Role of Forest Ecosystems in Carbon Sequestration and Climate

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Overview of Ecology

Science by which we study the relationships between organisms and their environment

Levels of Ecological Organization, study of……

Organismal Ecology

… organisms and how they interact with their environment.

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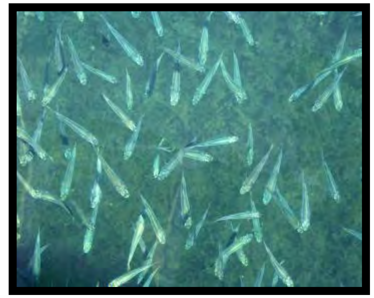

Population Ecology

… individuals of the same species living together.

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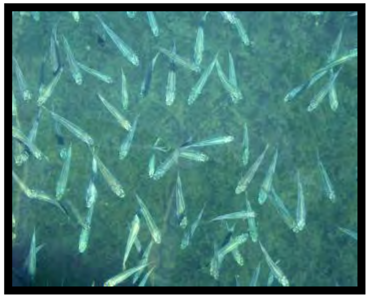

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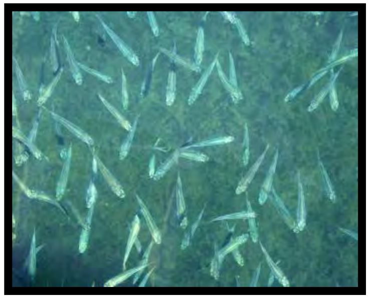

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Ecosystem Ecology

… interactions among organisms and their physical environment as an integrated system

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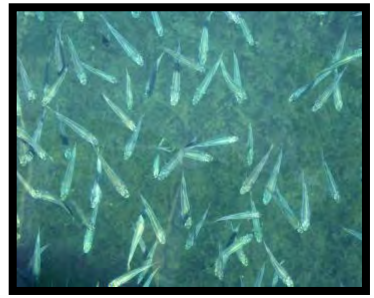

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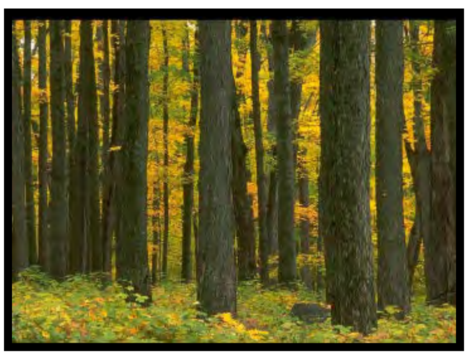

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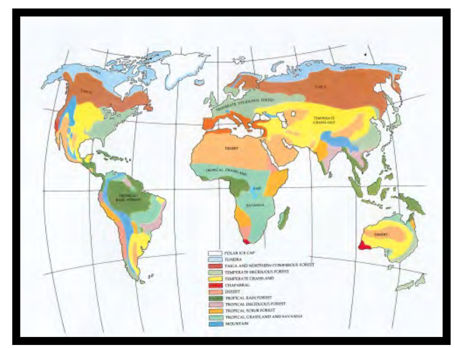

Biosphere Approach

… the movement of air, water, nutrients, energy and organisms around the earth.

Role of Forest Ecosystems in Carbon Sequestration and Climate

- Natural variability in climate
- Rise of CO_2 concentrations and climate change
- Forests as carbon sinks

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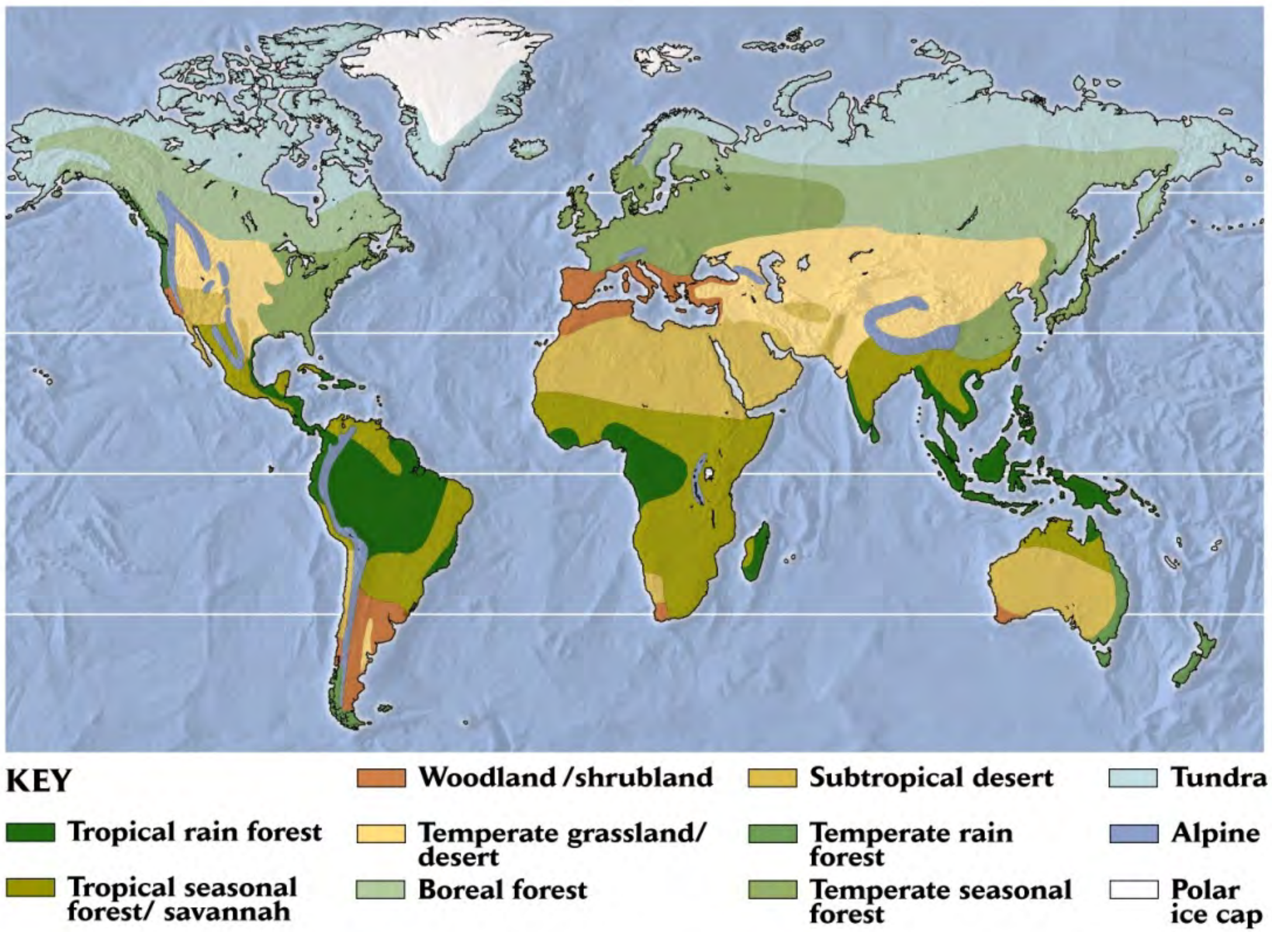
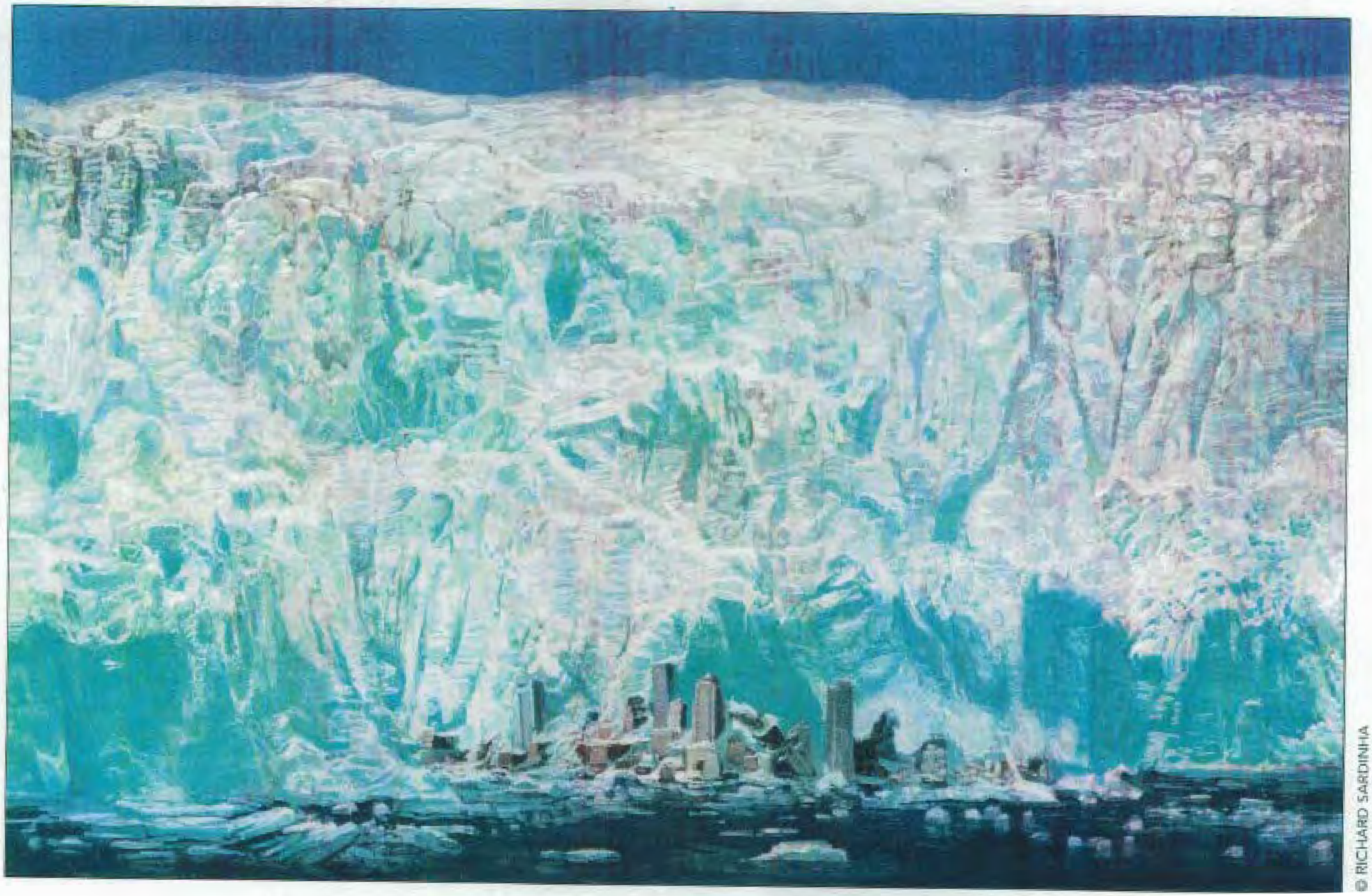


Biomes

Ice ages naturally occur every ~100,000

- Milankovitch Cycles: cyclical changes in Earth's movement around the Sun
- Cause variation in amount of solar radiation reaching Earth's surface
- Predicts global cooling for next 1000 years

Contemporary Boston Superimposed with Glacier During Last Ice Age



Role of Forest Ecosystems in Carbon Sequestration and Climate

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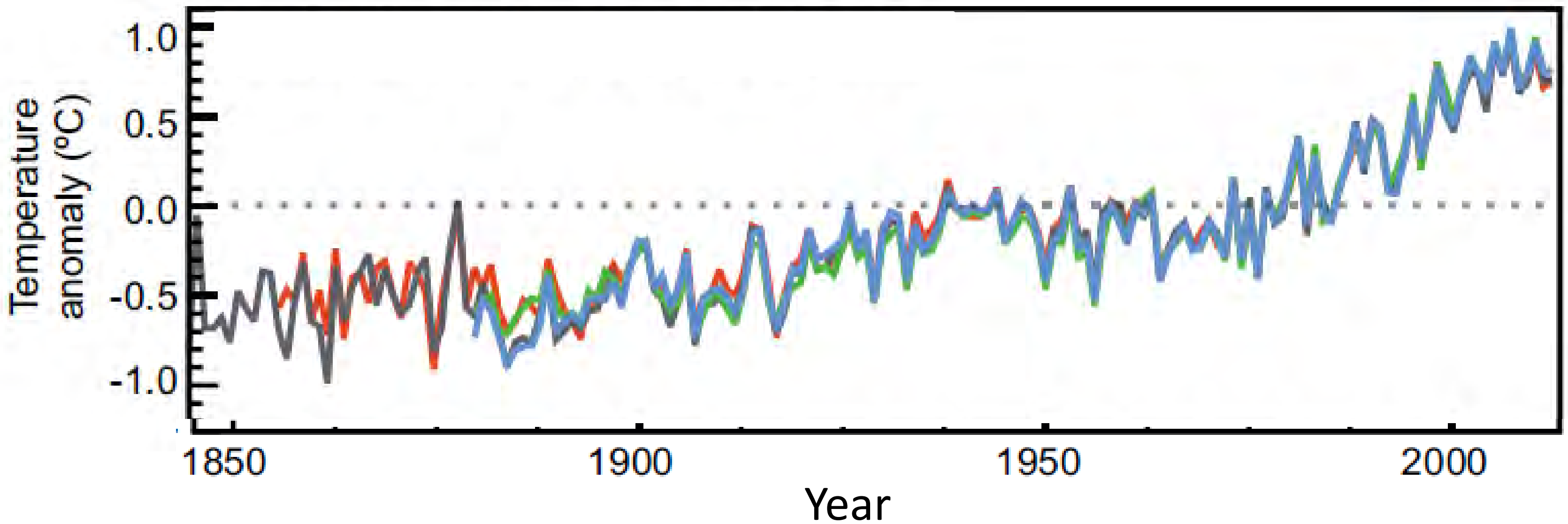
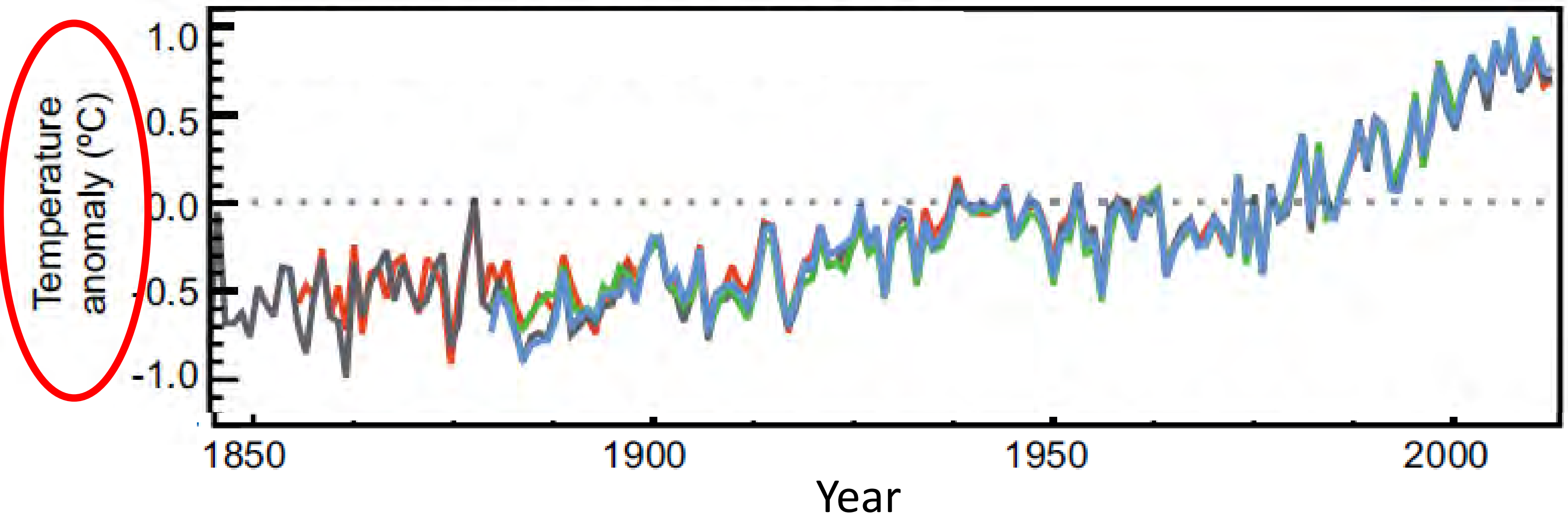
Recent Temperature Change



IPCC 2014 Technical Summary Figure 1

Recent Temperature Change



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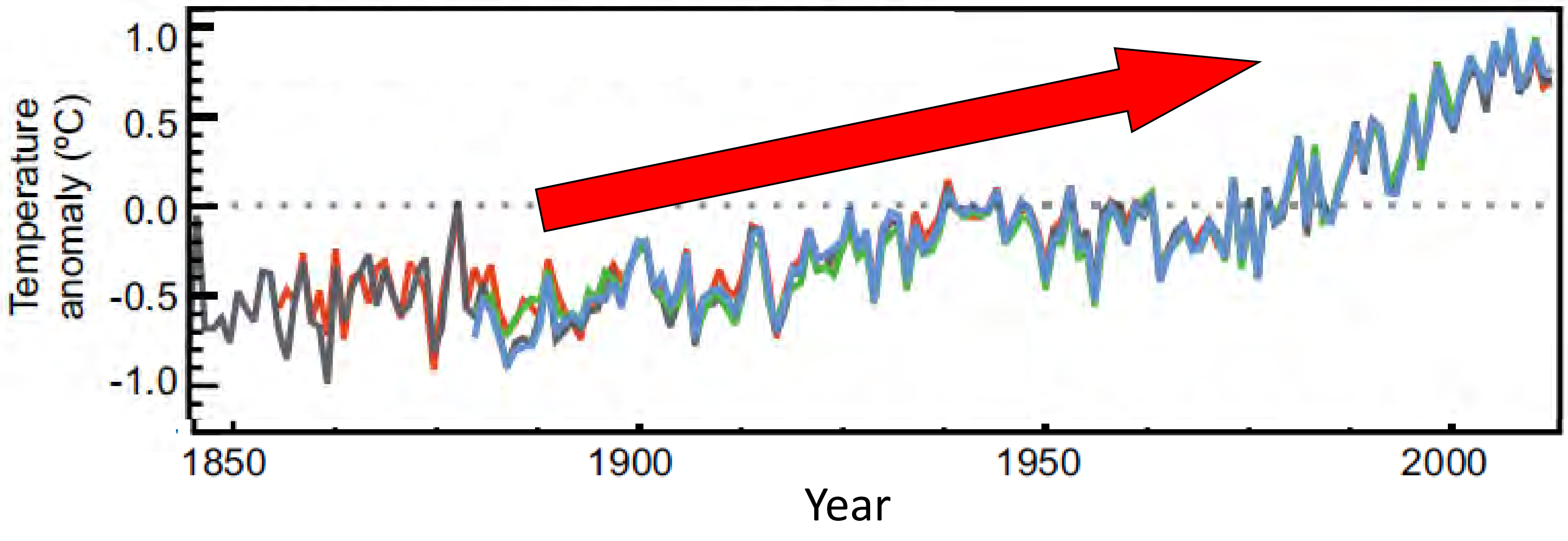

- General increase in global temperatures since 1880

IPCC 2014 Technical Summary Figure 1

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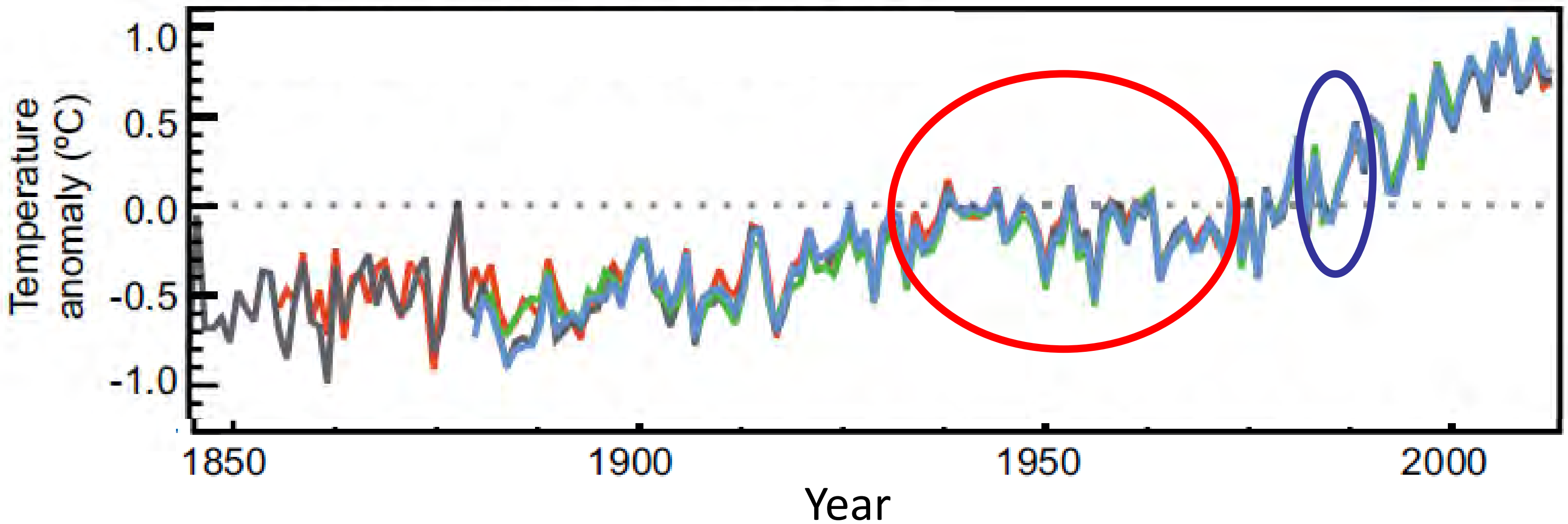

- General increase in global temperatures since 1880
- What causes temporary cooling in global air temperature?

IPCC 2014 Technical Summary Figure 1

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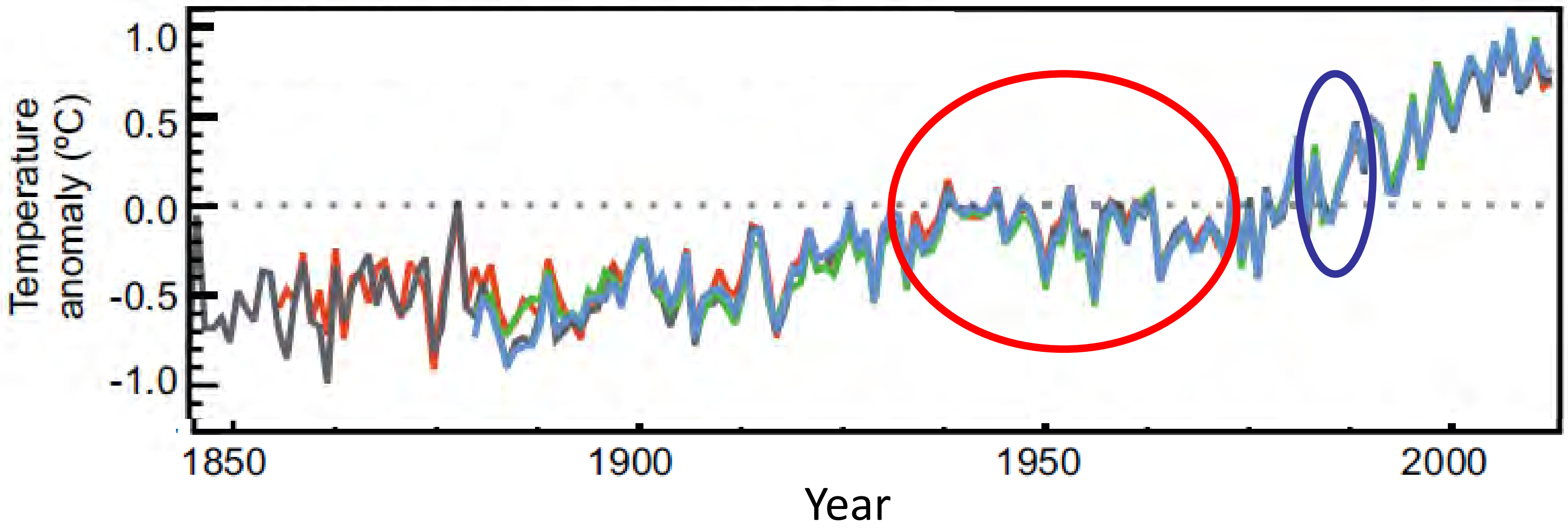

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- 1940-1980: Particulates and aerosol pollution counter-acted effects of elevated CO_2

IPCC 2014 Technical Summary Figure 1

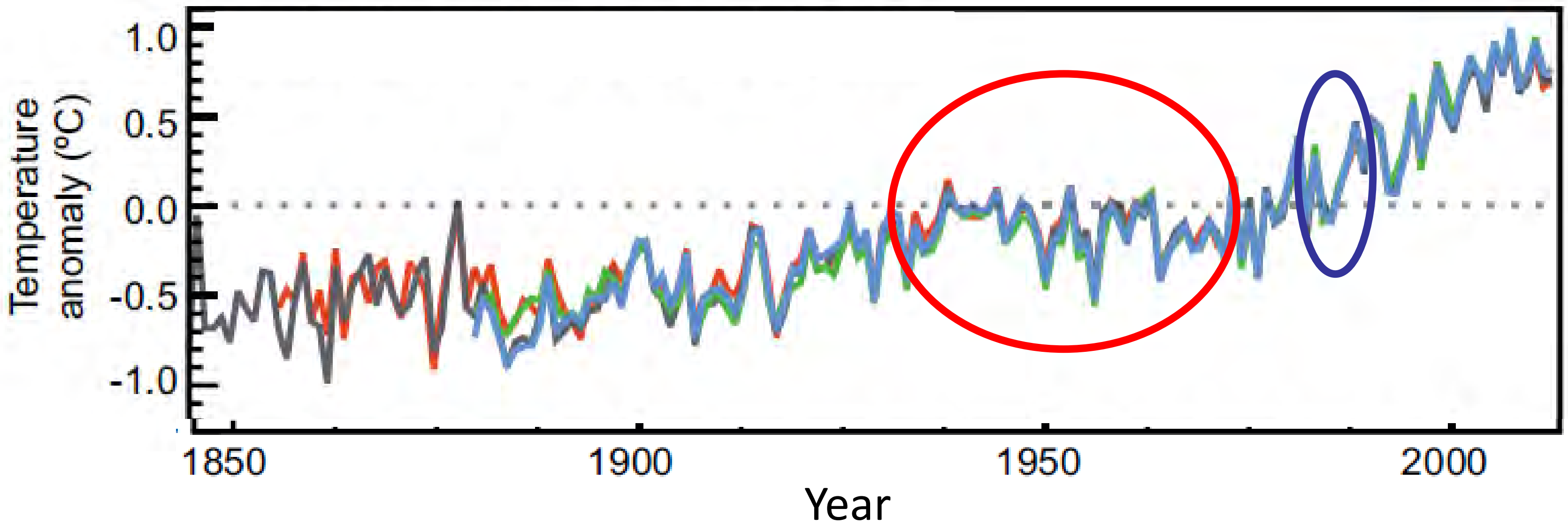
Newsweek

The Cooling World
***Newsweek*, April 28, 1975**

"There are ominous signs that the Earth's weather patterns have begun to change dramatically and that these changes may portend a drastic decline in food production – with serious political implications for just about every nation on Earth. The drop in food output could begin quite soon, perhaps only 10 years from now….

….The central fact is that after three quarters of a century of extraordinarily mild conditions, the earth's climate seems to be cooling down."

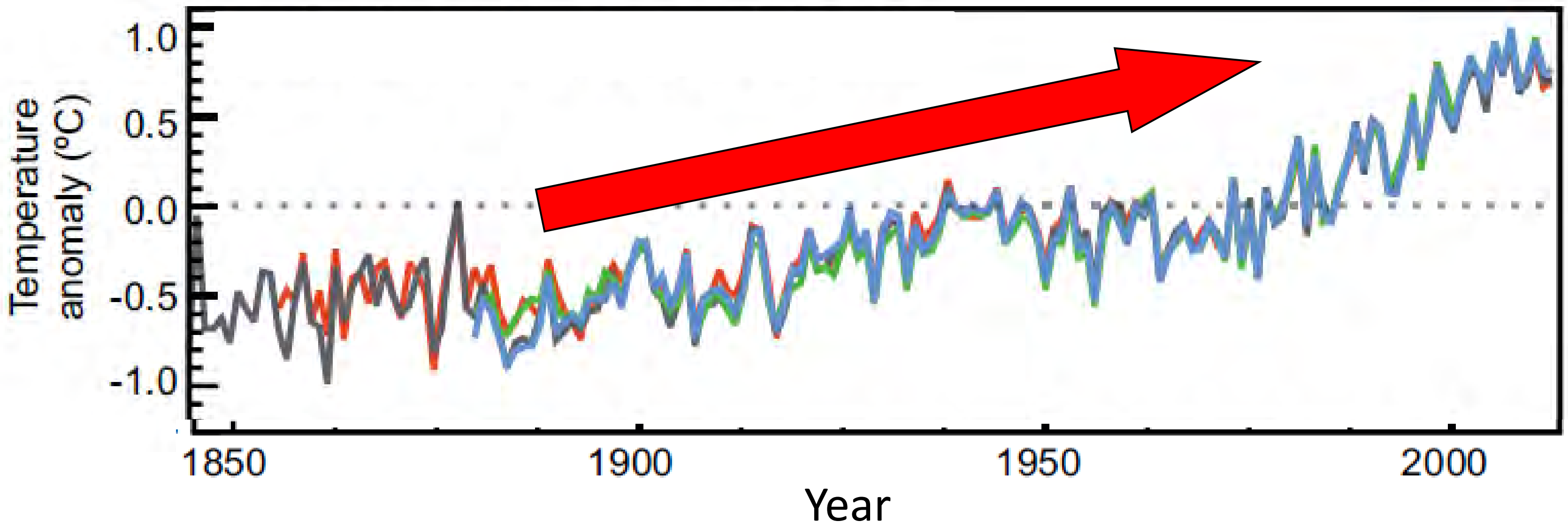
Recent Temperature Change



- General increase in global temperatures since 1880
- What causes temporary cooling in global air temperature?
- 1940-1980: Particulates and aerosol pollution counter-acted effects of elevated CO_2
- 1990s: Mount Pinatubo erupted →high SO_2 concentrations in stratosphere reflected incoming radiation
- Both periods of time: Resulted in temporary cooling

IPCC 2014 Technical Summary Figure 1

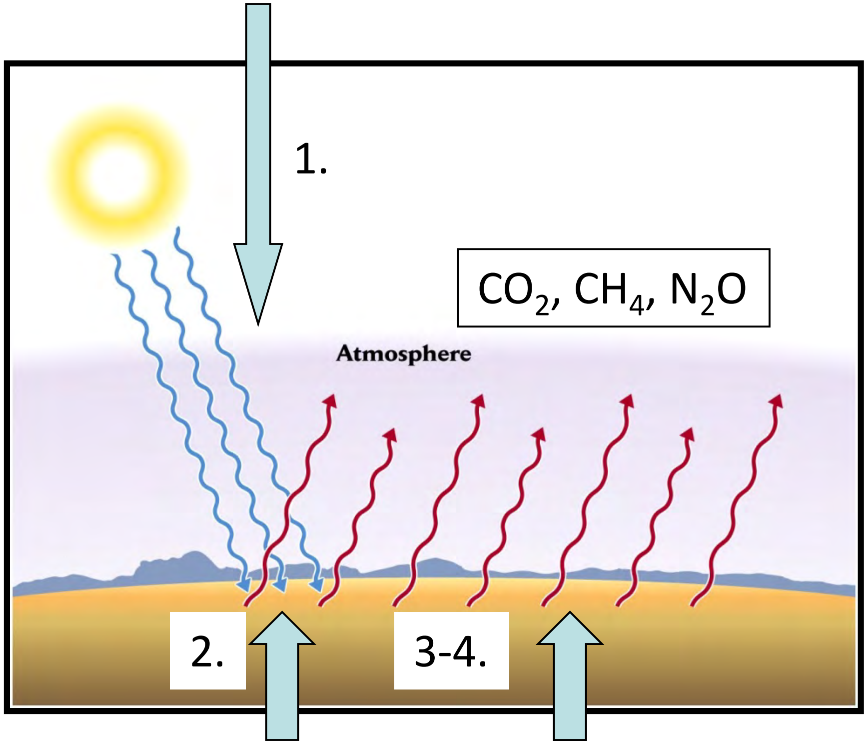
Recent Temperature Change



- What is causing general increases in global temperature?

IPCC 2014 Technical Summary Figure 1

Greenhouse Effect



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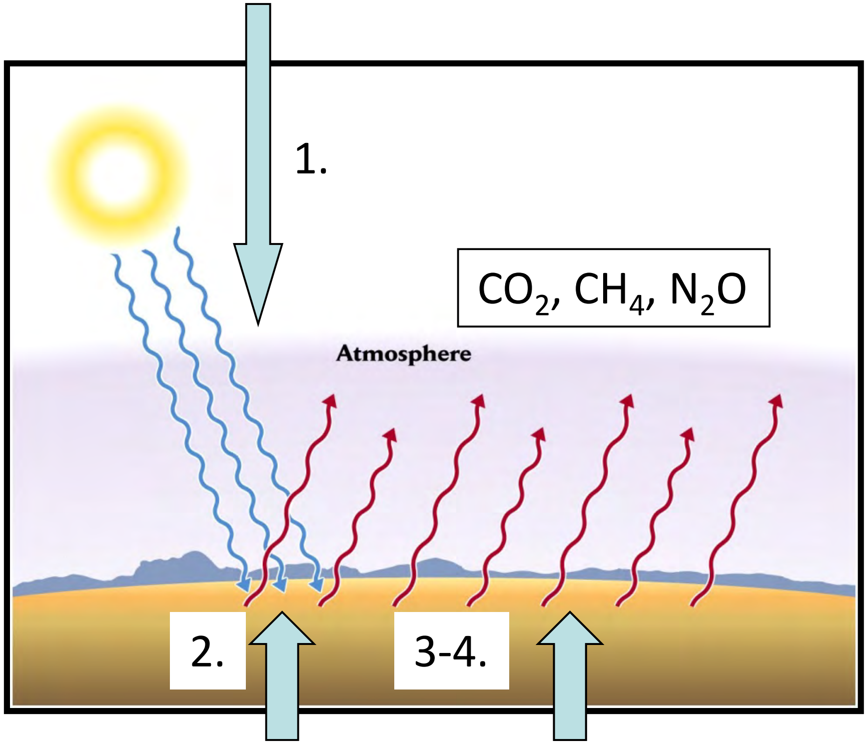
4. Infrared radiation absorbed by atmosphere (CO_2, H_2O, CH_4) and converted to heat

Greenhouse Effect



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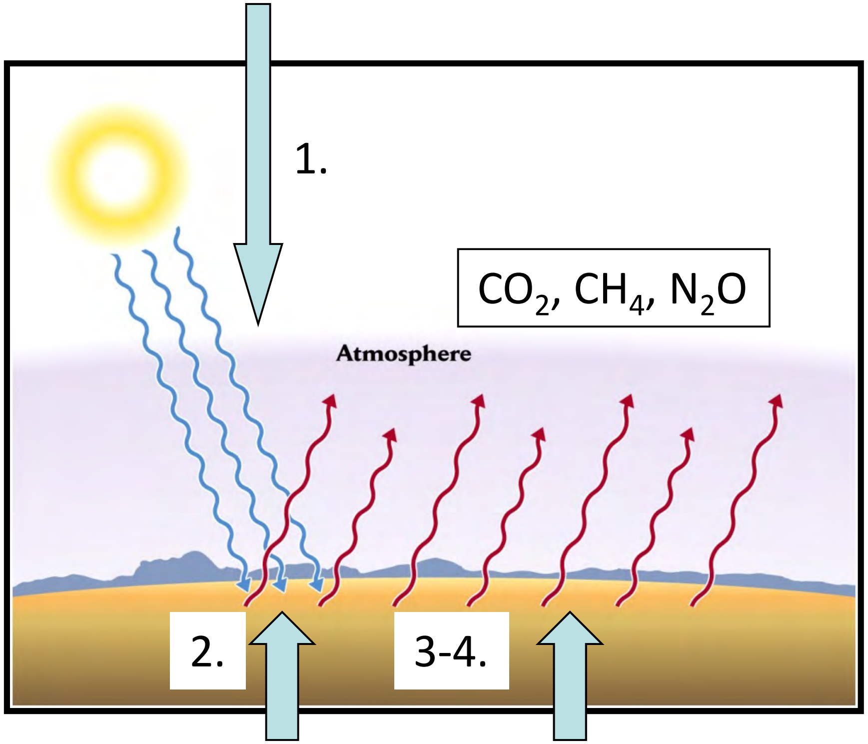

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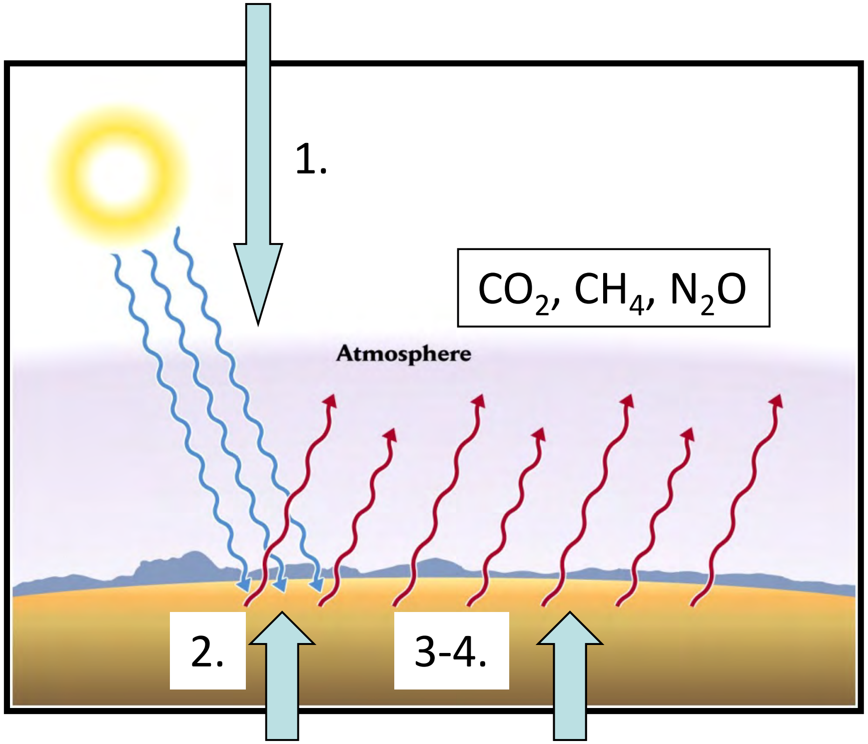

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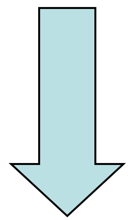
Greenhouse Effect - Summary

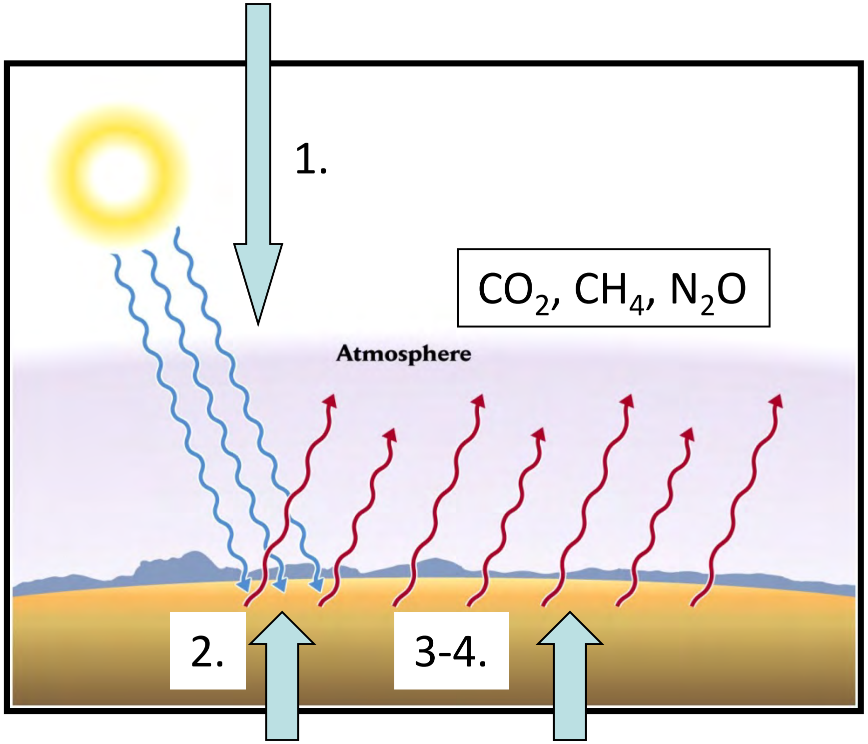
Greenhouse effect is essential to life on earth

(we would freeze without it → 33^{0}C cooler based on distance from sun)



but <u>enhanced</u> greenhouse effect may lead to further warming

Greenhouse Effect



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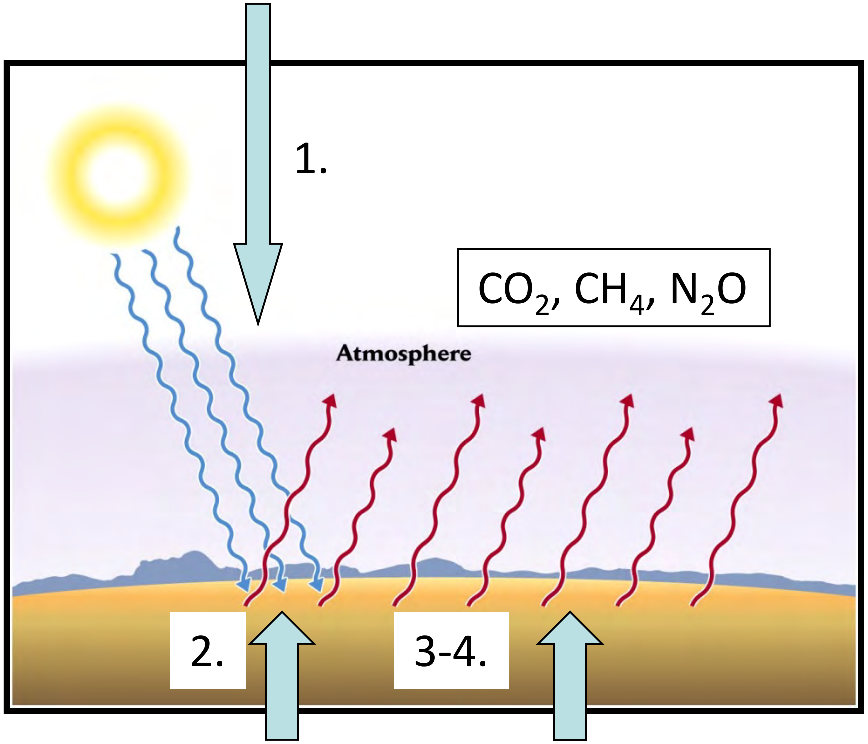

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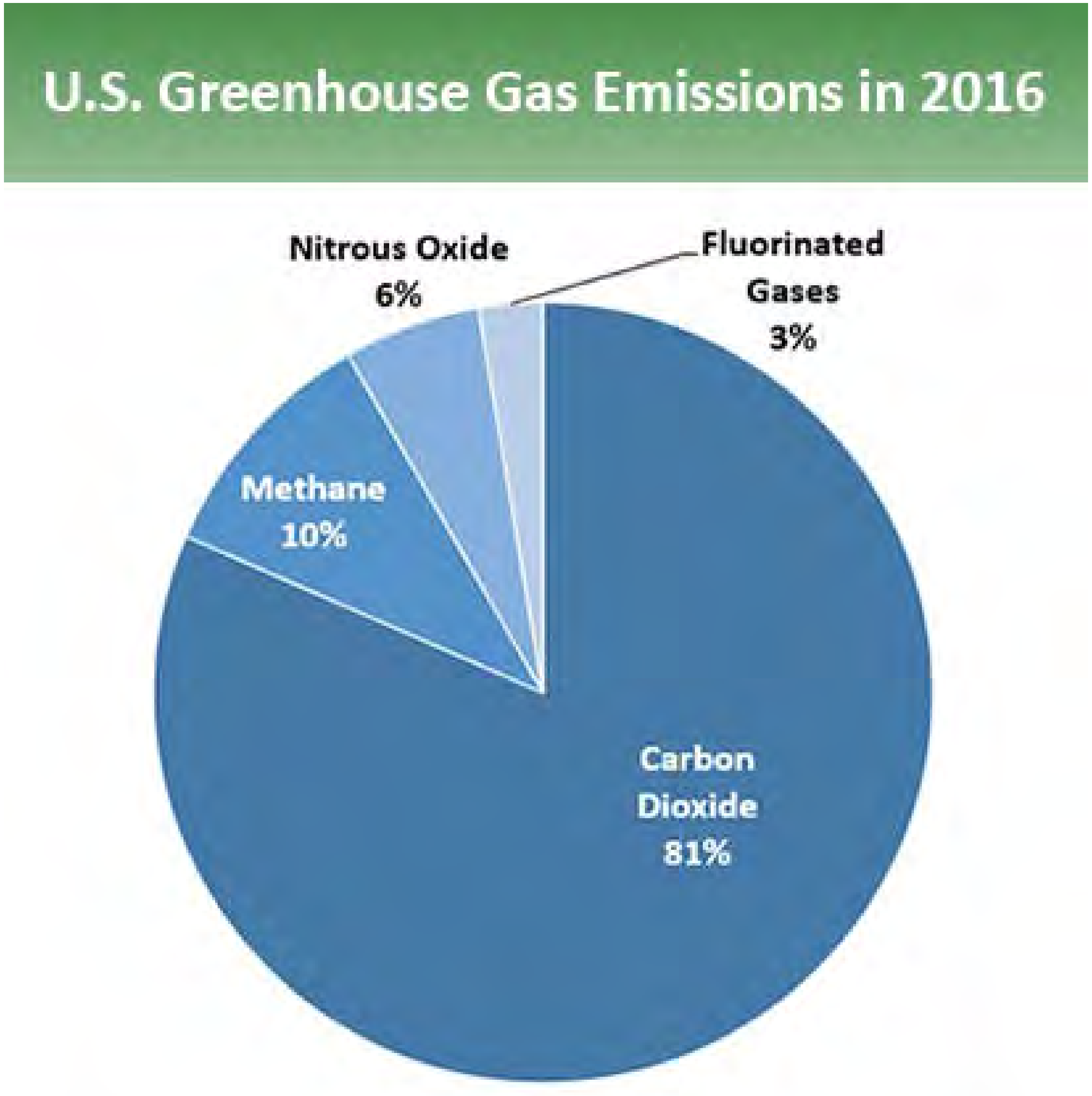
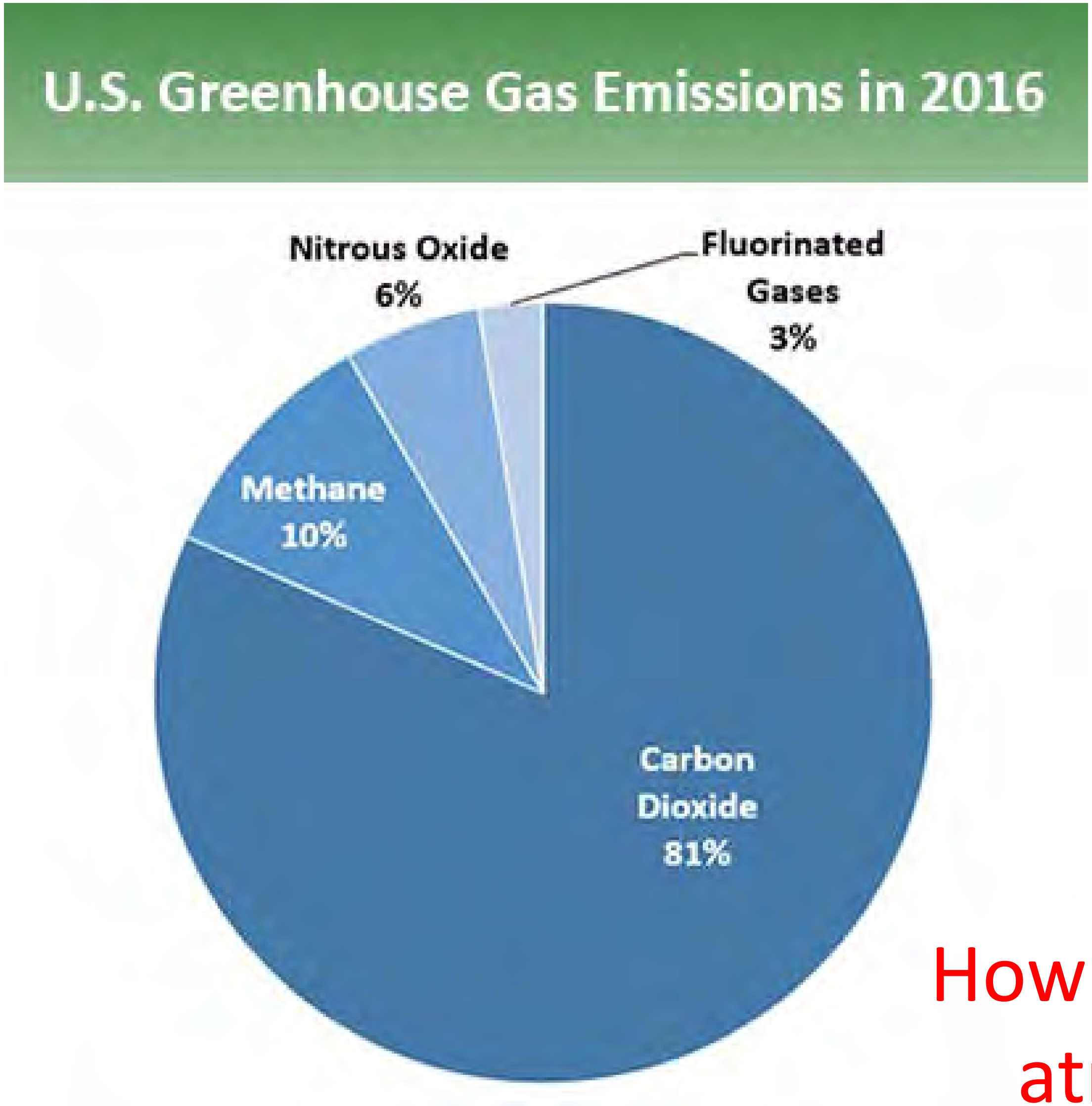
Why Such Focus on CO_2?



CO_2: makes up largest proportion of greenhouse gas emissions

https://www.epa.gov/ghgemissions/overview-greenhouse-gases



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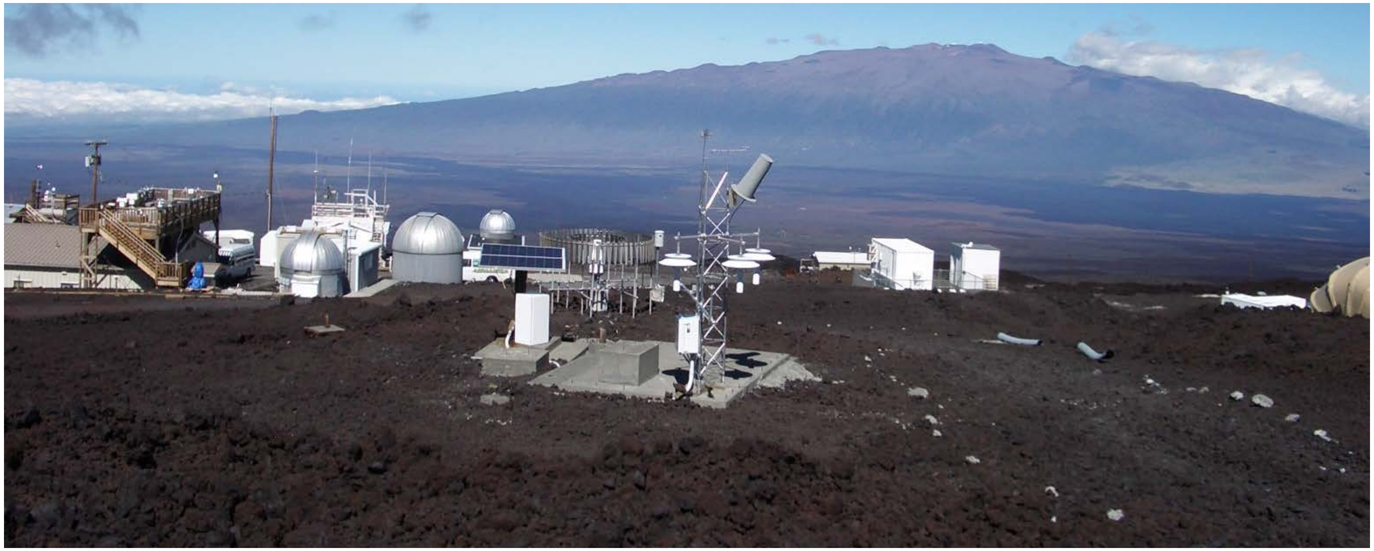
How do we know that atmospheric CO_2 concentrations are rising?

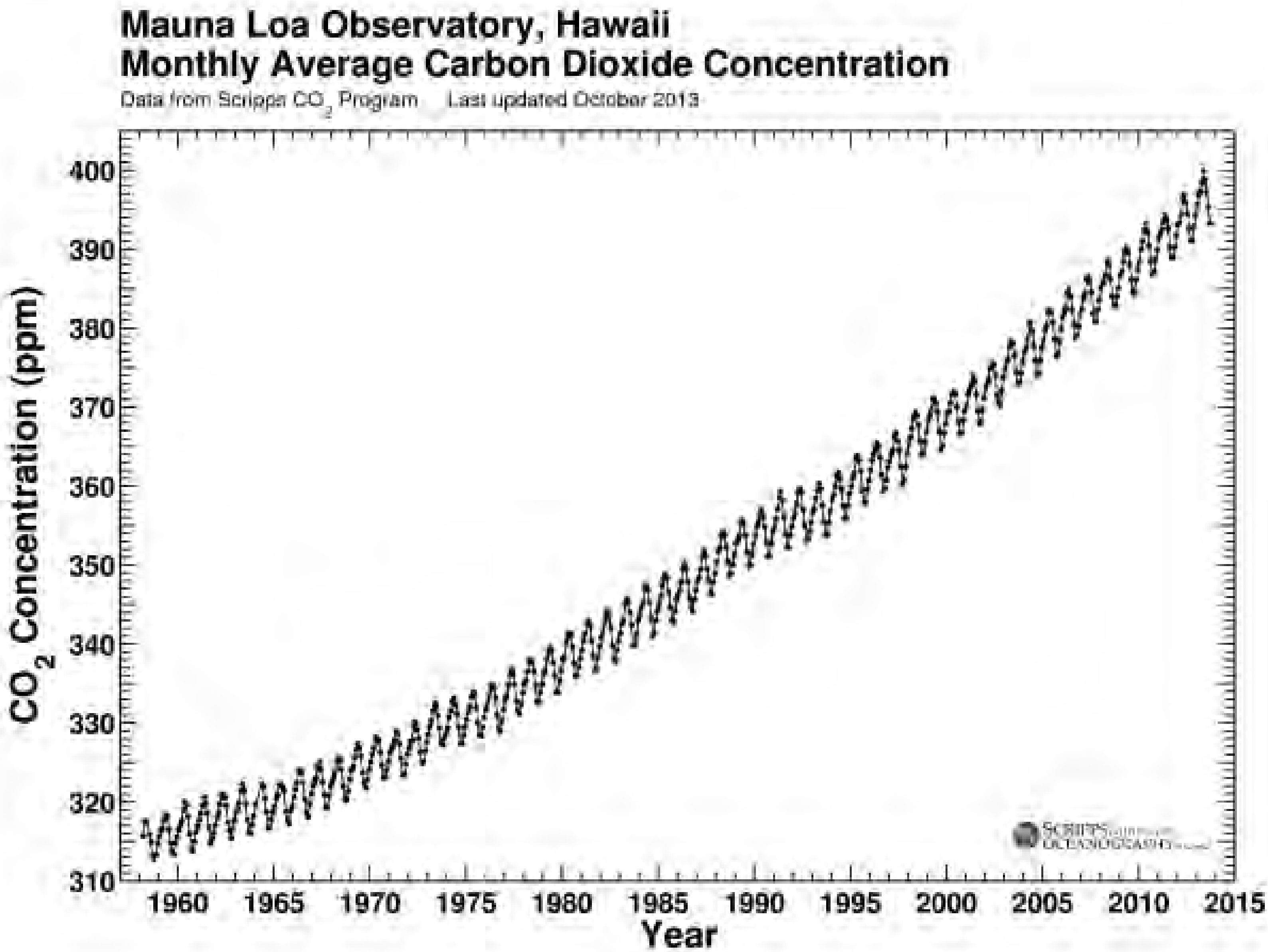
https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Charles Keeling

- Funded to develop analytical equipment to measure atmospheric CO_2
- Chose Mauna Loa, Hawaii since isolated: very little CO_2 from human activities
- Only asked to measure multiple years to determine exact global concentration
- Decided to measure multiple times within 1st year
- Discovered within 1st year of measurement that CO_2 concentration was rising



ete.cet.edu/gcc/?/globaltemp_carbon_cycle


Mauna Loa Observatory, Hawaii
Monthly Average Carbon Dioxide Concentration
Data from Scripps CO2 Program Last updated October 2013
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CO2 Concentration (ppm)
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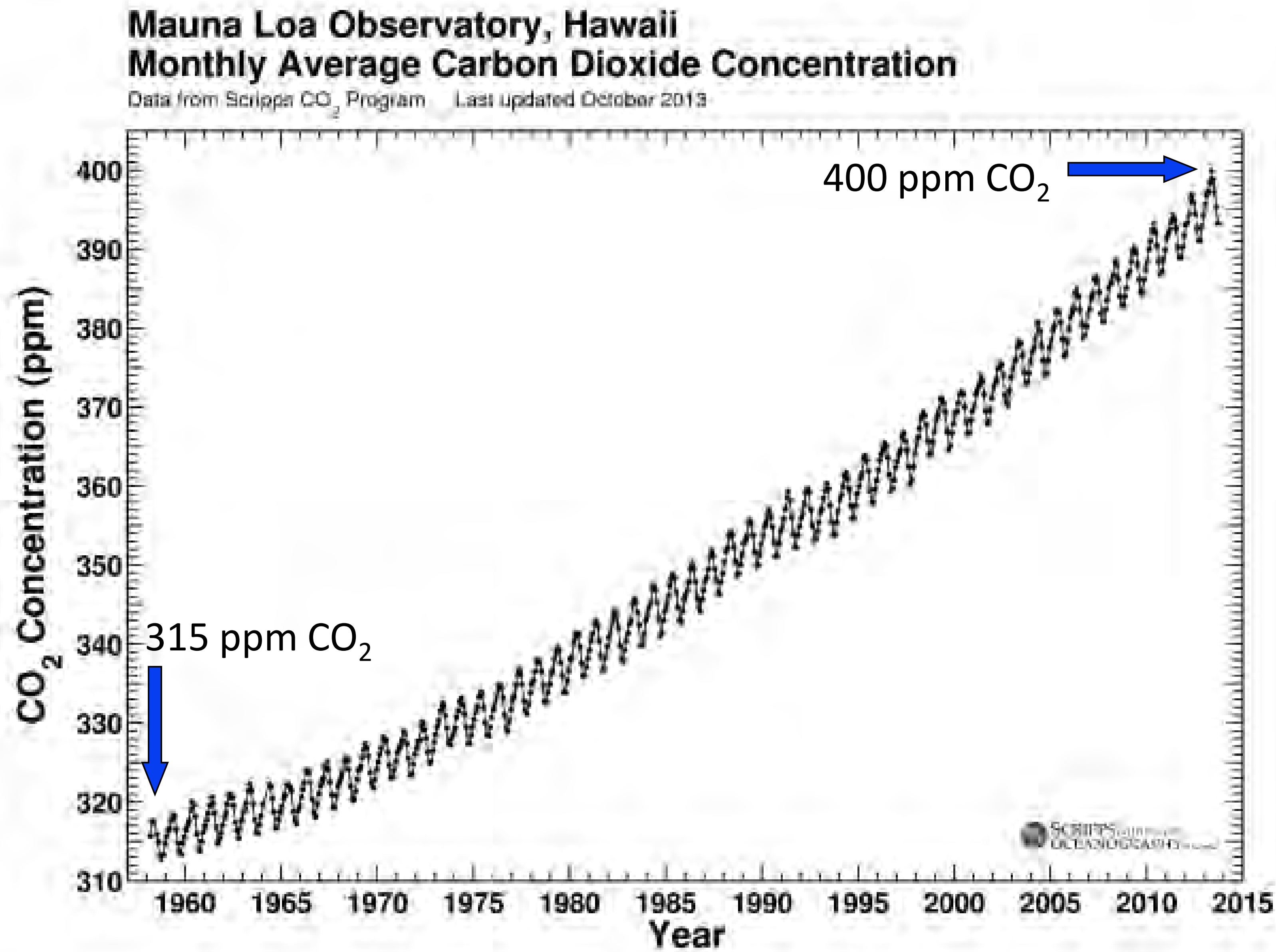
NOAA.gov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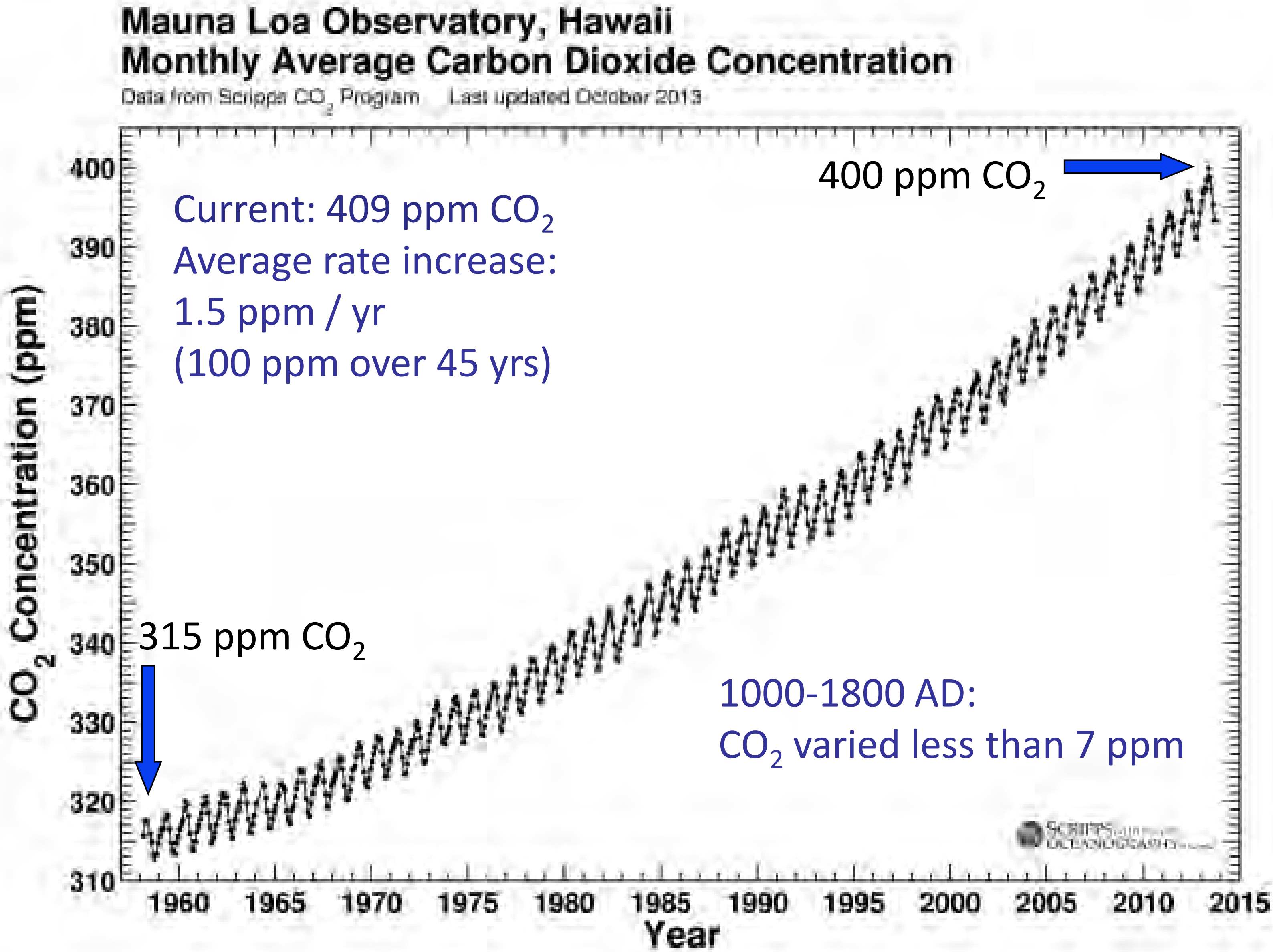
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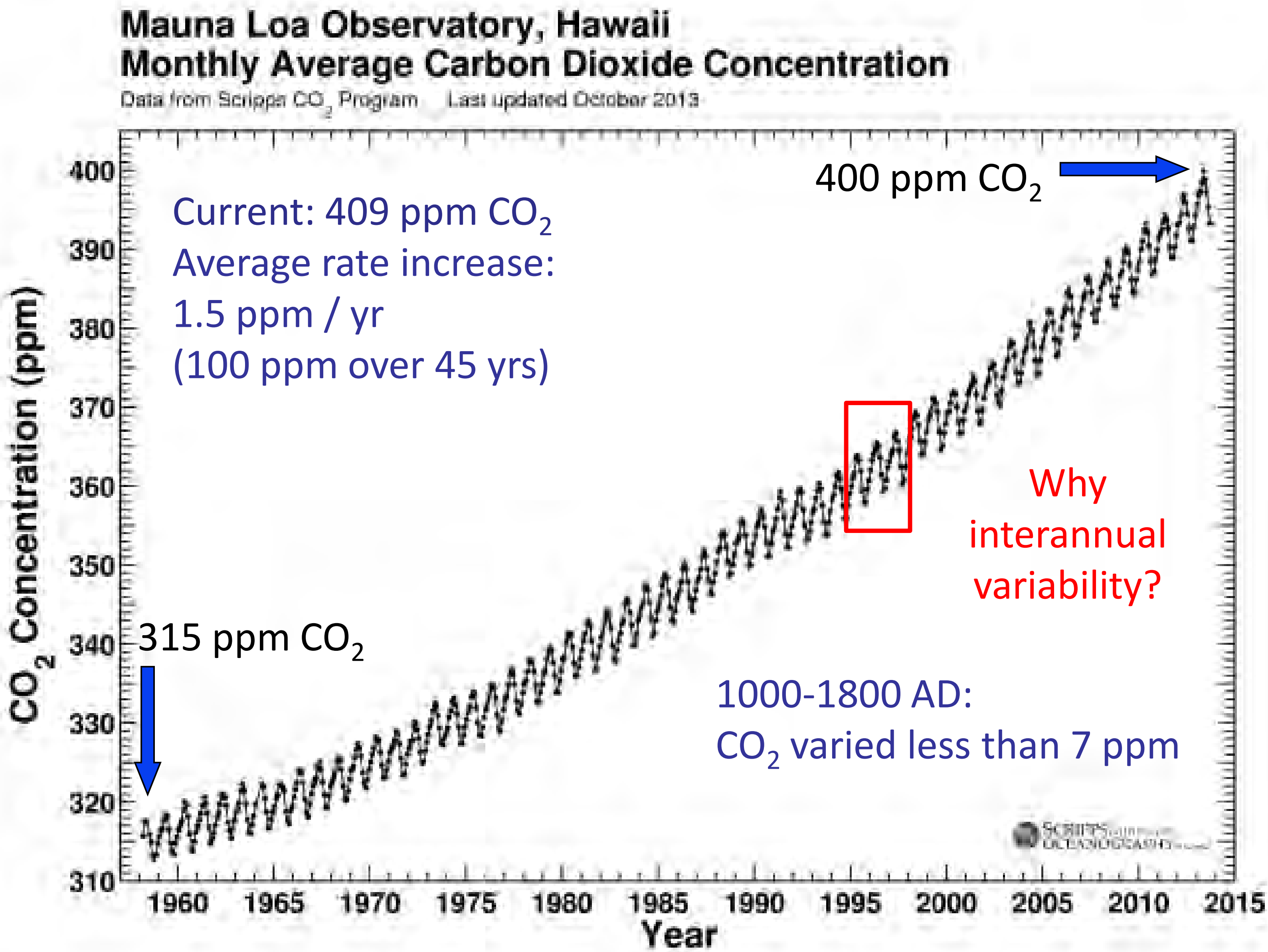

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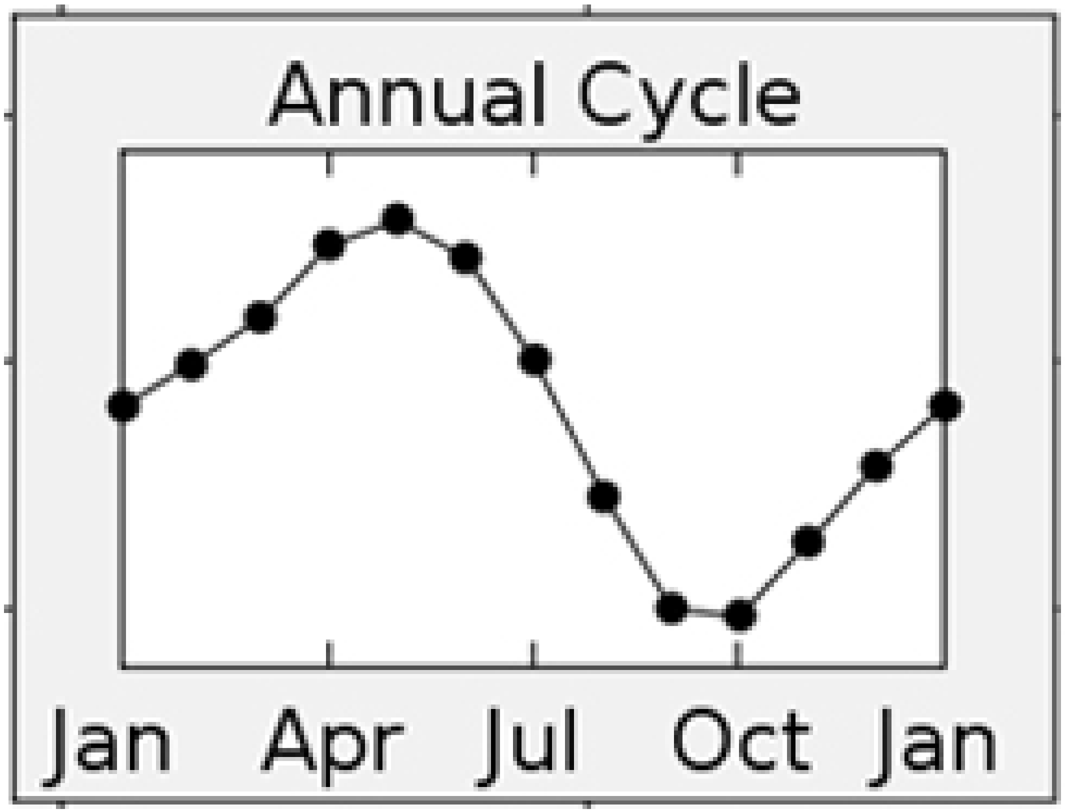
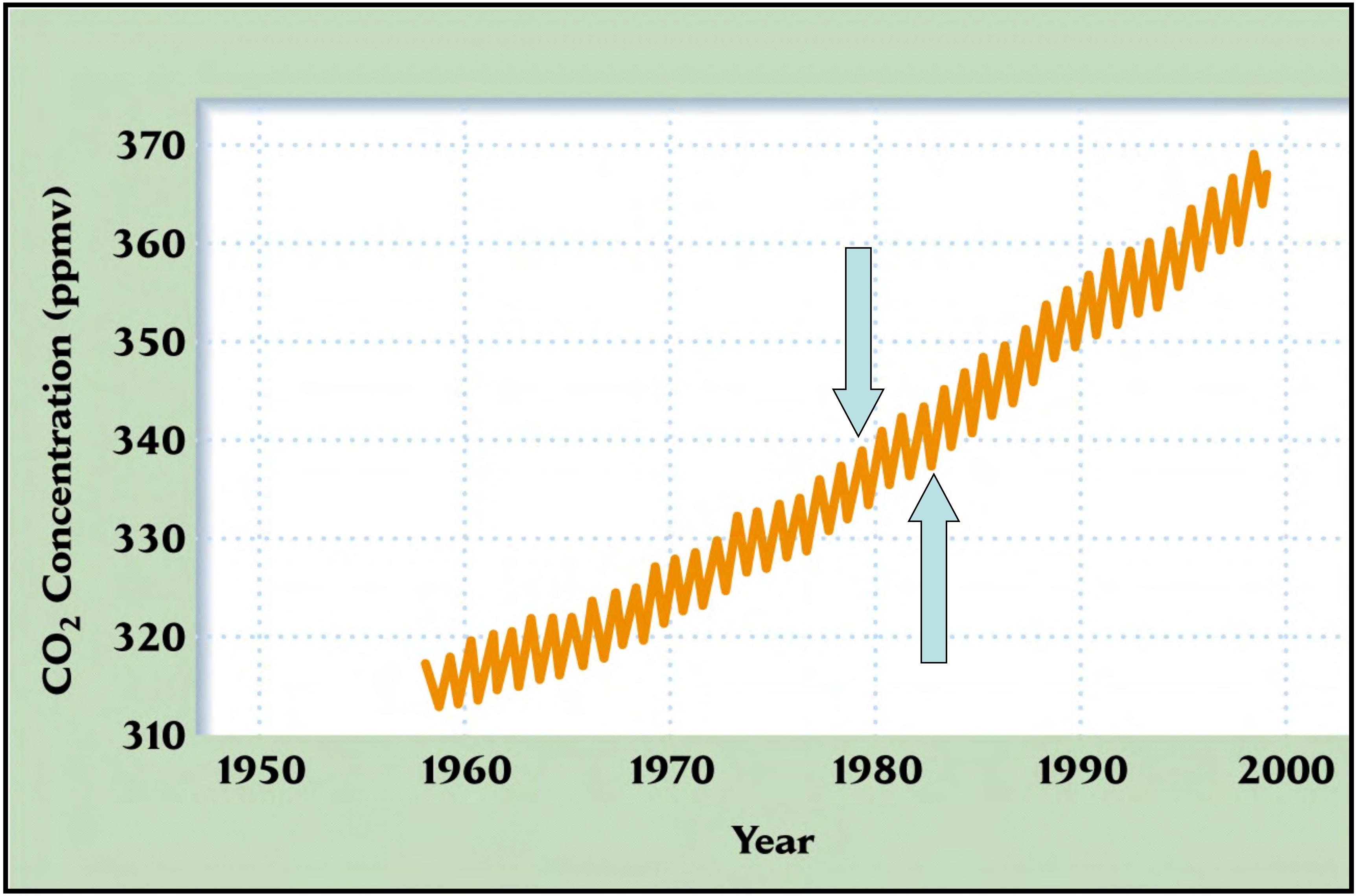
Mauna Loa Record



Why Is there Variability Within Each Year?



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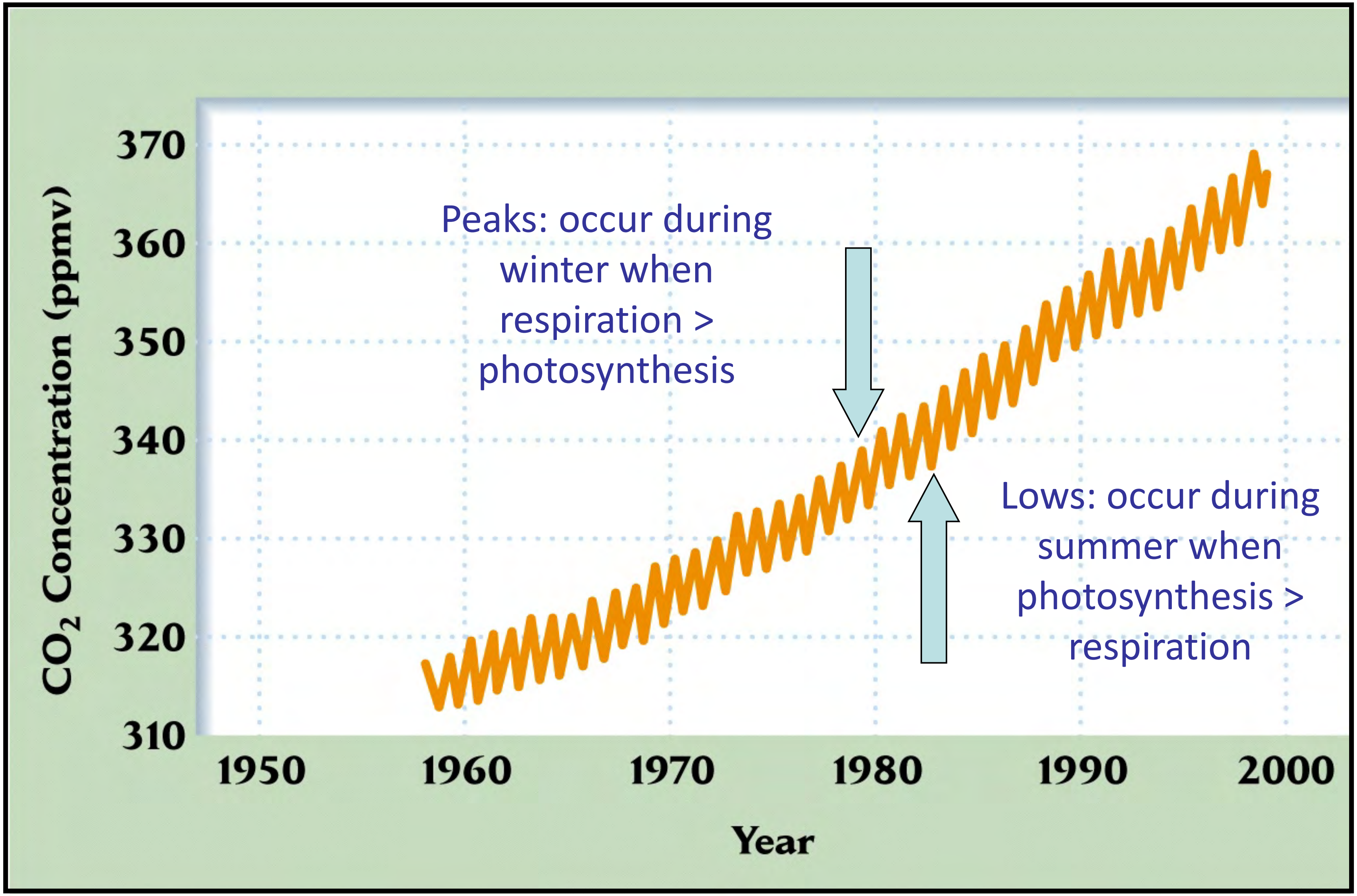

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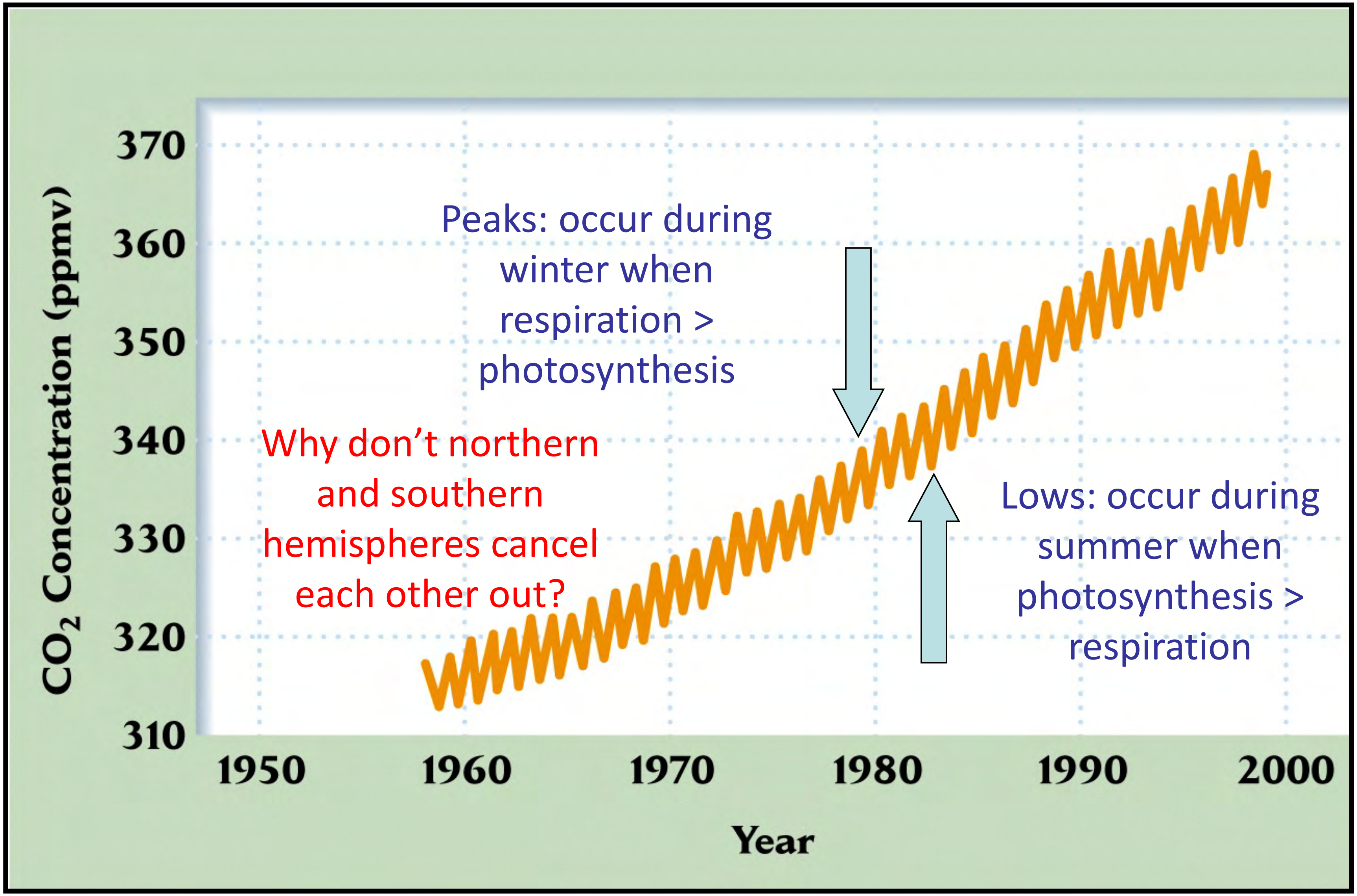

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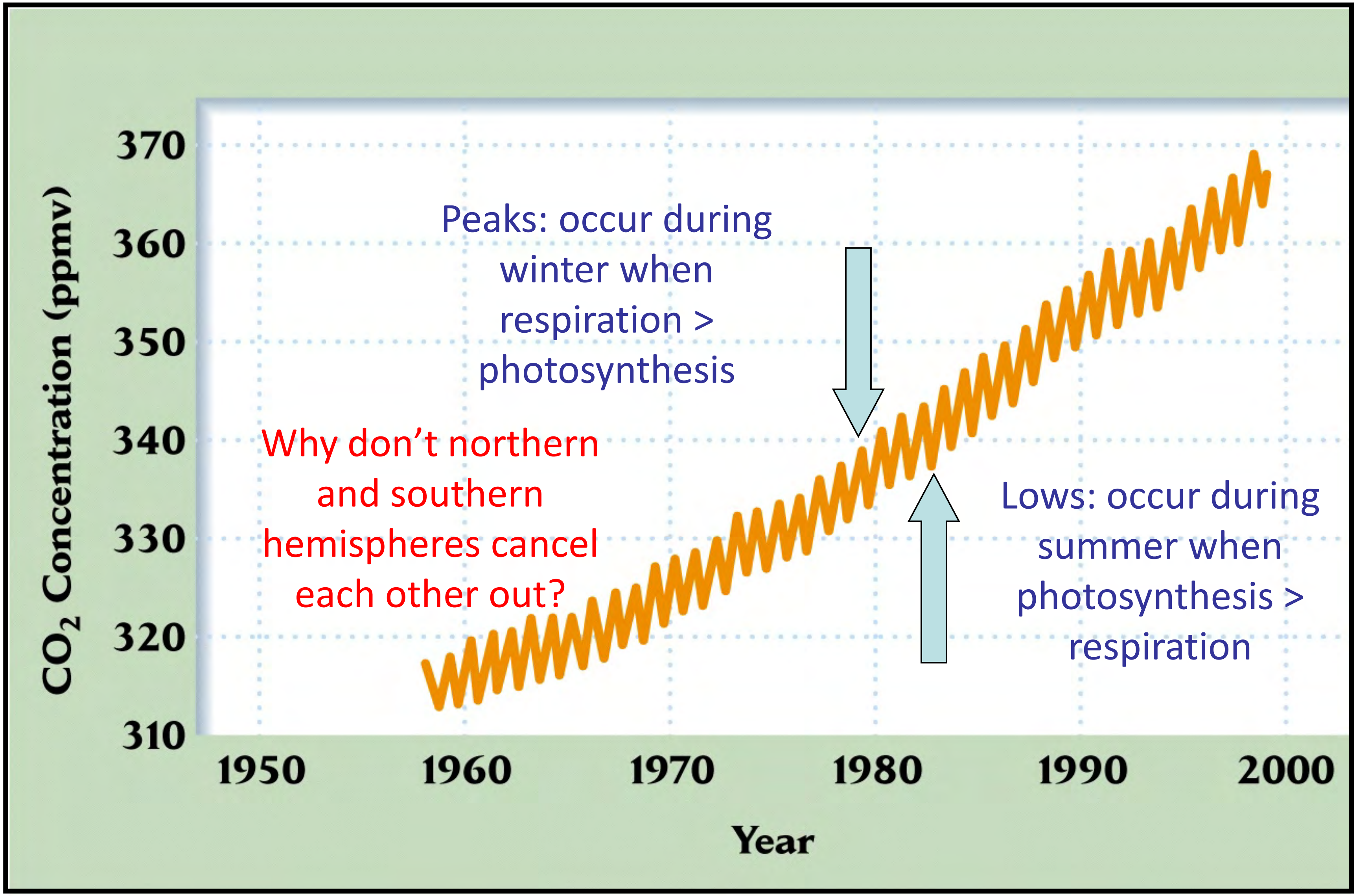


Greater Land Mass in Northern Hemisphere

Change in CO_2 Concentration over Long-Time Periods: Evidence from Ice Cores

Vostok Ice Core (Antarctica):

- Longest continuous record of Antarctic climatic history
- Gas gets trapped in ice
- Analysis of the core: to depth of 3600 m depth > 400,000 years of climate history

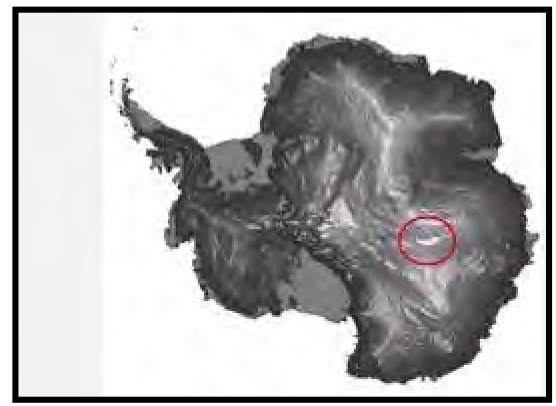
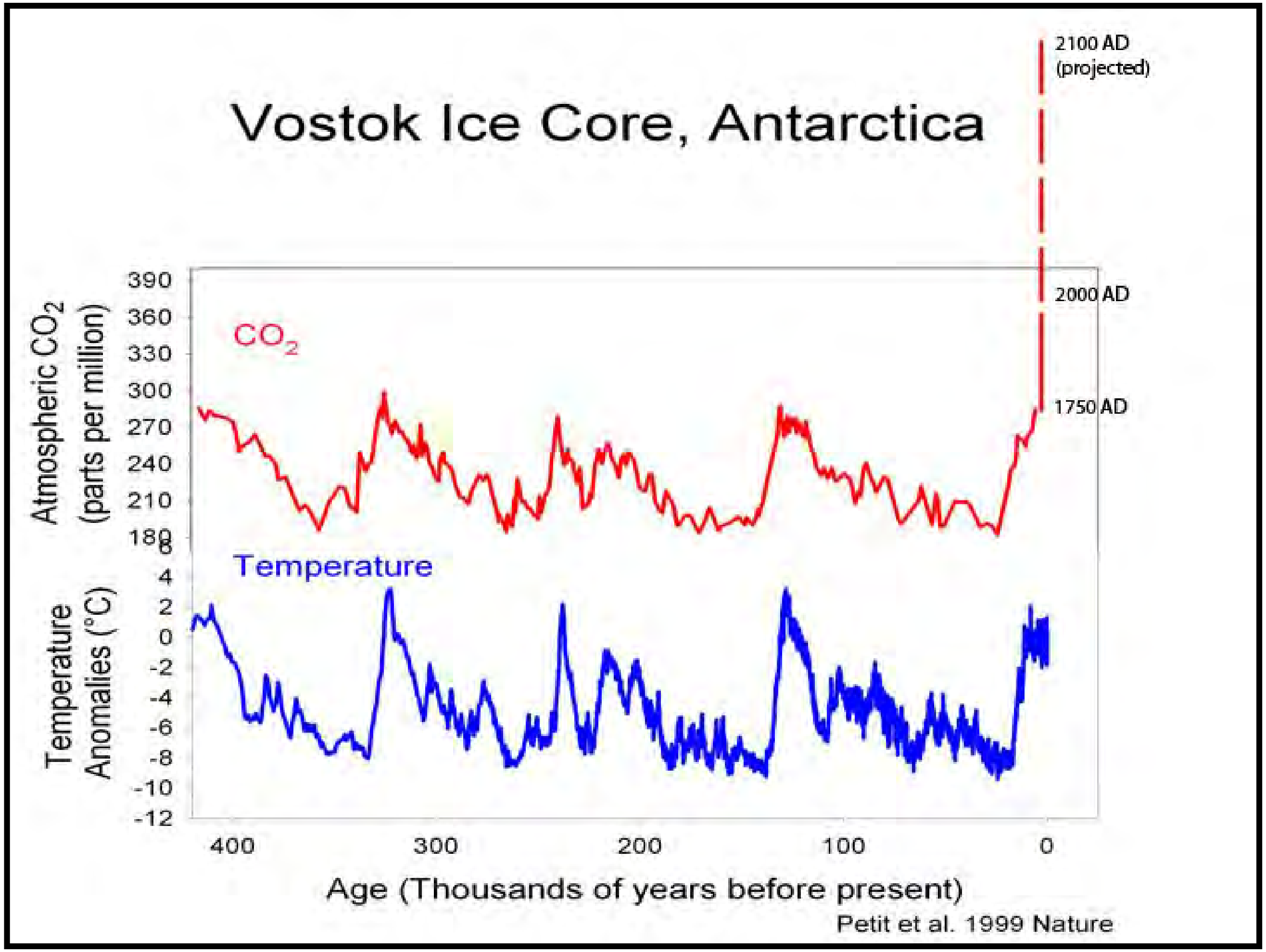


Photo Credits: National Ice Core Laboratory

Link Between Atmospheric CO_2 Concentrations and Average Global Temperature



Atmospheric CO_2 and global temperatures correlated for last 400,000 years

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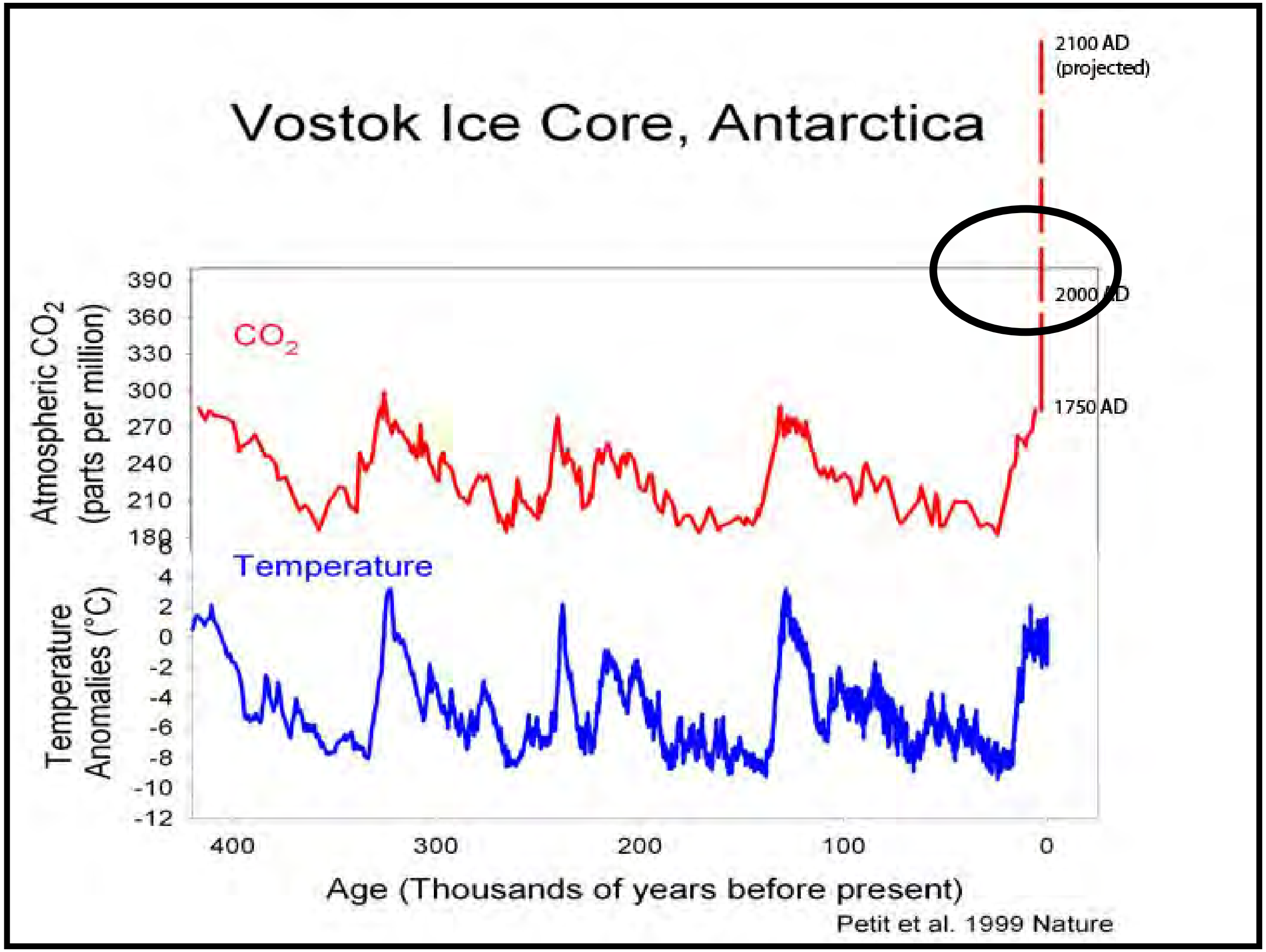

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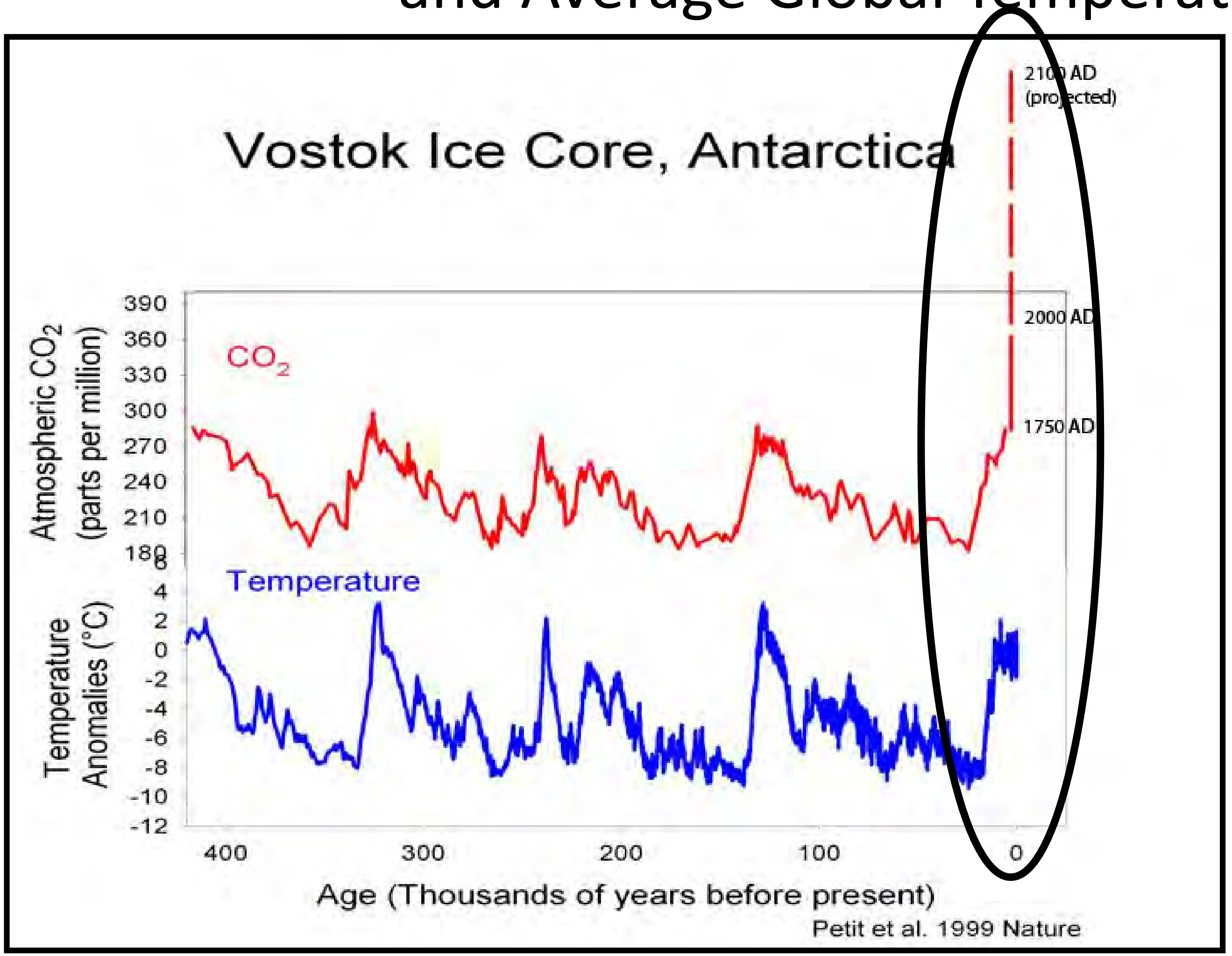

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Models predict future increase 1.4° - 5.8°C between now and 2100

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- <u>Forests as carbon sinks</u>

Natural Sources of Atmospheric CO_2

- CO_2 released during plant and microbial respiration
- Ocean-atmosphere exchange
- Volcanic eruptions

Natural Sinks Atmospheric CO_2

- CO_2 fixed during photosynthesis (C sequestration in plants)
- C sequestration in soils (indirect sink)
- Ocean uptake
  - Directly: photosynthesis
  - Indirectly: sedimentation at bottom of ocean

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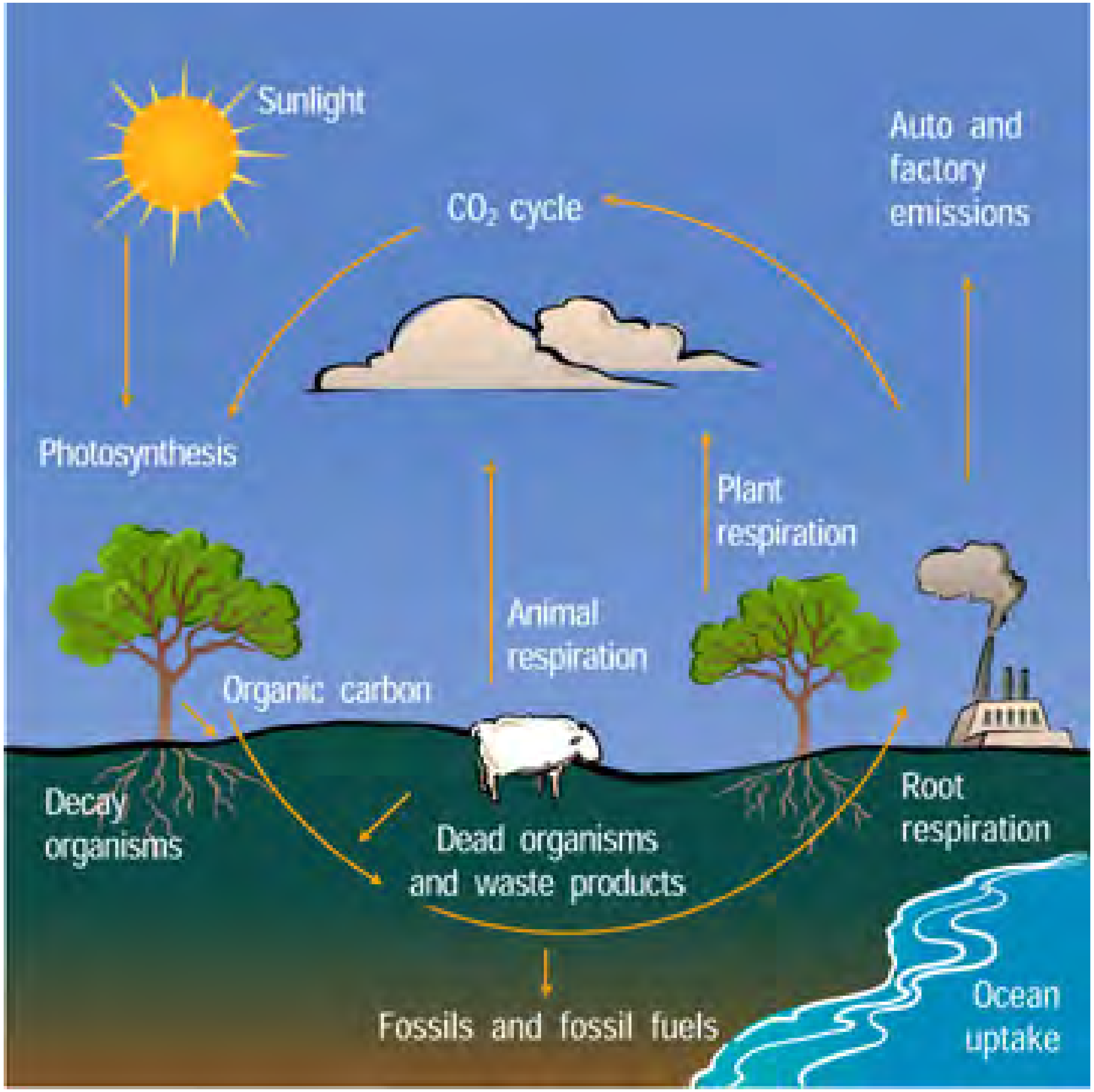
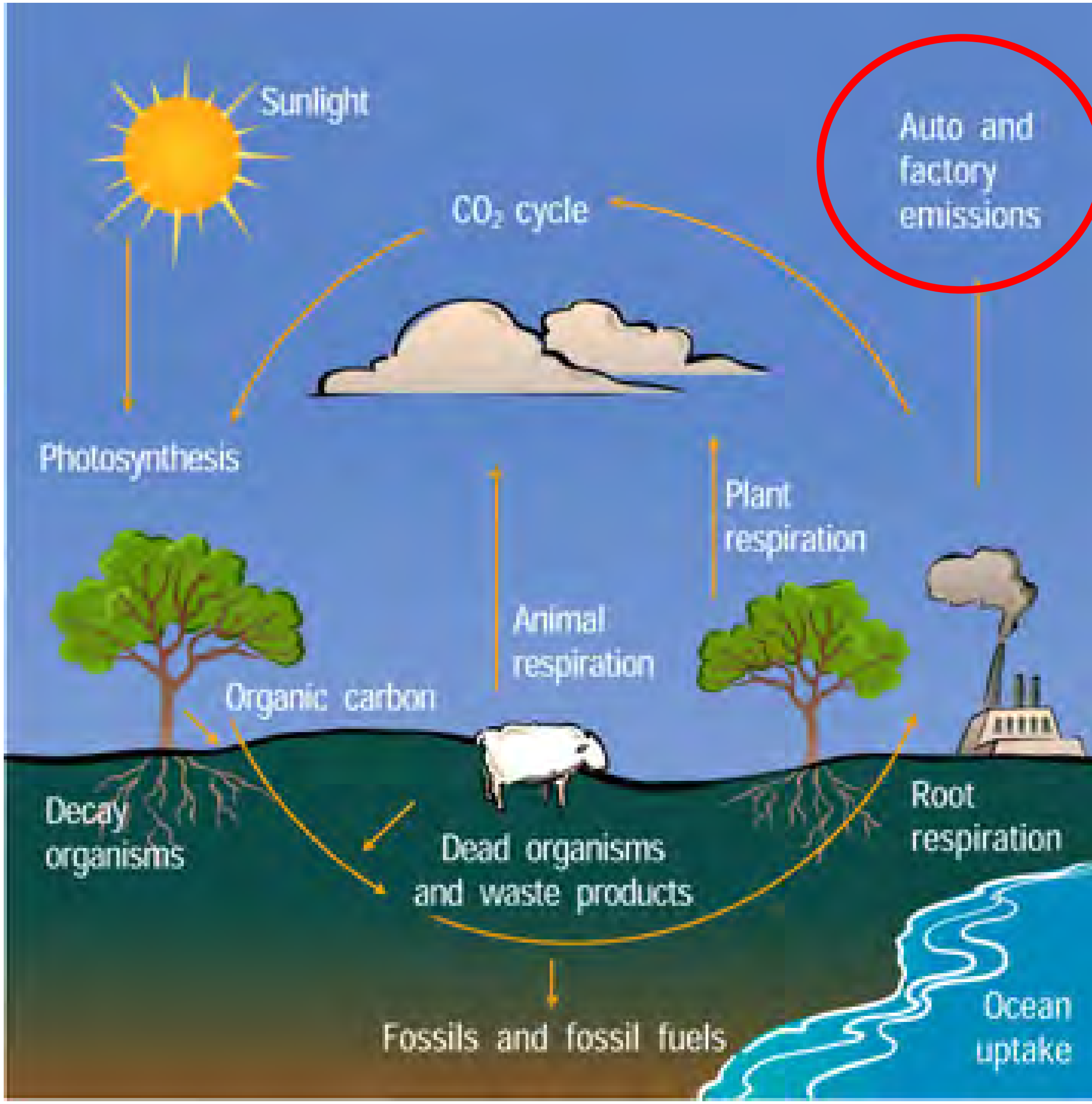
Why does this matter?
Carbon uptake by plants
offsets fossil fuel emissions ~30%

Global Carbon Cycle



http://eo.ucar.edu/kids/green/cycles6.htm

Global Carbon Cycle



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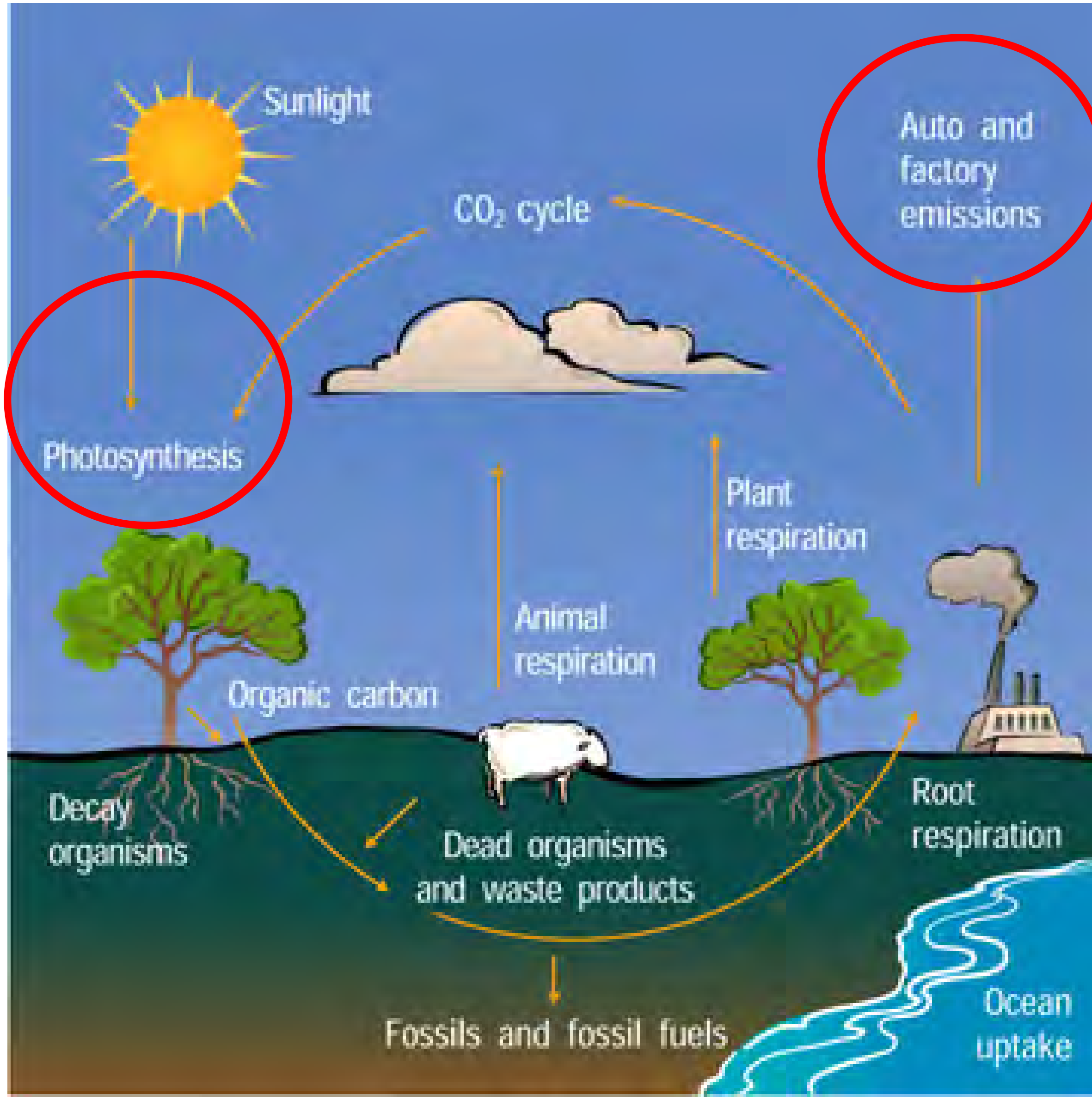

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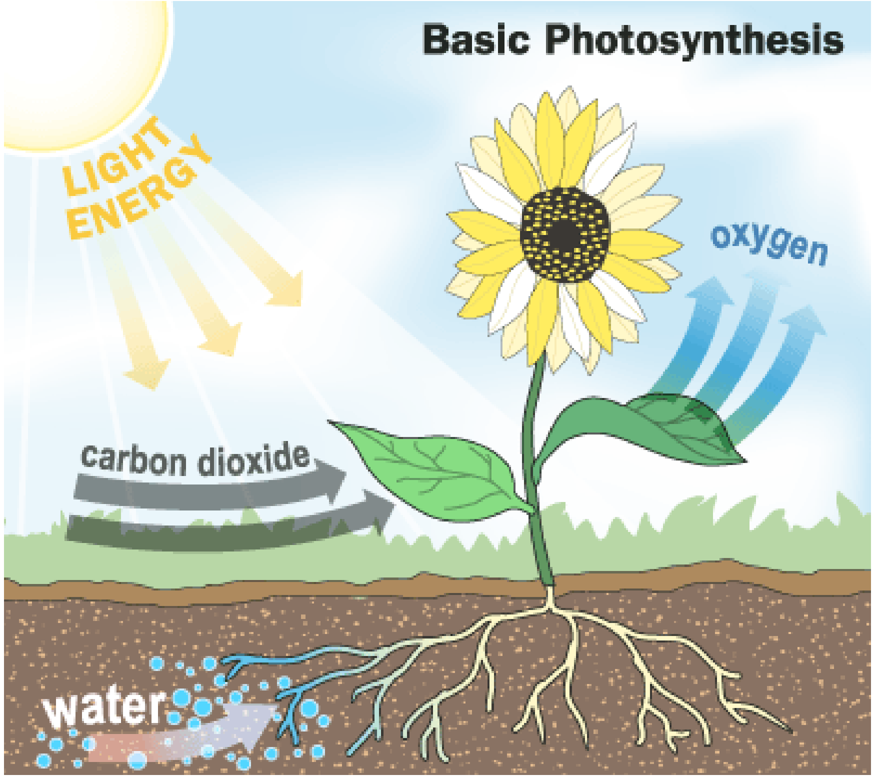
Photosynthesis: Carbon inputs to ecosystems

- Single most important chemical process on Earth
- Energy that drives all biotic processes
- C accounts for half of organic matter on Earth
  (remainder is mostly H and O)



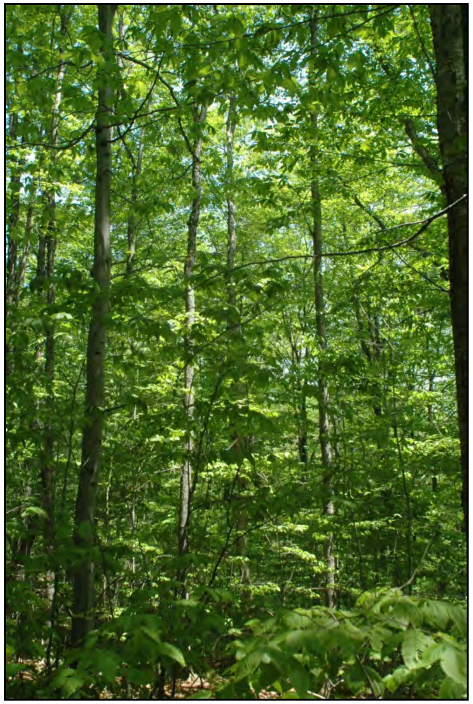
http://science.howstuffworks.com/environmental/earth/geophysics/earth3.htm

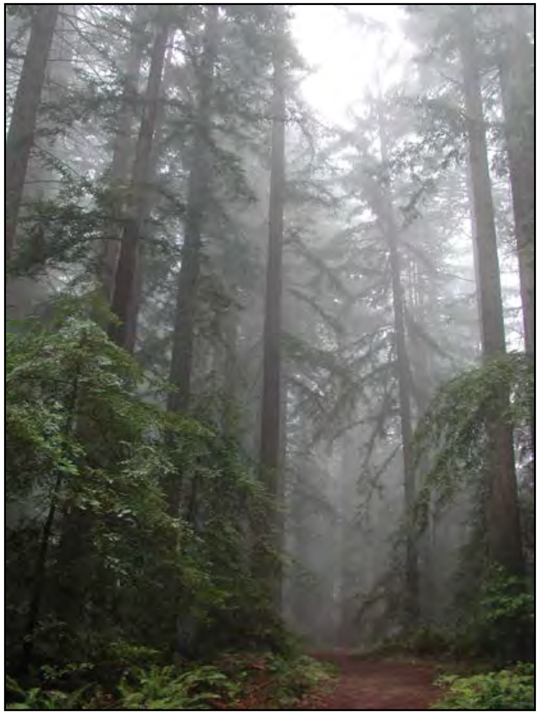
What controls the amount of carbon taken up by plants?

- Temperature
- Water (precipitation)
- Nitrogen
- Stomatal conductance (water uptake)
- CO_2

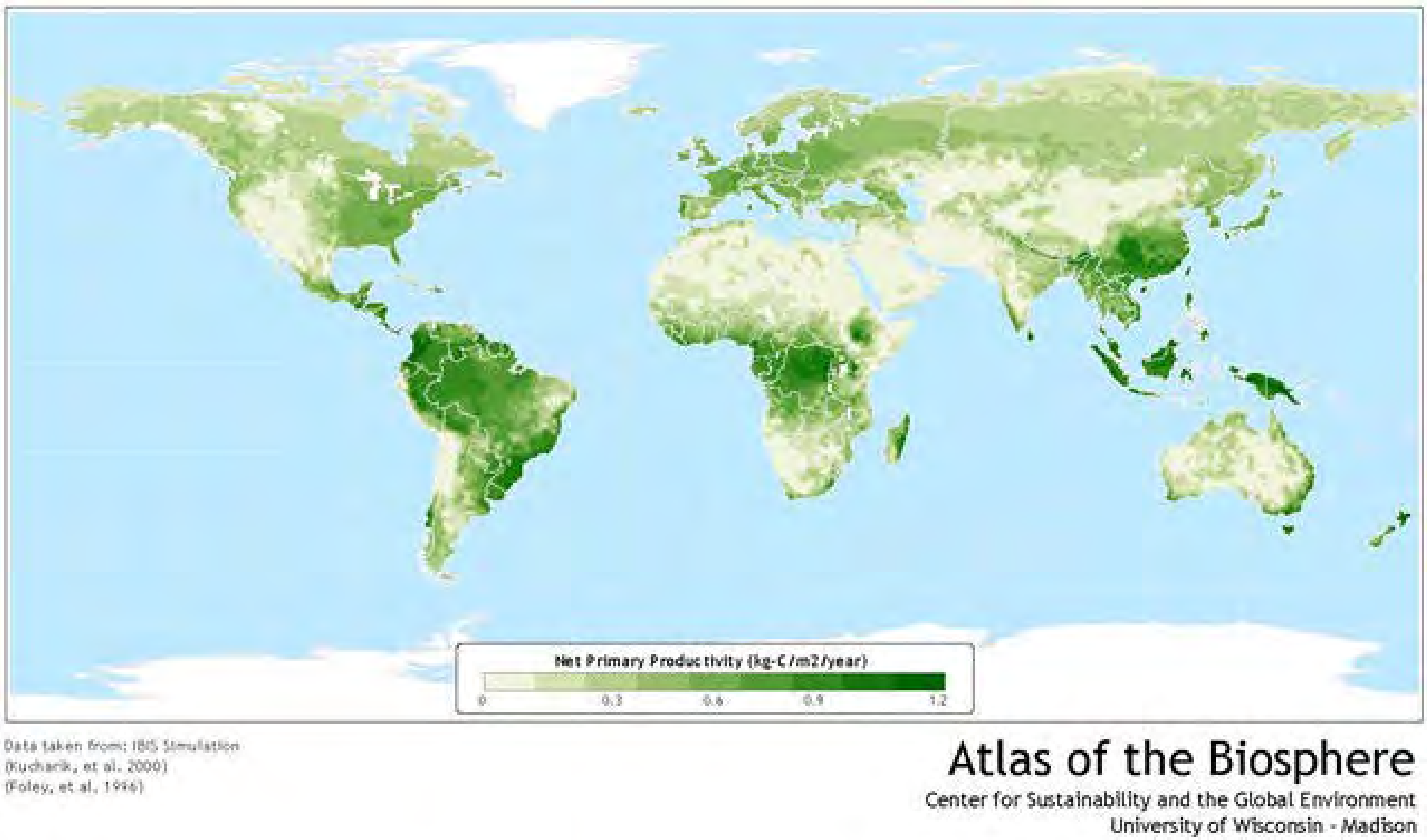
What is Net Primary Productivity?

total net photosynthesis (or carbon gain)
at the ecosystem scale

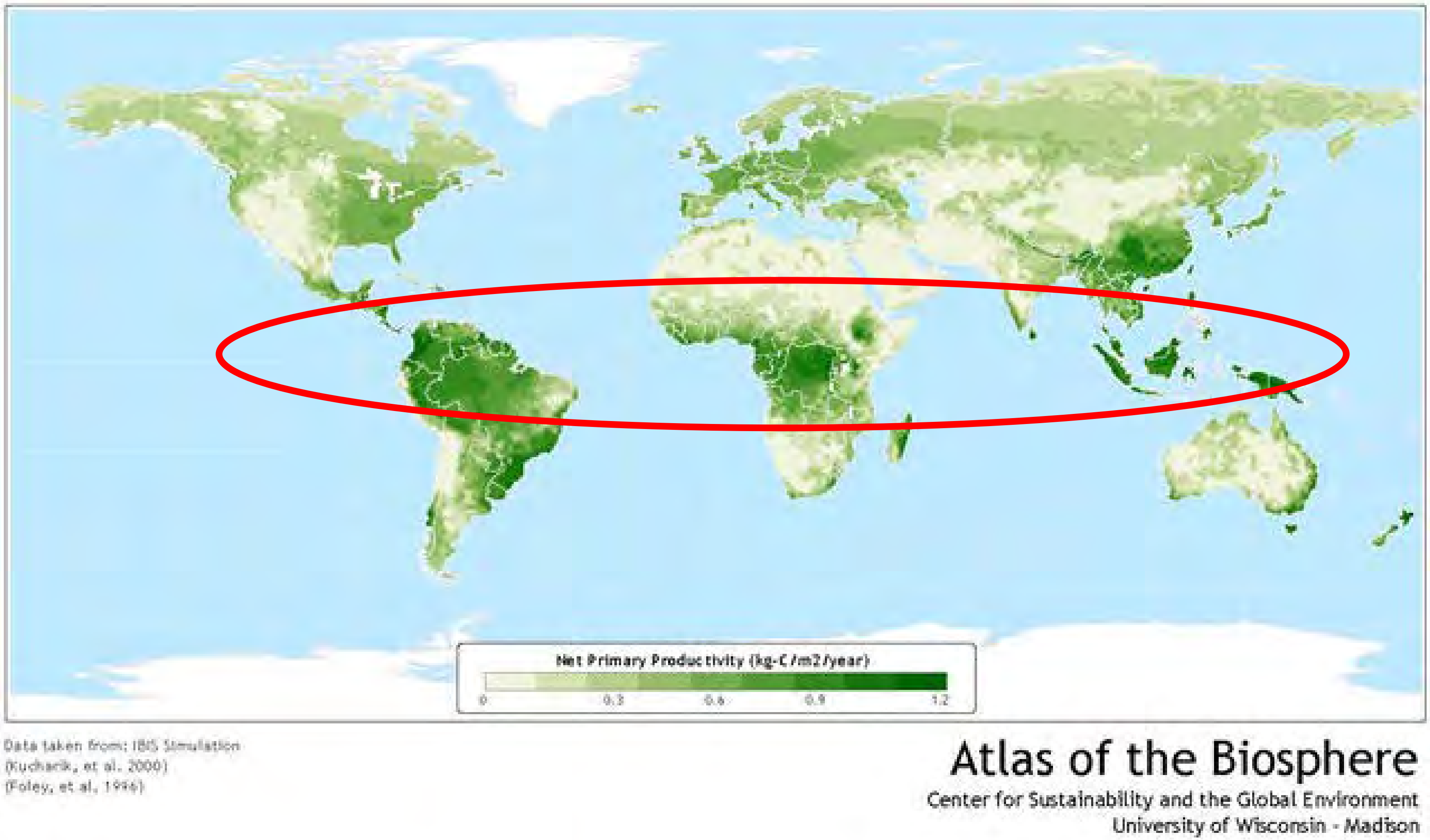




Net Primary Productivity



Net Primary Productivity: Highest in the Tropics

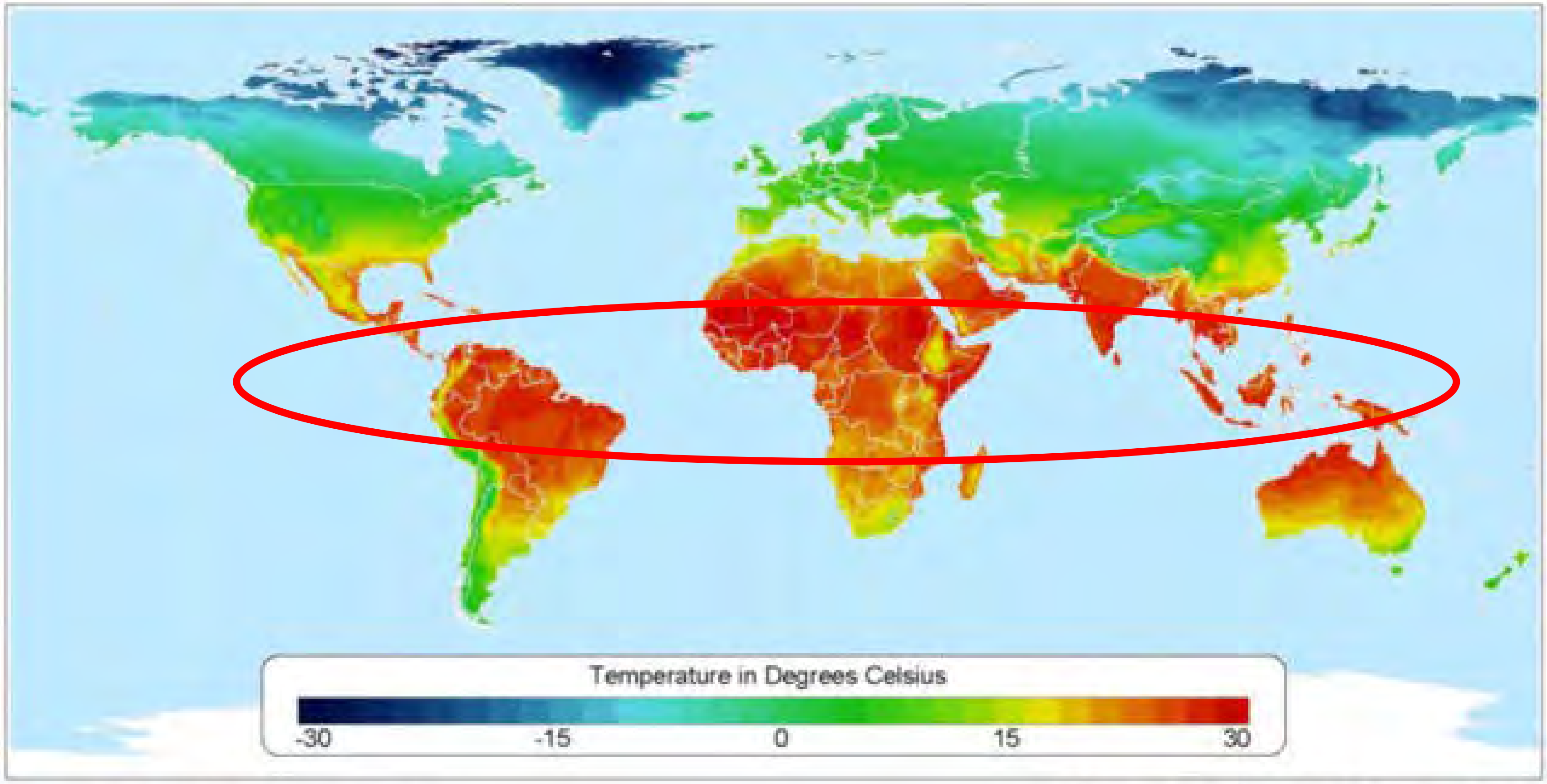


Annual Total Precipitation: Highest in the Tropics

Data taken from: CRU 0.5 Degree Dataset (New et al)

Atlas of the Biosphere
Center for Sustainability and the Global Environment
University of Wisconsin - Madison

Annual Temperature: Highest in the Tropics



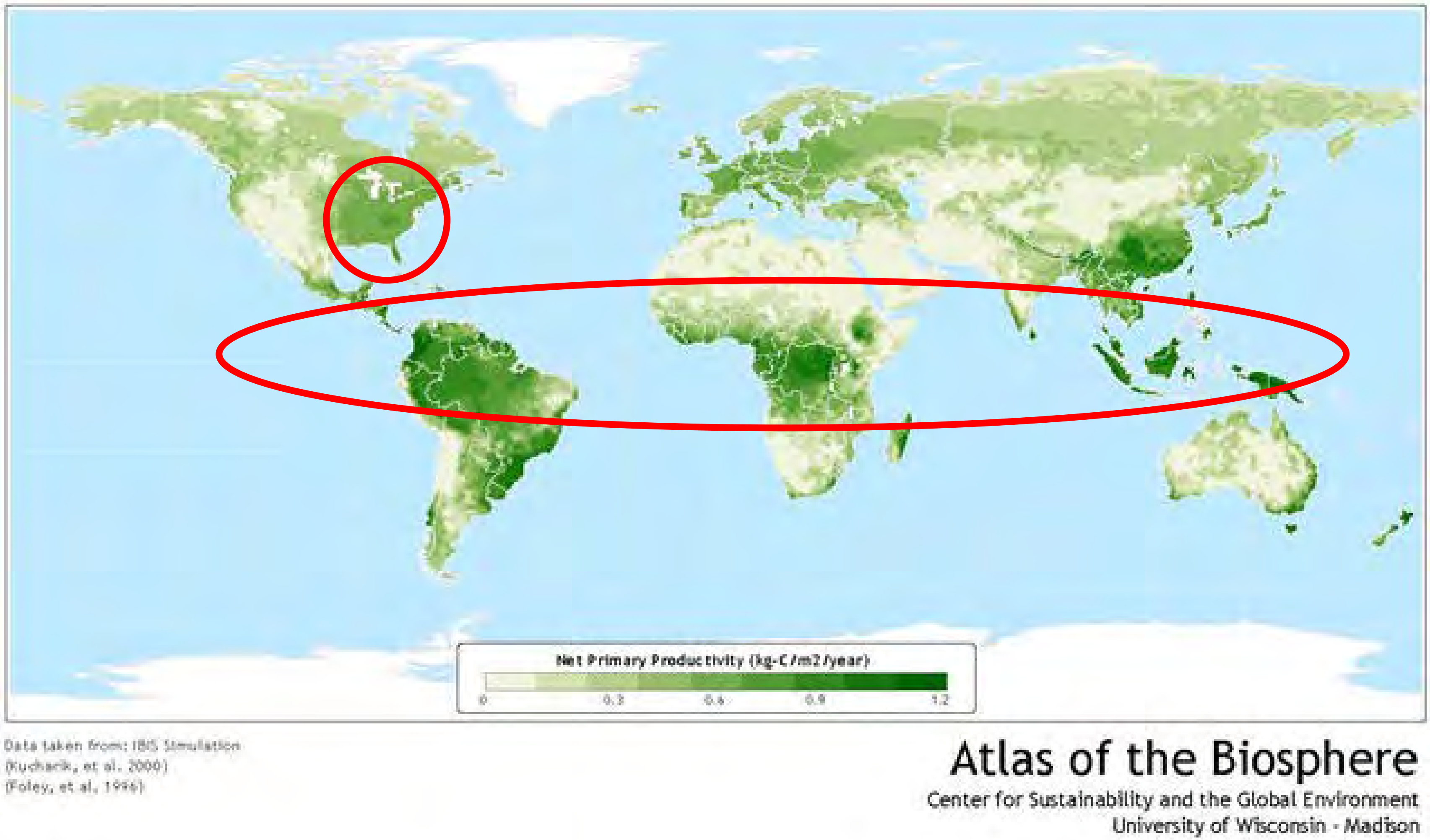
Data taken from: CRU 0.5 Degree Dataset (New, et al.)

Atlas of the Biosphere

Center for Sustainability and the Global Environment

University of Wisconsin - Madison

Net Primary Productivity: Highest in the Tropics, But still significant in forests of eastern U.S.



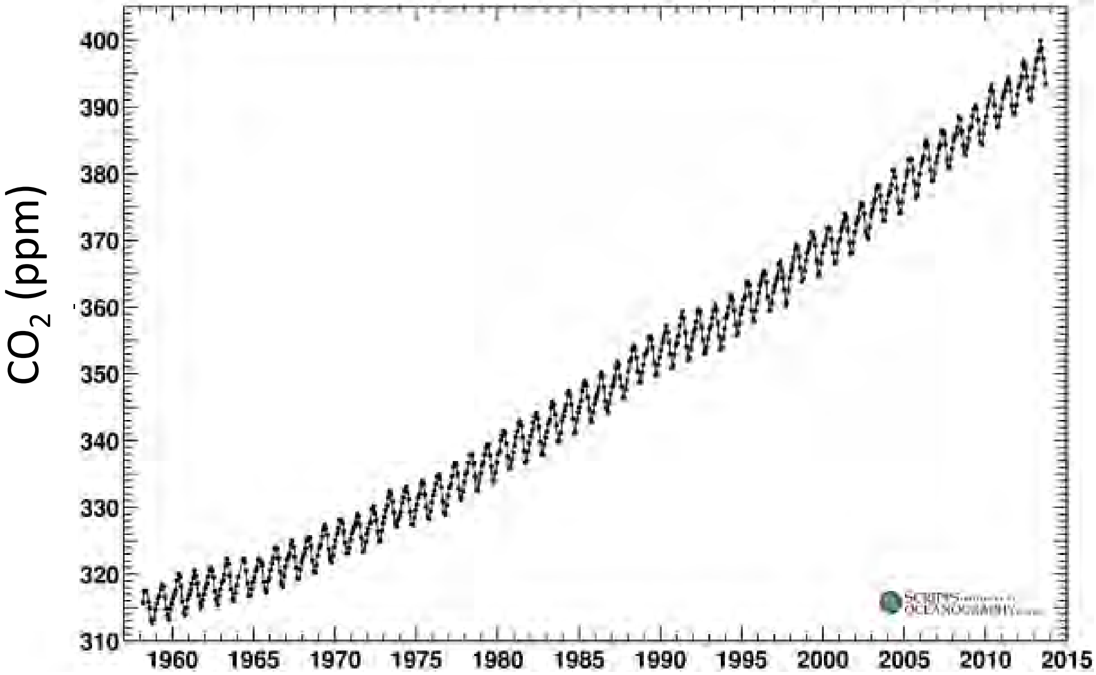
How to measure net primary productivity = total carbon uptake?

- Measure DBH (diameter at breast height)
- Use allometric equations to convert DBH to total biomass
- Convert total biomass to total carbon (~50% tree biomass = carbon)

Ongoing Research in Our Lab

- What are effects of urbanization, elevated CO_2, and air quality on carbon sequestration in New England Forests?
- What are effects of climate warming and smaller winter snowpack on carbon sequestration in New England Forests?

Why Focus on Carbon Sequestration?



Scripps Institution of Oceanography

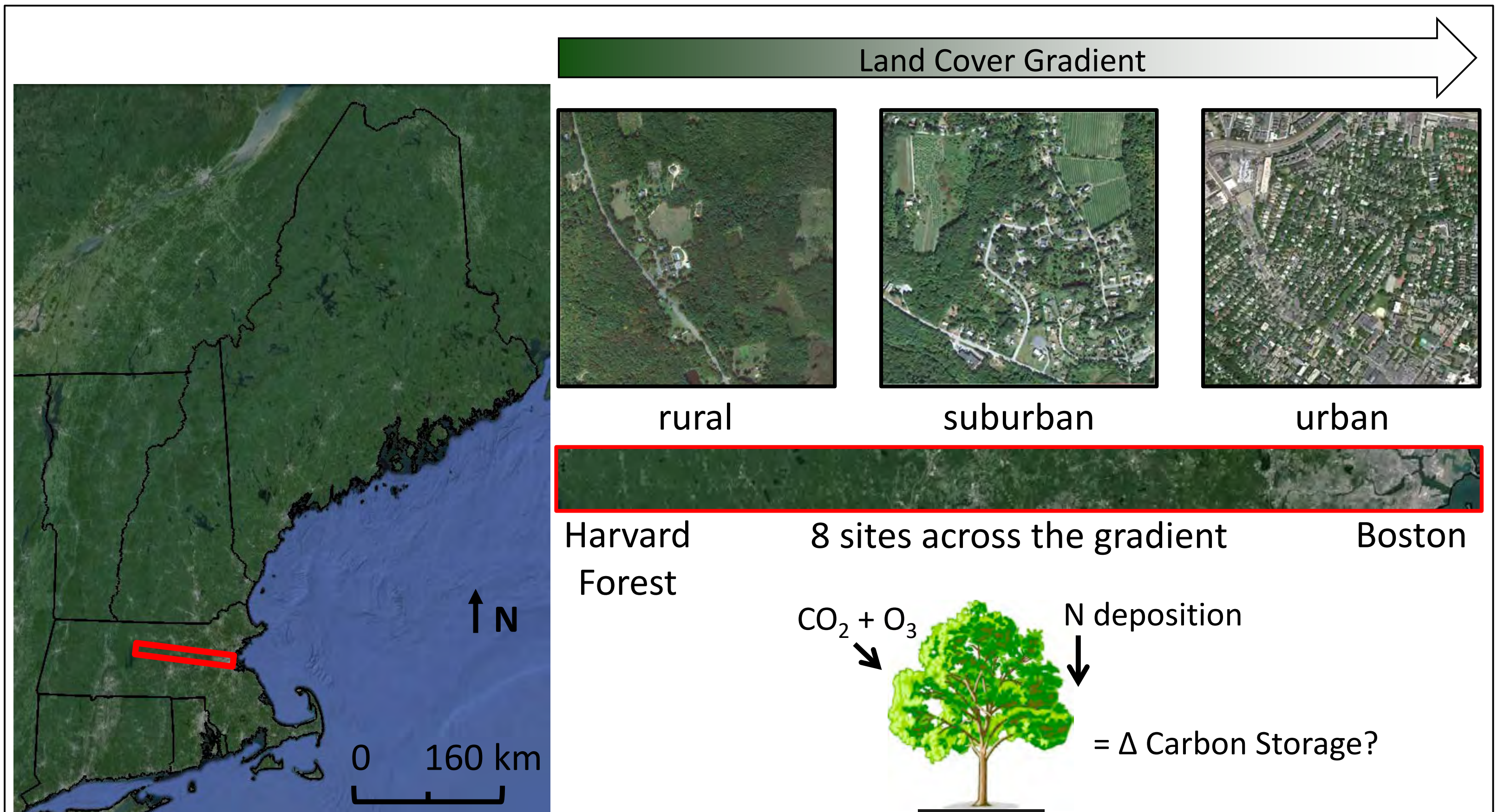
- Rising CO_2 due to deforestation and burning of fossil fuels
- Natural ecosystems on land can take up~30% of this atmospheric CO_2

britannica.com

byjus.com

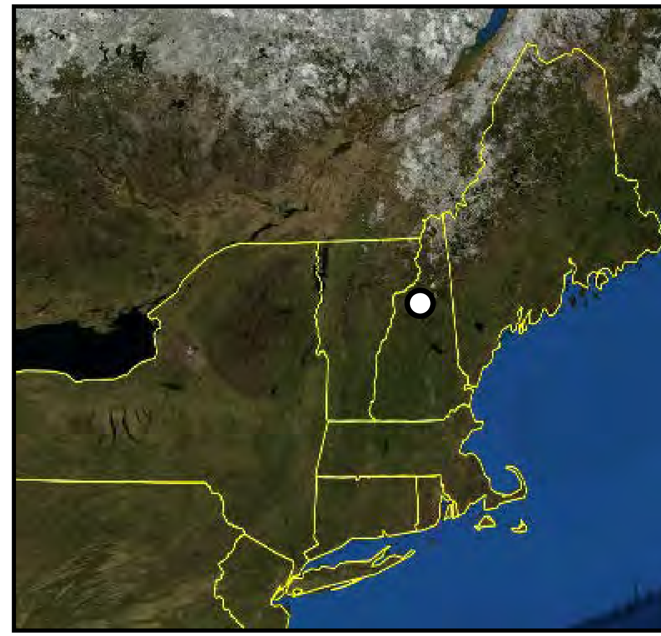
Urban New England Project

Identify how land cover (i.e., forest, urban, agriculture), CO_2, and air quality (nitrogen deposition and ozone) affect carbon sequestration throughout ecosystems of New England



Climate Change Across Seasons Experiment at Hubbard Brook in New Hampshire

Determine how warmer temperatures in the growing season and smaller snowpack affects carbon sequestration in northern forests



14 X 11m^2 plots in hardwood forest

- 2 plots: reference
- 2 plots: soils warmed 5^{0}C in growing season
- 2 plots: soils warmed 5^{0}C in growing season and less snow in winter

Role of Forest Ecosystems in Carbon Sequestration and Climate

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