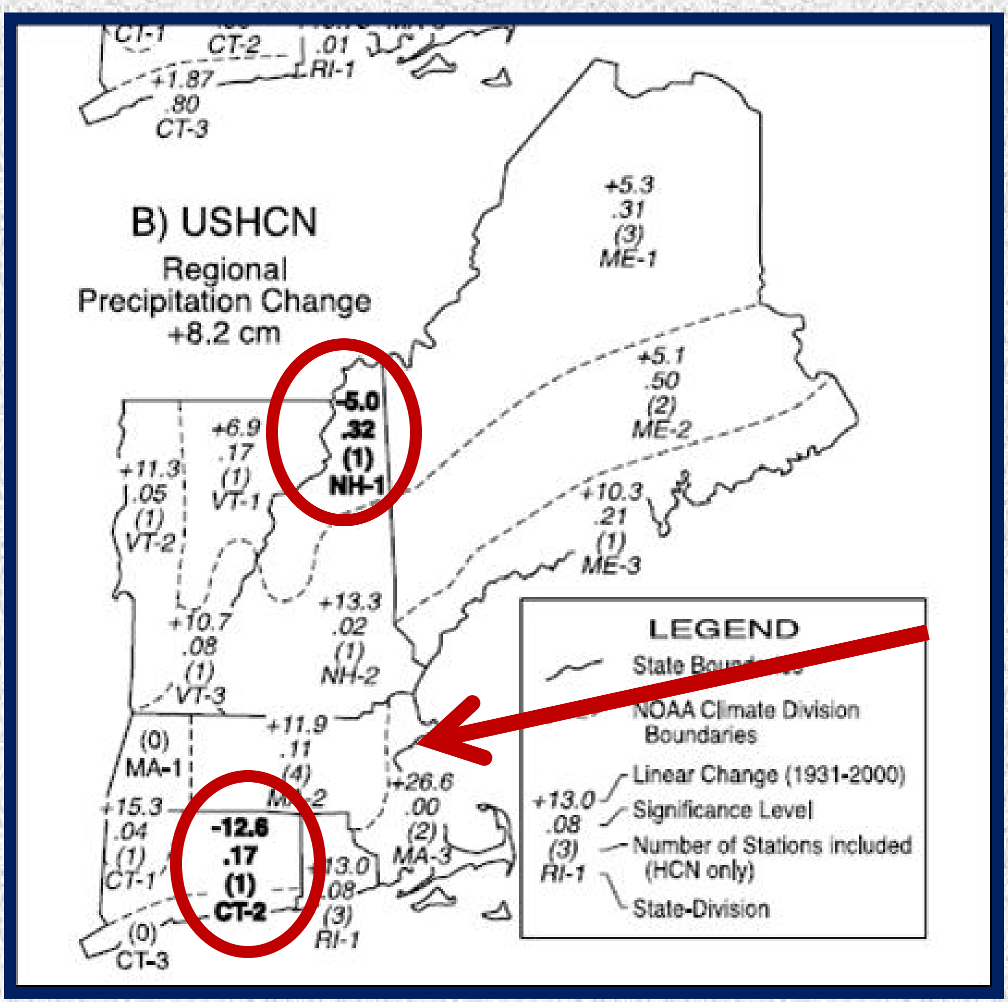
- Seasonal Differences
  - Winter (DJF) temperatures have increased by +1.2ºC
  - Summer (JJA) temperatures have increased by 0.7ºC
- Minimum temperature extremes warmed.
- Minimum temperatures are increasing more than maximum temperatures.
- Diurnal temperature range decreased.

Observed Changes: Precipitation



- **Average annual precipitation increased by <u>+9.5 cm (~9%)</u> over the last century**

Observed Changes: Precipitation



- Trends in precipitation were highly variable in space and time (data for 1931 to 2000; Keim et al. 2005)

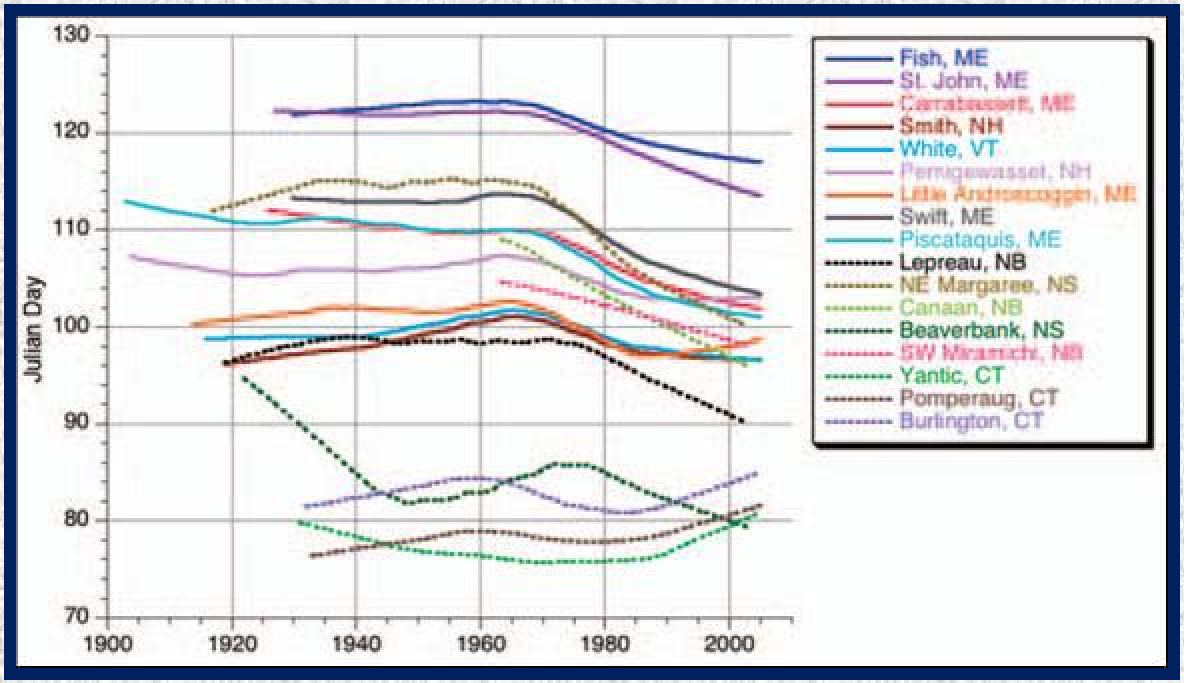
Observed Changes: Precipitation

- **Increase in the *intensity* and *frequency* of larger precipitation events**

- **Increase in the duration of periods without rainfall during summer months**

Observed Changes: Stream Flow

- Flood peaks have increased
- *Average* annual streamflow has increased and timing has changed
- Earlier dates for peak snowmelt discharge (1-2 weeks earlier)

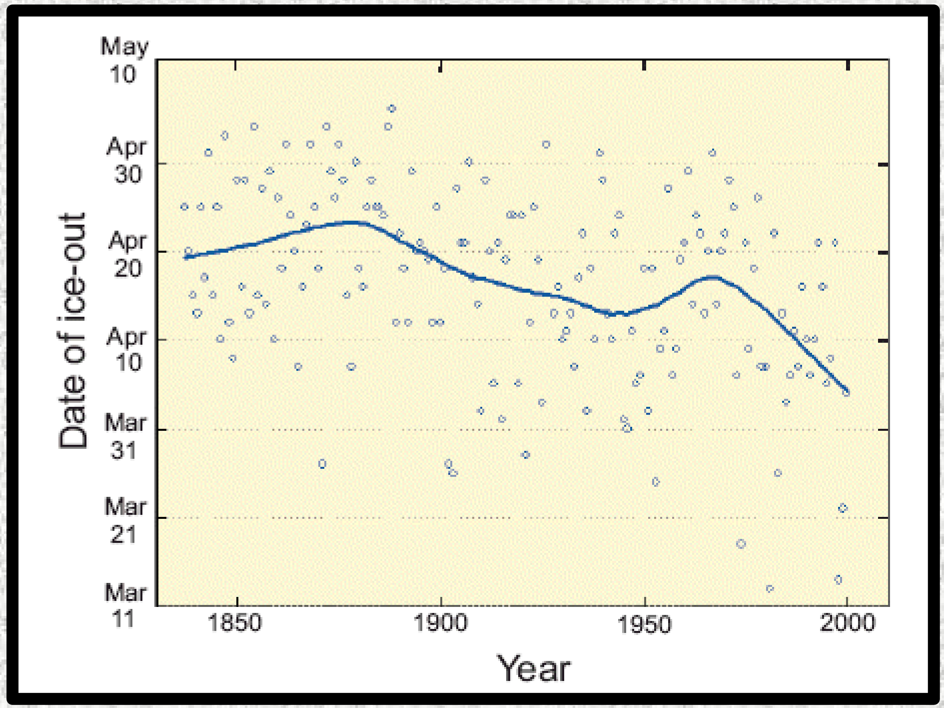


Observed Changes: Snow

- Greater % of winter precipitation occurring as rain vs snow
- Decrease in total # of days with snowfall
- Decrease of 20 snow cover days
- General decrease in snowpack depth

Observed Changes: Ice

- Total number of ice cover days has decreased
- Average ice thickness has decreased
- Ice out has advanced by 1-2 weeks



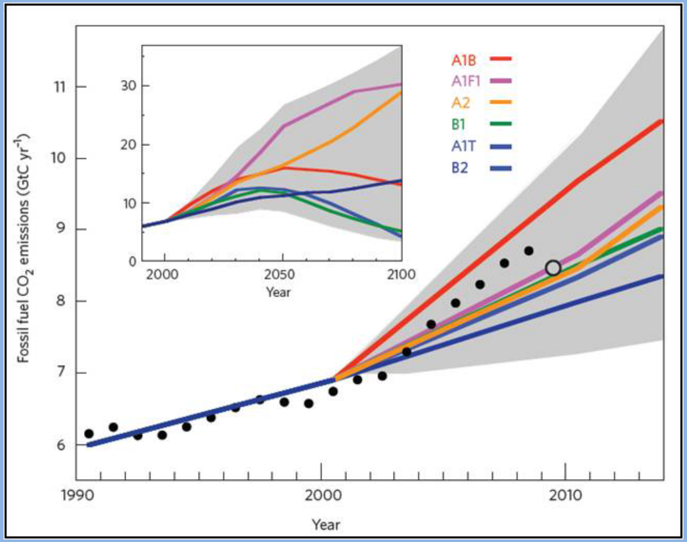
In Sum:

The 20th century climate of the region has become warmer and wetter !

Climate Projections - Models

- Based on: 9 coupled AOGCMs

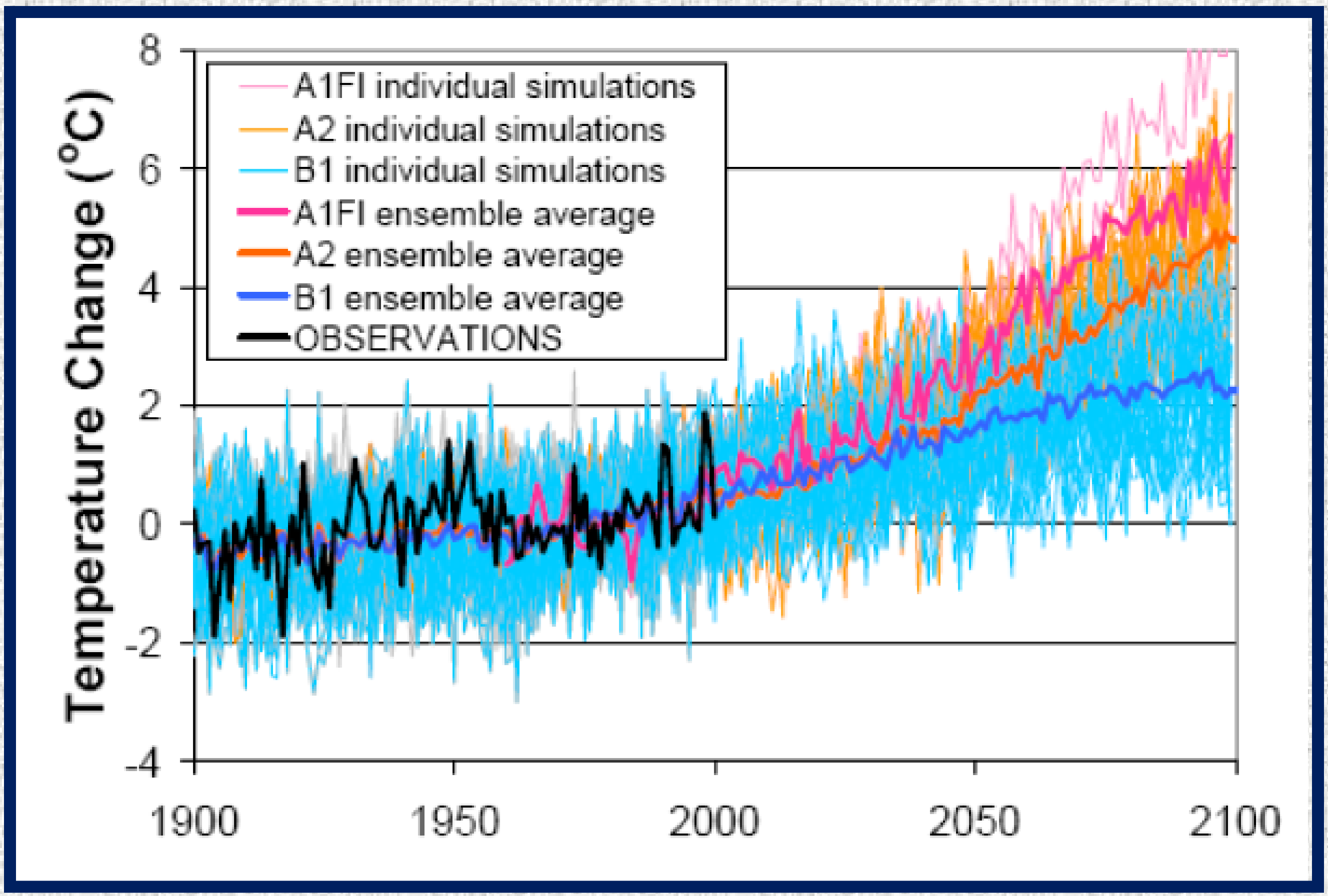
- 3 emission scenarios
  - low (B1)
  - mid-high (A2)
  - high (A1F1)



- Monthly AOGCM output statistically downscaled to daily values, with a resolution of 1/8° (150 km²)
- Daily values were input to VIC model to simulate EVT, run off, snow water equivalent, and soil moisture

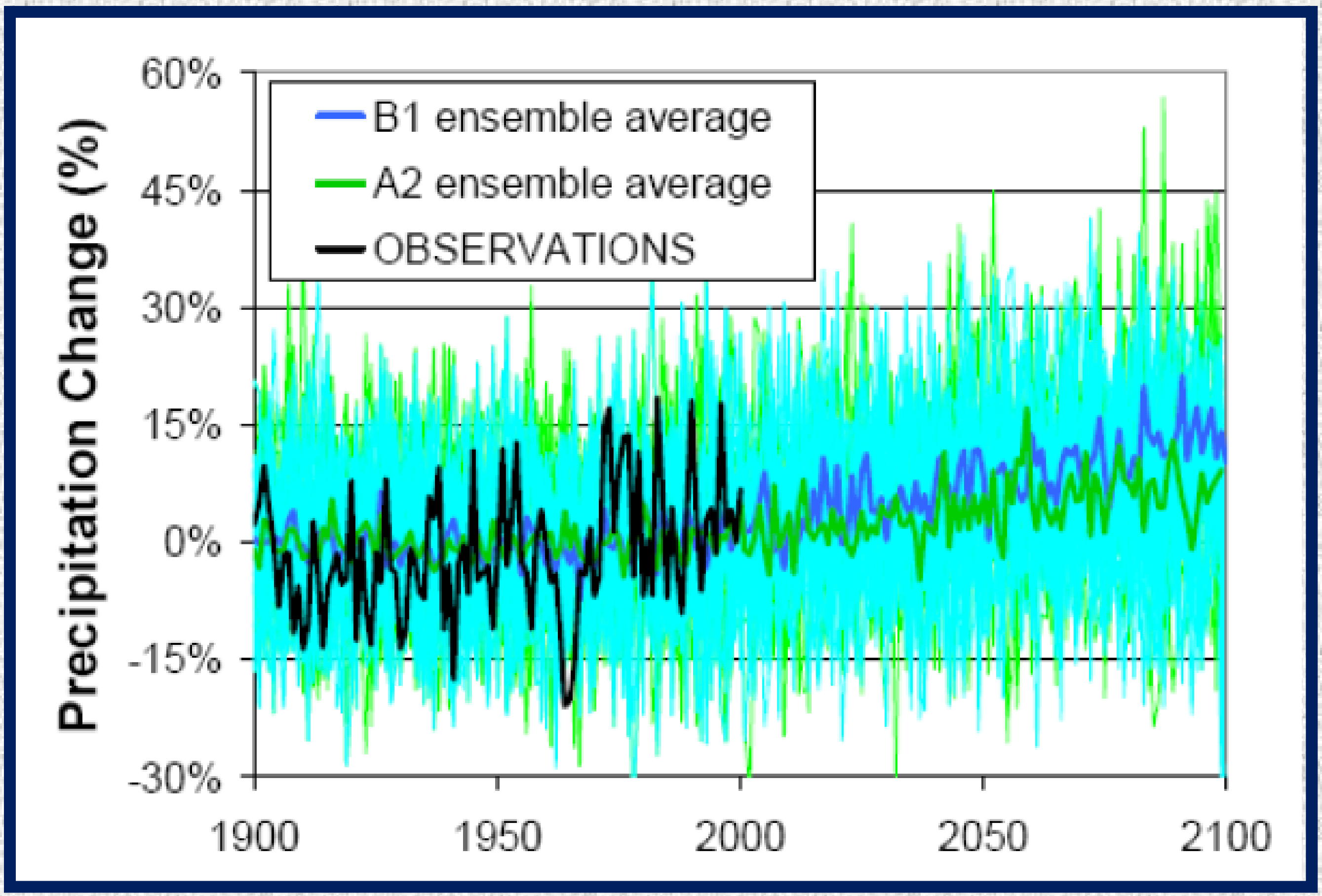
Hayhoe et al. 2007. *Climate Dynamics*

Temperature Projections



- **2.9 to 5.3°C increase by 2100**
- **Projected increases are *higher for summer (JJA)* than winter (DJF)**

Precipitation Projections



- **7 to 14% increase by 2100**
- **Projected increases are highest for winter (DJF; 12-30%).**
- ***No projected increase for summer (JJA)***

Other Climate Projections

- Earlier onset of growing season by 7-10 days.
- Overall increase in growing season by 9-43 days.
- Decline or elimination of snowpack.
- Overall increase in stream flow.
- Decreases in soil moisture during summer (JJA).

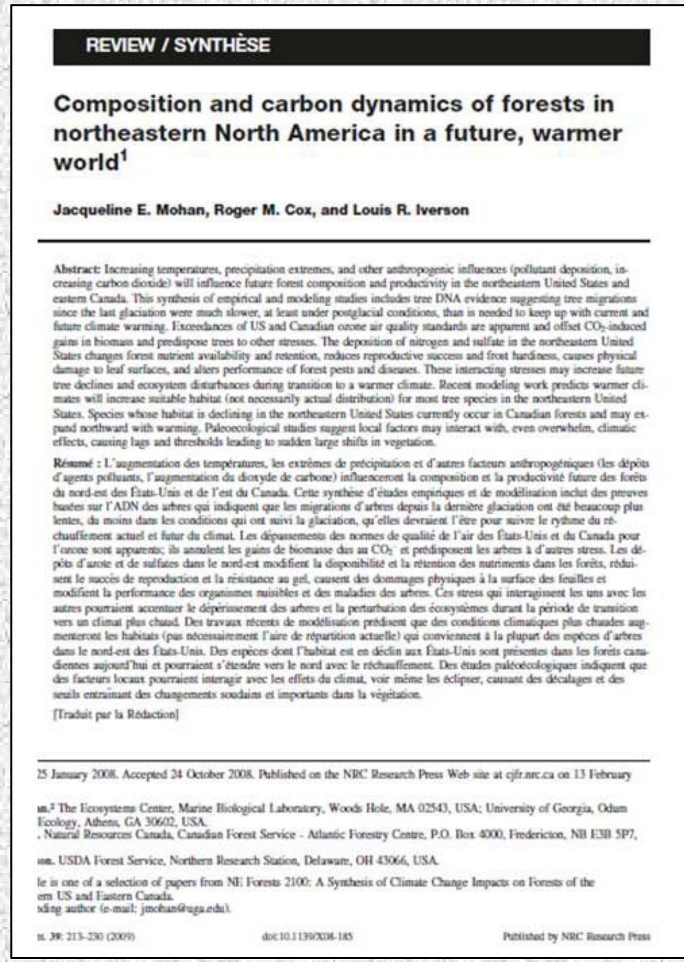
In Sum:

The climate of the region is projected to get warmer, wetter, and drier!!

How is the Composition and Productivity of Northeast Forests Responding to Climate Change?

Authors

- Jacqueline Mohan (Univ. Georgia)
- Roger Cox (Canadian FS)
- Louis Iverson (USFS)



REVIEW / SYNTHÈSE

Composition and carbon dynamics of forests in northeastern North America in a future, warmer world[1]

Jacqueline E. Mohan, Roger M. Cox, and Louis R. Iverson

Abstract: Increasing temperatures, precipitation extremes, and other anthropogenic influences (pollutant deposition, increasing carbon dioxide) will influence future forest composition and productivity in the northeastern United States and eastern Canada. This synthesis of empirical and modeling studies includes tree DNA evidence suggesting tree migrations since the last glaciation were much slower, at least under postglacial conditions, than is needed to keep up with current and future climate warming. Exceedances of US and Canadian ozone air quality standards are apparent and offset CO_2-induced gains in biomass and predispose trees to other stresses. The deposition of nitrogen and sulfate in the northeastern United States changes forest nutrient availability and retention, reduces reproductive success and frost hardiness, causes physical damage to leaf surfaces, and alters performance of forest pests and diseases. These interacting stresses may increase future tree declines and ecosystem disturbances during transition to a warmer climate. Recent modeling work predicts warmer climates will increase suitable habitat (not necessarily actual distribution) for most tree species in the northeastern United States. Species whose habitat is declining in the northeastern United States currently occur in Canadian forests and may expand northward with warming. Paleoecological studies suggest local factors may interact with, even overwhelm, climatic effects, causing lags and thresholds leading to sudden large shifts in vegetation.

Résumé : L'augmentation des températures, les extrêmes de précipitation et d'autres facteurs anthropogéniques (les dépôts d'agents polluants, l'augmentation du dioxyde de carbone) influenceront la composition et la productivité future des forêts du nord-est des États-Unis et de l'est du Canada. Cette synthèse d'études empiriques et de modélisation inclut des preuves basées sur l'ADN des arbres qui indiquent que les migrations d'arbres depuis la dernière glaciation ont été beaucoup plus lentes, du moins dans les conditions qui ont suivi la glaciation, qu'elles devraient l'être pour suivre le rythme du réchauffement actuel et futur du climat. Les dépassements des normes de qualité de l'air des États-Unis et du Canada pour l'ozone sont apparents; ils annulent les gains de biomasse dus au CO_2 et prédisposent les arbres à d'autres stress. Les dépôts d'azote et de sulfates dans le nord-est modifient la disponibilité et la rétention des nutriments dans les forêts, réduisent le succès de reproduction et la résistance au gel, causent des dommages physiques à la surface des feuilles et modifient la performance des organismes nuisibles et des maladies des arbres. Ces stress qui interagissent les uns avec les autres pourraient accentuer le dépérissement des arbres et la perturbation des écosystèmes durant la période de transition vers un climat plus chaud. Des travaux récents de modélisation prédisent que des conditions climatiques plus chaudes augmenteront les habitats (pas nécessairement l'aire de répartition actuelle) qui conviennent à la plupart des espèces d'arbres dans le nord-est des États-Unis. Des espèces dont l'habitat est en déclin aux États-Unis sont présentes dans les forêts canadiennes aujourd'hui et pourraient s'étendre vers le nord avec le réchauffement. Des études paléoécologiques indiquent que des facteurs locaux pourraient interagir avec les effets du climat, voir même les éclipser, causant des décalages et des seuils entraînant des changements soudains et importants dans la végétation.

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nding author (e-mail: jmohan@uga.edu).

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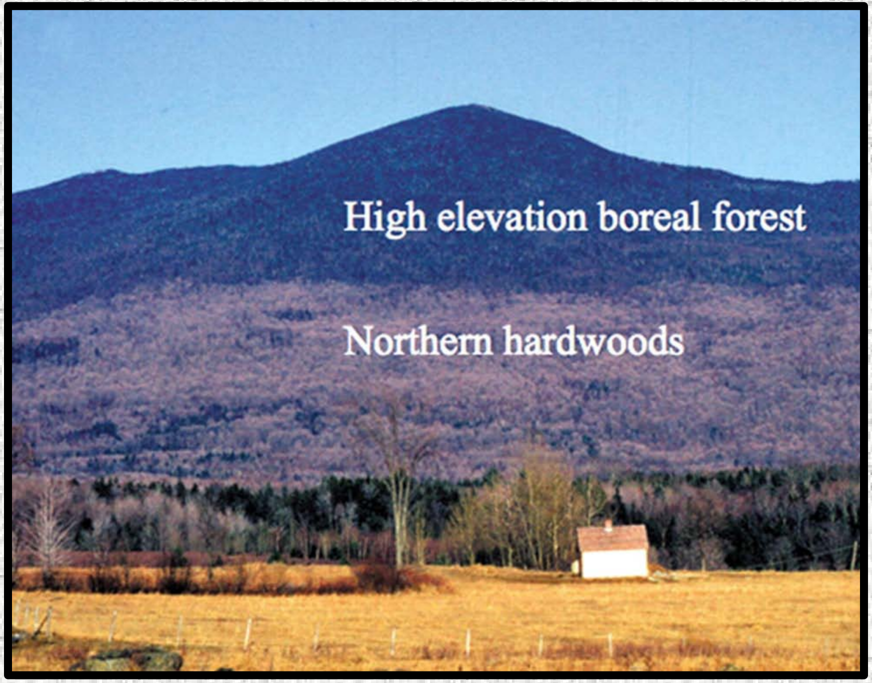
Forest Composition

- In general, expect *'envelopes of tolerance'* to move north in latitude and higher in elevation, due to changes in temperature and rainfall.
- ***BUT,*** expect ***lags*** in response due reproduction, recruitment, migration, other drivers (S, N, Hg, O_3, extreme events, fire, etc.)

Observed Changes: Composition

- upslope shift in northern hardwood – boreal forest ecotone by 91 – 119 m (1964 – 2004)
- ***Jury is out***



(Beckage et al. 2008. PNAS)

Forest Productivity

Increased productivity due to:

- Warmer temperatures
- Longer growing seasons
- CO_2 fertilization
- N Fertilization

Forest Productivity

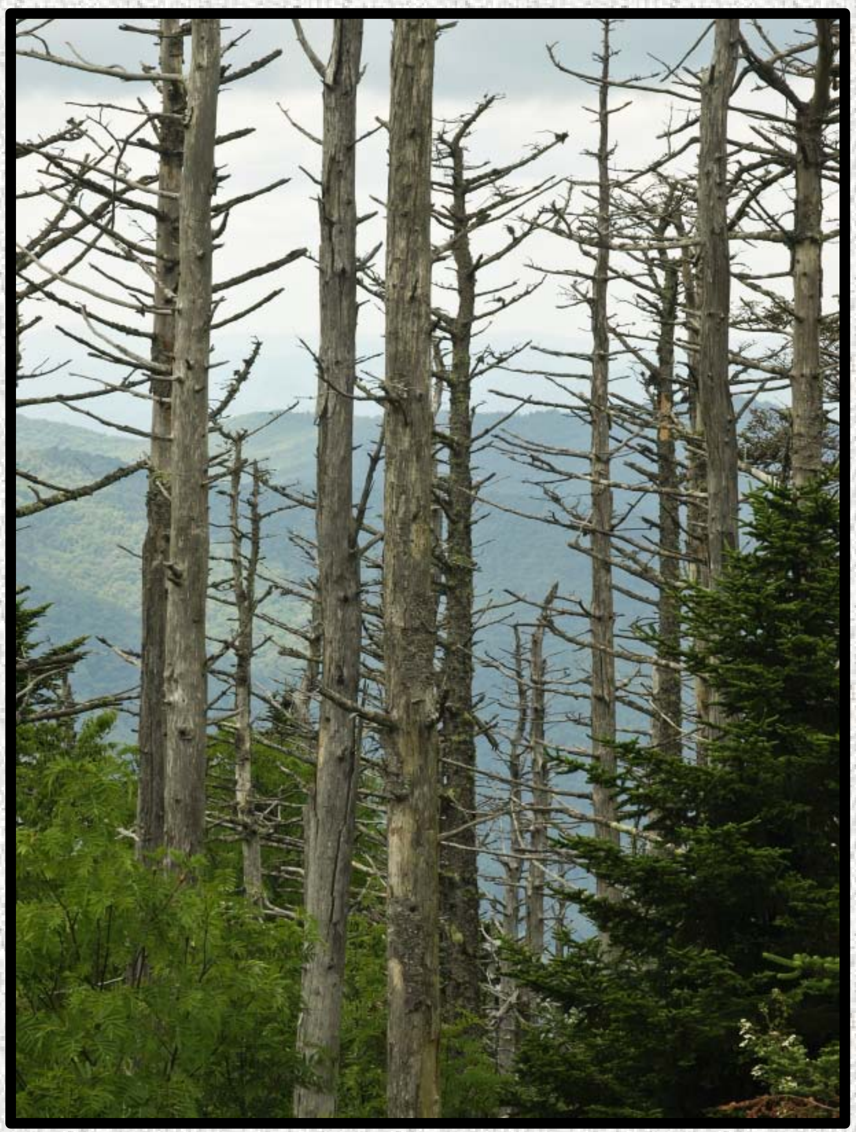
Decreased productivity due to:

- Extreme climatic events
- "Acid Rain"
- "N Saturation"
- Ozone
- Pest & Pathogens

Observed Changes: Tree Declines

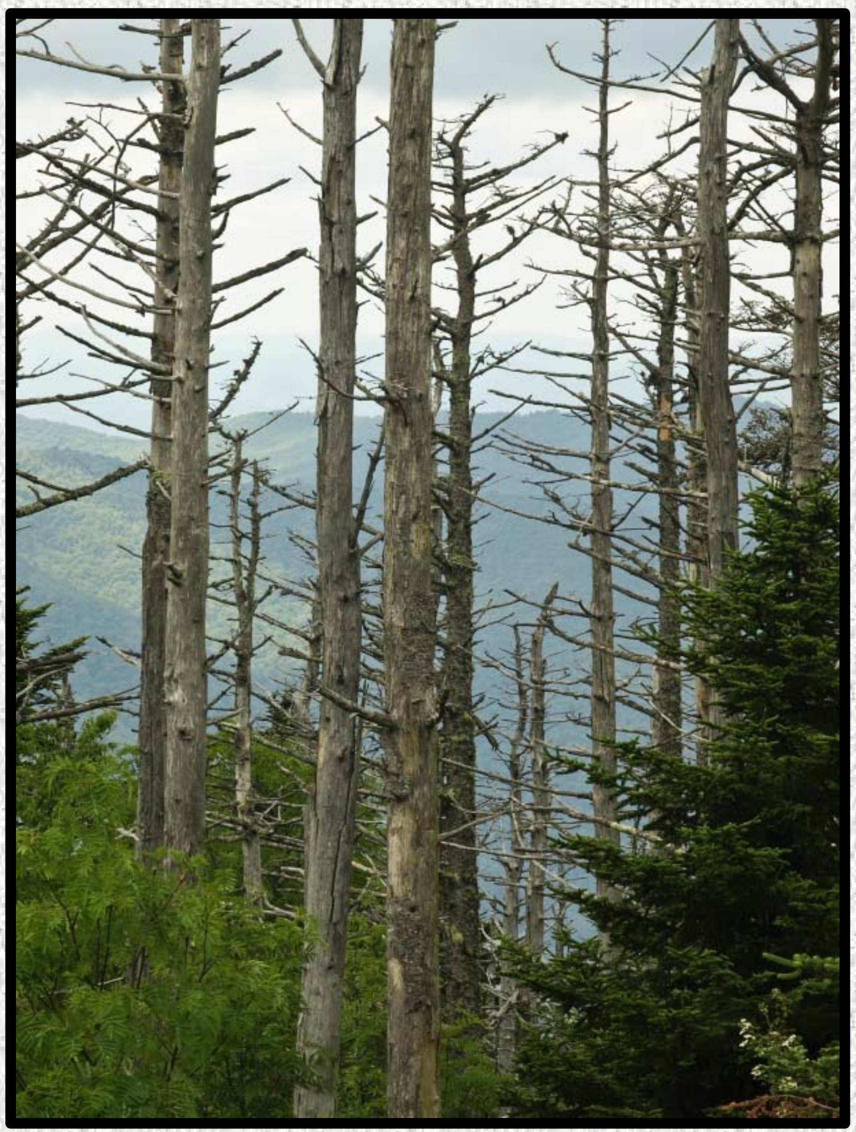
Table 4: Tree Decline and Associated Climate Factors

Species	*Decline History*	*Role of Climate*	*Other factors*	*References*
Birch	Widespread declines first reported in 1944	Maps of birch decline areas coincide with areas of experiencing extended winter thaw cycles	None cited	Balch 1944 Bourque et al. 2005 Braathe 1995
Maple	26 widespread decline episodes reported between 1912 and 1986	Prolonged thaw-freeze events and associated fine root damage have been implicated in sugar maple decline	Insect and disease Changes in soil nutrients	Millers et al 1989 Bertrand et al. 1994 Decker et al. 2003 Fitzhugh et al. 2003
Oak	Large areas of oak mortality recorded in New England and the Appalachian Mts in the early 1900s	Drought stresses have been reported as important initiating factors in oak decline.	Insect outbreak Secondary pathogens	Millers et al. 1989
Ash	White ash dieback noted in across the northeast since the 1920s	Drought and freezing damage have been identified as inciting factors, with drought playing a particularly important role	Phytoplasmal disease Asian beetle, emerald ash borer	Millers et al. 1989 Poland and McCullough 2006
Red Spruce	Widespread decline through the Northeast from the 1960s, increasing over the last few decades	Reduced cold tolerance leads to winter injury which is intensified by freeze-thaw events, rapid rates of thaw and subsequent exposure to refreezing	Acid deposition Weather anomalies	Friedland et al. 1984 Johnson 1992 Schaberg and DeHayes 2000 Bourque et al. 2005



Observed Changes: Tree Declines

- Birch (spp.): extended winter thaw
- Sugar Maple: extended freeze-thaw; mid-winter thaws
- Red Spruce: late freeze, freeze-thaw, reduced cold tolerance
- Oak (spp.): drought
- Ash: drought



Climate and Vegetation Models

- Based on: 4 GCMs
- 2 emission scenarios
  - low (energy conservation)
  - high (current trajectory to 2050)
- Random Forests Model
  - FIA Data (134 species; over 100,000 plots)
  - 7 climate variables
  - 22 soil variables
  - 5 topographic variables
  - 4 land-use variables

Iverson et al. Mitig Adapt Strat Glob Change 2008

Model Projections: ***Suitable Habitat***

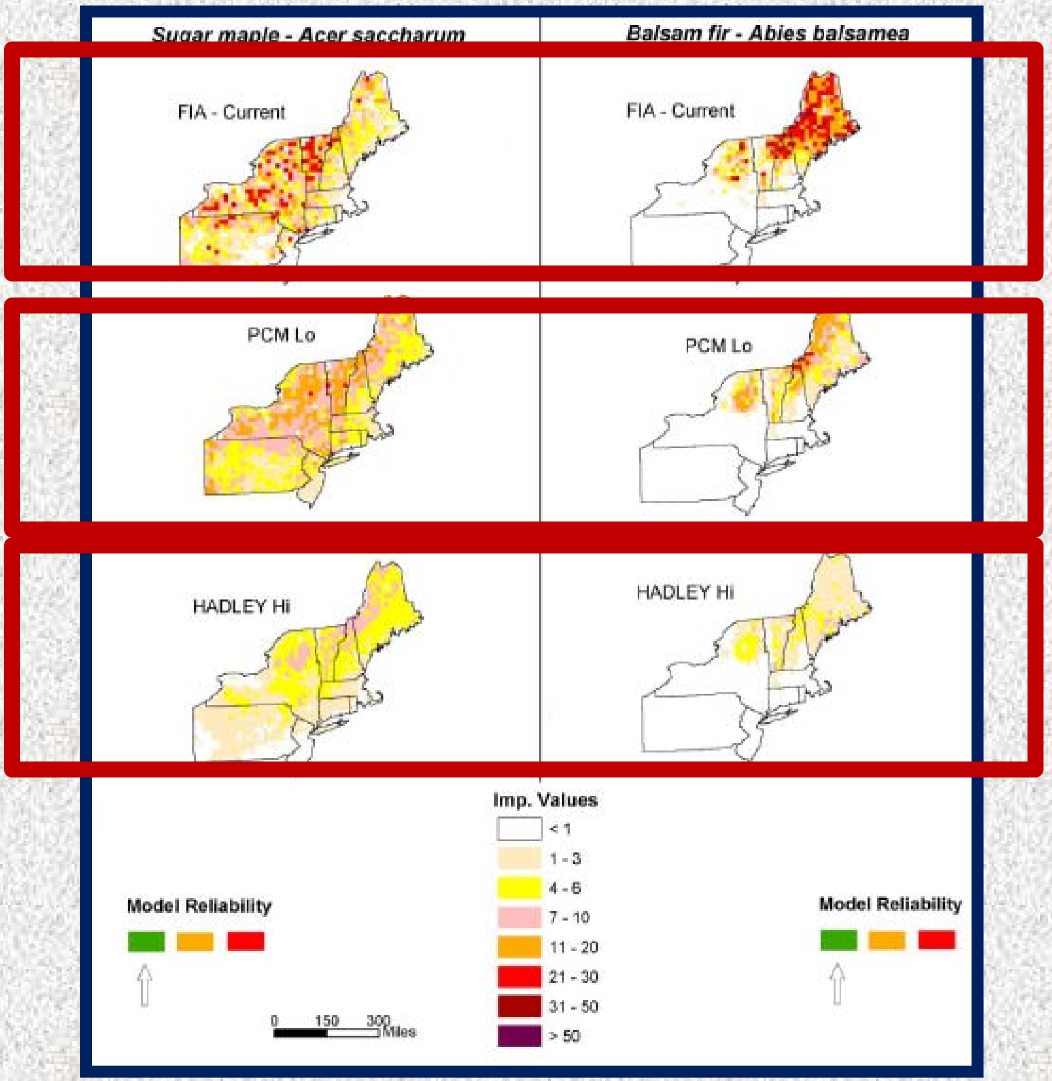
Scenario	Decreased	Unchanged	Increased
Low emissions scenario	23	10	48
High emissions scenario	33	1	50
Average for 8 scenarios	31	6	47

Summary of decreasing and increasing species' area of suitable habitat by scenario for the NE USA.

Model Projections: Top-12 Most-Affected Common Tree Species

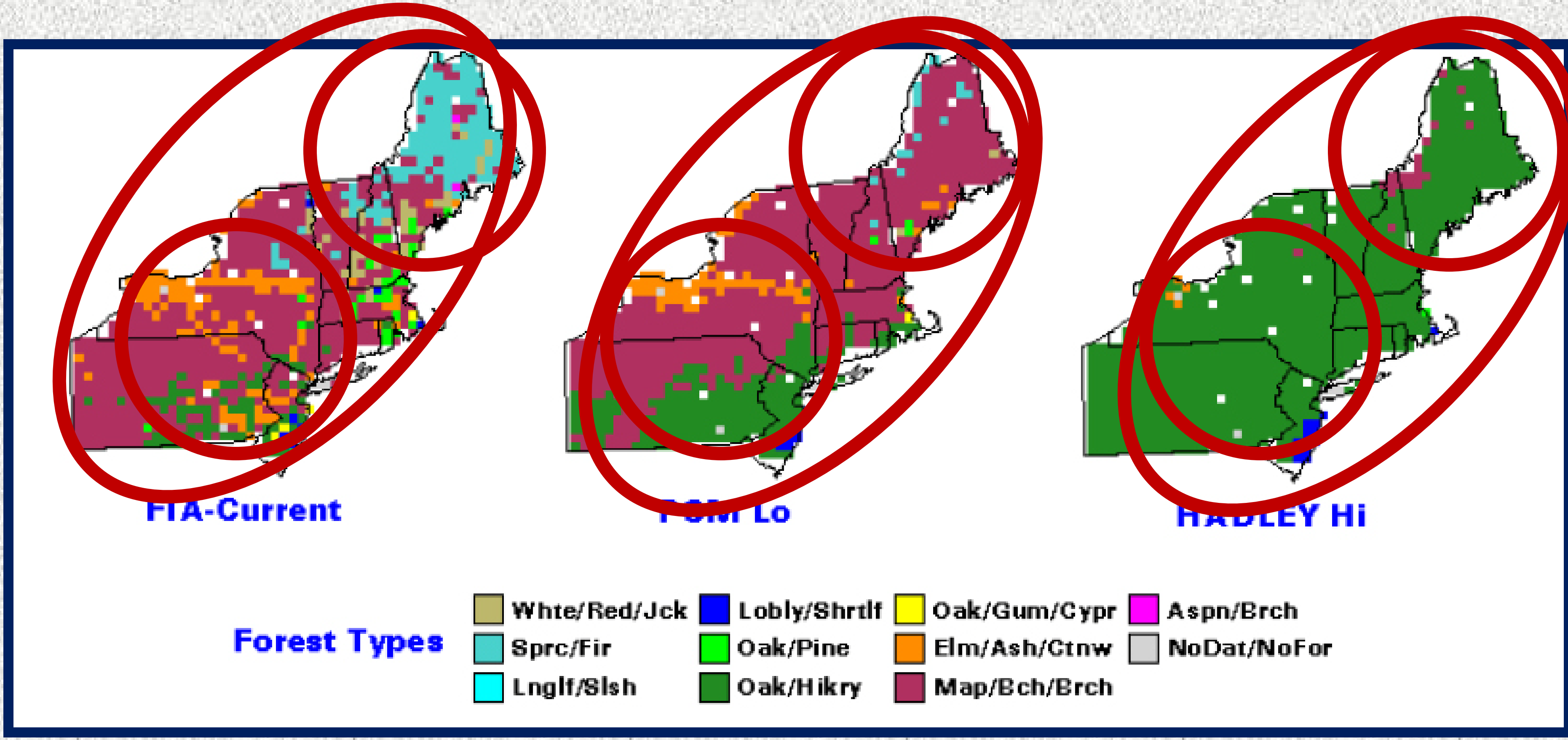
Species	Percent change
Black oak	+333
White oak	+268
Paper birch	-87%
Quaking aspen	-81%
Balsam fir	-80%
Northern white cedar	-73%
Big tooth aspen	-72%
Yellow birch	-68%
Red spruce	-66%
Striped maple	-65%
American beech	-60%
Pin cherry	-52%

Model Projections: By Species



No change in distribution; negative change in suitable habitat.

Model Projections: By Forest Type



Decrease in Spruce/Fir
Decrease in beech/birch/maple
Increase in oak/hickory

Conclusions

- Climate change in NE is real.
- Regional models suggest that the climate of the NE will become warmer, wetter, and drier.
- The hydrology of the region has changed, is changing and is projected to continue to change.
- These changes in climate and hydrology will have profound and quantifiable impacts on forest productivity and species composition (and wildlife, “nuisance species”, and biogeochemistry) of northern forests.

Questions posed

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Conclusions and Implications for Policy: Mitigating and Adapting to Climate Change in Northeast Forests

Pew Research Center Poll
October 27, 2010

Opinions About Global Warming: 2006-2010

Is there solid evidence the earth is warming?	**July 2006**	**Jan 2007**	**April 2008**	**Oct 2009**	**Oct 2010**
	%	%	%	%	%
Yes	79	77	71	57	59
Because of human activity	50	47	47	36	34
Because of natural patterns	23	20	18	16	18
Don't know	6	10	6	6	6
No	17	16	21	33	32
Mixed/Don't know	4	7	8	10	9
	100	100	100	100	100

Thank you for your attention!

NE Forests 2100

Understanding the Impacts of Climate Change on Northeastern Forests

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