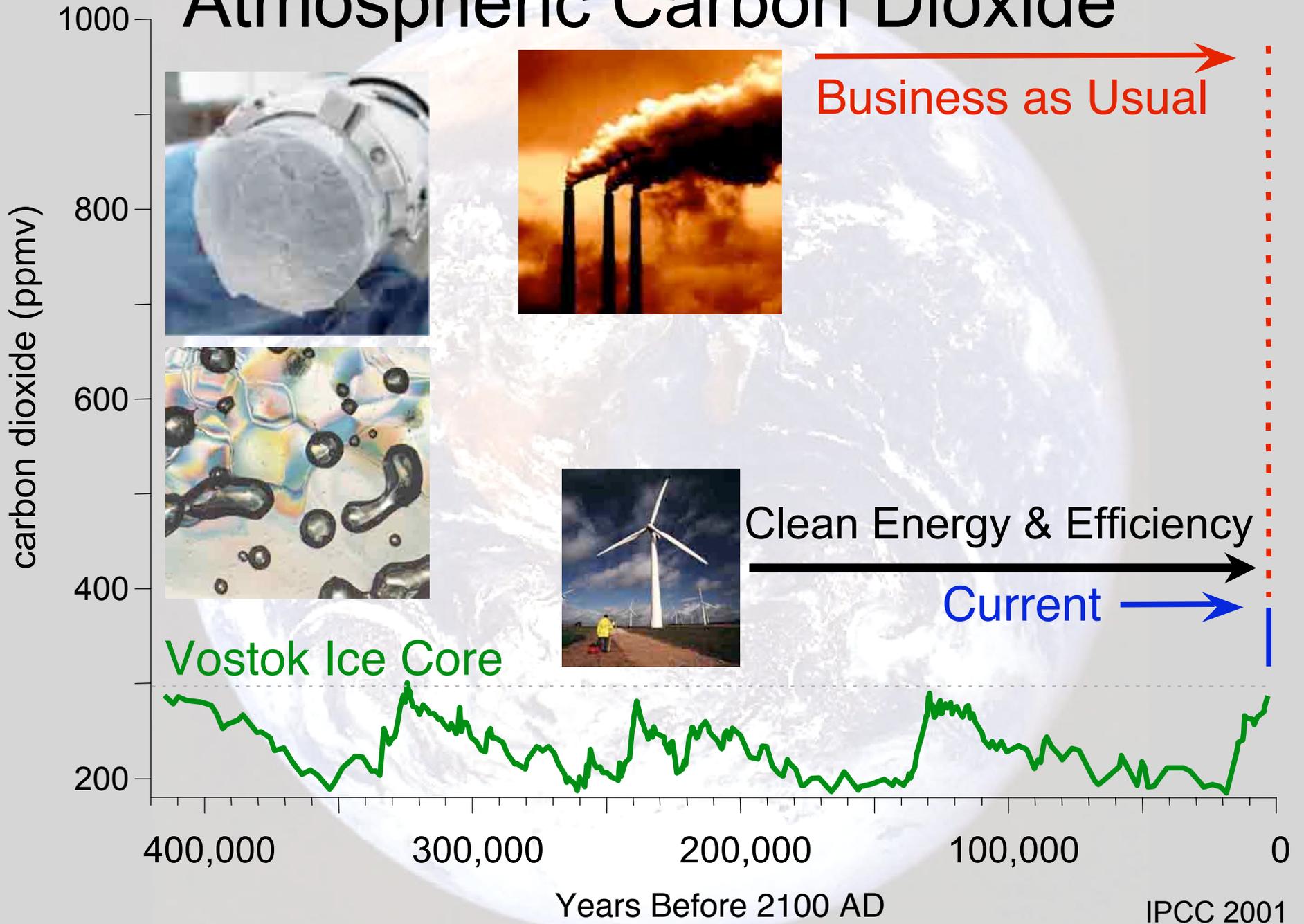
A satellite image of Earth showing a large hurricane over the Atlantic Ocean. The hurricane is a large, white, circular cloud system with a clear eye, rotating over the ocean. The surrounding clouds are white and wispy. The landmasses of North and South America are visible in shades of green and brown. The ocean is a deep blue. The horizon of the Earth is visible at the top of the image.

Climate Change in the Northeast: Past, Present, and Future

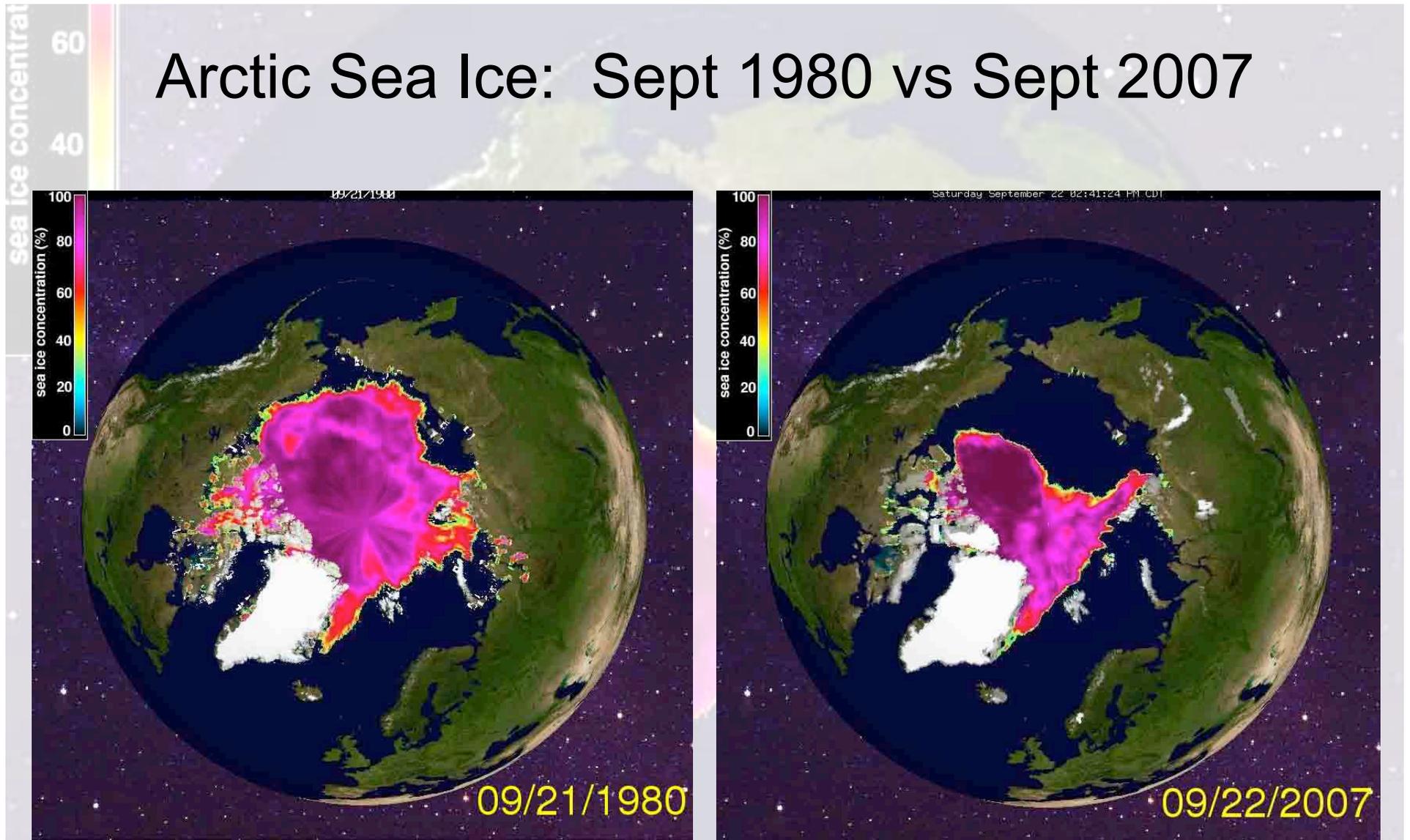
**Cameron Wake
Institute for the Study of Earth, Oceans, and Space (EOS)
University of New Hampshire**

Northeast Region Coastal Hazards Workshop
New London 19 November 2008

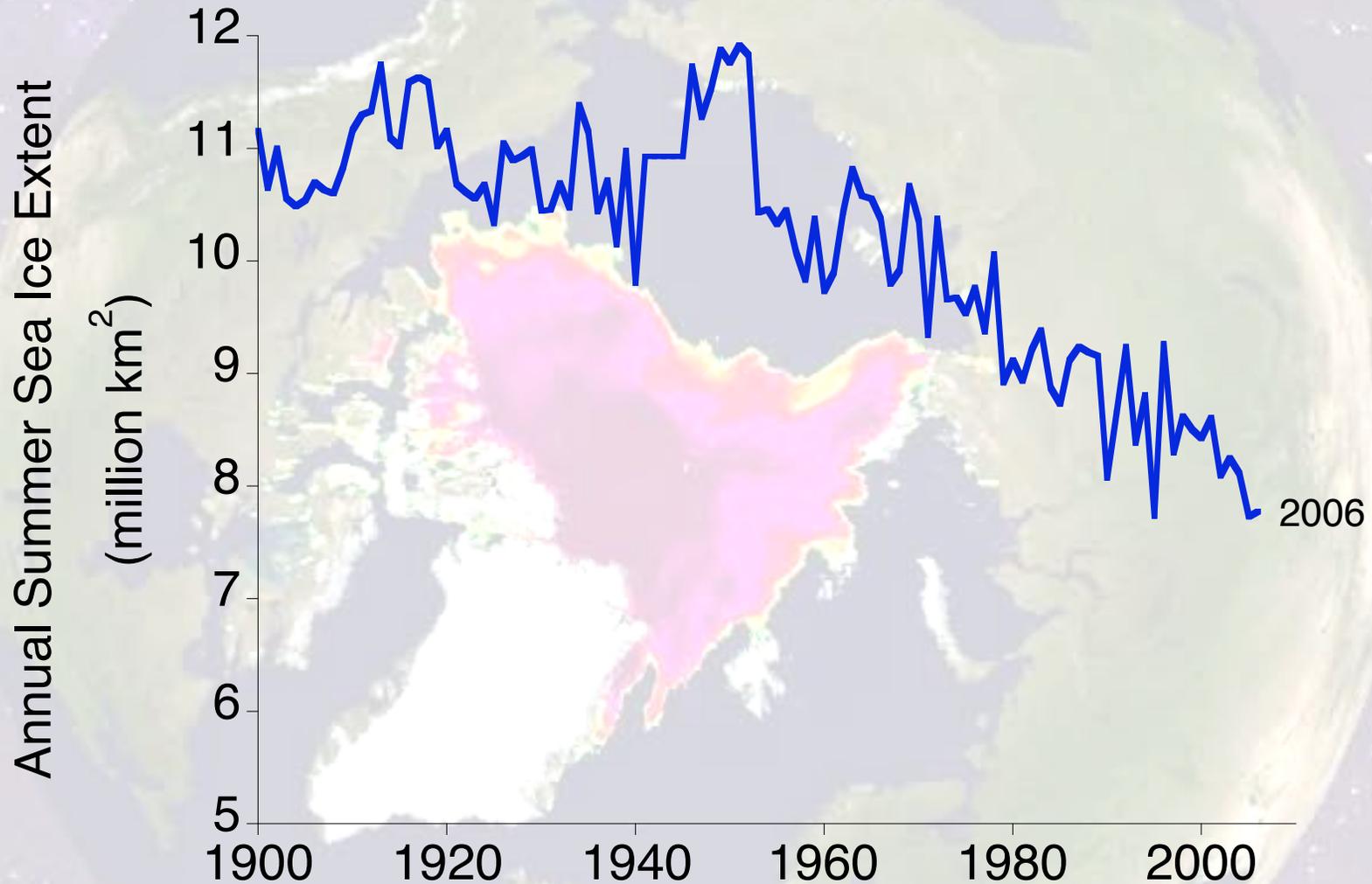
Atmospheric Carbon Dioxide



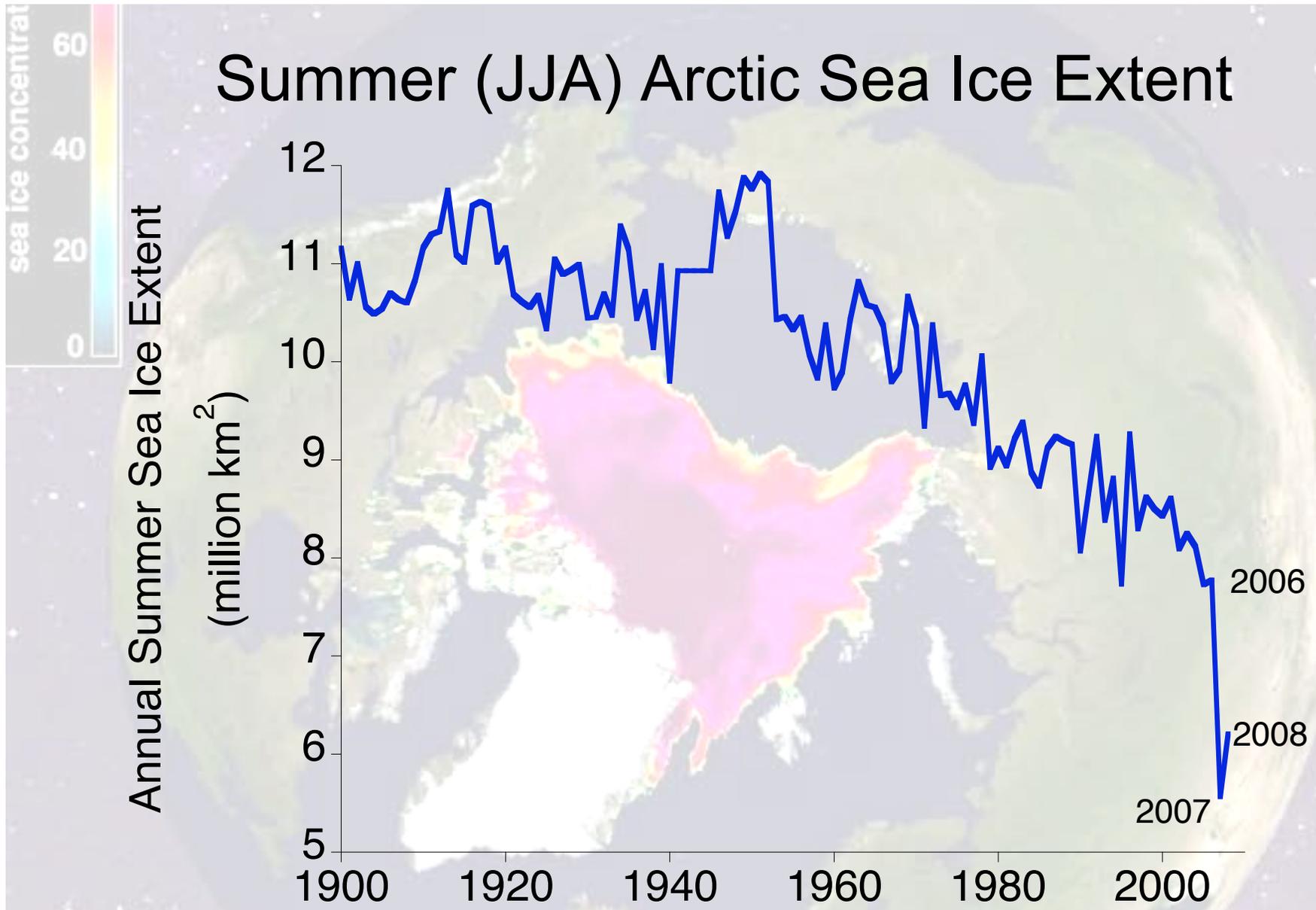
Arctic Sea Ice: Sept 1980 vs Sept 2007



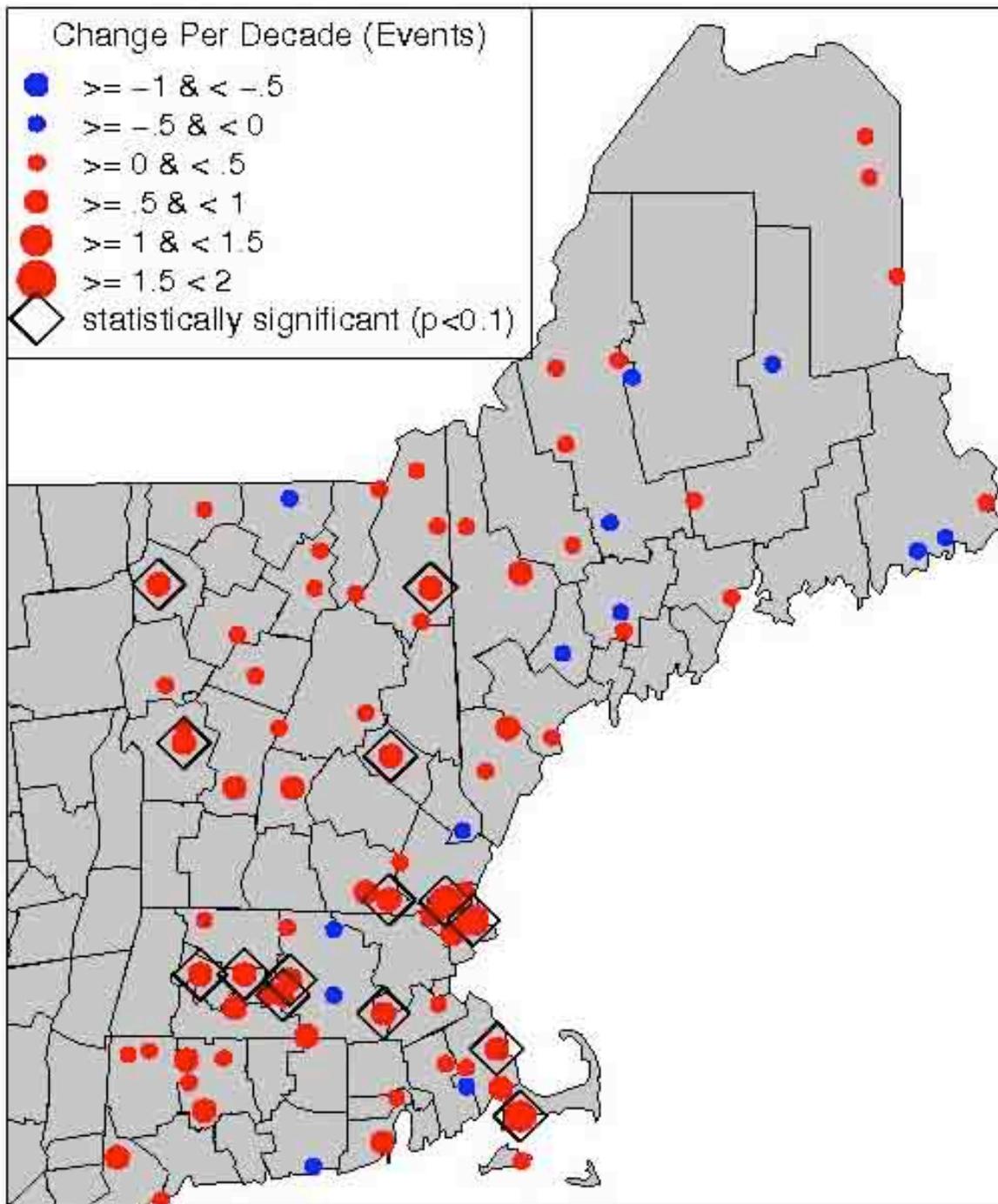
Summer (JJA) Arctic Sea Ice Extent



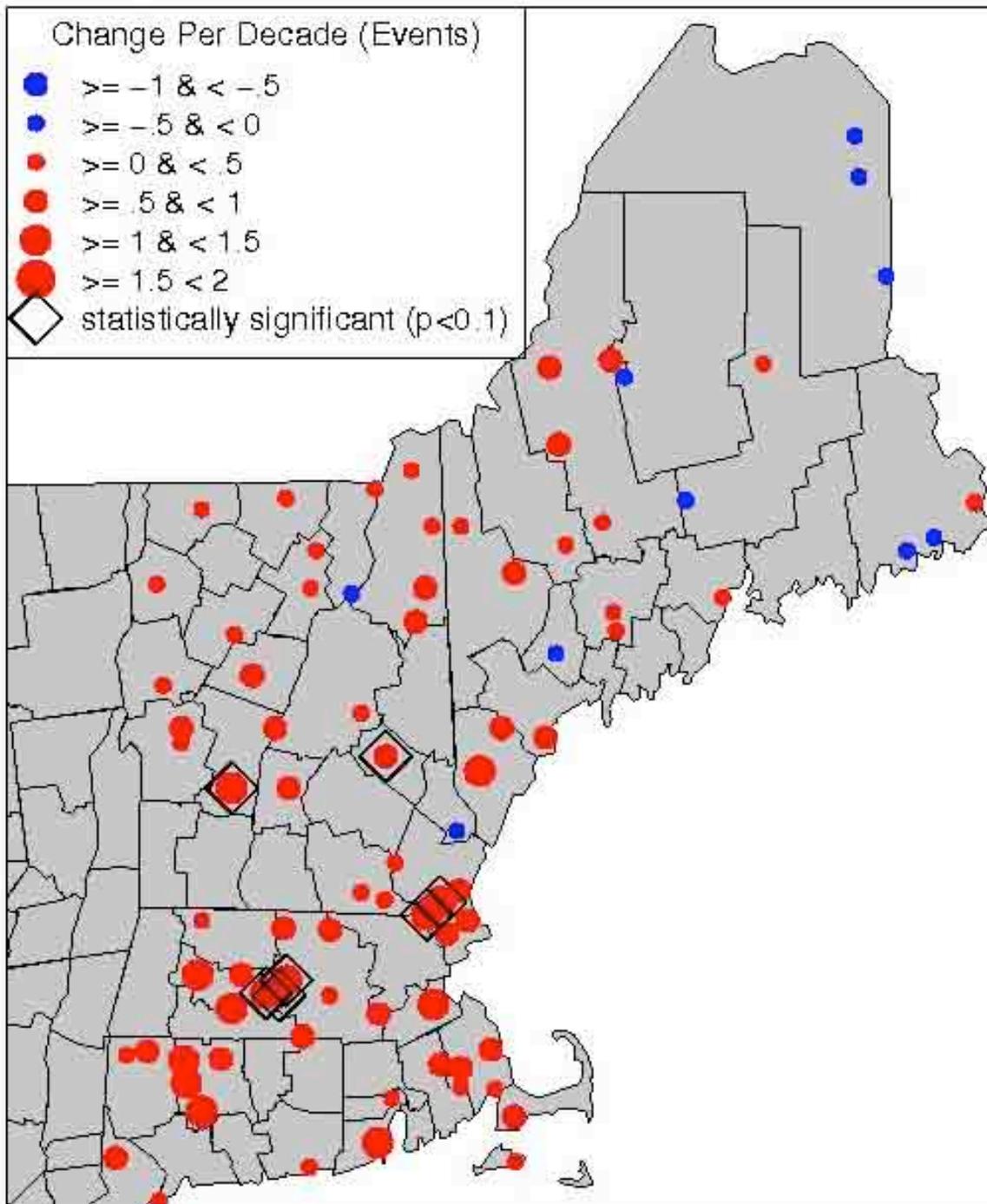
Summer (JJA) Arctic Sea Ice Extent



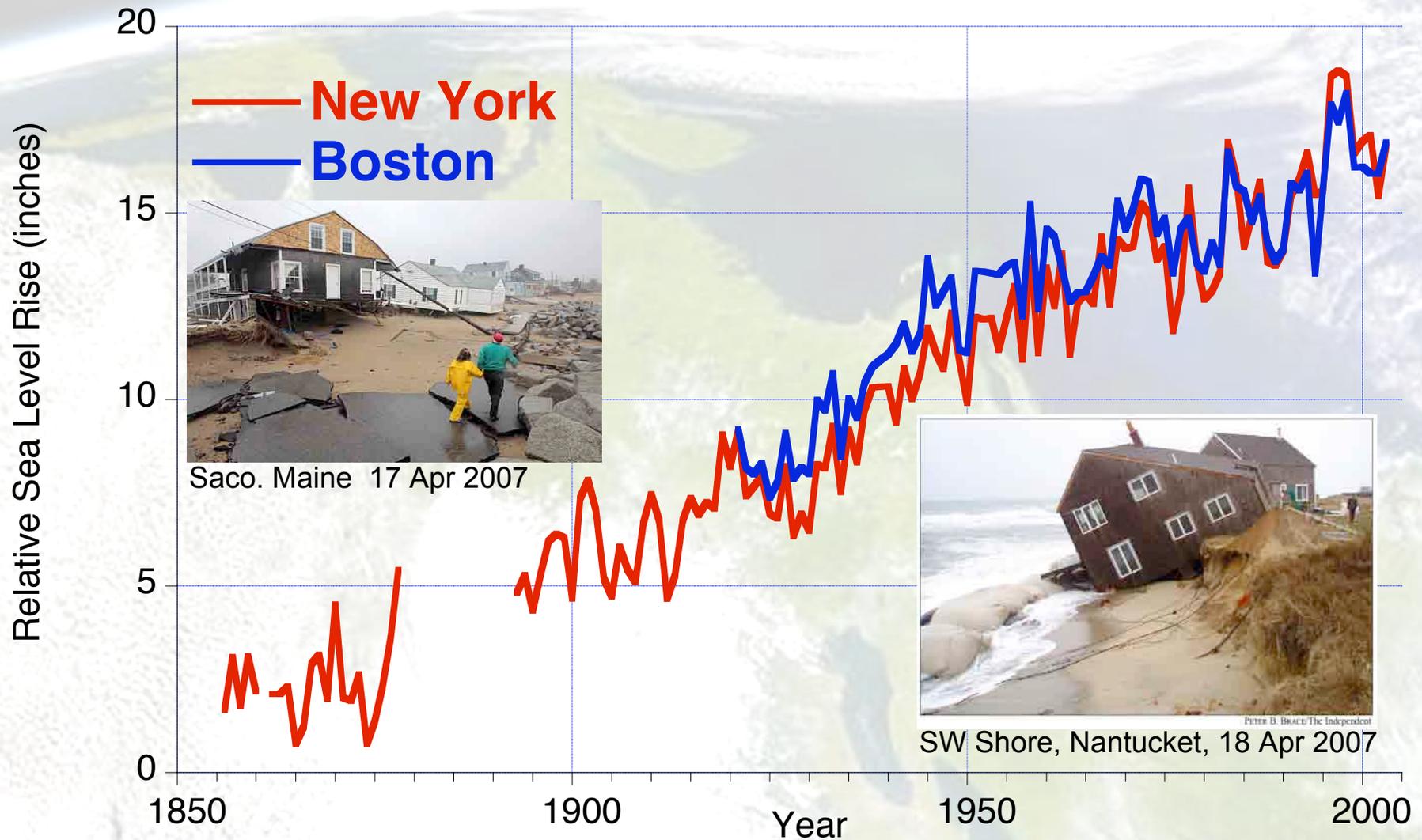
Decadal Trends in 1 inch Precipitation Events 1948-2007



Decadal Trends in 2 inch Precipitation Events 1948-2007



Relative Sea Level Rise 1856 - 2005



Data from Permanent Service for Mean Sea Level <http://www.pol.ac.uk/psmsl/>

Indicators of Climate Change in the Northeast US over the last 30-40 yrs

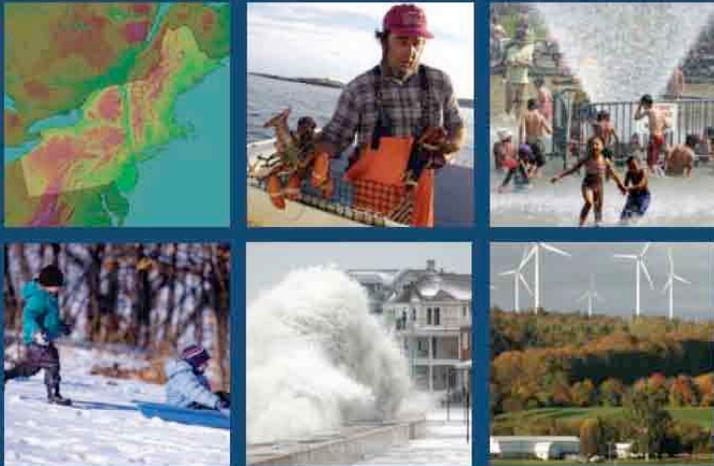
- **Winter warming**
- **Decreased snowfall**
- **Fewer days with snow on ground**
- **Lake ice out dates earlier**
- **Lilac bloom dates earlier**
- **More frequent extreme precipitation**
- **Earlier spring runoff**
- **Sea levels continuing to rise**

Hodgkins et al., 2002; 2003; Wolfe et al., 2005;
Wake and Markham, 2005; Wake et al., 2006

Northeast Climate Impacts Assessment

A Report of the Northeast Climate Impacts Assessment

Confronting Climate Change in the U.S. Northeast



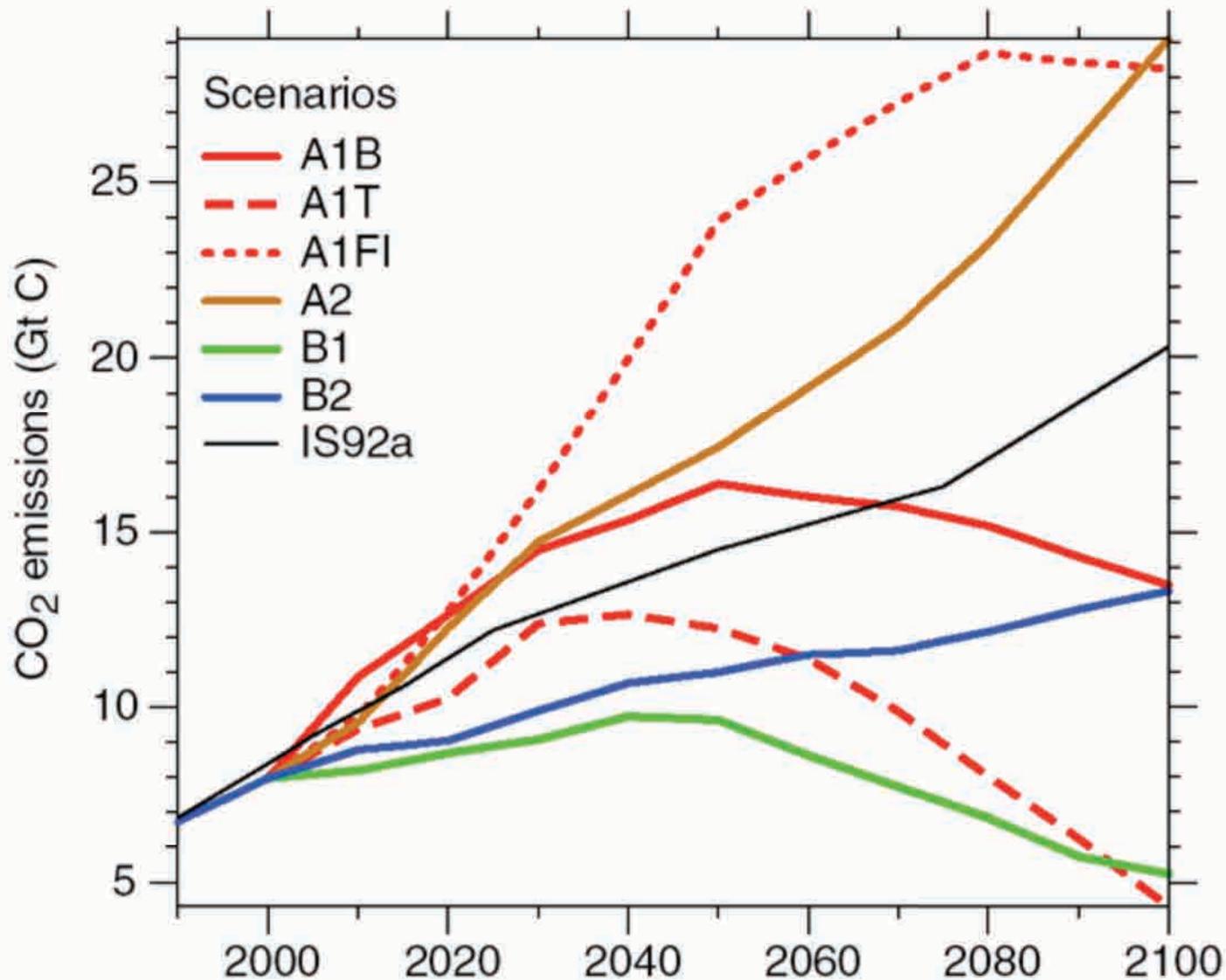
SCIENCE, IMPACTS, AND SOLUTIONS

JULY 2007

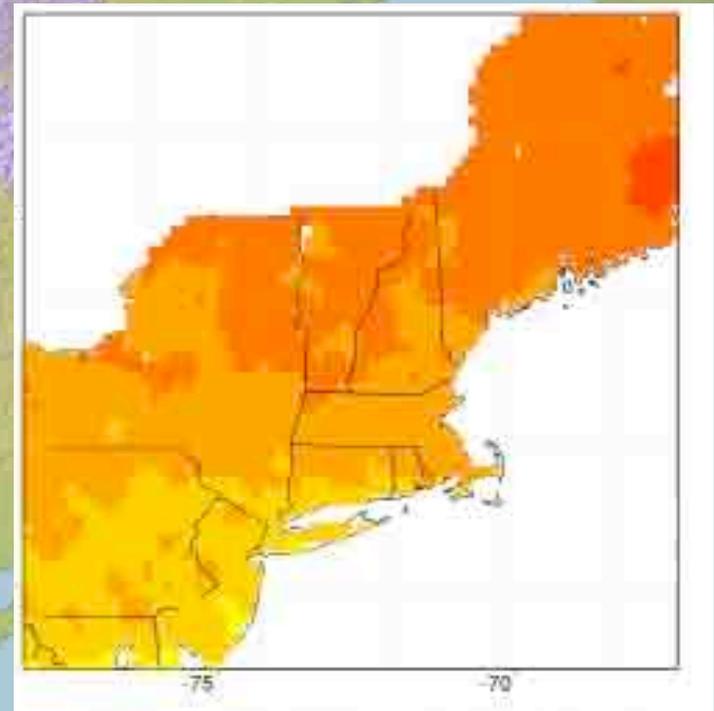
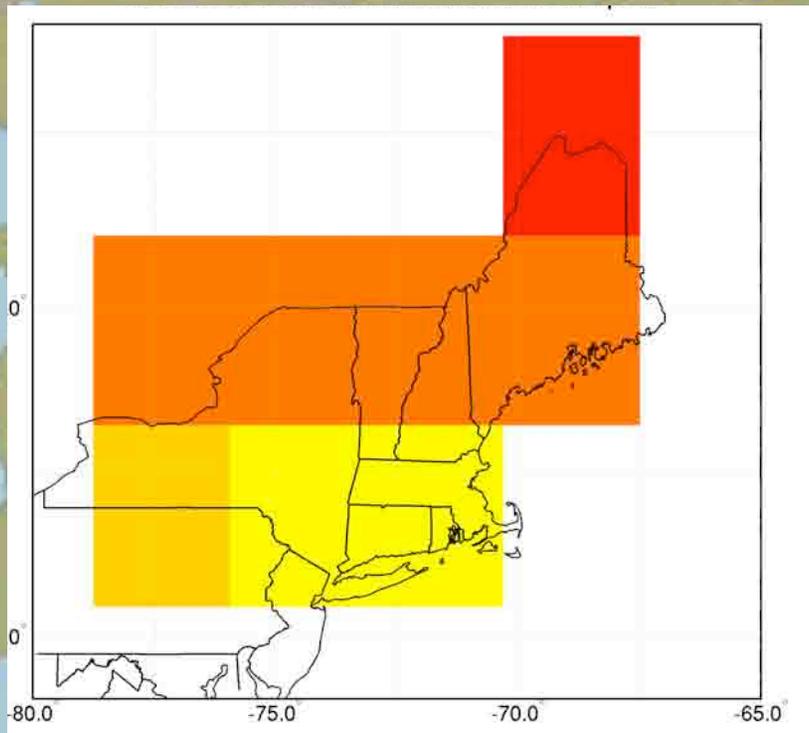
www.climatechoices.org

- Collaboration between Union of Concerned Scientists and 50 independent scientists
- **Geographic Scope**
Nine Northeast states, from Maine to Pennsylvania
- **Peer Review**
Climate Dynamics, 2007
14 papers in *Adaptation and Mitigation of Climate Change*, 2008

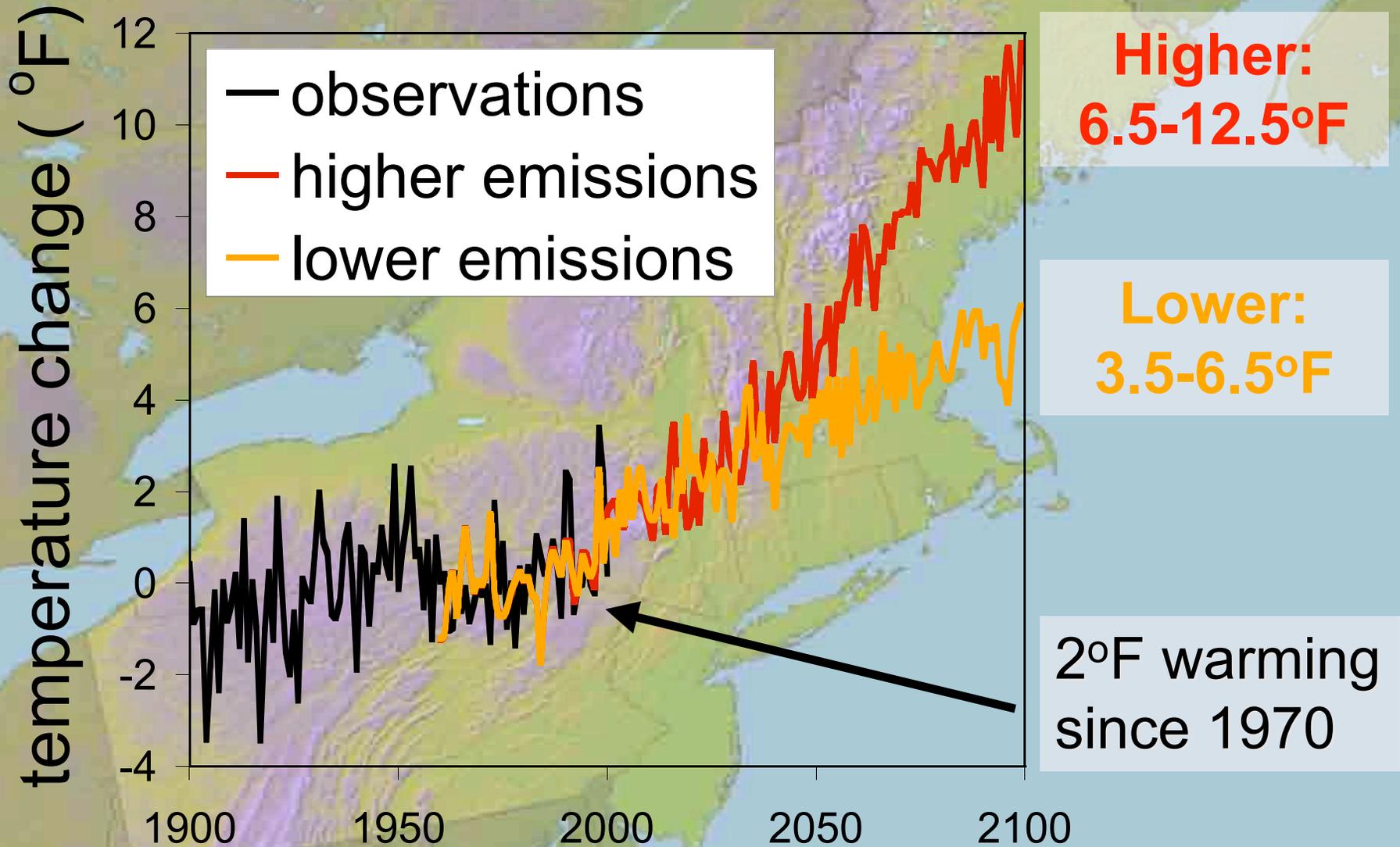
Projecting Future Climate Change for the Northeast: Greenhouse Gas Emission Scenarios



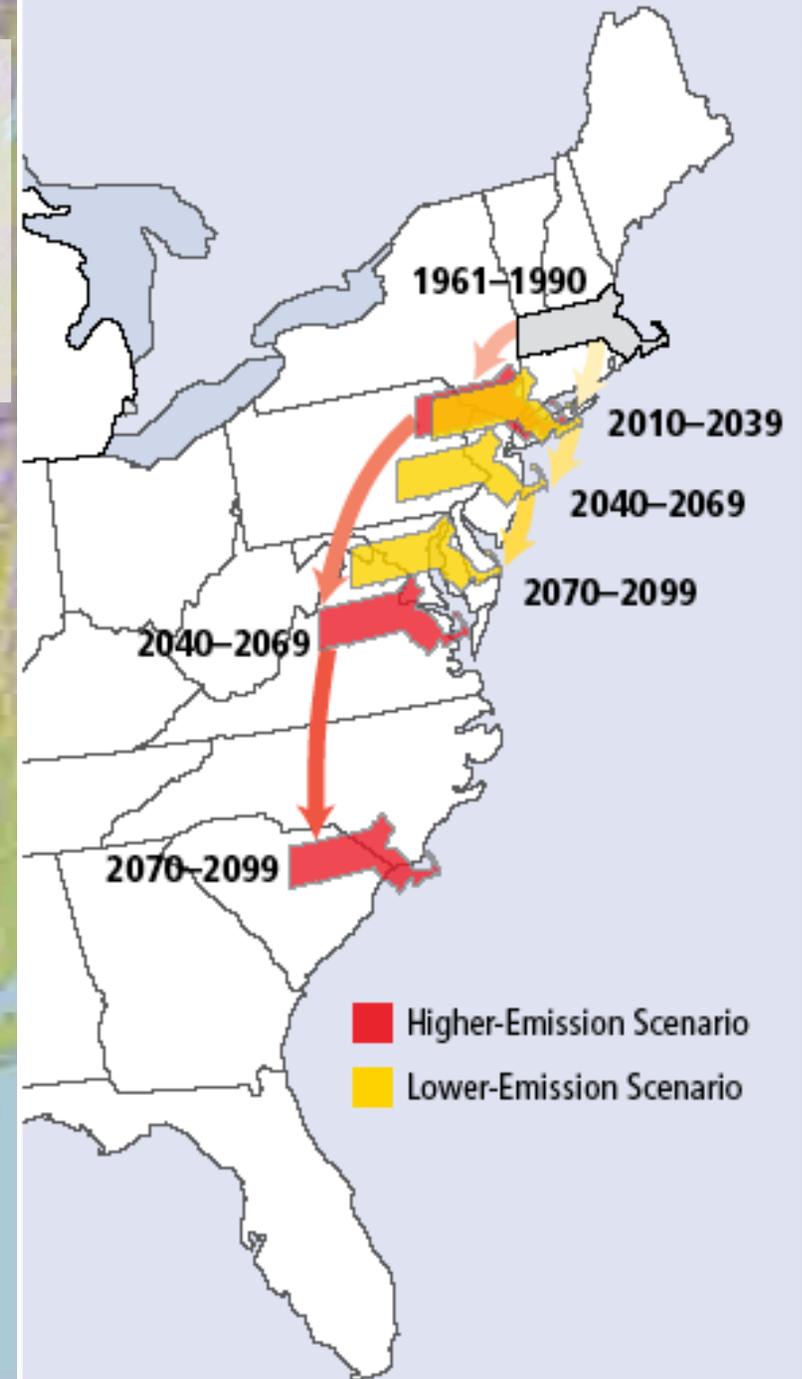
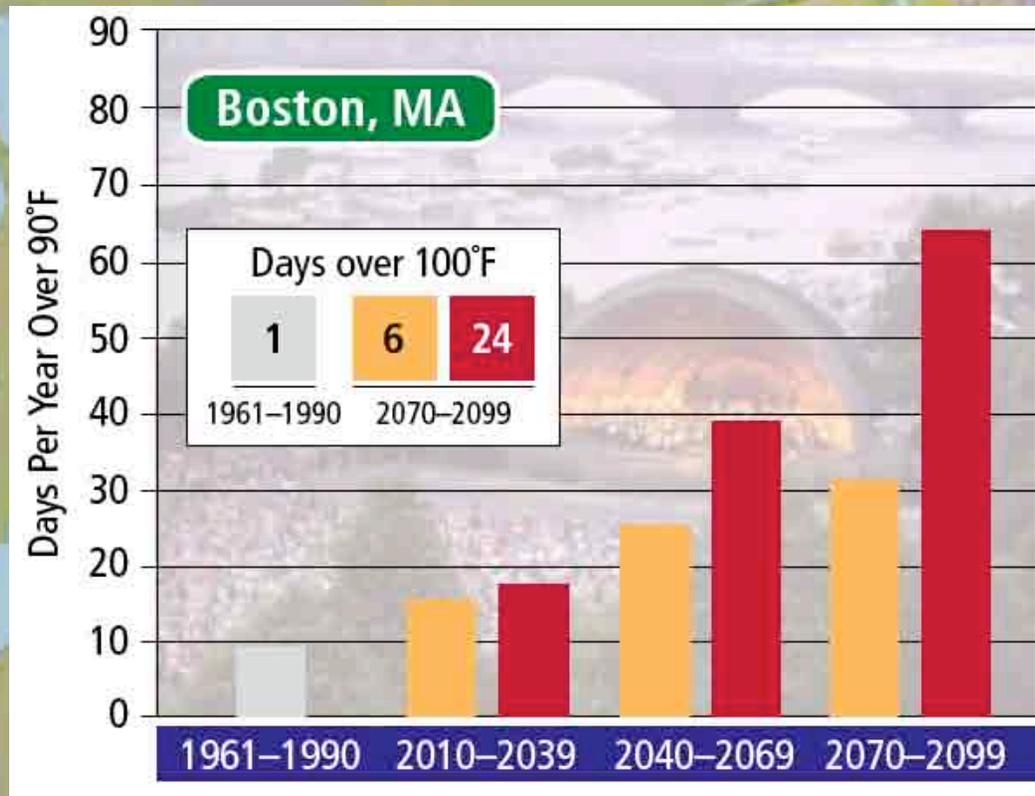
Projecting Future Climate Change for the Northeast: Downscale Global Projections to Regional Level



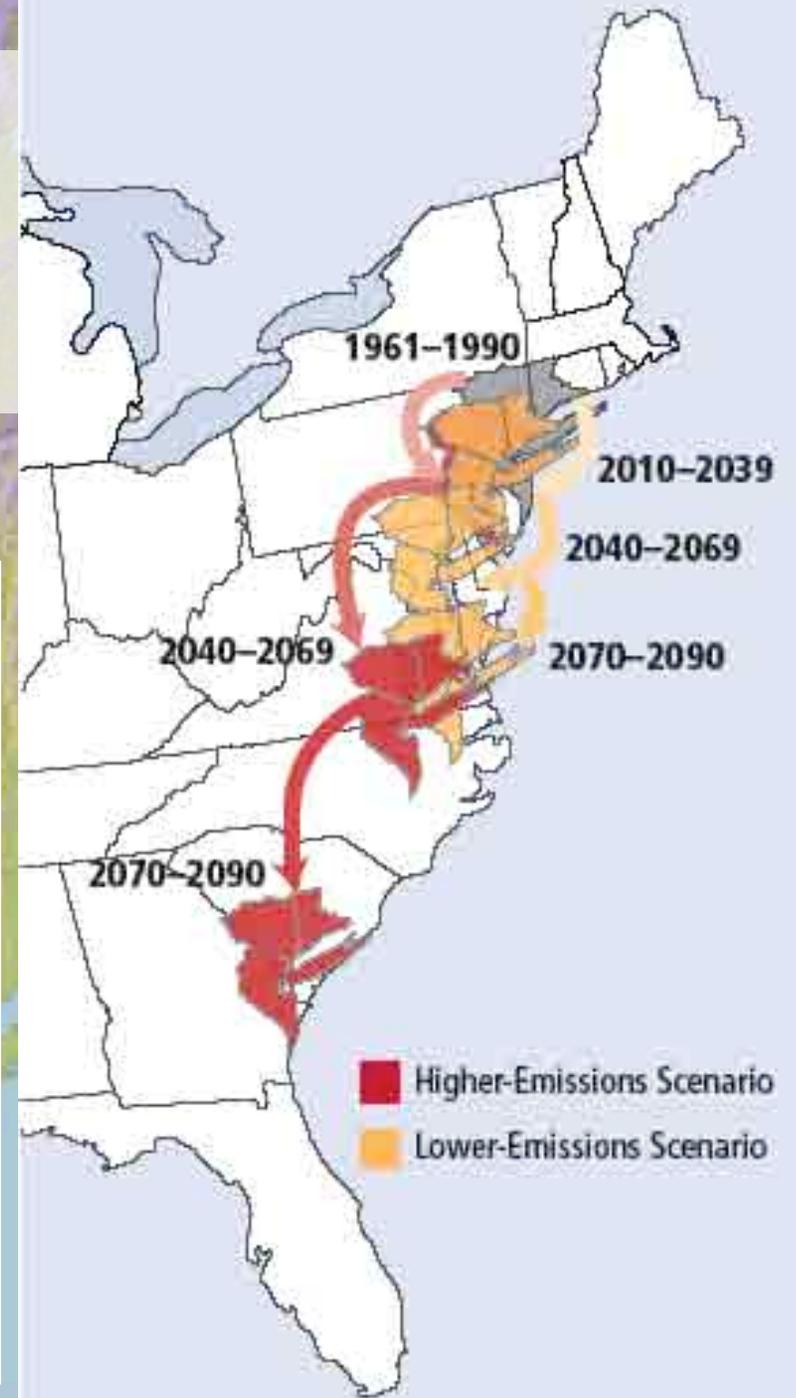
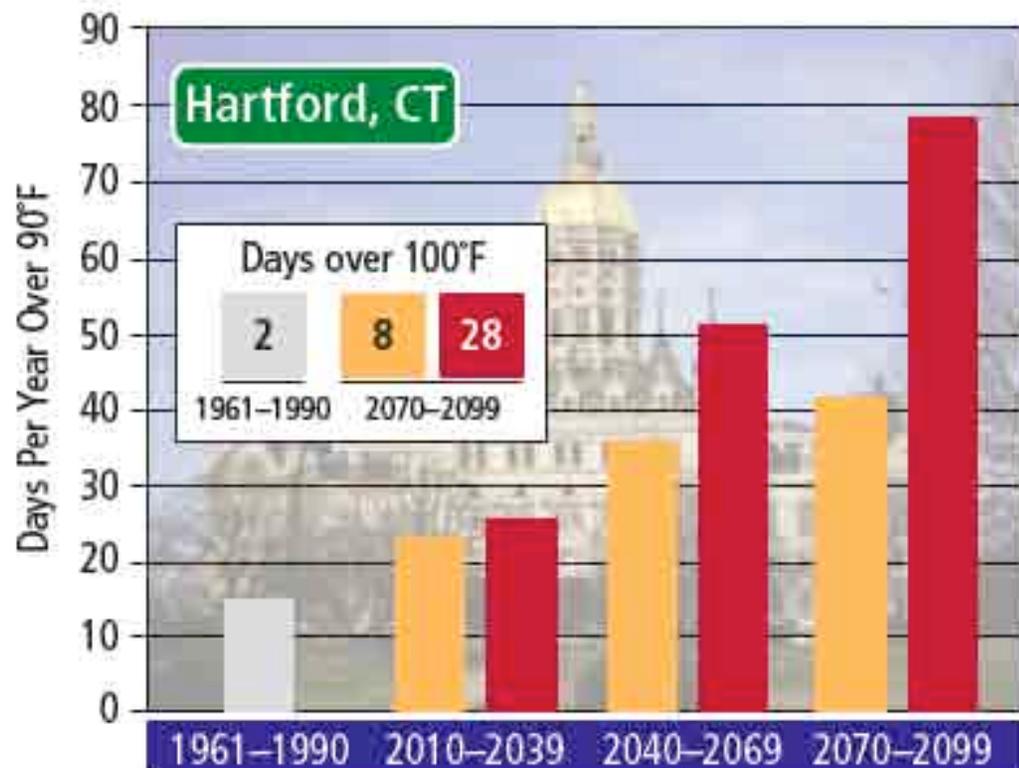
Projecting Future Climate Change for the Northeast: Rising Annual Temperatures



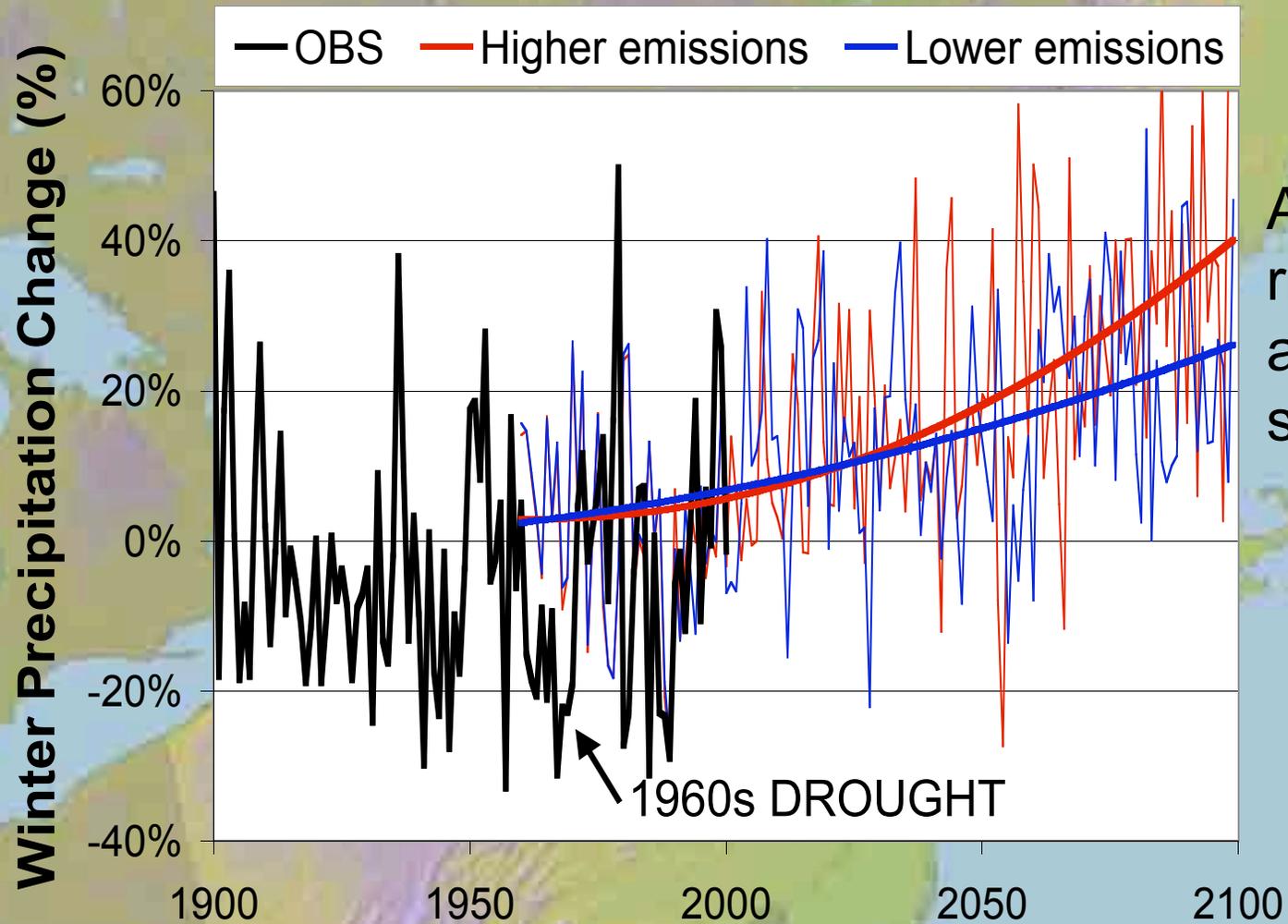
Summer heat index: *How hot summers will “feel” in Massachusetts*



Summer heat index: *How hot summers will “feel” in Connecticut*



Increasing winter precipitation



As temperatures rise, more falling as rain, less as snow

Extreme Precipitation Events Increase

- Heavy rainfall events are becoming more frequent across the Northeast
- Under both emissions scenarios
 - rainfall is expected to become more intense
 - periods of heavy rainfall are expected to become more frequent



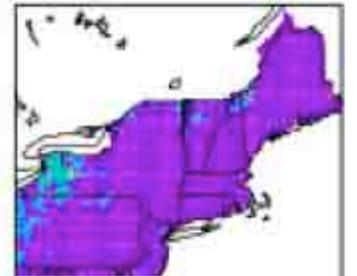
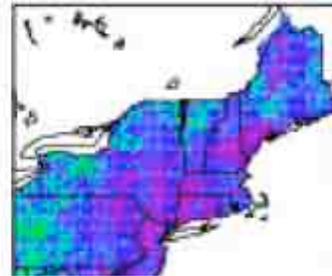
Bridge over Axe Handle Brook, Rochester, NH
May 2006.

credit: Associated Press

Drought

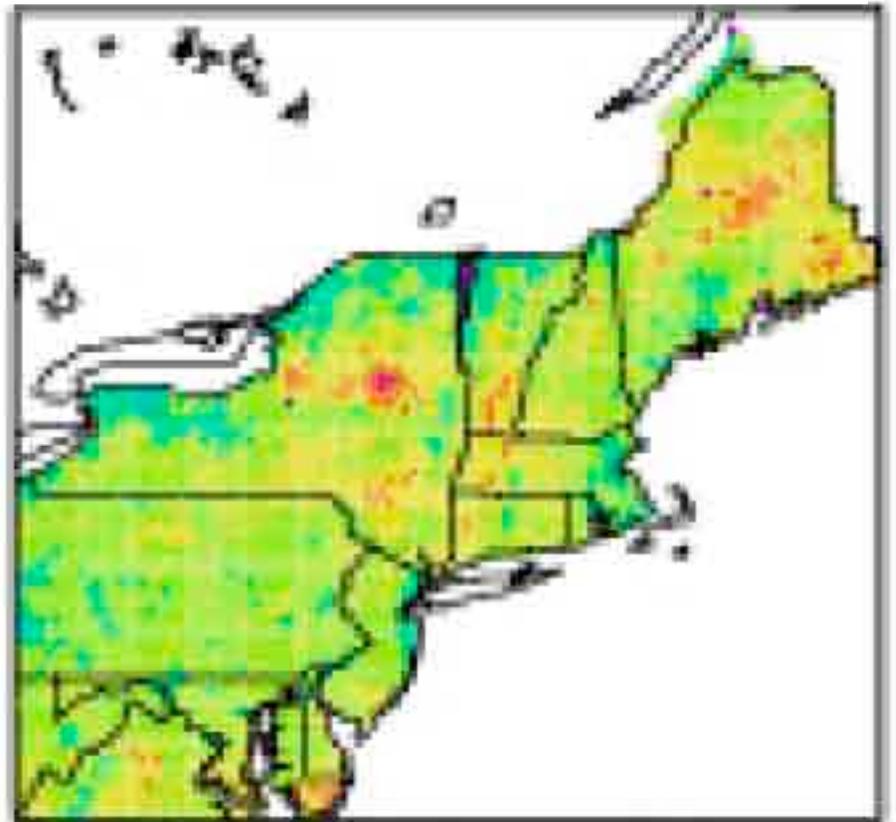
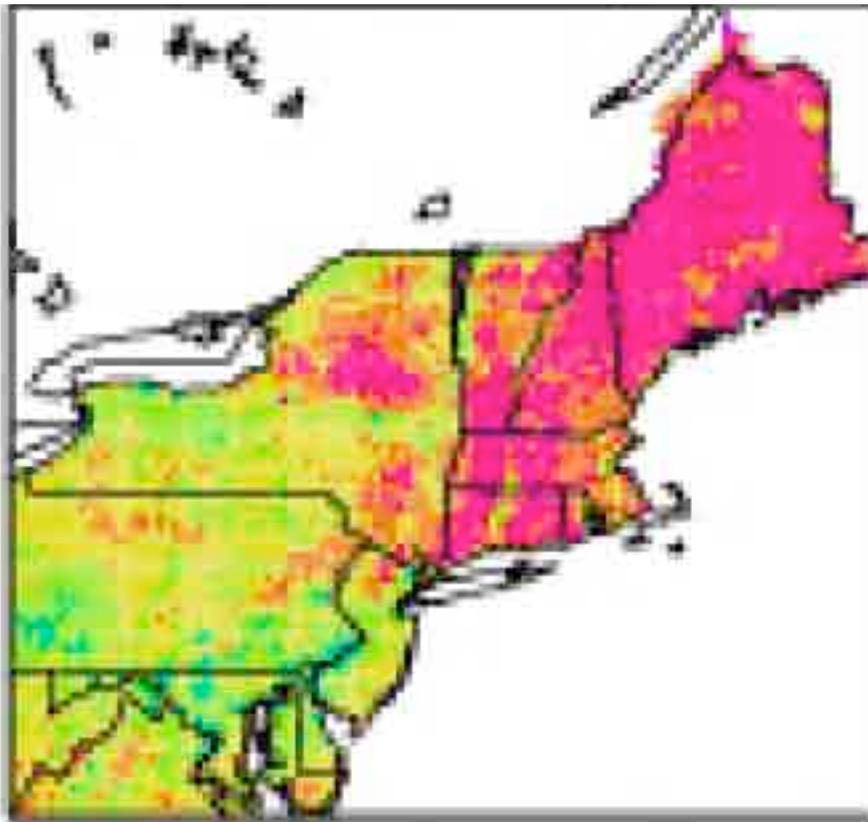


1961-1990

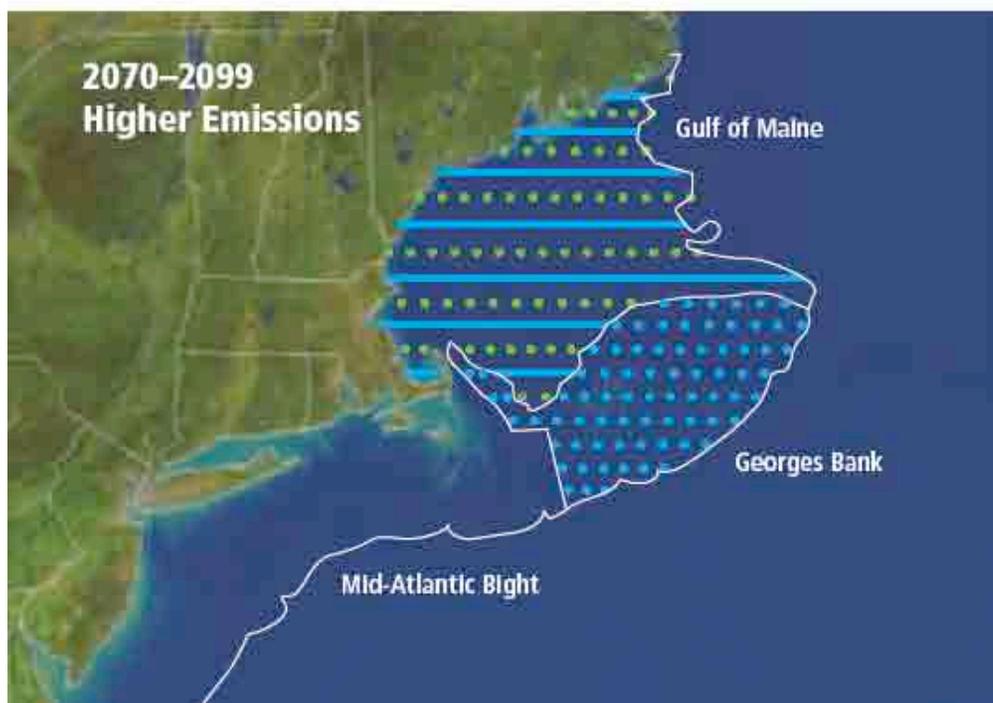
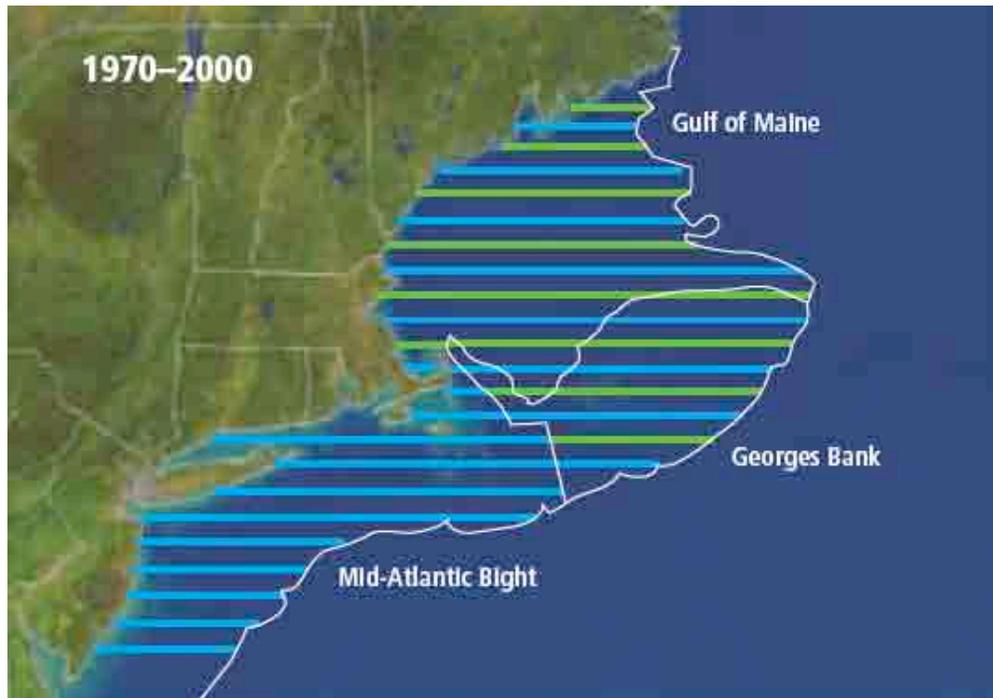


High Emissions

Low Emissions

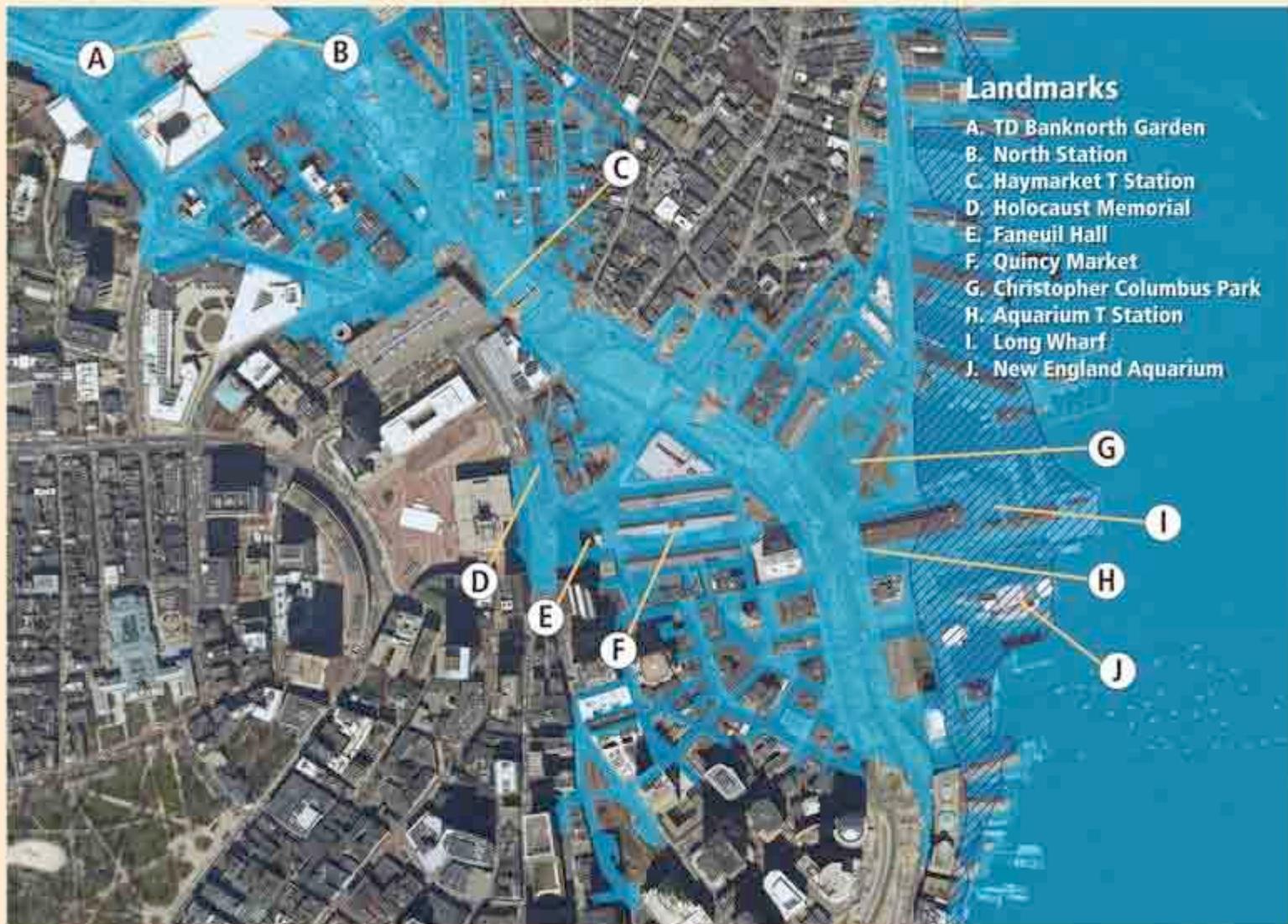


Potential Loss of Commercial Cod Fishery



■ adult cod thermal habitat ■ young cod thermal habitat
full lines: suitable dotted lines: marginal

Boston: The 100-Year Coastal Flood in 2100 (Higher-Emissions Scenario; 16 inches of SLR)



■ Current 100-year flood zone
■ Projected 100-year flooded area (higher-emissions scenario)

Boston: The Future 100-Year Flood under the Higher-Emissions Scenario (16" of sea level rise)



■ Current 100-year flood zone
■ Projected 100-year flooded area (higher-emissions scenario)

New London/Groton: 100-Year Flood



New London/Groton Flooding

Kinematic Constraints on Glacier Contributions to 21st-Century Sea-Level Rise

W. T. Pfeffer,^{1*} J. T. Harper,² S. O'Neel³

On the basis of climate modeling and analogies with past conditions, the potential for multimeter increases in sea level by the end of the 21st century has been proposed. We consider glaciological conditions required for large sea-level rise to occur by 2100 and conclude that increases in excess of 2 meters are physically untenable. We find that a total sea-level rise of about 2 meters by 2100 could occur under physically possible glaciological conditions but only if all variables are quickly accelerated to extremely high limits. More plausible but still accelerated conditions lead to total sea-level rise by 2100 of about 0.8 meter. These roughly constrained scenarios provide a "most likely" starting point for refinements in sea-level forecasts that include ice flow dynamics.

5 SEPTEMBER 2008 VOL 321 **SCIENCE**

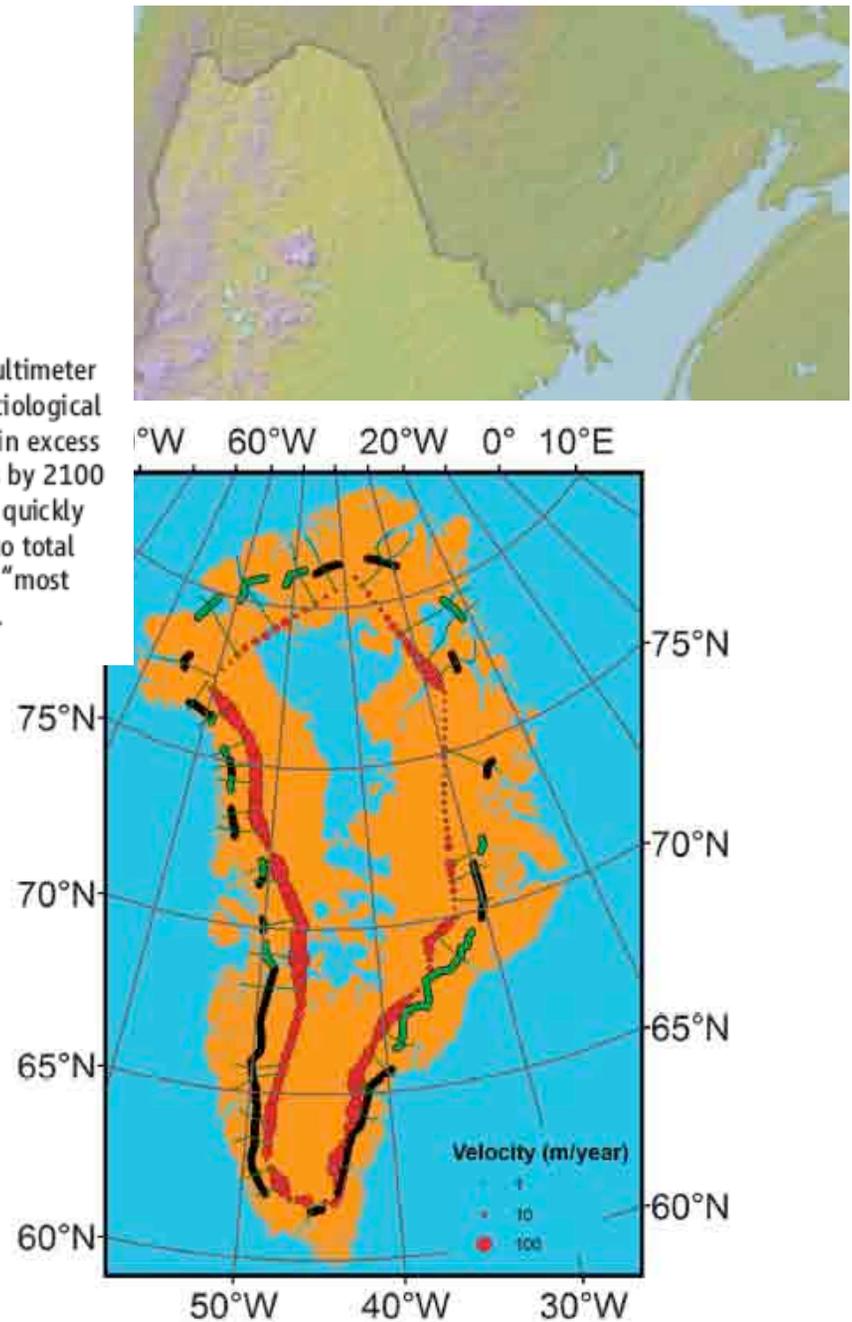
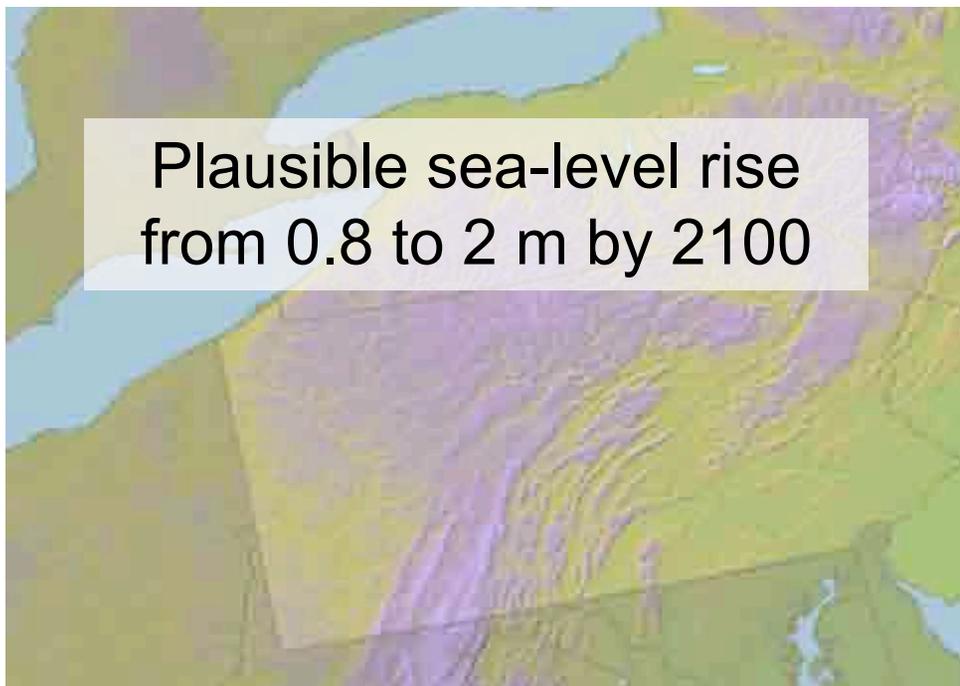
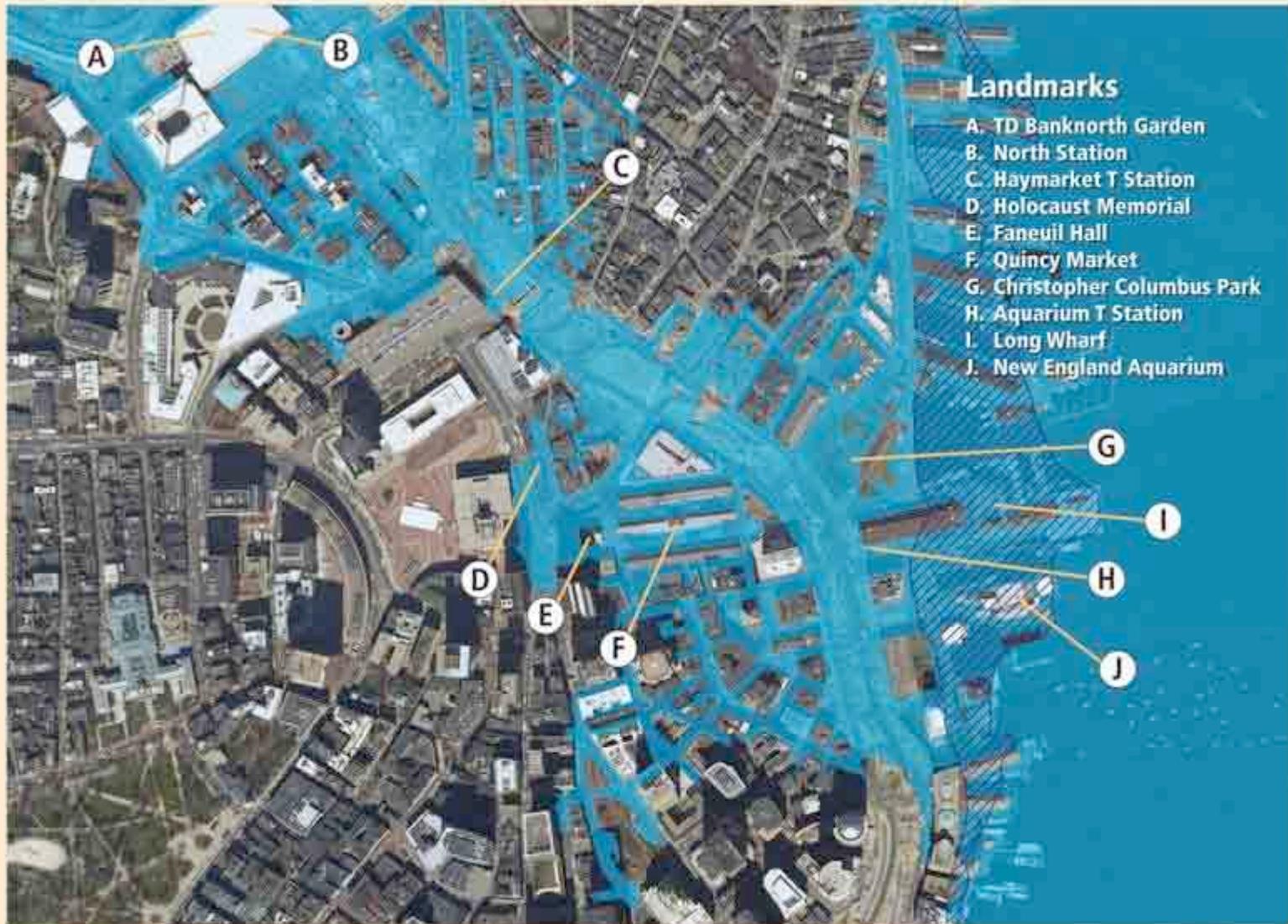


Fig. 1. Map showing Greenland and outlet glacier gates; marine-based gates are shown as dark green and nonmarine as black. Regions below sea level are colored blue. Ice velocities at -2000 m elevation from (21) shown by red dots.

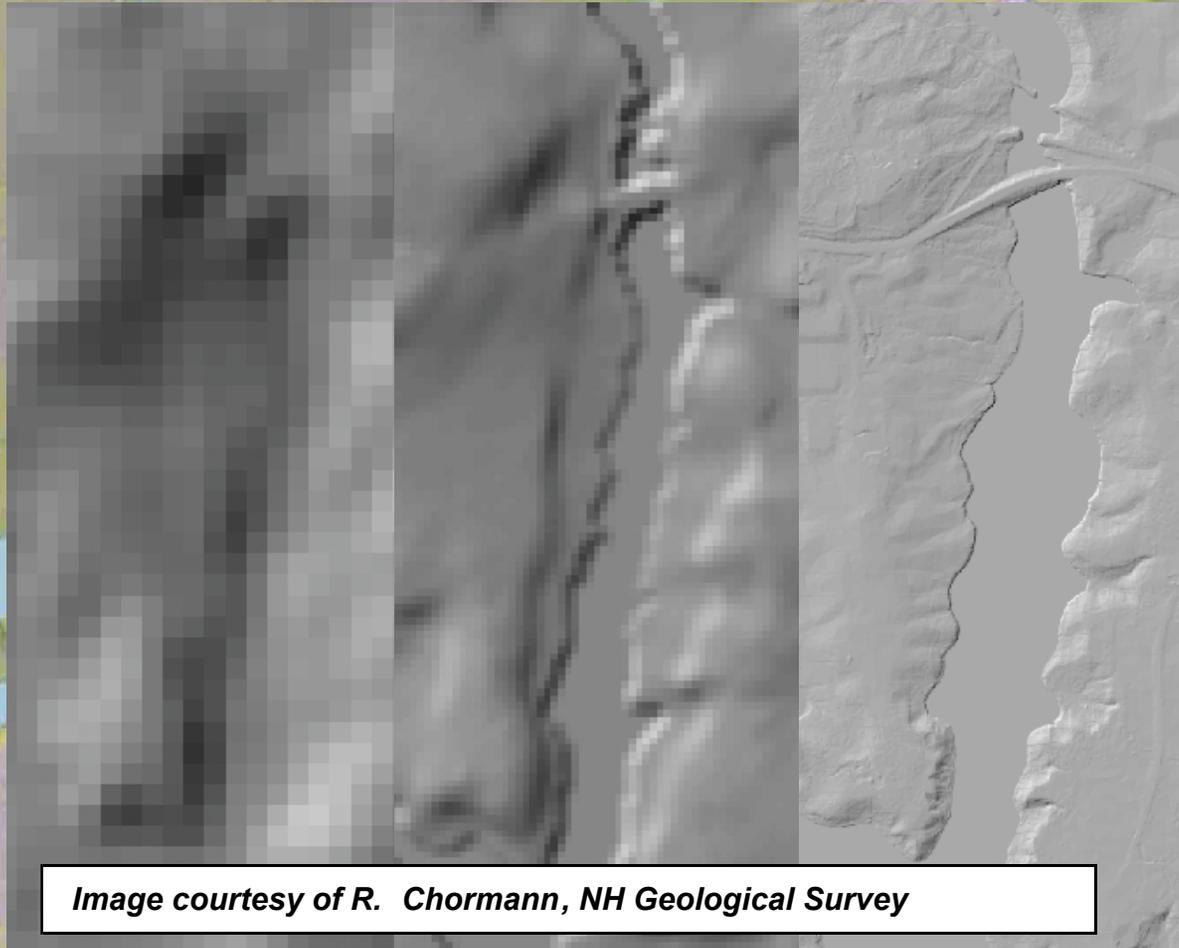
Boston: The 100-Year Coastal Flood in 2100 (Higher-Emissions Scenario; 16 inches of SLR)



■ Current 100-year flood zone
■ Projected 100-year flooded area (higher-emissions scenario)

Resolution of Topographic Data Matters!

Comparison of terrain models for Fresh Creek, Strafford County, NH: NED 30-meter and 10-meter DEMs versus 1-meter LiDAR



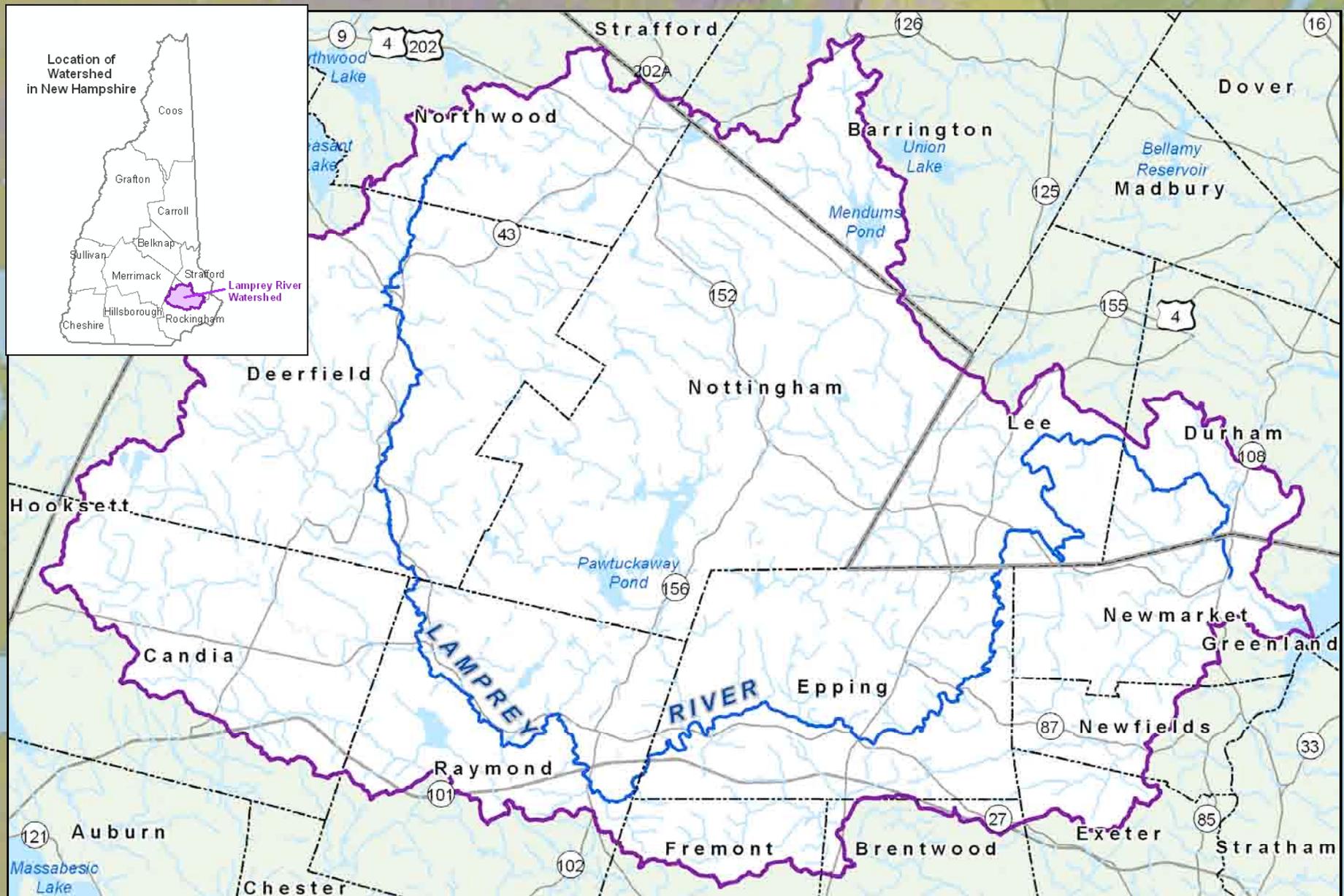
30-meter DEM

10-meter DEM

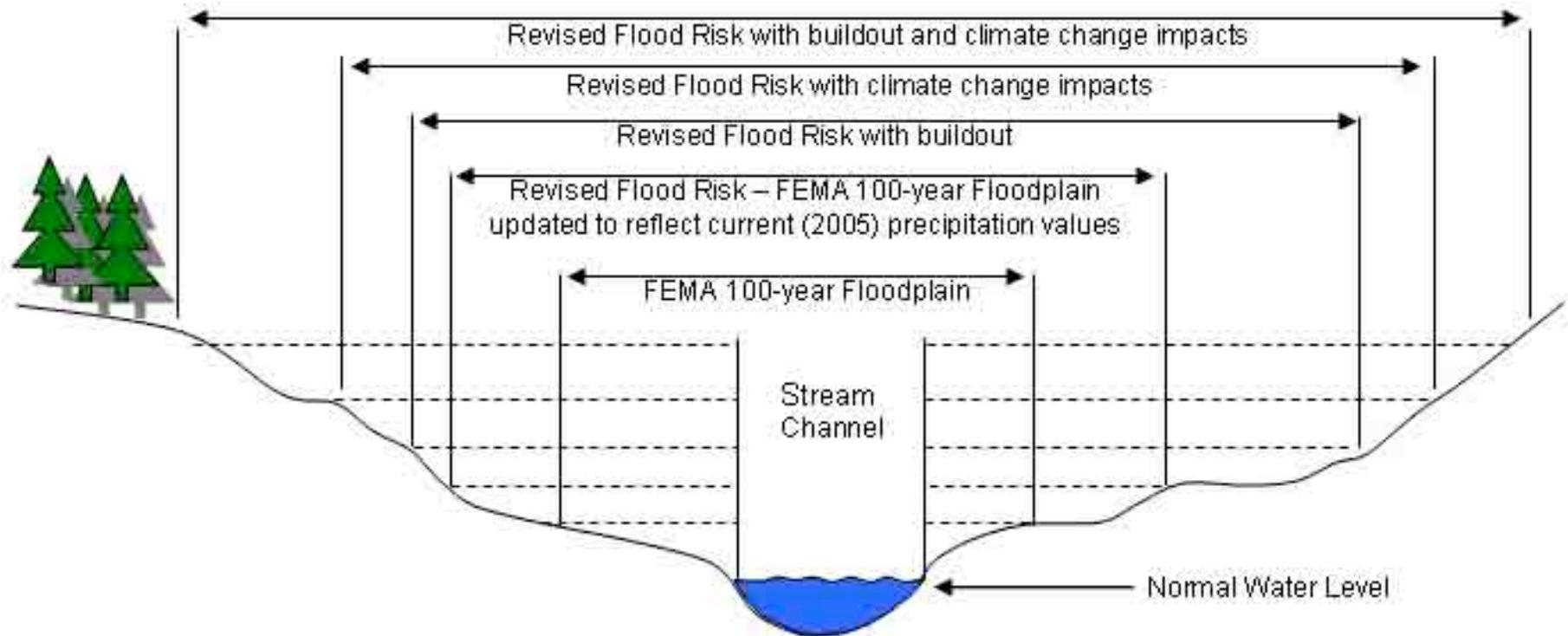
1-meter DEM



Assessing the Risk of 100-year Freshwater Floods in the Lamprey River Watershed from Changes in Climate and Land Use

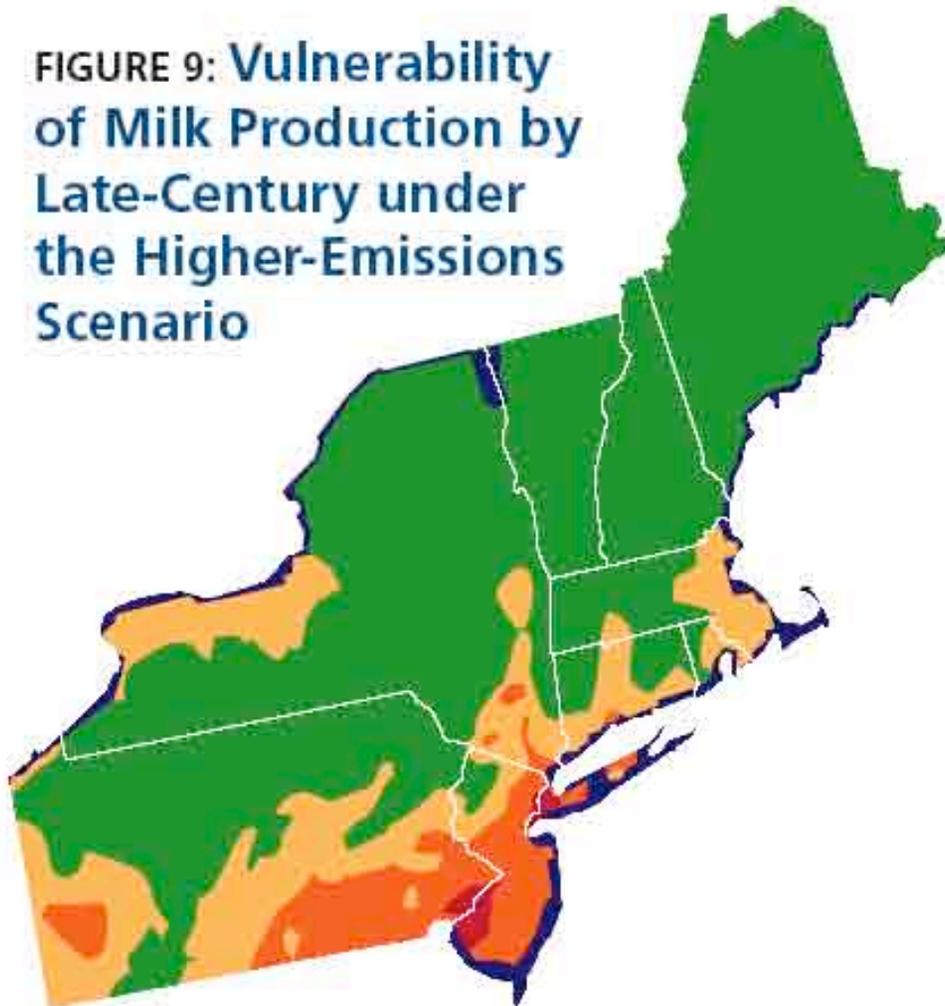


Assessing the Risk of 100-year Freshwater Floods in the Lamprey River Watershed from Changes in Climate and Land Use



Impacts on Agriculture: Dairy

FIGURE 9: Vulnerability of Milk Production by Late-Century under the Higher-Emissions Scenario



■ 0–10% decline ■ 10%–15% decline
■ 15%–20% decline ■ >20% decline
■ no data



Higher Temperatures Depress Milk Production

Impacts on Agriculture: Crops

Traditional Fruit
Crops May Suffer in
a Warmer Climate



What path will we take to the future?



Two roads diverged in a wood, and I -
I took the one less traveled by,
And that has made all the difference.

Robert Frost

New England: Six Teams - or One?

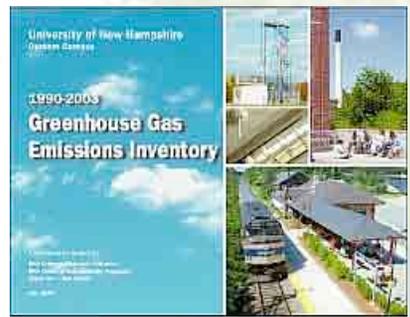
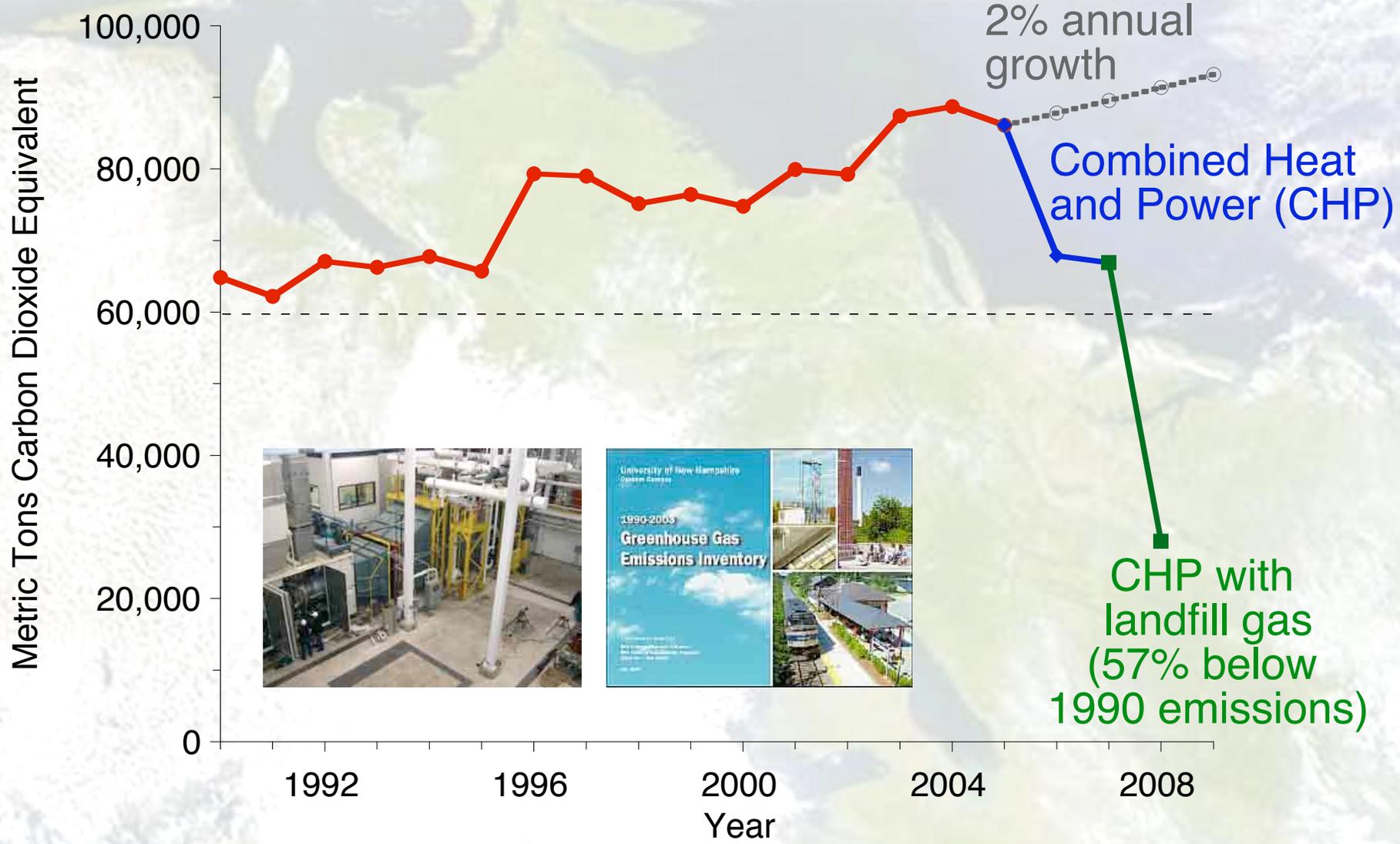
The logo for New England Futures is centered on a white rectangular background. It features the words "NEW ENGLAND" in a bold, dark blue, sans-serif font. Below this, the word "FUTURES" is written in a larger, bold, dark blue, sans-serif font. Underneath "FUTURES" is the tagline "NEW CENTURY, NEW GAME" in a smaller, orange, sans-serif font. At the bottom of the logo is the website address "www.newenglandfutures.org" in a dark blue, sans-serif font. A yellow and orange diagonal graphic element is positioned behind the text.

**NEW ENGLAND
FUTURES**
NEW CENTURY, NEW GAME
www.newenglandfutures.org

“We’re in peril. We New Englanders must strengthen ourselves, break historic precedent, find new and innovative ways to maximize our joint strengths, work together.”

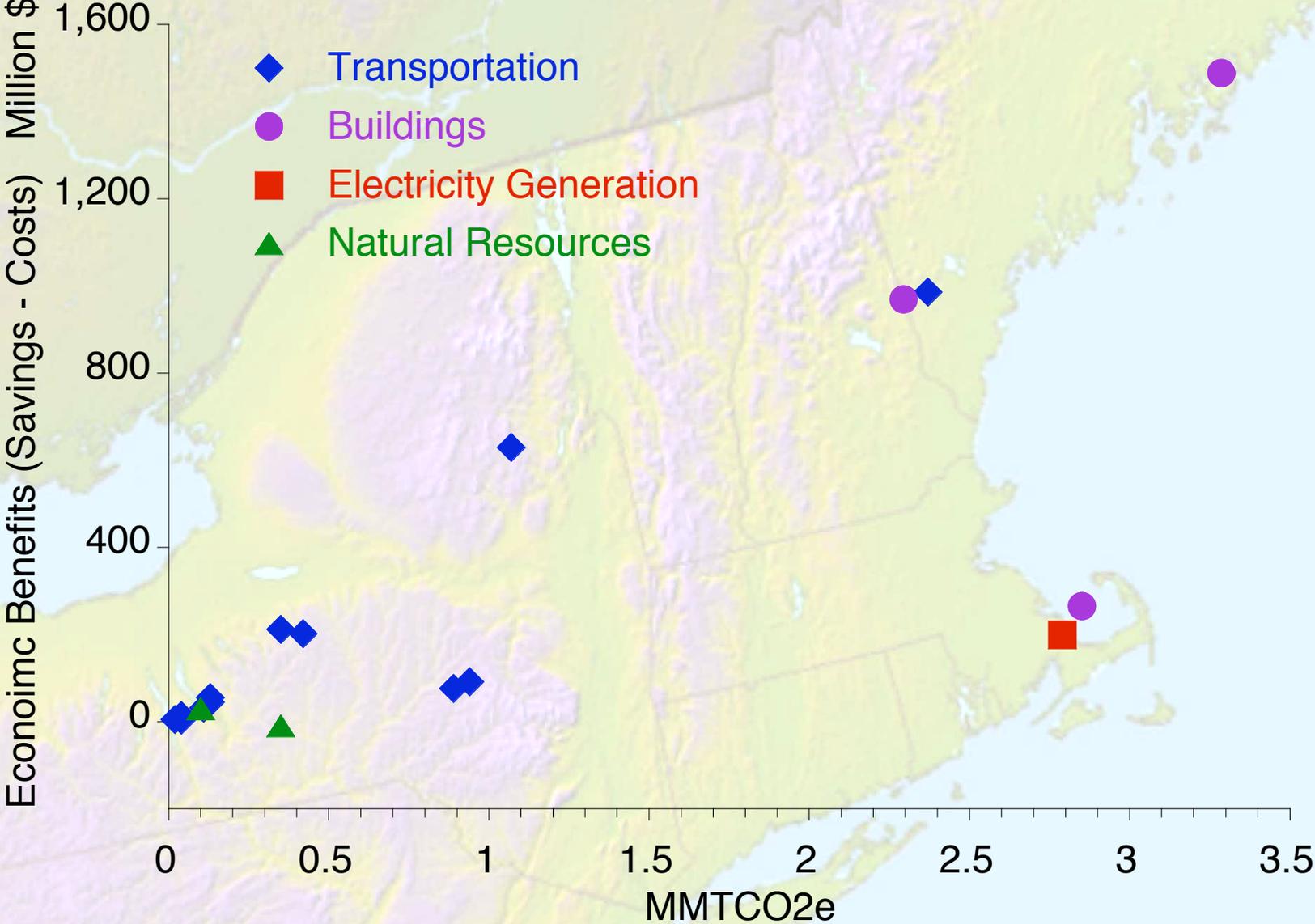
~Former Maine Governor Angus King’s message to the region

UNH Greenhouse Gas Emissions

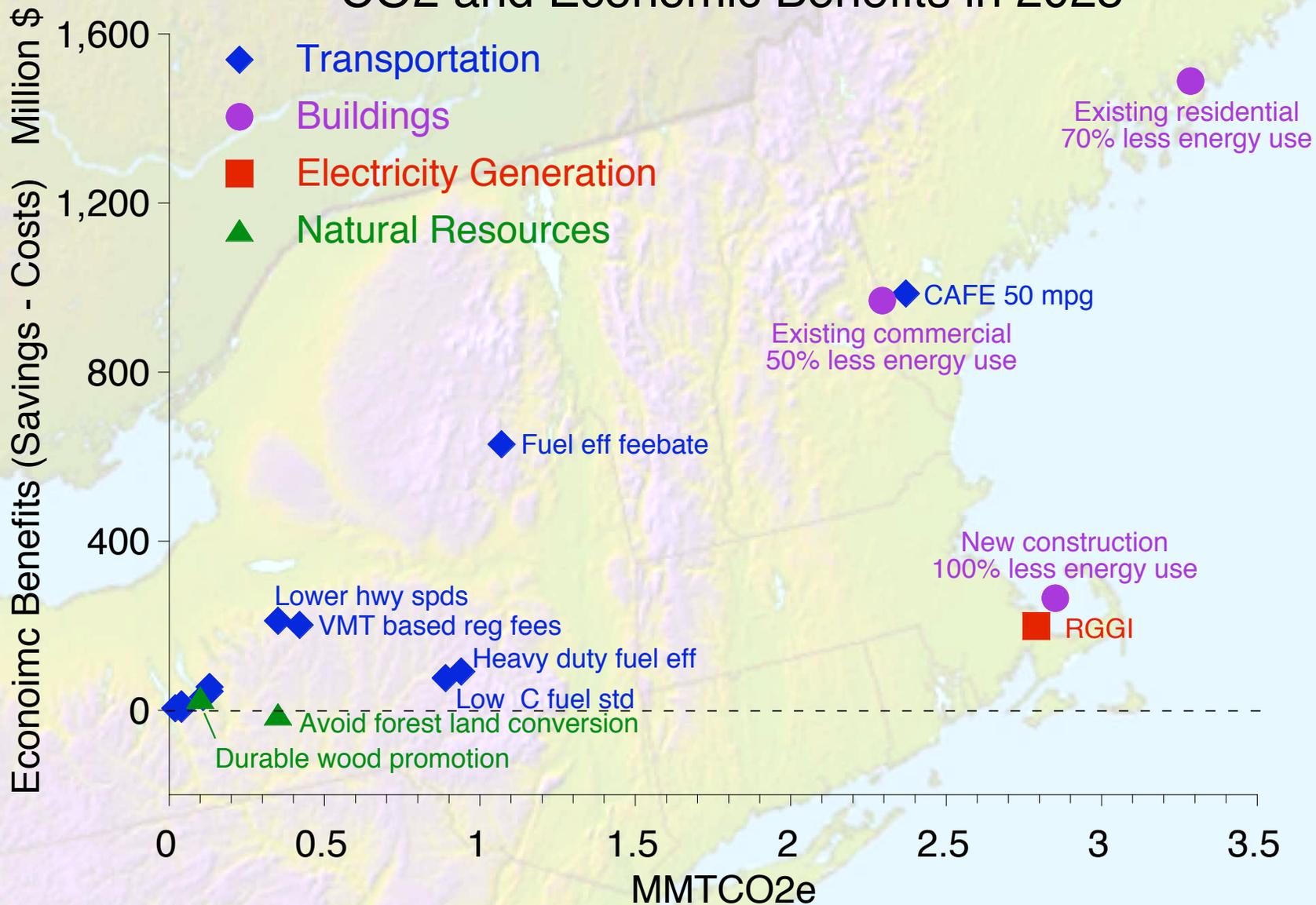


CHP with landfill gas (57% below 1990 emissions)

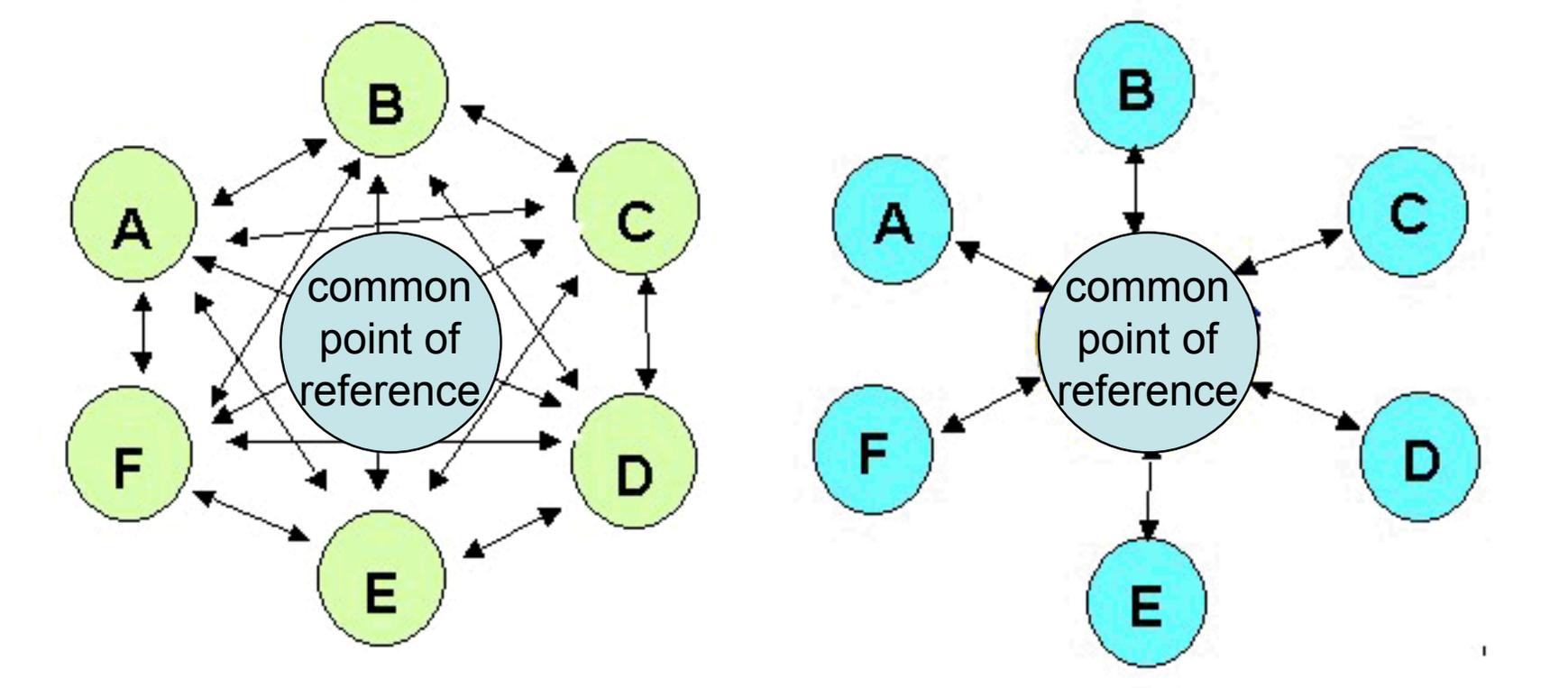
CO2 and Economic Benefits in 2025



CO2 and Economic Benefits in 2025



Integration and Coordination for Sustainability



Building New Institutional Arrangements



Carbon Solutions New England™

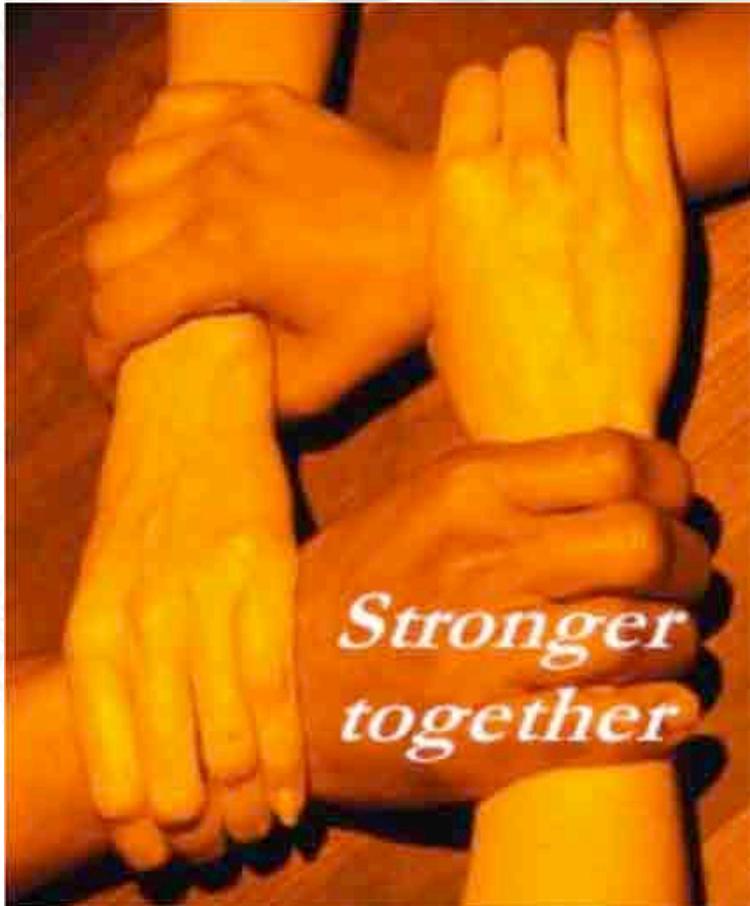
- Unite partners from the public, private, and non-profit sectors to build a clean energy future while sustaining our unique natural and cultural resources
- Harness New England's formidable intellectual and entrepreneurial capabilities
- Facilitate the spread of innovation through analysis and dissemination
- Our approach: Build an interdisciplinary and collaborative process across sectors to address a shared problem

Why Collaborate?

CSNE will build a regional collaborative that rewards and reinforces participation by:

- Pursuing a public good project focused on solutions and a collective legacy
- Facilitating a process focused on learning and innovation that adds value to both individual and collective goals
- Delivering products that are publicly accessible, transparent in purpose, method and reasoning, and valuable for creative problem solving

CSNE Process



Annual State of the Region
Assessment

Biannual Summits

Product Working Groups

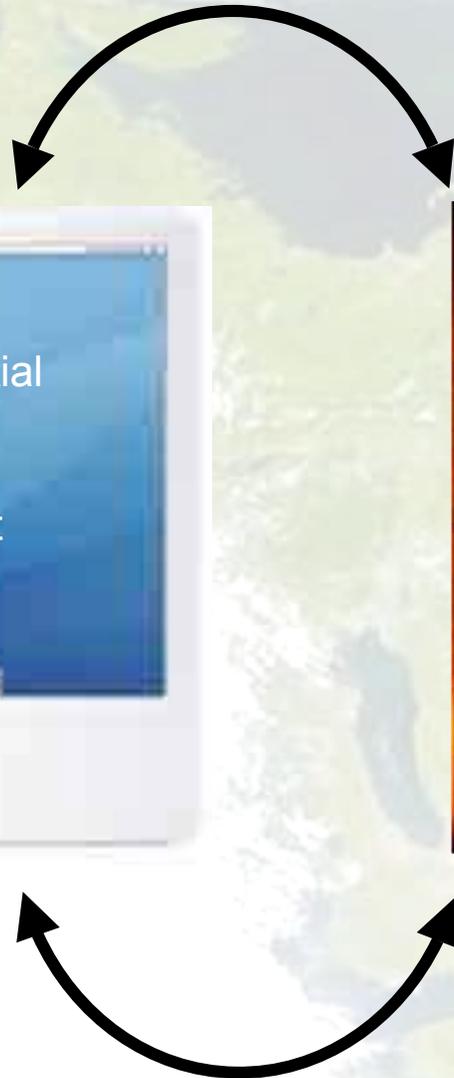
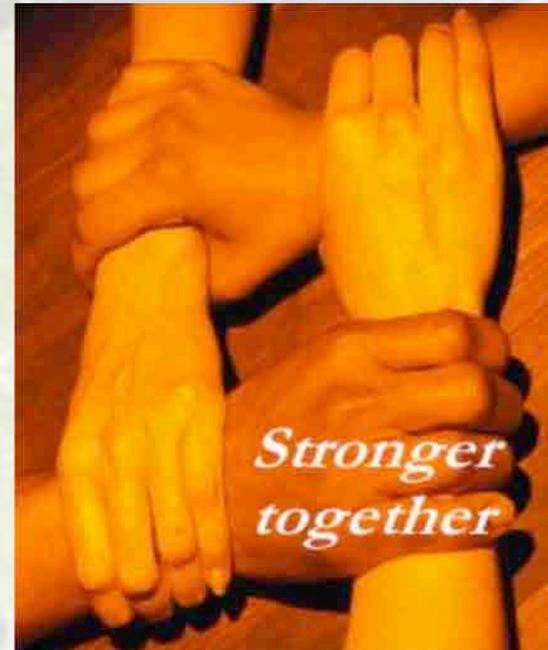
Mutual Learning

Shared Resources

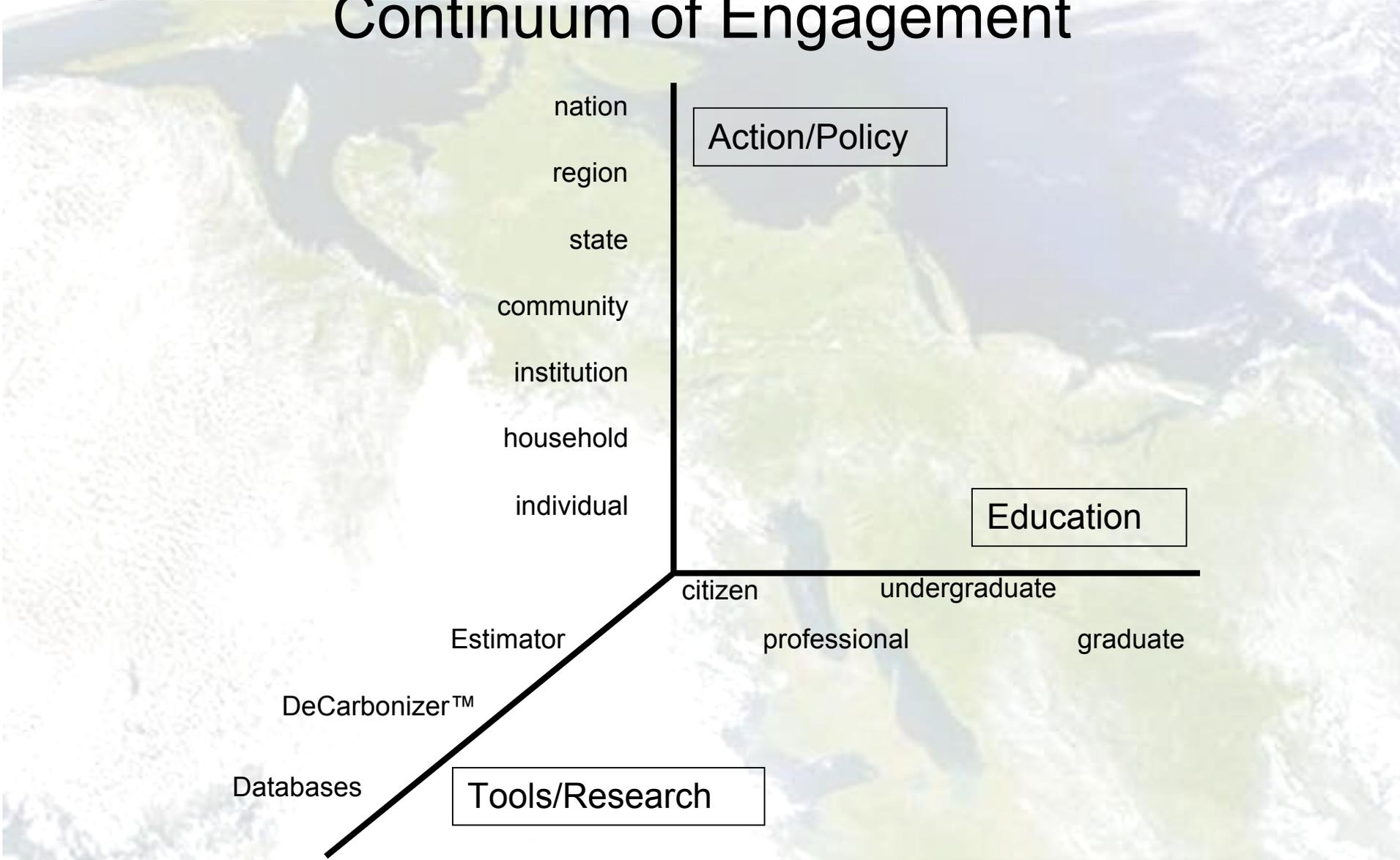
Products

- Regional CO₂ Emission
- Renewable Energy Potential
- Action in all Sectors
- Technologies Assessment
- Indicators & Monitoring

Process



Continuum of Engagement



Economic Framing: *The “big picture” economic case for New Hampshire Climate Change Policies*

- Reduce dependence on imported energy & electricity
- Energy efficiency & local energy sources keeps \$'s in the state
- Fosters business development and creates jobs
- Reduces risk and vulnerability to imported energy prices
- Reduces air pollution and environmental threats to key industries and the economy
 - Protect natural resources
 - Maintain tourism
 - Attract skilled workforce/entrepreneurs
 - Reduce health care costs

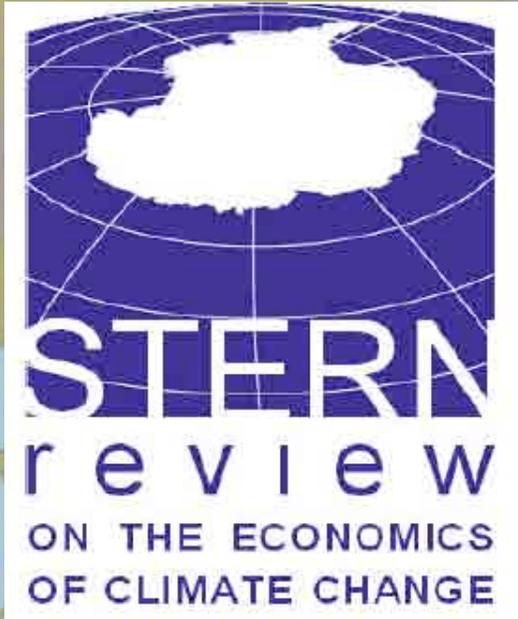
METHODS:

Limited to New Hampshire costs/benefits

Analysis does not consider all the potential benefits such as reduced health costs due to reduced air pollution emissions

Economic benefits include the multiplier benefit of “recycling” of \$'s in NH economy. A conservative 1-1 multiplier is used.

What if we do nothing??



October 2006

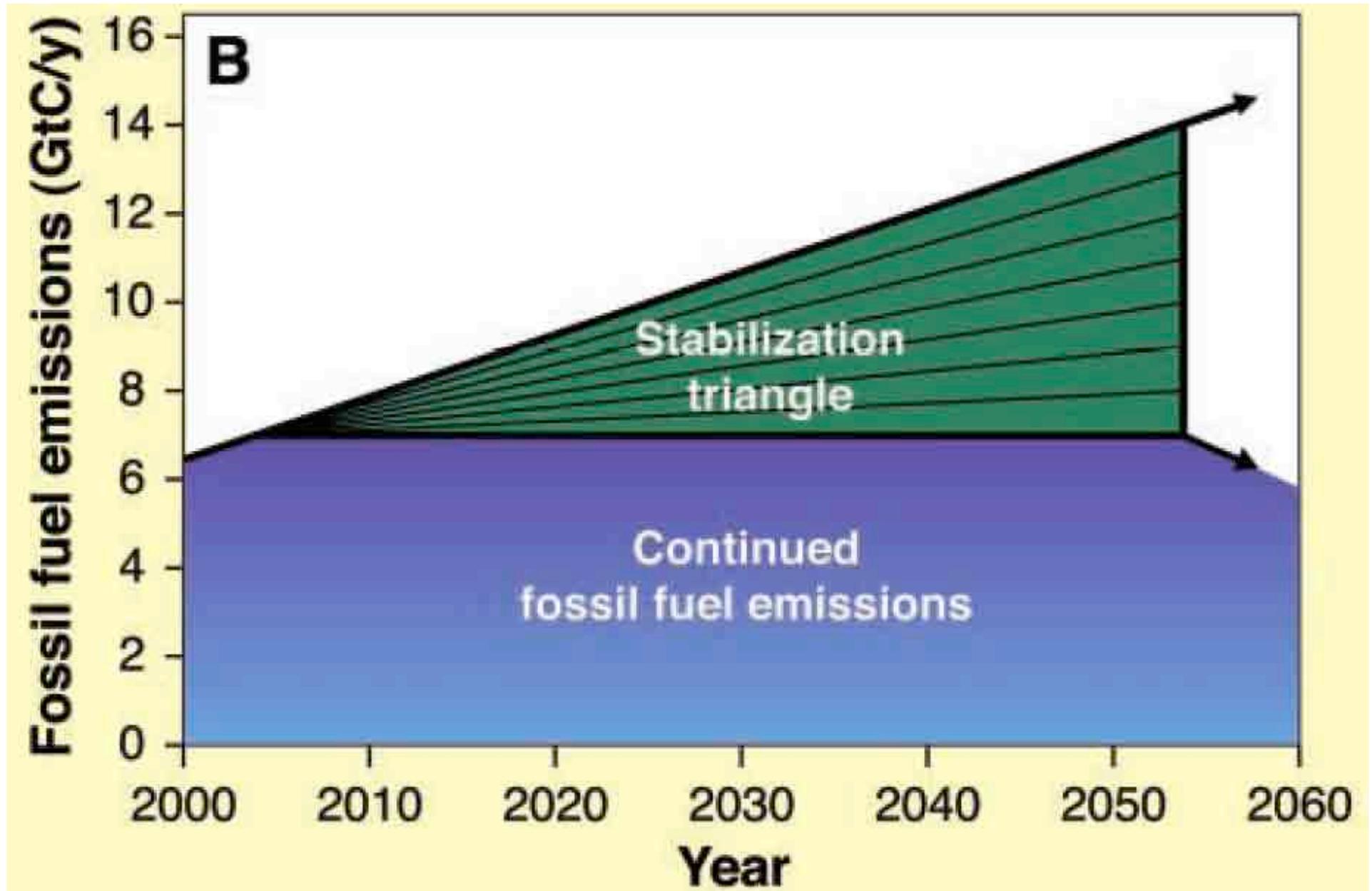
Climate change will affect the basic elements of life for people around the world – access to water, food production, health, and the environment.

If we don't act, the overall costs and risks of climate change will be equivalent to losing **at least 5%** of global GDP each year, now and forever.

If a wider range of risks and impacts is taken into account, the estimates of damage could **rise to 20%** of GDP or more.

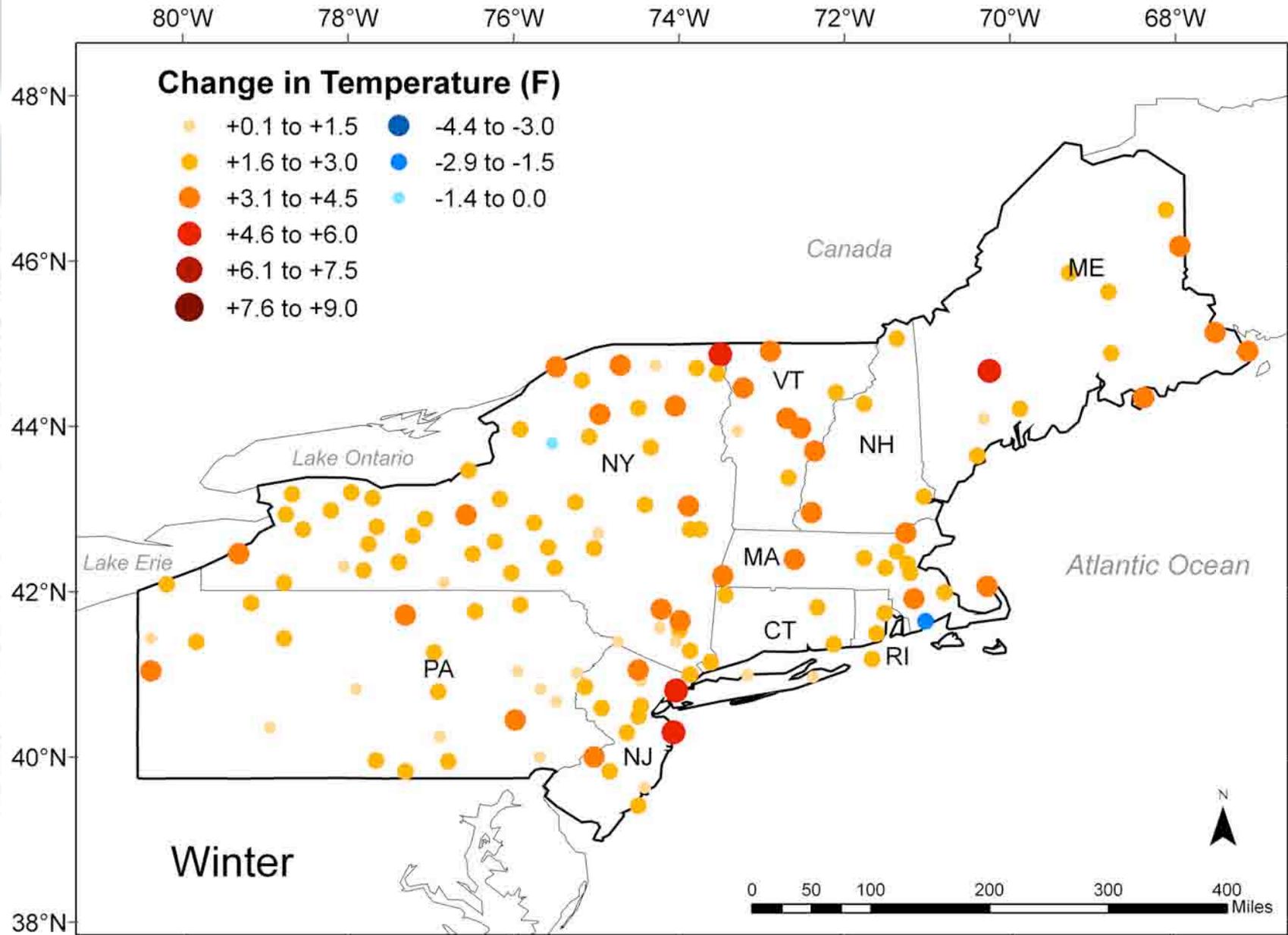
In contrast, the costs of action can be limited to **around 1%** of global GDP each year.

Potential Carbon Emission Reduction Wedges



Pacala and Socolow (2004) Science 304, 968-972.

Northeast Winter Temperature Trends 1970-2005



Burakowski et al., 2008, JGR

Northeast Snow Cover Day Trends 1970-2005

