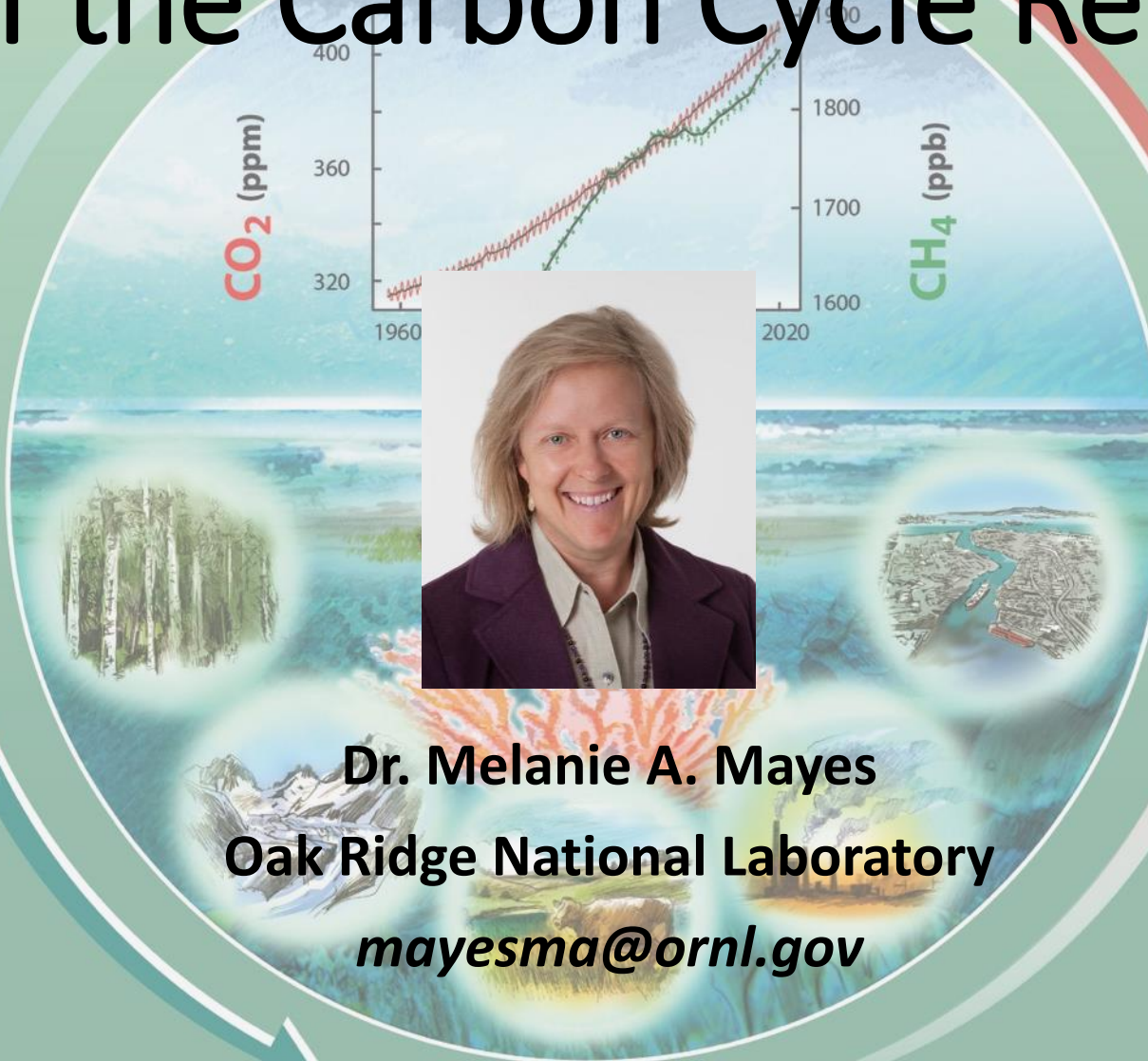


# *All About Carbon: Overview of the State of the Carbon Cycle Report*

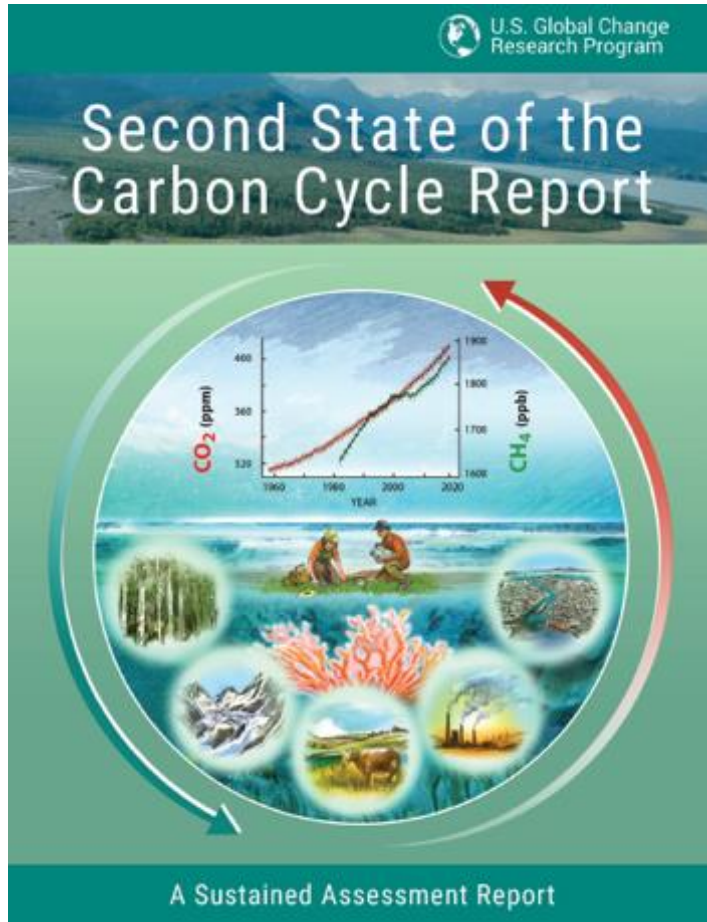


**Dr. Melanie A. Mayes**  
**Oak Ridge National Laboratory**  
*[mayesma@ornl.gov](mailto:mayesma@ornl.gov)*

# US Global Change Research Program

- 1990 Global Change Research Act
- Develop and coordinate “a comprehensive and integrated research program to assist the Nation and the world to understand, assess, predict, and respond to human-induced and natural processes of global change.”
- Involves 13 Federal agencies

## SOCCR-2



<https://www.globalchange.gov/content/about-soccr-2>

880 pp

## CSSR



<https://science2017.globalchange.gov/>

477 pp

*Executive summaries, highlights, reports in brief provide short & accessible summaries*

# Reports are *Assessments*

- SOCCR-2 involved over 200 authors from government, national labs, universities, & non-profits from US, Canada, Mexico
- Surveyed peer-reviewed scientific literature (*specific standards* following the Information Quality Act)
- Authors make assessments (*judgements*) on the content and quality of available information

Confidence Level	Likelihood
<b>Very High</b>	<b>Very High</b>
Strong evidence (established theory, multiple sources, consistent results, well-documented and accepted methods, etc.), high consensus	≥ 9 in 10
	<b>Likely</b>
	≥ 2 in 3
<b>High</b>	<b>As Likely As Not</b>
Moderate evidence (several sources, some consistency, methods vary and/or documentation limited, etc.), medium consensus	≈ 1 in 2
	<b>Unlikely</b>
	≤ 1 in 3
<b>Medium</b>	<b>Very Unlikely</b>
Suggestive evidence (a few sources, limited consistency, models incomplete, methods emerging, etc.), competing schools of thought	≤ 1 in 10
<b>Low</b>	
Inconclusive evidence (limited sources, extrapolations, inconsistent findings, poor documentation and/or methods not tested, etc.), disagreement or lack of opinions among experts	

## Statistical Uncertainties

- \*\*\*\*\* 95% certain within 10%
- \*\*\*\* 95% certain within 25%
- \*\*\* 95% certain within 50%
- \*\* 95% certain within 100%
- \* uncertainty > 100%

# These reports do not provide policy recommendations

- In accordance with the Federal Advisory Committee Act of 1972 "objective and accessible to the public" by formalizing the process for "establishing, operating, overseeing, and terminating" committees

# SOCCR2 Team Structure and Interactions

## U.S. Global Change Research Program

USGCRP Includes Principals from the Subcommittee on Global Change Research and USGCRP National Coordination Office Staff (e.g., National Climate Assessment, Global Change Information System, Others)

Carbon Cycle Science Interagency Working Group (CCIWG)  
and SOCCR2 Federal Steering Committee

**Lead Agency:**  
USDA (Legal)

U.S. Carbon Cycle Science Program Office  
with Logistical Support from UCAR CPAESS

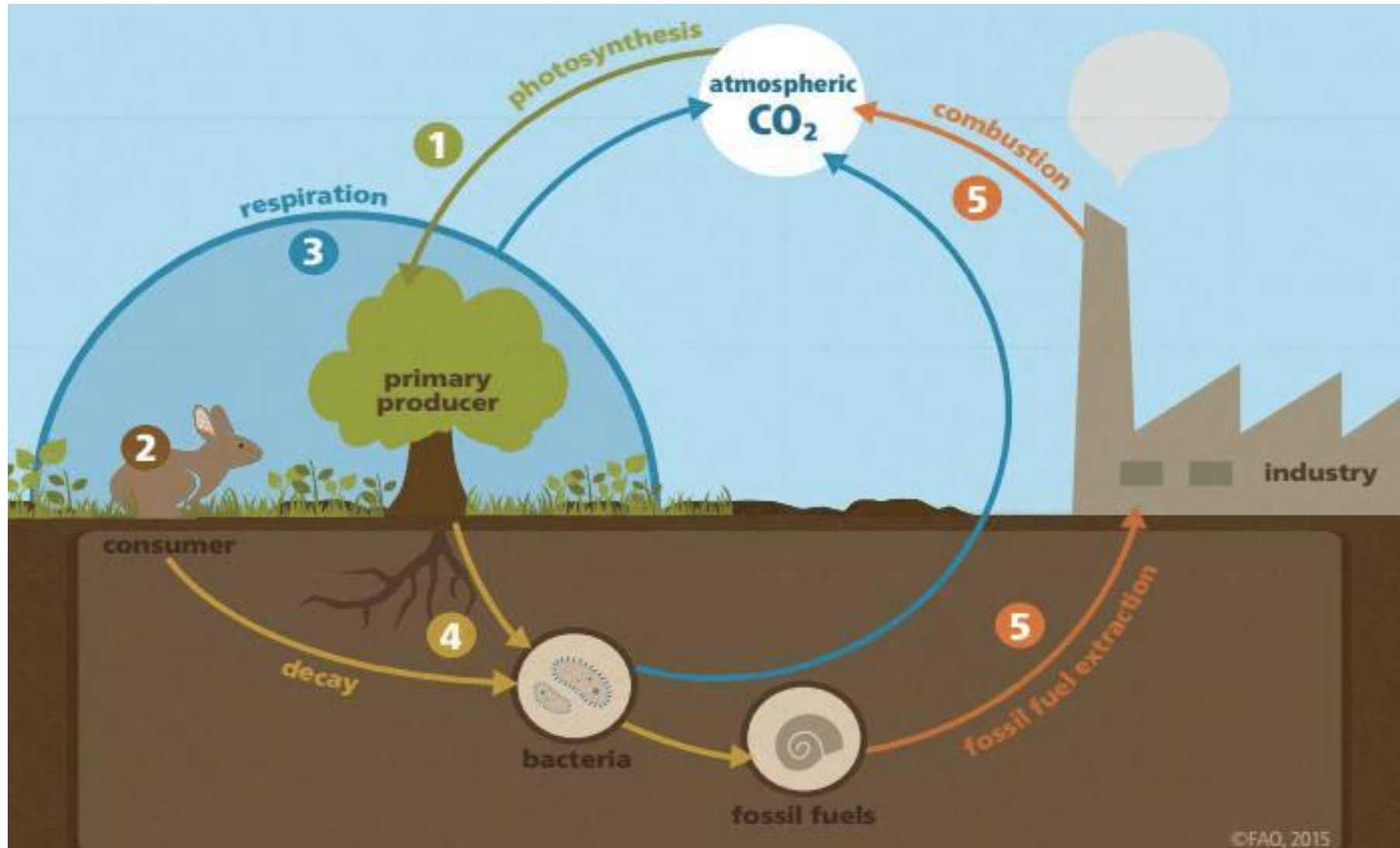
Federal Liaisons  
for Each Chapter

Five SOCCR2 Science Leads  
(Federal and Non-Federal Scientists)

Oak Ridge National Laboratory  
Editorial Team

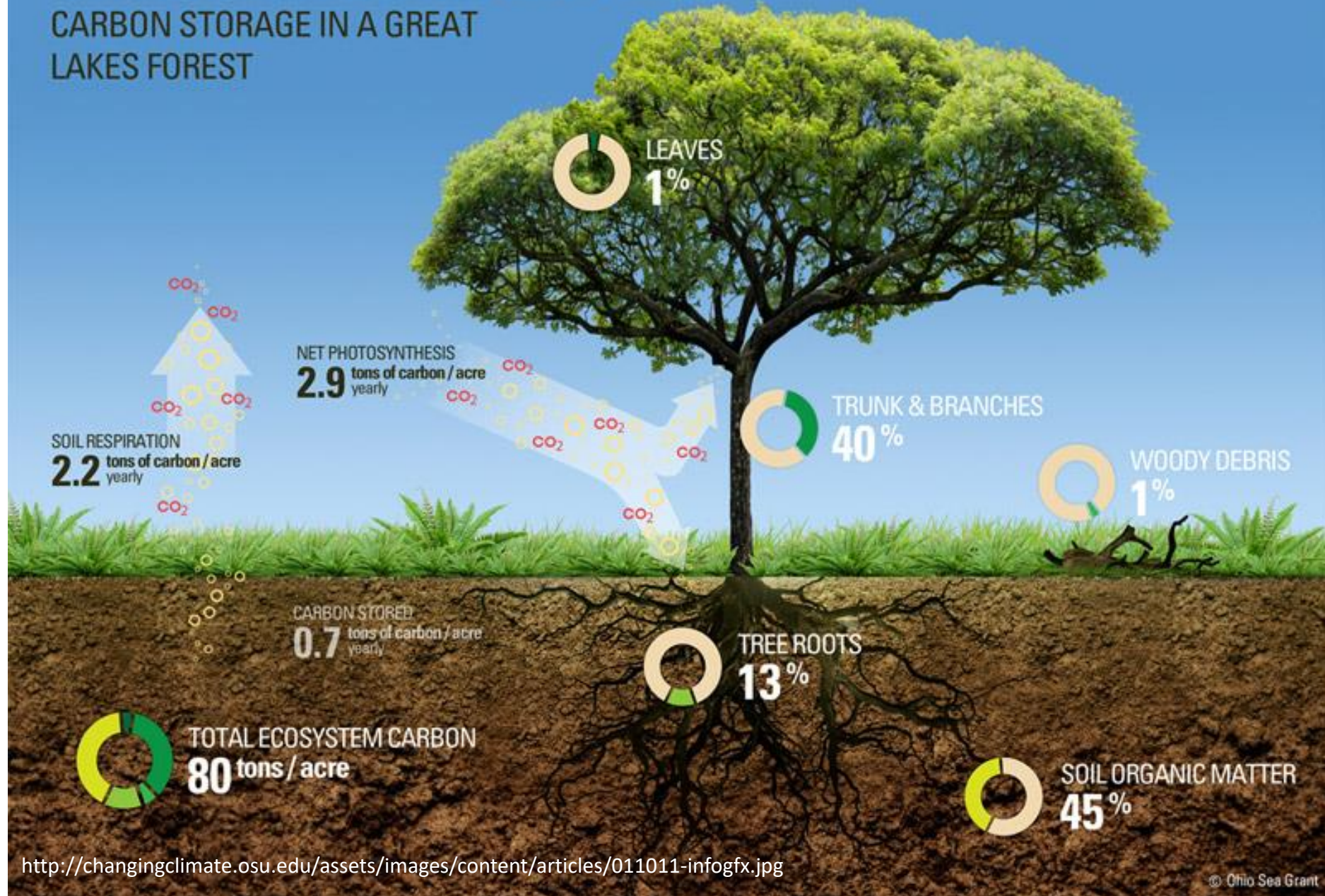
Chapter Leads, Chapter Contributors  
(Federal and Non-Federal Scientists from  
the United States, Canada, and Mexico)

# Simplified Carbon Cycle



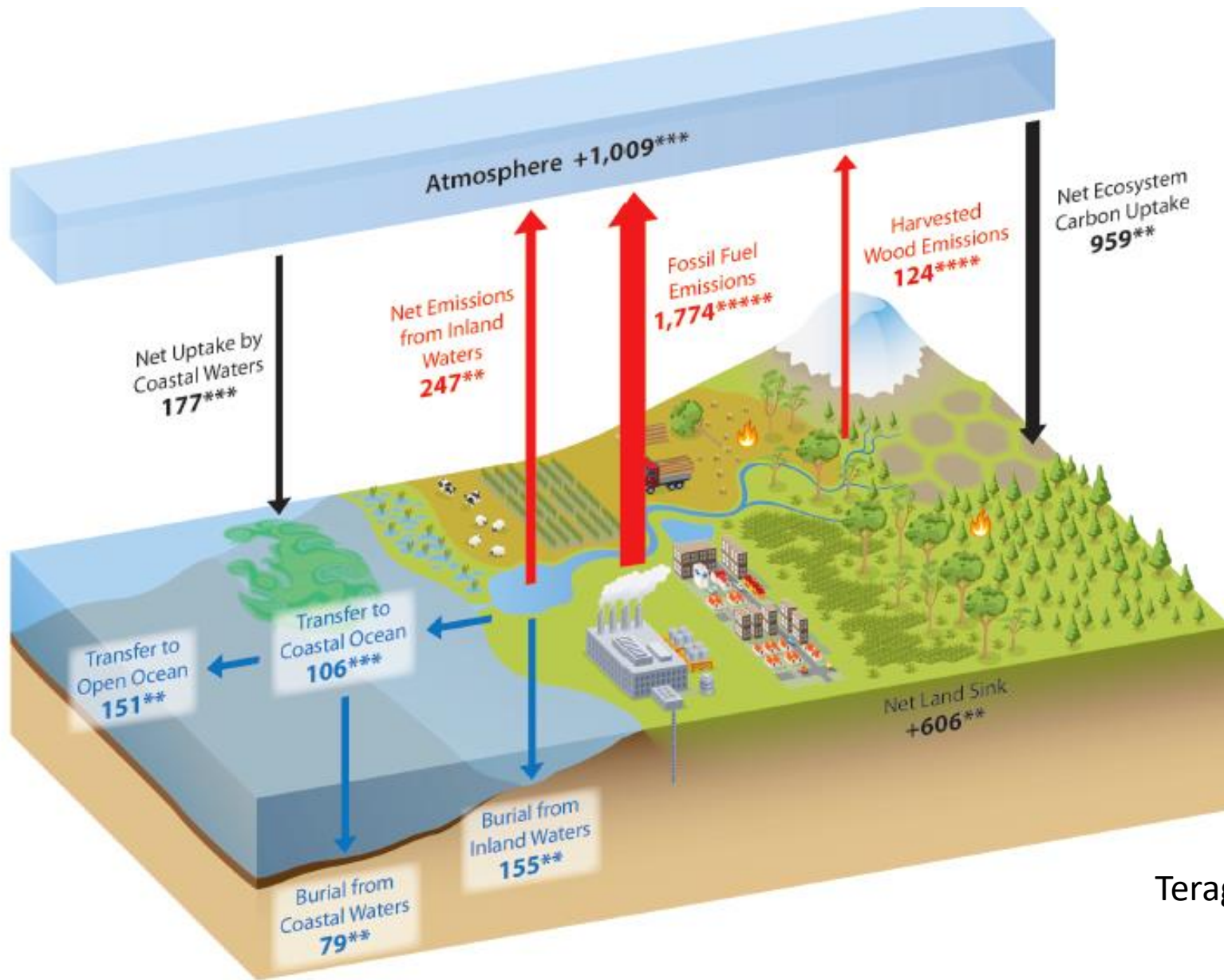
# WHERE DOES CARBON GO?

## CARBON STORAGE IN A GREAT LAKES FOREST





# North American Carbon Budget in SOCCR-2



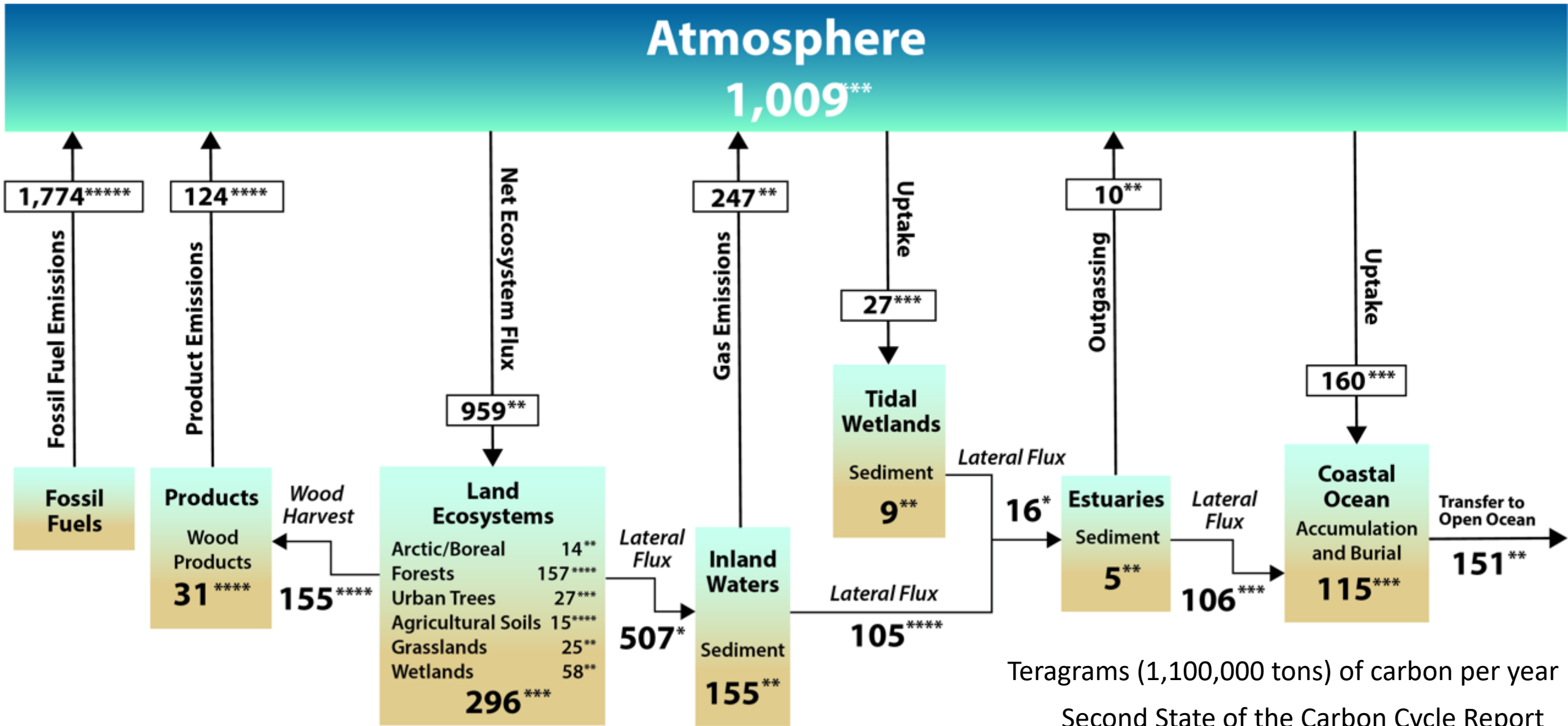
## Statistical Uncertainties

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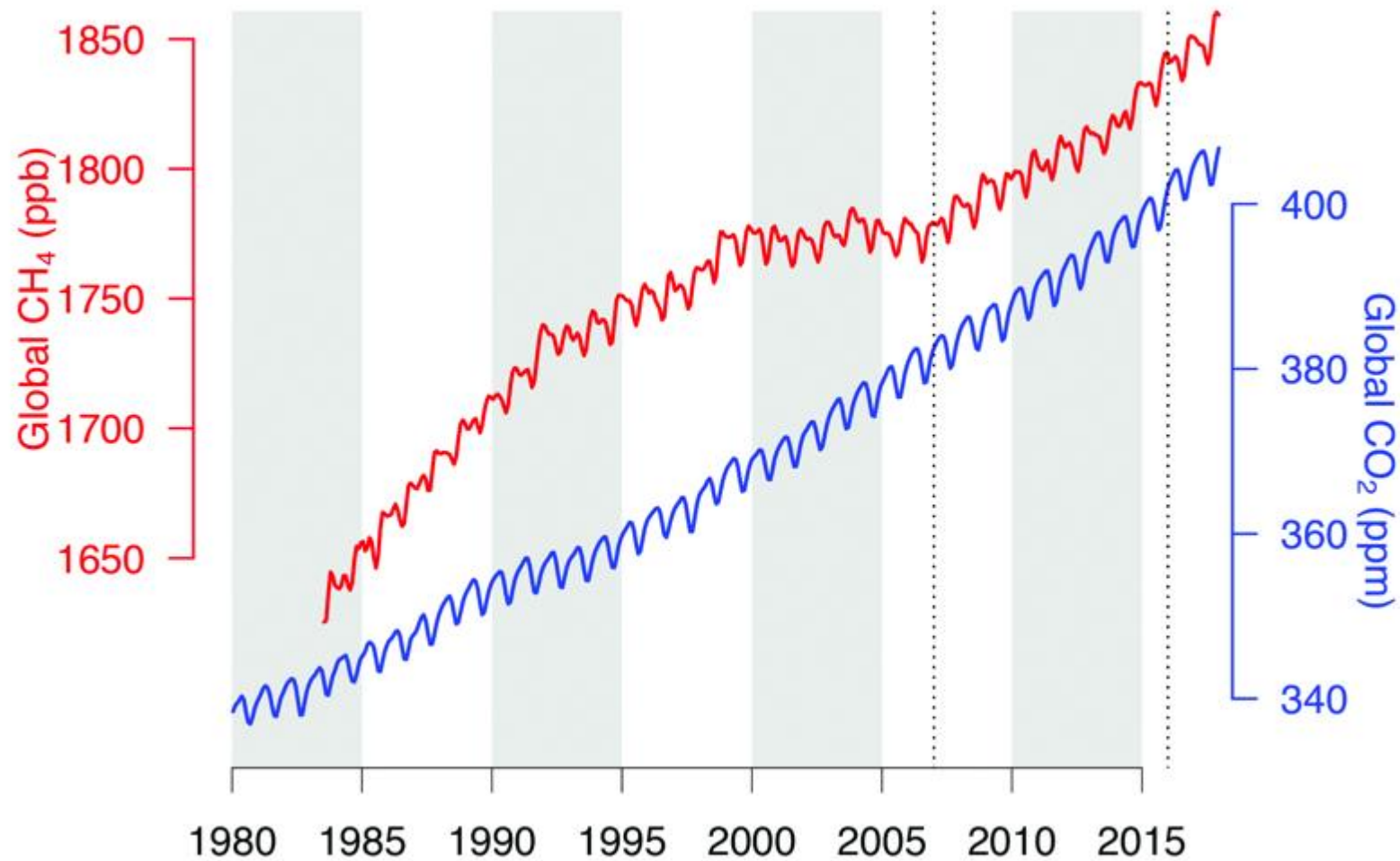
Teragrams (1,100,000 tons) of carbon per year

Second State of the Carbon Cycle Report

# Building the budget from ecosystems

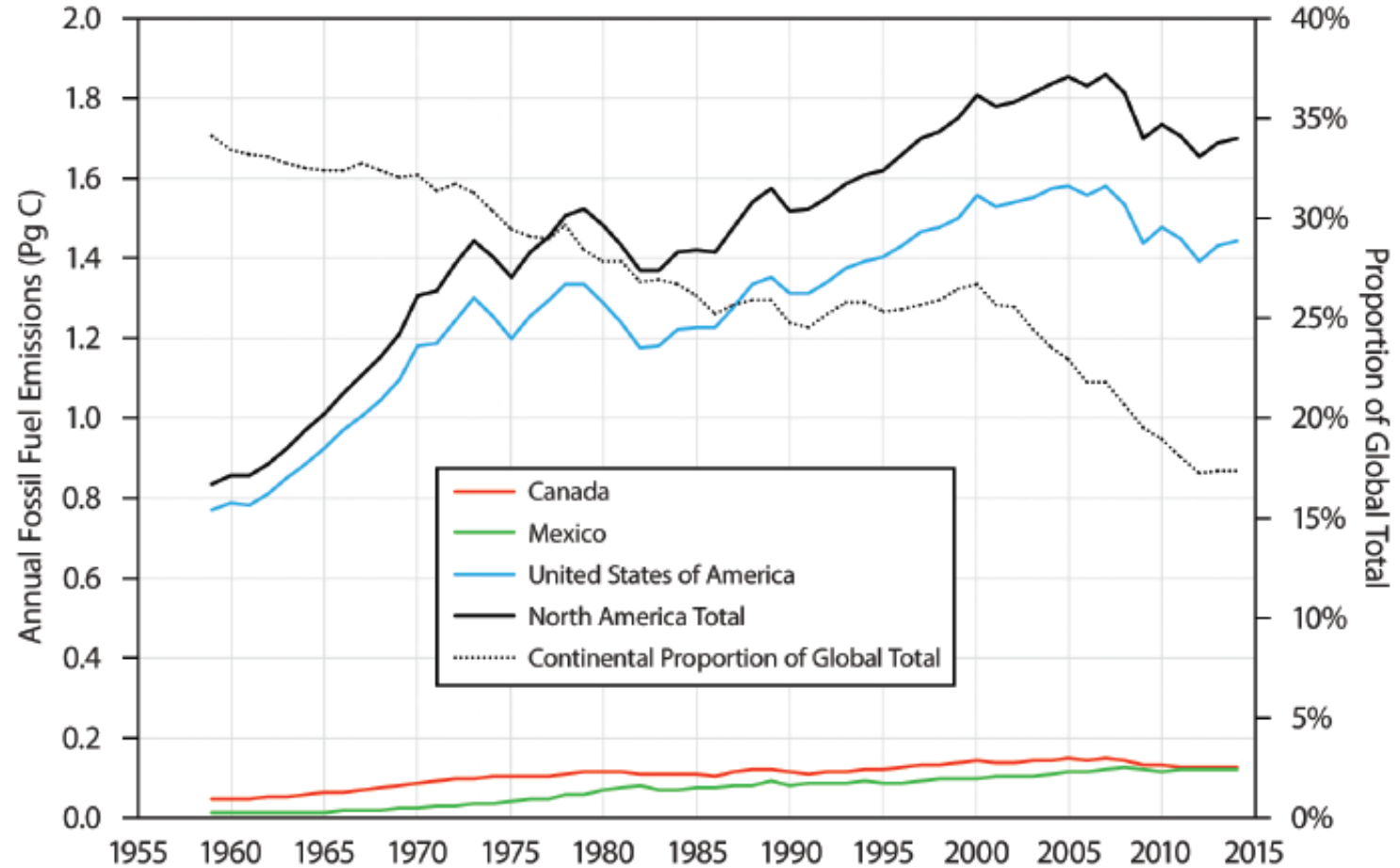


# Carbon dioxide and methane global trends

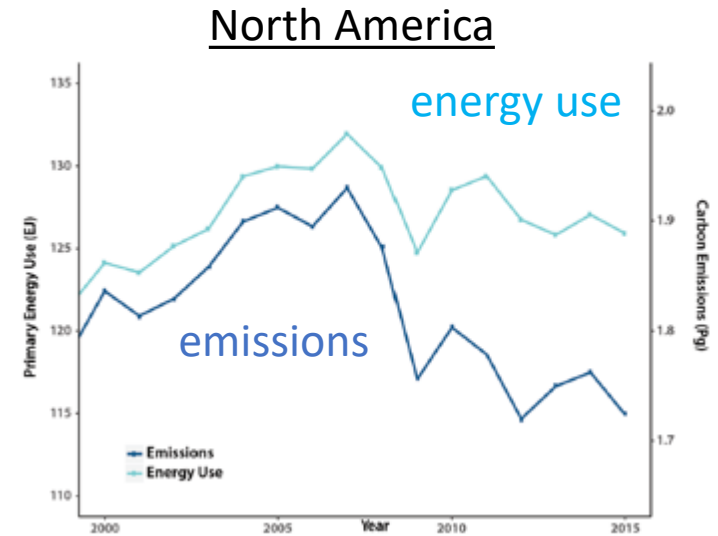
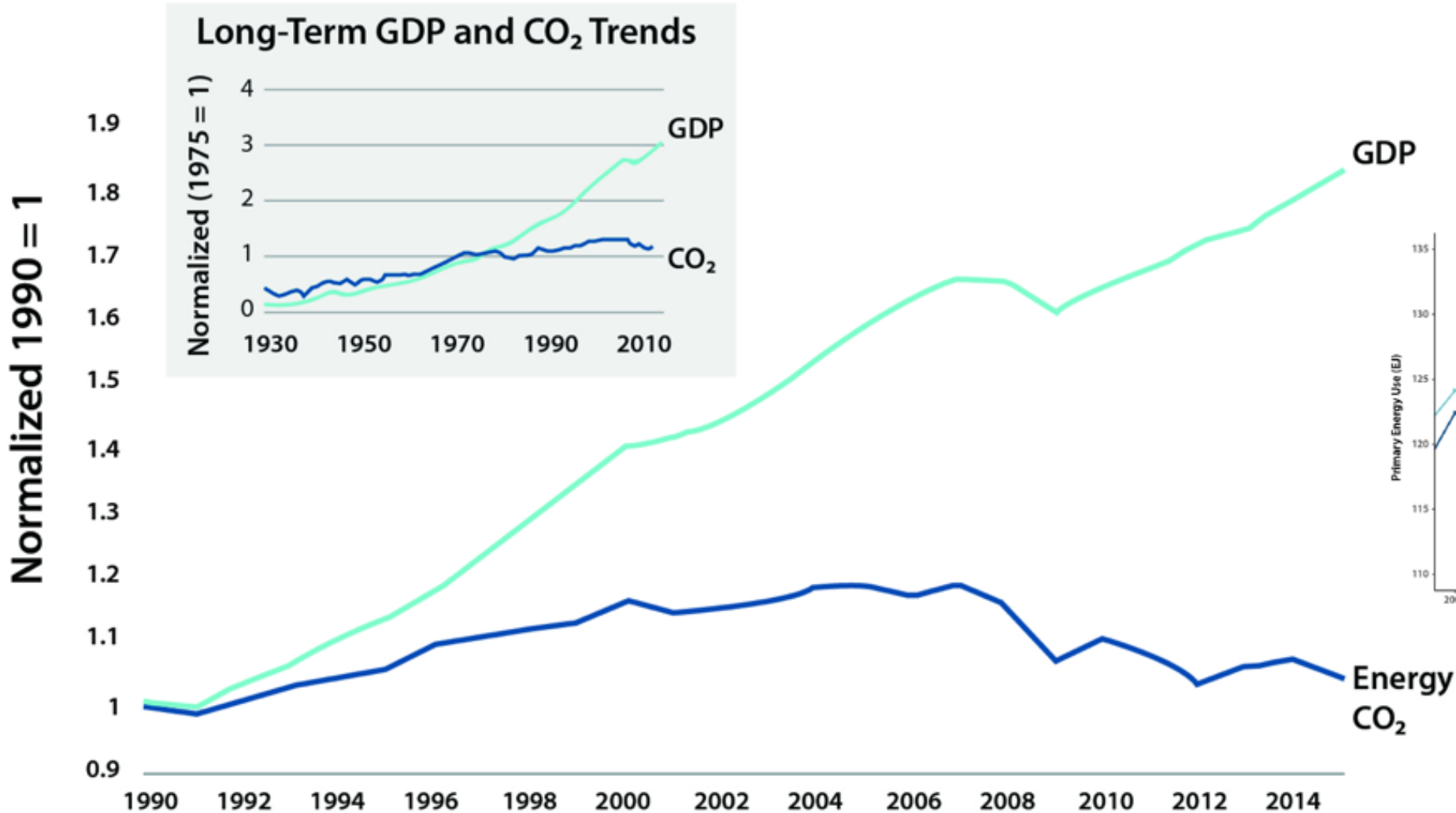


Second State of the Carbon Cycle Report

# Fossil fuel emission trends in North America



# Decreasing energy emissions with increasing U.S. gross domestic product (GDP)



# Important changes in carbon emissions across North America

- Transition from coal to natural gas
- Increases in renewables & alternative fuels
- Replaced aging infrastructure including pipelines & power plants

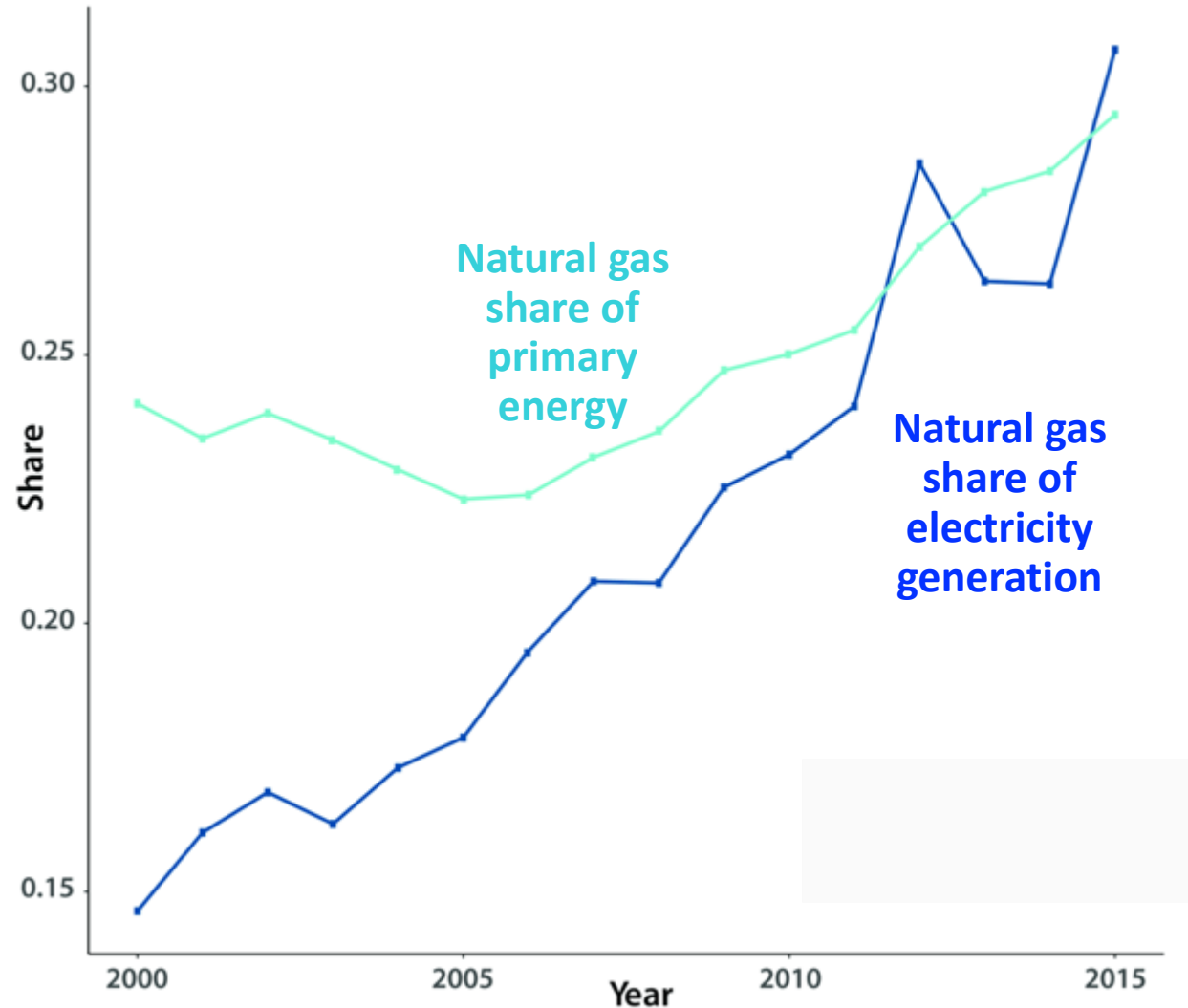


TVA Bull Run coal-fired power plant, with old & new stacks, retiring 2023. *Oak Ridge, TN*

## What else have we done?

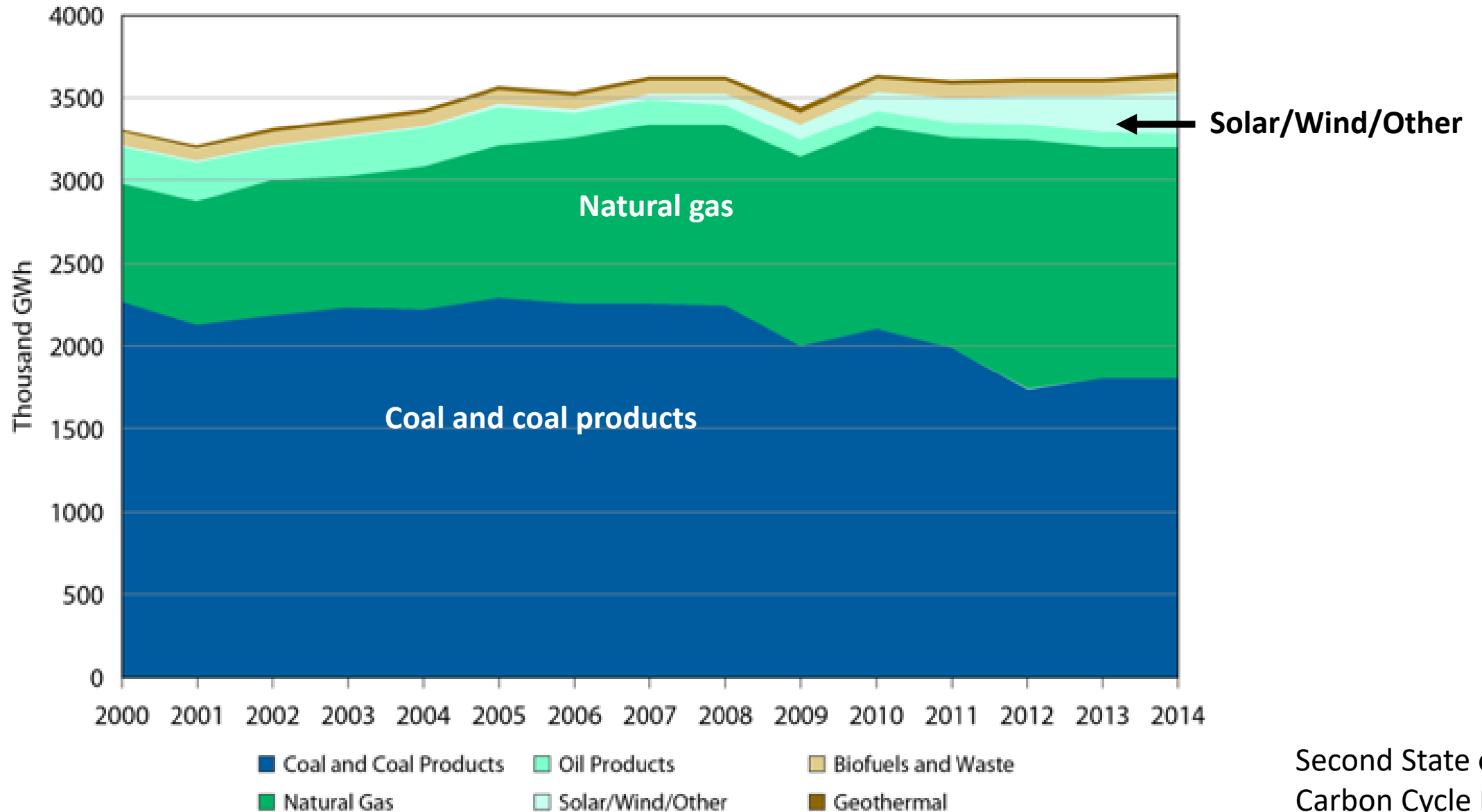
- Increased efficiencies of buildings
- Increased transportation alternatives such as biofuels & public transportation
- More stringent CAFE standards

# Natural gas use increasing in US



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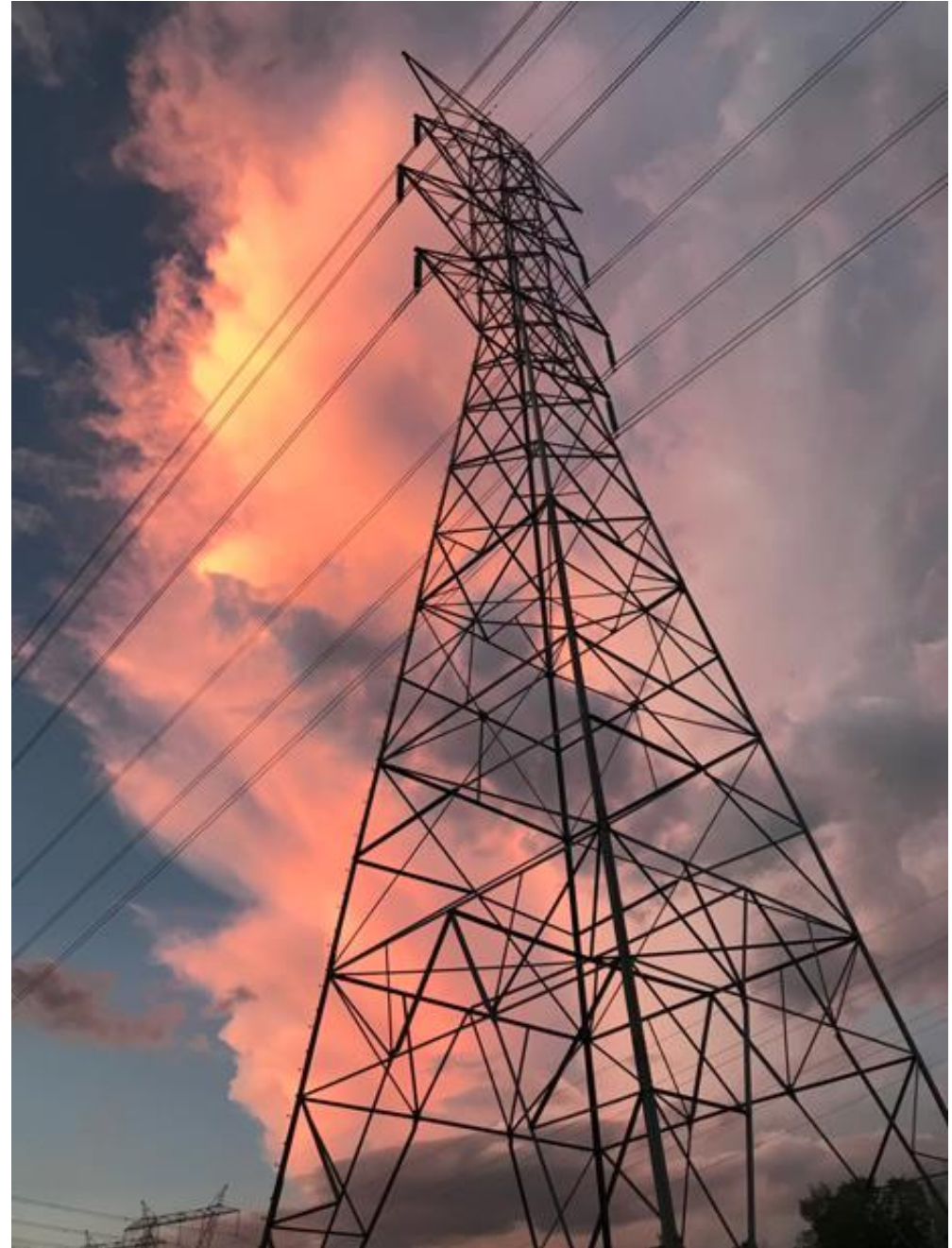
# Renewables making inroads in North America



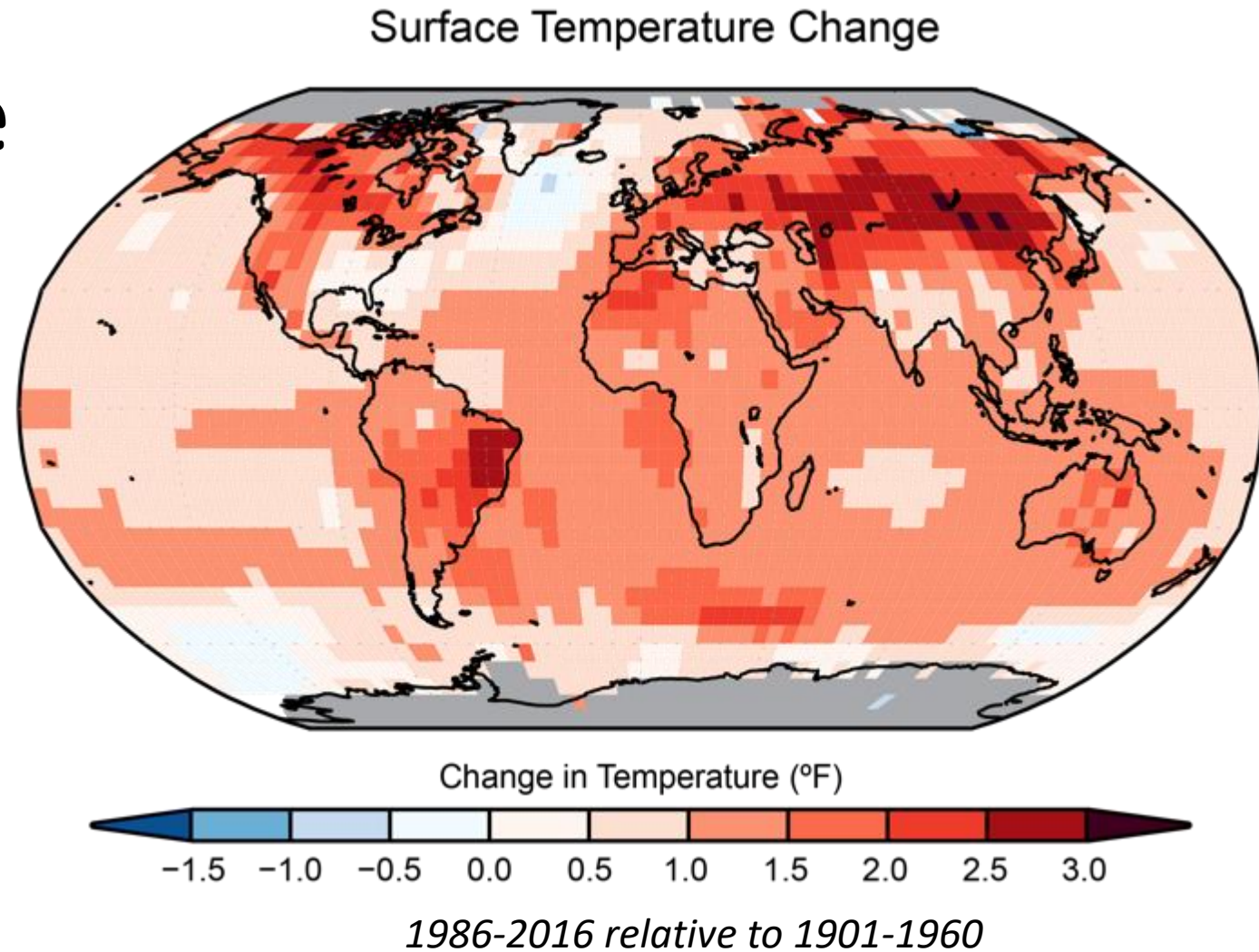
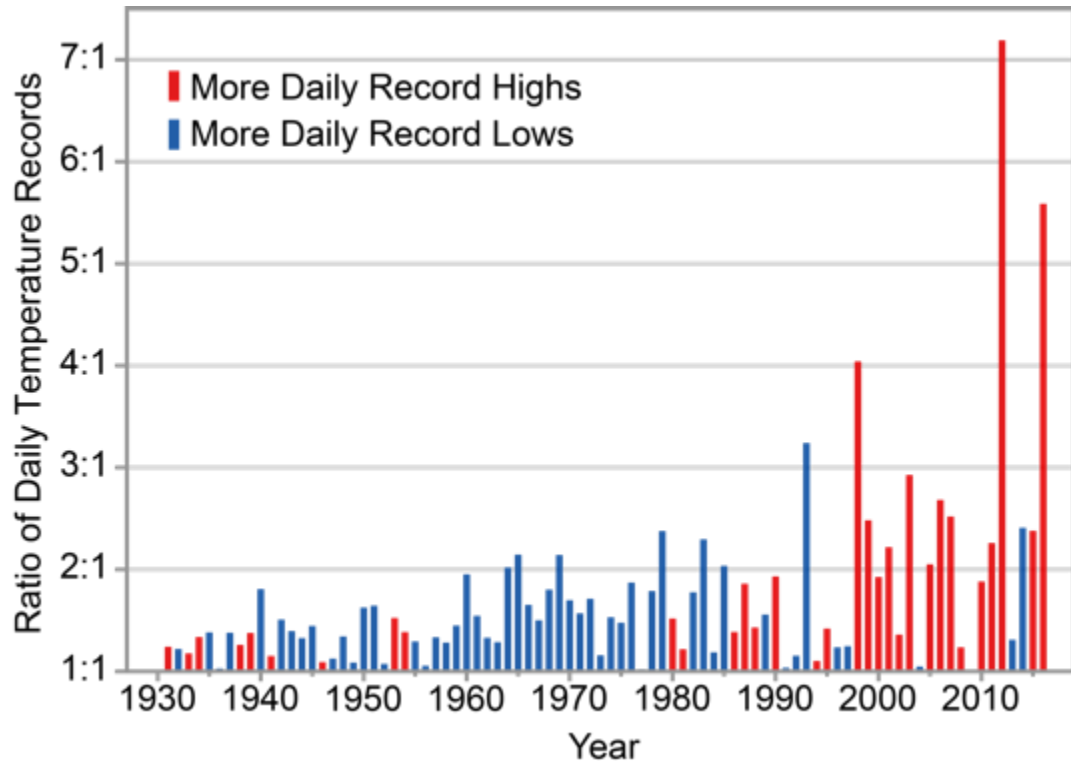


# What else can we do?

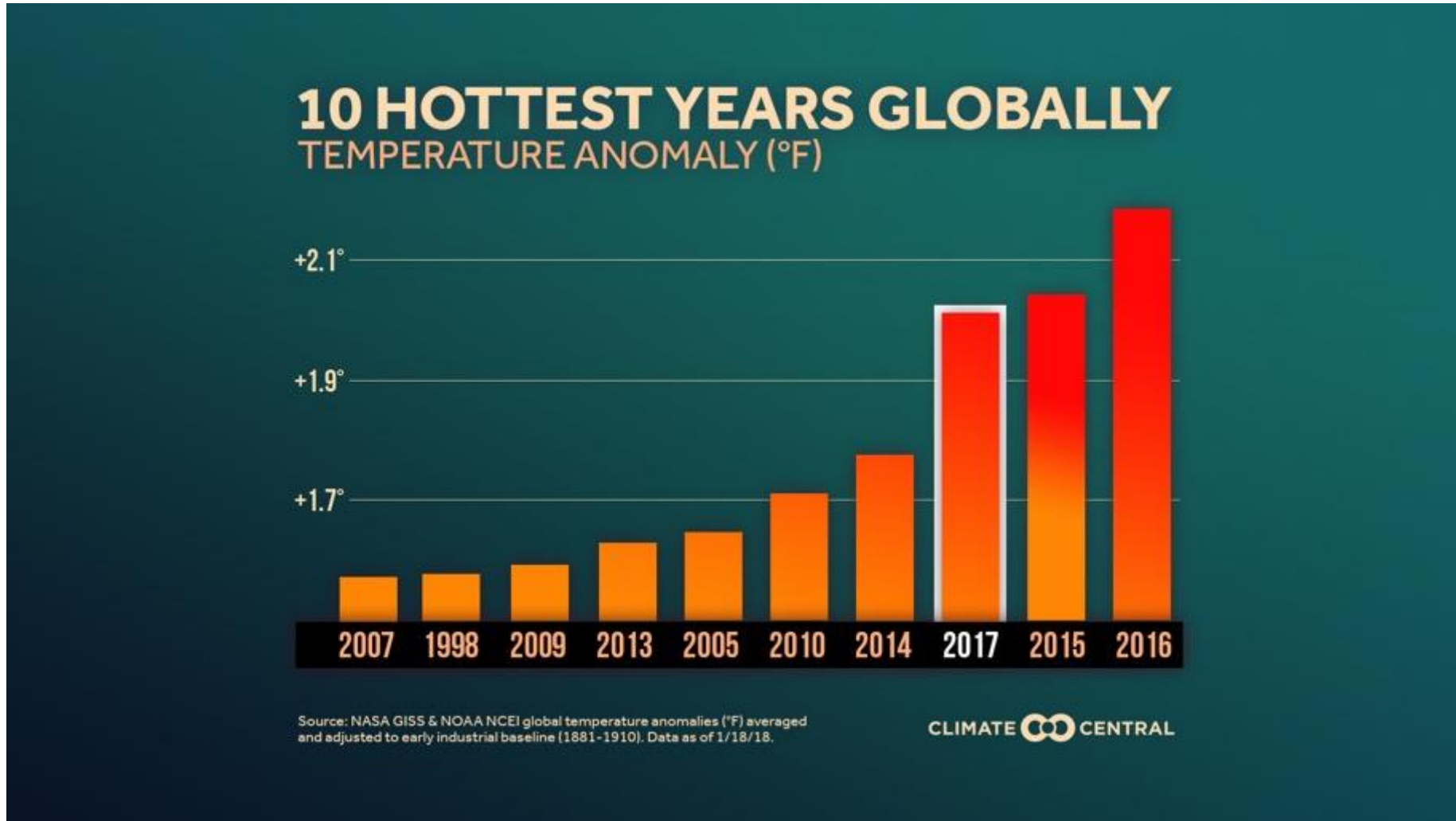
1. Decrease emissions
  - Decrease use
  - Increase efficiencies
  - Increase renewables
2. Carbon capture
3. Negative emissions
  - Remove previously emitted CO<sub>2</sub>



# Getting serious: Observed temperature increases



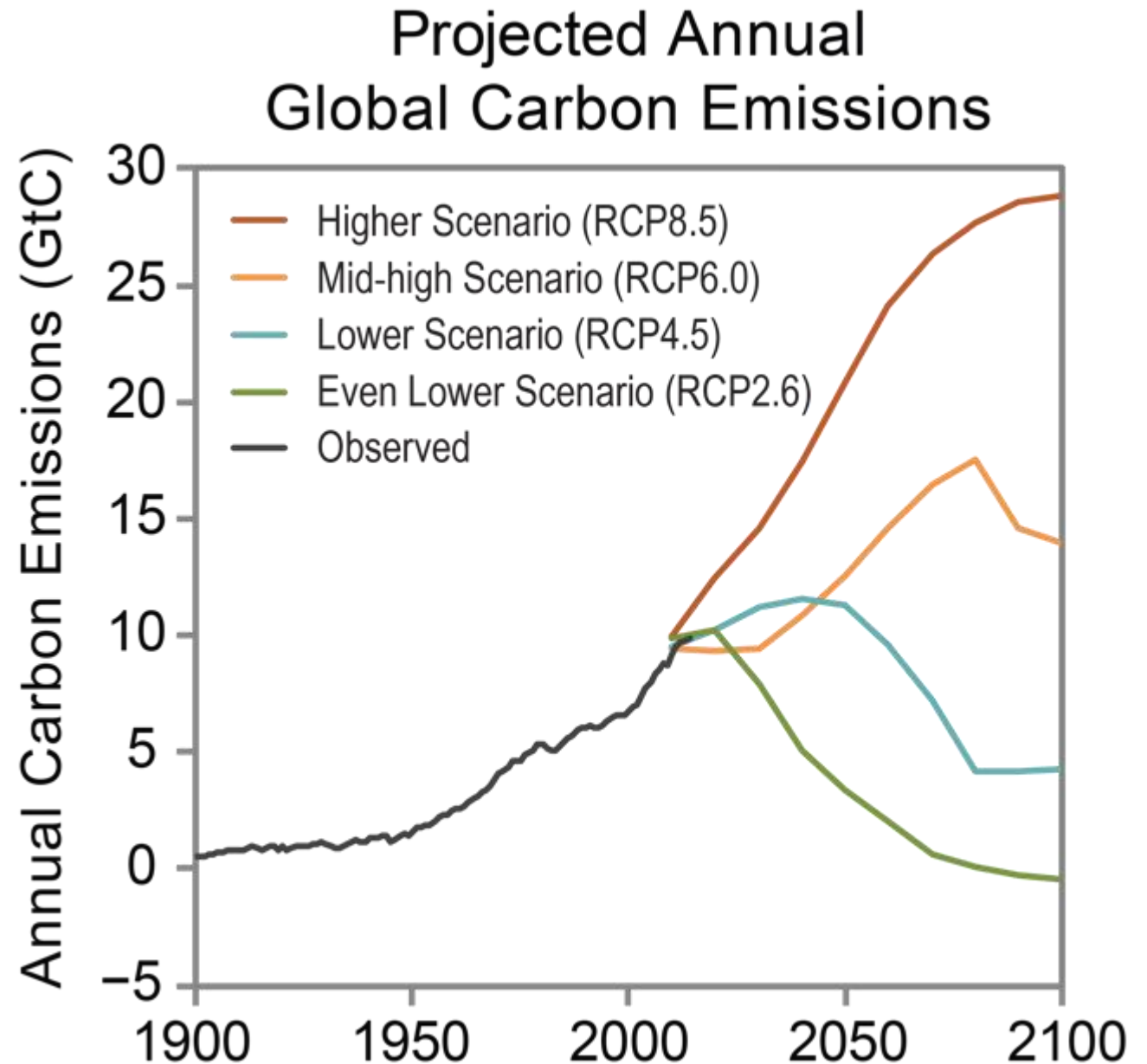
# It is getting hotter



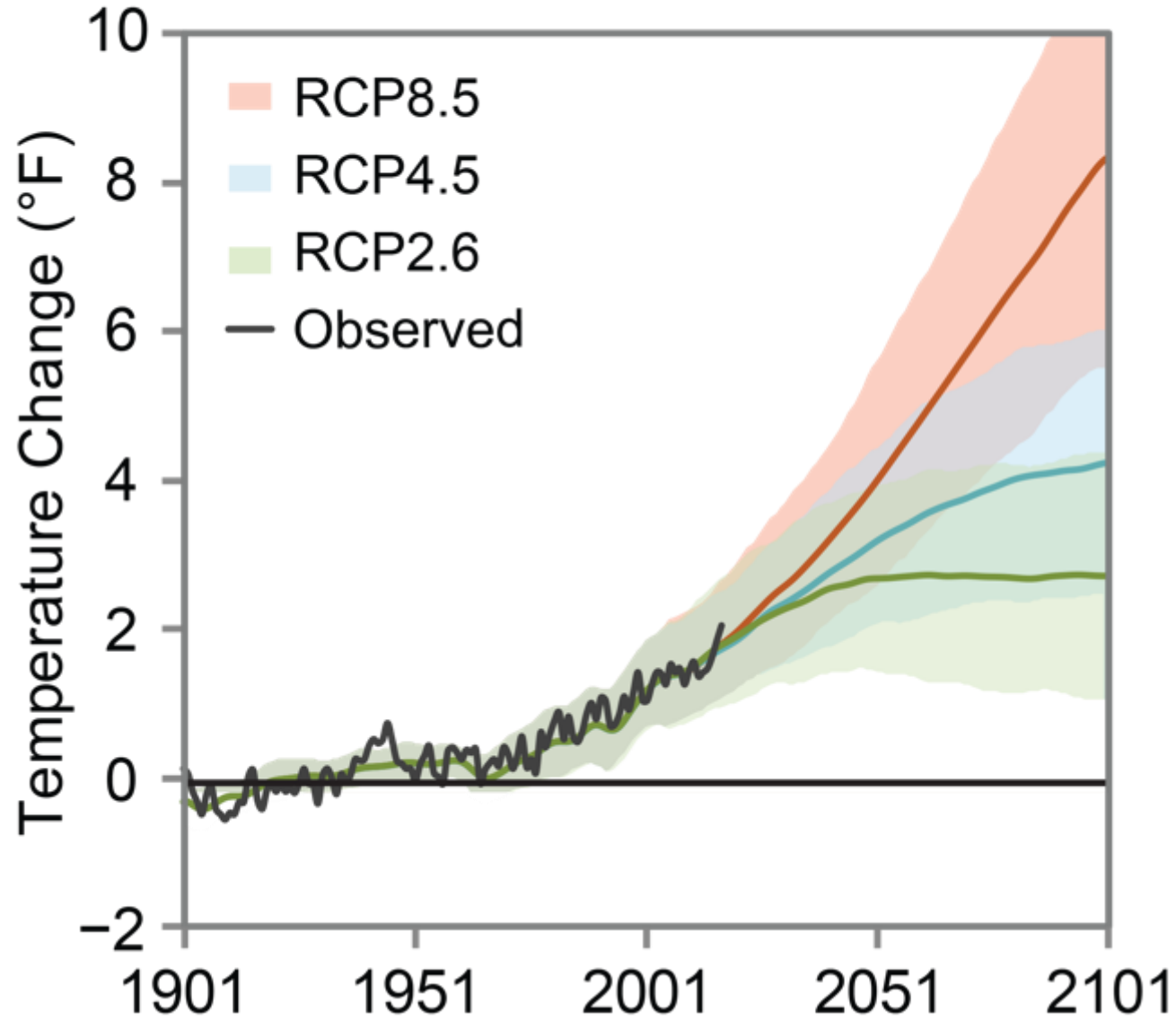
<http://www.climatecentral.org/gallery/graphics/the-10-hottest-global-years-on-record>

# How much worse will it be?

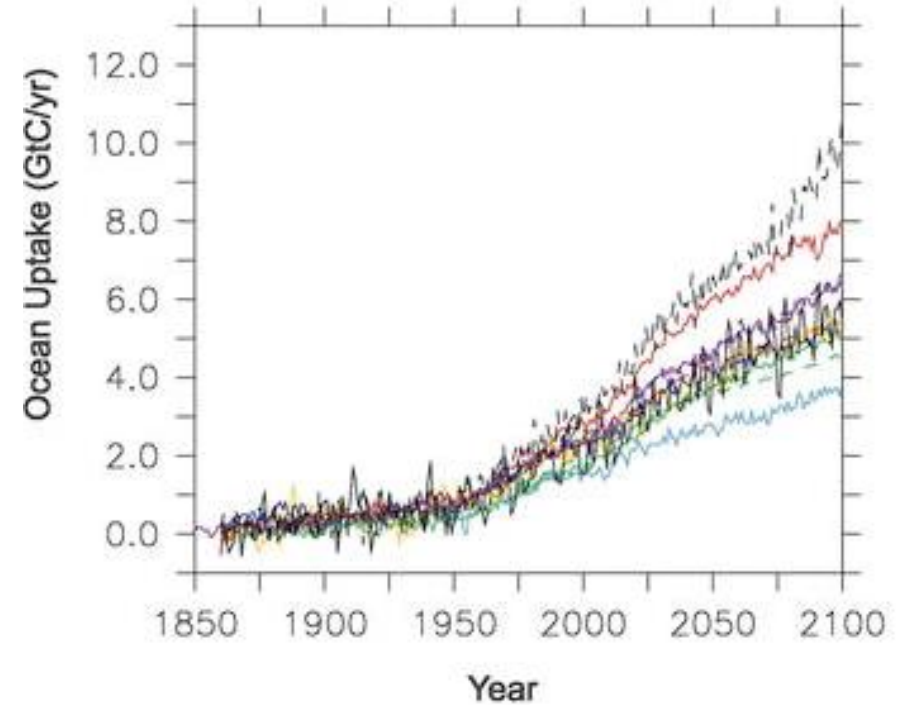
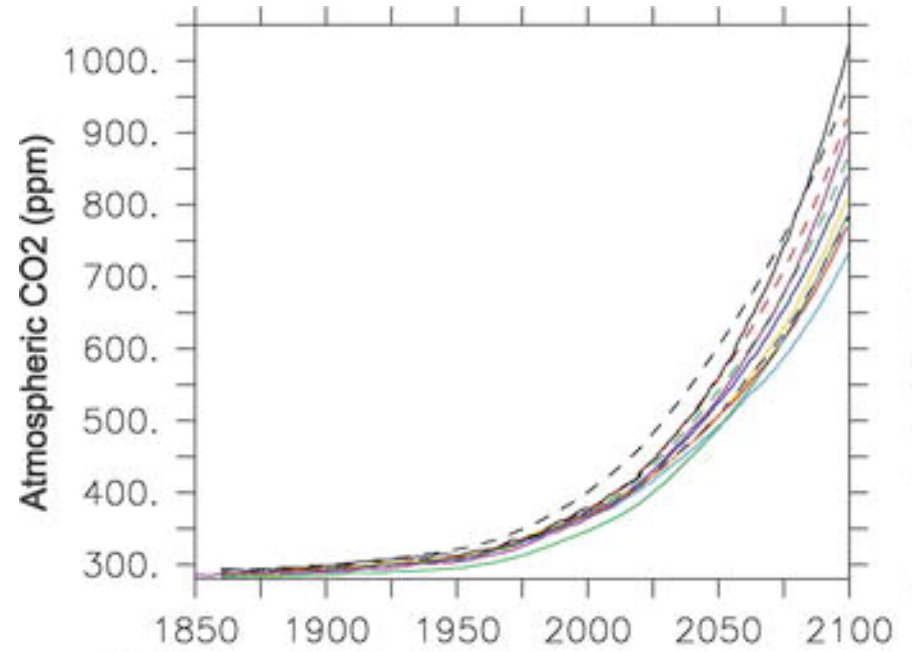
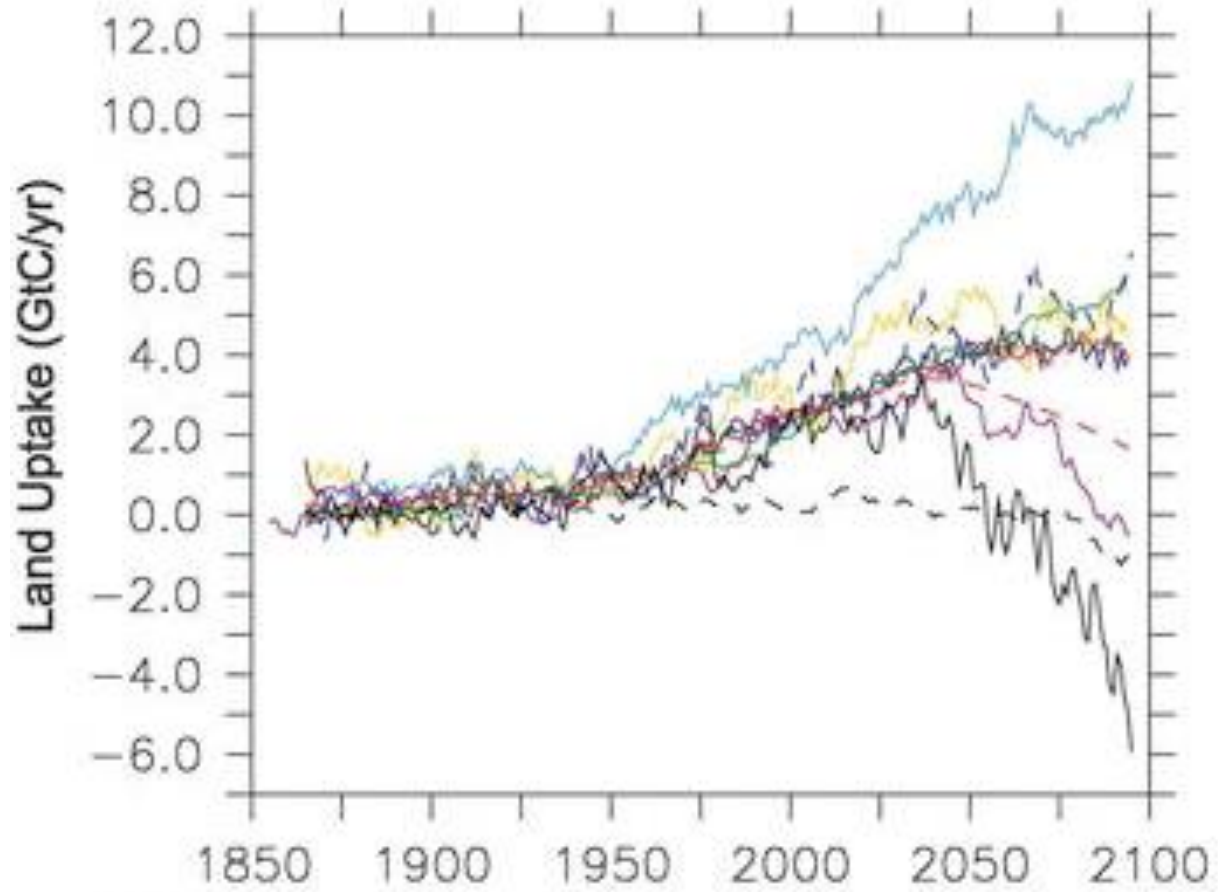
- RCP = Representative concentration pathways
- Represents a range of possible emissions outcomes
- Widely used (eg, IPCC)

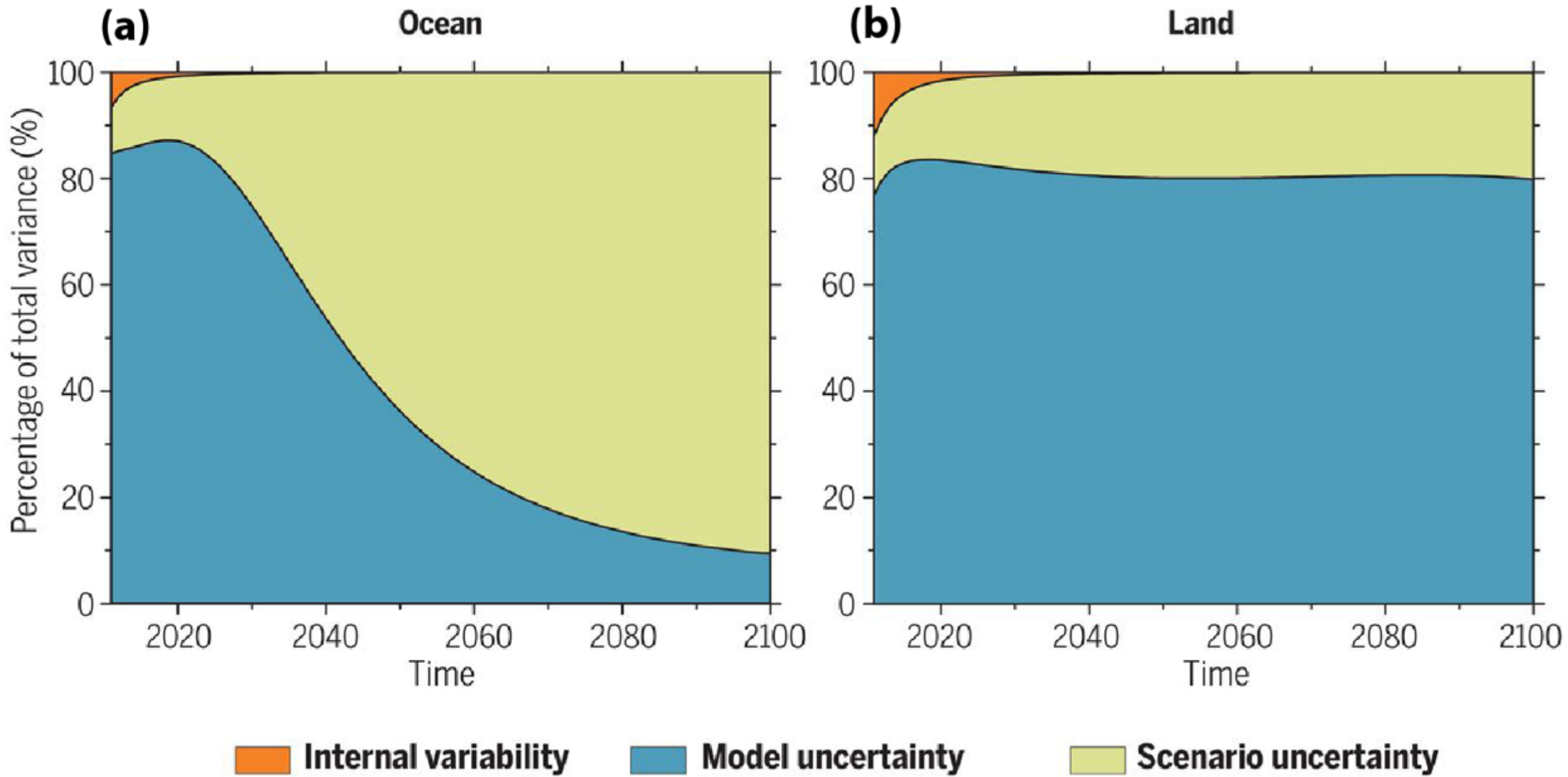


# Projected Global Temperatures

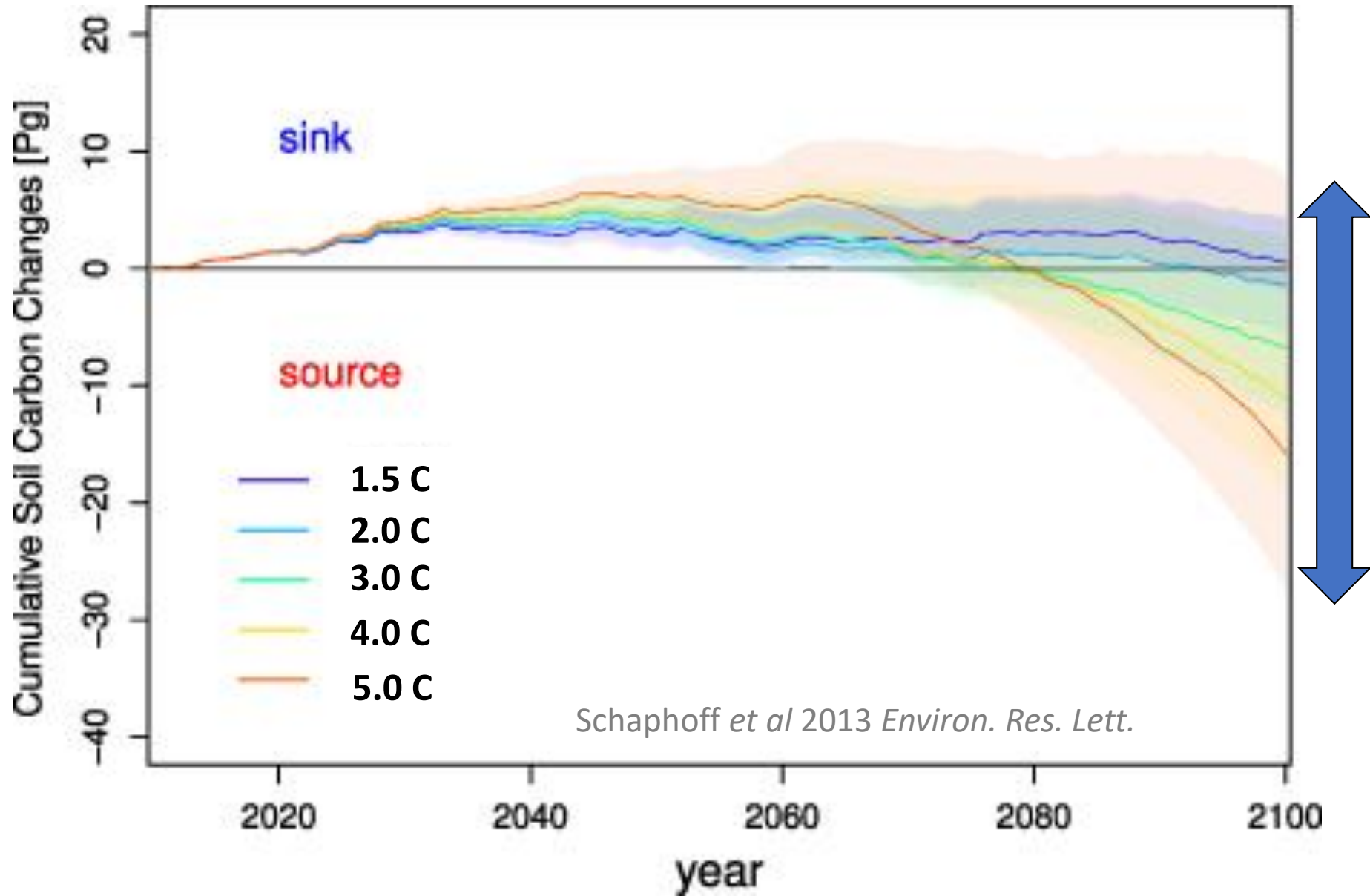


# Why the uncertainty?



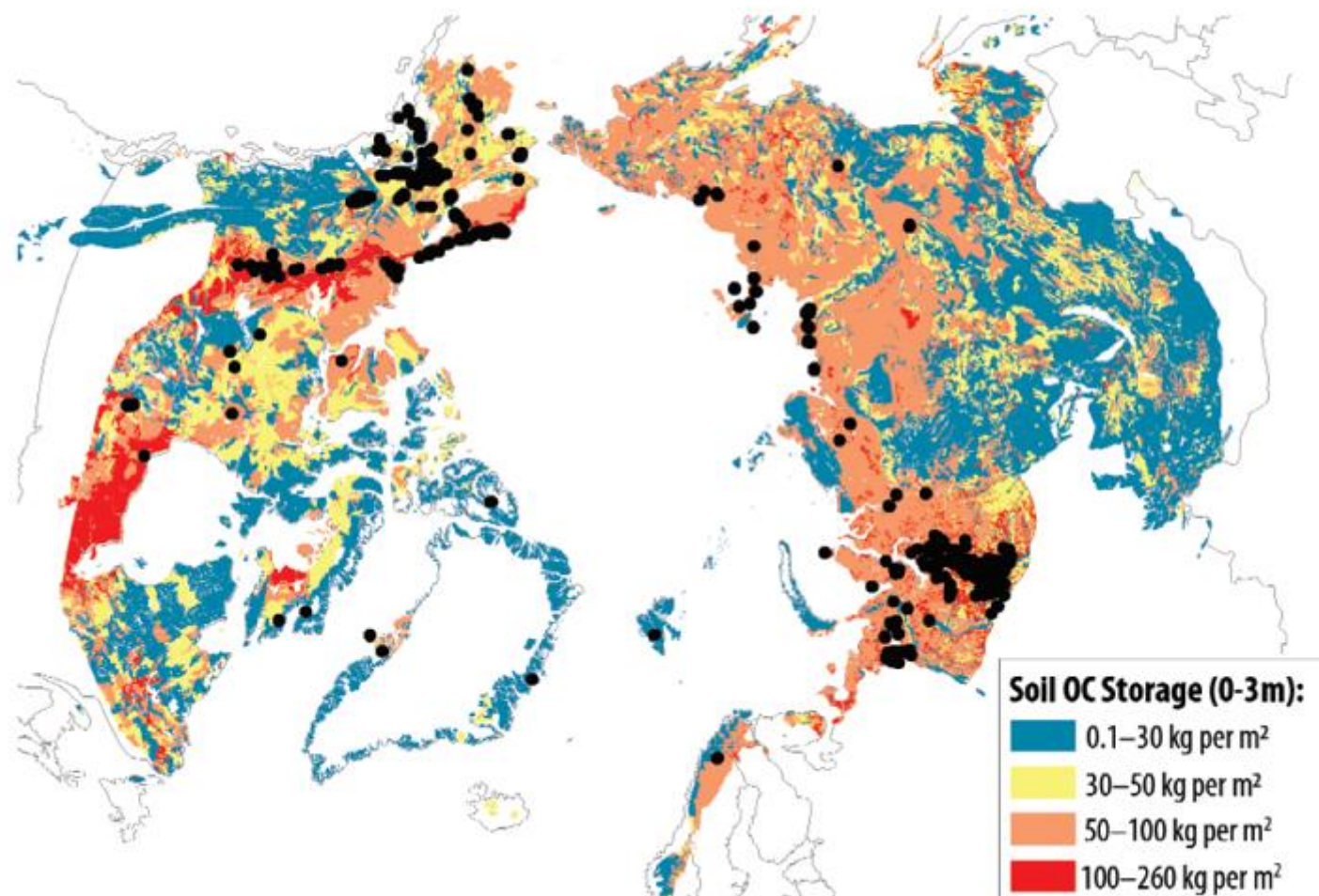


# Role of Permafrost soils

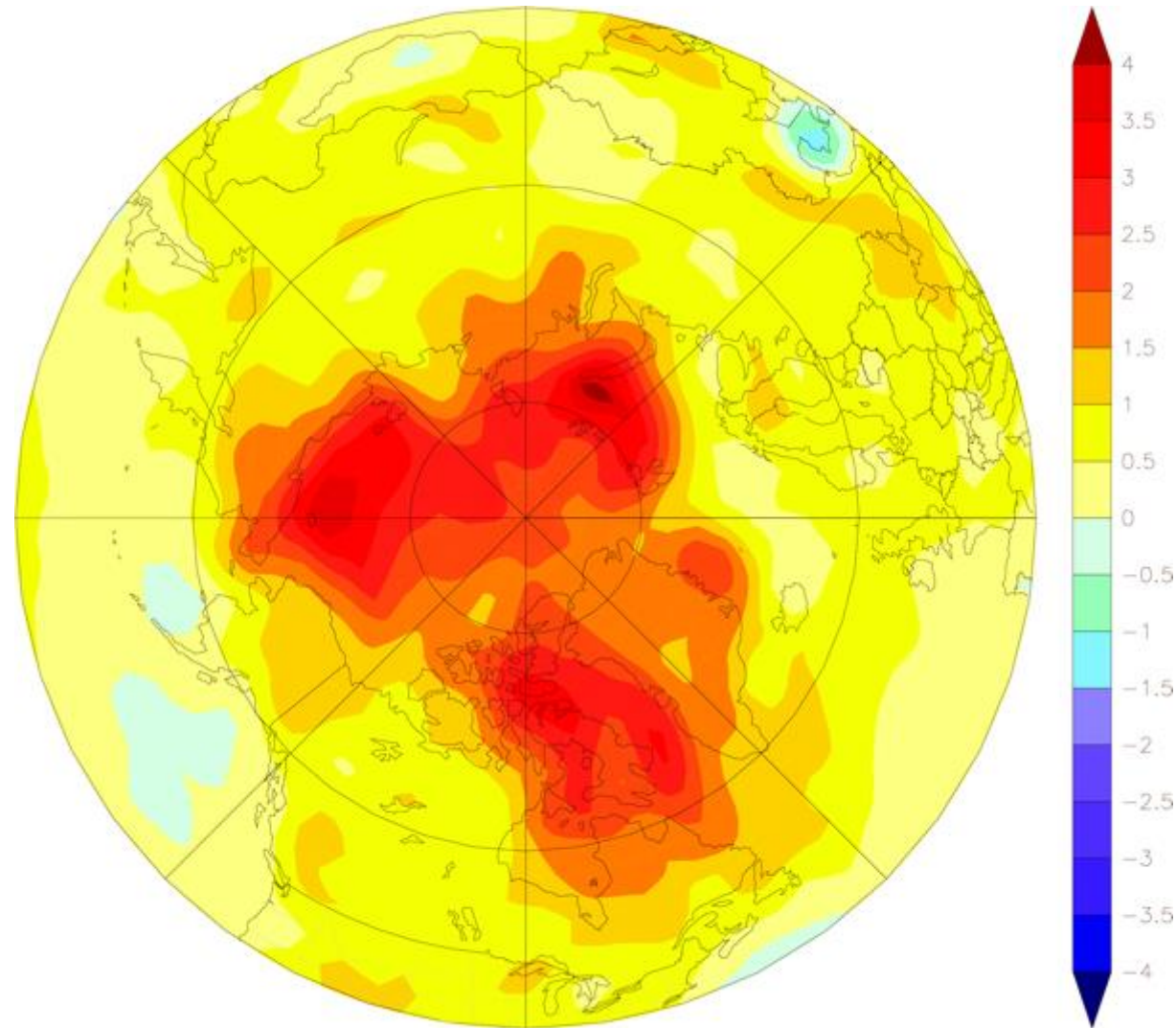




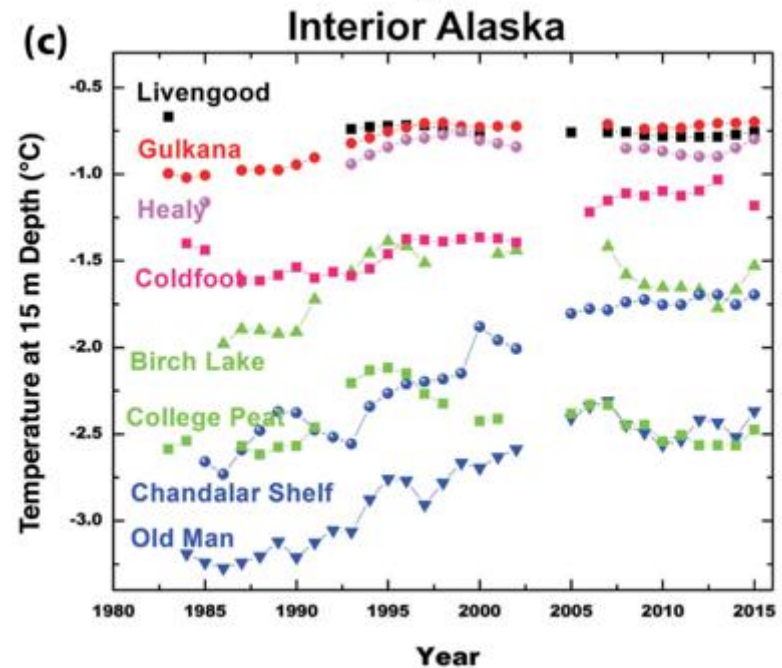
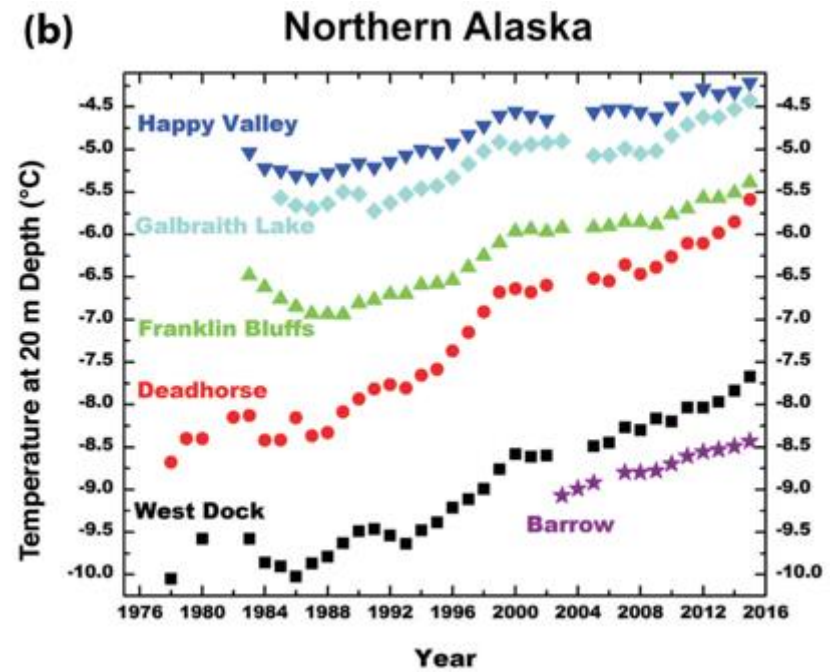
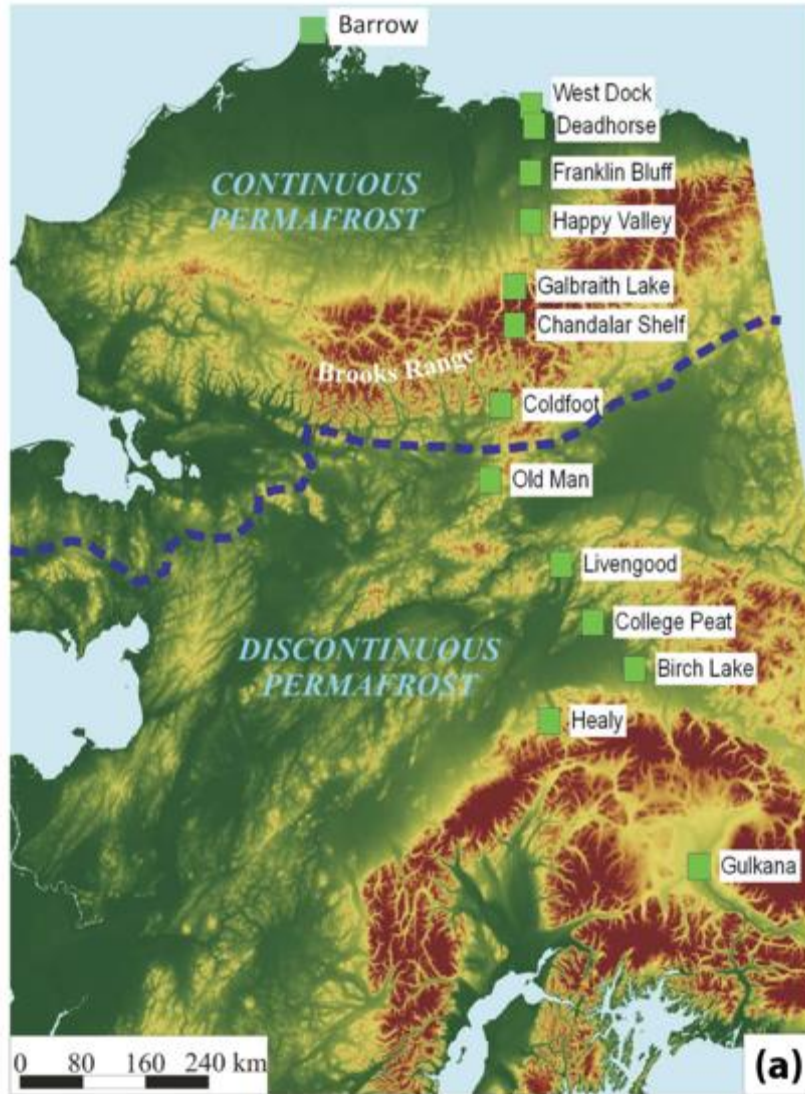
# Northern latitudes store substantial soil carbon



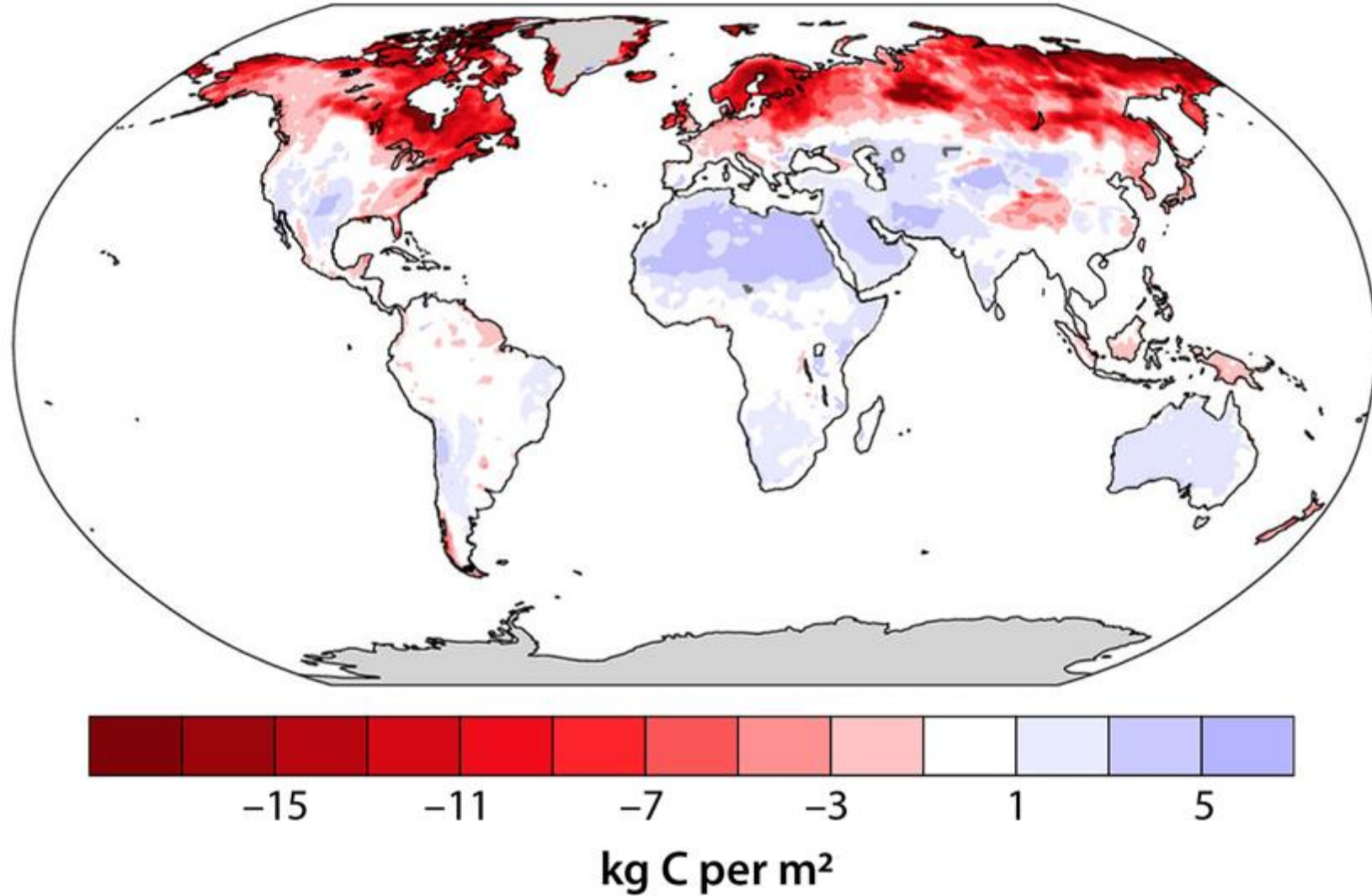
# Difference between mean annual Arctic surface air temperatures from 2001 to 2015



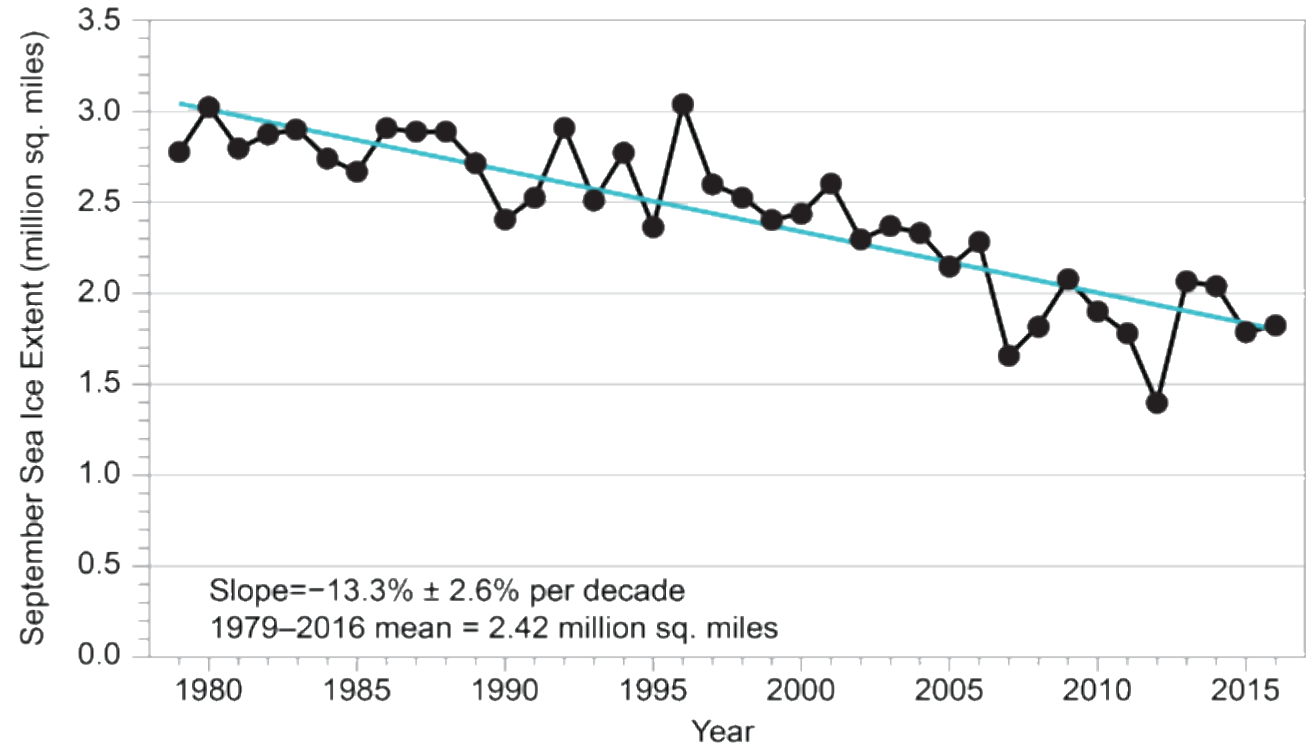
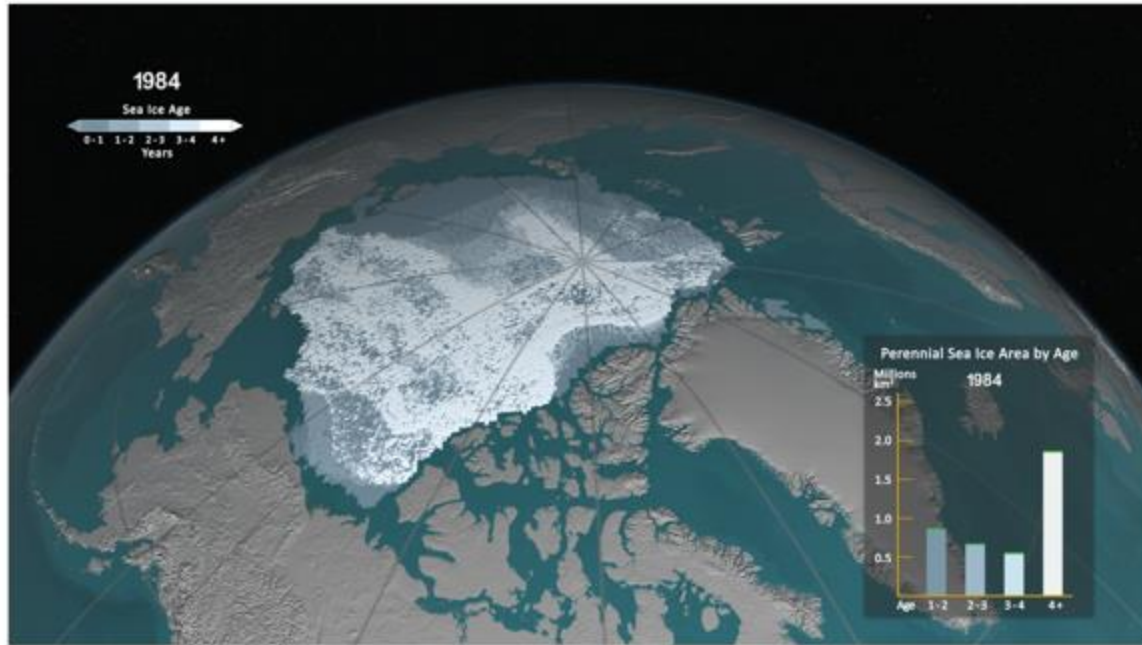
# Deep permafrost temperature over the last 60 years



# Projected carbon changes by 2050



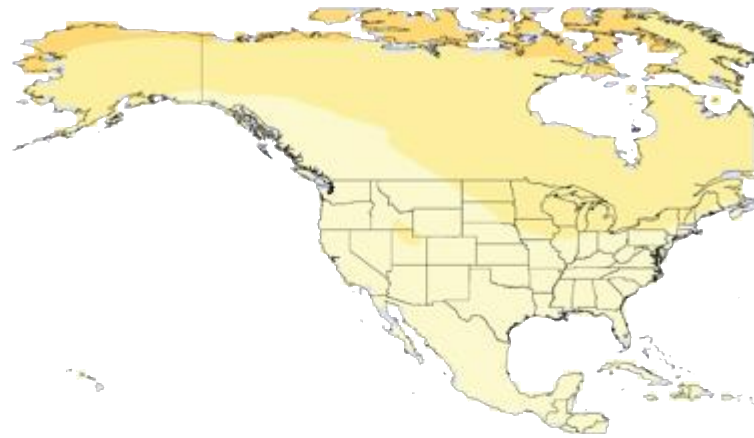
# Sea Ice Extent



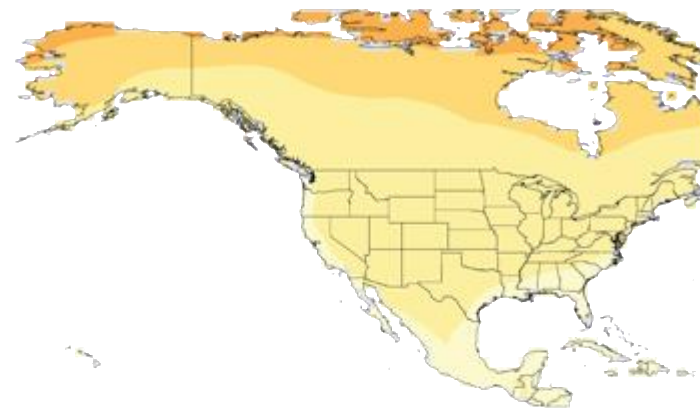
# Projected Changes in Average Annual Temperature

Mid 21st Century

Lower Scenario (RCP4.5)

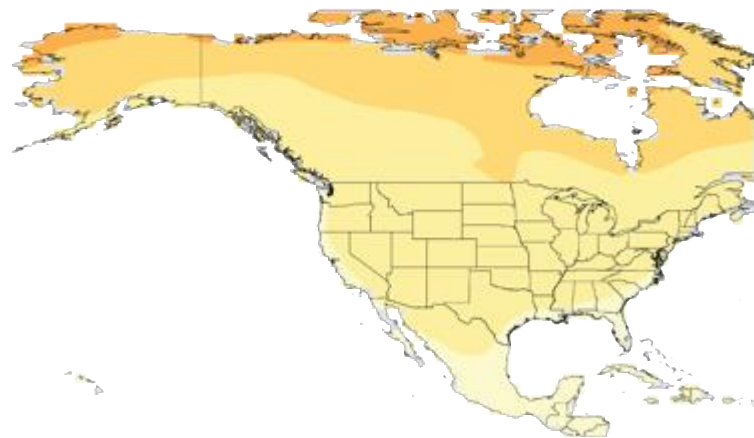


Higher Scenario (RCP8.5)

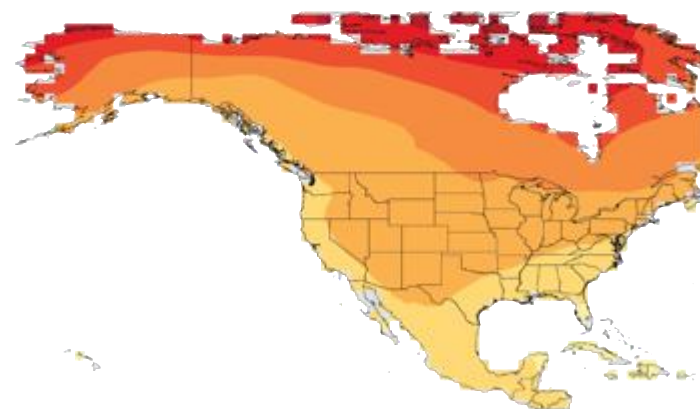


Late 21st Century

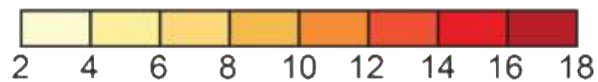
Lower Scenario (RCP4.5)



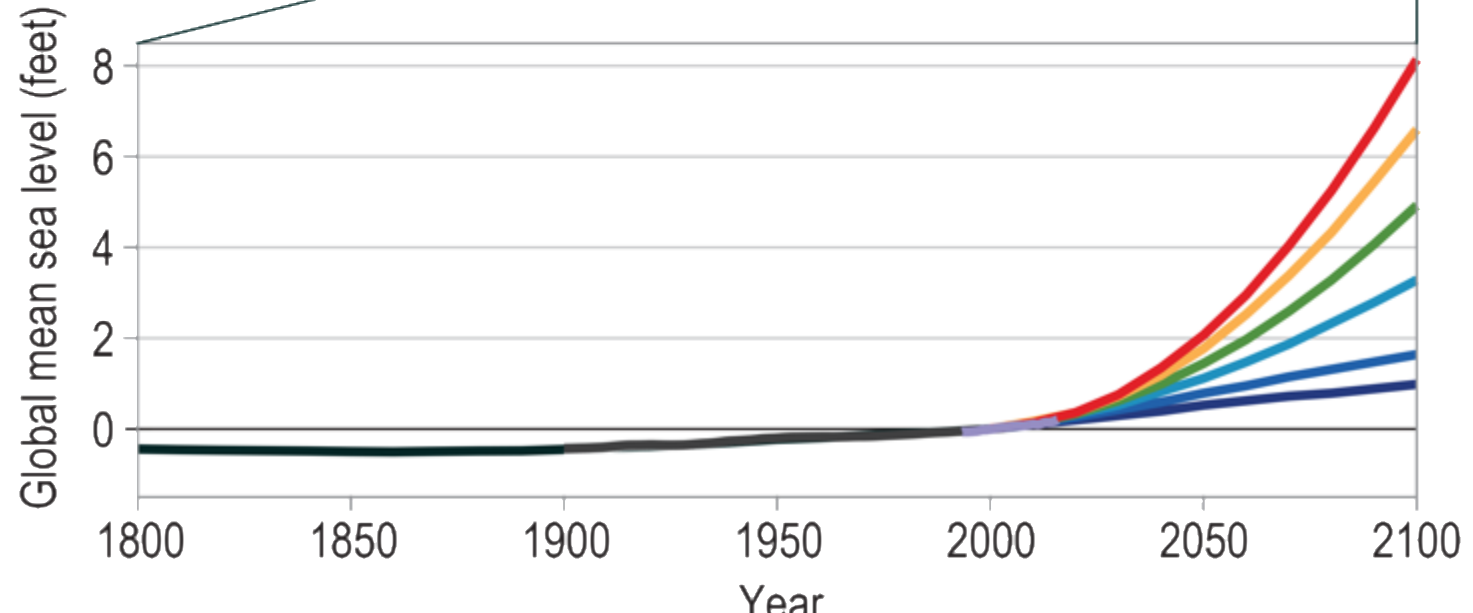
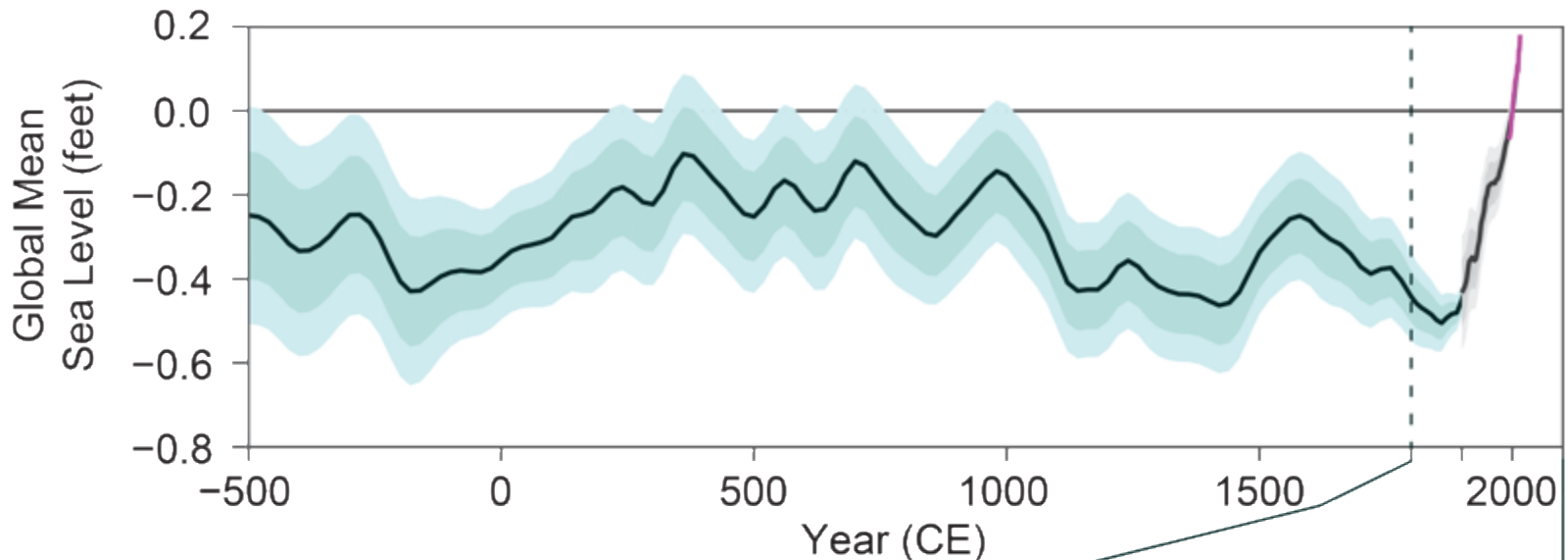
Higher Scenario (RCP8.5)

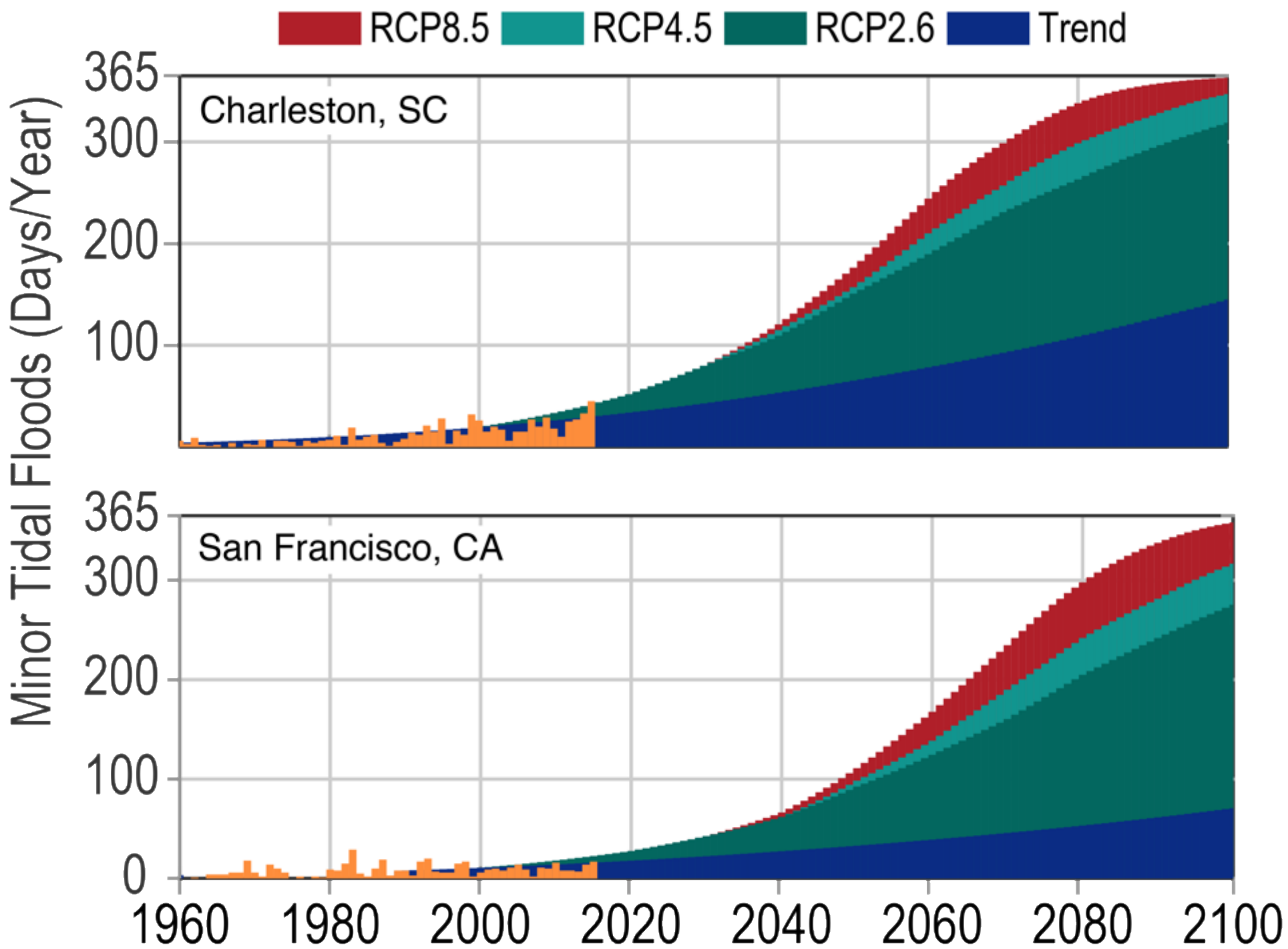


Change in Temperature (°F)



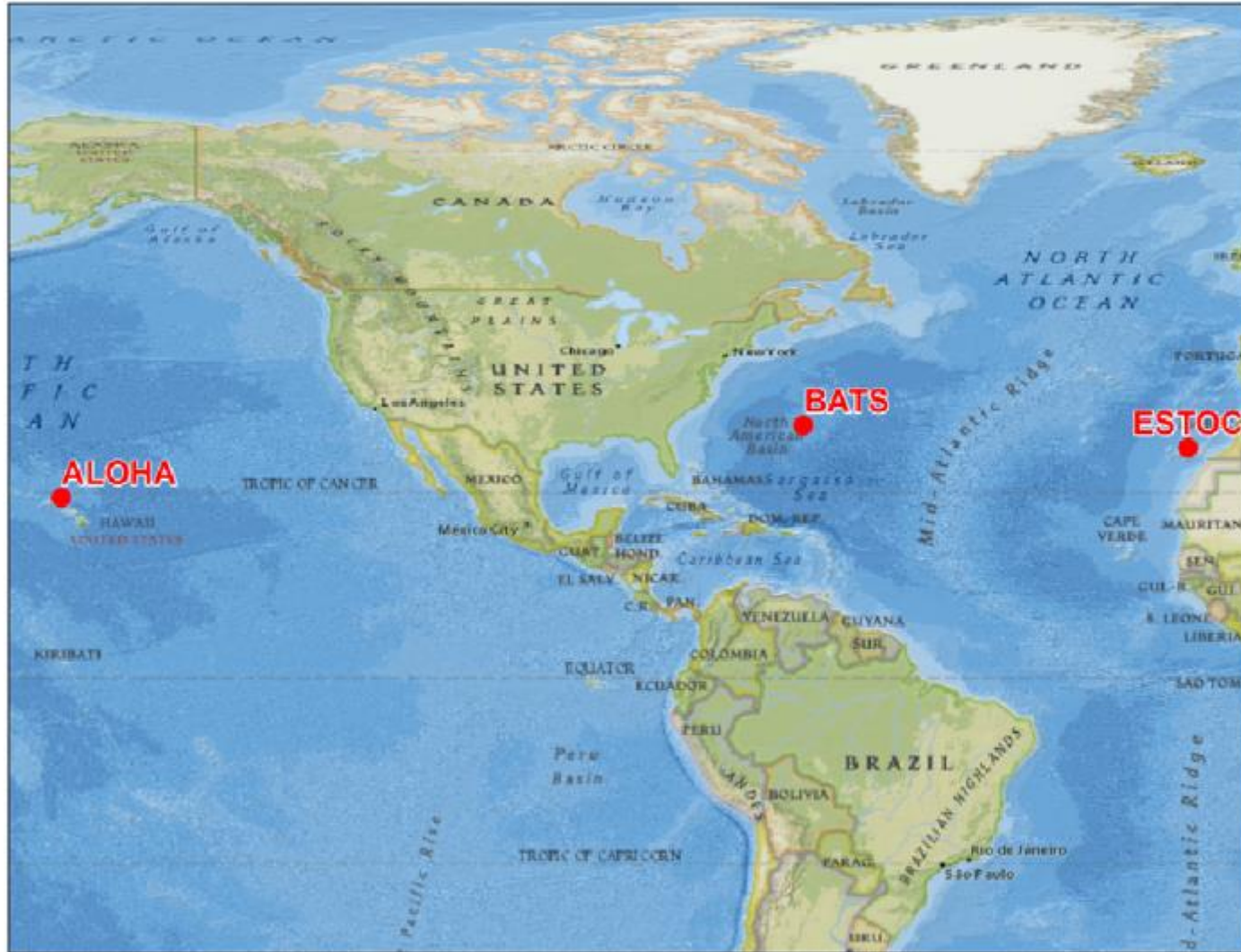
# Historical and Projected Global Mean Sea Level Rise



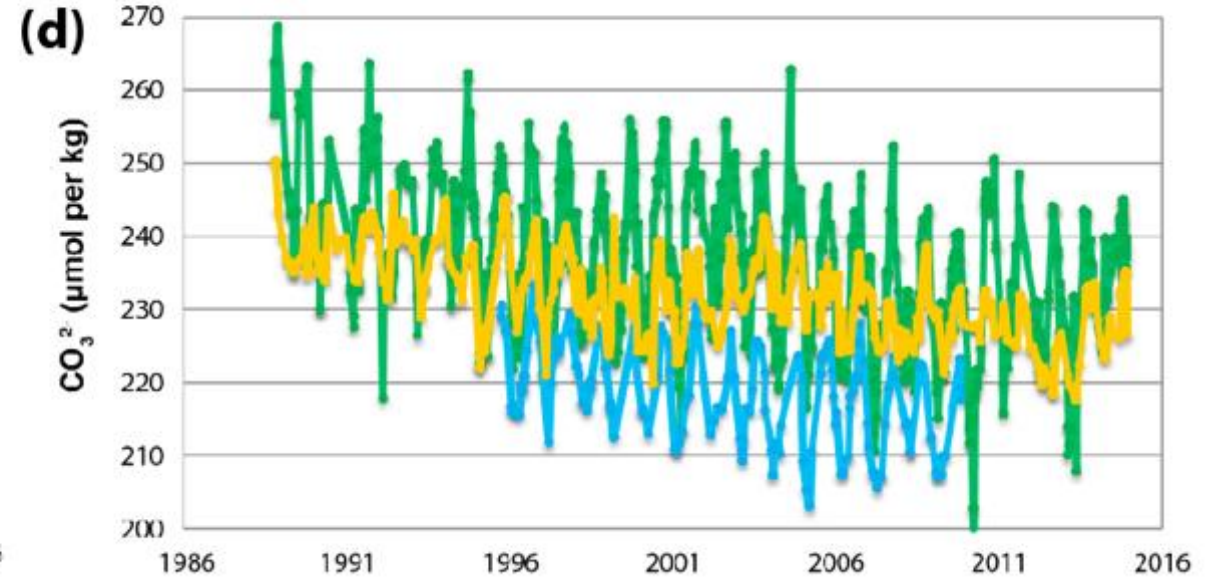
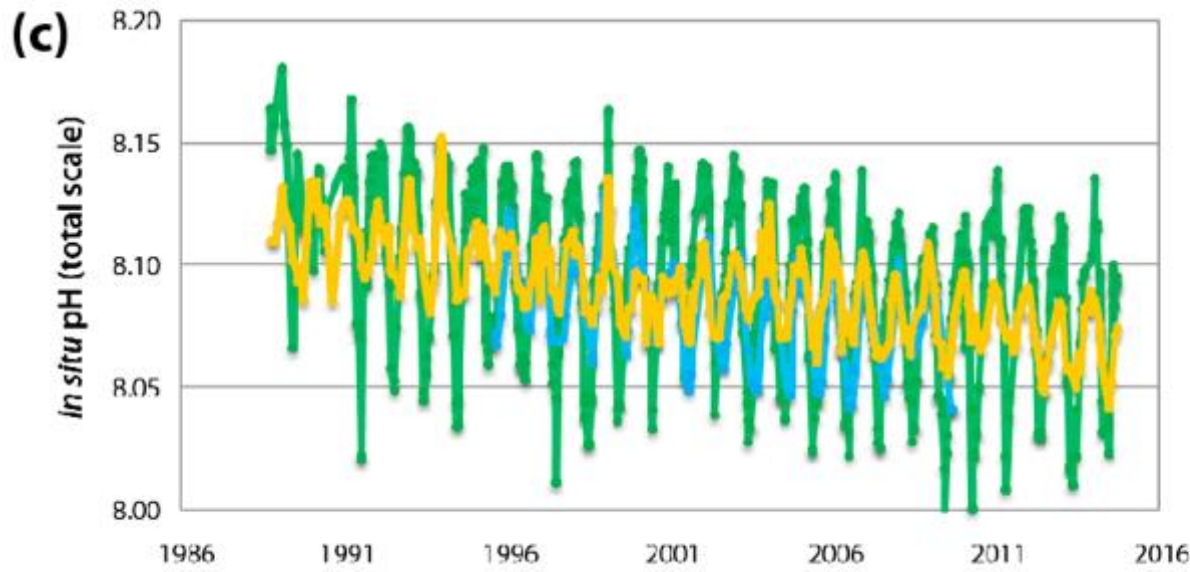
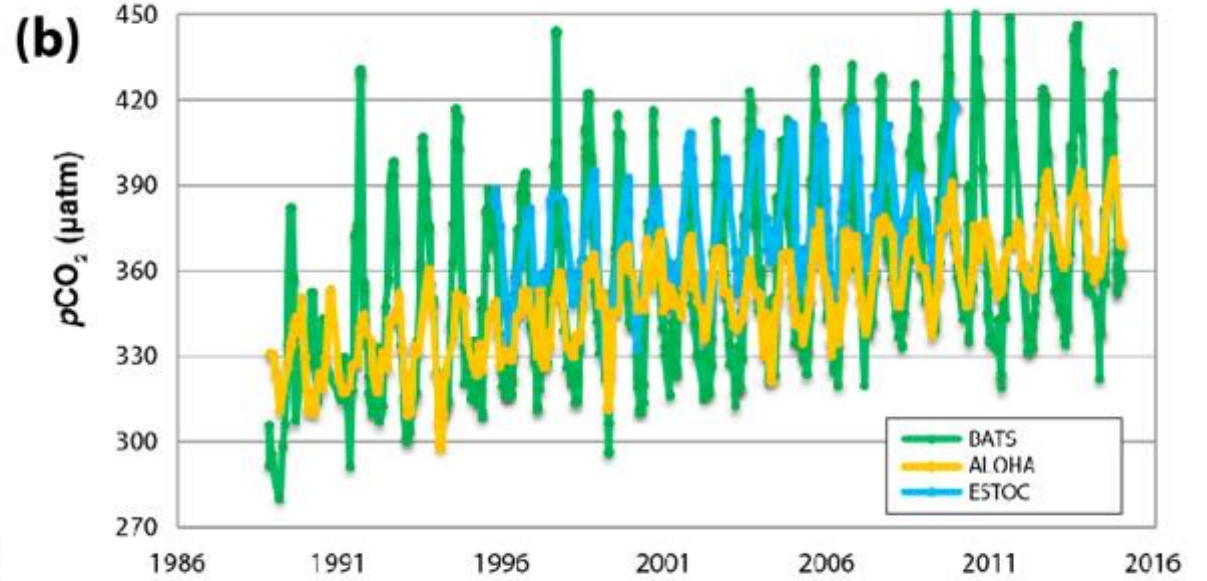
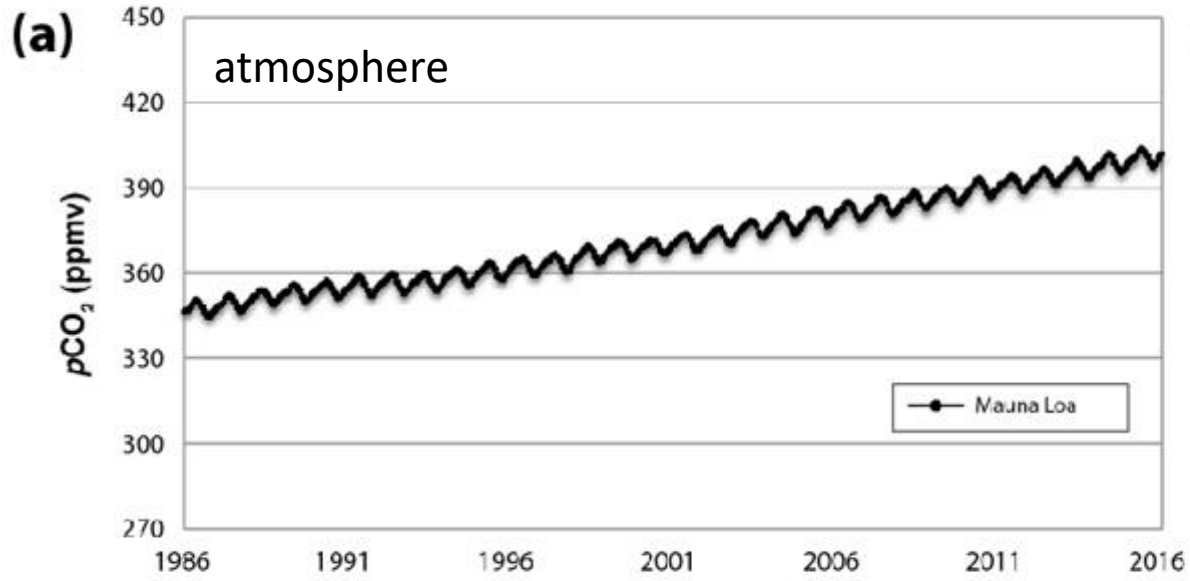


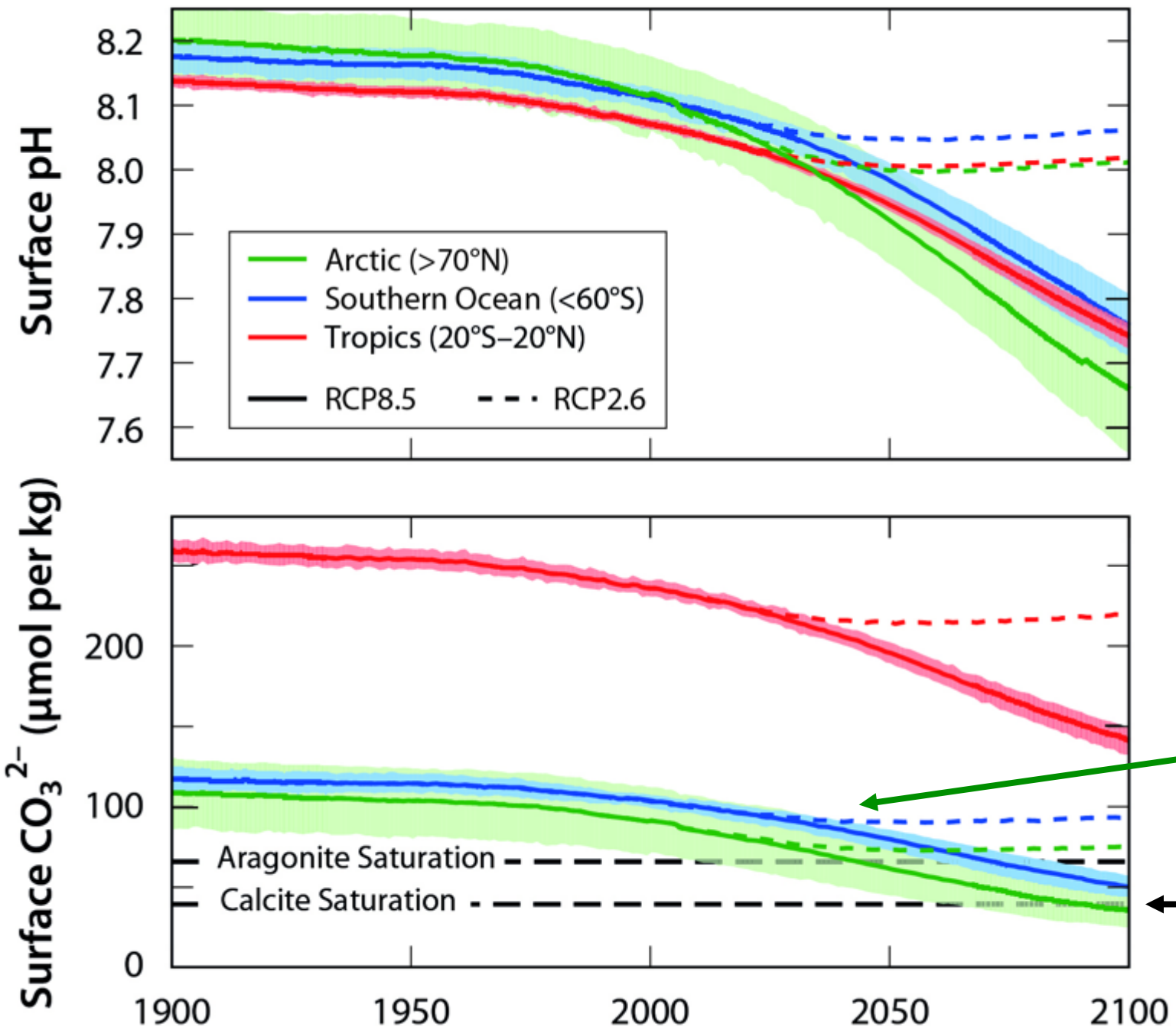


# Ocean chemistry measurements



Second State of the Carbon Cycle Report





The difference between RCP8.5 and RCP2.6

Critters can't precipitate carbonate shells in RCP8.5

# Summary


- Over half of North America's fossil emissions enter the atmosphere, but the land and coastal oceans continue to take up significant carbon
- Energy-related carbon emissions in North America have decreased due to fuel switching, increased efficiencies, renewables, etc
- Without a loss of GDP!

# Summary

- Carbon dioxide & methane concentrations continue to increase globally, with concomitant increases in temperature
- The Arctic experiences greater temperature increases than low latitudes
  - Significant potential for liberating substantial soil carbon, compounding the effects of fossil emissions
- Effects are already being felt – record-breaking temperatures, decreases in ocean pH, increases in sea level, more “nuisance” flooding

# What are the cost/benefits?

- Estimated cumulative cost from 2015 to 2050 for **the US to reduce emissions by 80%** relative to 2005 levels (an amount considered to be in line with a 2° C goal) is ~ **\$1 to \$4 trillion** (US\$2005)
- The total annual **cost in 2050 alone for climate change damages** across health, infrastructure, electricity, water resource, agriculture, and ecosystems in the US is estimated at **~\$170 to \$206 billion** (US\$2015)

- 
- ***Besides decreasing fossil fuel use, what can we do?***
    - Increased afforestation and improved agricultural practices
    - Minimize land-use change from forest and grasslands, reduce methane emissions from livestock, reduce the alteration of wetlands and coastal ecosystems, minimize food waste, and minimize nitrogen fertilizer

# Thank you!



Melanie A Mayes  
mayesma@ornl.gov

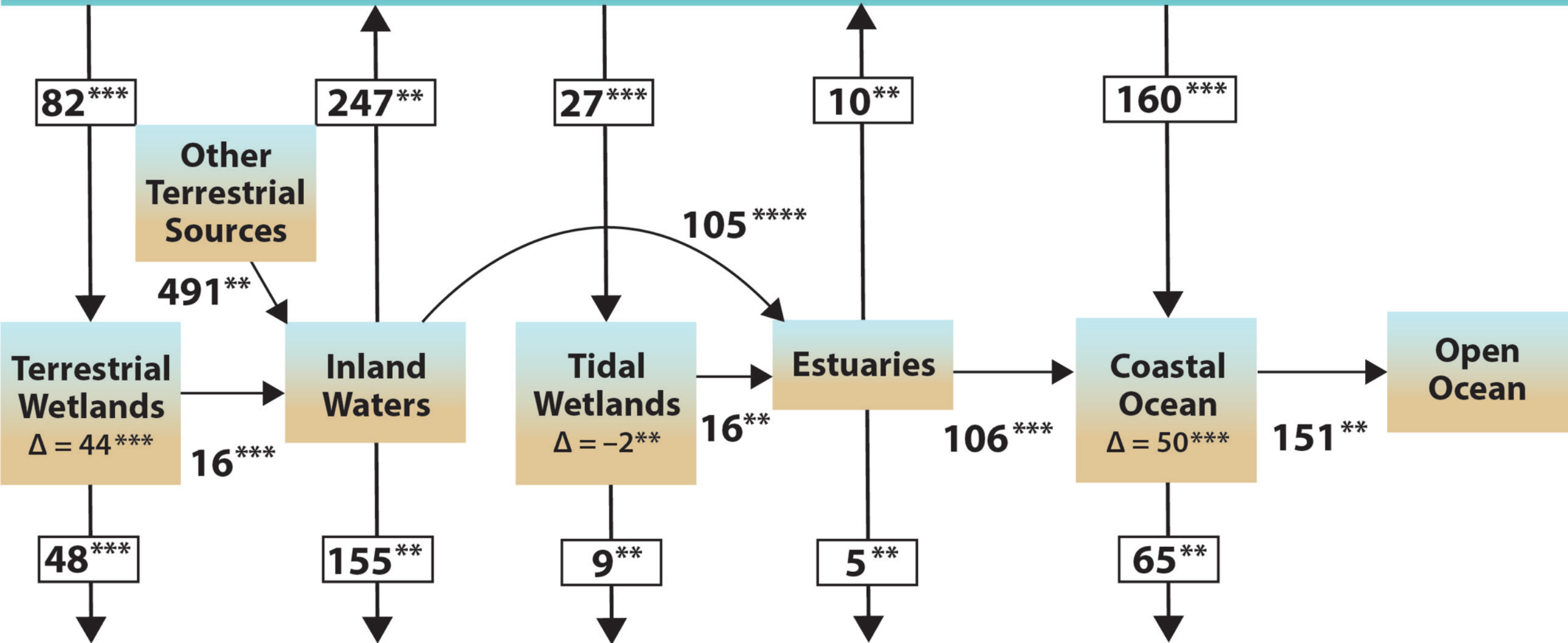
State of the Carbon Cycle Report

<https://www.globalchange.gov/content/about-soccr-2>

Climate Science Special Report <https://science2017.globalchange.gov/>



# Atmosphere



# Sediments or Soil