Climate Change & Northeastern Forests

November 19, 2014

NIACS
Northern Institute of Applied Climate Science

FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

www.forestadaptation.org

Reminder!

Please send us your Step 1 worksheets—we're taking a look at them this week!

Step 1. DEFINE area of interest, conservation/management goals and objectives, and time frames.

Area of Interest:			
Location:			
Ecosystem Type(s)	**Conservation Goals**	**Conservation Objectives**	**Time Frames**

Northern Institute of Applied Climate Science

Climate

Carbon

Bioenergy

NIACS
Northern Institute of
Applied Climate Science

www.nrs.fs.fed.us/niacs/

NIACS is a regional multi-institutional partnership

Forest Service

- Northern Research Station
- Eastern Region
- Northeastern Area S&PF

Non-FS partners

- Michigan Technological University
- National Council for Air & Stream Improvement
- Trust for Public Land

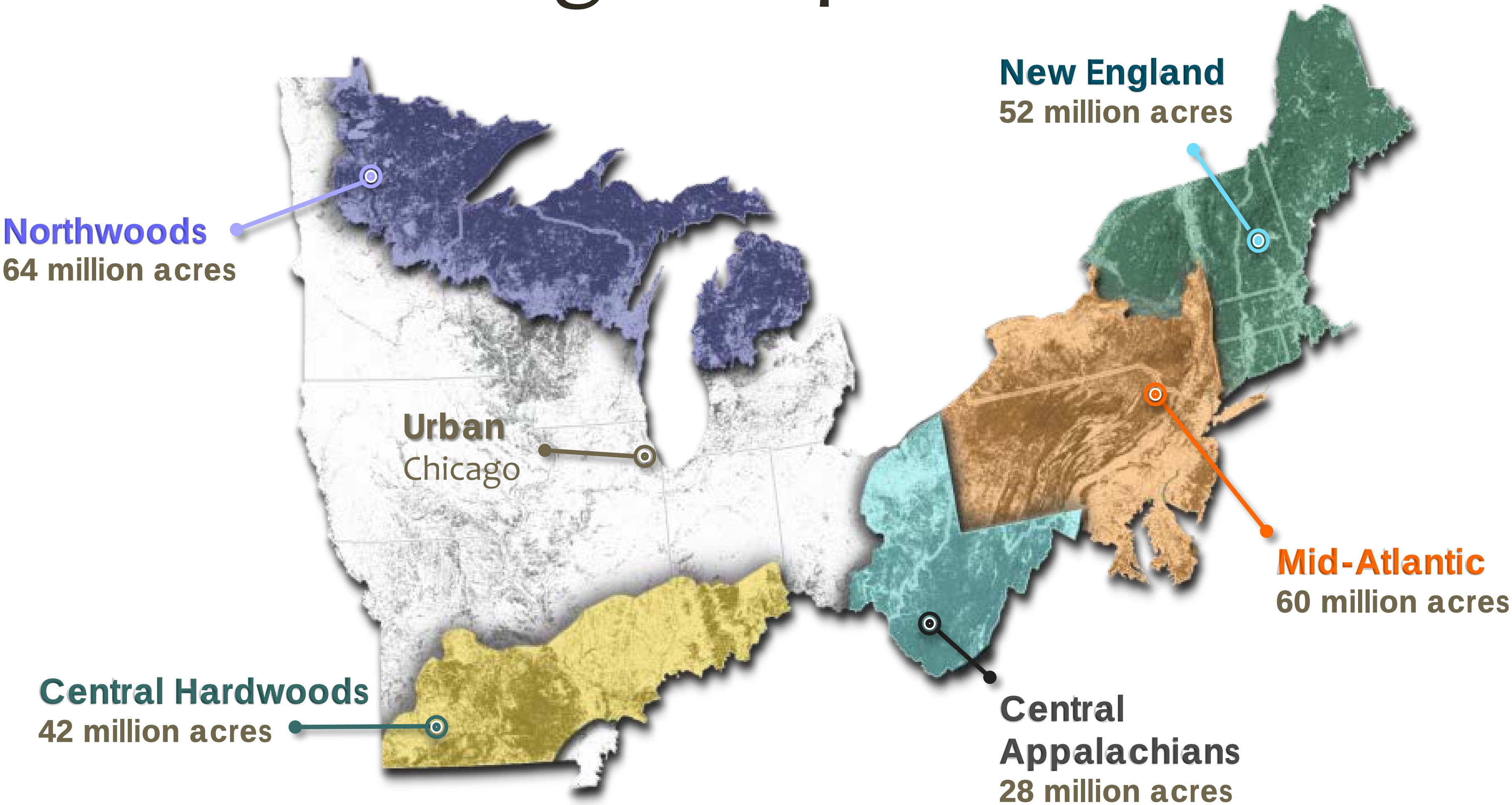
FOREST SERVICE U S DEPARTMENT OF AGRICULTURE

Michigan Tech

ncasi

THE TRUST for PUBLIC LAND

Climate Change Response Framework



Midwest USDA Climate Hub

Led by ARS with a **Northern Forests Sub-hub** based in Houghton, MI with NIACS as lead and CCRF integration

Northeast USDA Climate Hub

Led by FS NRS, where CCRFs are integrated into Hub and lead FS outreach and delivery to forest sector

Climate Change Response Framework

Structured, process oriented, works on multiple scales

Components:	Progress:
Partnerships	75+ partner organizations (and counting)
Vulnerability Assessment	3 published assessments, 3 more in press/revision
Forest Adaptation Resources	Published in 2012, updated and online versions in prep
Adaptation Demonstrations	50+ demonstrations underway

NIACS-led Vulnerability Assessments

Audience: Land managers

Scope: Forest ecosystems

Vulnerability of:

- Tree species
- Forest/natural communities

Scientific reports: Do not make recommendations

Place based, model-informed, expert-driven, transparent

***Ecosystem Vulnerability Assessment and Synthesis* reports:**

NIACS-led Vulnerability Assessments

General Approach:

- Summarize climate change projections (temp./precip)
- Describe expected impacts on forests based on model results and literature
- Use scientist and expert knowledge to assess vulnerability of individual forest types to climate change

NIACS-led Vulnerability Assessments

General Approach:

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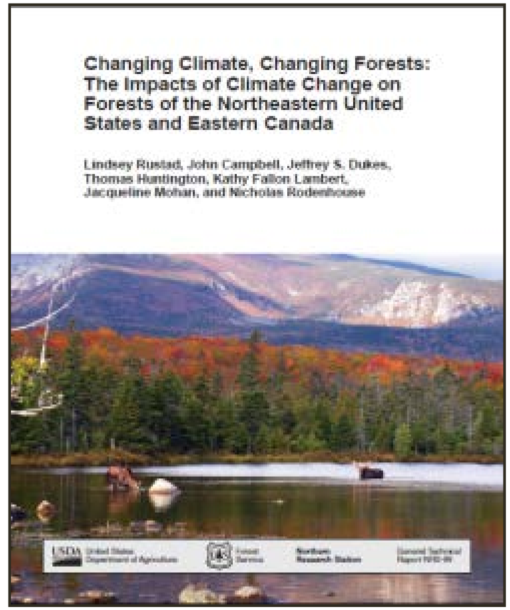
New England has (Much) More Info

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



Changing Climate, Changing Forests: The Impacts of Climate Change on Forests of the Northeastern United States and Eastern Canada

Lindsey Rustad, John Campbell, Jeffrey S. Dukes, Thomas Huntington, Kathy Fallon Lambert, Jacqueline Mohan, and Nicholas Rodenhouse

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

REVIEW / SYNTHÈSE

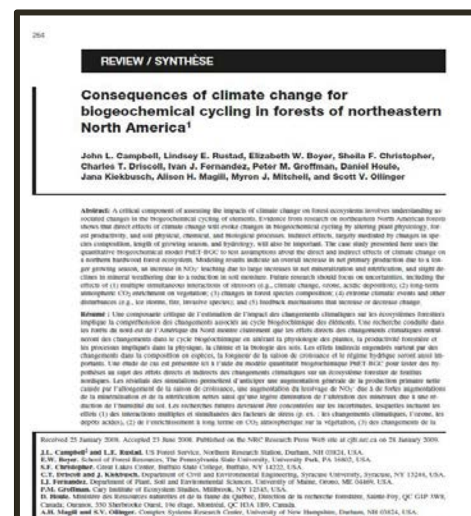
Climate change effects on native fauna of northeastern forests[1]

Nicholas L. Rodenhouse, Lynn M. Christenson, Dylan Parry, and Linda E. Green

REVIEW / SYNTHÈSE

Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict?[1]

Jeffrey S. Dukes, Jennifer Pontius, David Orwig, Jeffrey R. Garnas, Vikki L. Rodgers, Nicholas Brazee, Barry Cooke, Kathleen A. Theoharides, Erik E. Stange, Robin Harrington, Joan Ehrenfeld, Jessica Gurevitch, Manuel Lerdau, Kristina Stinson, Robert Wick, and Matthew Ayres



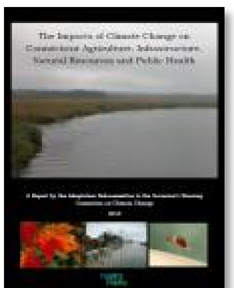
REVIEW / SYNTHÈSE

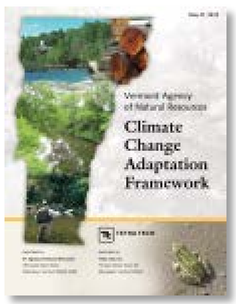
Consequences of climate change for biogeochemical cycling in forests of northeastern North America[1]

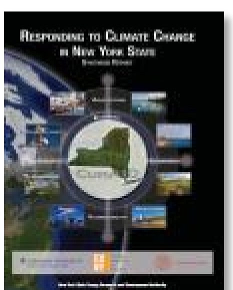
John L. Campbell, Lindsey E. Rustad, Elizabeth W. Boyer, Sheila F. Christopher, Charles T. Driscoll, Ivan J. Fernandez, Peter M. Groffman, Daniel Houle, Jana Kiekbusch, Alison H. Magill, Myron J. Mitchell, and Scott V. Ollinger

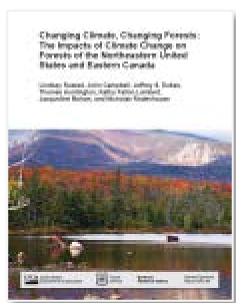
New England has (Much) More Info

- Much larger base of scientific research and climate change assessment.





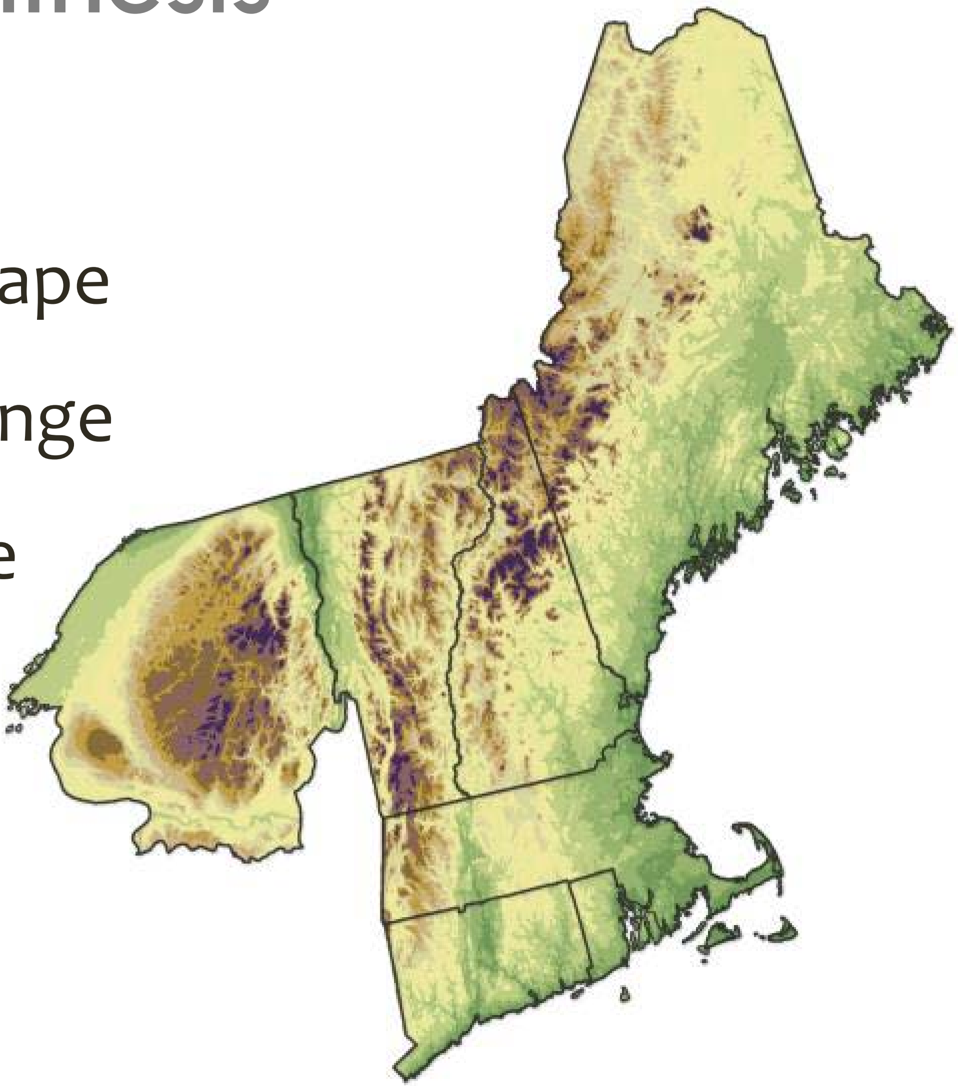




- Existing information allows for immediate integration of high-quality science into management
- Targeted assessments to fill information gaps and/or improve science delivery
  - Synthesis products: print, video, & web-based
  - Other?

New England Synthesis

1) Introduction
2) Contemporary Landscape
3) Observed Climate Change
4) Future Climate Change
5) Impacts on Forests
6) Conclusions



Timeline = in progress, draft this winter

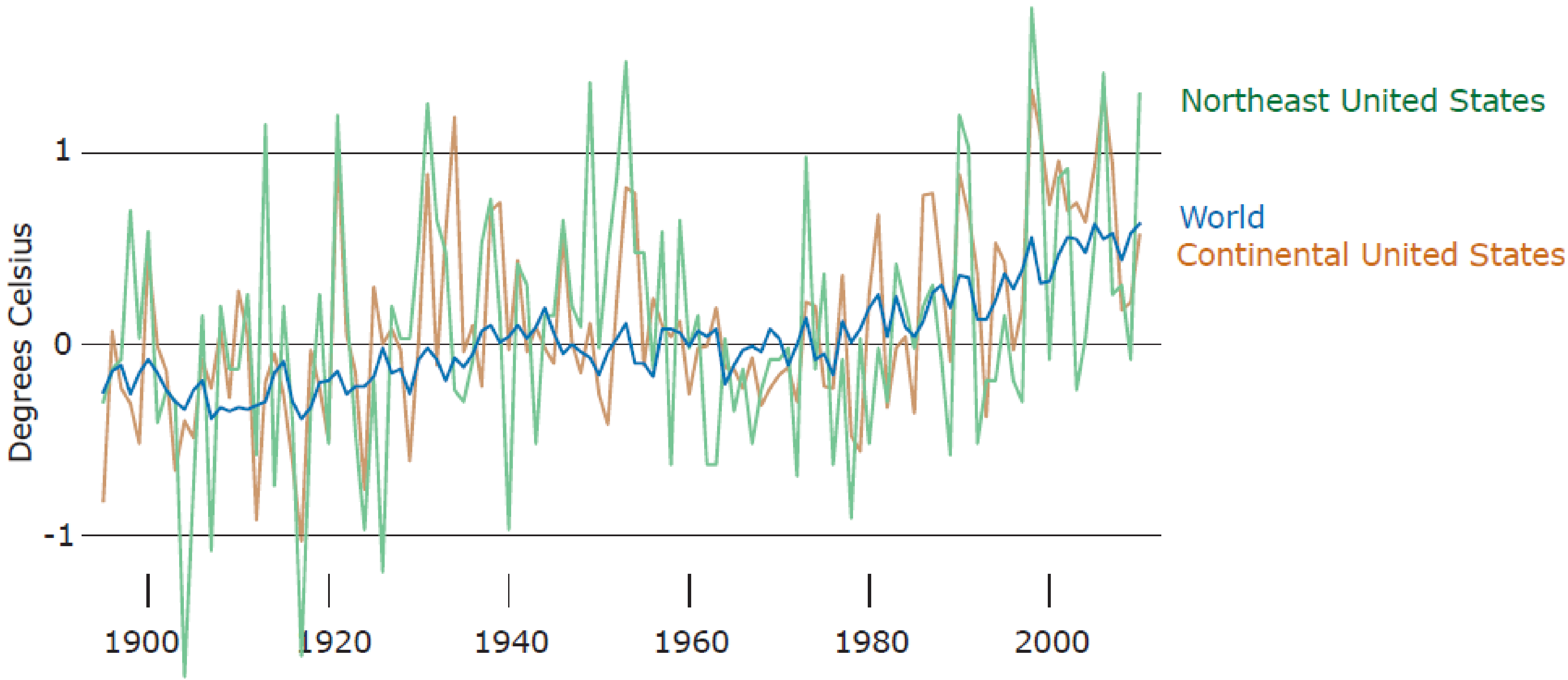
PAST AND FUTURE CLIMATE CHANGE

How has climate changed over the past century?

Observed Climate Trends

Mean temperature change compared to 1951-1980 average

(1 ^{o}C = 1.8 ^{o}F)

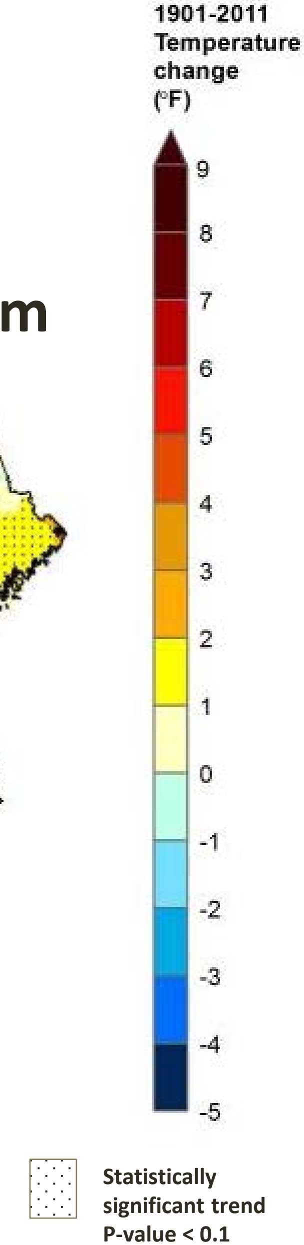


Rustad et al. 2012

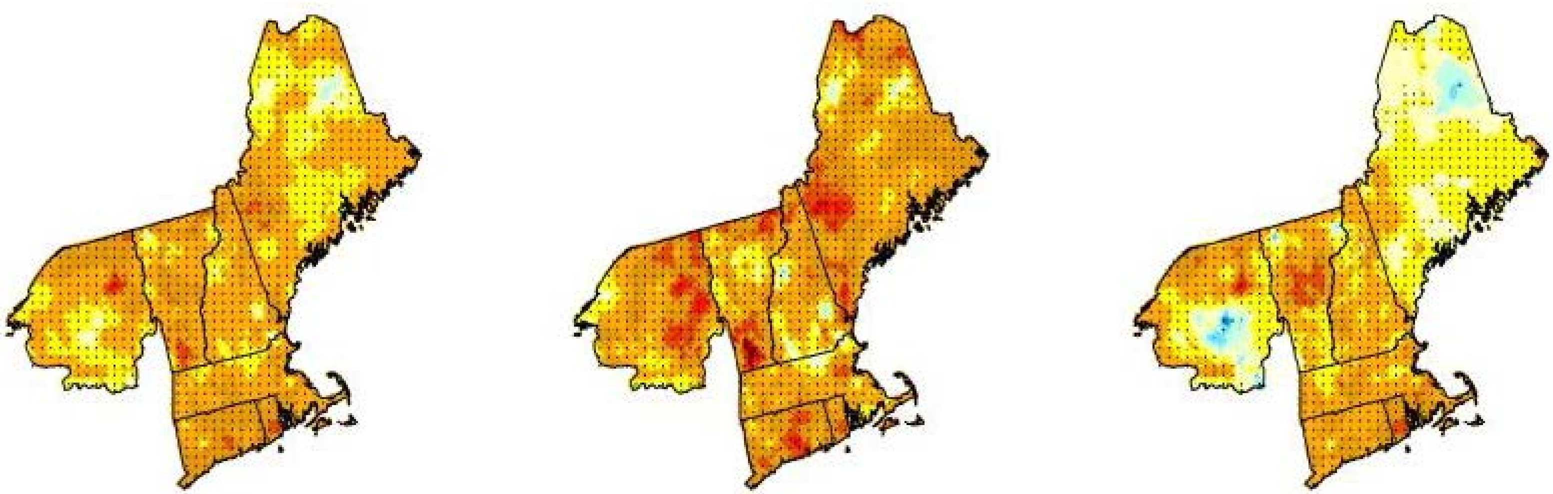
Observed Climate Trends

- ClimateWizardcustom.org
  - PRISM (Parameter-elevation Regressions on Independent Slopes Model)
  - 2.5-mile grid
- 1901 to 2011 departure analysis
  - Mean, Min, Max Temperatures
  - Precipitation
  - Yearly, seasonally

Annual Temperature Change



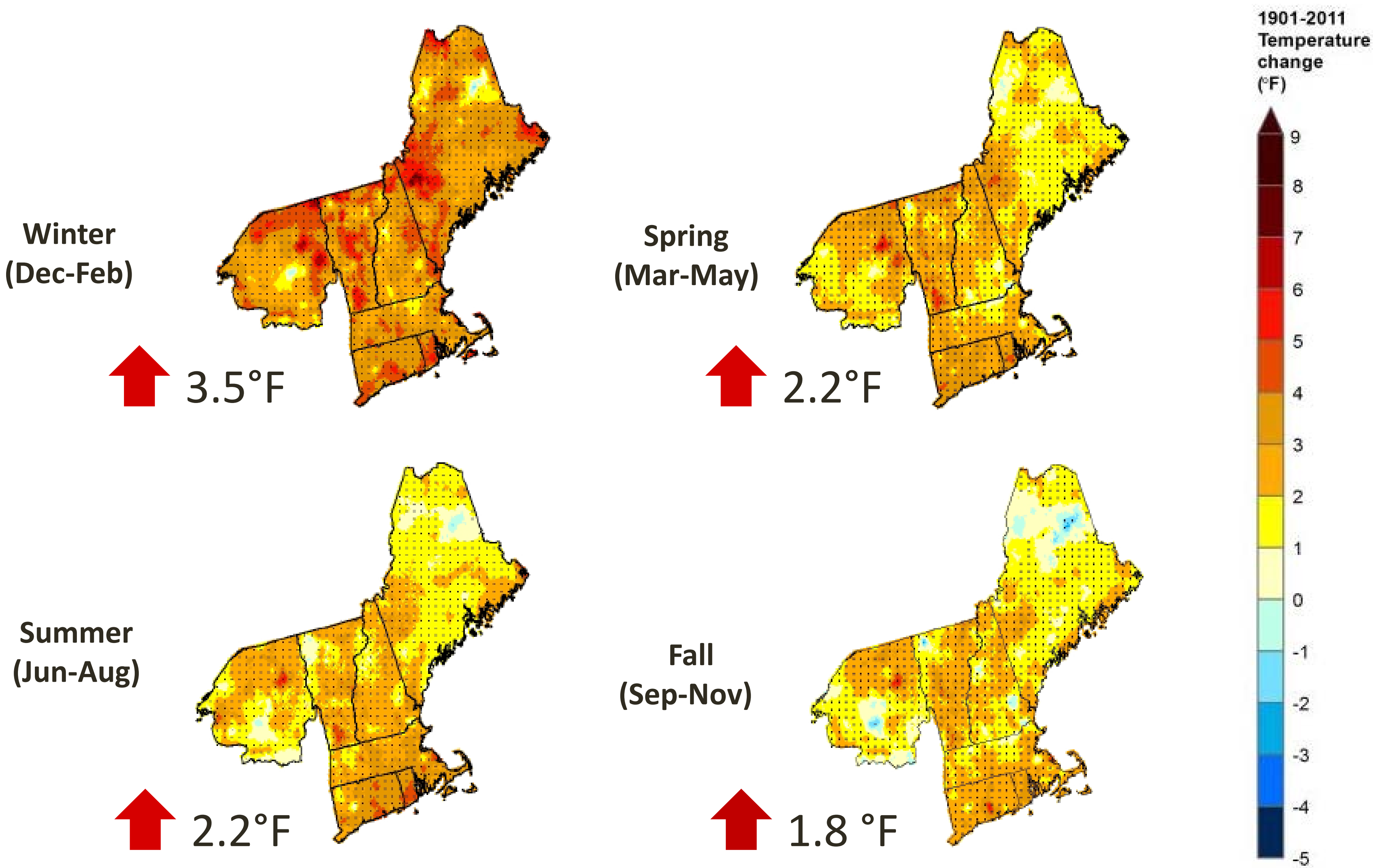
Mean | **Minimum** | **Maximum**



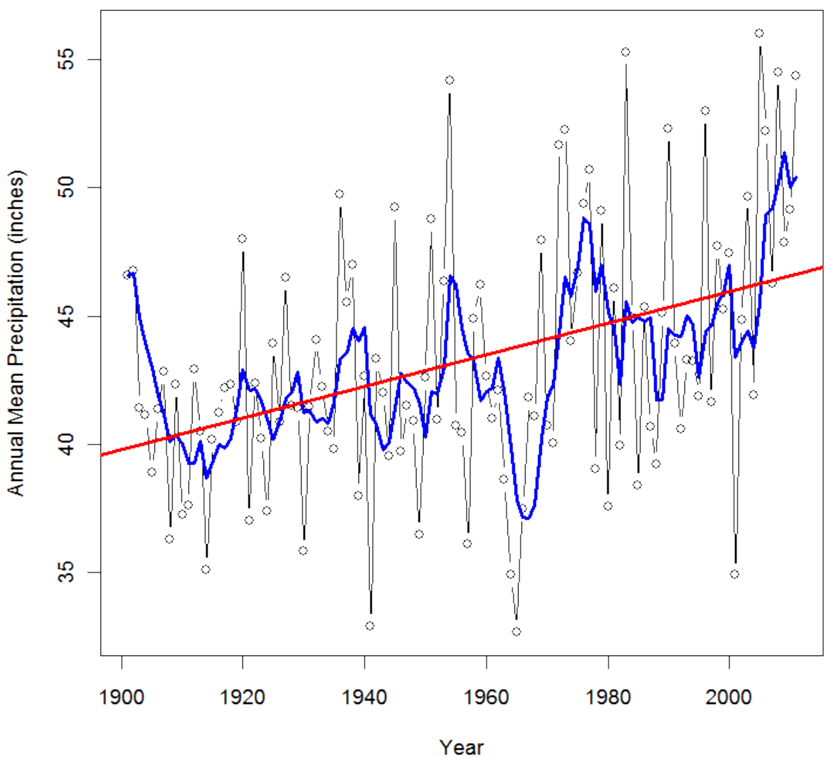
↑ 2.4 °F | ↑ 3.0 °F | ↑ 1.9 °F

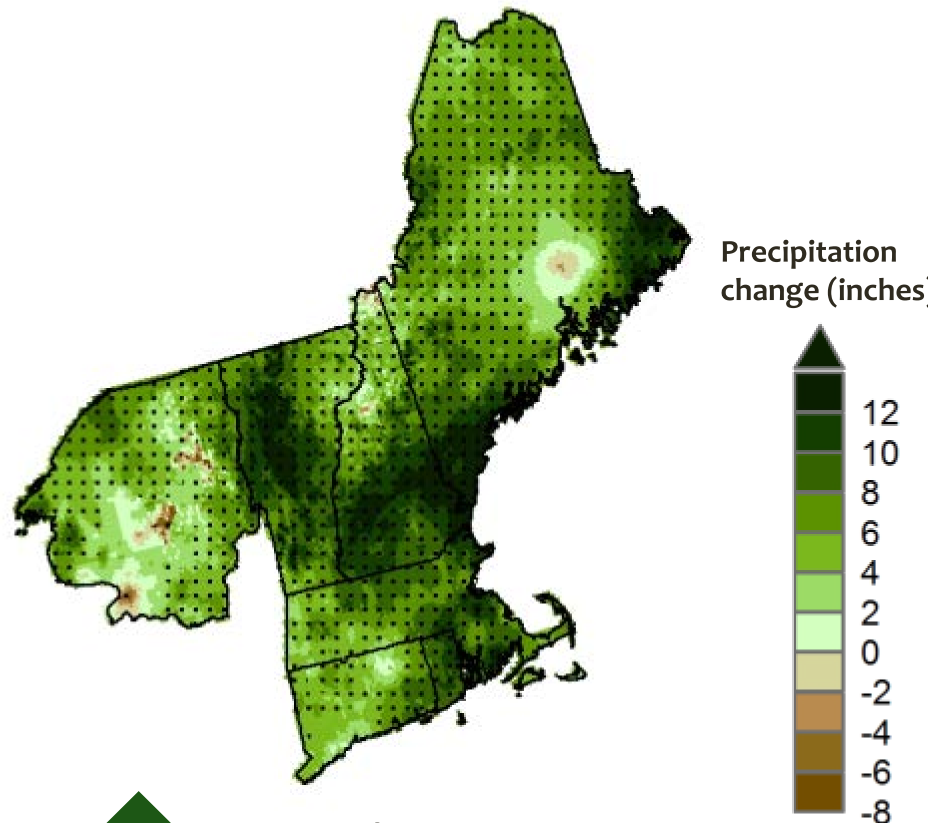
- 0.022 deg°F per year = 2.4°F over 111 years
- Substantial inter-annual fluctuation

Seasonal Mean Temperature Change



Annual Precipitation Change (1901-2011)

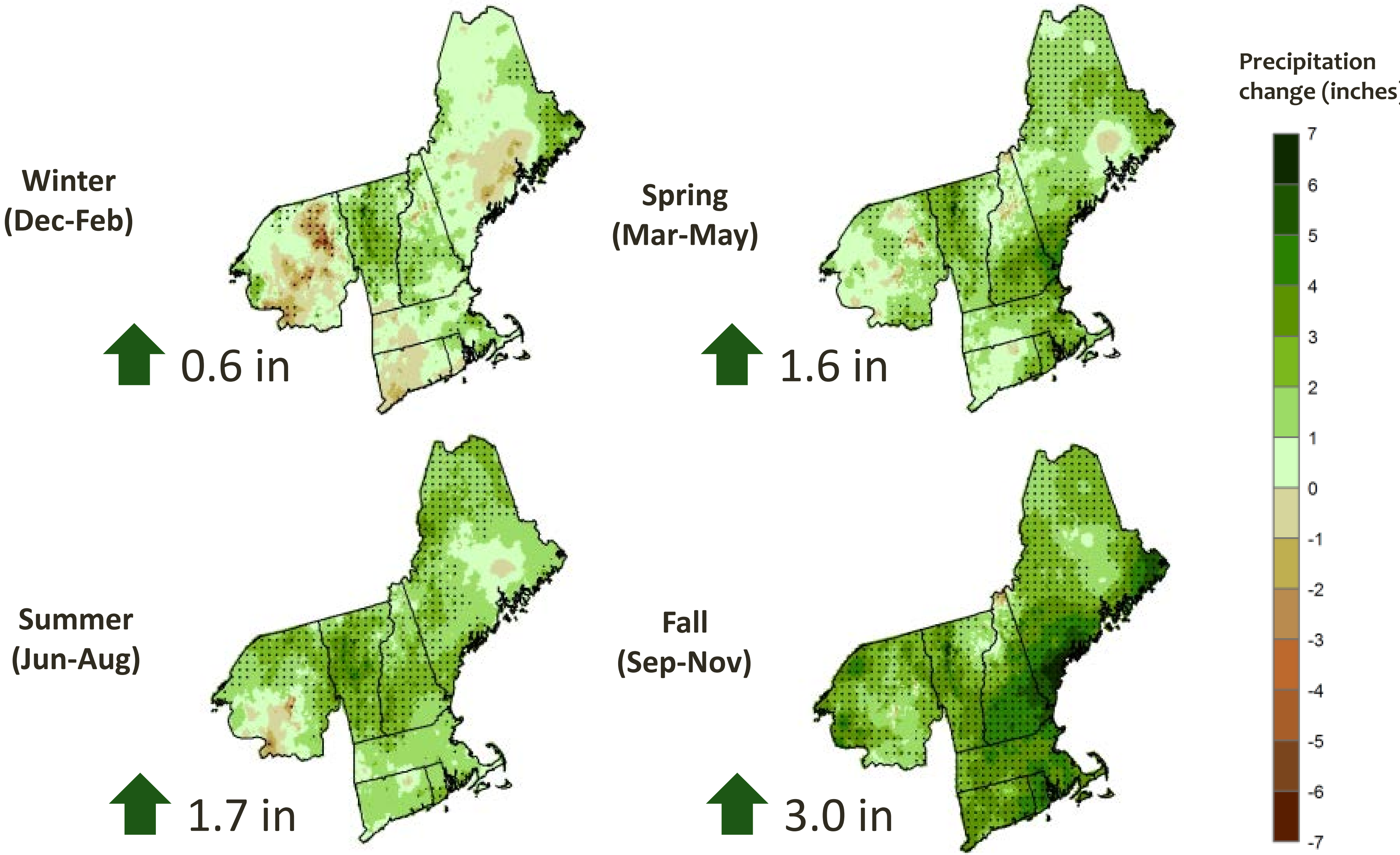




6.9 Inches

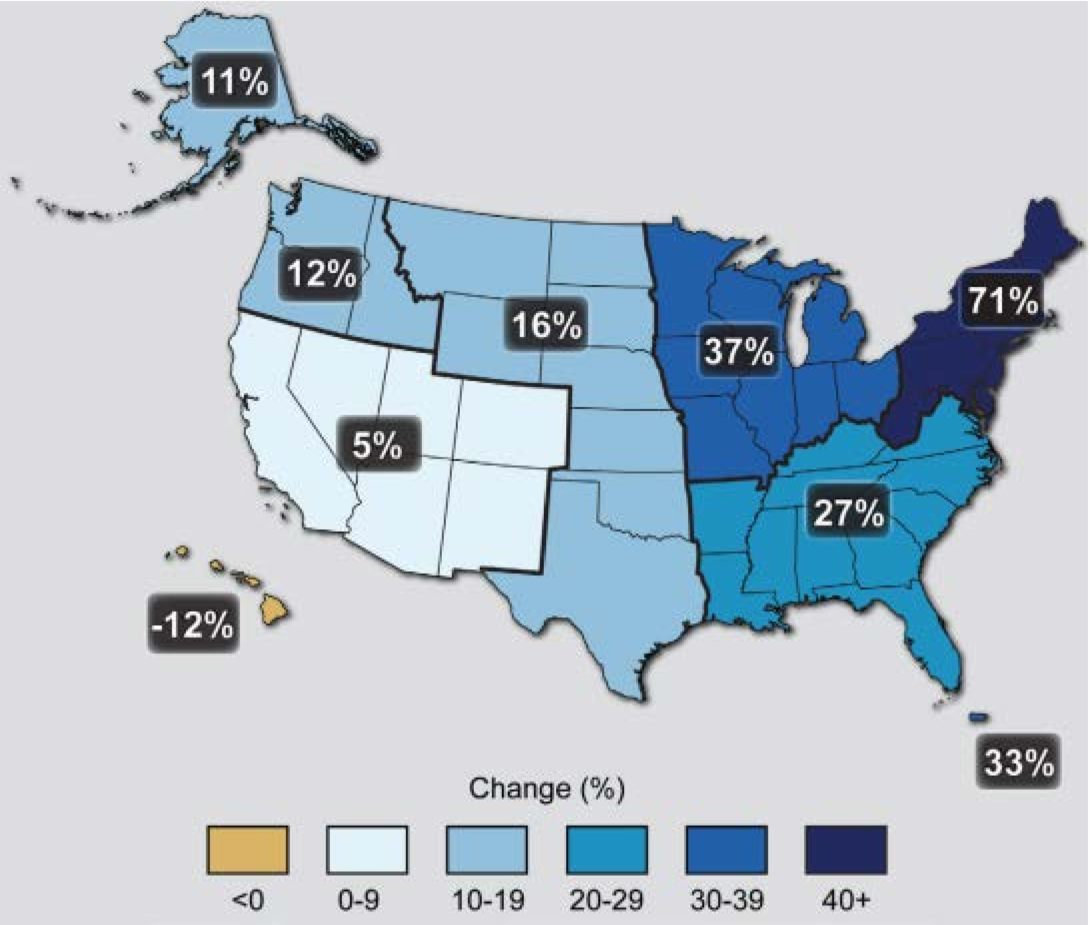
- 0.06 inches per year = 6.9 inches over 110 years
- Substantial inter-annual fluctuation

Seasonal Precipitation Change (1901-2011)



Extreme Precipitation Events

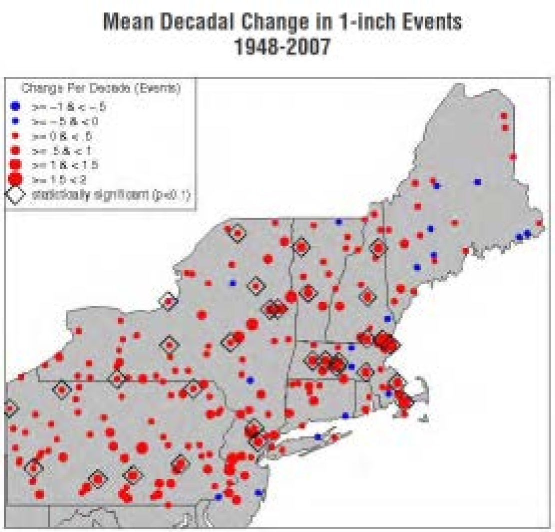
- The amount of precipitation falling in the heaviest 1% of events increased 71% between 1958 to 2012 *(NCA 2014)*

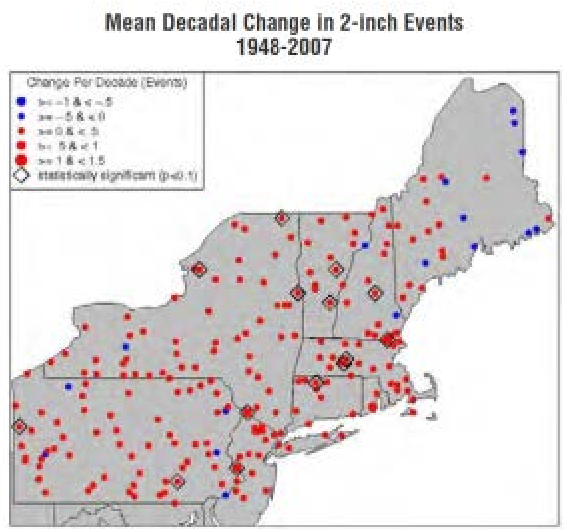


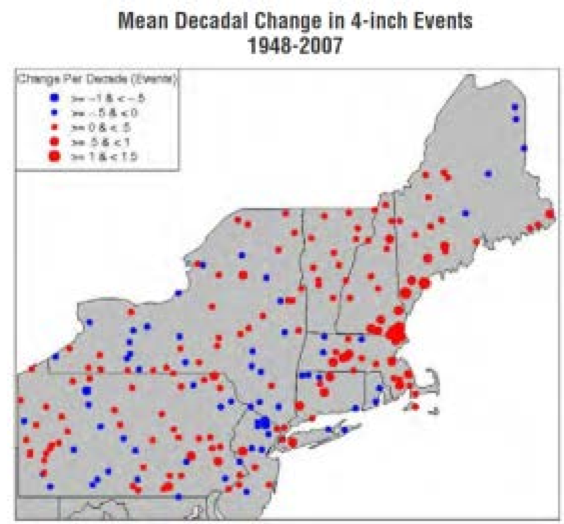
Melillo et al. 2014 (NCA)

Extreme Precipitation Events

The amount of precipitation falling in single events increased between 1948 and 2007





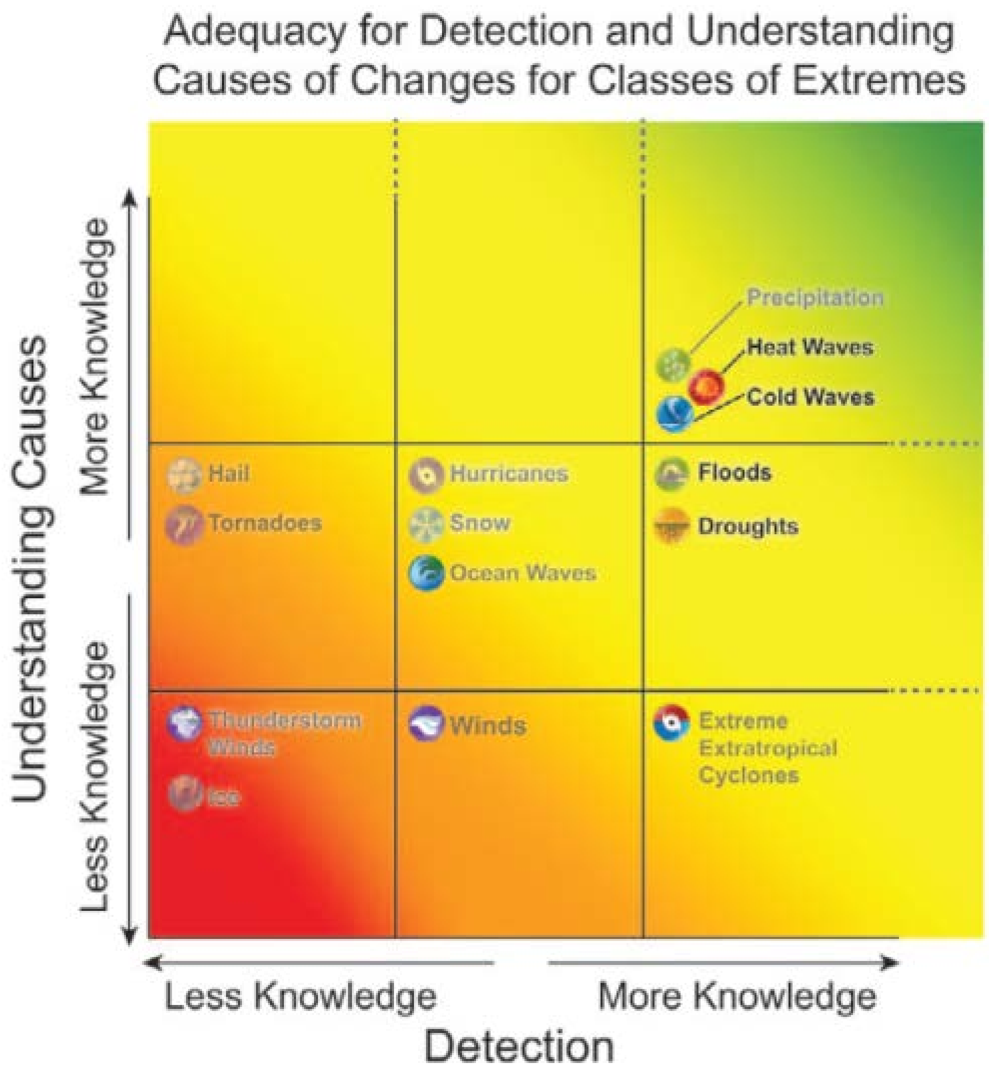


Spierre and Wake 2010

Extreme Events: Detection & Attribution

Factors influencing the understanding of extreme events:

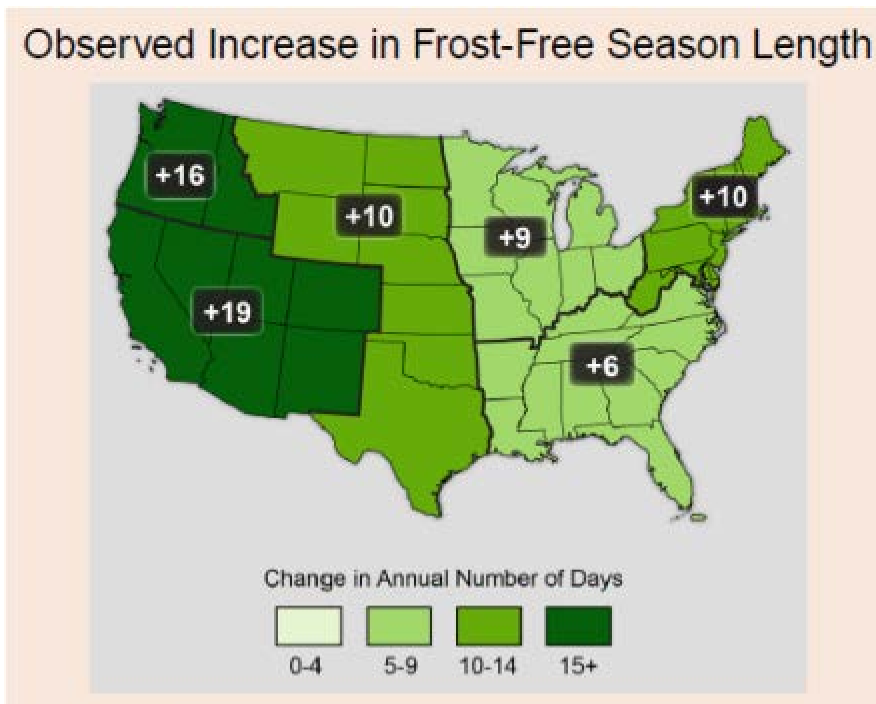
- Scientists' understanding of event & what would cause it to change
- Data quality
- Data quantity



Peterson et al. 2013

Additional Observations & Evidence

- US has warmed 1.3-1.9°F since 1895 *(Melillo et al. 2014)*
- Lower 48 warmed 1.3 °F per century during 1901-2009 *(EPA 2012)*
- Global sea level has risen about 8 inches since 1880 *(Melillo et al. 2014)*
- Growing seasons have lengthened *(Melillo et al. 2014)*

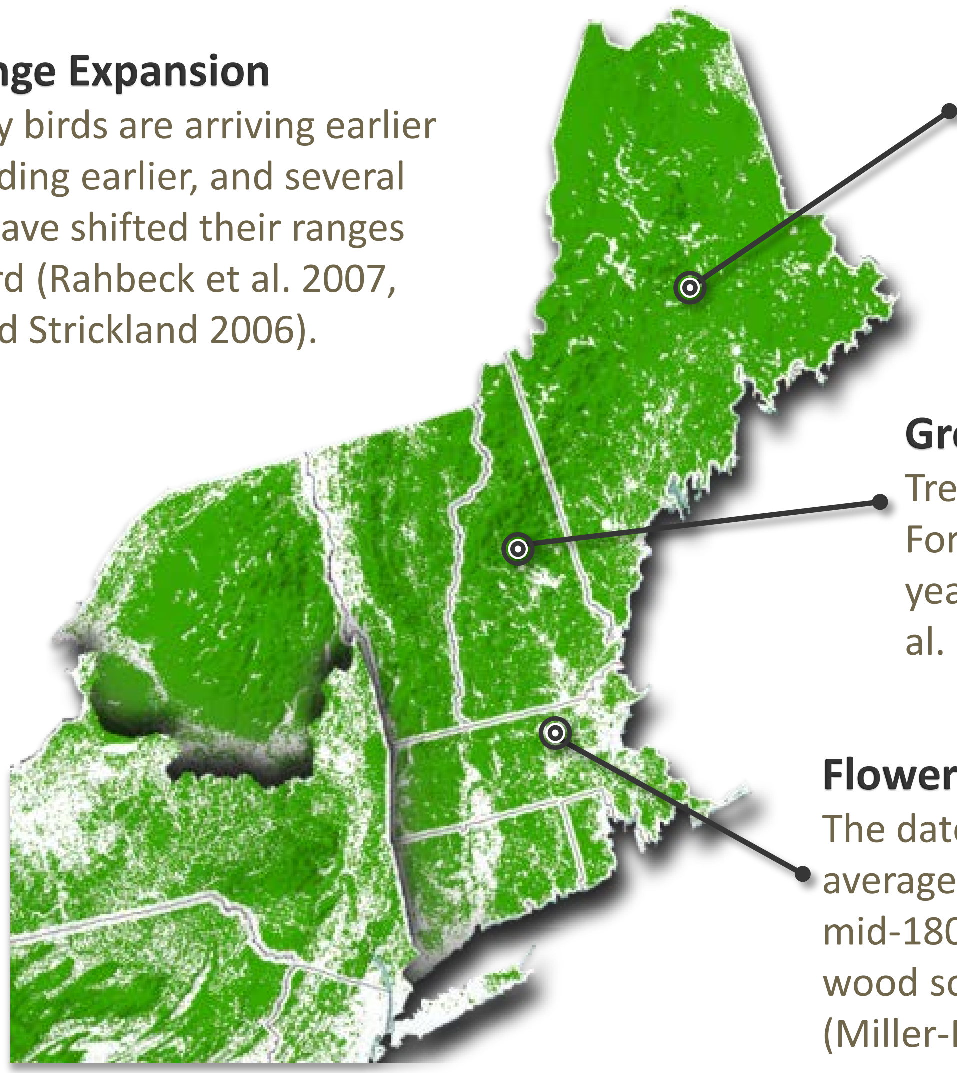


1991-2012 relative to 1901-1960.

Melillo et al. 2014 (NCA)

Phenological Changes

Bird Range Expansion
Migratory birds are arriving earlier and breeding earlier, and several species have shifted their ranges northward (Rahbeck et al. 2007, Waite and Strickland 2006).



Lake Ice
Lake ice-out dates have advanced across Maine, with many dates now two weeks earlier than in the 1800s (Jacobson et al. 2009)

Green Canopy Duration
Trees at Hubbard Brook Experimental Forest have about 10 more days per year of green canopy (Richardson et al. 2006)

Flowering Dates
The date of first flowering is a week earlier on average compared to Thoreau's records from the mid-1800s. Highbush blueberries and yellow wood sorrel are flowering several weeks earlier (Miller-Rushing and Primack 2009)

Sea Level Rise

Sea level increased by about 1 foot since 1900, which is greater than the global average of about 8 inches and has led to an increase in coastal flooding

Sea Level is Rising

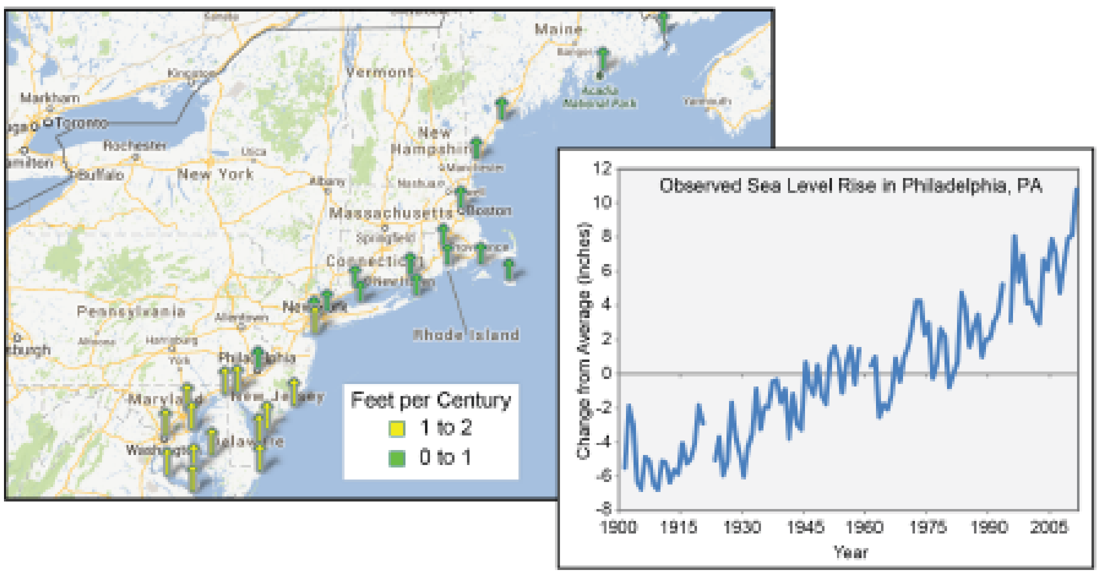


Figure 16.1. (Map) Local sea level trends in the Northeast region. Length of time series for each arrow varies by tide gauge location. (Figure source: NOAA[6]). (Graph) Observed sea level rise in Philadelphia, PA, has significantly exceeded the global average of 8 inches over the past century, increasing the risk of impacts to critical urban infrastructure in low-lying areas. Over 100 years (1901-2012), sea level increased 1.2 feet (Data from Permanent Service for Mean Sea Level).

Horton et al. 2014 (NCA)

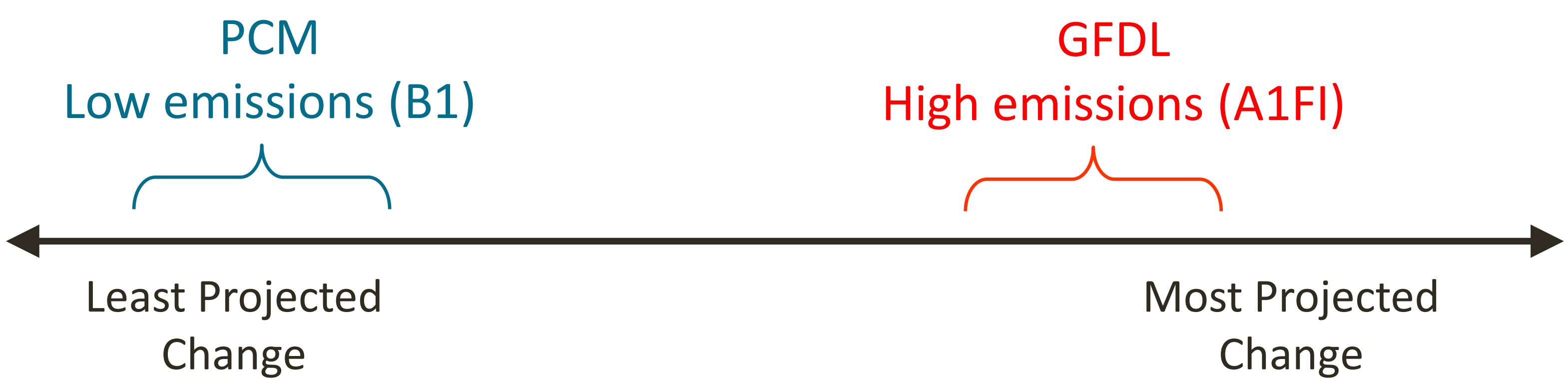
How is the climate expected to change over the next century?

Climate Scenarios Used

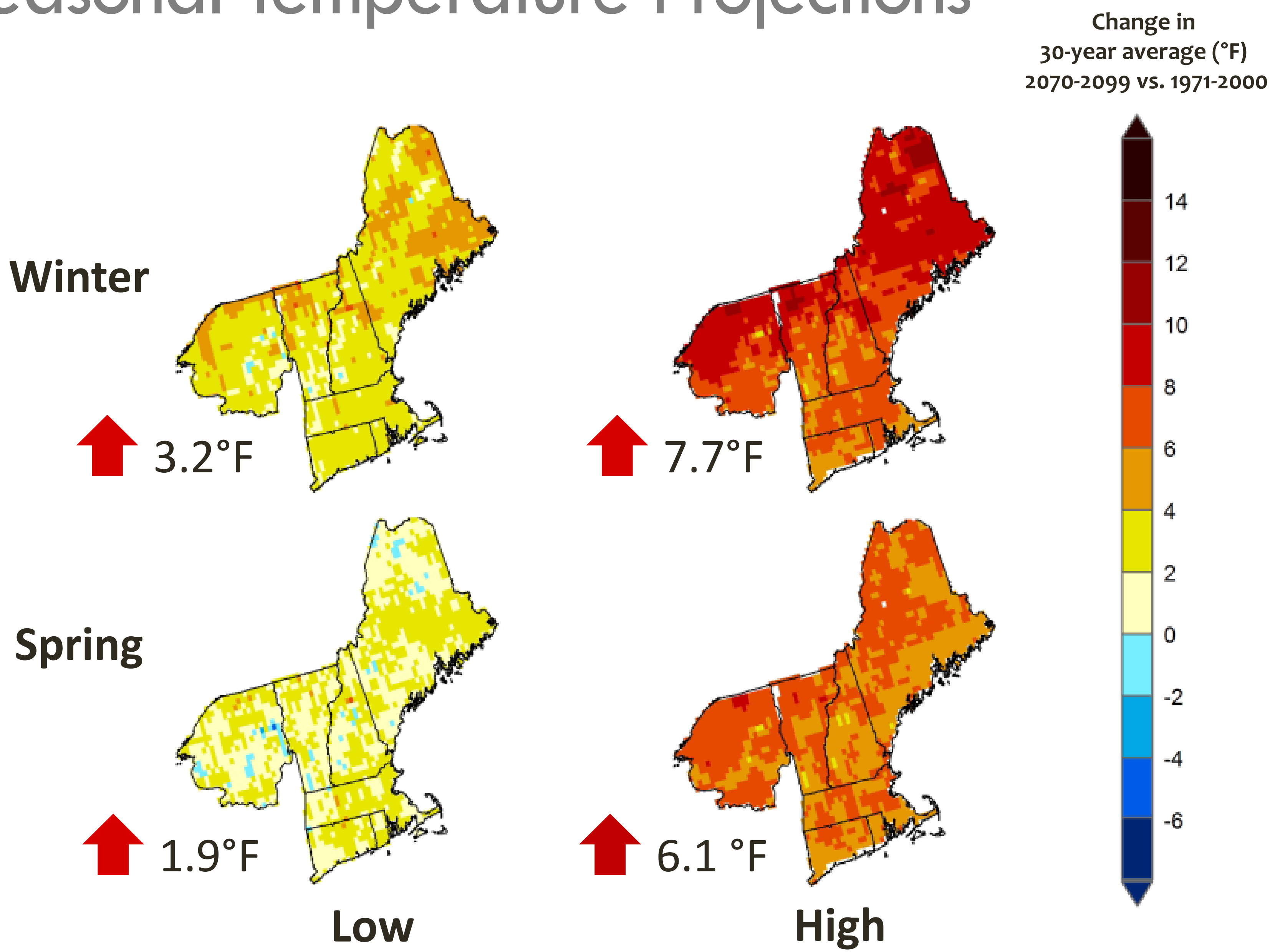
- Climate data downscaled by ATMOS/K. Hayhoe
- Three time periods
  - 2010 to 2039
  - 2040 to 2069
  - **2070 to 2099**
- 7.5-mile grid
- Annual and Seasonal changes
- Temperature: Mean, Minimum, Maximum
- Precipitation

Climate Scenarios Used

- Two scenarios show the range of possible change
  - PCM B1: Low emissions scenario + less sensitive GCM
  - GFDL A1FI: High emissions + more sensitive GCM
- Projections are consistent with other data sets
- Think of them like bookends:



Seasonal Temperature Projections



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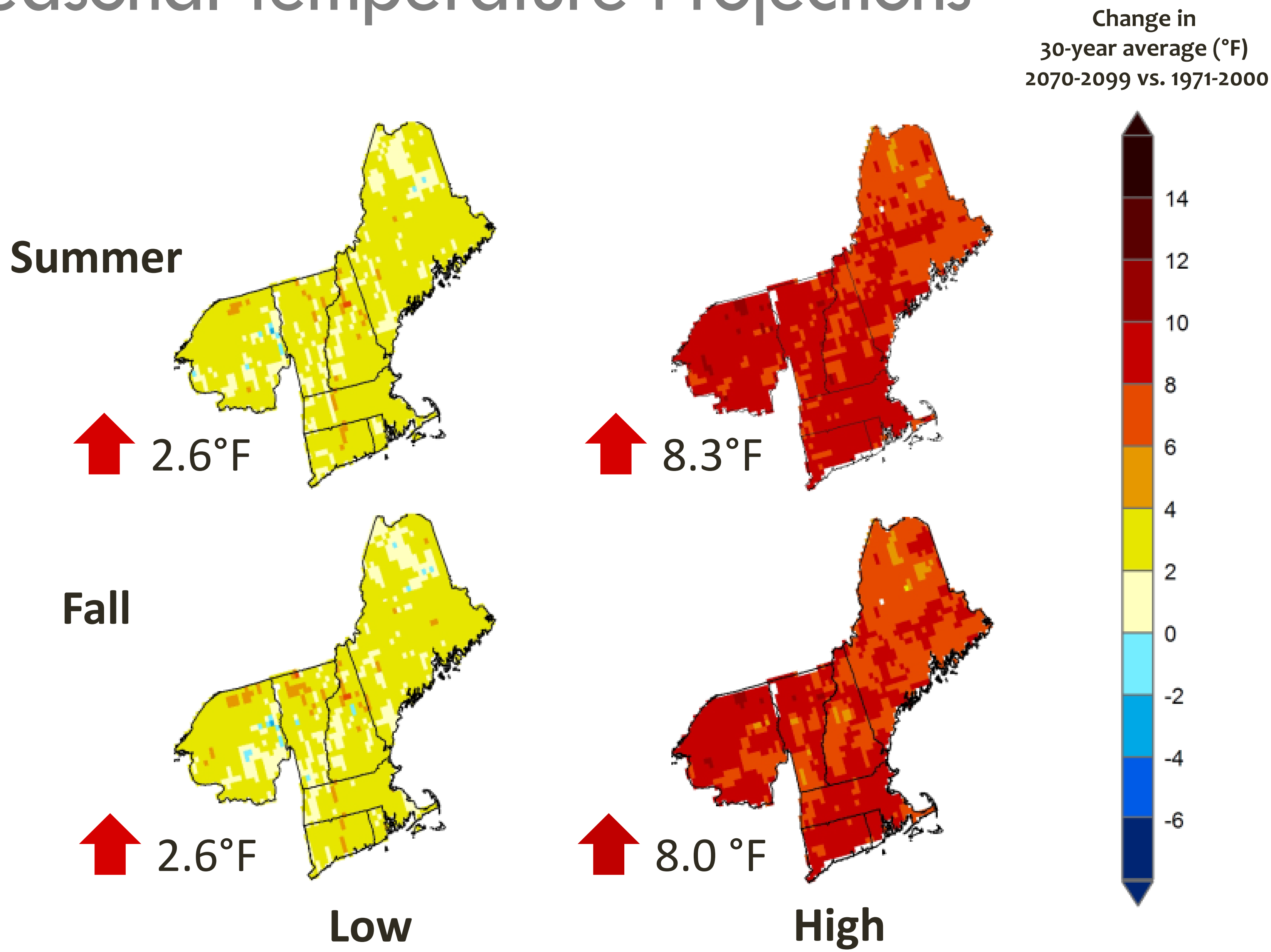
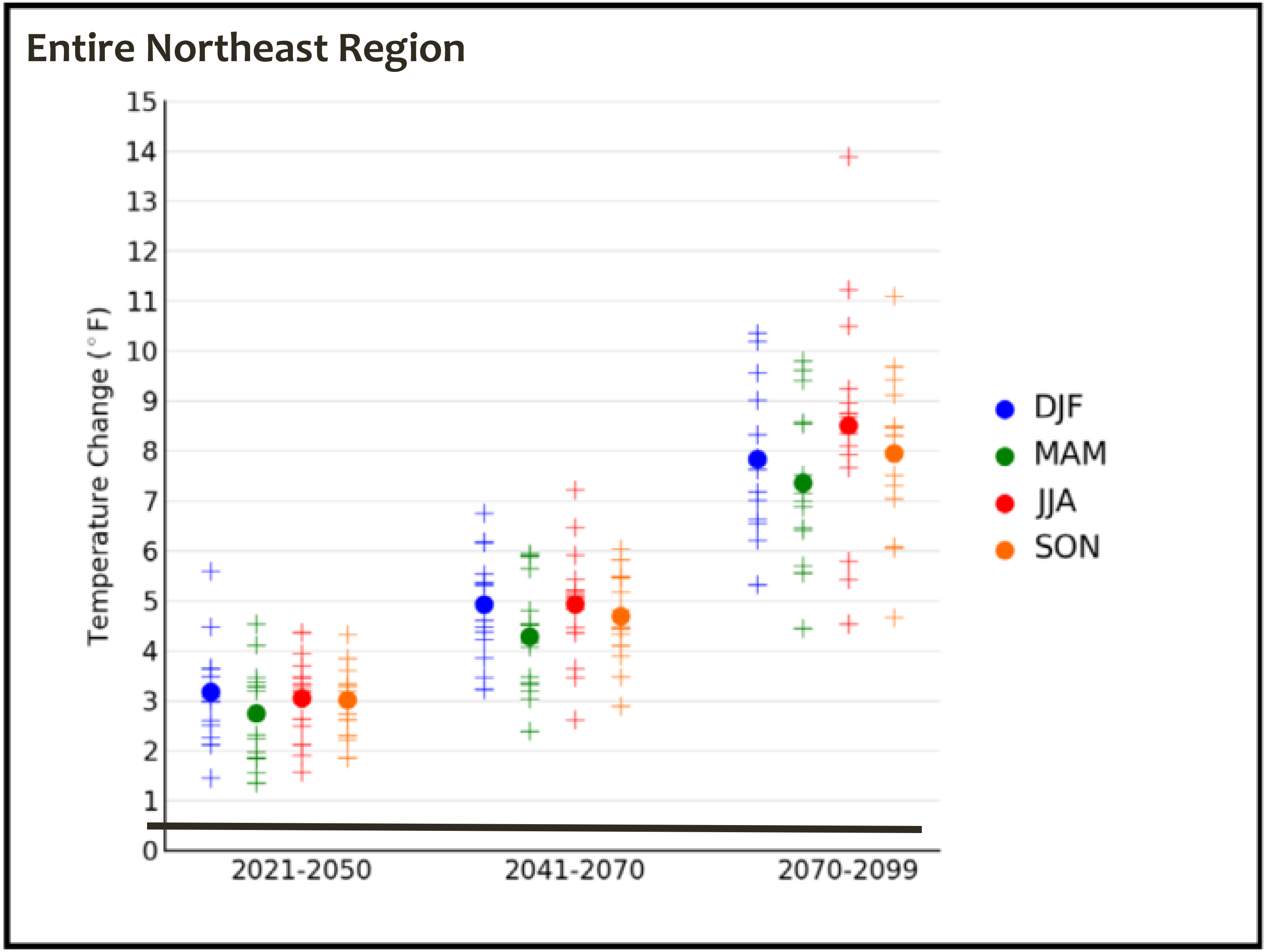
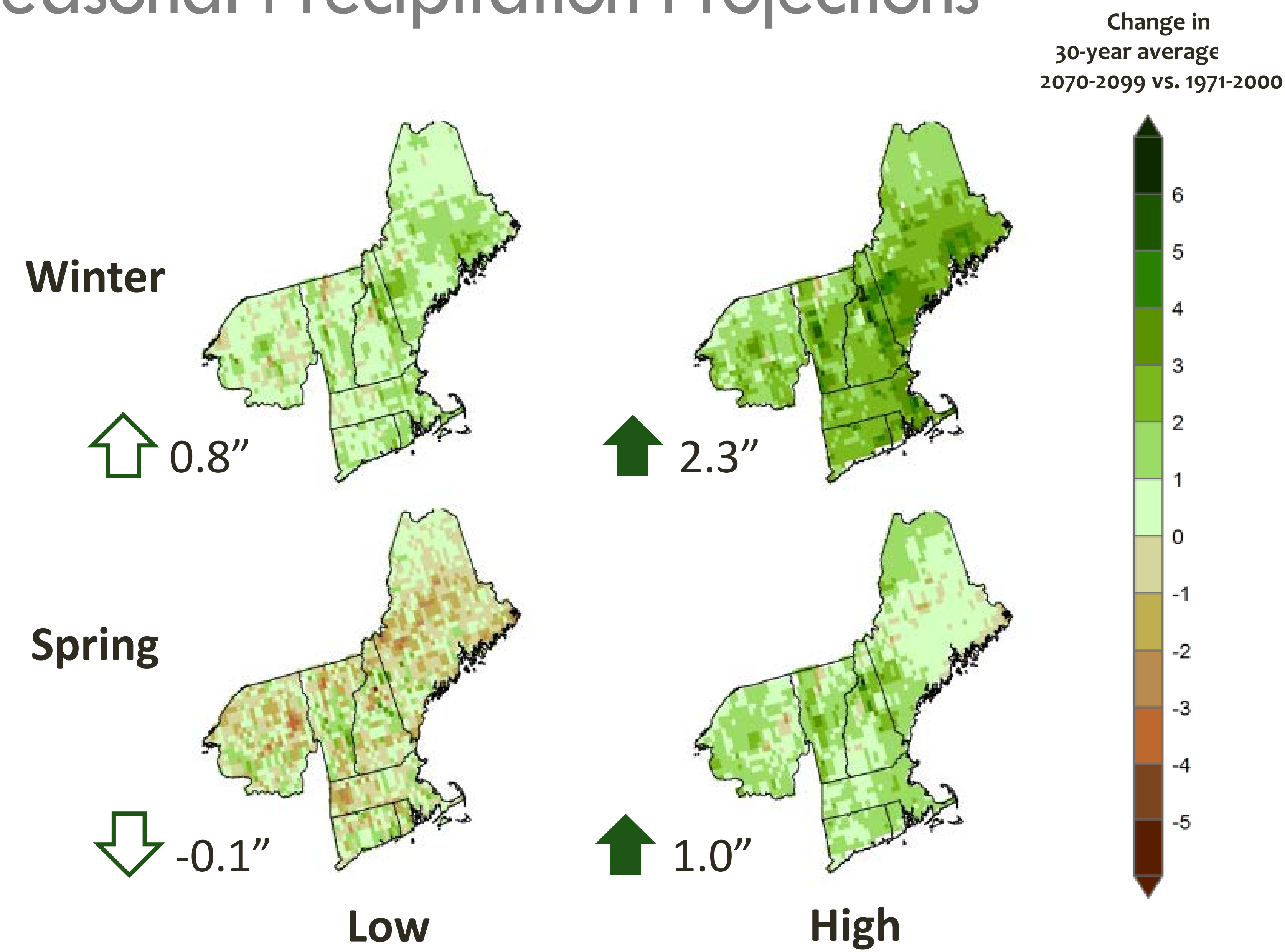


Temperature Change Projections

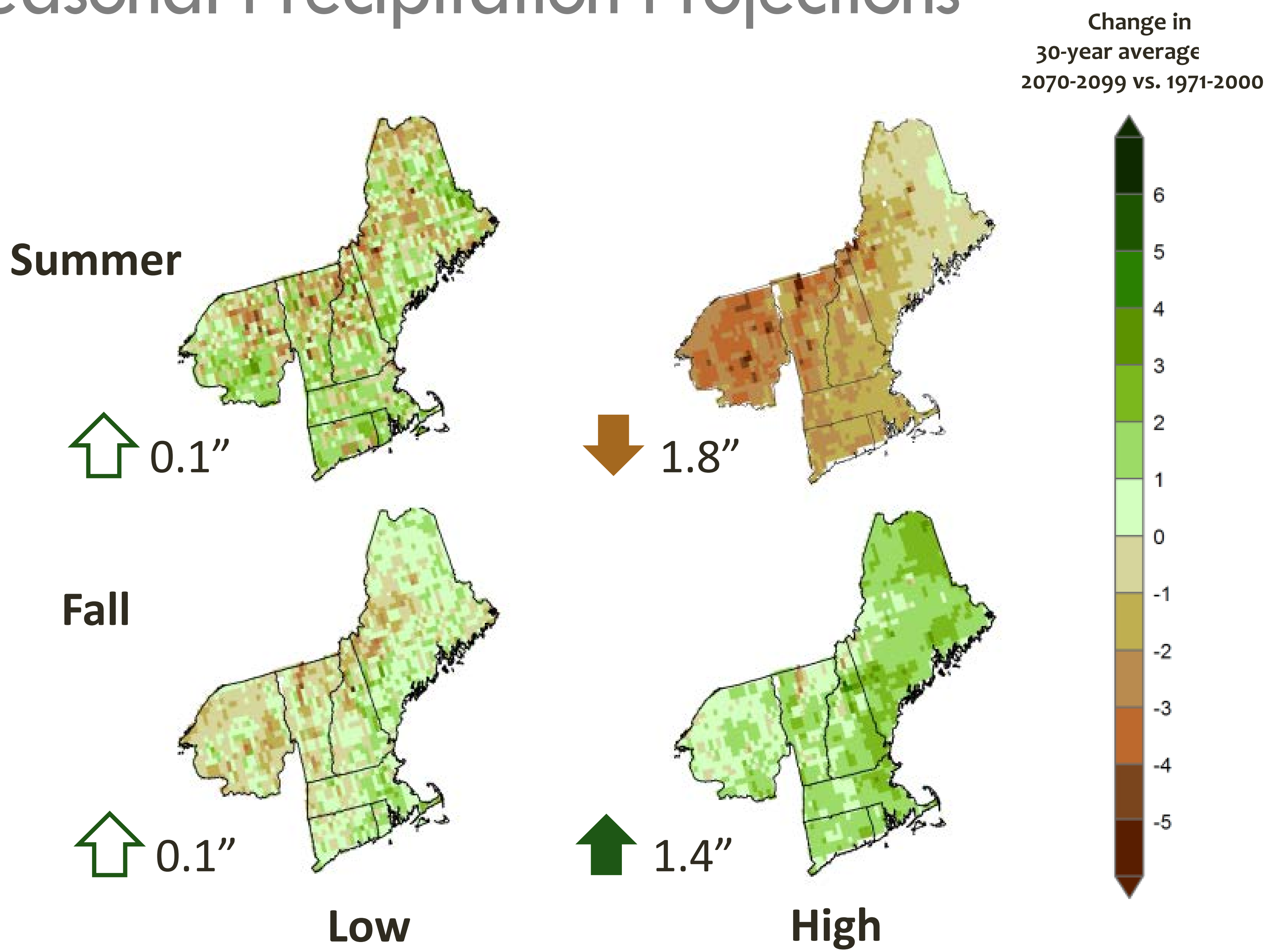


Kunkel et al. 2013

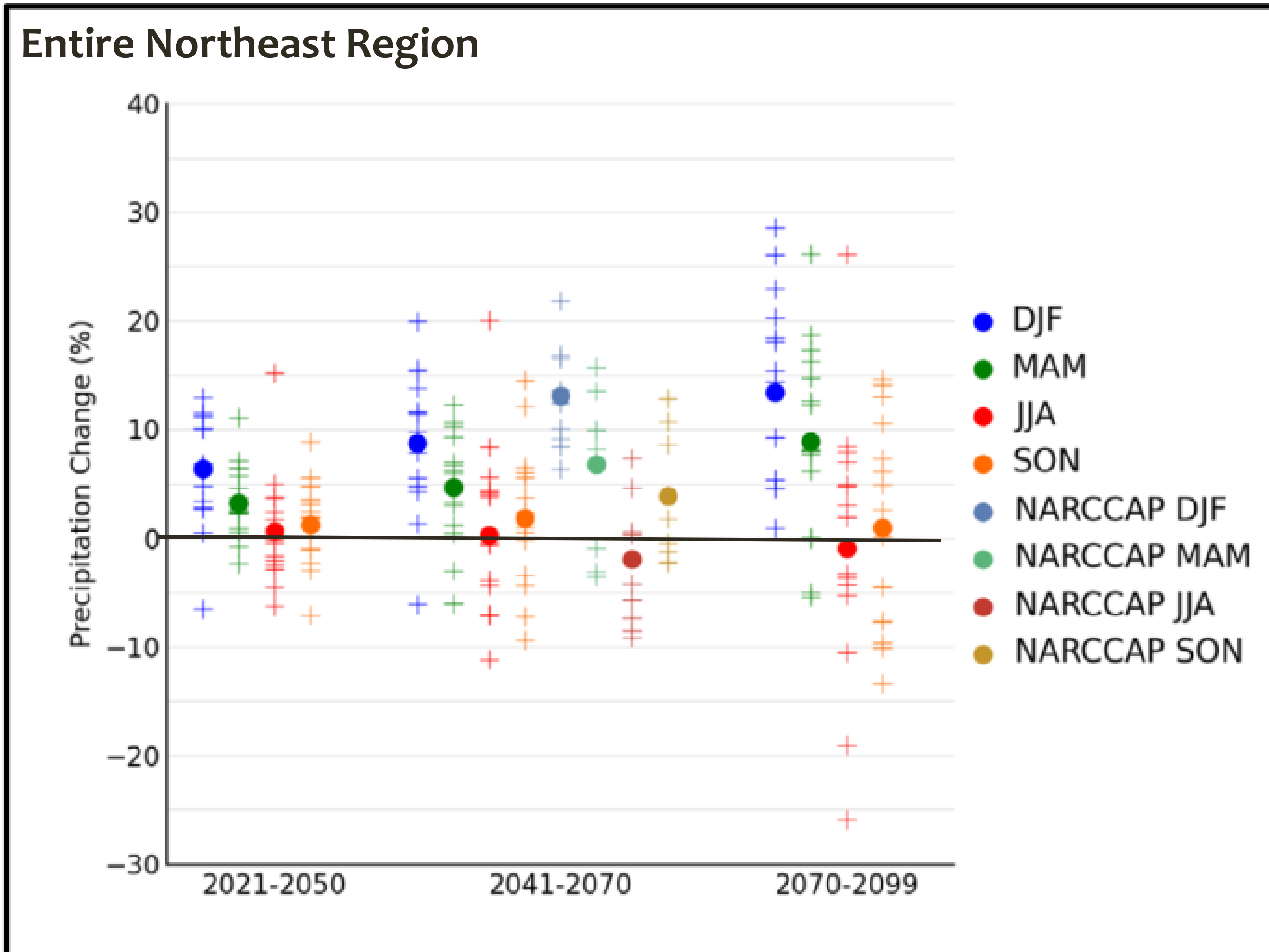
Seasonal Precipitation Projections



Seasonal Precipitation Projections



Precipitation Change Projections

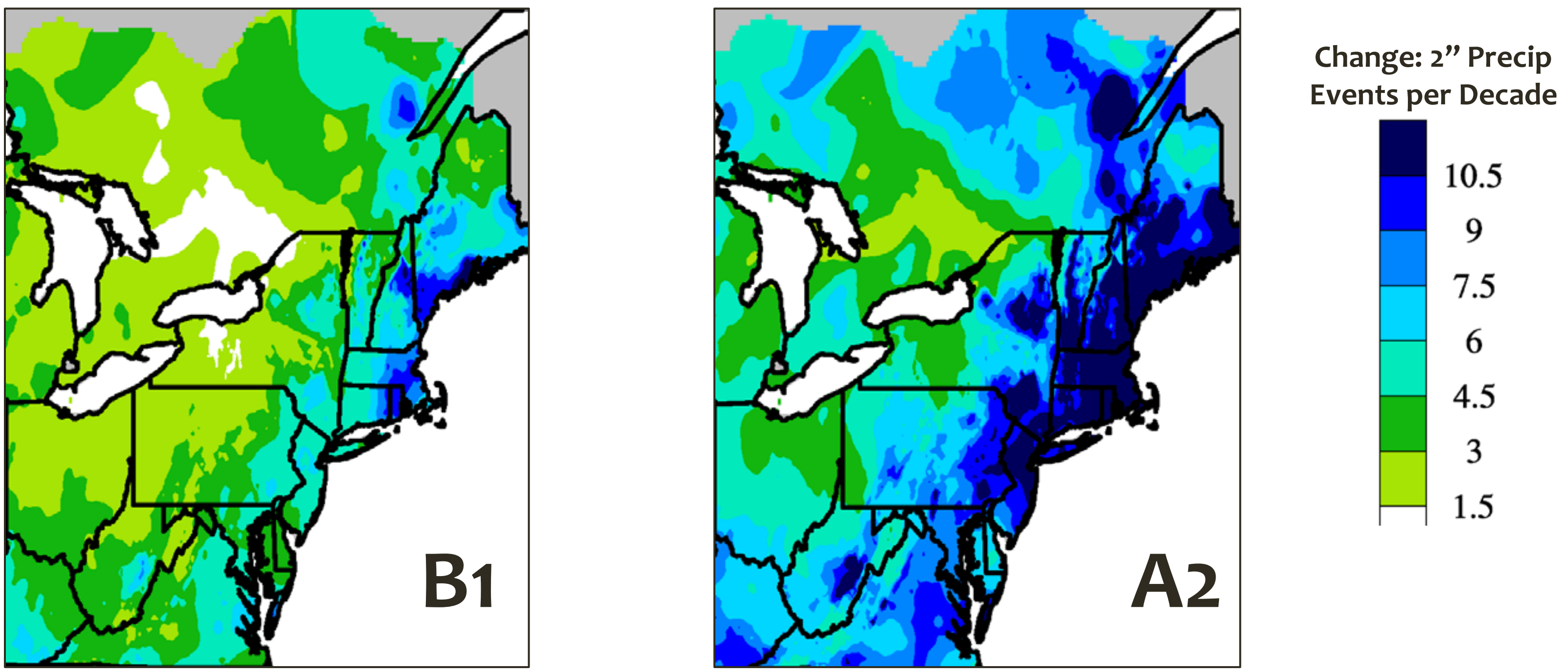


Kunkel et al. 2013

Extreme Precipitation Events

- Extreme precipitation has increased dramatically
  - Precip in heaviest 1% of events increased 71% between 1958 to 2012
- Trend expected to continue/increase

Change in 2-inch Precipitation Events (late 21st century)

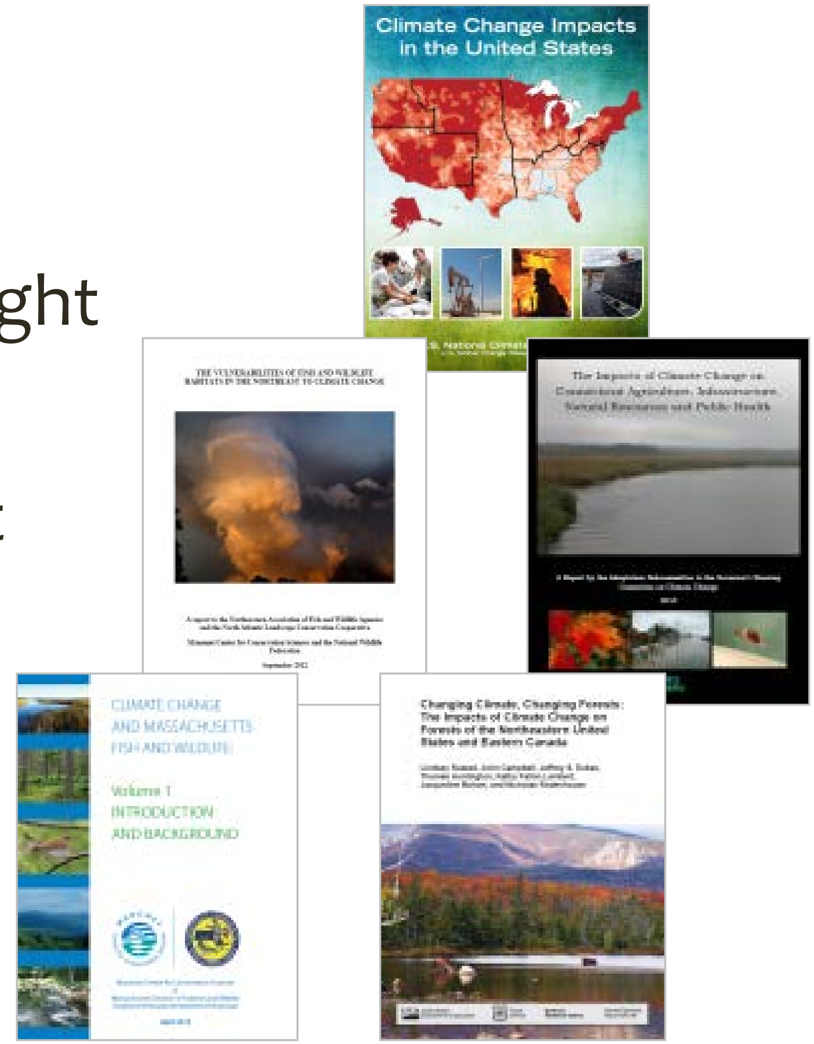


Kunkel et al. 2013; Figure: Center for Climatic Change, http://ccr.aos.wisc.edu/resources/data_scripts/LCC/

How could forests be affected?

Nine Impacts on New England Forests

1) Longer Growing Season
2) Shorter Winters
3) Potential for Summer Drought
4) CO_2 Fertilization
5) Changes in Suitable Habitat
6) Extreme Events
7) Wildfire Risk
8) Forest Pests and Diseases
9) Invasive Plants

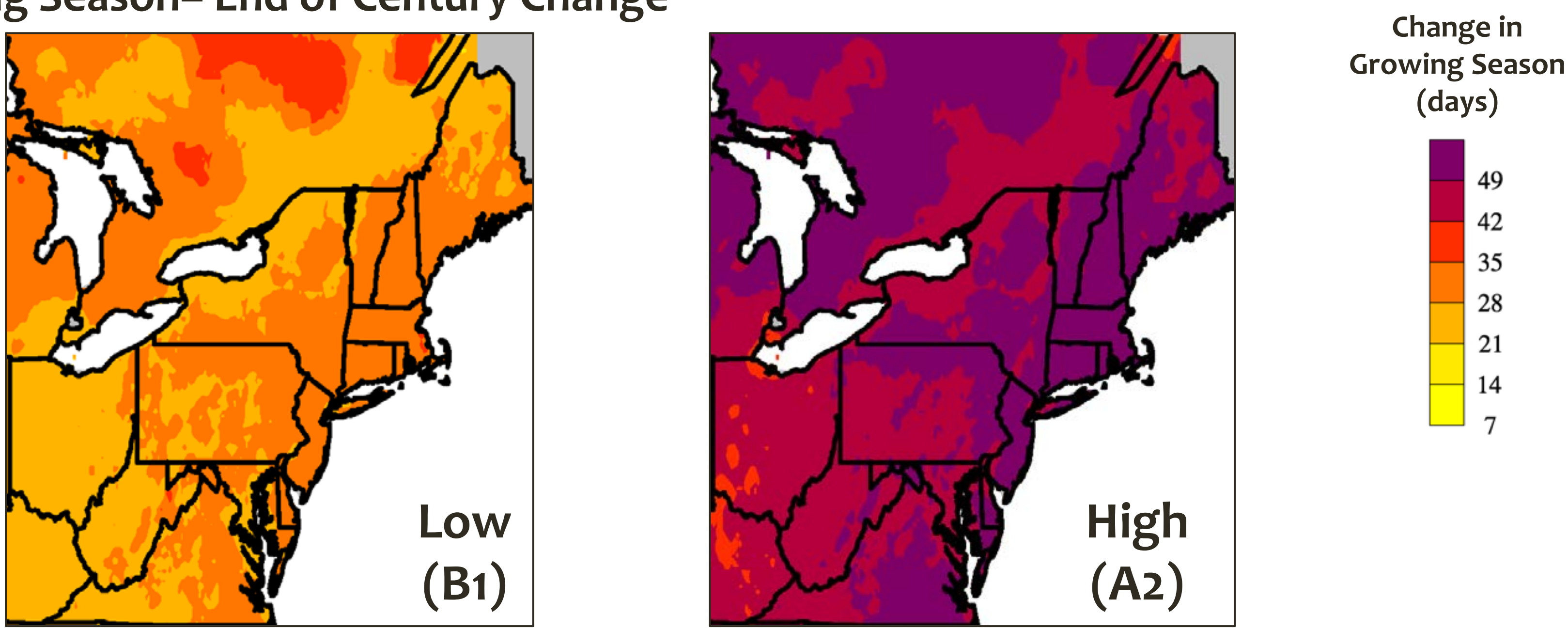


1: *Longer Growing Seasons*

Warmer temps result in longer growing seasons

- Projected to increase 3-7+ weeks by 2100

Growing Season– End of Century Change



Center for Climatic Change, http://ccr.aos.wisc.edu/resources/data_scripts/LCC/

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Warmer temps result in longer growing seasons

- Evidence of phenological shifts
- Projected to increase 3-7+ weeks

Longer period for plant growth

Melillo et al. 2014, Nelson Center 2014

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Warmer temps result in longer growing seasons

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Longer period for plant growth

Potential risks:

- Early bud break/loss of cold hardening
- Frost damage during spring freezing

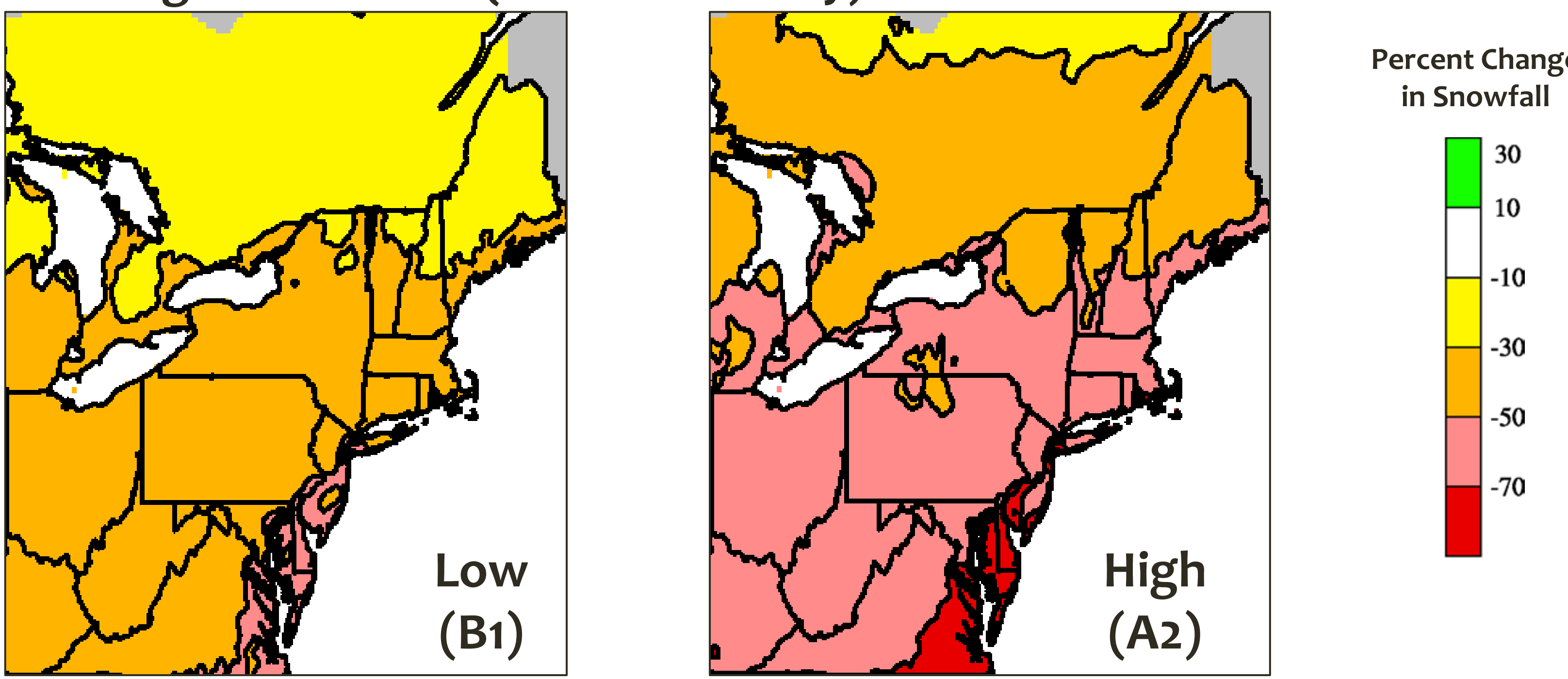
Melillo et al. 2014, Nelson Center 2014

2: *Shorter Winter (Less Snow)*

Projected decreases in snow fall, cover, and depth

- 30-70% decreases in snowfall
- Greatest snowfall decreases in December or January

Percent change in snowfall (late 21st century)



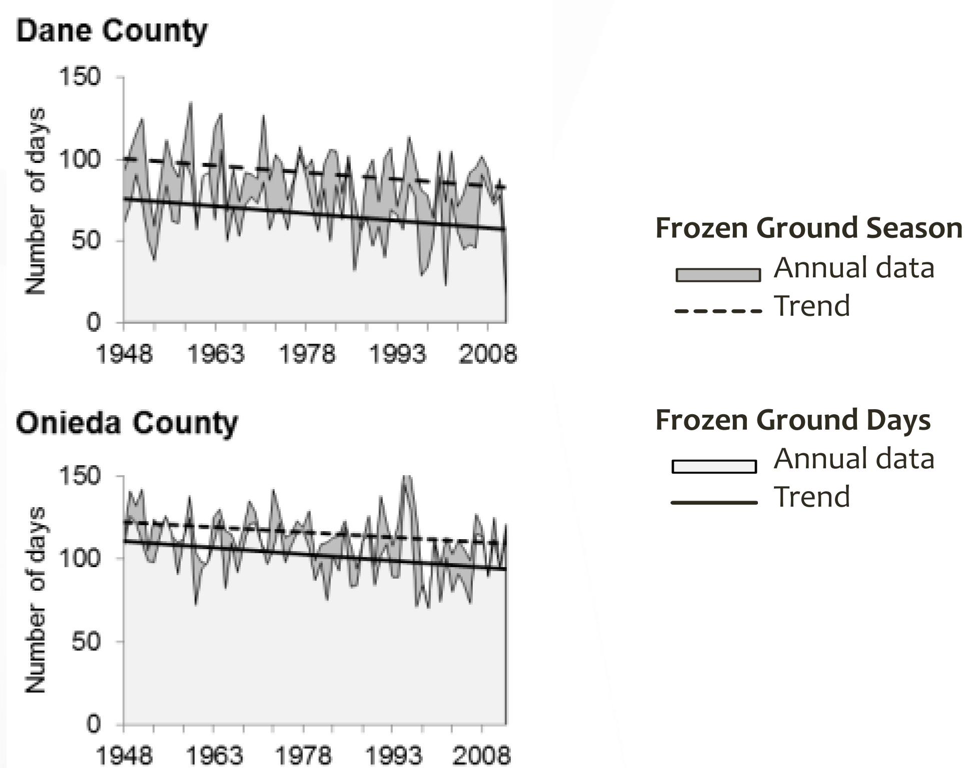
Notaro et al. 2014; Figure: Center for Climatic Change, http://ccr.aos.wisc.edu/resources/data_scripts/LCC/

2: *Shorter Winter (Less Snow)*

Decreased snowpack

- Increased soil frost and root damage in cold temps
- Warmer soil temperatures and altered processes

Wisconsin Frozen Ground



Source: C. Rittenhouse (UConn) and A. Rissman (UW-Madison), in review

2: *Shorter Winter (Less Snow, More Rain)*

Precipitation is projected to increase = more rain

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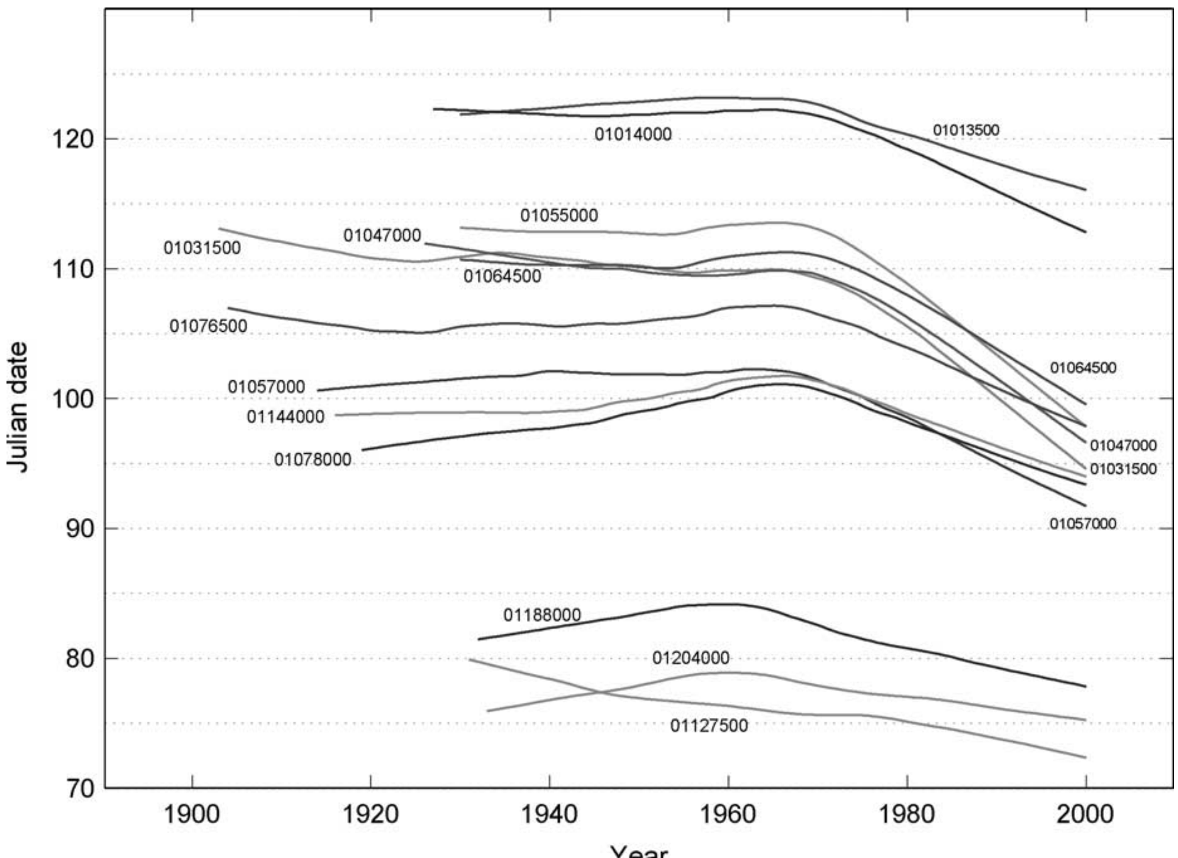
Altered streamflow timing and amount

- Earlier spring peak flows
- Potential increases in flashiness and episodic high flows
- Potential declines in summer seasonal stream flow

2: *Shorter Winter (Less Snow, More Rain)*

Altered streamflow timing and amount

Winter/spring center of volume dates for 13 New England rivers

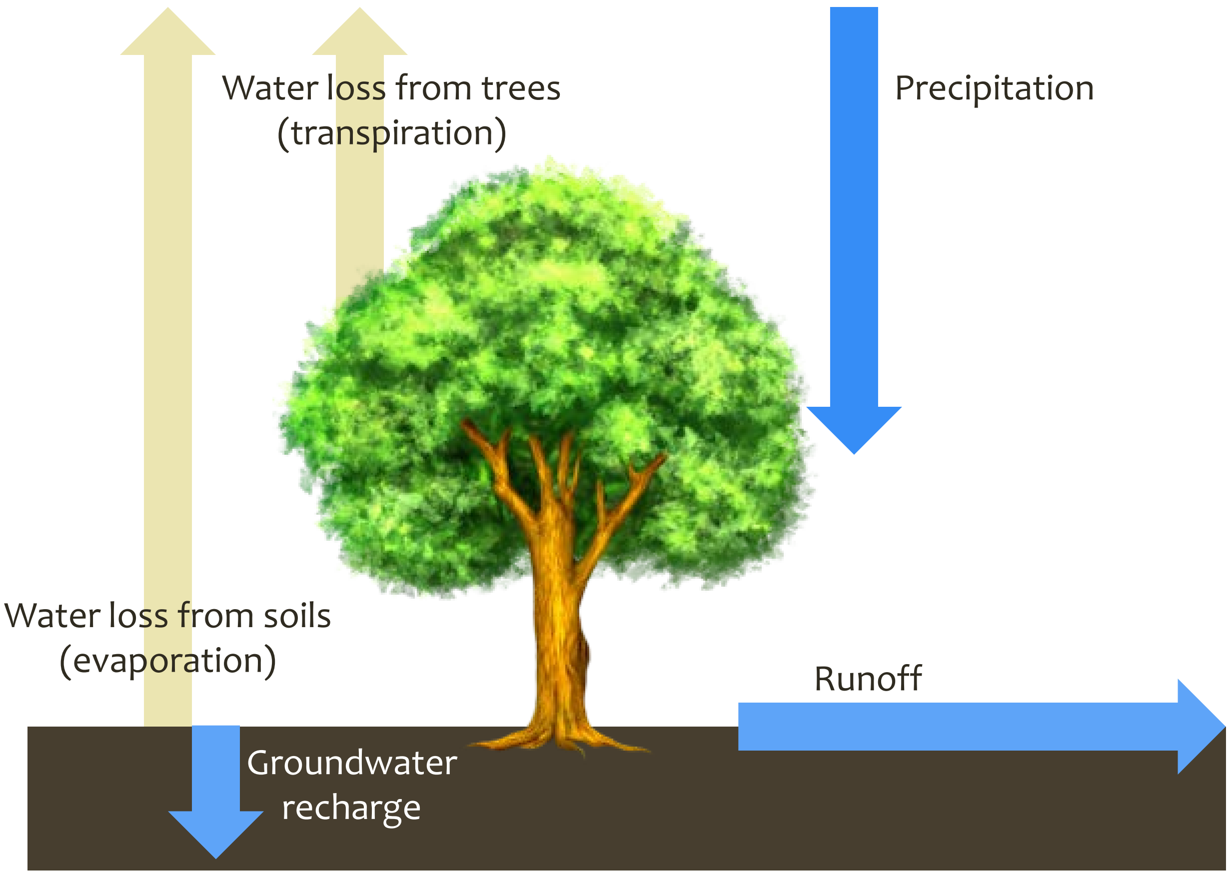


Most change in past 30 years, dates advancing 1-2 weeks

Hodgkins et al. 2003

3: *Potential for Summer Drought*

Greater uncertainty about future precipitation, but increased risk of summer moisture stress



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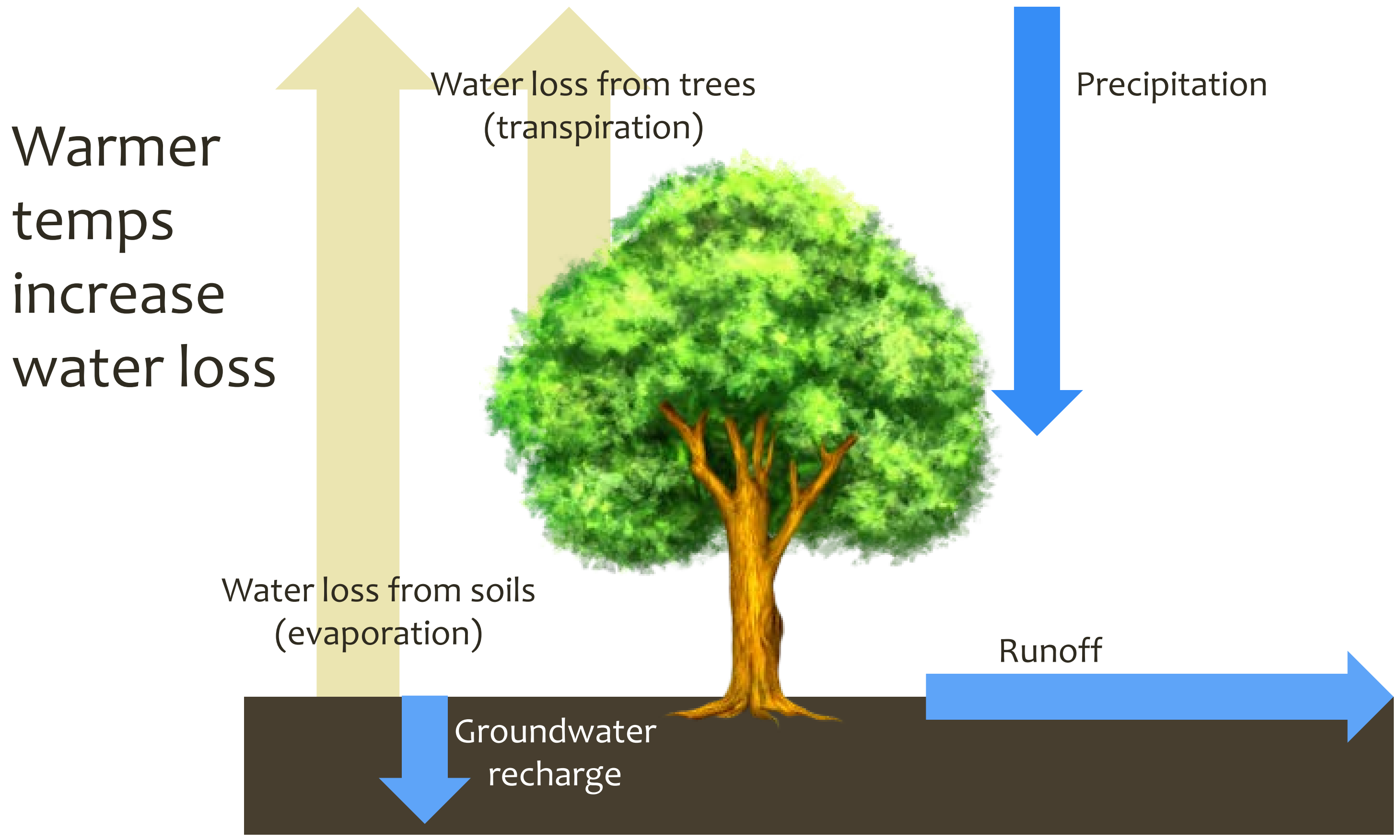
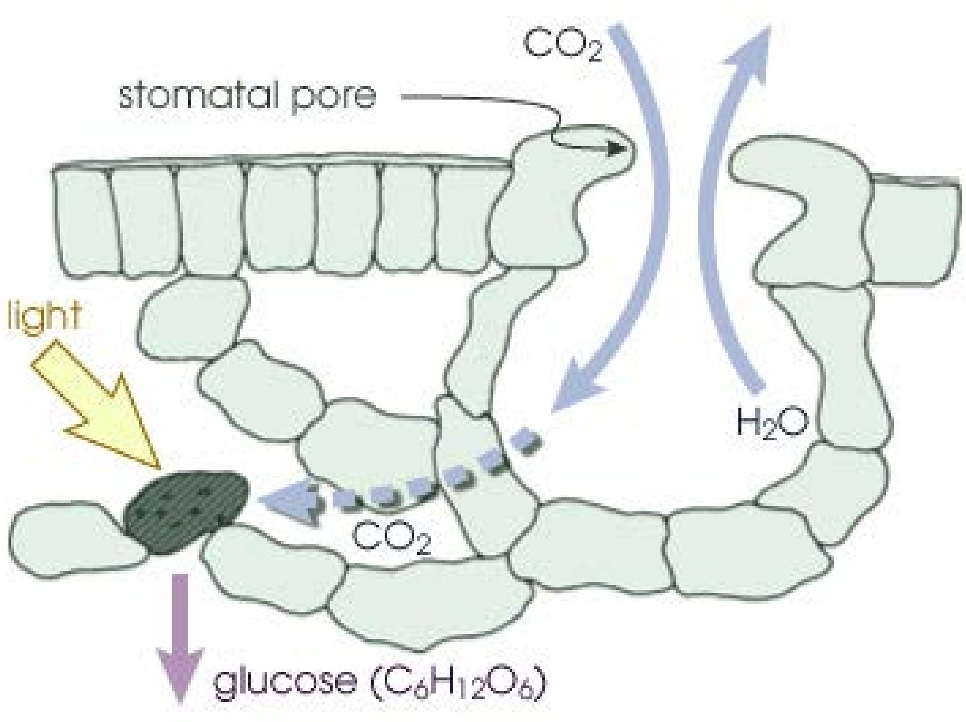


4: CO_2 *Fertilization*

Benefits

- Increased photosynthesis
- Increased water use efficiency

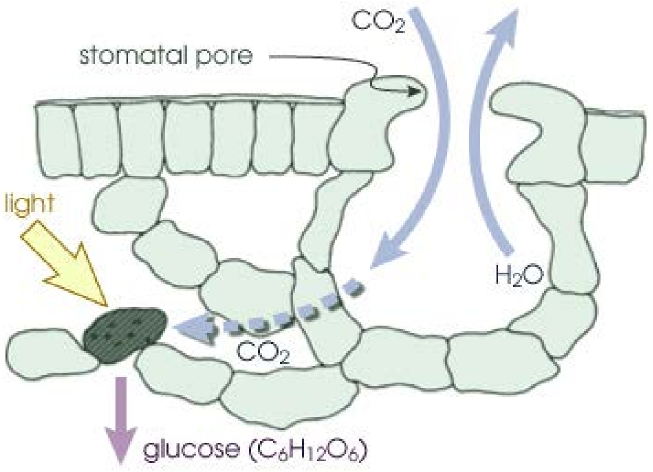


Ainsworth and Long 2005, Ainsworth and Rogers 2007, Norby and Zak 2011

4: CO_2 *Fertilization*

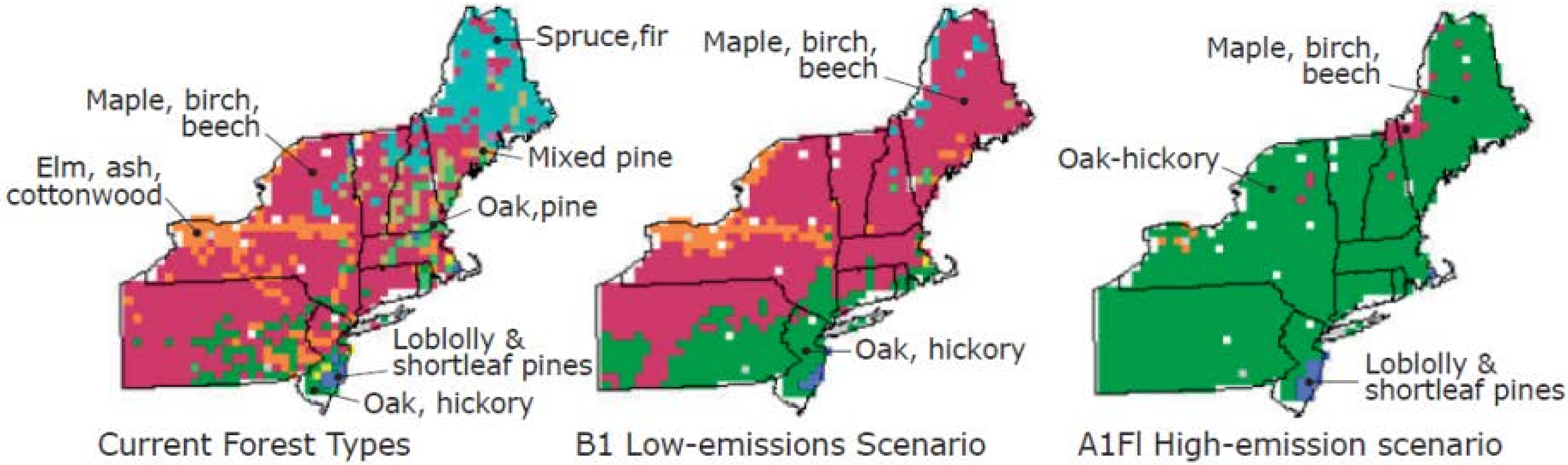
Limits to CO_2 fertilization

- Varies by species and site
- Nutrient deficiencies (especially N)
- Sensitive to ozone pollution
- Limited sink strength
- Limited evidence of long-term sequestration
- Any productivity increases may be offset by reductions from increased drought stress or disturbance



Ainsworth and Long 2005, Ainsworth and Rogers 2007, Norby and Zak 2011

5: *Changes in Suitable Habitat*



Iverson et al. 2007, Rustad et al. 2012

5: *Changes in Suitable Habitat*

Habitat based on:

- Temperature
- Precipitation
- Elevation
- Latitude
- Soils
- Slope & Aspect
- Land use
- Competition
- Past management




5: *Changes in Suitable Habitat*

Habitat based on:

- ***Temperature***
- ***Precipitation***
- Elevation
- Latitude
- Soils
- Slope & Aspect
- Land use
- Competition
- Past management

Climate Change Atlas:

What happens to tree and bird habitat when climate changes?

- 134 Trees
- 147 Birds

www.fs.fed.us/nrs/atlas/

Iverson et al. 2008; Atlas website: **www.fs.fed.us/nrs/atlas/**

5: *Changes in Suitable Habitat*

Habitat based on:

- ***Temperature***
- ***Precipitation***
- Elevation
- Latitude
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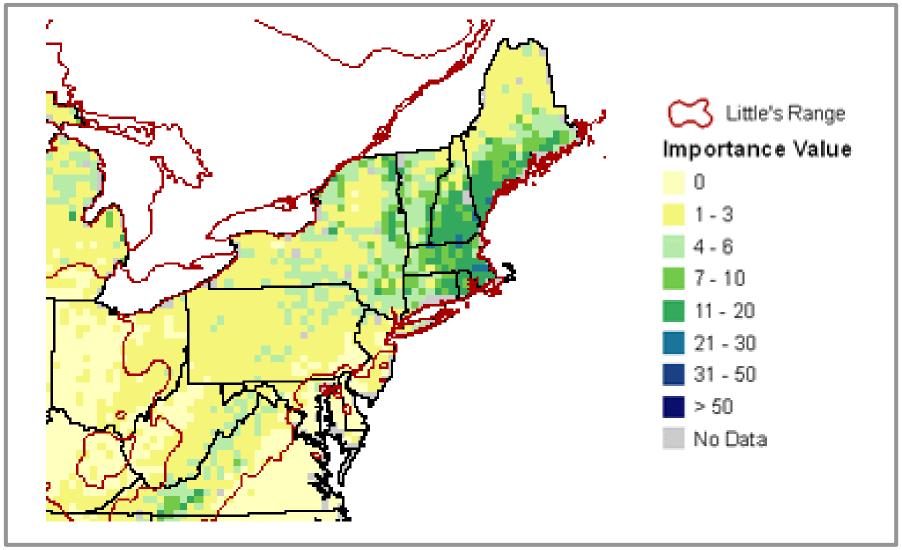
White Pine: Current Habitat (modeled)



www.fs.fed.us/nrs/atlas/

5: *Changes in Suitable Habitat*

Habitat based on:

- ***Temperature***
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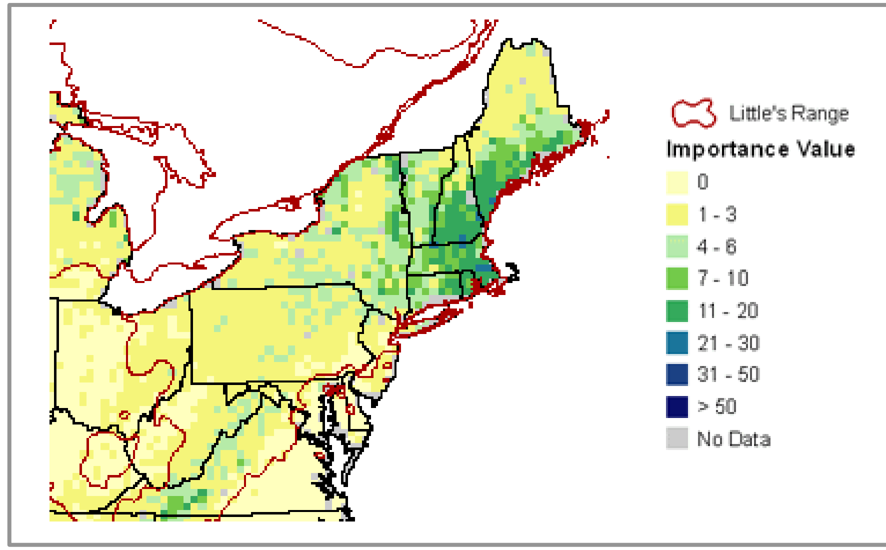
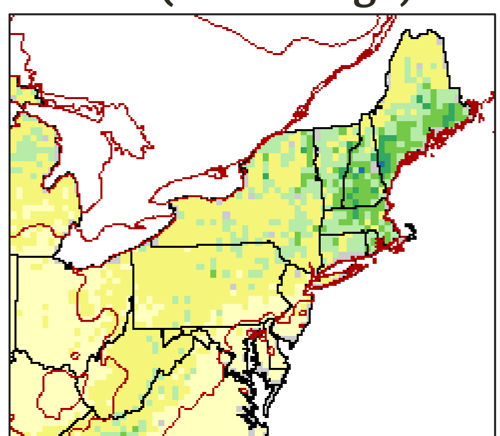
www.fs.fed.us/nrs/atlas/

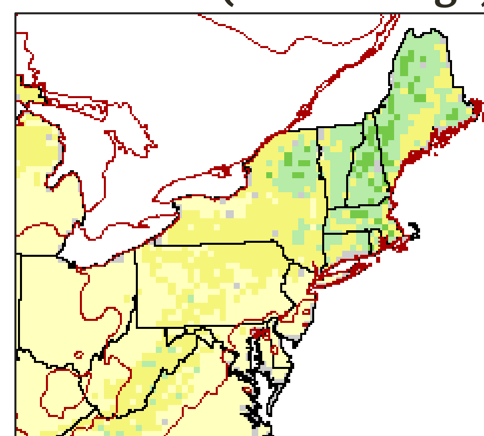
White Pine: Current Habitat (modeled)



PCM B1 (Less Change)



GFDL A1FI (More Change)

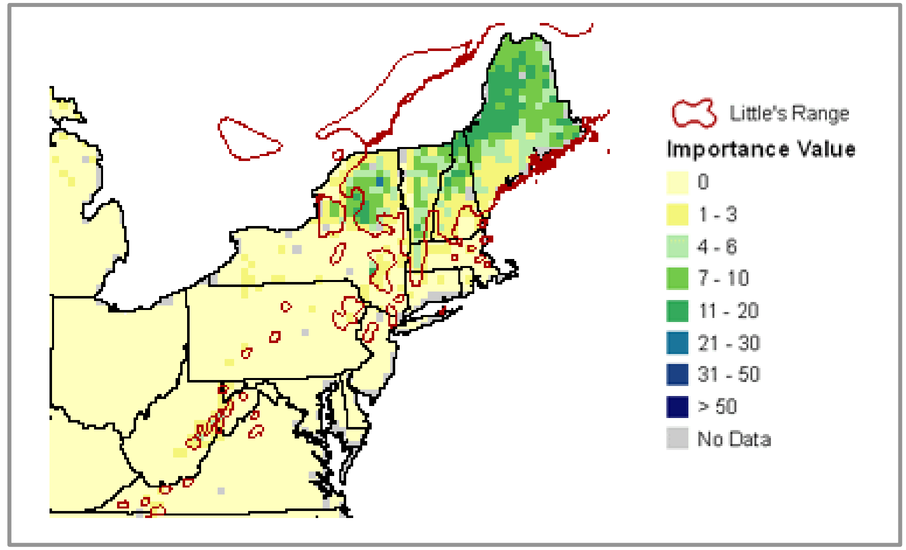


5: *Changes in Suitable Habitat*

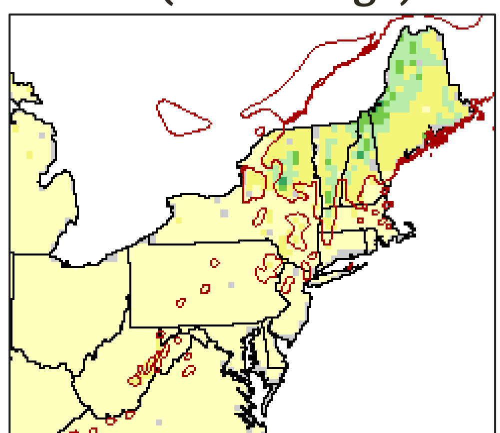
Habitat based on:

- ***Temperature***
- ***Precipitation***
- Elevation
- Latitude
- Soils
- Slope & Aspect

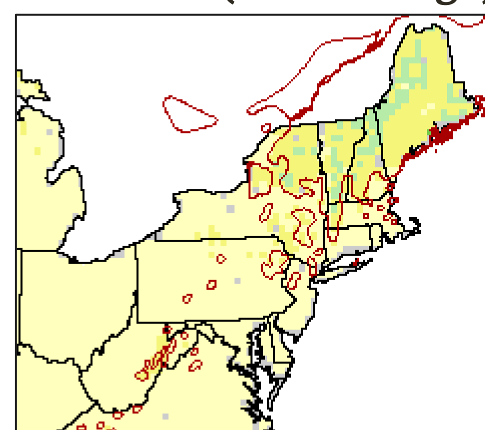
Red Spruce: Current Habitat (modeled)



PCM B1 (Less Change)



GFDL A1FI (More Change)



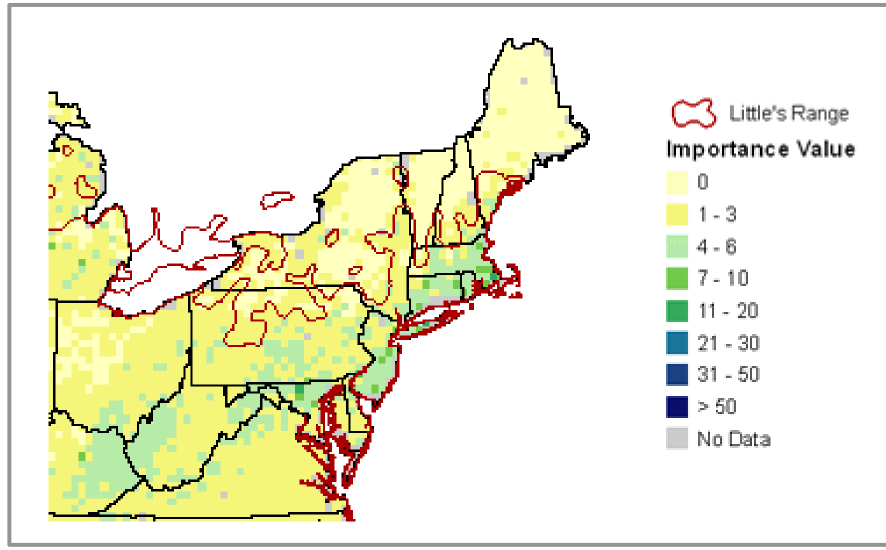
www.fs.fed.us/nrs/atlas/

5: *Changes in Suitable Habitat*

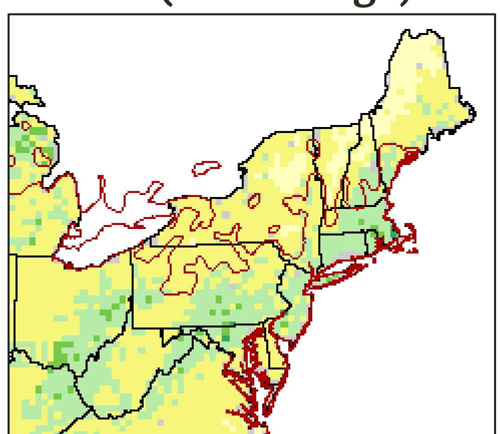
Habitat based on:

- ***Temperature***
- ***Precipitation***
- Elevation
- Latitude
- Soils
- Slope & Aspect

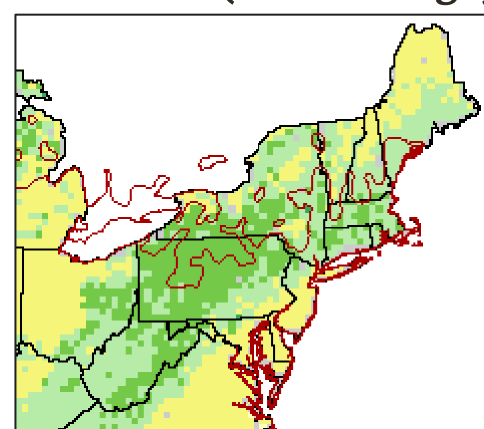
Black Oak: Current Habitat (modeled)



PCM B1 (Less Change)



GFDL A1FI (More Change)



www.fs.fed.us/nrs/atlas/

5: *Changes in Suitable Habitat*

- Immense lag times
  - Range shifts ≠ instant catastrophic dieback
  - Changes over time: temperature, moisture, competition
- Mature and established trees should fare better
  - Developed root system, Greater carbohydrate reserves
- Game changers: Disturbance, Land use, …

Dale et al. 2001, Iverson et al. 2008

5: *Changes in Suitable Habitat*

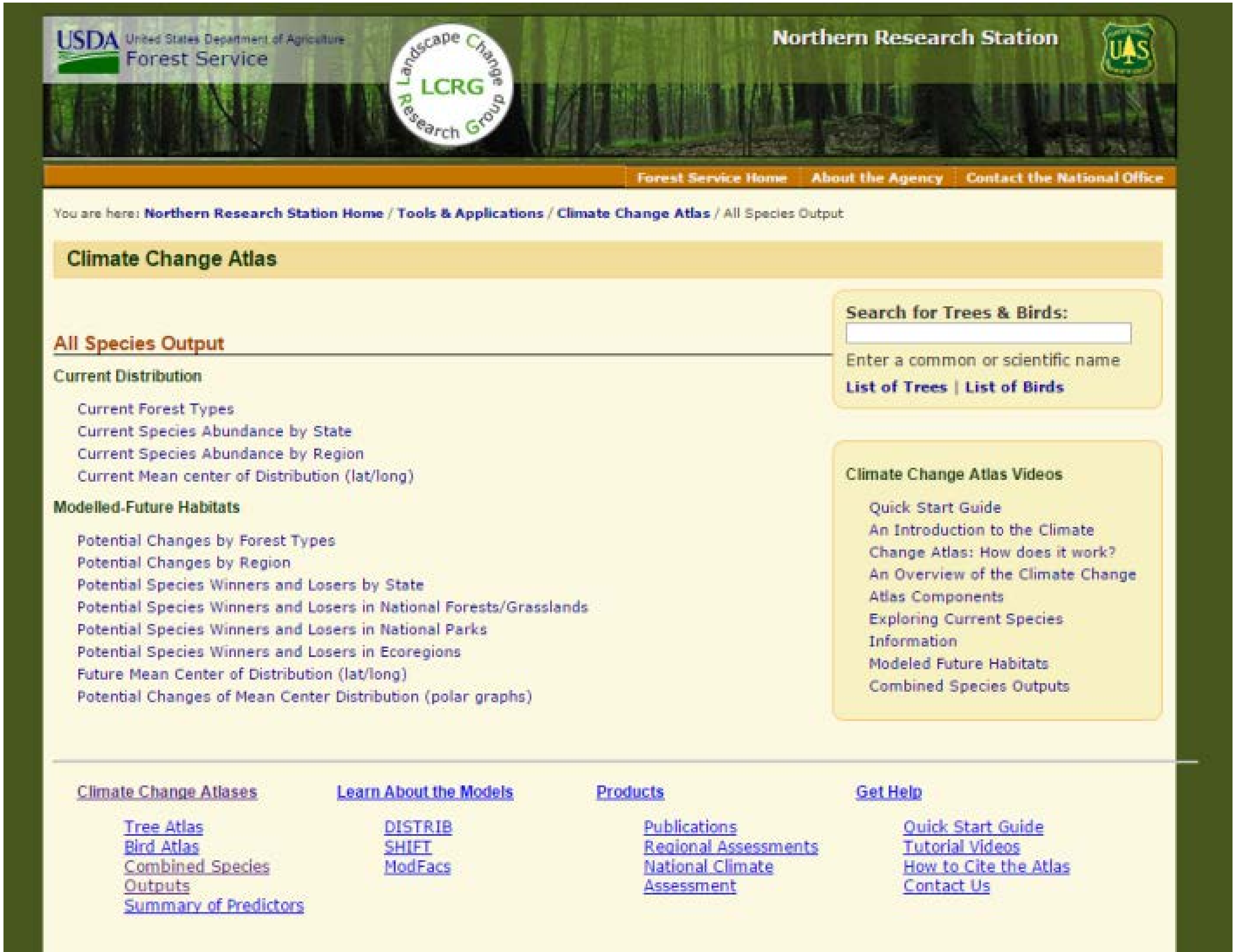
Use the Climate Change Atlas to:

- Evaluate how suitable habitat may change for species
  - Species more likely to decline or increase
  - Consider multiple scenarios
  - Consider local conditions and anticipated impacts
- Identify factors driving the modeled changes
- Generate ideas for potential future-adapted species

Dale et al. 2001, Iverson et al. 2008

5: *Changes in Suitable Habitat*

www.fs.fed.us/nrs/atlas/combined/



6: *Extreme Events*

- Heavy precipitation
- Ice storms
- **“Events” are not well modeled**
- Heat waves/droughts
- Wind storms
- Hurricanes

Dan Turner, Cambridge Fire Dept.

NY DEC

VTRANS/VT ANR

7: *Wildfire Risk*

Fire may increase:

- Warmer/drier summers
- Increased stress or mortality from less suitable conditions
- Shift toward fire-associated species like oaks and pines

Prescribed fire – MASS DCR

Fire may not change:

- Spring/early summer moisture
- Current regeneration of more mesic species
- Spatial patterns of land use and fragmentation
- Fire suppression

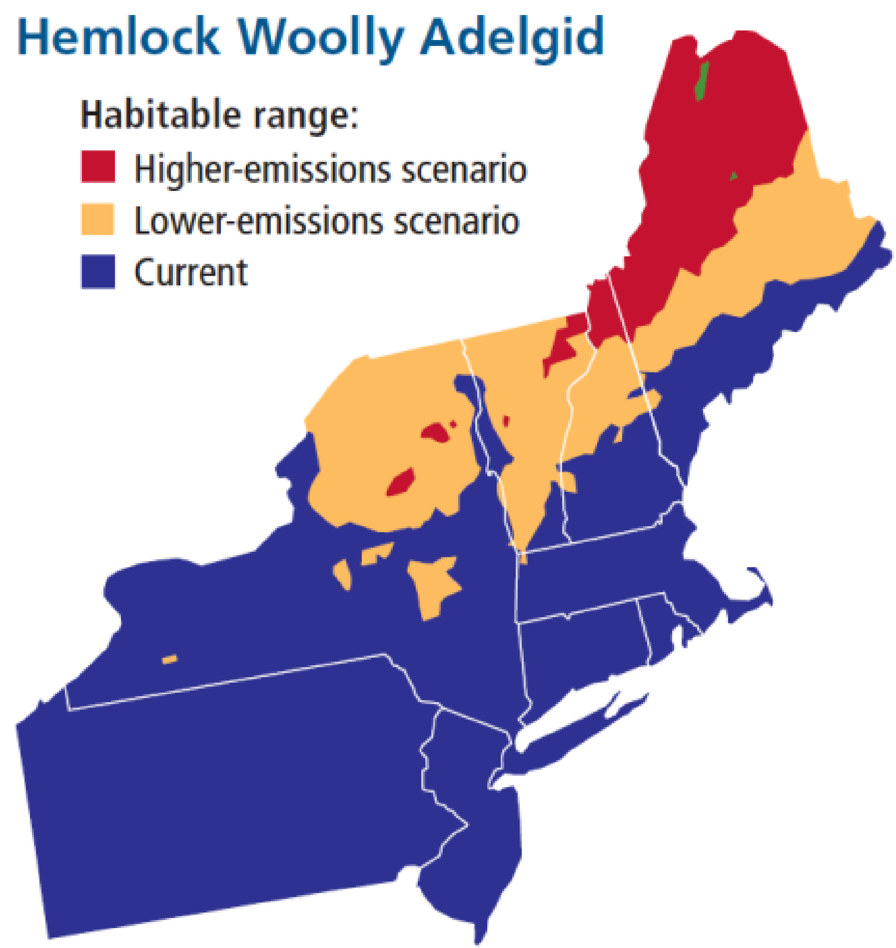
Clark et al. 2014

8: *Forest Pests and Diseases*

Indirect: Stress from other impacts increases susceptibility

Direct:

- Pests migrating northward
- Decreased probability of cold lethal temperatures
- Accelerated lifecycles



HWA lethal temp: -20 to -30°F

Ayres and Lombardero 2000, Woods et al. 2005, Parmesan 2006, Dukes et al. 2009 Image: Frumhoff et al. 2007

9: *Invasive Plants*

Indirect: Stress or disturbance from other impacts can affect the potential for invasion or success

Direct:

- Expanded ranges under warmer conditions
- Increased competitiveness from ability of some plants to take advantage of elevated CO_2




Invasives Plants Atlas of New England (www.eddmaps.org)

Dukes et al. 2009, Rustad et al. 2011

Climate Change Impacts

1) Longer Growing Season
2) Shorter Winters
3) Potential for Summer Drought
4) CO_2 Fertilization
5) Changes in Suitable Habitat
6) Extreme Events
7) Wildfire Risk
8) Forest Pests and Diseases
9) Invasive Plants

What conclusions can we draw from all this?

Vulnerability: *Forest Communities*

Forest communities will be affected differently

May have greater risk:

- Low diversity
- Static
- Threatened, rare, or endangered
- Already in decline
- Fragmented

May have less risk:

- More diversity (species, genetics, …)
- Adapted to disturbance
- Wider ecological range of tolerances
- Currently increasing
- Larger, contiguous blocks

Vulnerability: *Spruce-fir*

Impacts:

- Warm temperatures
- Declines in boreal tree species
- Extreme storms

Adaptive Capacity:

- Generally slow to adjust to change
- Constrained by elevation/latitude
- Isolated mountaintops

Generally rated as most vulnerable forest community, especially at southern extent of range.

Connecticut Climate Change 2010, Manomet and Mass. Dept. of Fish and Wildlife 2010, Manomet and NWF 2012

Vulnerability: *Hardwood Forests*

Impacts:

- Extreme storms
- Several diseases, pests, invasives
- Several northern species projected to decline

Adaptive Capacity:

- Mixed species forests
- Several southern species projected to increase
- Extensive type, exists farther south

Vulnerability rated as low (central hardwoods) or moderate (northern hardwoods) based on species and location.

Connecticut Climate Change 2010, Manomet and Mass. Dept. of Fish and Wildlife 2010, Manomet and NWF 2012

Vulnerability: *Local Considerations*

Research and assessments describe **broad trends** but **local conditions** make the difference.

So… before the training

Start to think about how your particular project area could be affected by climate change

Focus on the place (we'll get to management a tad later):

- **Location:** elevation, latitude, inland/coastal, …
- **Landform:** topographic position, geology, complexity, …
- **Soil characteristics:** moisture, productivity, …
- **Management:** Past, current, …
- **Diversity:** species composition, structural complexity, …
- **Presence of or susceptibility to stressors:** pests, diseases, nonnative species, herbivores, …

Given these considerations, how vulnerable is your site to the anticipated effects of climate change?