Lecture 28: Anthropogenic Inputs of Greenhouse Gases in the Past 200 Years

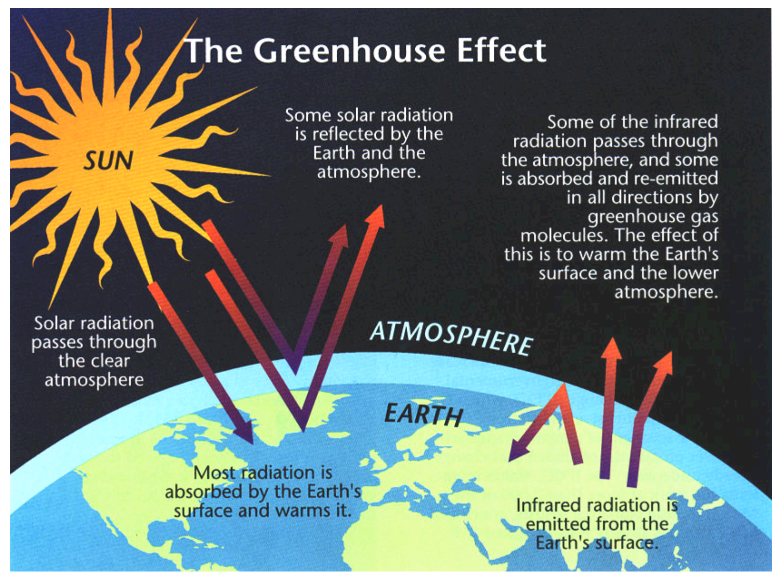
Chapter 18 (325-335)

1. **Greenhouse Effects and Global Warming**
2. **Carbon Dioxide**
   - Where CO2 comes from?
   - Where it is absorbed?
   - How long the CO2 would stay in the atmosphere?
   - How the strength of the sink responds to the CO2 rise?
3. **Methane**
4. **Nitrous Oxide**

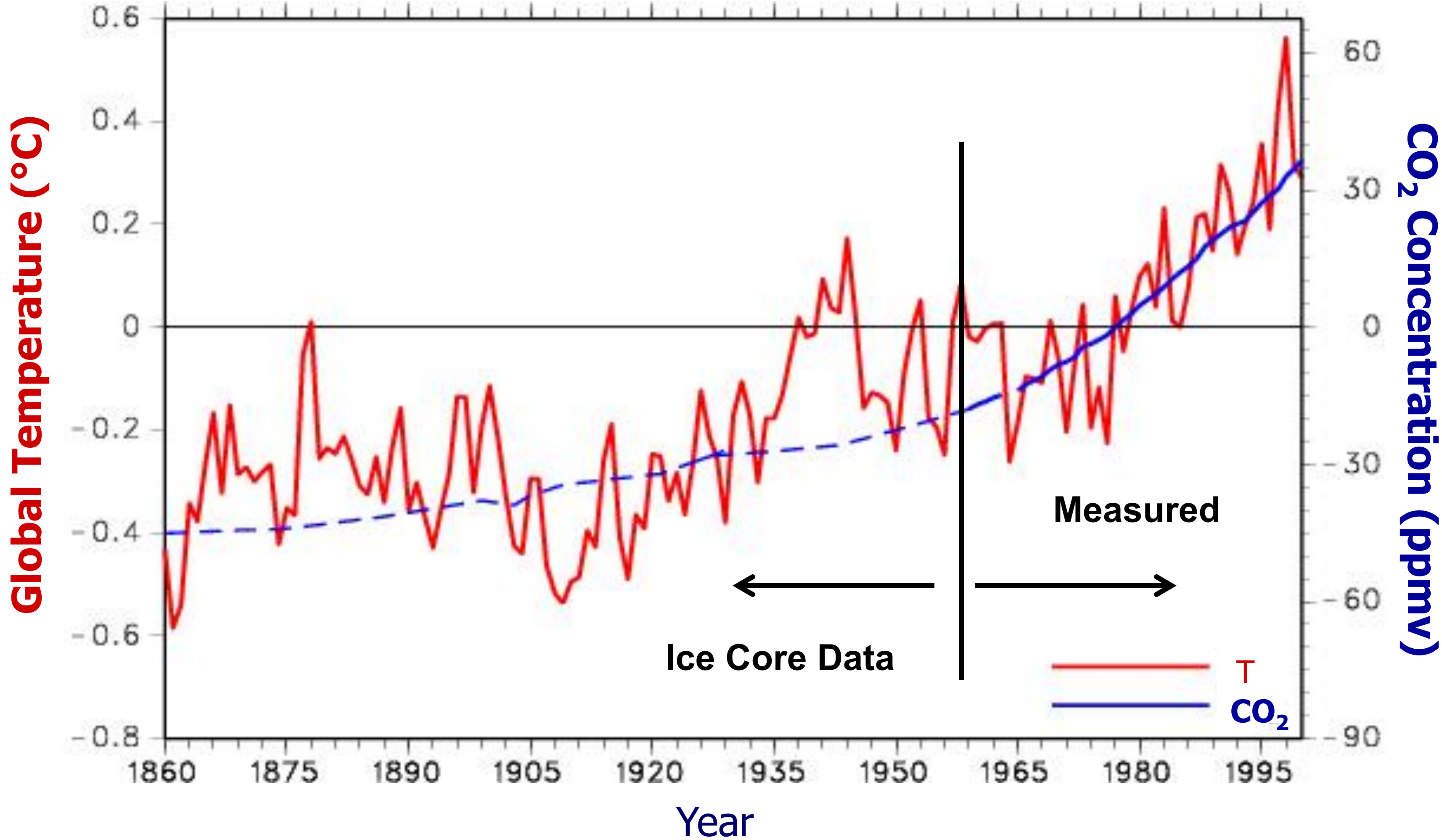
- “Greenhouse Effects”

Both the greenhouse and increase of “greenhouse” gases trap heat and cause increase of temperature within the system.

But they trap different form of the “heat”. What different form of heat does the greenhouse and earth’s climate trap?



Annual Global Mean Surface Temperature and Carbon Dioxide Concentrations



How is carbon cycled in the Earth's climate system?

Tectonic-scale cycling: hundreds of millions of years (plate tectonics and weathering)

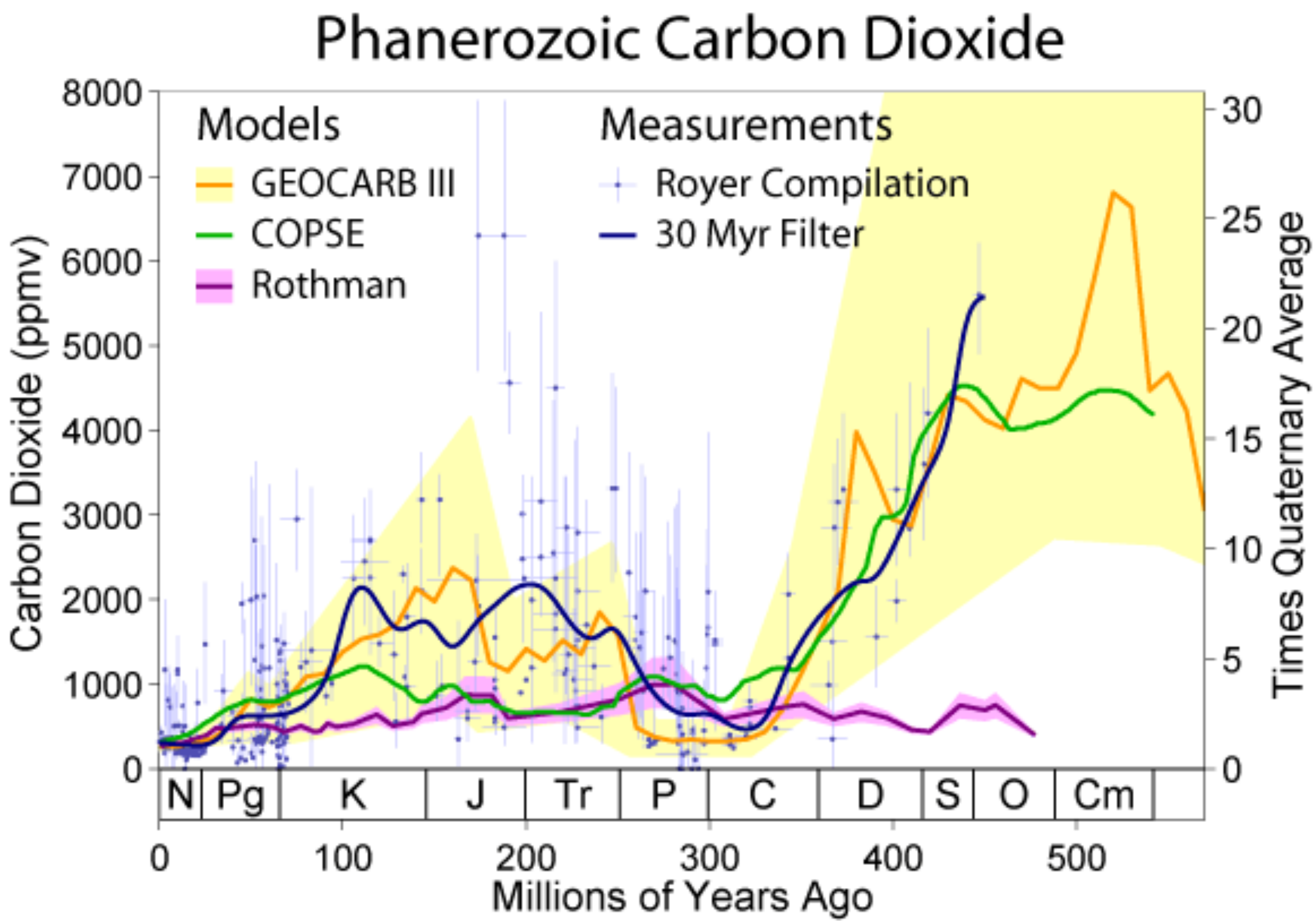
Orbital-scale cycling: hundreds of thousands of years (glacial and interglacial cycles)

Seasonal-scale cycling: seasonal variations (biological activity)

Human-caused (anthropogenic) trends

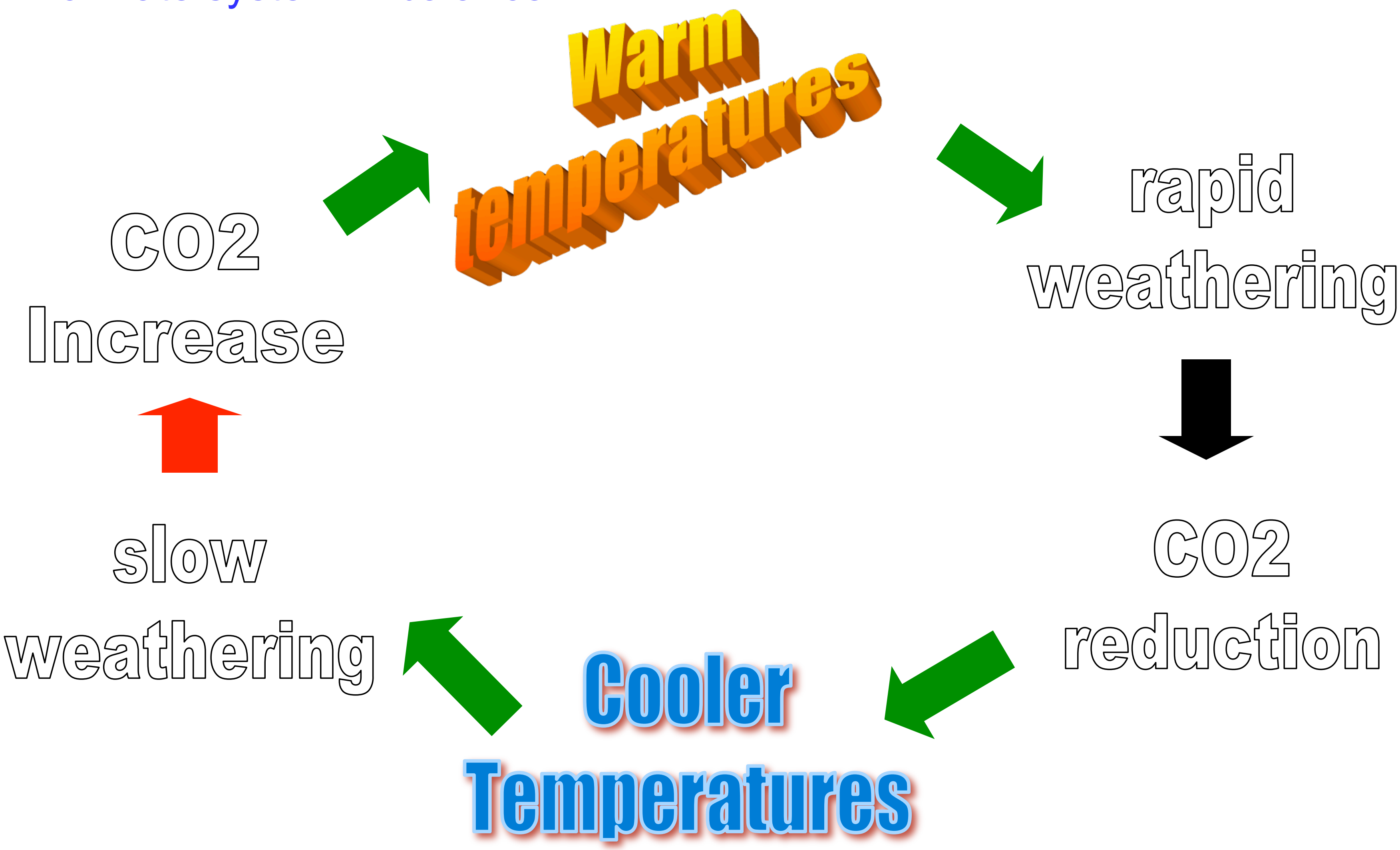
Icehouse – Hothouse (= Greenhouse) cycles (~ 200 million year cycles)

Tectonic-scale cycling Weathering of rocks removes CO_2 from the atmosphere, and volcanic-metamorphic processes restore it

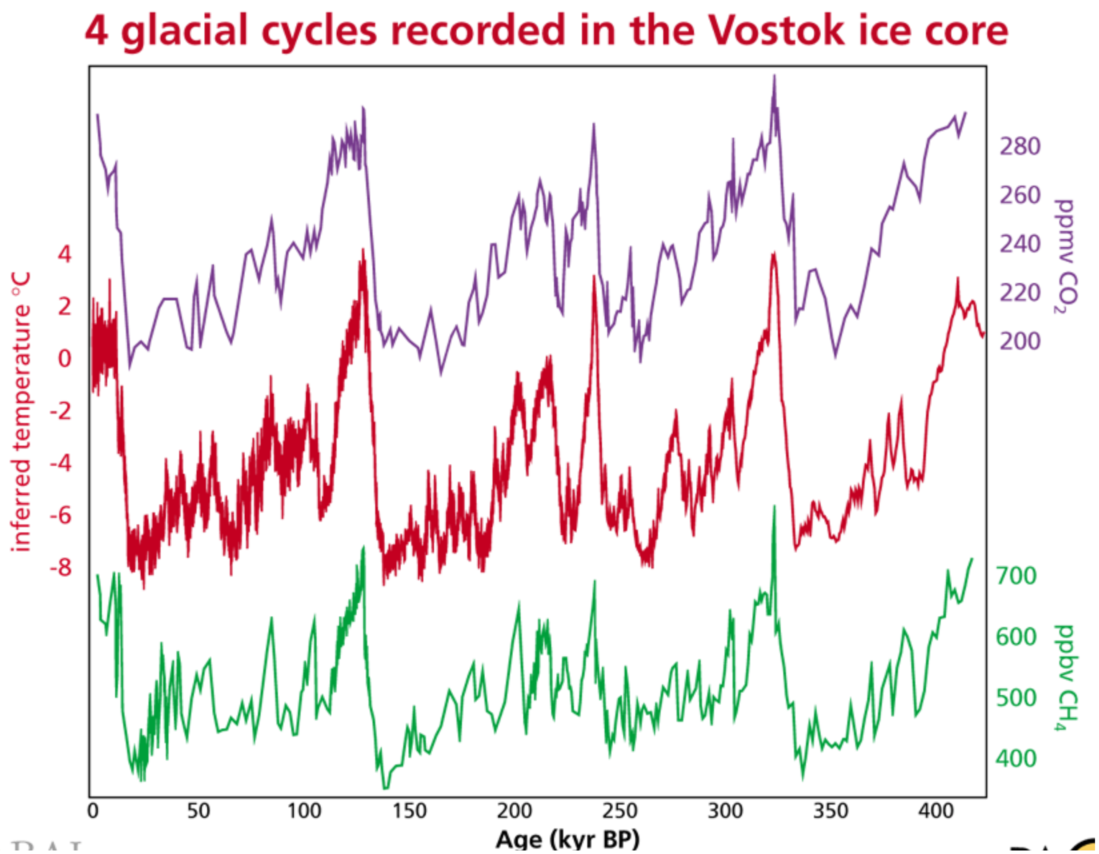


Warm planets weather more rapidly, causing CO_2 in atmosphere to decrease

This is a "negative feedback" mechanism, which keeps the climate system in balance.



Orbital-scale Cycling: CO_2 over last 400,000 years



Carbon dioxide has varied from ~ 190 – 280 ppmv. Present (in year 2006) concentration is 381 ppmv.

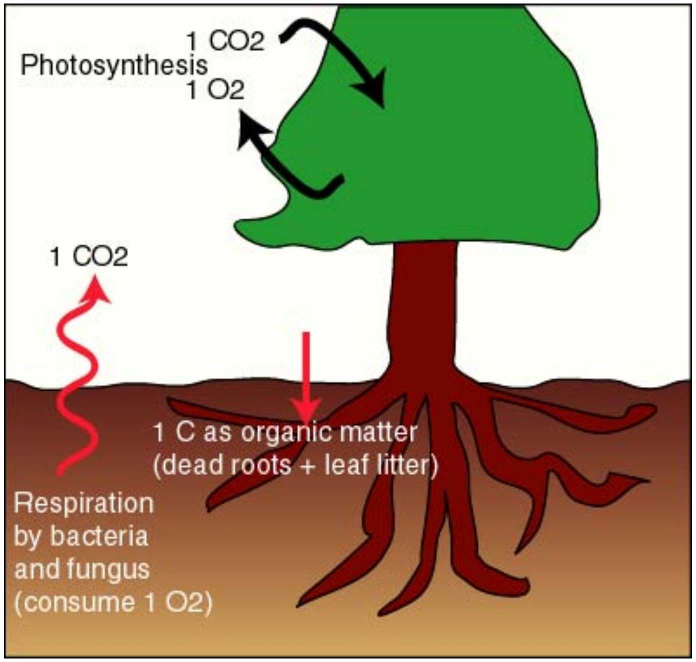
Hypothesis: Iron enrichment of the oceans

During glacial periods, more dust → more iron fallout into the oceans → more phytoplankton → more photosynthesis → lower CO_2 → colder climate → windier → more dust

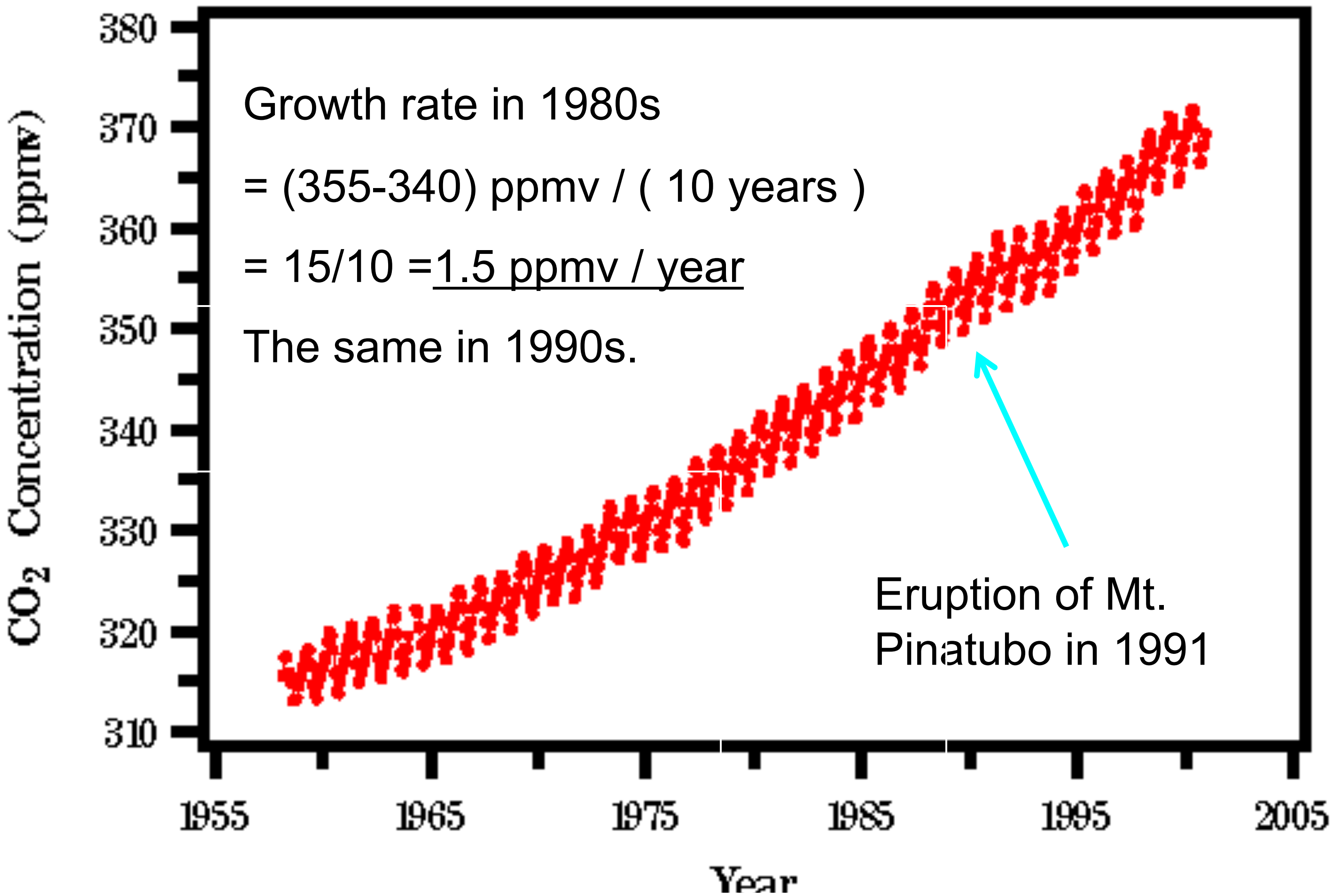
- Methane has varied from ~ 350 – 800 ppbv. Present (in year 2006) concentration is 1751 ppbv.

Seasonal Cycling: Seasonal Variations

$$CO_2 + H_2O + sunlight = CH_2O + O_2$$



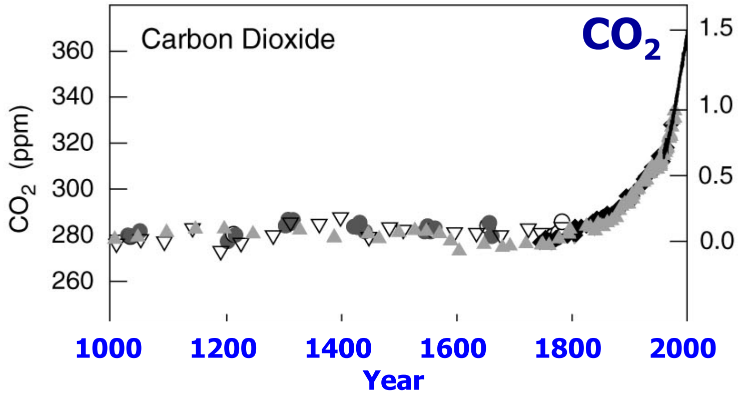
- Seasonal cycle of atmospheric CO_2 (Mauna Loa record)



In addition to documenting the large increase in atmospheric CO_2 over the last several decades, these data clearly identify the signature of the terrestrial biosphere in the annual CO_2 fluctuations.

Changing Atmospheric Composition: Indicators of the Human Influence

Global, well-mixed greenhouse gas (GHG) concentrations



- ***31% increase since 1750: Highest levels since at least 420,000 years ago***
- ***Rate of increase unprecedented over at least the last 20,000 years***

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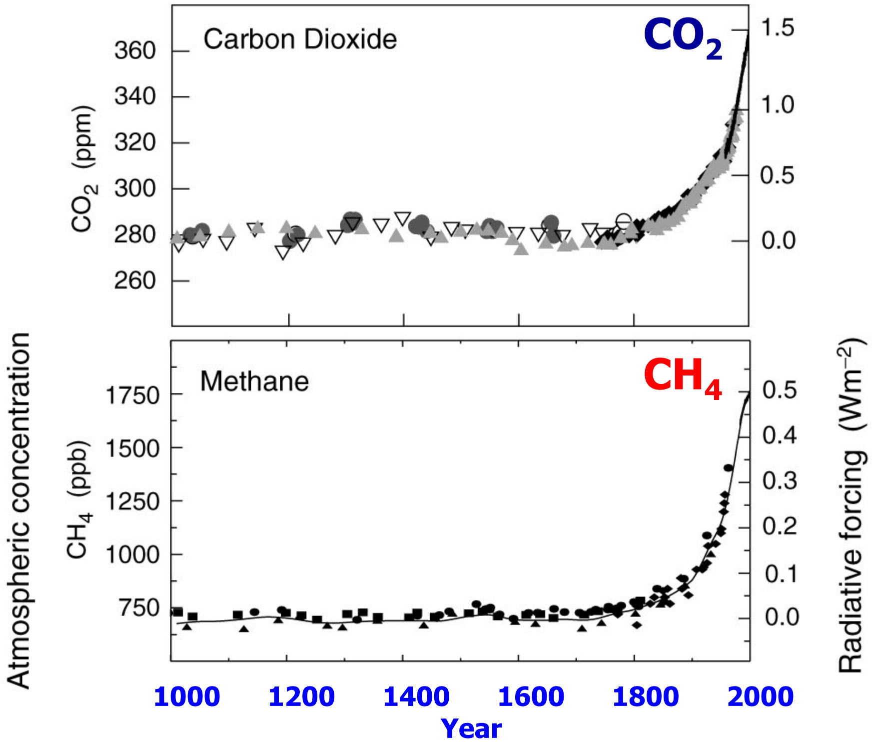

- ***31% increase since 1750: Highest levels since at least 420,000 years ago***
- ***Rate of increase unprecedented over at least the last 20,000 years***

- ***Increased 150% since 1750 to its highest levels in at least 420,000 years***

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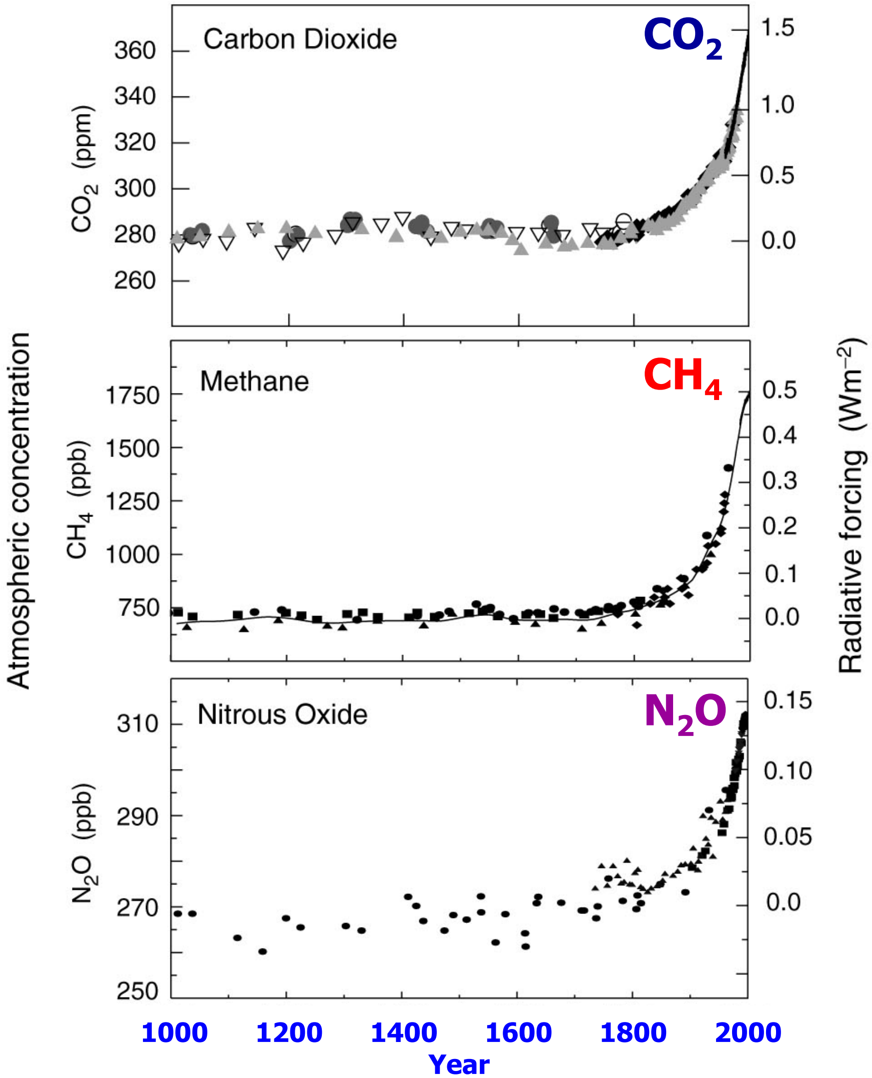
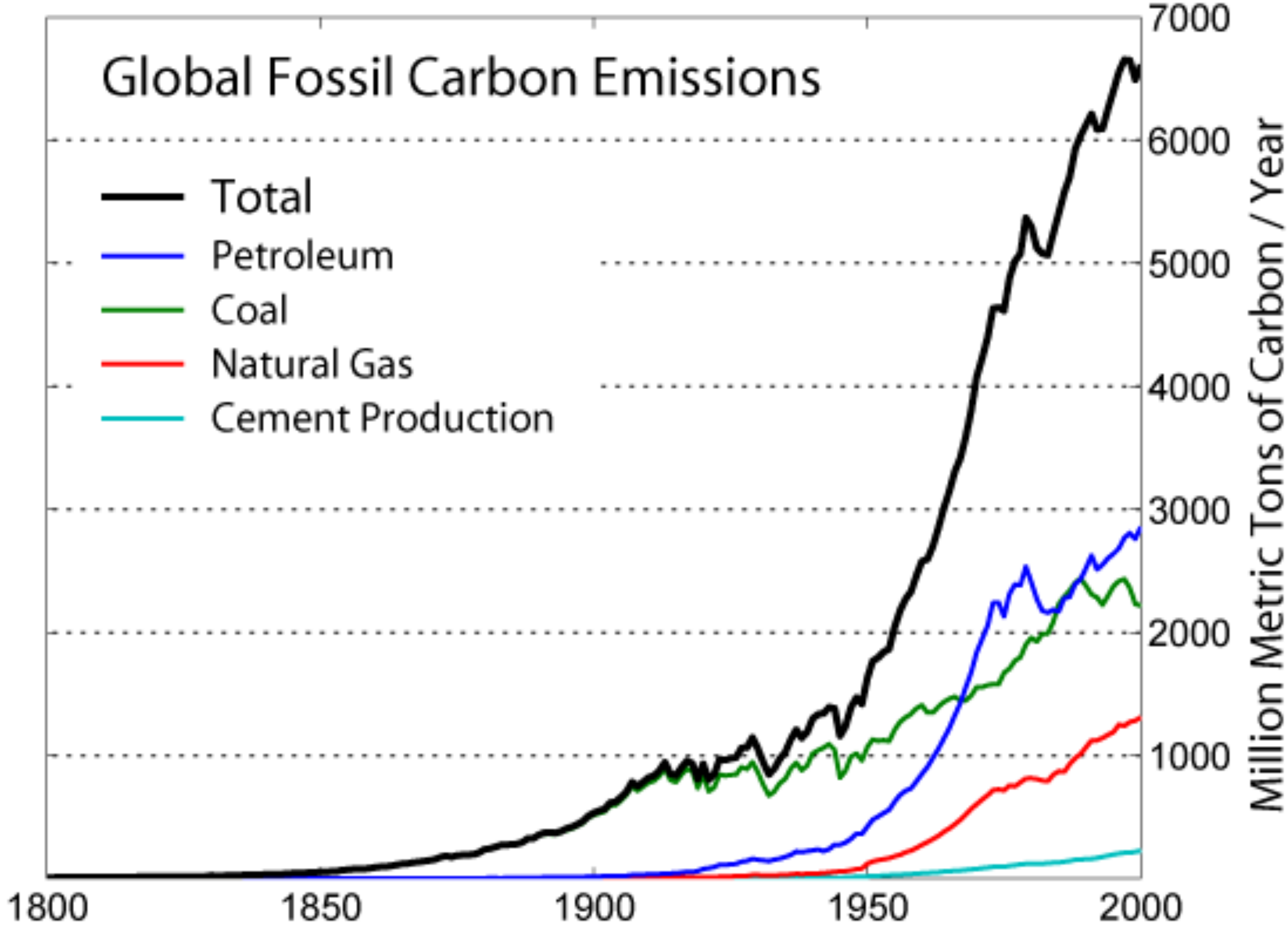


- ***31% increase since 1750: Highest levels since at least 650,000 years ago***
- ***Rate of increase unprecedented over at least the last 20,000 years***

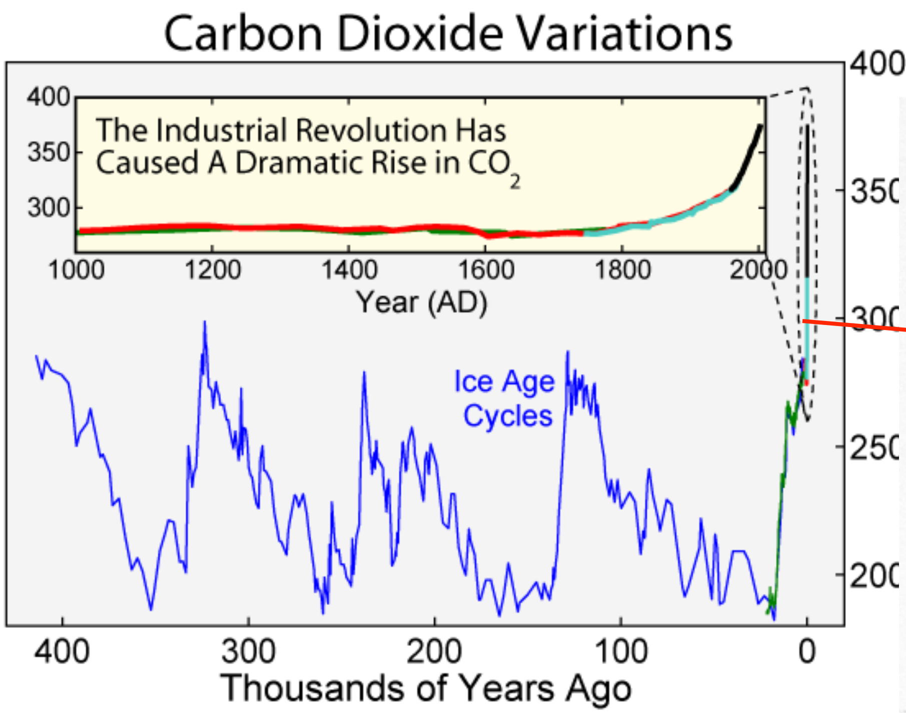
- ***Increased 150% since 1750 to its highest levels in at least 420,000 years***

- ***Increased 16% since 1750 to its highest levels in at least 1,000 years***

Global Fossil Carbon Emissions



Human Impacts on Atmospheric CO_2



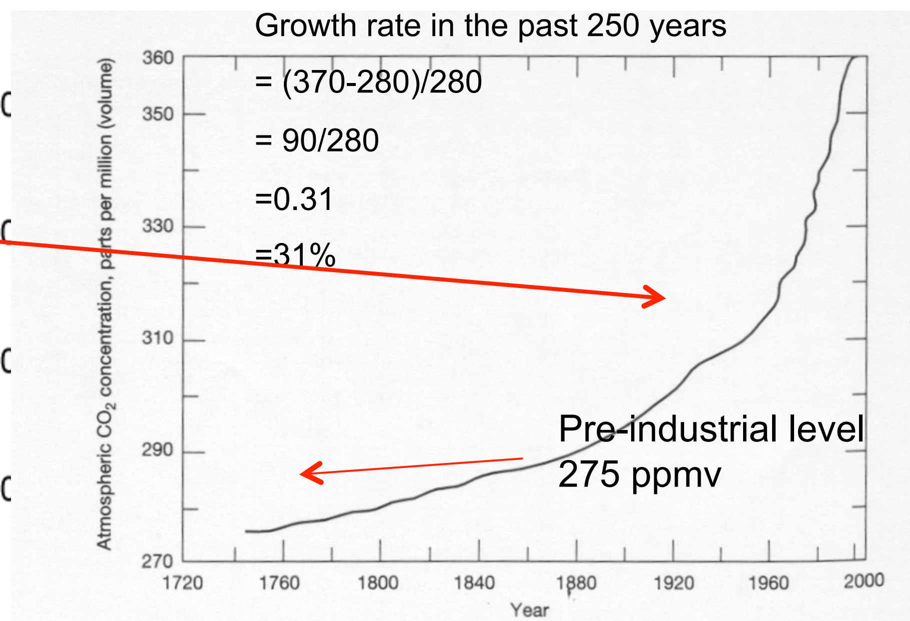
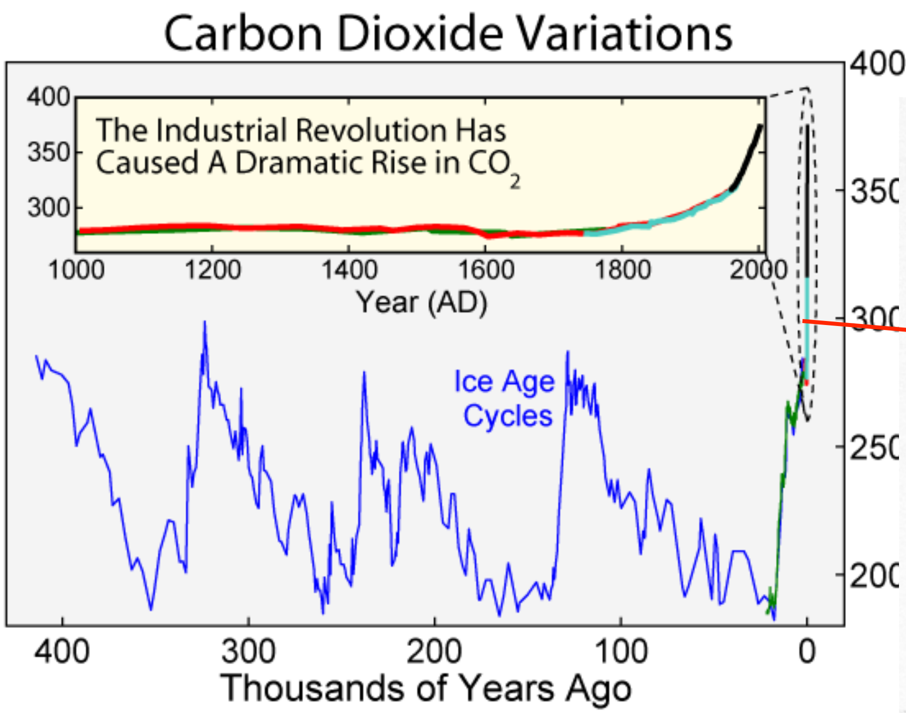
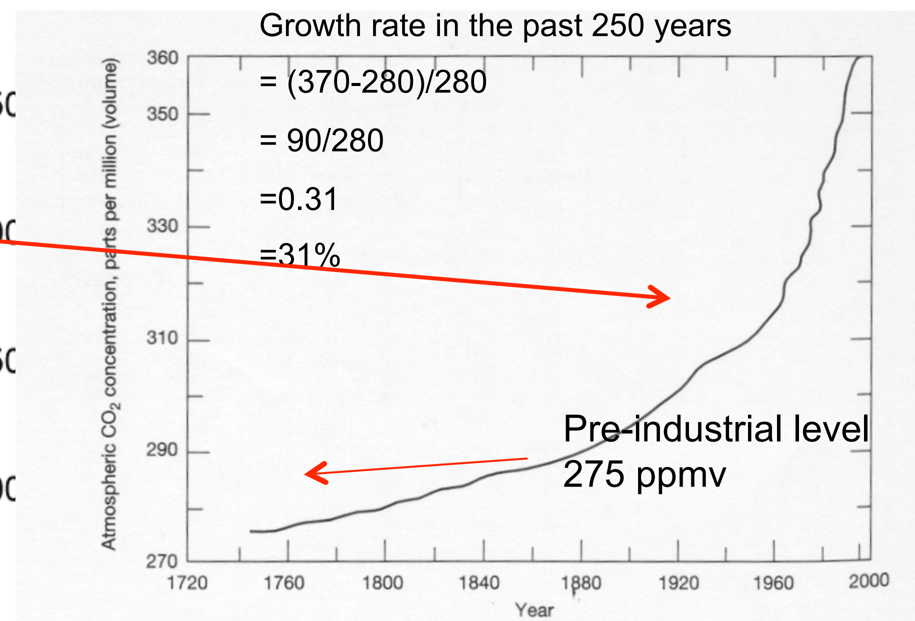


Figure 11.15 Atmospheric carbon dioxide concentrations over the last approximately 300 years from ice core data and atmospheric measurements at Mauna Loa Observatory, Hawaii. (After Siegenthaler and Oeschger, 1987; Boden et al., 1991; Halpert and Ropelewski, 1993; NOAA/CMDL Carbon Dioxide Measurements, 1997.)

How old is human?

Human Impacts on Atmospheric CO_2





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How old is human?

The oldest human we know: Ethiopian rift valley: 276KY old

USA 27.8%
Europe 18.3%
China: 7.8%
Russia: 7.5%
Germany: 6.7%
UK: 6.1%
Ships/air: 4%
Japan: 3.9%
CanAus: 3.0%
India: 2.4%
Rest of world: 12.5%

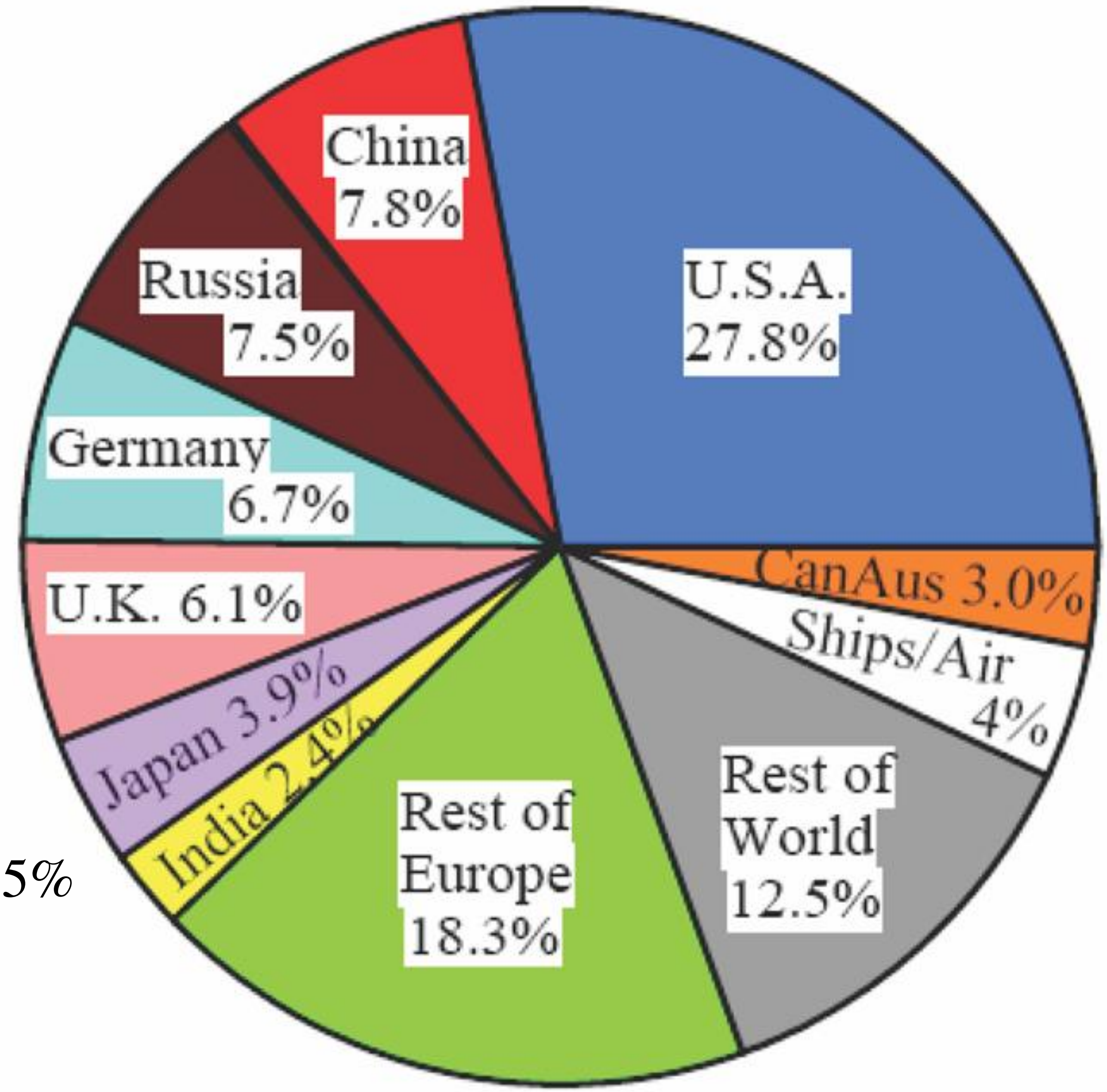
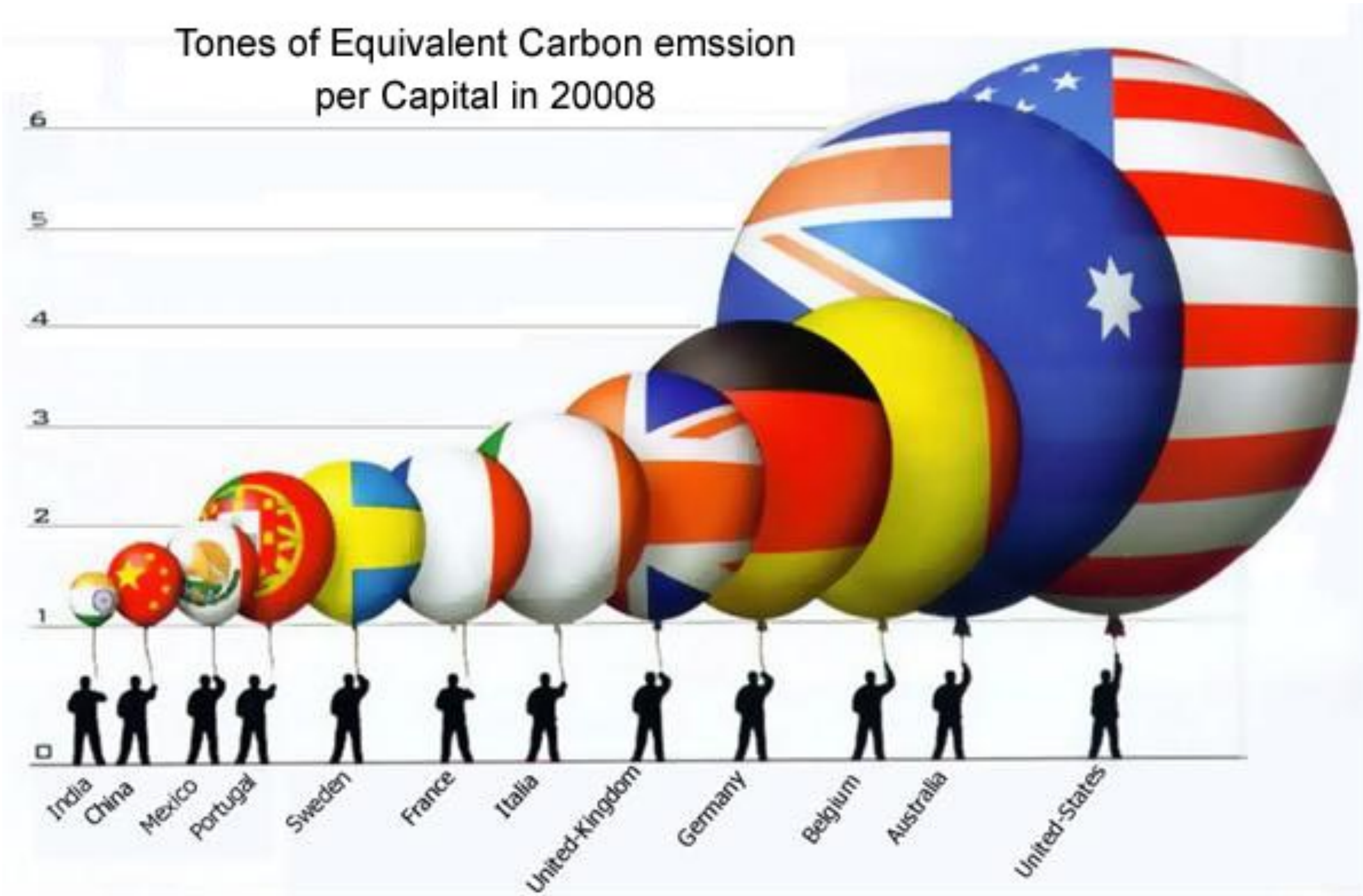
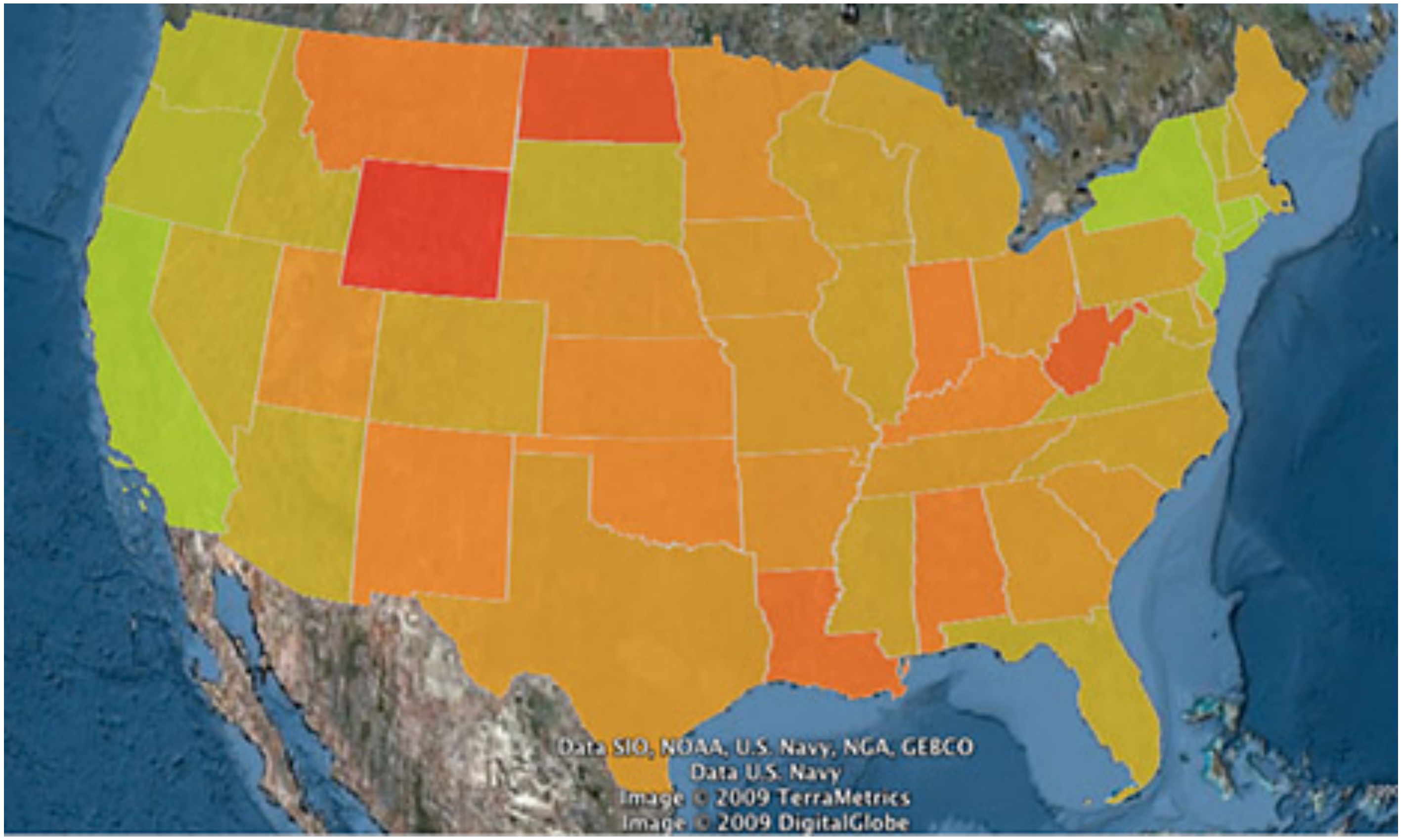


Figure 2. CO_2 emissions from 1750-2005 (Image created by James Hanse

Greenhouse Gas Emissions per Capita





Carbon emissions by state per capita. The redder the color, the more emissions per person.

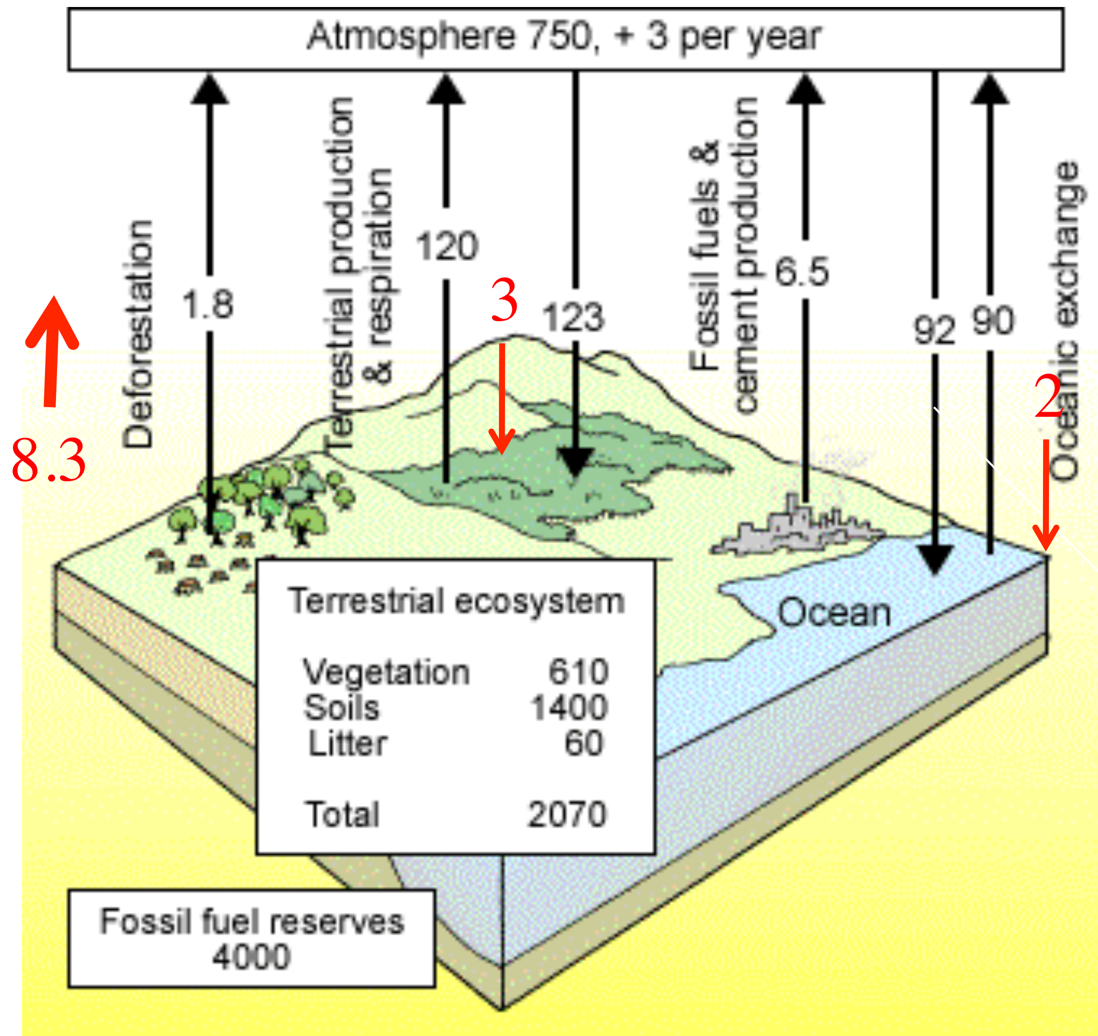
Source:

Where Does Carbon Go (Carbon Sink)?

Human impact on global C cycle: Burning of fossil fuels, deforestation
Net emissions by humans = Net changes in carbon cycle

Total human emission:
- Industrial: 6.5
- Land-use: 1.8

Absorbed by land +ocean:
Land: 3
Ocean: 2
Stay in the atmosphere: 3
?? 0.3



Missing Carbon Sink

– The mysterious removal of a large amount of carbon dioxide from the Earth's atmosphere.

– The missing sink has partially offset the atmospheric CO_2 amount

– Previous reports:

  – The southern oceans were a massive sink.

  – The CO_2 sink on land in the Northern Hemisphere was entirely in North America

– New findings:

  – The southern oceans are taking up less than previously thought

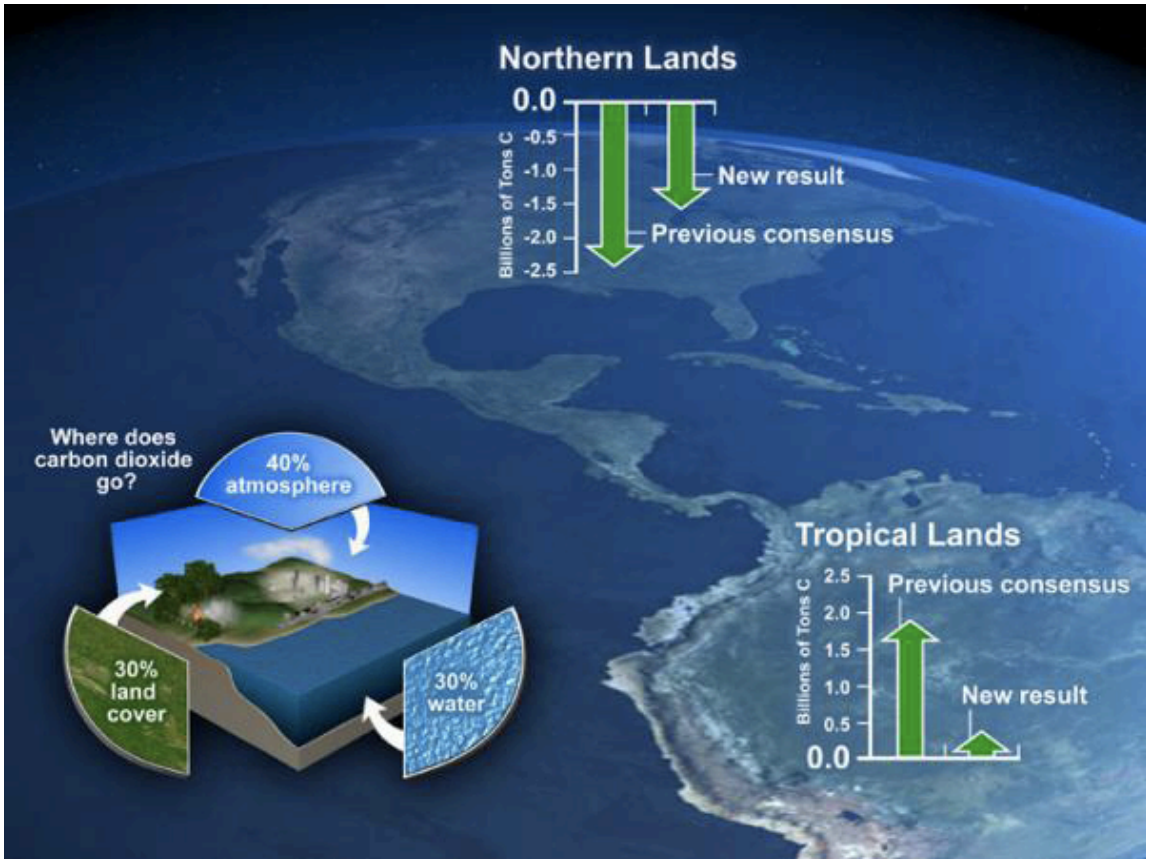
  – The Northern Hemisphere landmass absorbs more than previously thought

  – The North American sink was smaller than the earlier estimate

– Questions: Where CO_2 comes from, where it is absorbed? How long it works? How the strength of the sink responds to the CO_2 rise?

– Unraveling this mystery is important to predict future CO_2 build-up and the resultant global warming. Implications for "carbon trade".

Where is the missing carbon sink? Tropical forests.
Steven et al. 2007 Science.



Terrestrial Carbon Sink Why and How Long?

–Human activities (fossil fuel use and land-use) perturb the carbon cycle -- increasing the atmospheric concentration of carbon dioxide

–The current terrestrial carbon sink is caused by land management practices, higher carbon dioxide, nitrogen deposition and possibly recent changes in climate

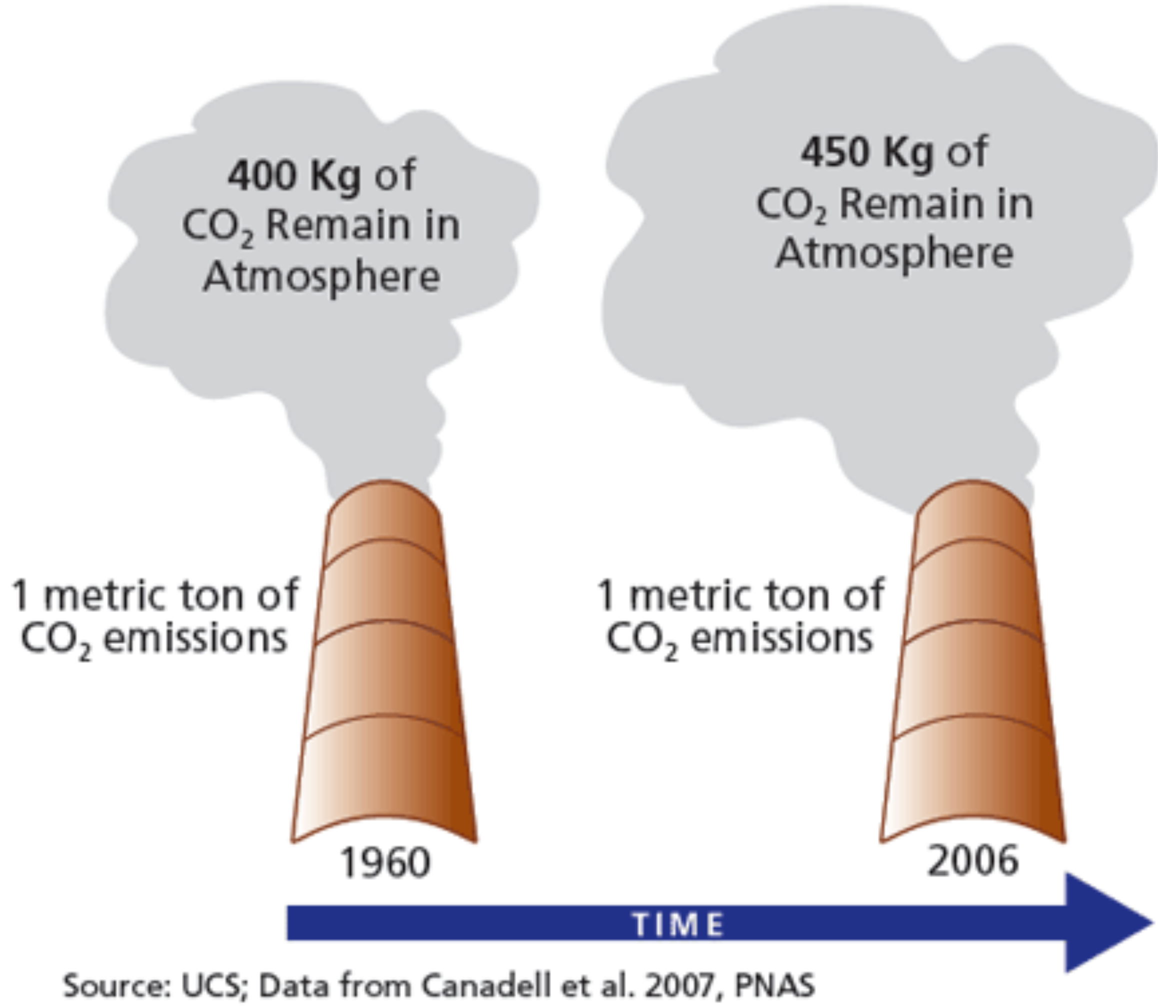
–This uptake by the terrestrial biosphere will not continue indefinitely. The question is when will this slow down, stop or even become a source?

–Land management results in the sequestration of carbon in three main pools -- above and below ground biomass and soils

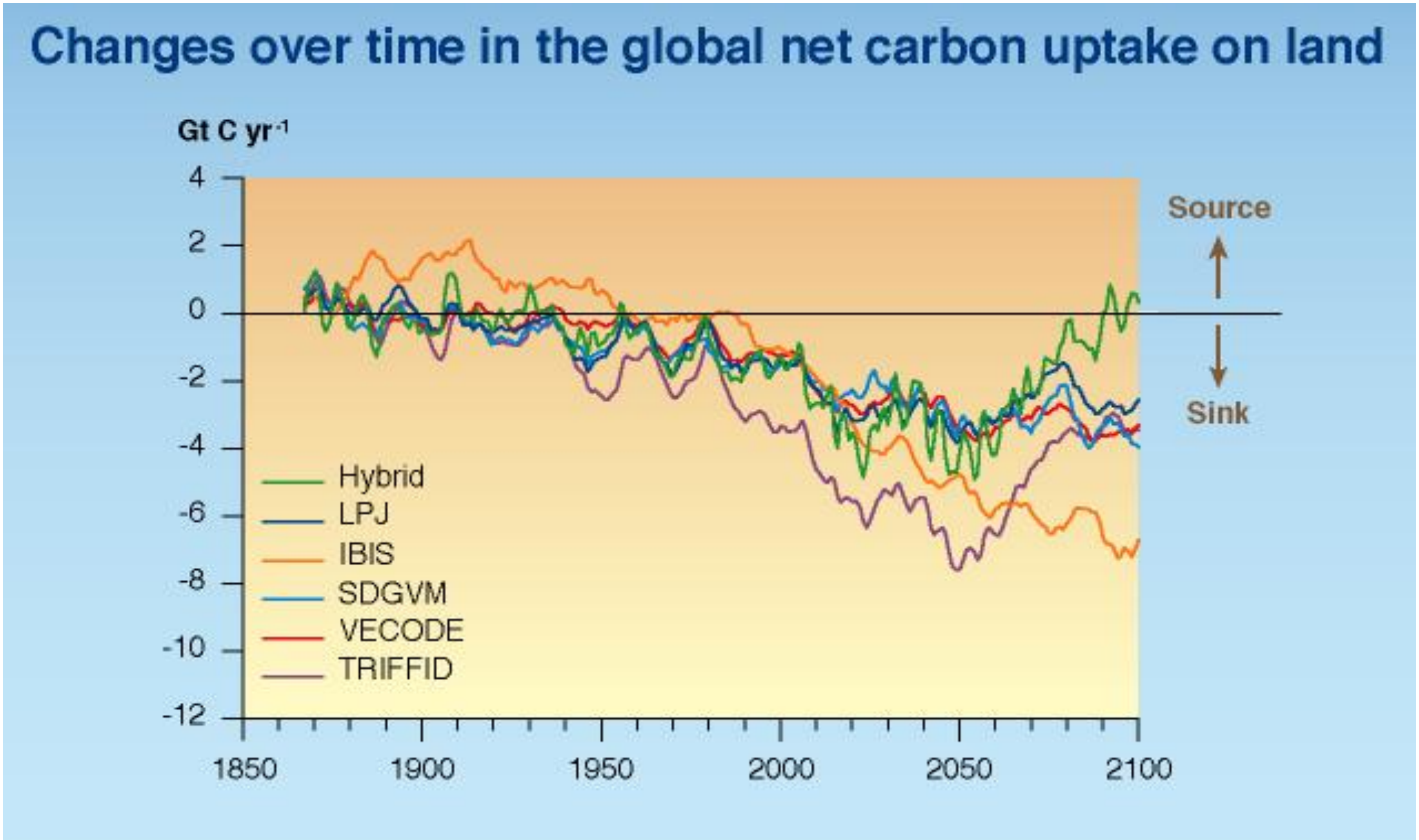
How does natural CO2 sink changes with time?

Ocean absorbed less CO2 as its surface temperature and acidity increase;

Terrestrial ecosystem also absorbed less due to e.g., droughts.



Terrestrial Biosphere predicted to take up C but will level off or reverse next century



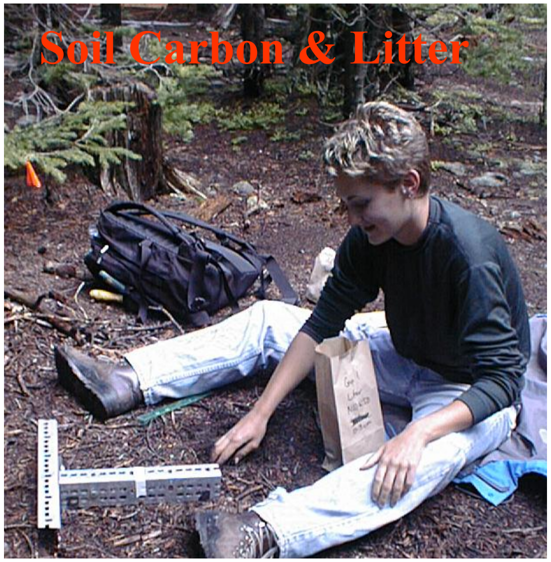
Above-Canopy Towers for Measuring Ecosystem CO_2 Exchange

Towers are instrumented to measure instantaneous fluxes of CO_2 to or from the forest ecosystem, using a technique called Eddy Covariance or Eddy Correlation. Summed over time, these measurements can give us daily, weekly or annual Carbon balances, to answer the question:

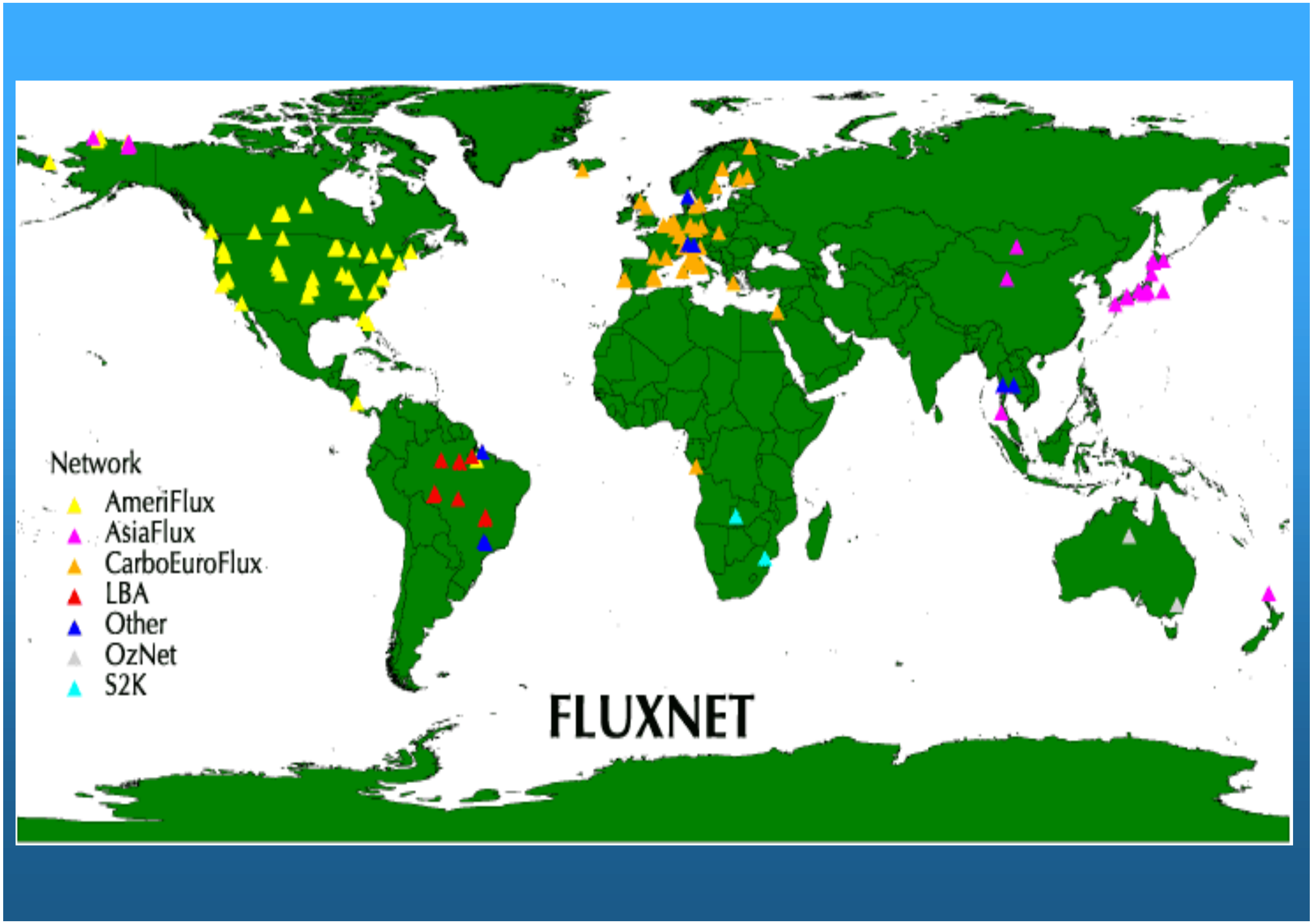
Is the forest a source of CO_2 to the atmosphere or a sink which removes CO_2 from the atmosphere?

What environmental factors control how much Carbon is removed?

Ancillary Measurements Understanding CO_2 Uptake/Release



Global CO_2 Flux Network



Principal Anthropogenic Sources for Methane

Domesticated livestock, cultivated rice paddies, fossil fuel and biomass burning, and the mining of coal, oil and gas

Summary-Discussion:

Tectonic-scale cycling: hundreds of millions of years,

- What control atmospheric CO_2 on this time scale?
- How does the atmospheric CO_2 concentration during the last 1 million year compared to that during most of the last 500 MY?

Orbital-scale cycling: hundreds of thousands of years (glacial and interglacial cycles):

- What controls CO_2 change on this time scale?
- How does CO_2 during the last 400KY compares to today's CO_2 value?

Seasonal-scale cycling: seasonal variations (biological activity)

- What controls atmospheric CO_2 on this time scale?
- What role does biosphere play in regulate CO_2?

Human-caused (anthropogenic):

What are the main sources of human-caused increase of CO_2?
How much human-emitted CO_2 during the past century stays in the atmosphere?
Where did the rest of the CO_2 go?
Do you expect the natural carbon sink to increase or decrease?