Interactions between climate, carbon, and forests

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Adapting to Climate Change in the Mid-Atlantic
Cambridge, Maryland
March 23-25, 2010

Northern Institute of Applied Carbon Science

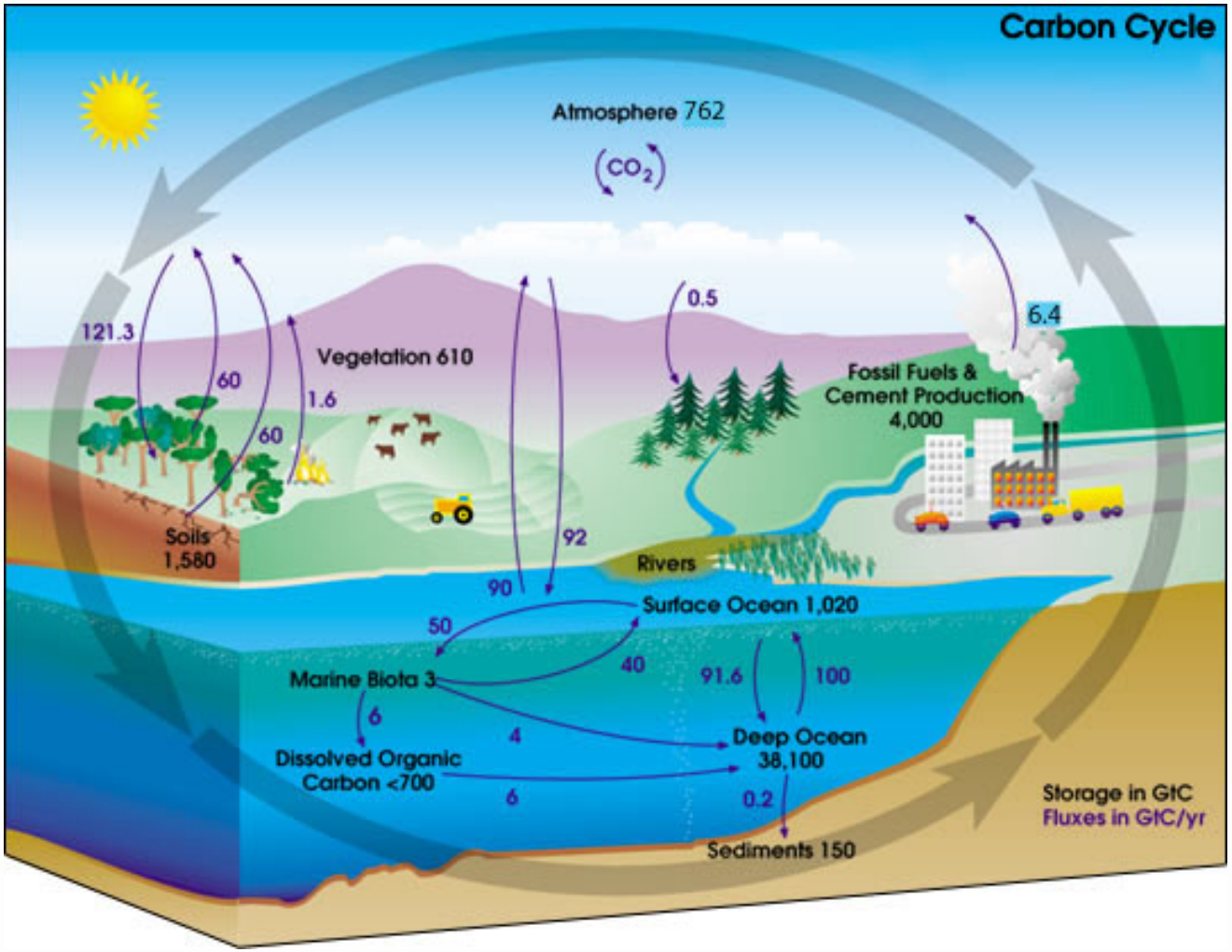
Northern Research Station
USDA Forest Service

Climate, Fire, and Carbon Cycle Sciences Group

Introduction …outline

- Global carbon cycle
- Forest carbon
  - Distribution and density
- Climate uncertainty
  - Sources
  - Perspectives
- Climate change and forests
  - Benefits to forest productivity
  - Deleterious effects on forest productivity
  - Synthesis exercise (northern Wisconsin)

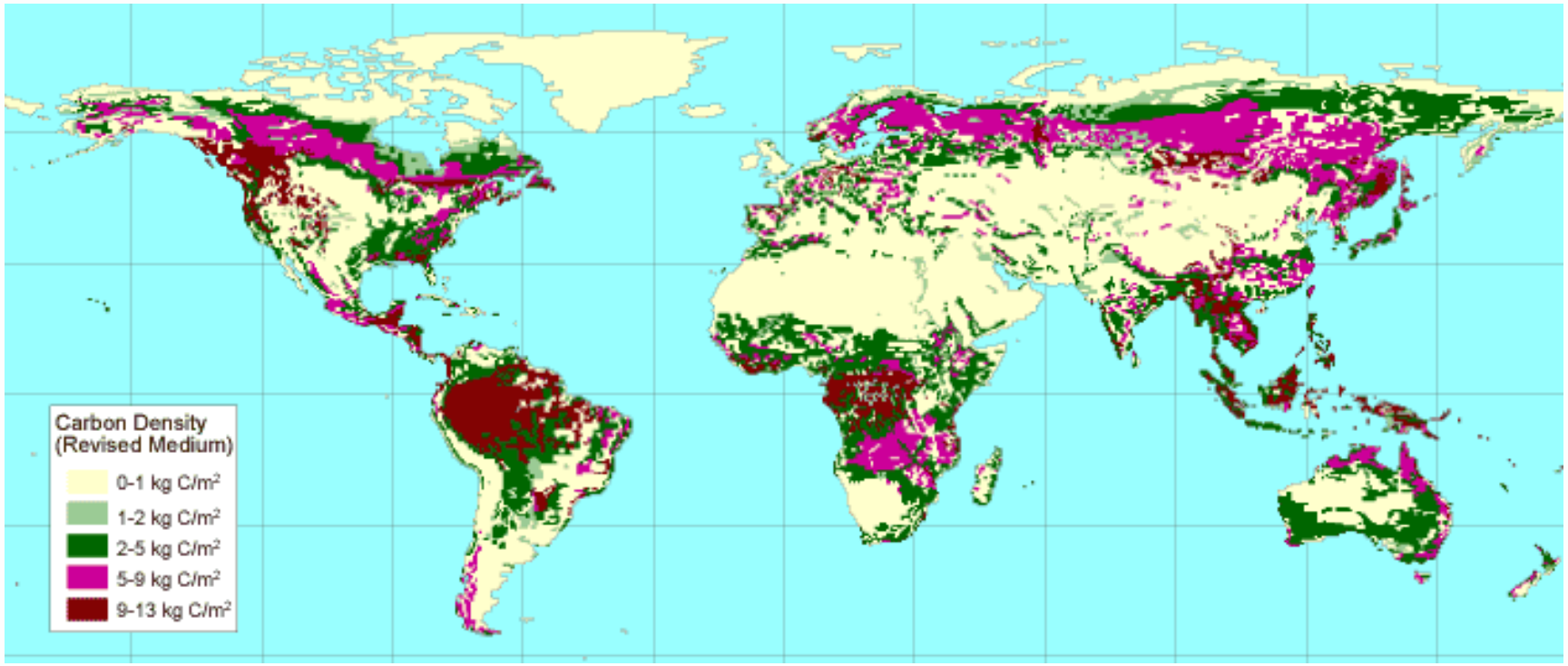
Global Carbon …pools and cycles



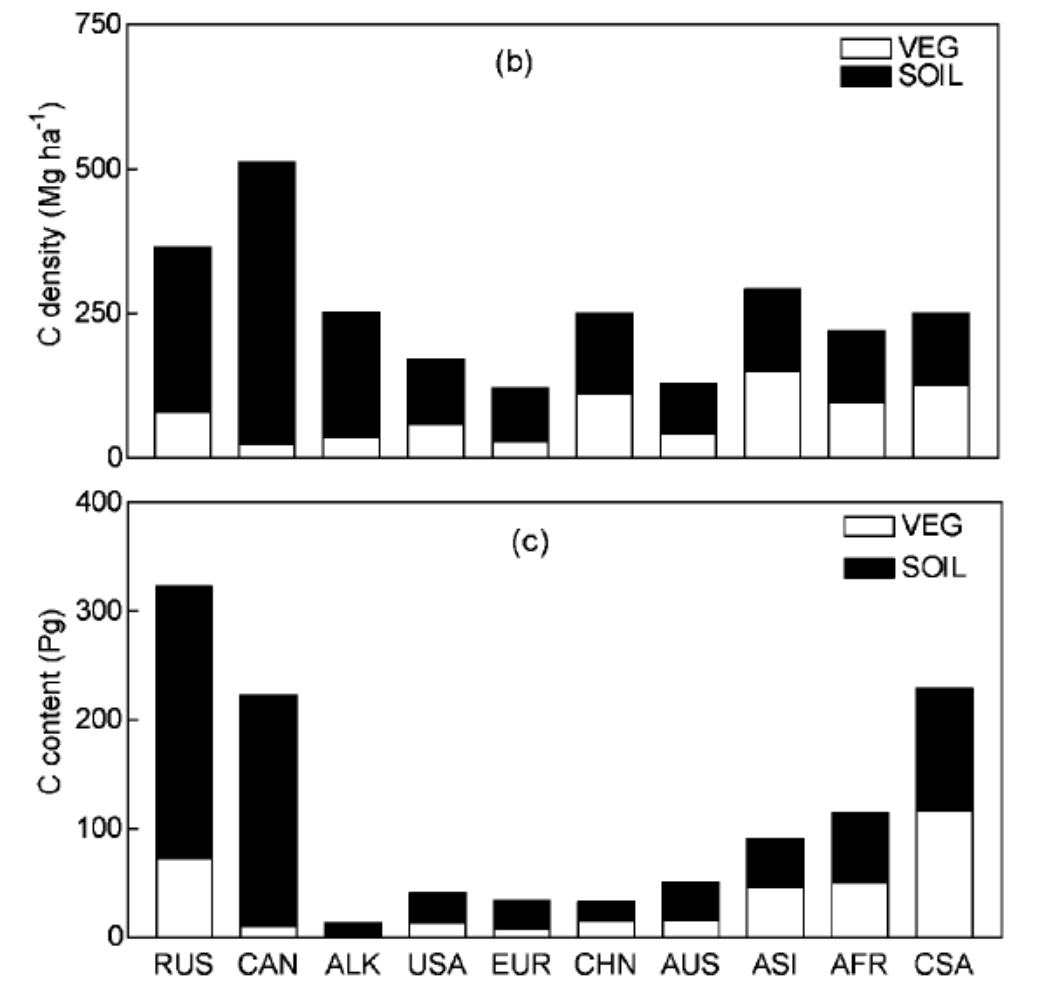
Courtesy of NASA (modified)

Forest Carbon …global density

Carbon density in live vegetation



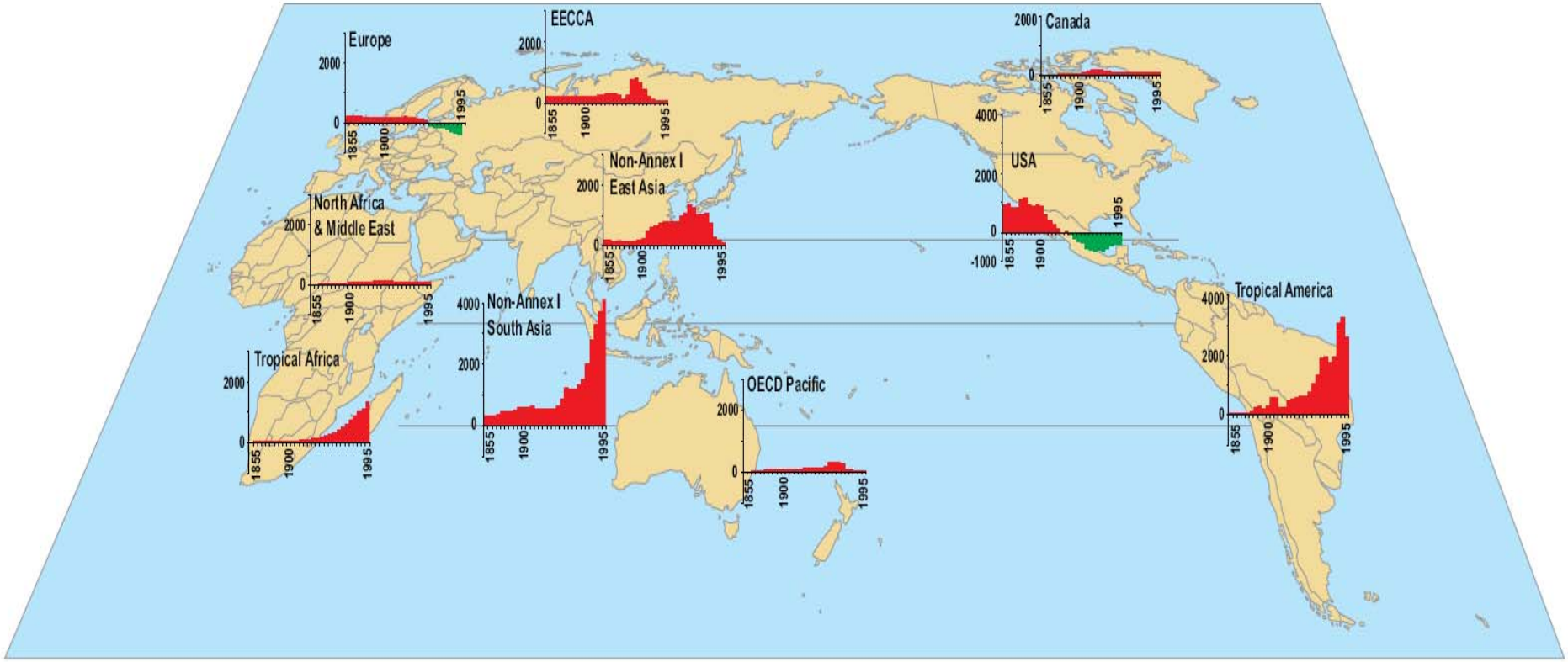
Forest Carbon …global density



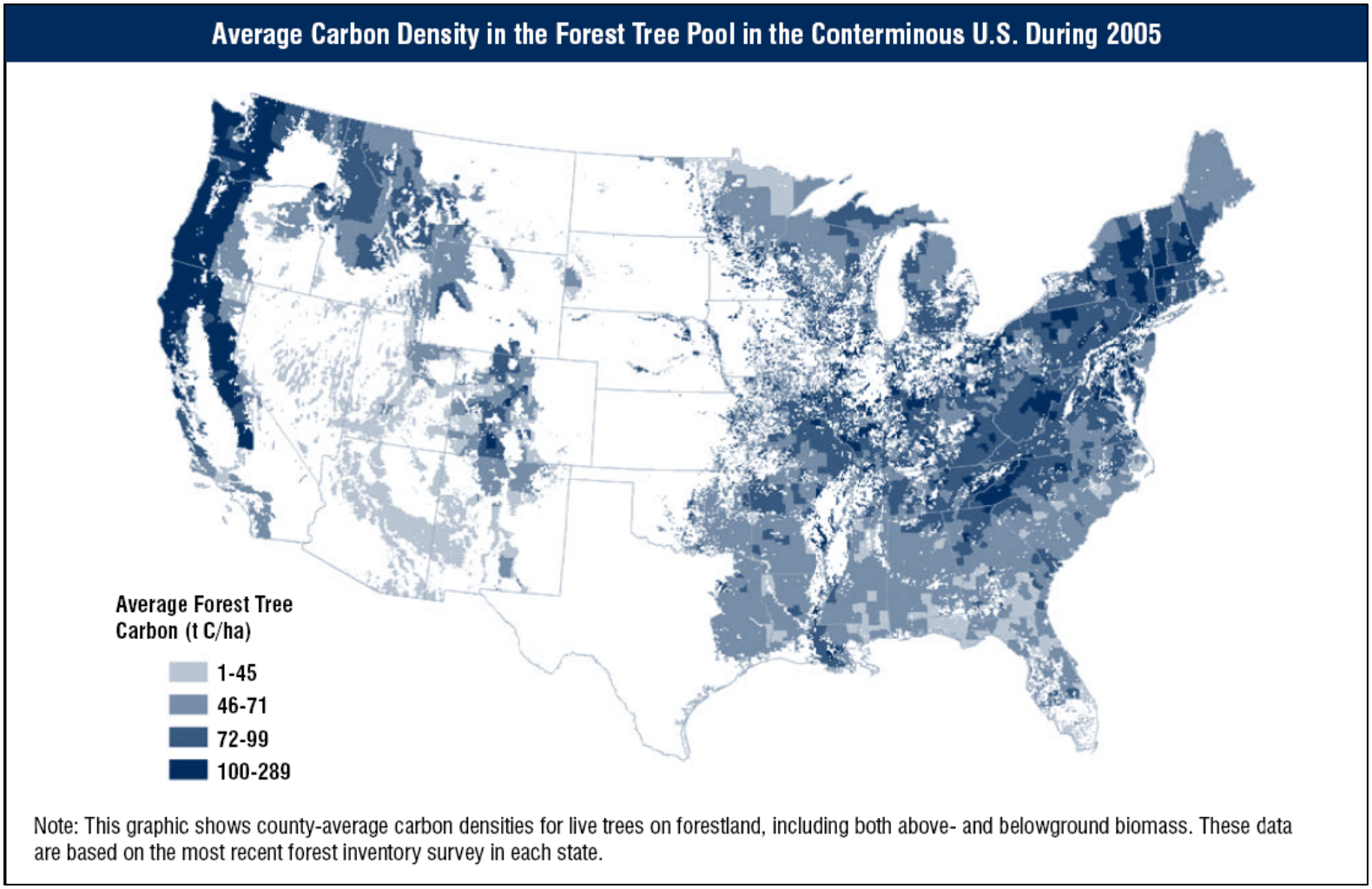
Gower 2003

Forest Carbon …global trends

Regional carbon balance ($MtCO_2$), 1855-2000.

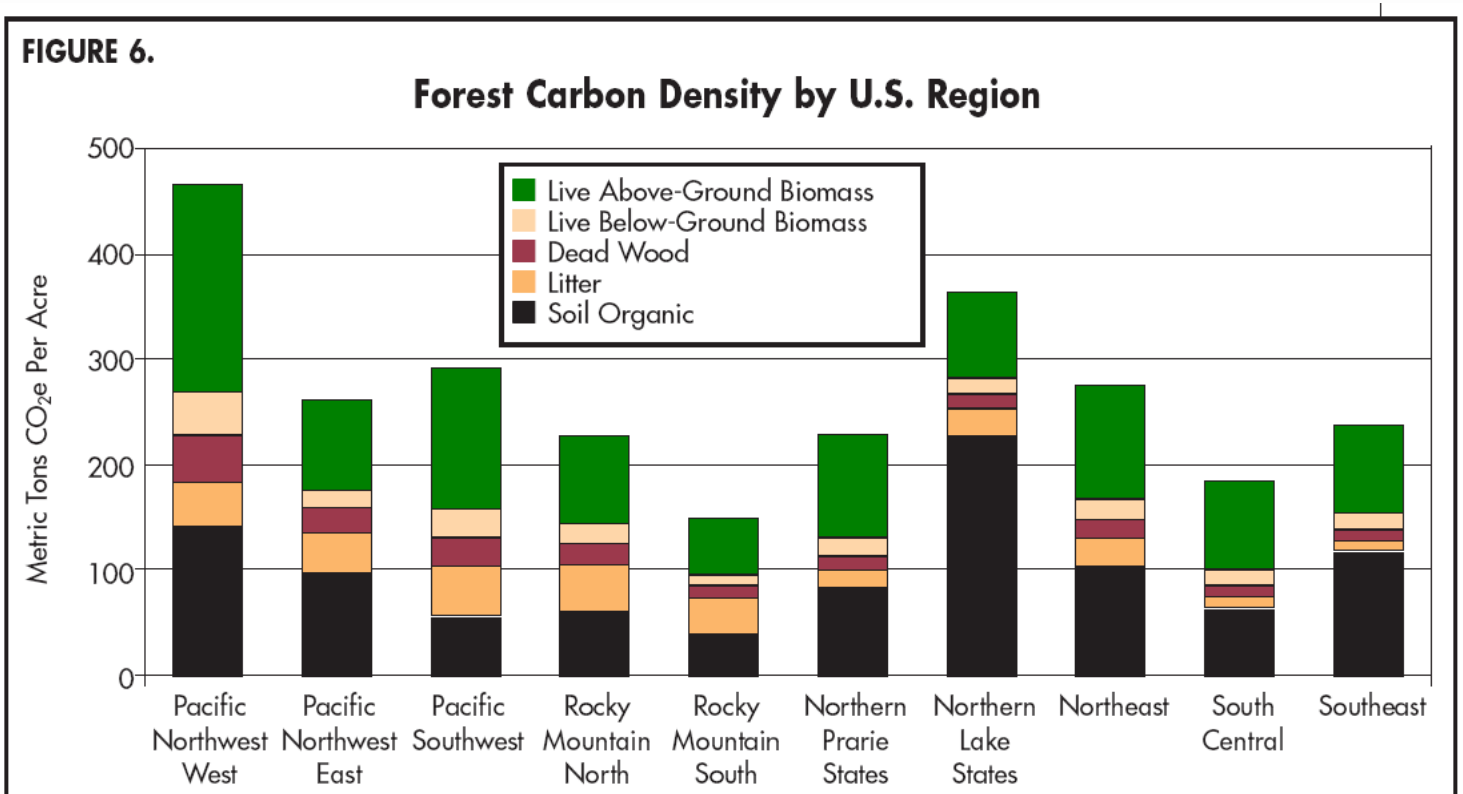


Forest Carbon …US density



EPA 2006

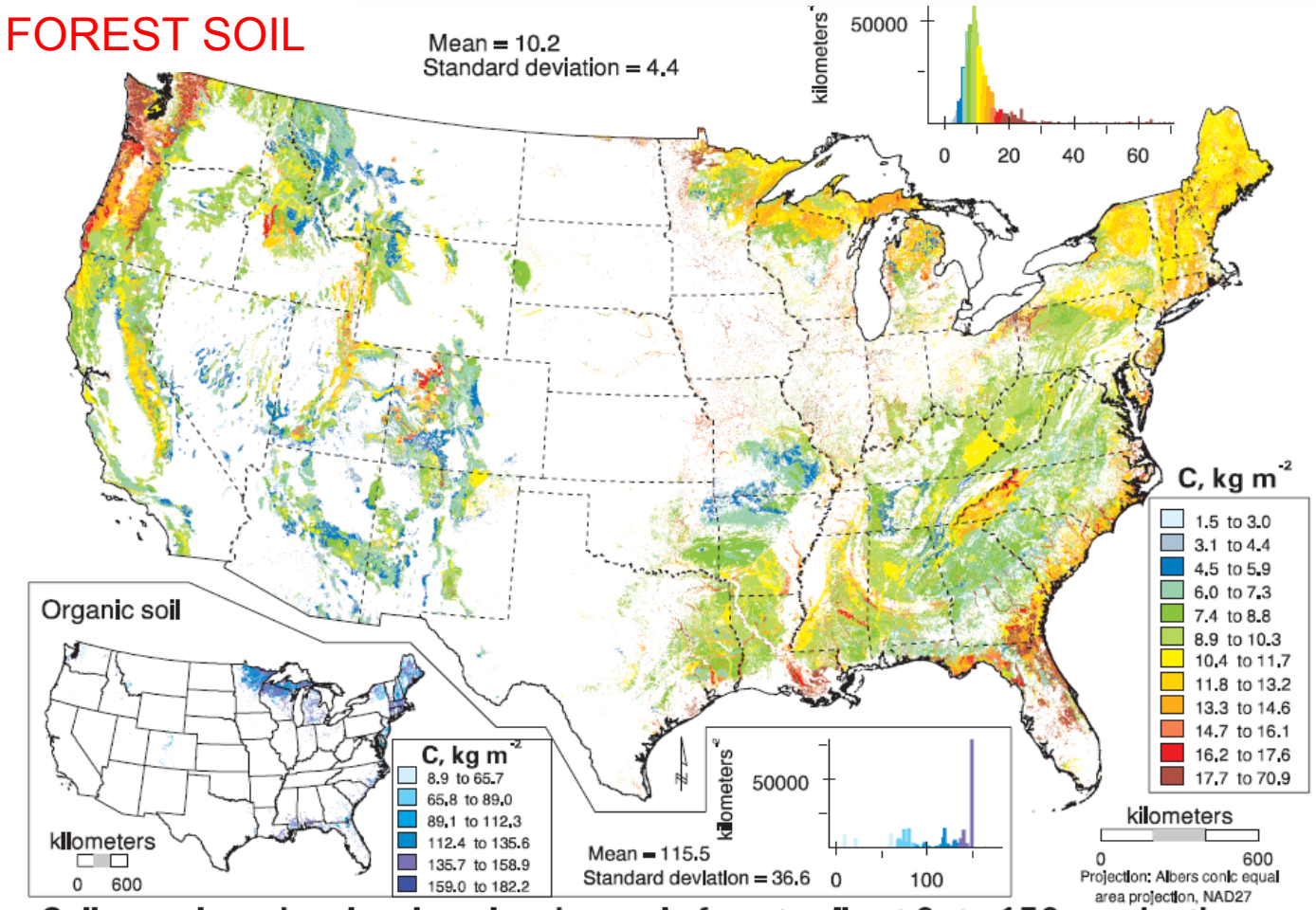
Forest Carbon …US pools



Regions: PNWW (Western OR and WA); PNWE (Eastern OR and WA); PSW (CA); RMN (ID, MT); RMS (AZ, CO, NM, NV, UT, WY); NPS (IA, IL, IN, KS, MO, ND, NE, SD); NLS (MI, MN, WI); NE (CT, DE, MA, MD, ME, NH, NJ, NY, OH, PA, RI, VT, WV); SC (AL, AR, KY, LA, MS, OK, TN, TX); SE (FL, GA, NC, SC, VA).

Data from Smith and Heath 2006.

Forest Carbon …soils



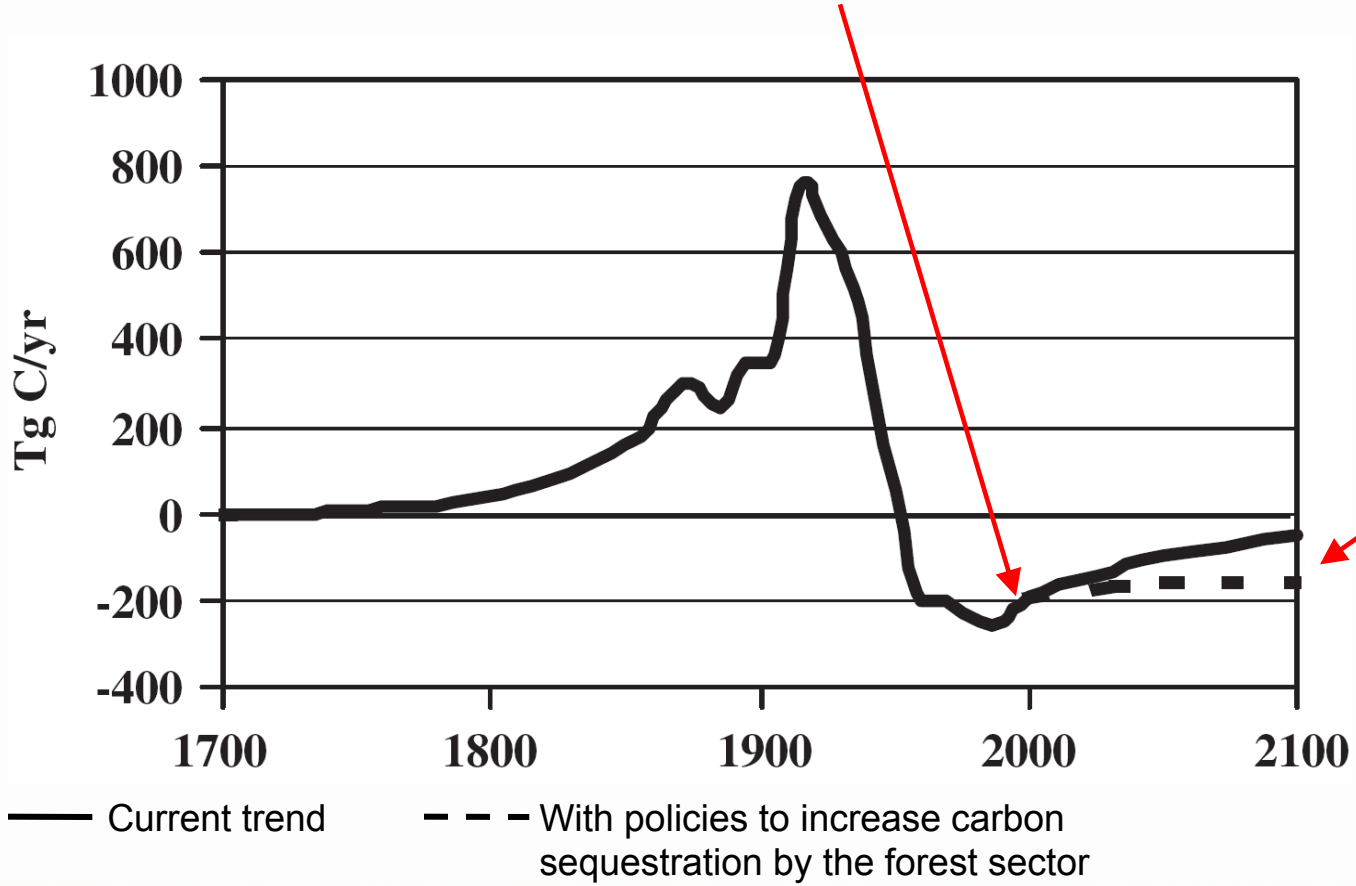
Soil organic carbon in mineral and organic forest soils at 0- to 150-cm depth layer for the contiguous US using STATSGO and NSCD

J.S. Kern, 31 Jan 02

Courtesy of EPA

Forest Carbon …sequestration

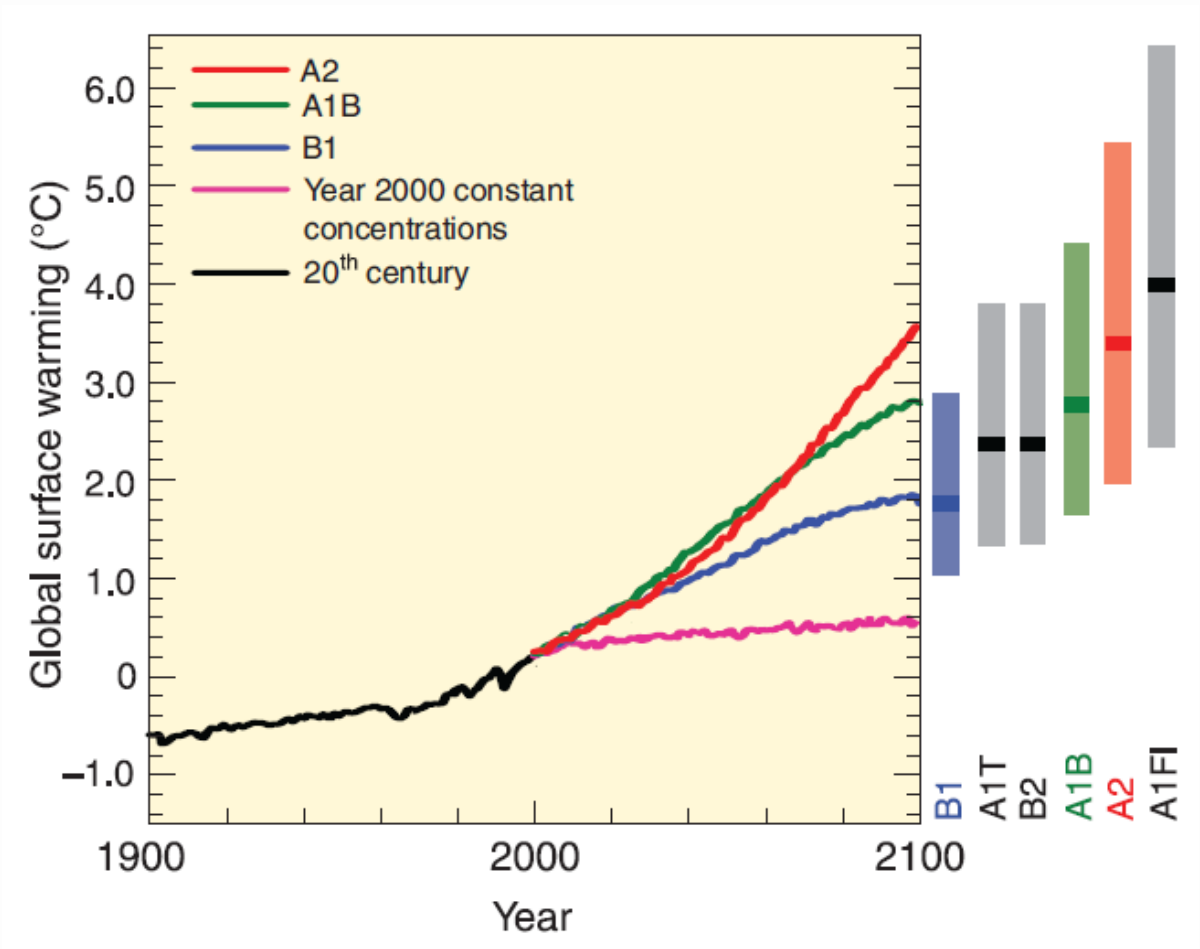
US forests annually sequester the equivalent of 10% of US CO_2 emissions from burning fossil fuels



Forestry activities could remove another 100 to 200 Tg C/yr

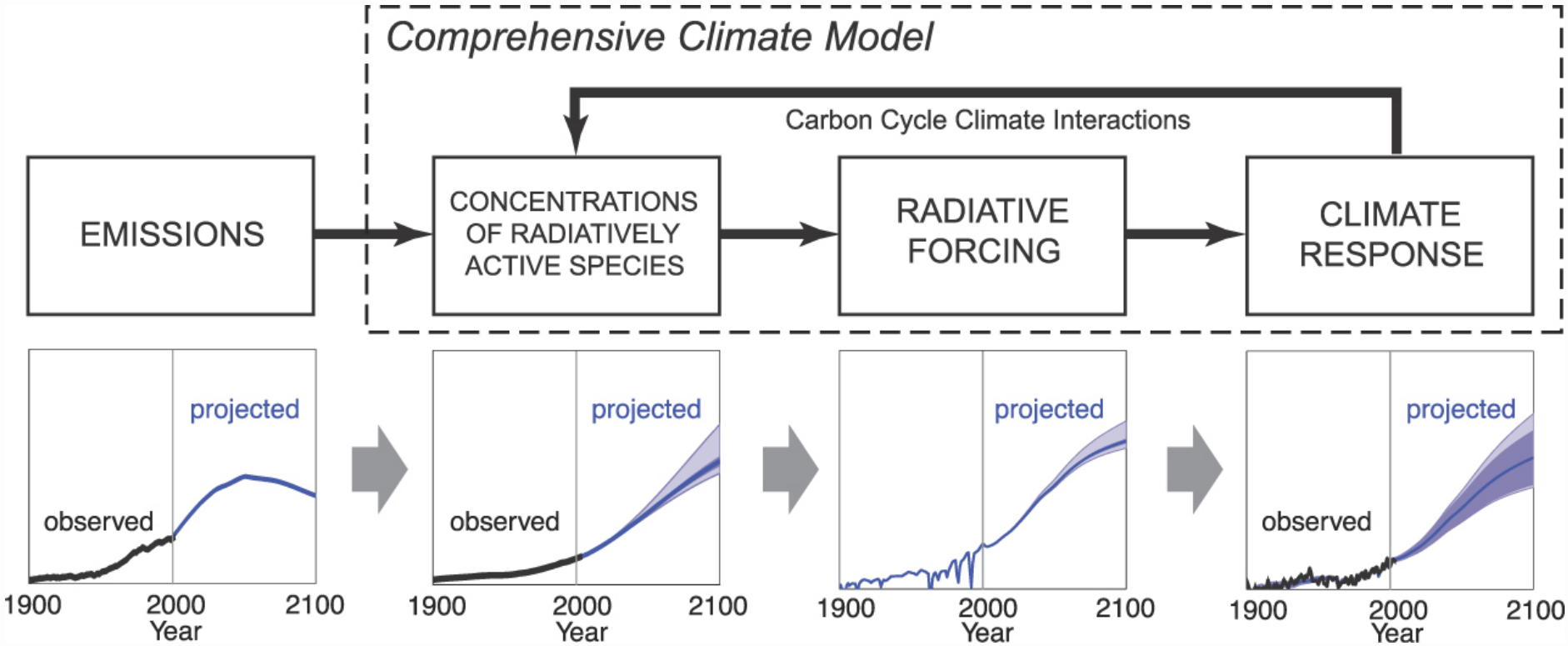
Smith and Heath 2004, EPA 2005, Birdsey et al. 2006

Climate uncertainty …scenarios



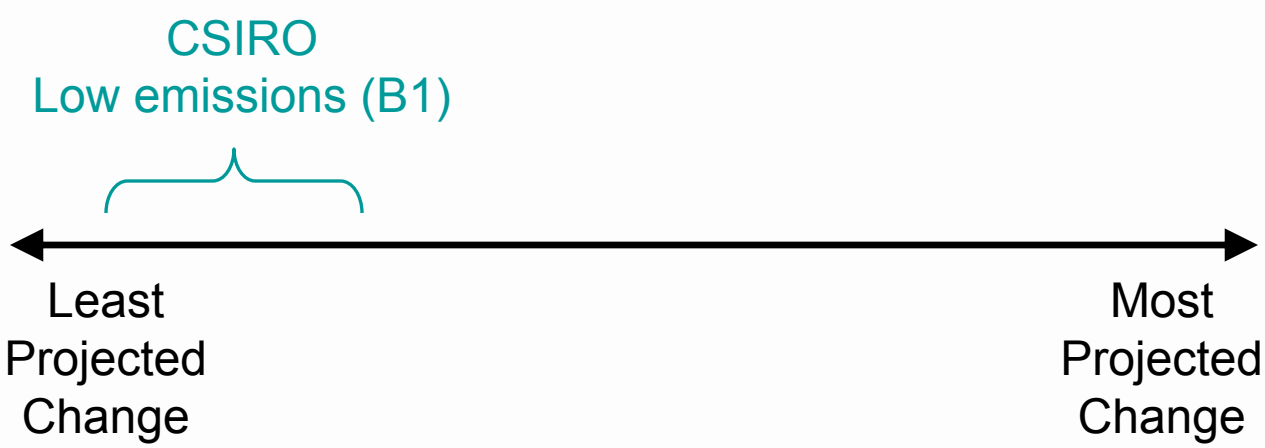
IPCC 2007

Climate uncertainty …feedbacks



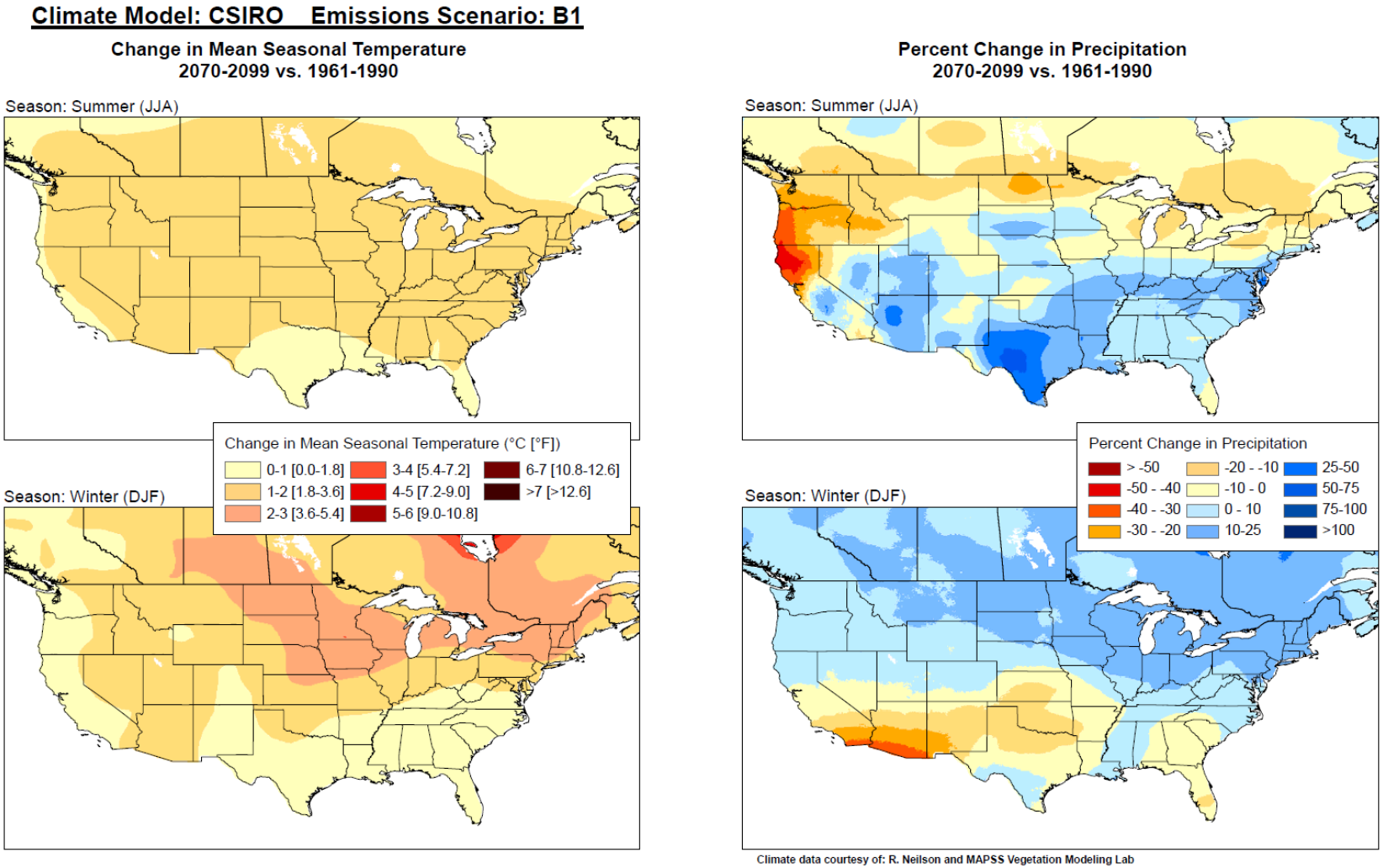
IPCC 2007

Climate uncertainty …simulations



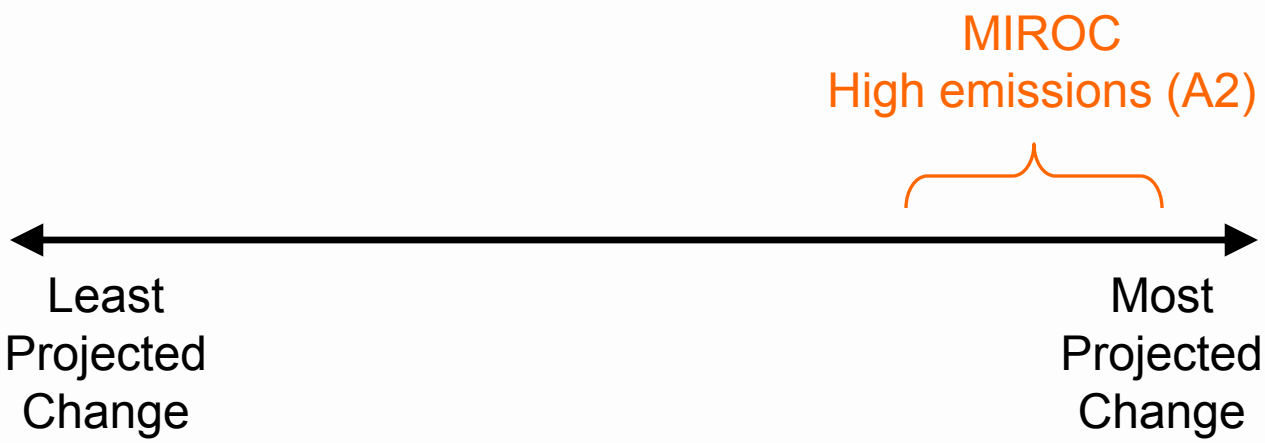
Model with less warming sensitivity to greenhouse gases
Fewer emissions

Climate uncertainty …simulations



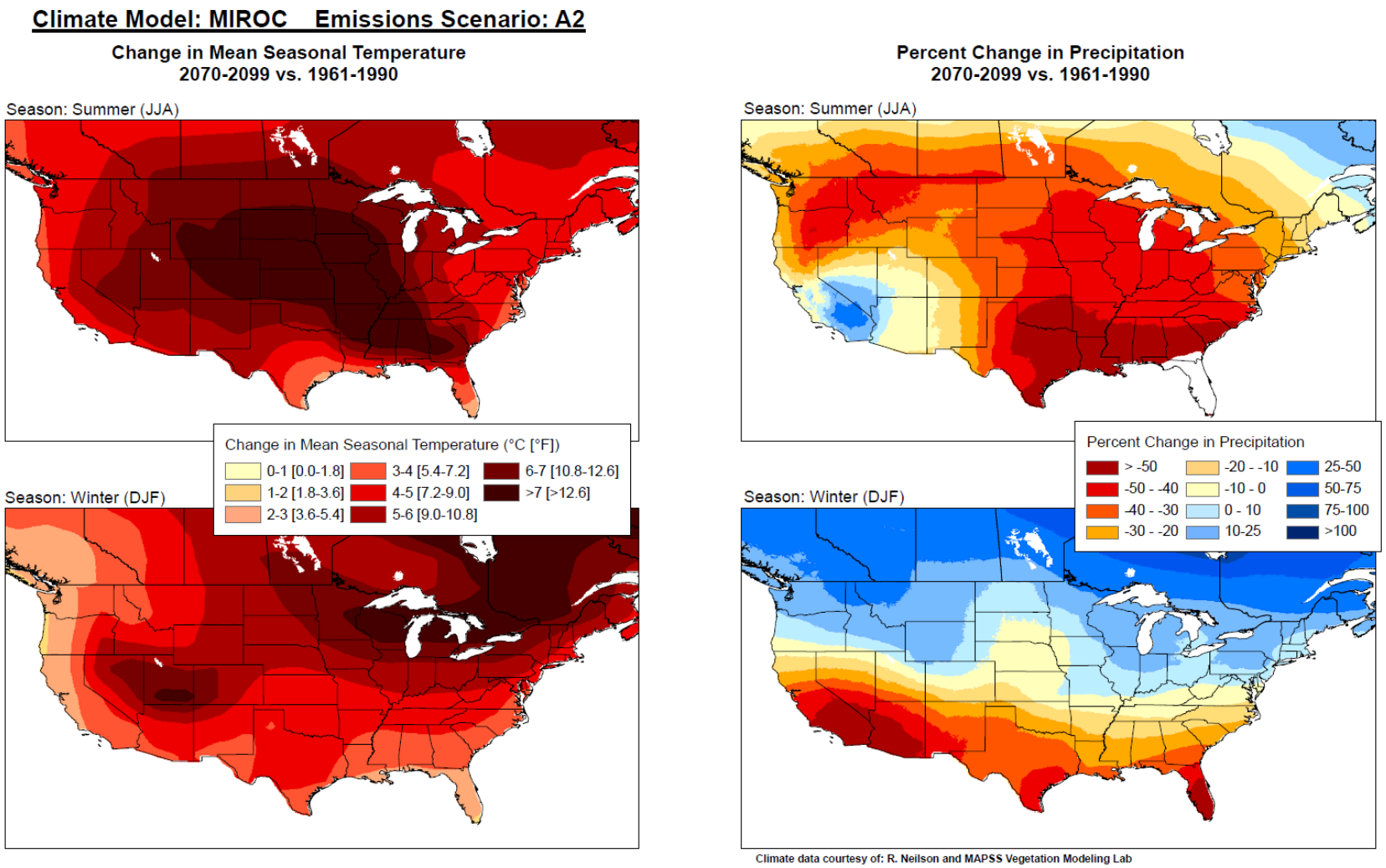
Climate data courtesy of R. Neilson and MAPSS Vegetation Modeling Lab

Climate uncertainty …simulations



Model with more warming sensitivity to greenhouse gases
Higher emissions

Climate uncertainty …simulations



Climate data courtesy of R. Neilson and MAPSS Vegetation Modeling Lab

Climate Change …the positives

Increased forest productivity through:

Climate Change …the positives

Increased forest productivity through:

- Longer growing seasons

McCarty 2001

Climate Change …the positives

Increased forest productivity through:

- Longer growing seasons
  - Evidence of phenological shifts
    - Meta-analysis
    - 677 species (>400 plant spp.)
    - 87% shifted in direction expected by climate change

Parmesan and Yohe 2003

Climate Change …the positives

Increased forest productivity through:

- Longer growing seasons
- Increased precipitation in some regions

IPCC 2007

Climate Change …the positives

Increased forest productivity through:

- Longer growing seasons
- Increased precipitation in some regions
  - Precipitation has increased in the 20th century
    - Not a uniform increase!
    - Wet areas have gotten wetter, and dry areas drier
    - Increases in high latitudes
    - Greater variability in equatorial regions
  - Variability in future projections is very high

Dore 2005, IPCC 2007

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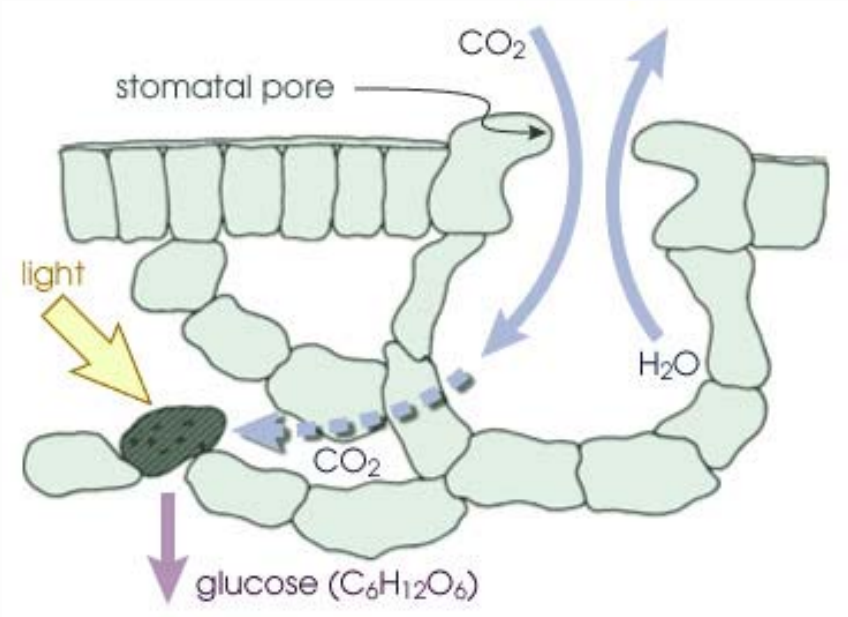
Climate Change …the positives

Increased forest productivity through:

- Longer growing seasons
- Increased precipitation in some regions
- CO_2 fertilization

Climate Change …the positives

CO_2 fertilization:



- Increased photosynthesis
  - More CO_2 in stomatal cavity
  - Greater RuBisCO activity
    - Increased carboxylation
    - Decreased oxygenation
- Reduced stomatal conductance
  - Increase in water use efficiency
- Potential increases in NPP
- Greater biomass (trees: 28%)
- Potential increases in soil inputs

Ainsworth and Long 2005, Jones et al. 2005, Norby et al. 2005, Ainsworth and Rogers 2007

Climate Change …the positives

Increased forest productivity through:

- Longer growing seasons
- Increased precipitation in some regions
- CO_2 fertilization

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization

Climate Change …the negatives

Acclimation of CO_2 fertilization:

- Varies by species and site
- Nutrient deficiencies (especially N)
- Limited sink strength
- Sensitive to ozone pollution (mostly negative)
- Evidence increased NPP and biomass, but limited evidence of long-term sequestration
  - Old trees
  - Wood growth and soil carbon - varies

Oren et al. 2001, Ainsworth and Long 2005, Jones et al. 2005, Norby et al. 2005, Ainsworth and Rogers 2007

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→ The fertilization effect may be transitory – photosynthesis may not stay elevated, ecosystem carbon may not increase.

Oren et al. 2001, Ainsworth and Long 2005, Jones et al. 2005, Norby et al. 2005, Ainsworth and Rogers 2007

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events
  - Wind storms and hurricanes
  - Ice storms
  - Heat waves and droughts
  - Heavy precipitation
  - “Events” are not well modeled

Ciais 2005, WMO 2007, IPCC 2007

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
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- Longer growing seasons

IPCC 2007

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
  - Altered timing of aquifer recharge
  - Potential declines in summer seasonal stream flow
  - Increased drought stress in late summer

Dale et al. 2001, Huntington 2004

Climate Change …the negatives

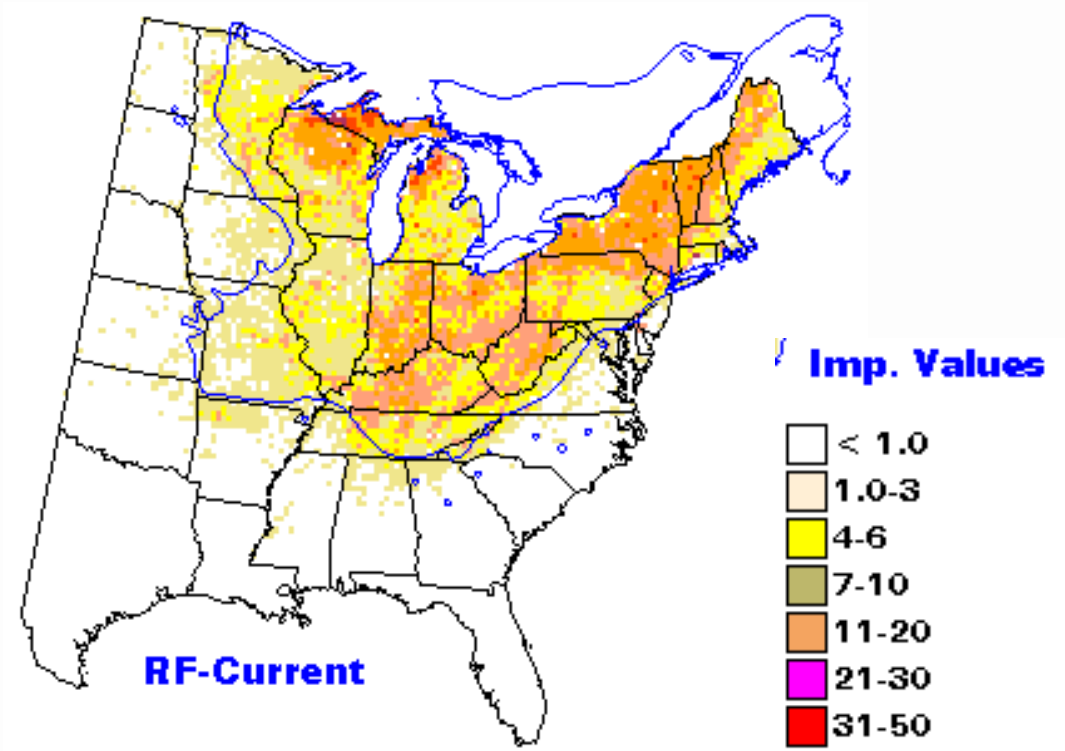
Limits on forest productivity:

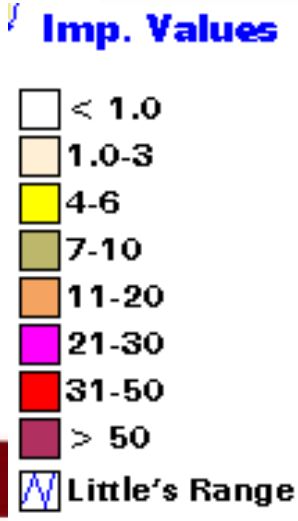
- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Species range shifts

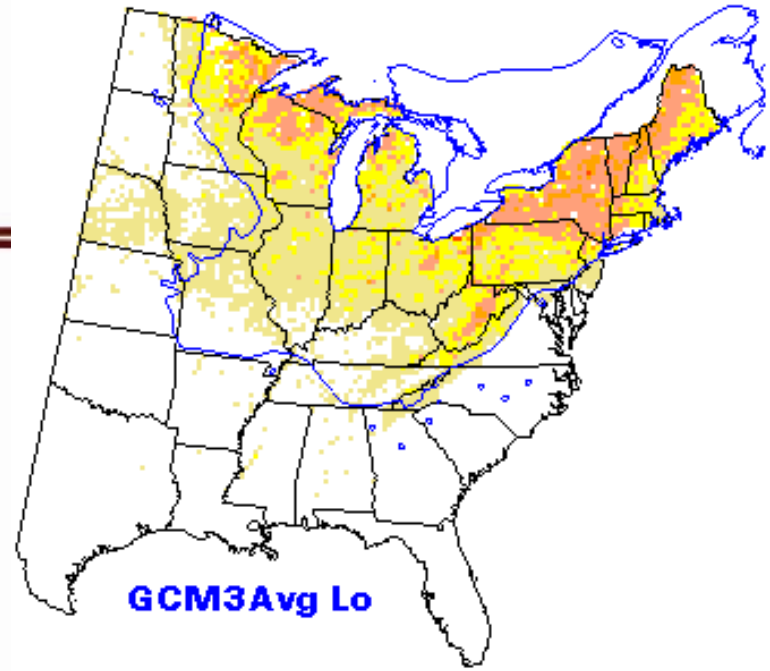
Climate Change

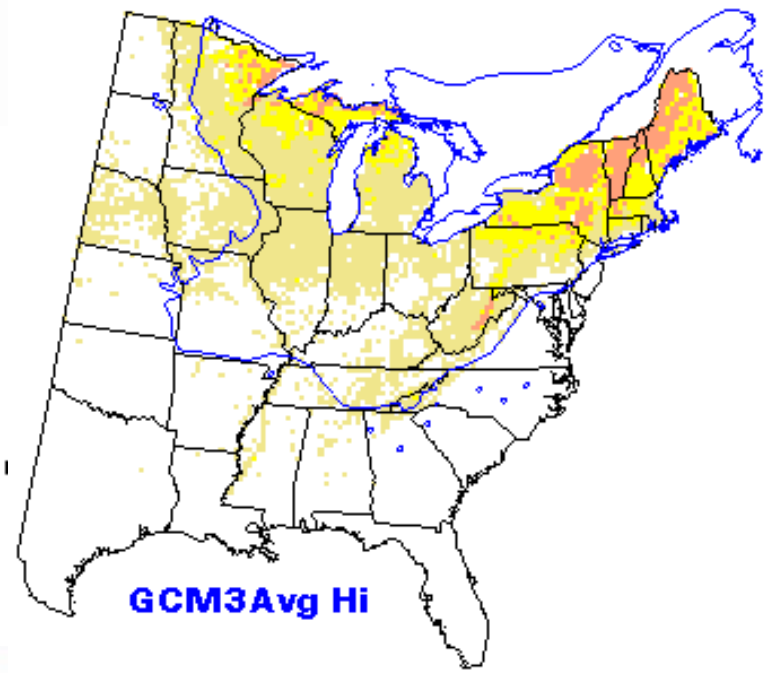
Species range shifts

Sugar maple (decline)









Figures courtesy of Climate Change Atlas Lab

Climate Change …the negatives

Species range shifts:

- Range shifts ≠ instant catastrophic dieback
- Mature trees should fare better
  - Developed root systems
  - Greater carbohydrate reserves
- Stress factors will increase in severity
  - Temperature
  - Moisture
  - Competition
- Increased susceptibility to disturbance

Dale et al. 2001, Iverson et al. 2008

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Species range shifts
- Expanded pest and disease ranges

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Species range shifts
- Expanded pest and disease ranges
  - Pests migrating northward
  - Accelerated lifecycles
  - Decreased probability of lower lethal temperatures

Ayres and Lombardero 2000, Woods et al. 2005, Parmesan 2006

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Species range shifts
- Expanded pest and disease ranges
- Decreased snow pack and early thaw

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Species range shifts
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
  - Early bud break and loss of cold hardening
  - Frost damage during spring freezing

Ayres and Lombardero 2000, Hennon et al. 2006

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Species range shifts
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
- Increased frequency and intensity of fire

Climate Change …the negatives

Increased frequency and intensity of fire:

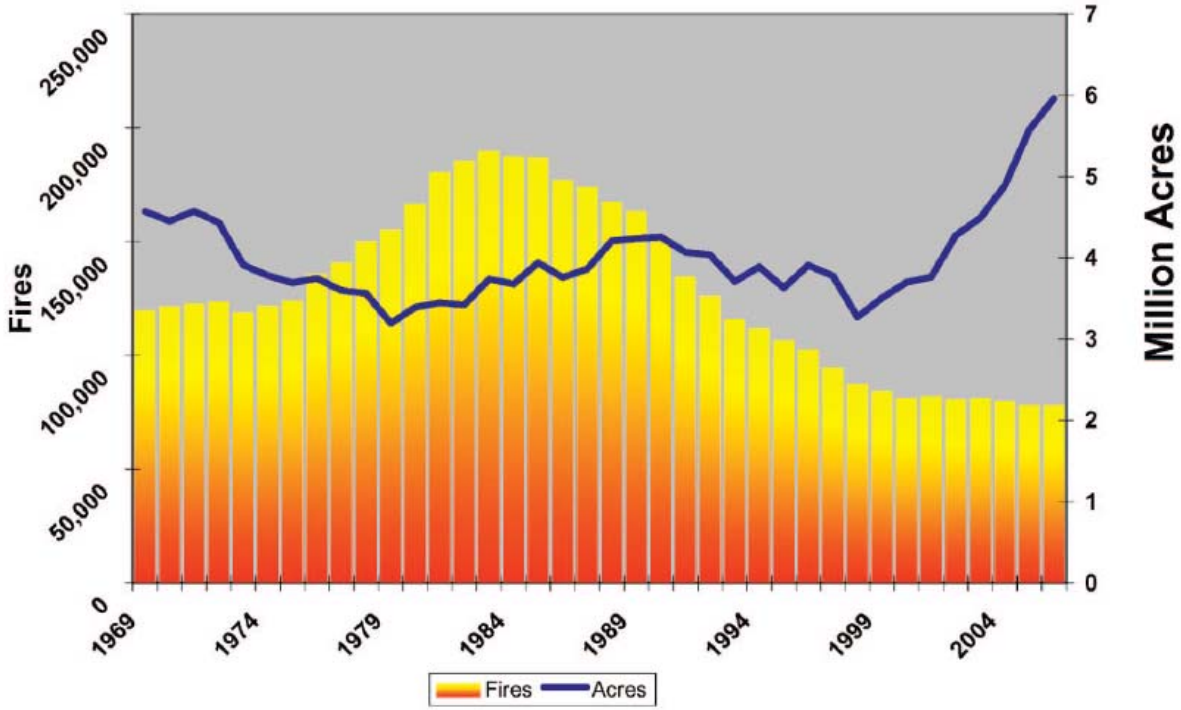


Figure 5-1. Ten-year averages of acres burned and number of fires (Source: Compiled from National Interagency Fire Center 2007).

Climate Change …the negatives

Limits on forest productivity:

- Acclimation to CO_2 fertilization
- Extreme weather events
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→ ***Interactions*** *between these limits are highly likely.*

Climate Change, Forests, and Carbon

Climate is changing. Forests are adapting. What is our role?

- Precipitation
- Temperature
- CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Species range shifts
- Expanded pest and disease ranges
- Decreased snow pack and early thaw
- Increased frequency and intensity of fire

Change – maybe.
Stress – yes.

Consider local species, trends, and landscape!

Synthesis exercise …Wisconsin

Climate Change Response Framework Project

Northern Research Station

Lead: Chris Swanston (also NIACS)

Collaborators: Rich Birdsey, Louis Iverson, Sarah Hines

Chequamegon-Nicolet National Forest

Lead: Tony Erba (formerly Jeanne Higgins)

Collaborators: Geoff Chandler, Linda Parker, Matt St. Pierre, Suzanne Flory, Connie Chaney

Eastern Region Regional Office

Lead: Tom Doane

Northeastern Area State and Private Forestry

Lead: Barbara Tormoehlen

Collaborators: Gina Childs, Sarah Hines

Northern Institute of Applied Carbon Scier

Project Coordinator: Maria Janowiak

Collaborators: Leslie Brandt, Patricia Butler

University of Wisconsin-Madison

Lead: David Mladenoff

Additional Collaborators

Avery Dorland (Wisconsin Department of Nat. Res

Wisconsin Initiative on Climate Change Impacts (WICCI)

Synthesis exercise …Wisconsin

- Risk will be greater in low diversity ecosystems
  - Low species diversity
  - Low functional diversity
    - Reliance on saturated soils (e.g., lowland conifers)

Synthesis exercise …Wisconsin

- Risk will be greater in low diversity ecosystems
- Disturbance will destabilize static ecosystems
  - Low resilience
    - Lowland conifers, lowland hardwoods, and hemlock

Synthesis exercise …Wisconsin

- Risk will be greater in low diversity ecosystems
- Disturbance will destabilize static ecosystems
- Greater problems for species already in decline
  - Mostly from reduced habitat suitability
    - hemlock, white cedar, yellow birch, and white spruce

Synthesis exercise …Wisconsin

- Risk will be greater in low diversity ecosystems
- Disturbance will destabilize static ecosystems
- Greater problems for species already in decline
- Resilience may be weakened in fragmented ecosystems
  - Isolated fragments may not adapt as easily as continuous areas
  - Smaller patch sizes support less species and genetic diversity
  - Greater inhibition of dispersal

Synthesis exercise …Wisconsin

- Risk will be greater in low diversity ecosystems
- Disturbance will destabilize static ecosystems
- Greater problems for species already in decline
- Resilience may be weakened in fragmented ecosystems
- Further reductions in habitat will impact threatened, endangered, and rare species
  - Often rare due to specific habitat requirements or low resilience

Synthesis exercise …Wisconsin

- Risk will be greater in low diversity ecosystems
- Disturbance will destabilize static ecosystems
- Greater problems for species already in decline
- Resilience may be weakened in fragmented ecosystems
- Further reductions in habitat will impact threatened, endangered, and rare species
- Ecosystem changes will have significant effects on wildlife
  - Spruce grouse – dependent on black spruce, jack pine, balsam fir

Synthesis exercise …Wisconsin

- Risk will be greater in low diversity ecosystems
- Disturbance will destabilize static ecosystems
- Greater problems for species already in decline
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- Ecosystem changes will have significant effects on wildlife

Key concept: Beware of generalities!

Consider local species, trends, and landscape!

Summary

- Climate change and forests; the same old stresses, but worse.
- Future change is uncertain in severity, but certainly coming.
- We know enough to begin planning and communicating…*now*.

Thank you!