Interactions between carbon, climate, and forests

Northeastern Area State & Private Forestry
Northern Research Station
Climate Change Continuing Education Webinar Series
14 January 2009

Northern Institute of Applied Carbon Science

Northern Research Station
USDA Forest Service

Climate, Fire, and Carbon Cycle Sciences Group

Contributors

"Forest Management for an Uncertain Climate Future"
→ Funded by the USFS Global Change Program

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  Maria Janowiak

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Introduction …outline

- Climate change overview
- Global carbon cycle
- Forest carbon
  - Distribution and density
- Climate change and forests
  - Benefits to forest productivity
  - Deleterious effects on forest productivity

Climate Change …overview

- Global climate is changing
  - Intergovernmental Panel on Climate Change (2007)
    - Evidence for climate change is ‘unequivocal’
    - It is “extremely likely” that humans are major contributors
    - Future changes depend partly on human actions
  - World Meteorological Organization (2007)
    - “2007 amongst 10 warmest years on record”
    - 8 of 10 warmest years on record were in this decade
- Regional changes are variable and more uncertain
  - Precipitation
  - Temperature
  - Extreme weather events

Climate Change …warming trend

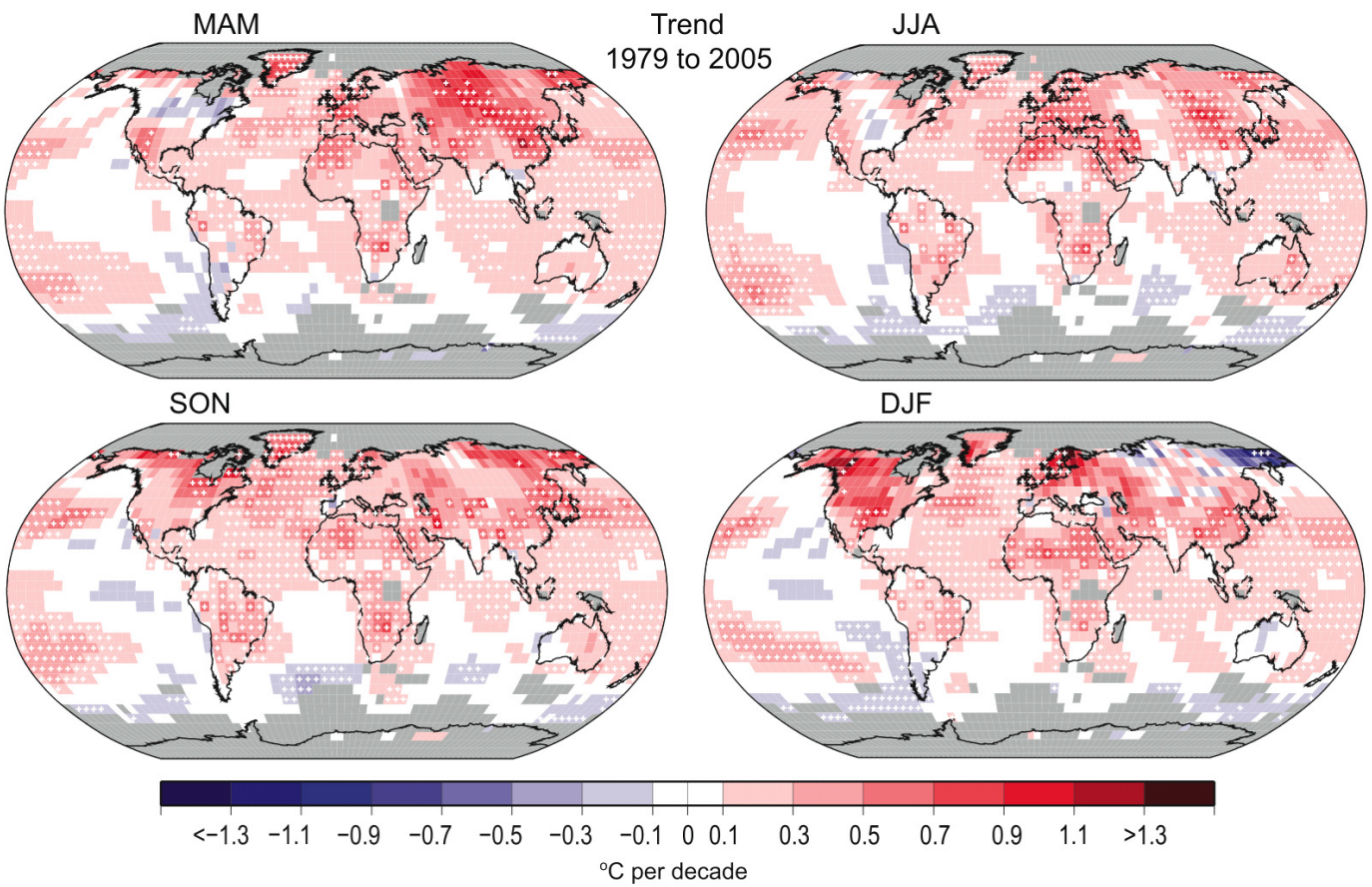


Figure 3.10

IPCC 2007

Climate Change …precipitation trend

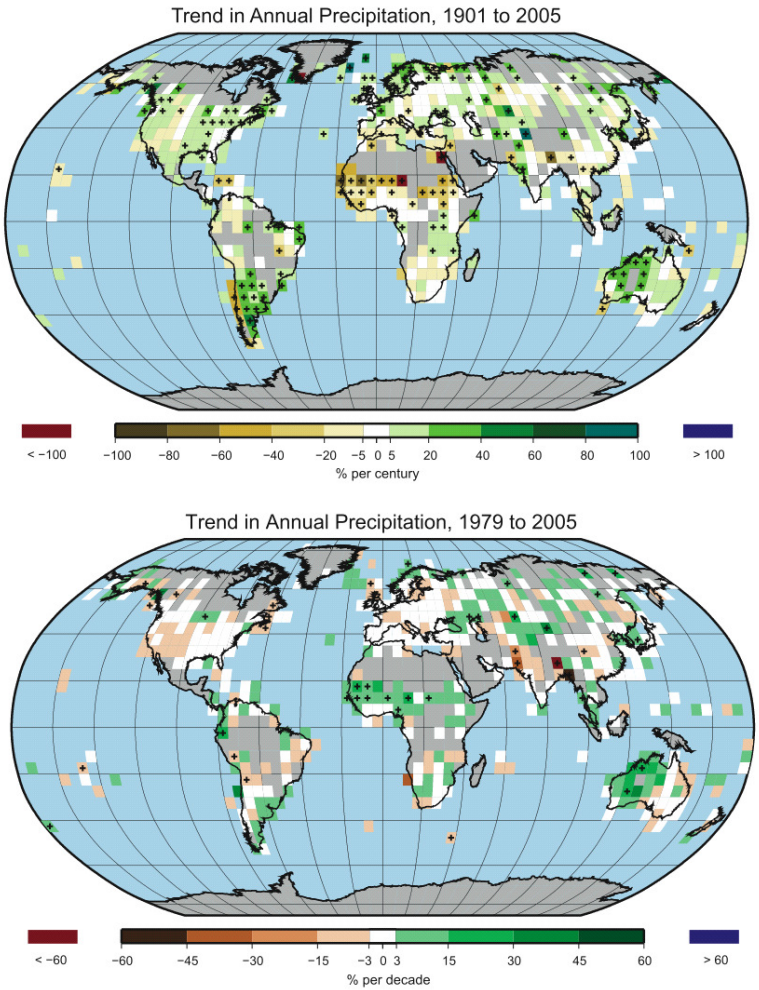
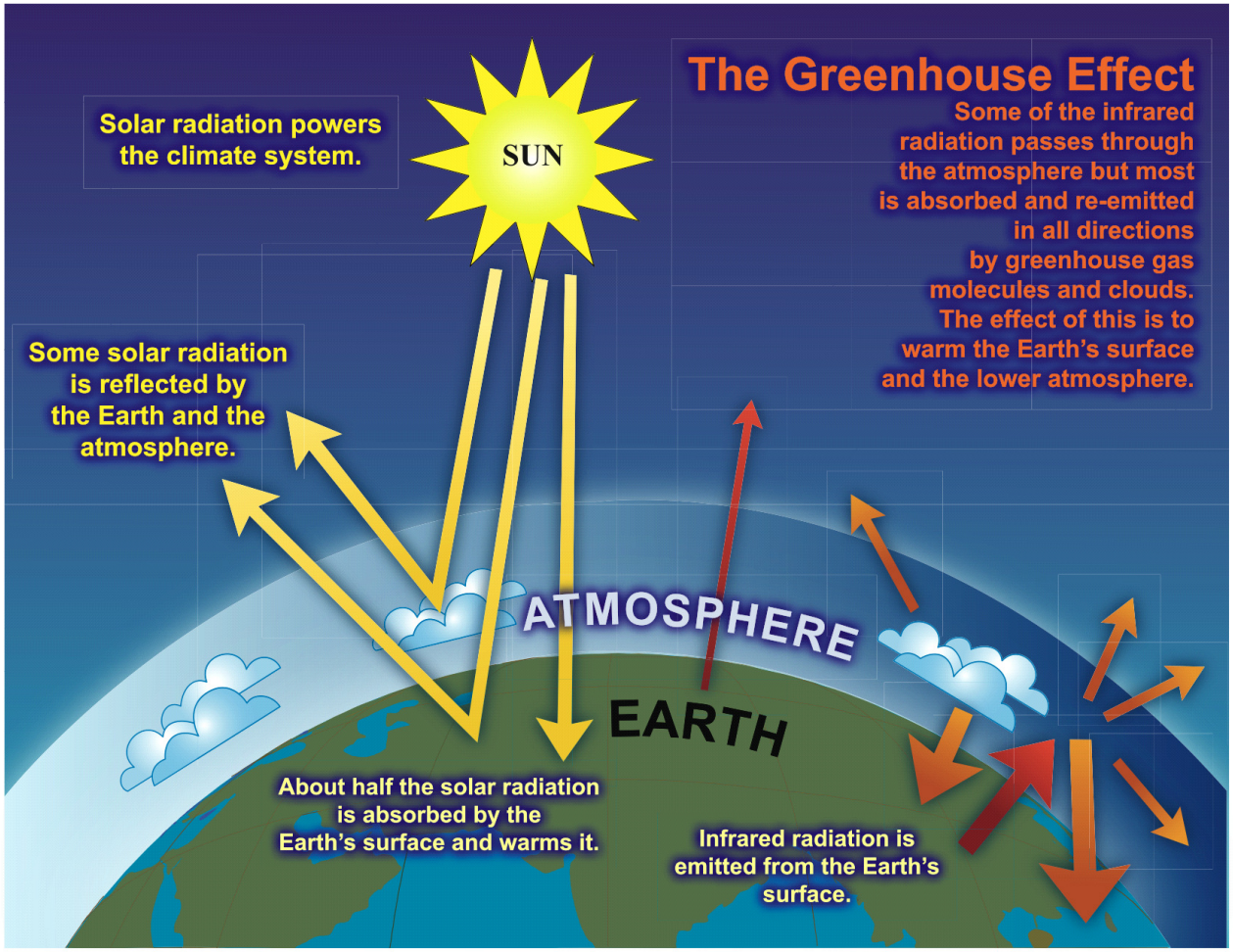


Figure 3.13

Climate Change …greenhouse effect



IPCC 2007

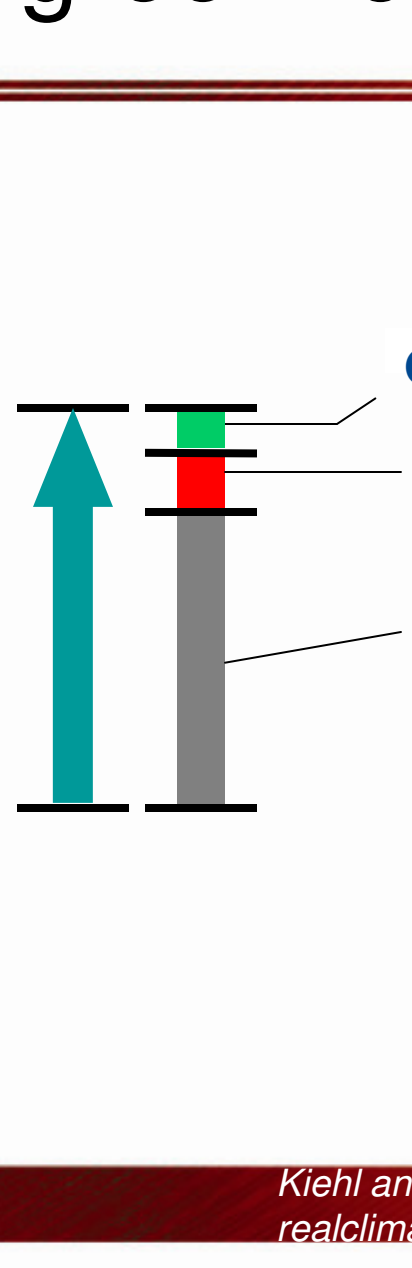
Climate Change …greenhouse effect

Average Surface Temperature

+57 °F

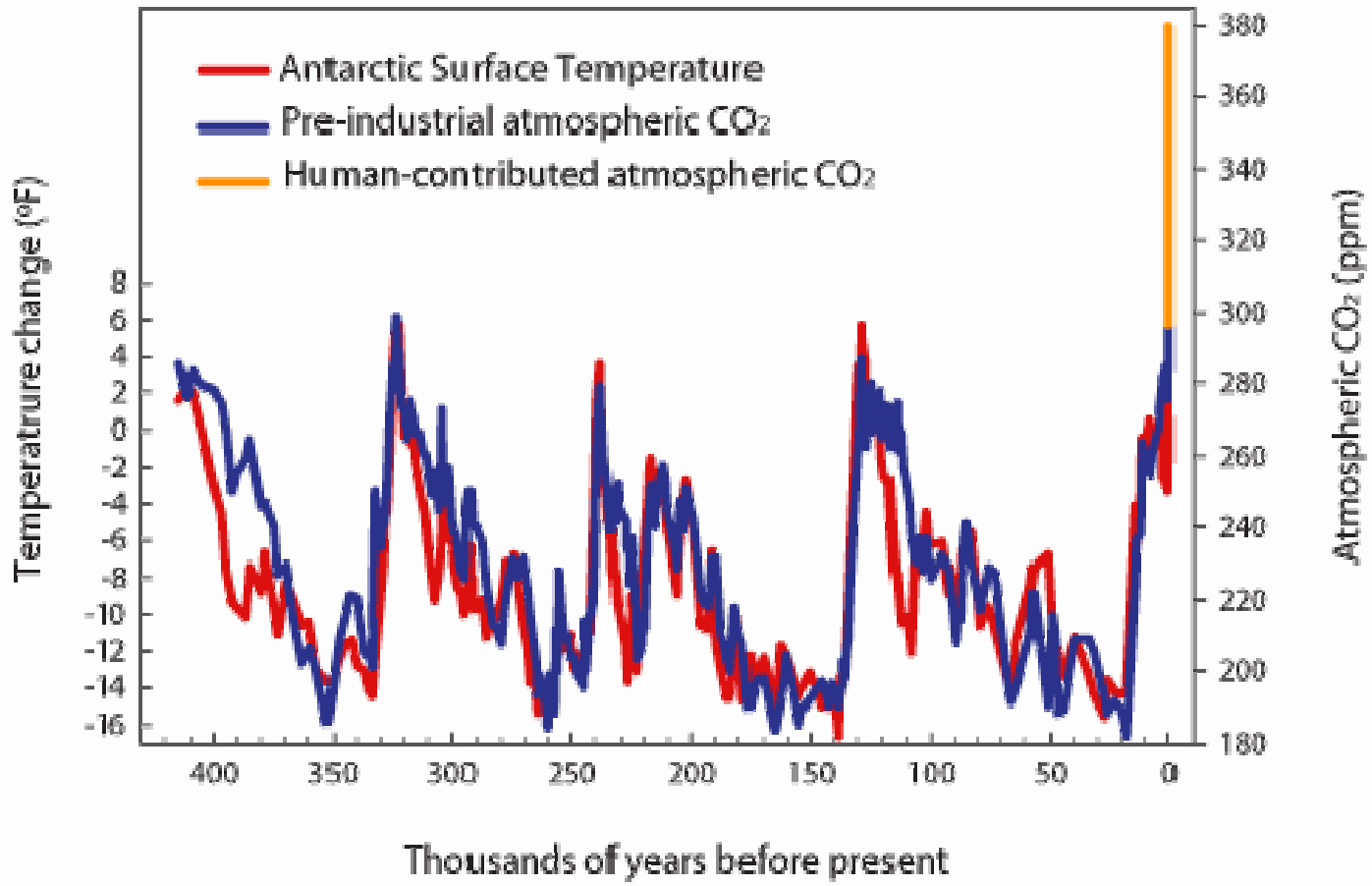
Temperature without greenhouse effect

-0.4 °F



Kiehl and Trenberth 1997, realclimate.org (G. Schmidt, NASA)

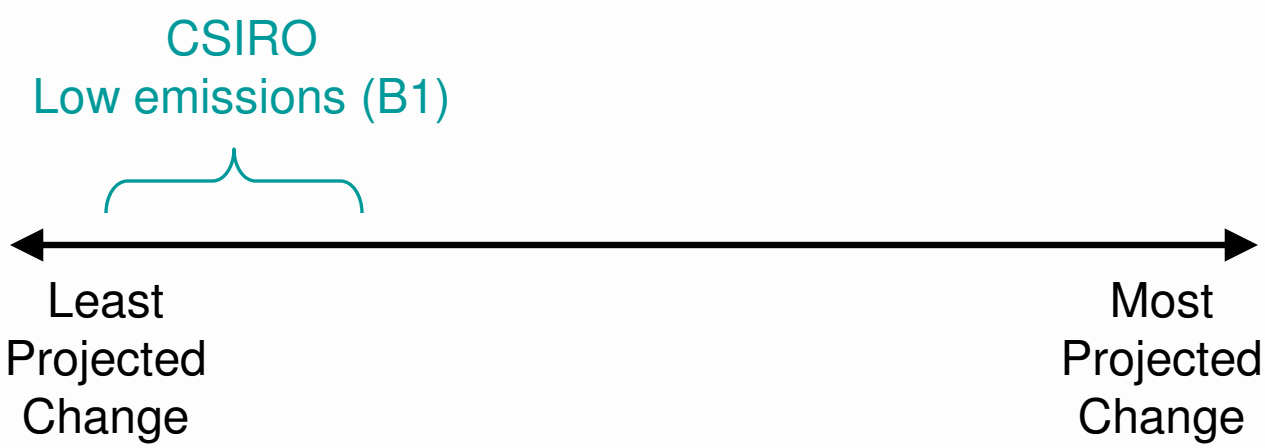
Climate Change …greenhouse effect



Courtesy of The Pew Center on Climate Change

Climate Change …simulations

Uncertainty in future precipitation simulations:



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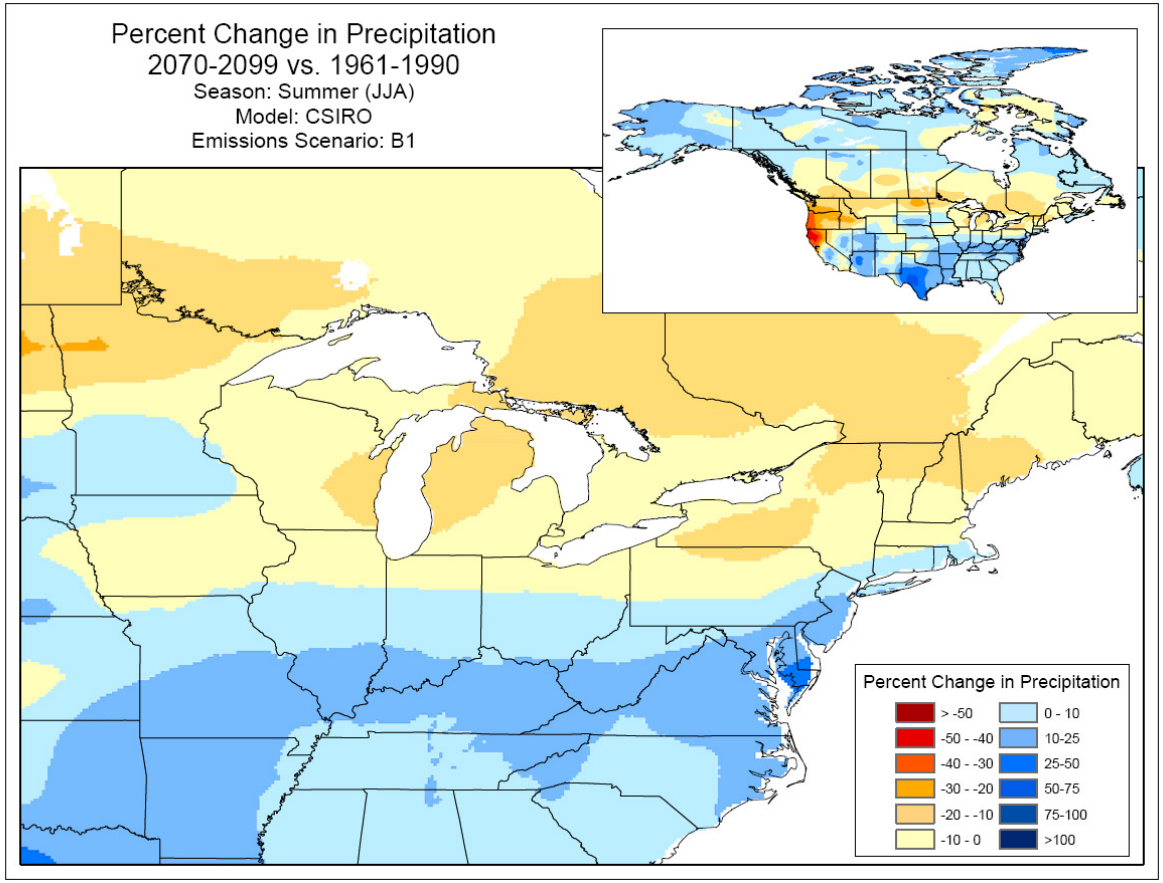

Climate data courtesy of R. Neilson and MAPSS Vegetation Modeling Lab

Climate Change …simulations

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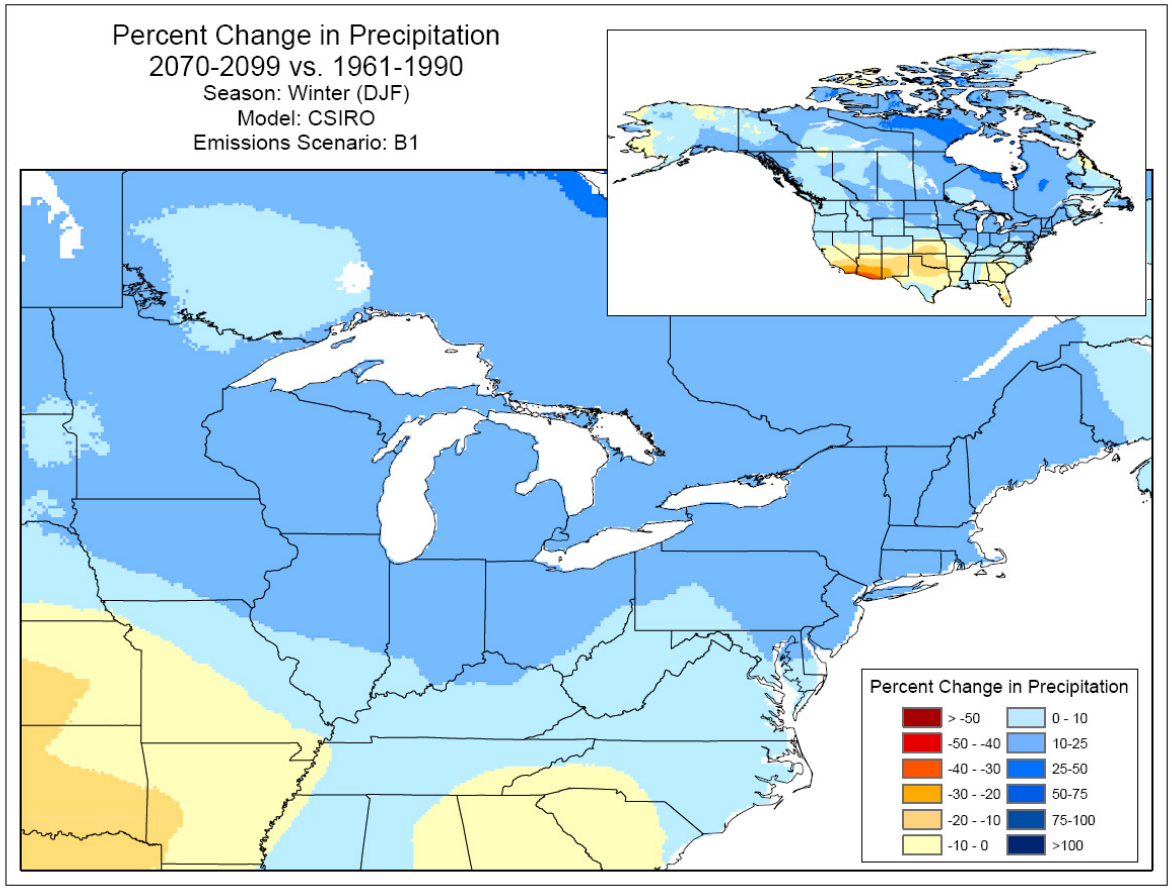

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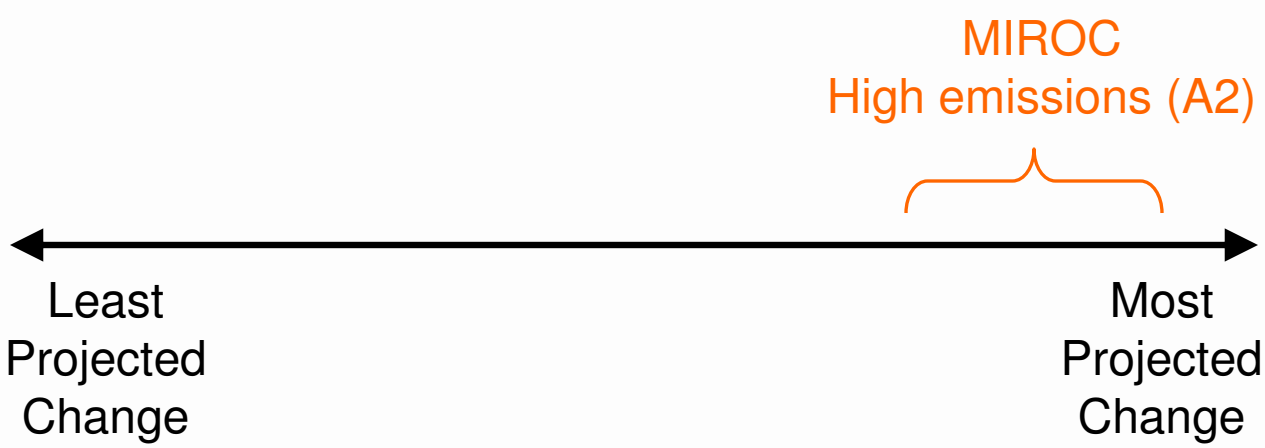

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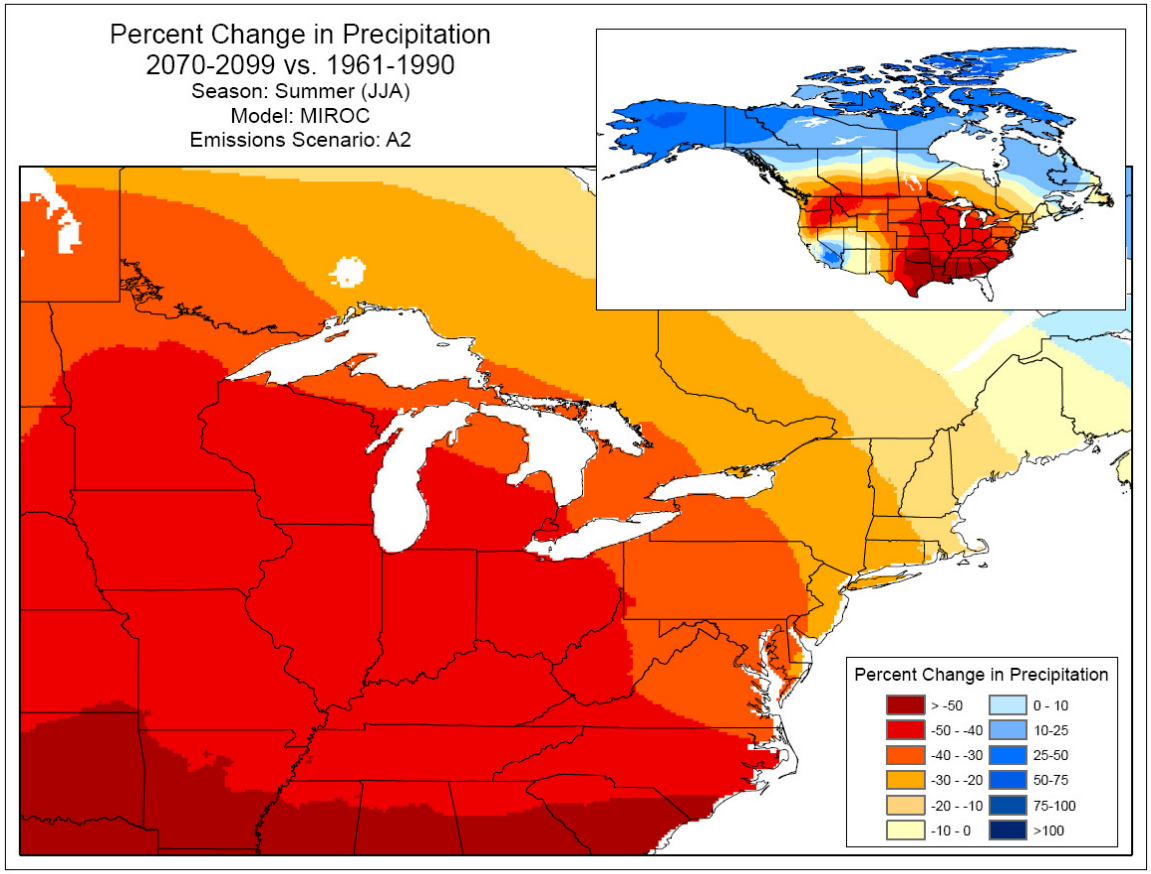

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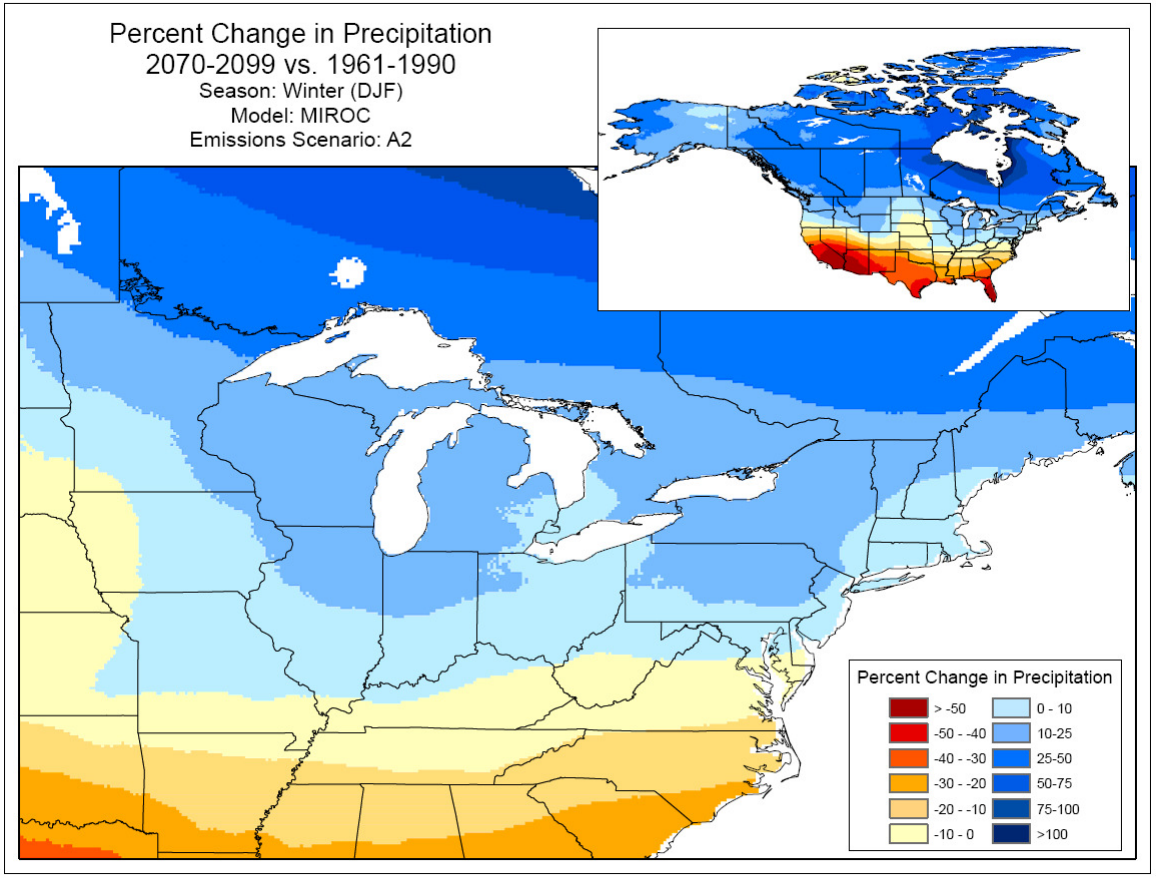

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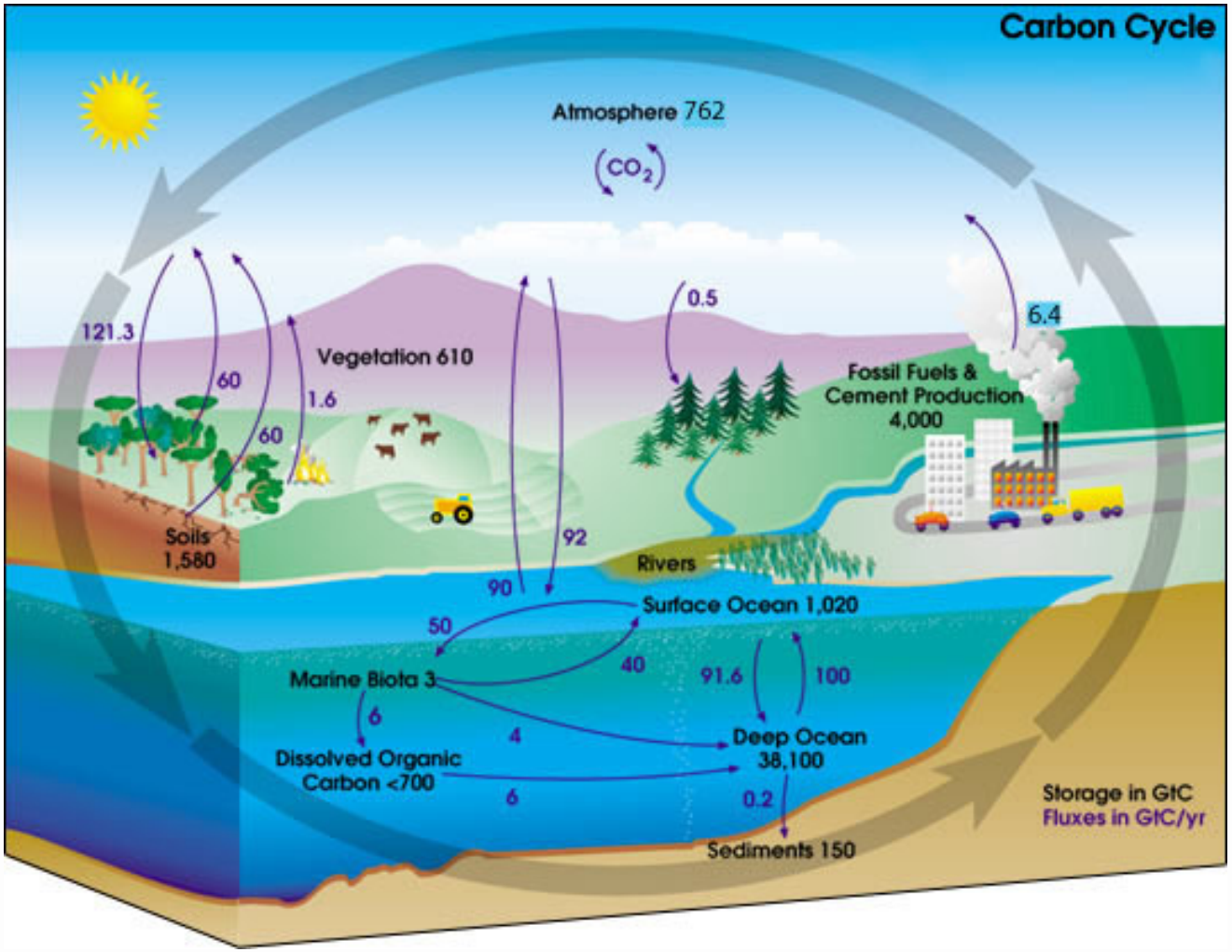
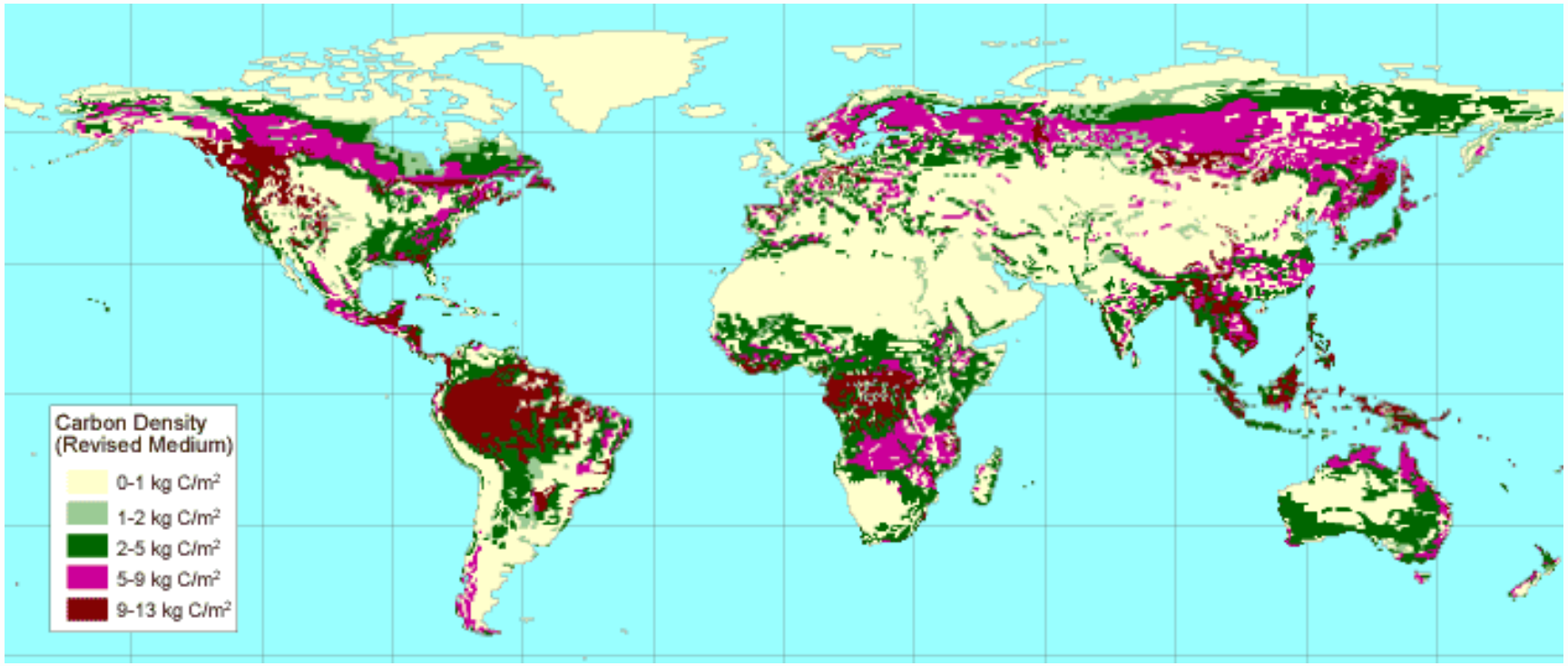
Global Carbon …pools and cycles



Courtesy of NASA (modified)

Forest Carbon …global density

Carbon density in live vegetation



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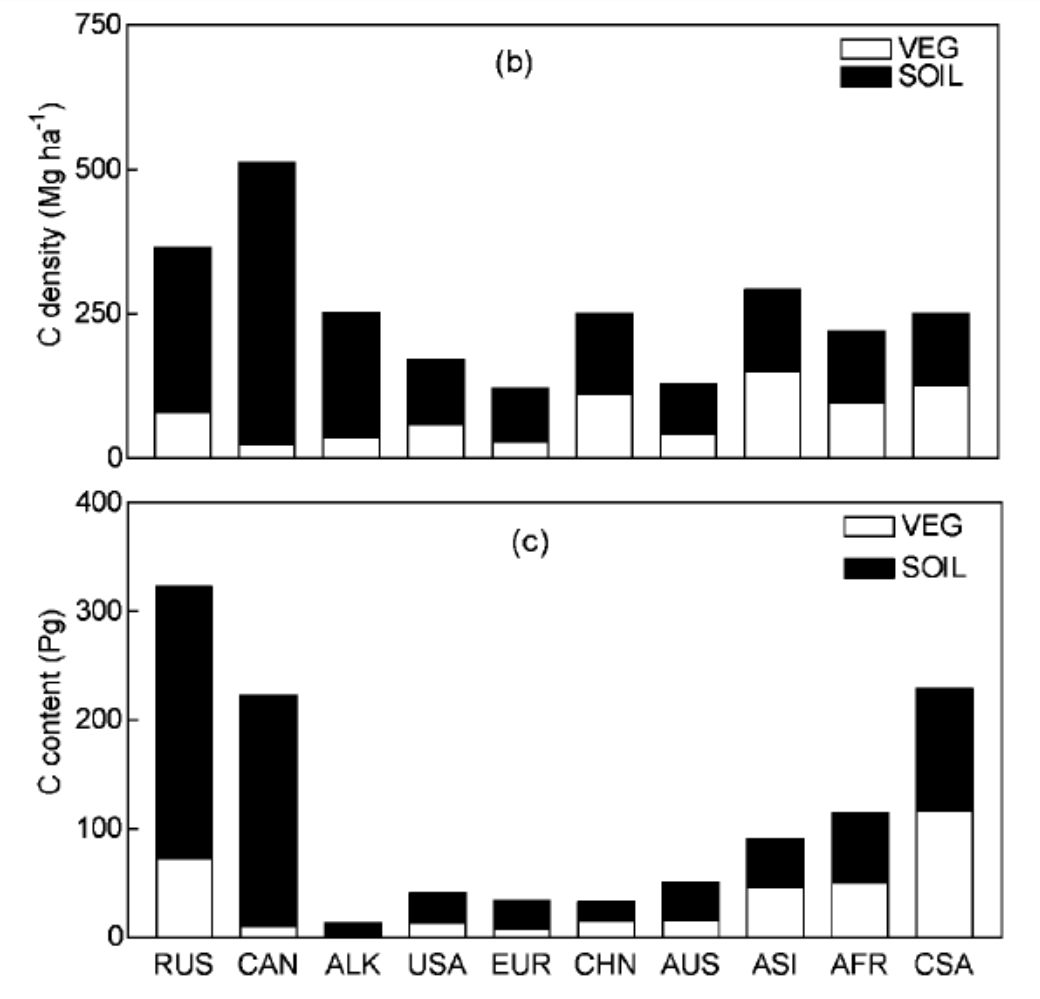
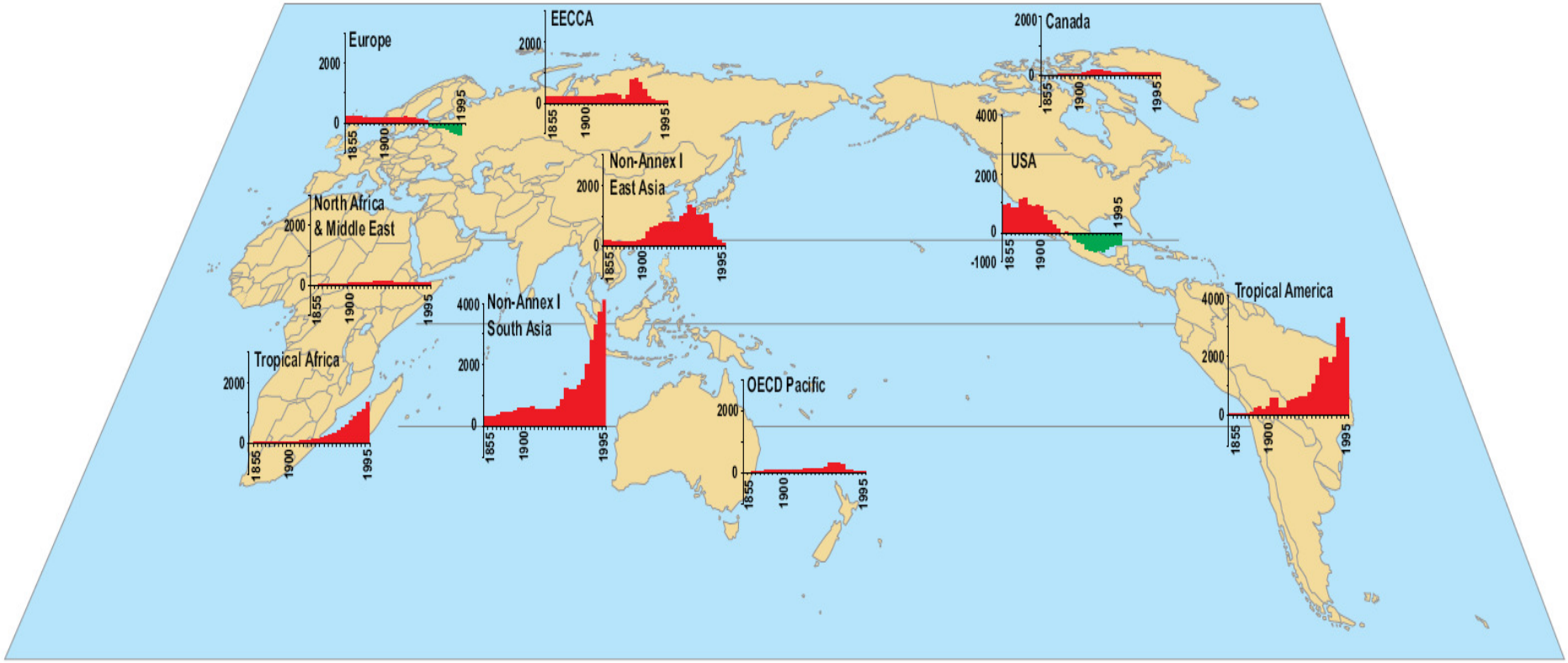


Gower 2003

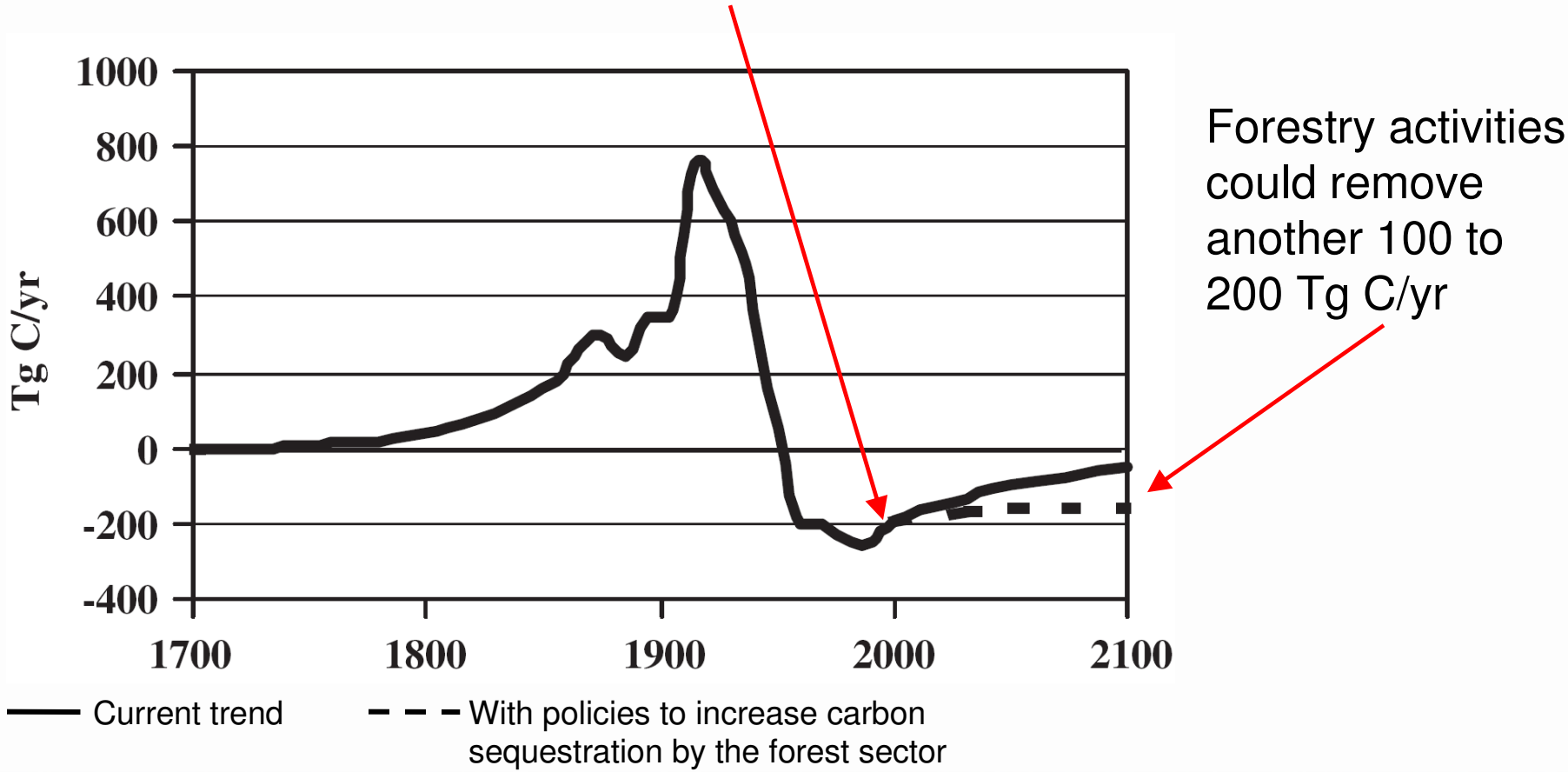
Forest Carbon …global trends

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



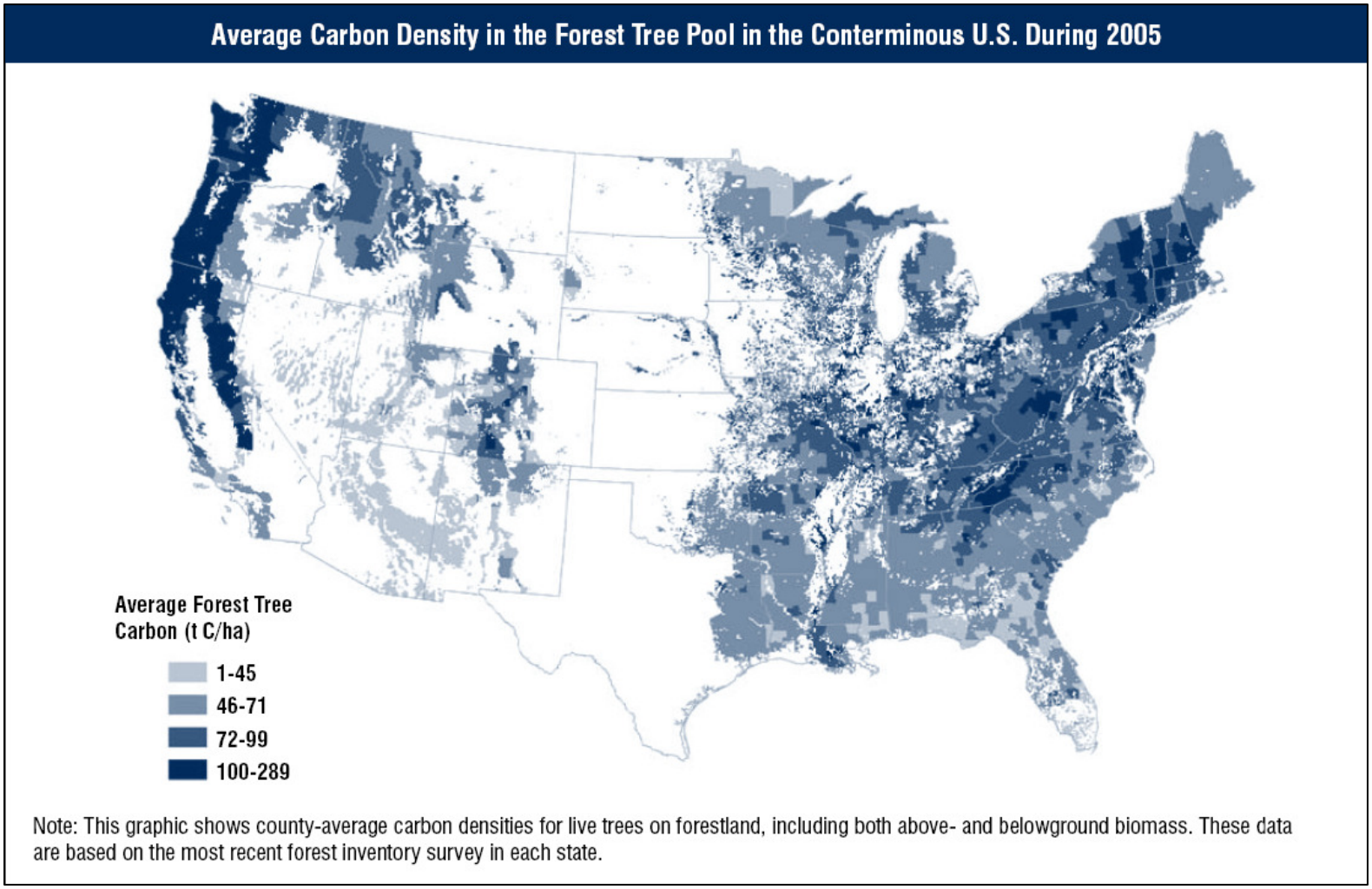
Forest Carbon …US trends

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



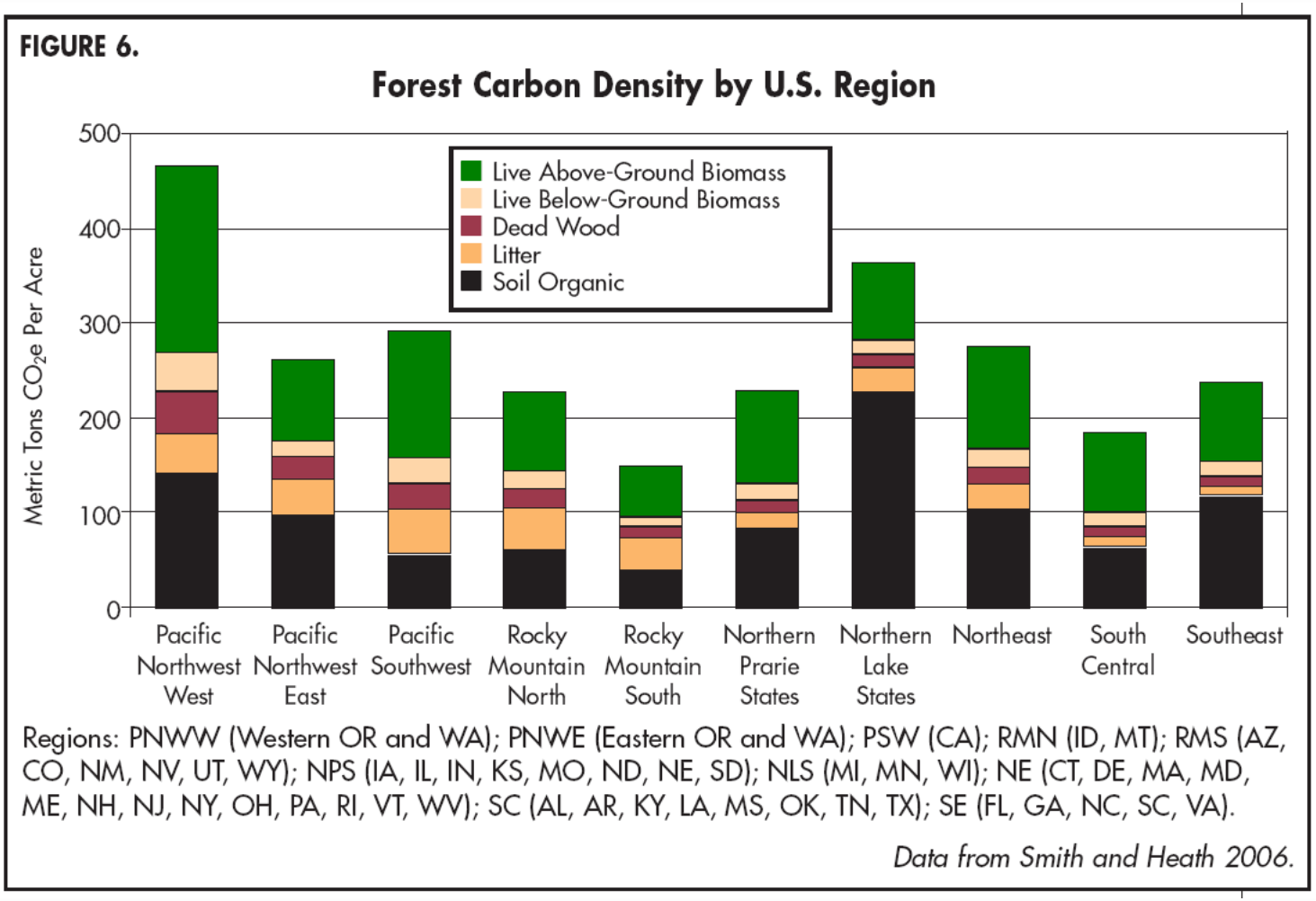
Smith and Heath 2004, EPA 2005, Birdsey et al. 2006

Forest Carbon …US density

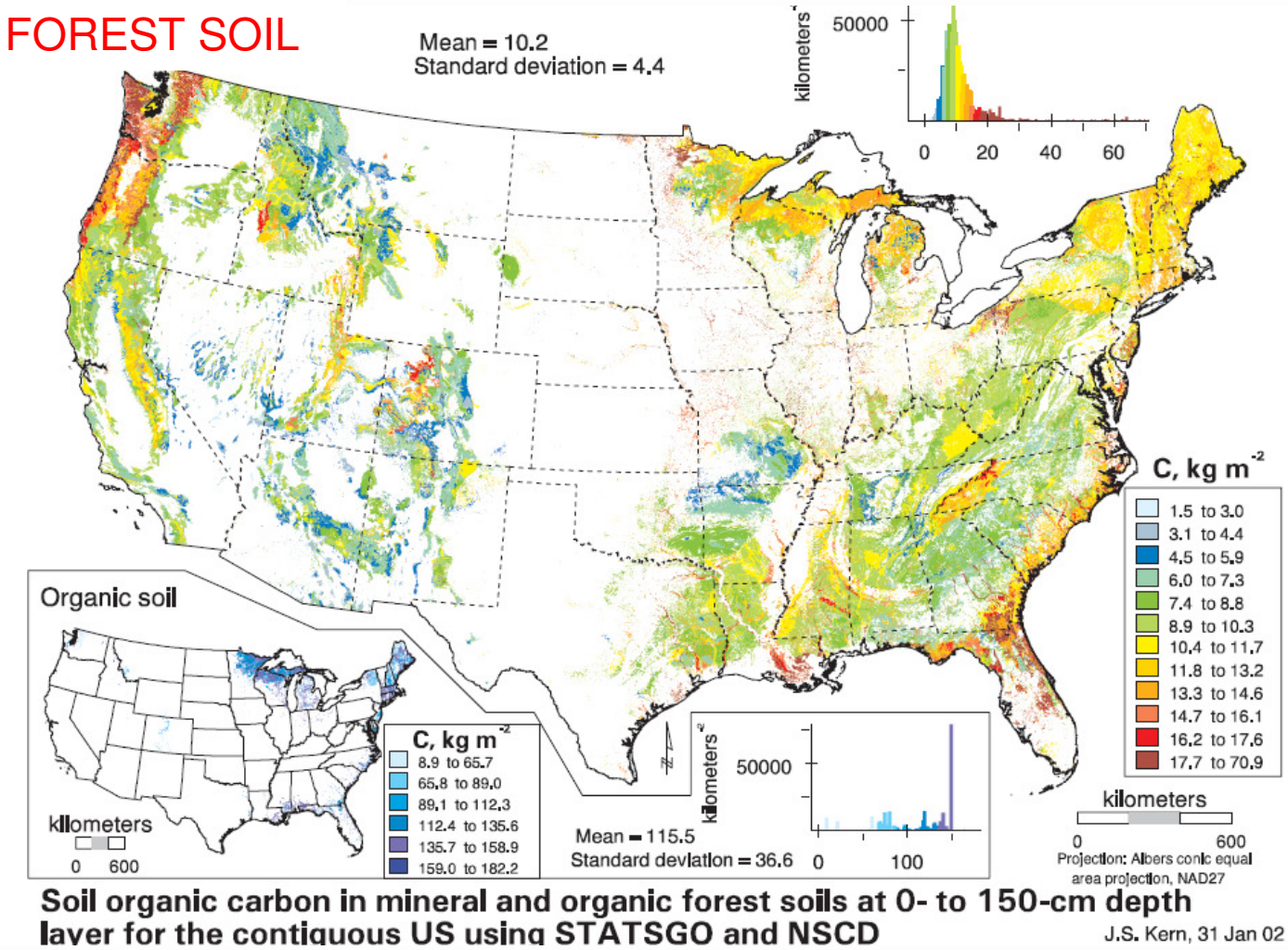


EPA 2006

Forest Carbon …US pools



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

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

Climate Change …the positives

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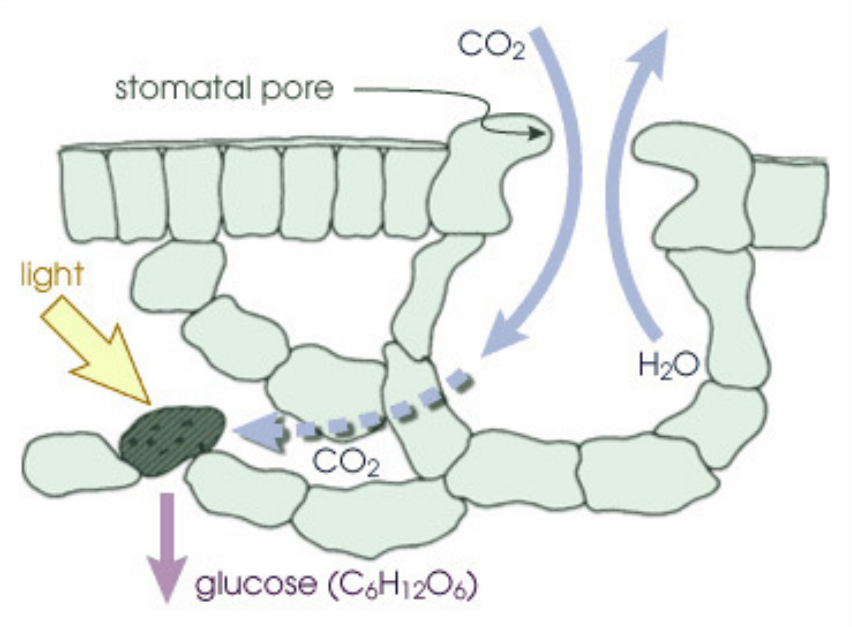
Climate Change …the positives

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 (+/-)
- 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
- Extreme weather events
- 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

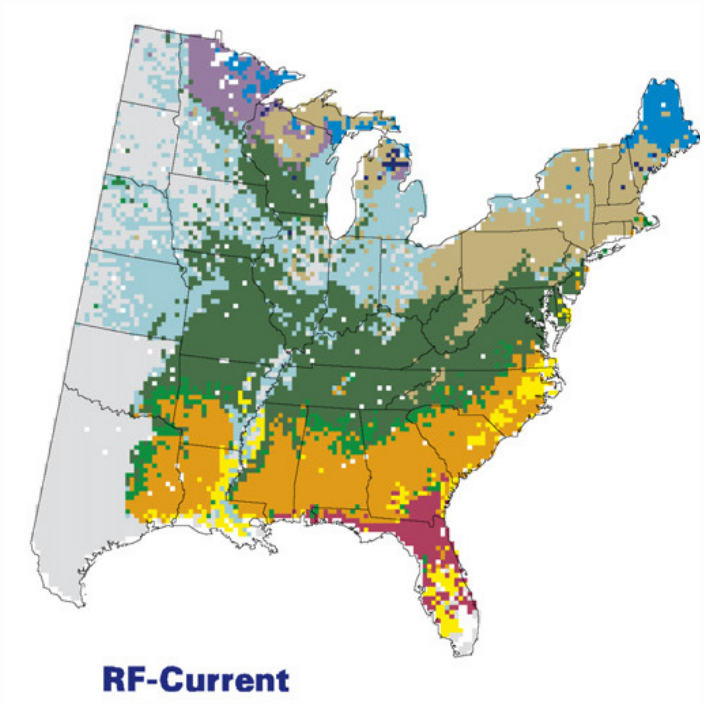
Climate Change …the negatives

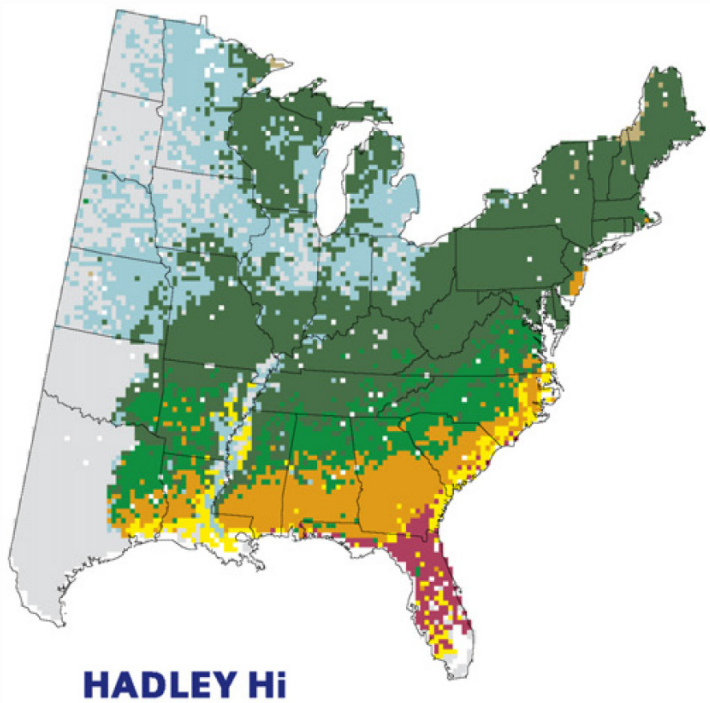
Limits on forest productivity:

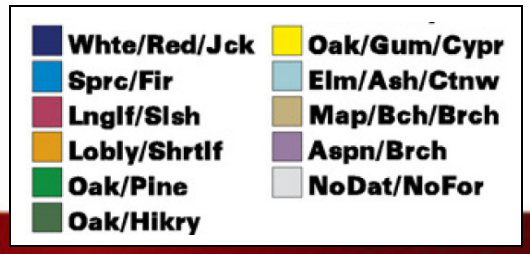
- Acclimation to CO_2 fertilization
- Extreme weather events
- Longer growing seasons
- Species range shifts

Climate Change …the negatives

Species range shifts:







Iverson et al. 2008

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 wildfire

Climate Change …the negatives

Increased frequency and intensity of wildfire:

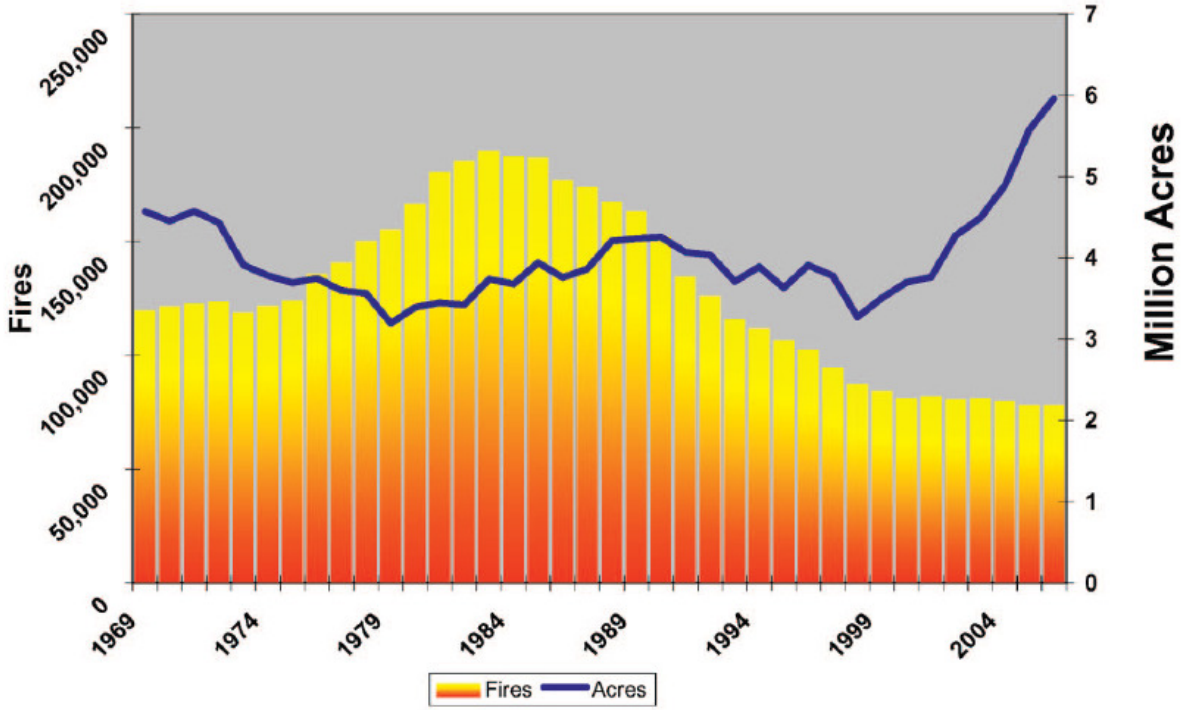


Figure 5-1. Ten-year averages of acres burned and number of fires (Source: Compiled from National Interagency Fire Center 2007).

Climate Change …the negatives

Limits on forest productivity:

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

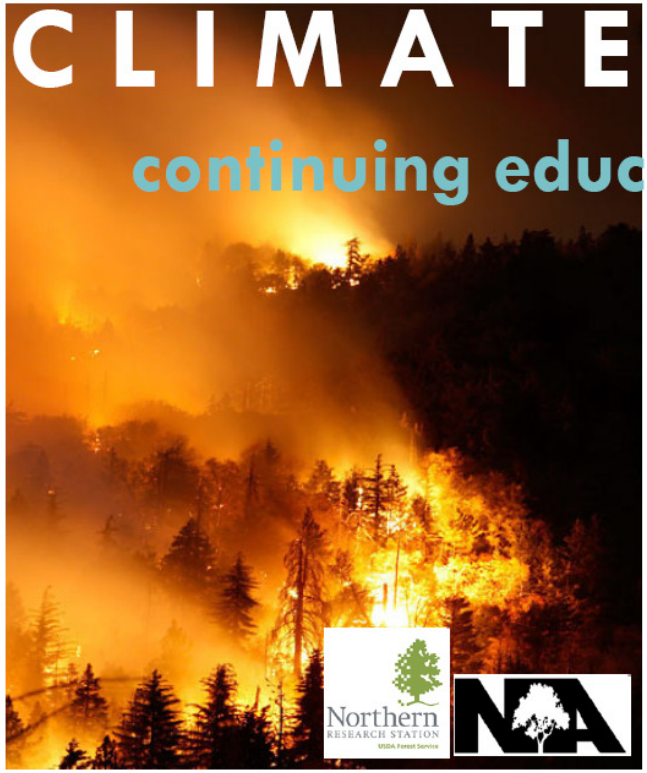
→ *Interactions between these limits are highly likely.*

Climate Change, Forests, and Carbon

…in the Great Lakes and Northeastern regions:

- 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 wildfire ☹… 😐

Thank you!



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Website:
http://www.mymeetings.com/nc/join.php?i=747085393&p=&t=c
Meeting Number: 747085393
Phone number: 1.866.581.6894
Passcode: 8623725

SPRING SEMESTER EVENTS:

January 14, 2009 | Wed | 2pm EST:
Interactions Between Carbon, Climate, and Forests
Chris Swanston (Research Ecologist, Northern Research Station, USFS)

February 11, 2009 | Wed | 2pm EST:
Forest Management During Climate Change
Maria Janowiak (Outreach Scientist, Northern Institute of Applied Carbon Science)

March 18, 2009 | Wed | 2pm EST:
CVal: A Carbon Valuation Tool for Foresters and Private Forest Landowners
Sarah Hines (Presidential Management Fellow, USFS)

April 15, 2009 & May 13 | Wed | 2pm EST:
TBA

Webinars are free and open to all members of the forestry community. Each counts for 1 hour of SAF Continuing Ed for Certified Foresters. Questions? Contact Sarah Hines (shines@fs.fed.us; 610.557.4218)