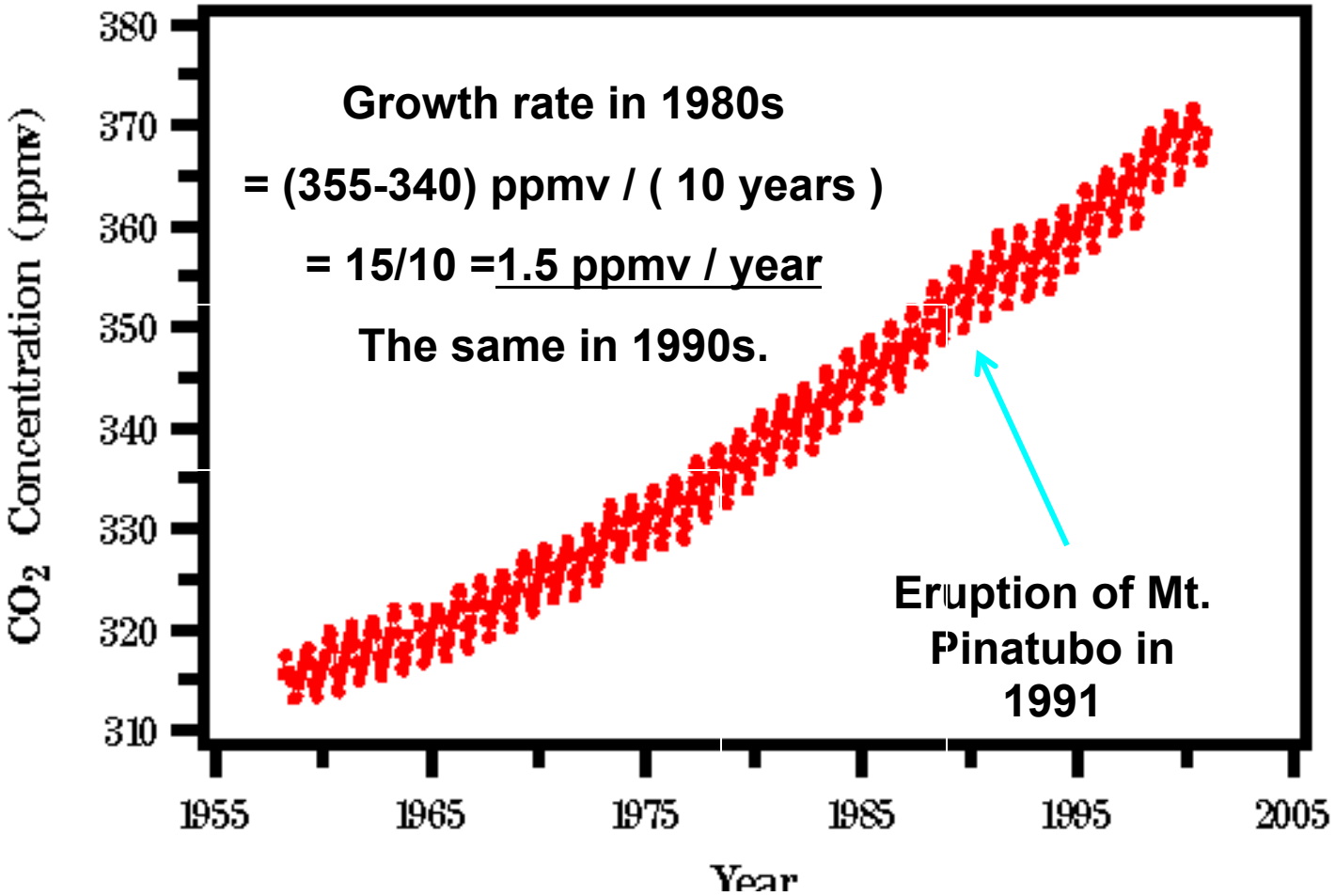
Lecture 30: Anthropogenic Inputs of Greenhouse Gases and causes of the global warming in the past 100 years

Chapter 18 (325-335)

1. Carbon Dioxide emission
   - Where CO2 comes from?
   - Where it is absorbed?
   - How long the CO2 would stay in the atmosphere?
2. Is global warming part of natural cycles? Or is it caused by humans? Why?
3. How much warming is caused by humans?
4. What are the certainty and uncertainties about future climate change.

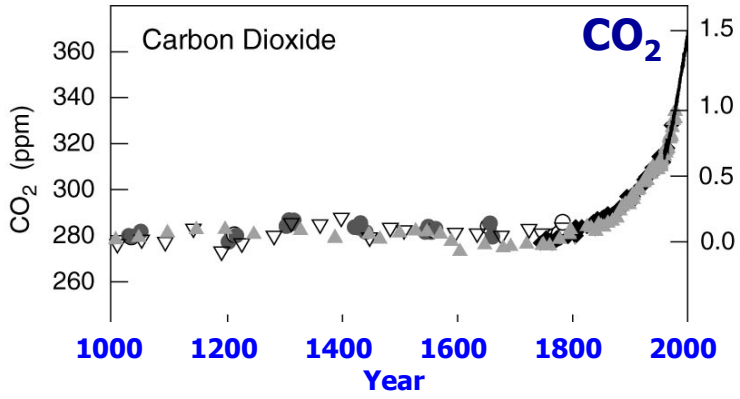
Seasonal cycle of atmospheric CO_2 (Mauna Loa record)



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***
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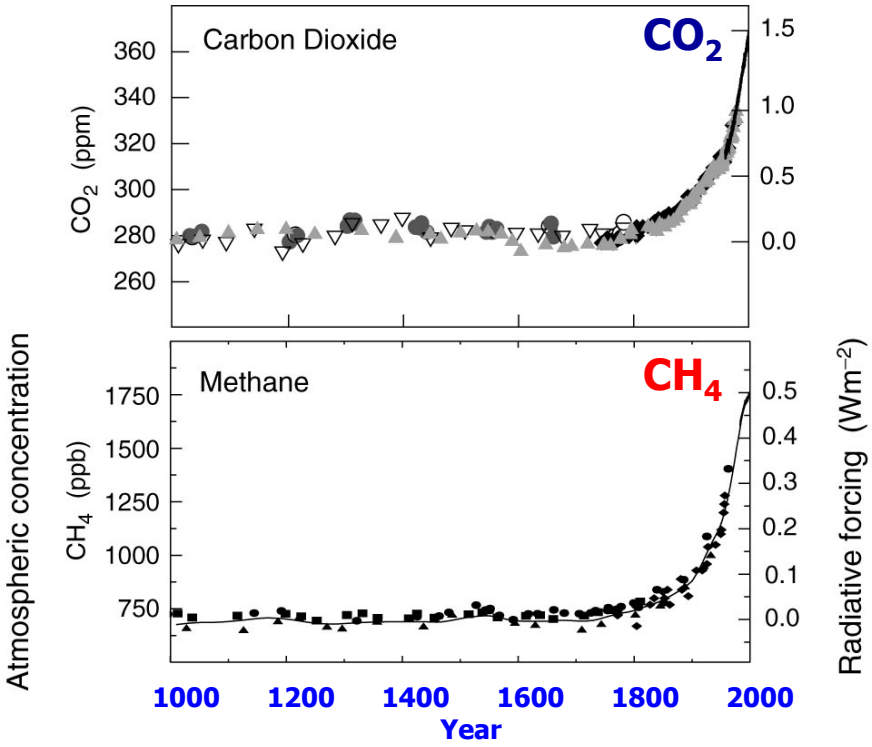

- ***31% increase since 1750: Highest levels since at least 420,000 years ago***
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- ***Increased 150% since 1750 to its highest levels in at least 420,000 years***

Changing Atmospheric Composition: Indicators of the Human Influence

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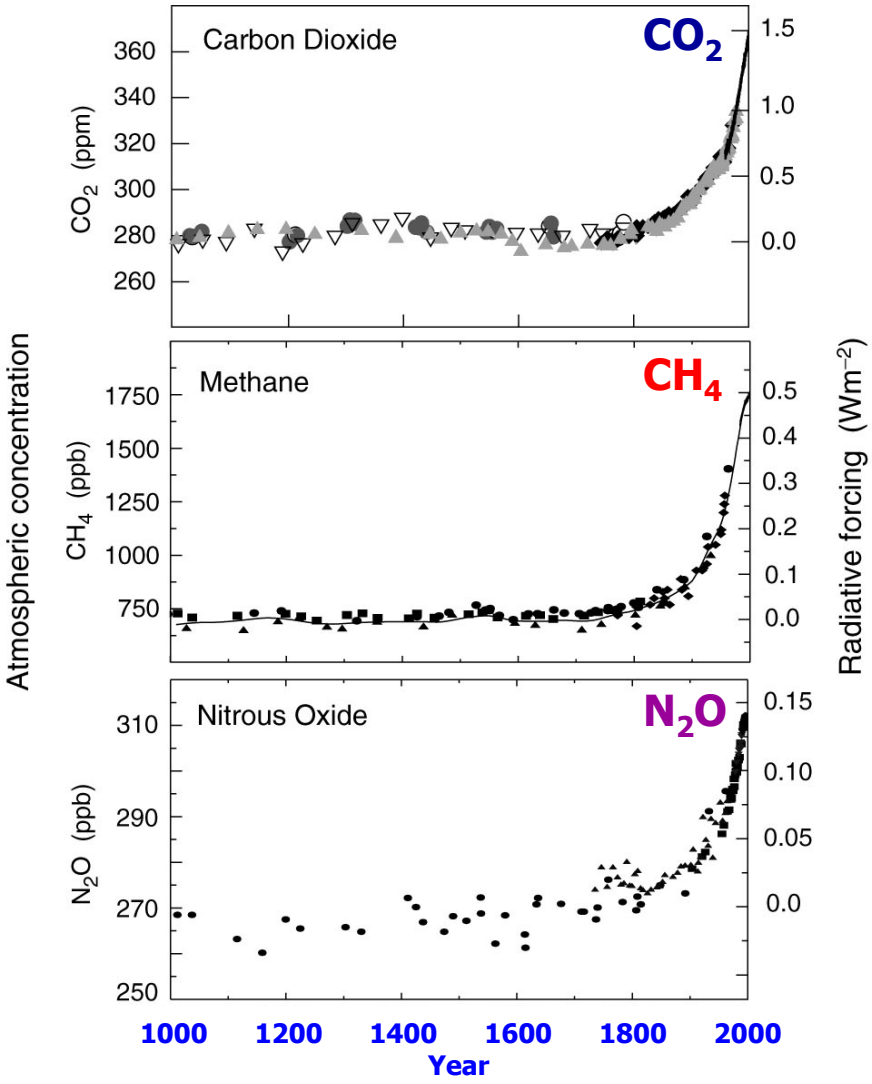
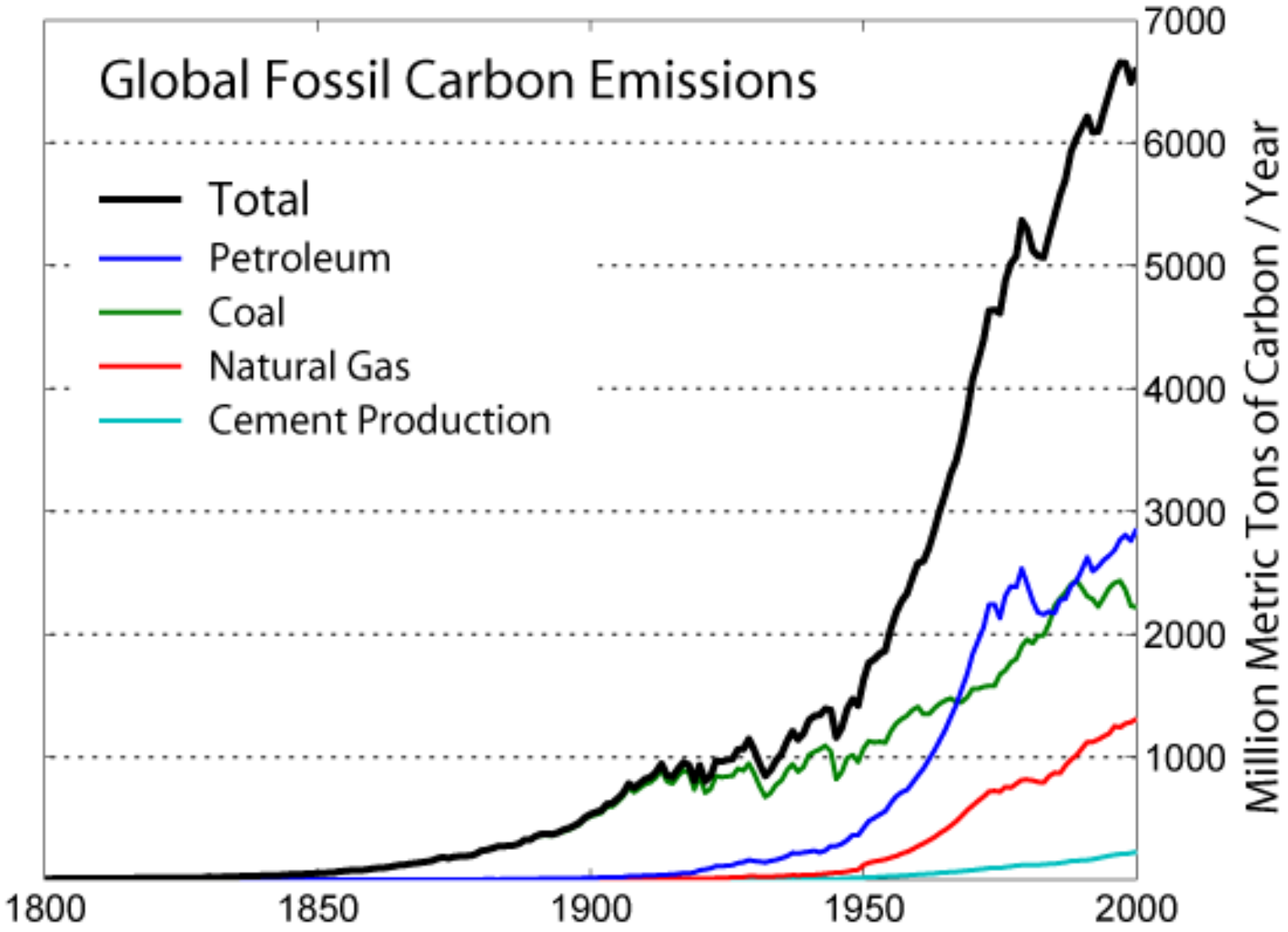
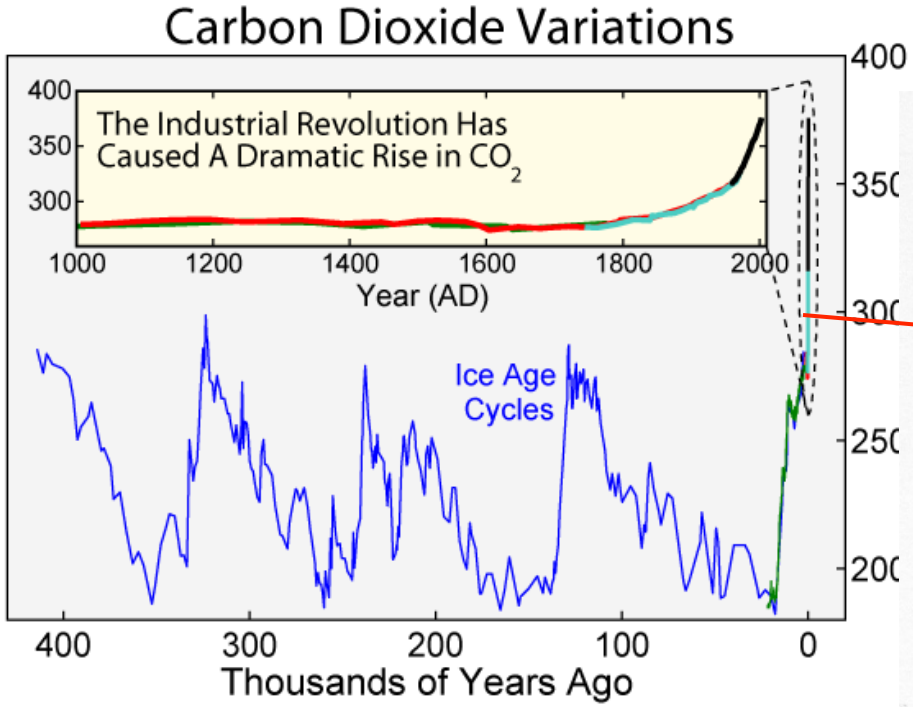


- ***31% increase since 1750: Highest levels since at least 650,000 years ago***
- ***Increased 150% since 1750 to its highest levels in at least 420,000 years***
- ***Increased 16% since 1750 to its highest levels in at least 1,000 years***

Global Fossil Carbon Emissions



Human Impacts on Atmospheric CO_2



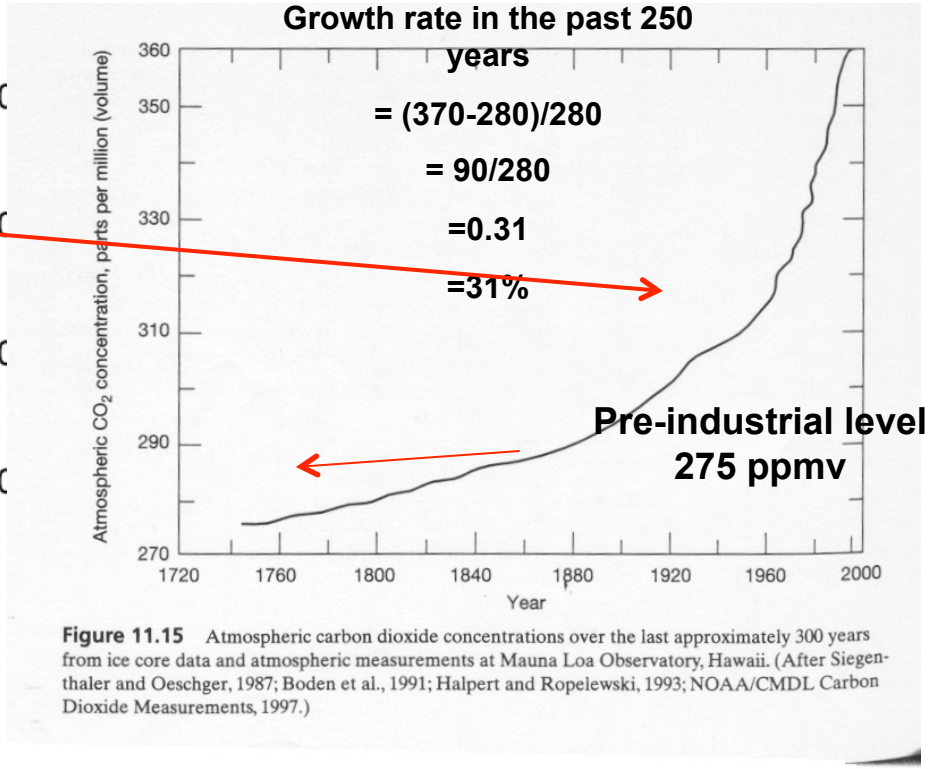
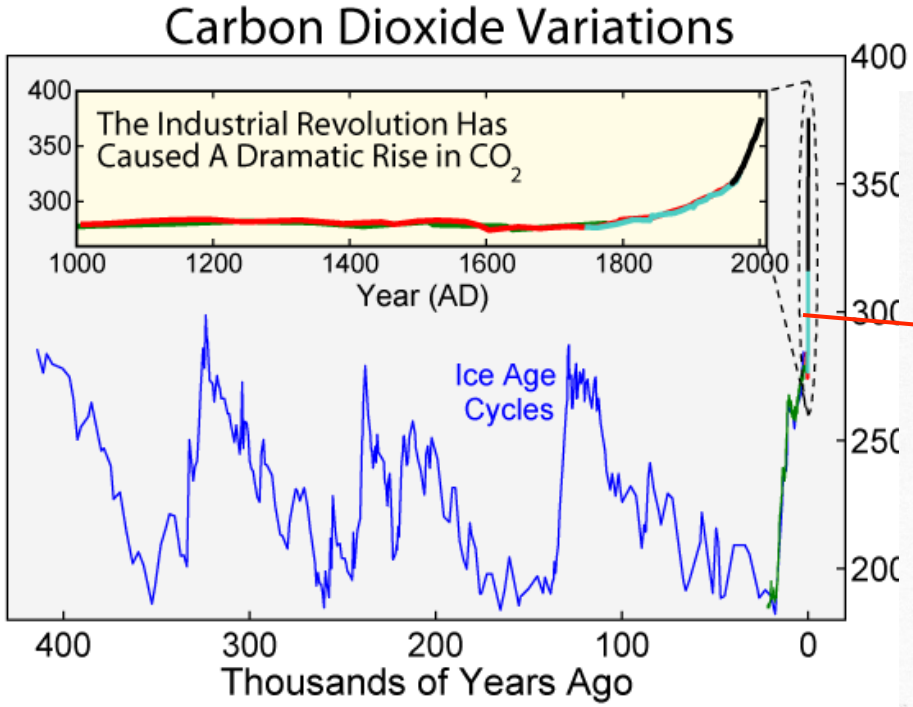
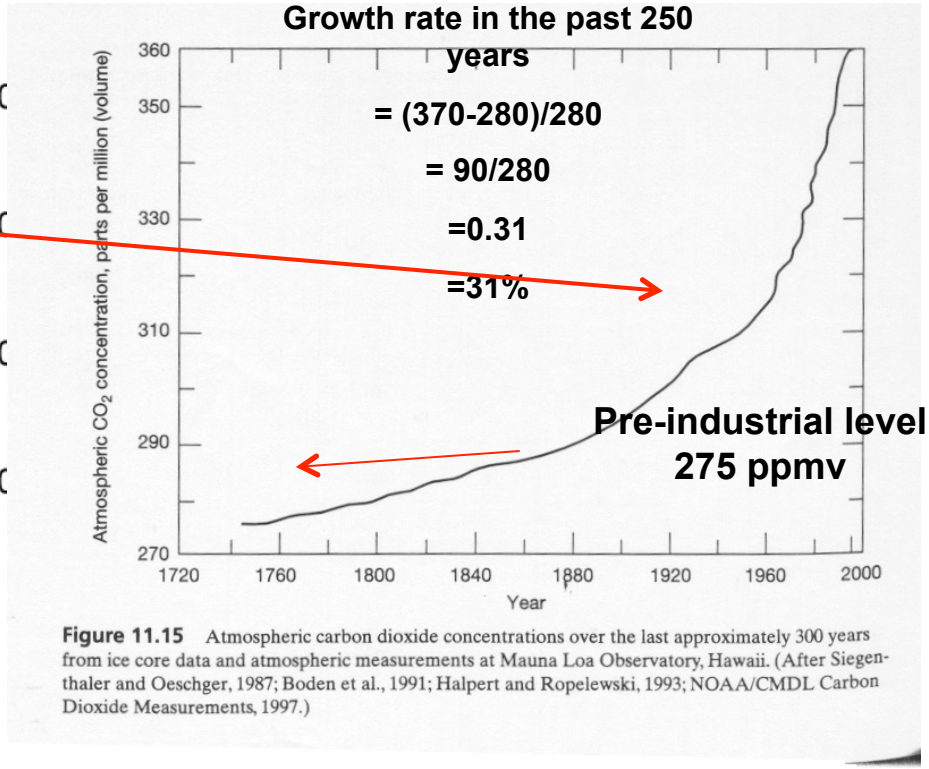


Figure 11.15 Atmospheric carbon dioxide concentrations over the last approximately 300 years from ice core data and atmospheric measurements at Mauna Loa Observatory, Hawaii. (After Siegenthaler and Oeschger, 1987; Boden et al., 1991; Halpert and Ropelewski, 1993; NOAA/CMDL Carbon Dioxide Measurements,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

Total emission:

- **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%**

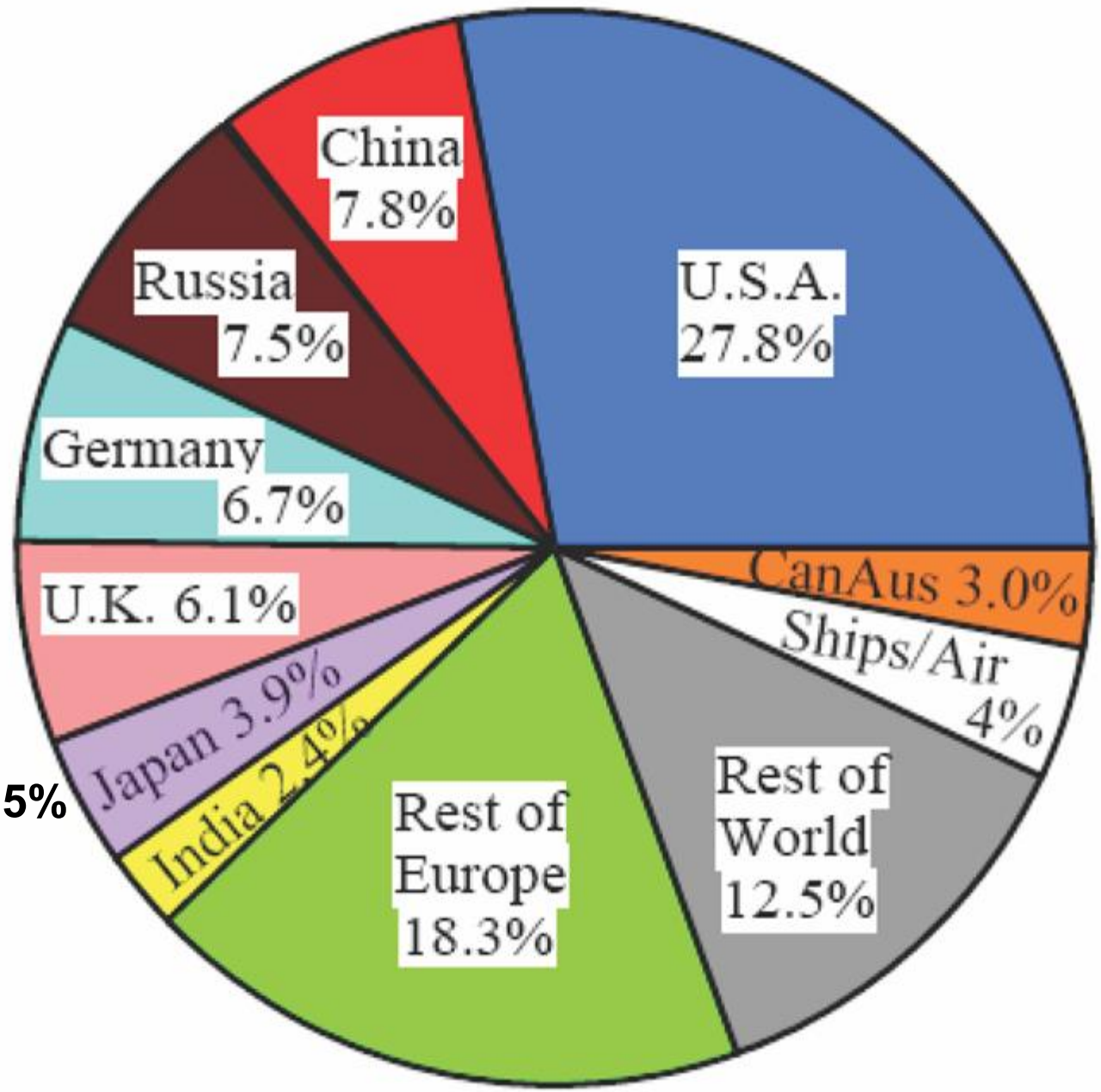
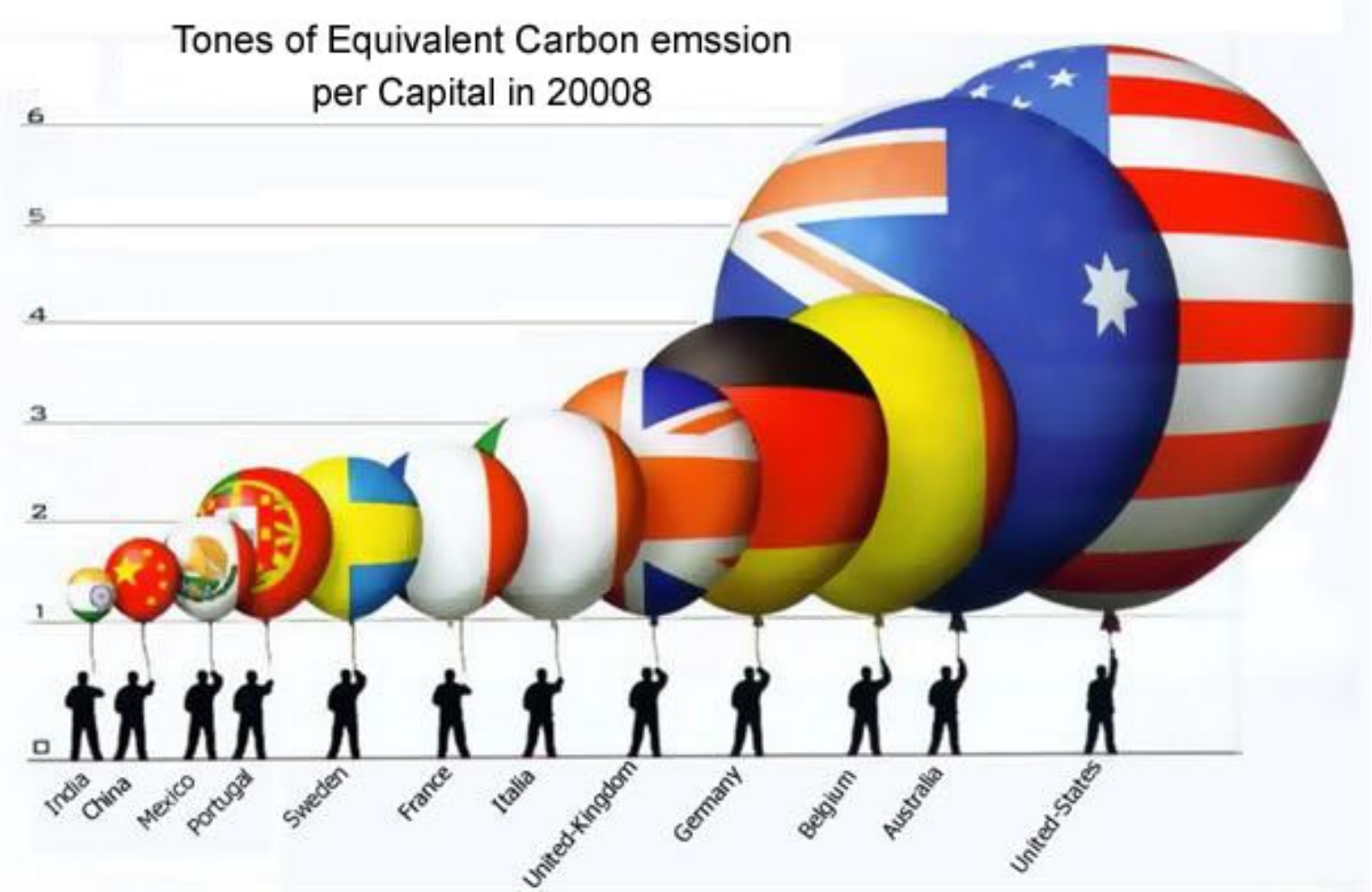
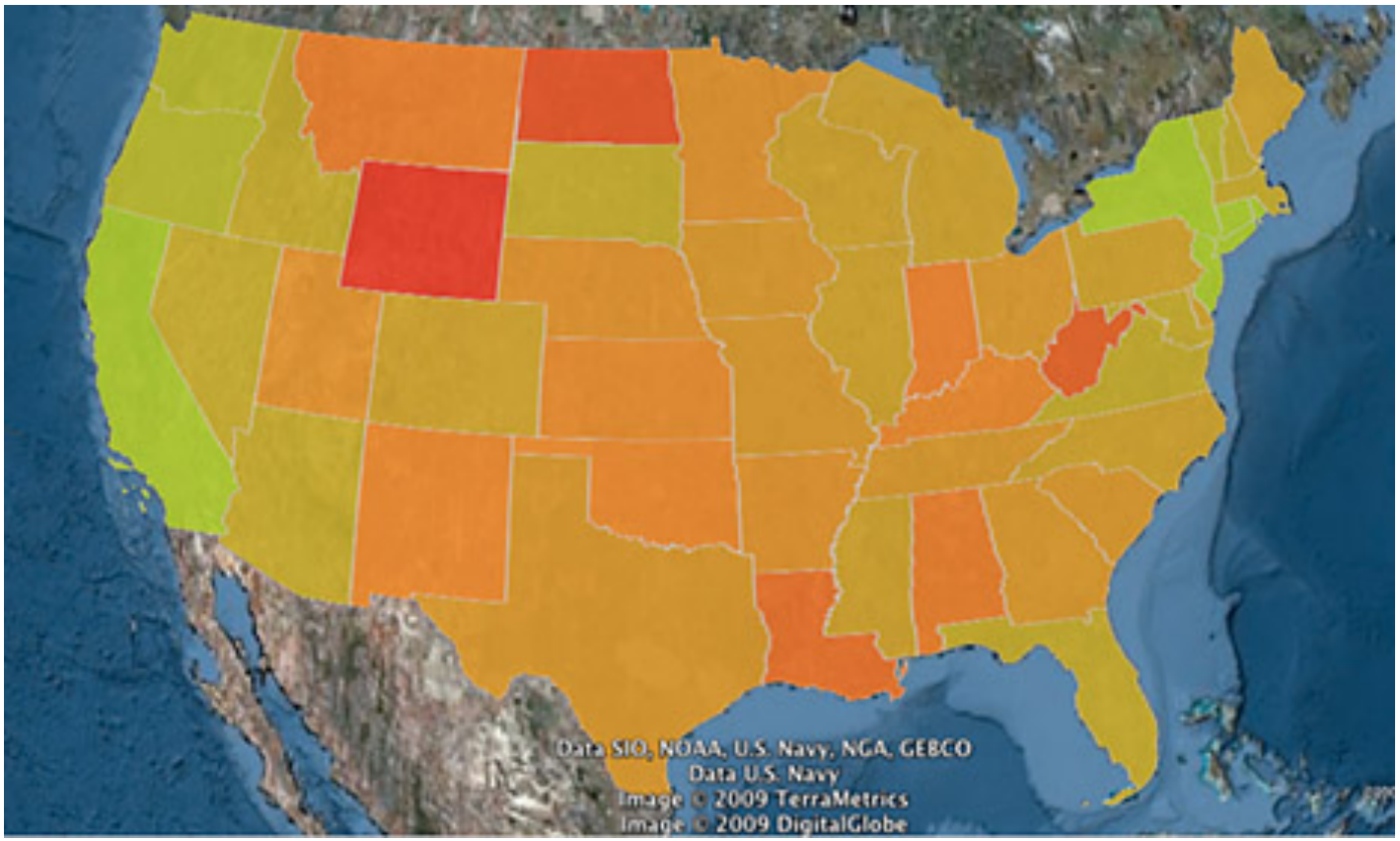


Figure 2. CO_2 emissions from 1750-2005 (Image created by James Hanse

Greenhouse Gas Emissions per Capita





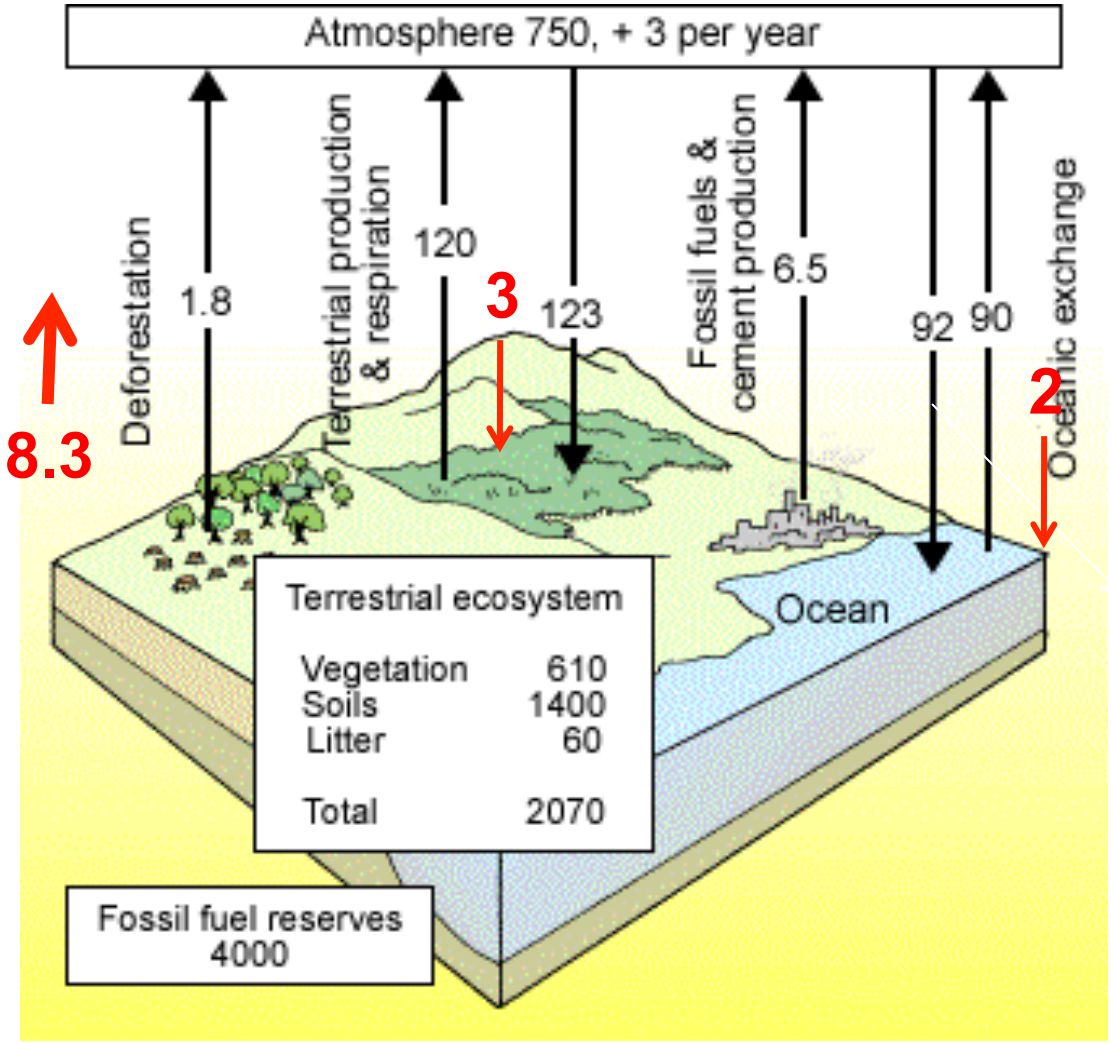
Carbon emissions by state per capita. The redder the color, the more emissions per person.

Where Does Carbon Go (Carbon Sink)?

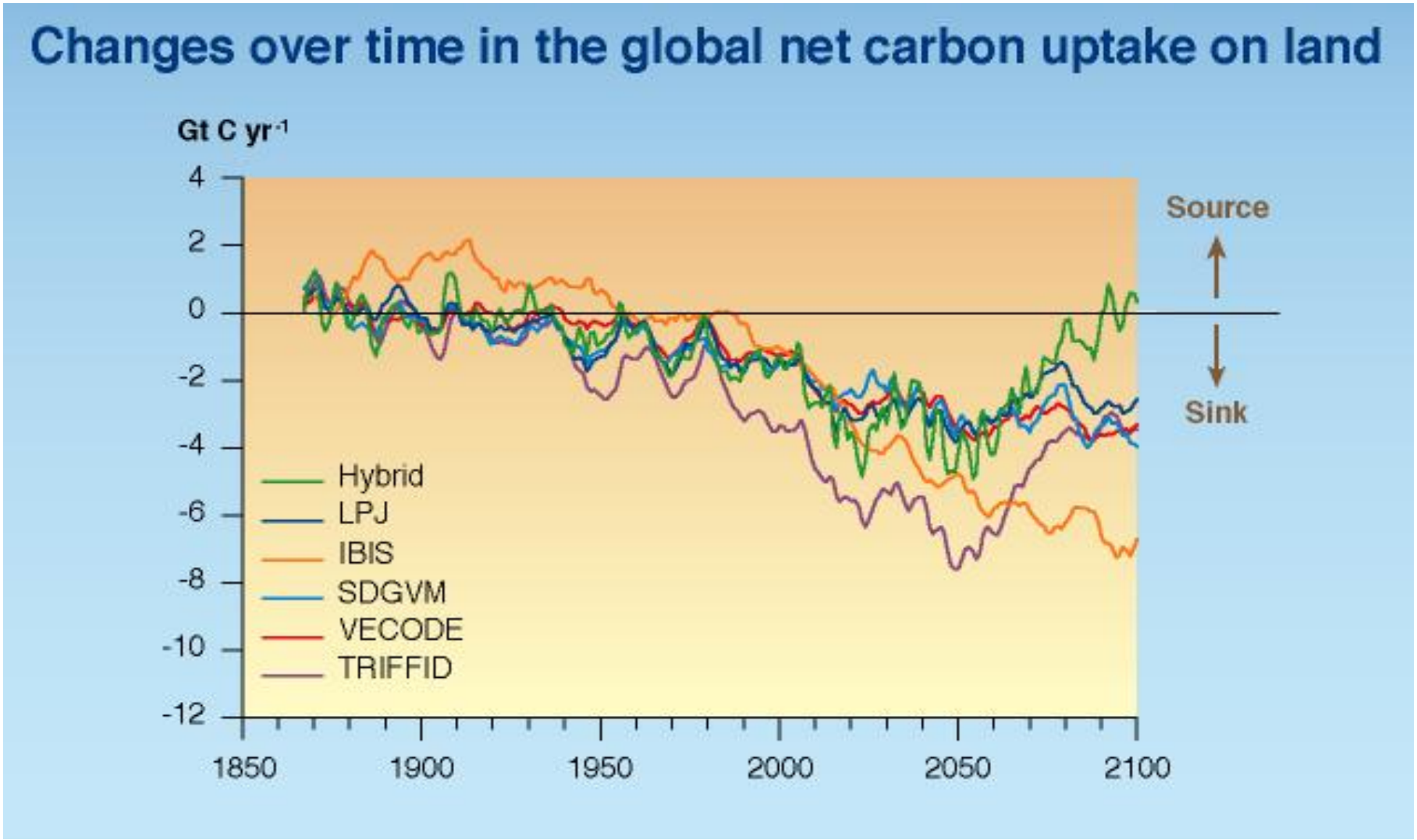
Human impact on global C cycle: Burning of fossil fuels, deforestation
Net emissions by humans = Net changes in carbon cycle

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



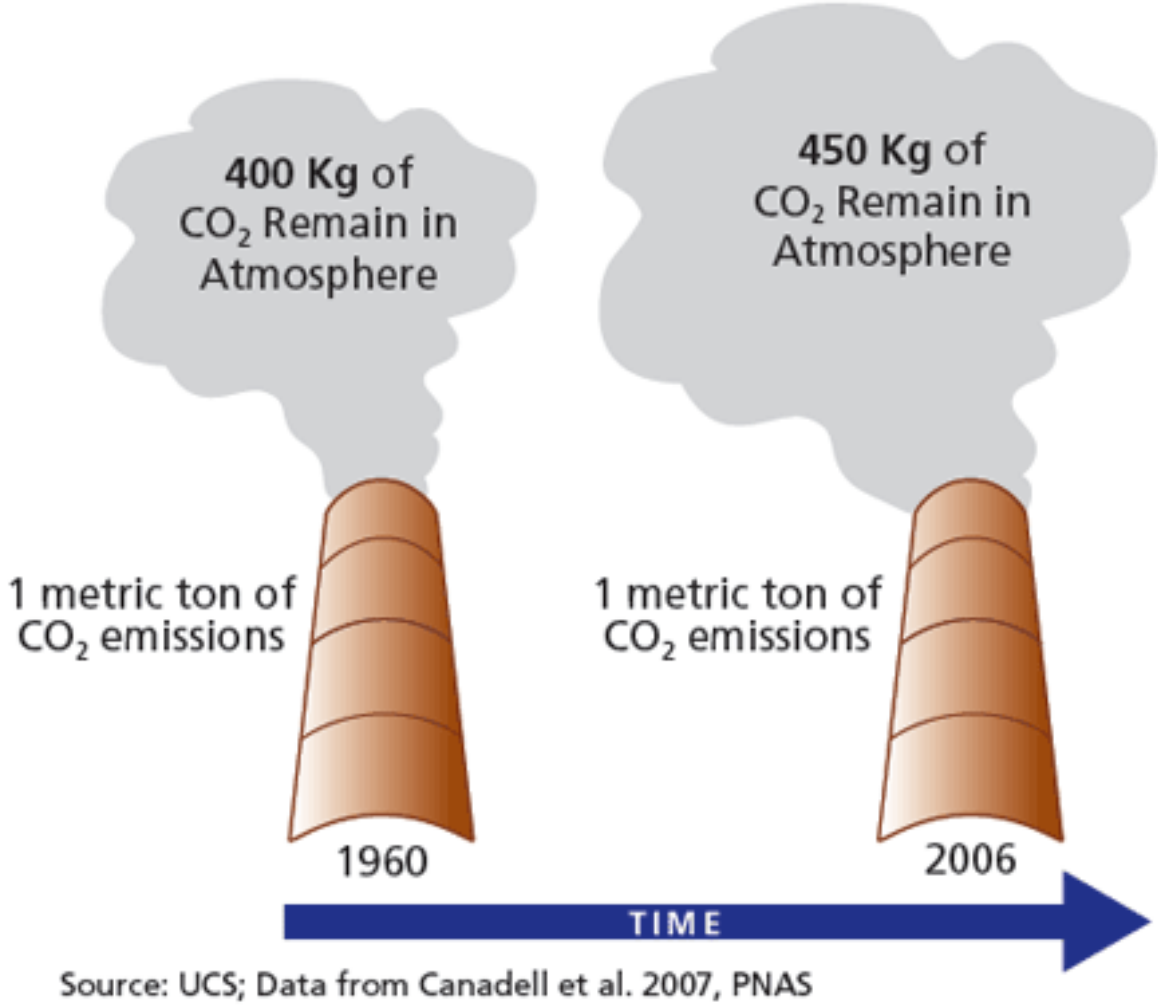
Terrestrial Biosphere predicted to take up C but will level off or reverse next century



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.



How is the increase of Greenhouse gases linked to observed climate change?

- **Results of climate models simulations**
- **Results of paleo-climate records**

Uncertainties about the Global Warming of the Past Century

Skeptics

a. No warming discernable in data

b. If warming, not from human activities

The sunspot cycle	The role of ozone
The role of clouds	The role of sulphate aerosols
The role of dust	The role of oceans

c. If warming, and from human activities, maybe warming not so bad

d. If warming, and from human activities, and it is a problem, then engineer a solution to pull CO_2 out of the atmosphere, e.g., through carbon sequestration, while conducting other business as usual (i.e., don't cut CO_2 emissions).

Uncertainties in the temperature data

early records are subject to instrumental error and improper sitting

uneven land and sea stations

too many Northern Hemisphere records

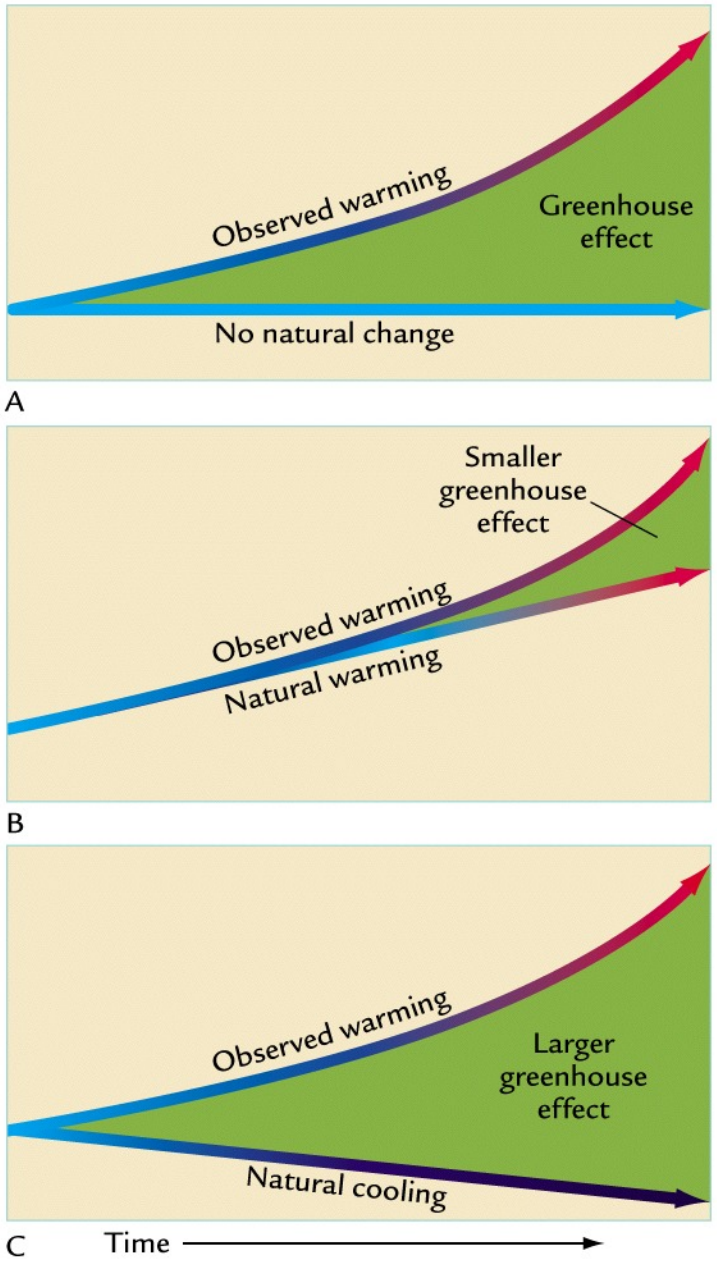
urban heat island effect

mismatch between satellite, balloon and surface data

ALL THESE HAVE BEEN CAREFULLY ACCOUNTED FOR OR MOSTLY RESOLVED

Natural Warming and Greenhouse Effects

both natural and human induced changes would contribute to the observed climate change.



How does so-called “climategate” affect conclusion of climate change?

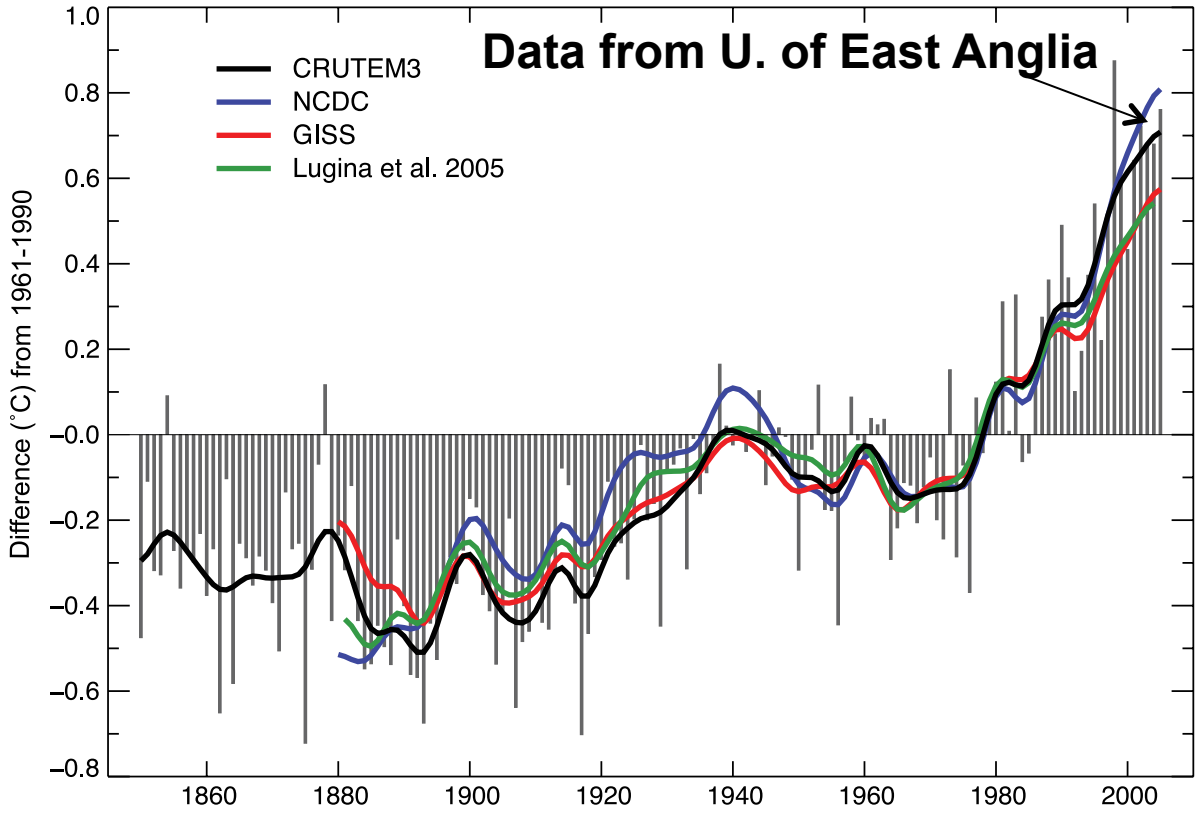
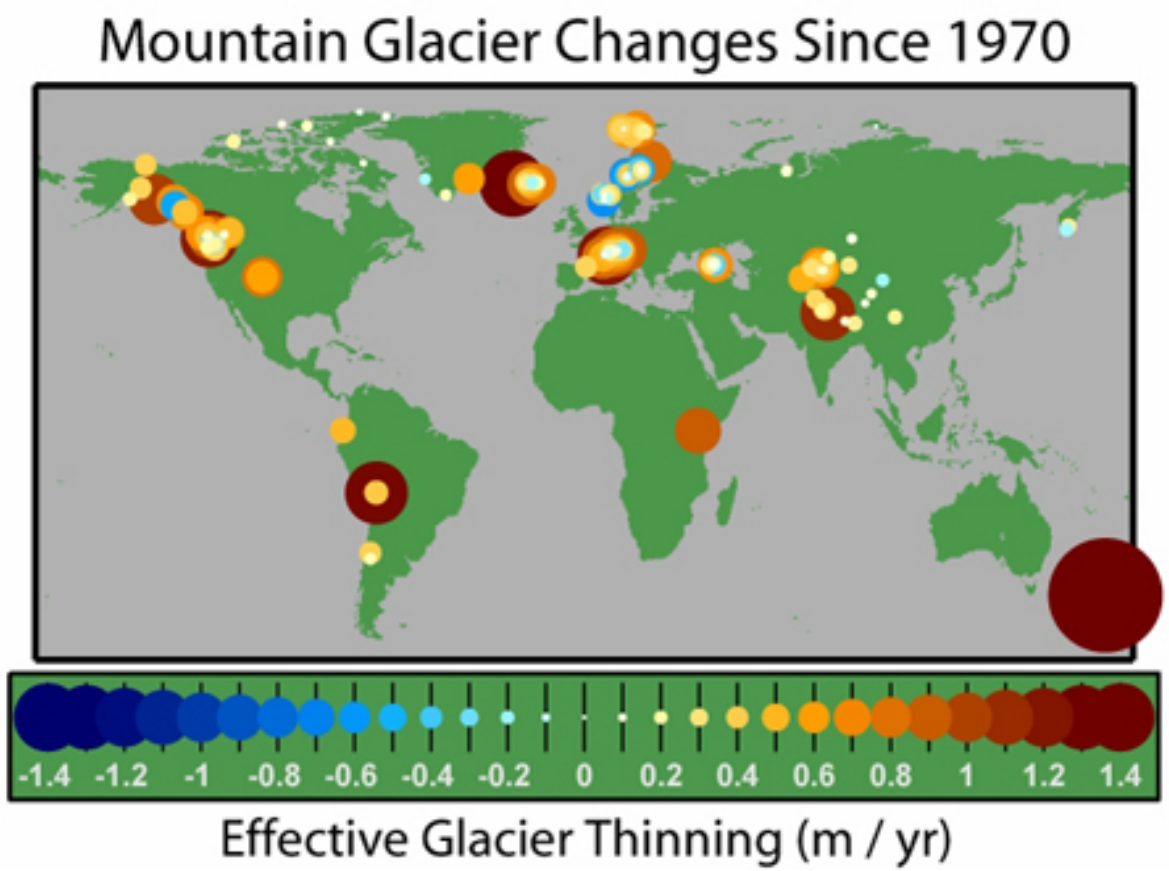
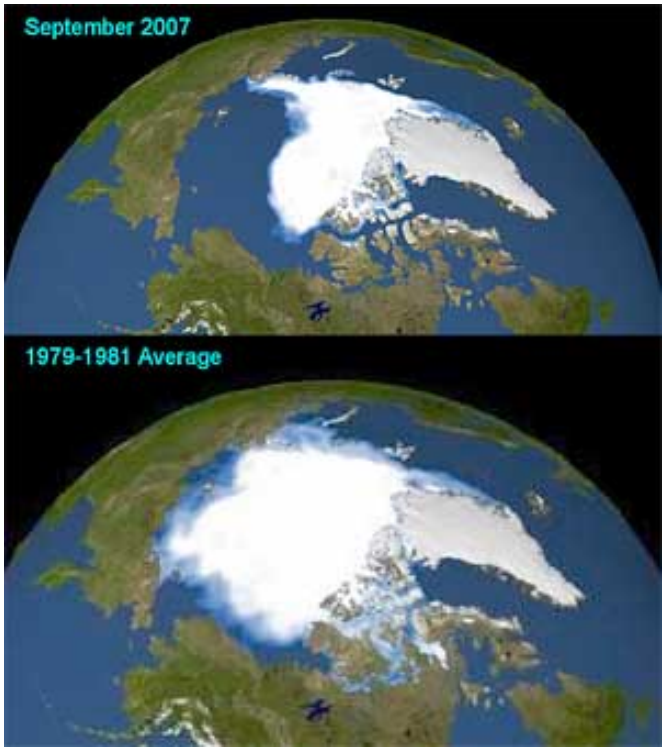


Figure 3.1. *Annual anomalies of global land-surface air temperature (°C), 1850 to 2005, relative to the 1961 to 1990 mean for CRUTEM3 updated from Brohan et al. (2006). The smooth curves show decadal variations (see Appendix 3.A). The black curve from CRUTEM3 is compared with those from NCDC (Smith and Reynolds, 2005; blue), GISS (Hansen et al., 2001; red) and Lugina et al. (2005; green).*

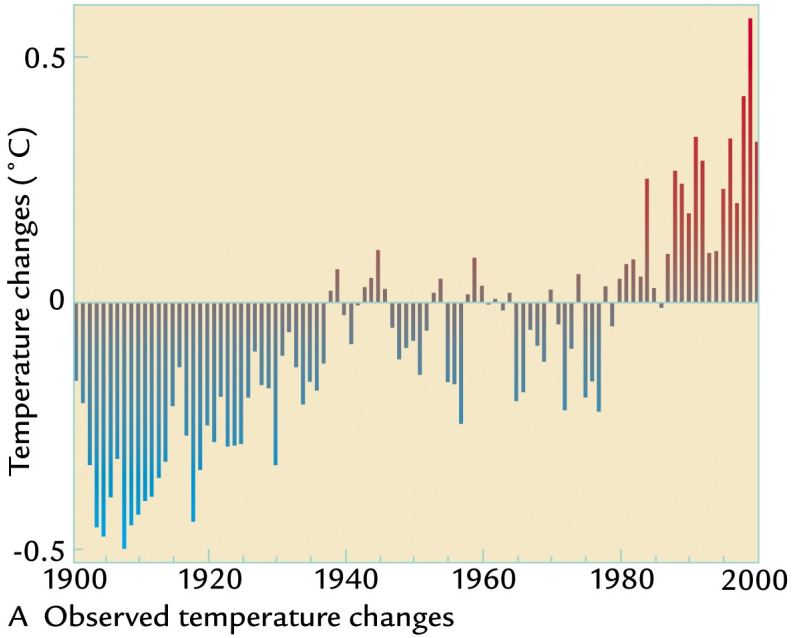
a. Original data are available to public freely so anyone can verify the results
b. Even when we drop the data from U. of E. Anglia, evidence for warming is still overwhelm.

Anyone can verify glacier melting with their own eyes.



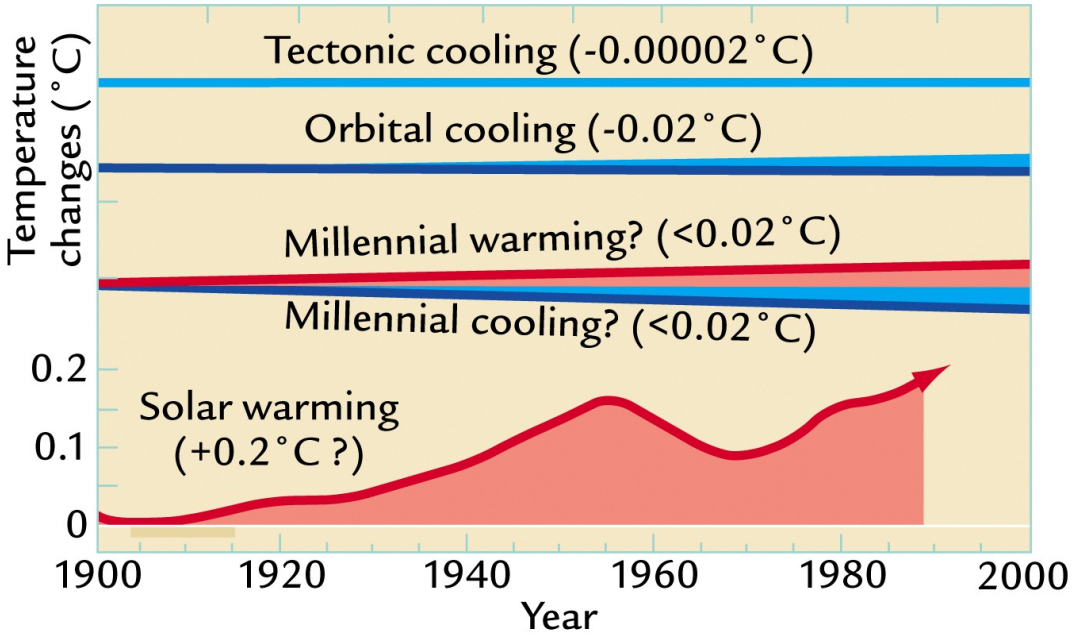


Observed Temperature Changes and Natural Contributions



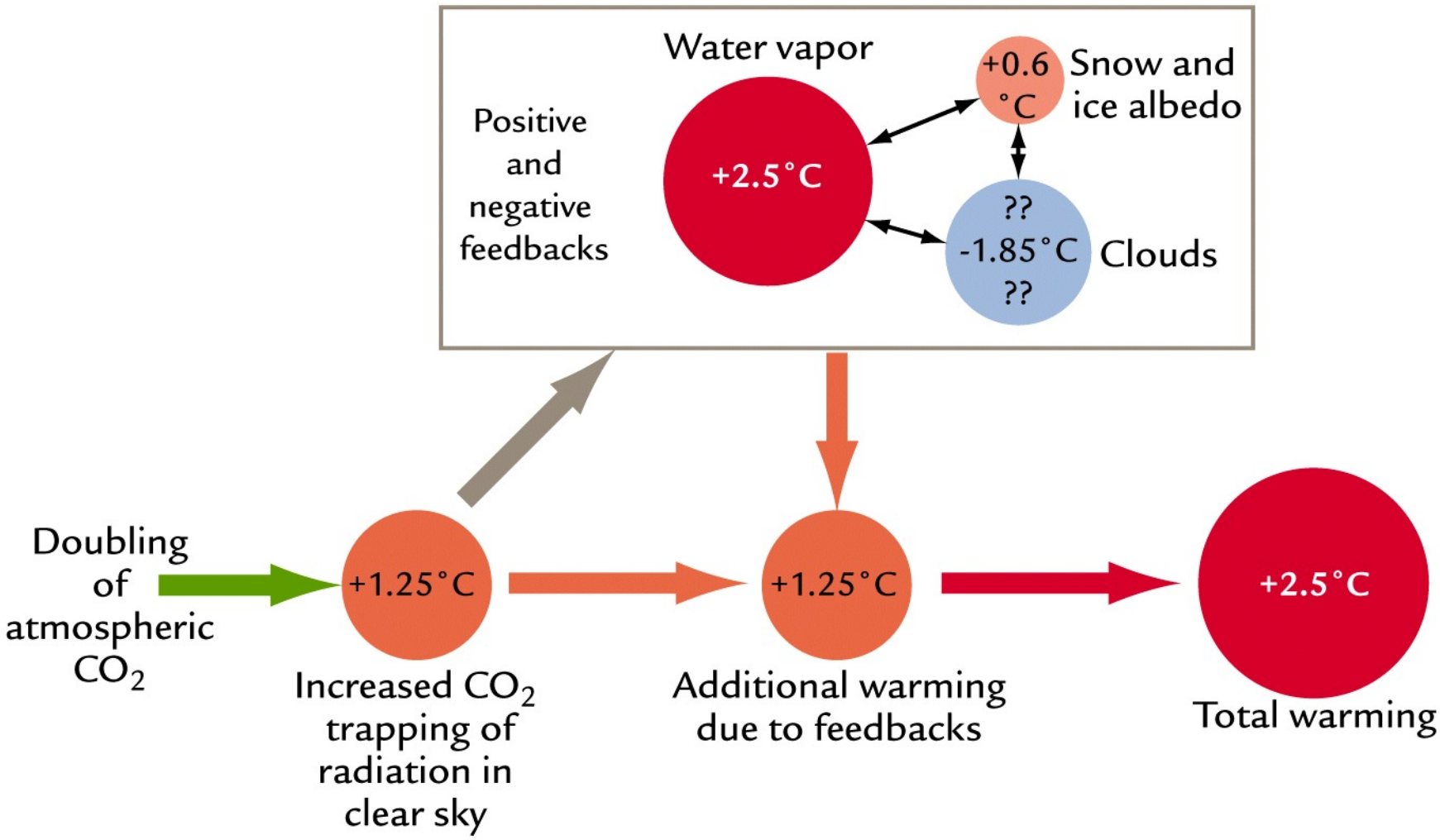
A Observed temperature changes

Observed trend 0.6°C/century, natural climate changes may contribute <0.2°C)

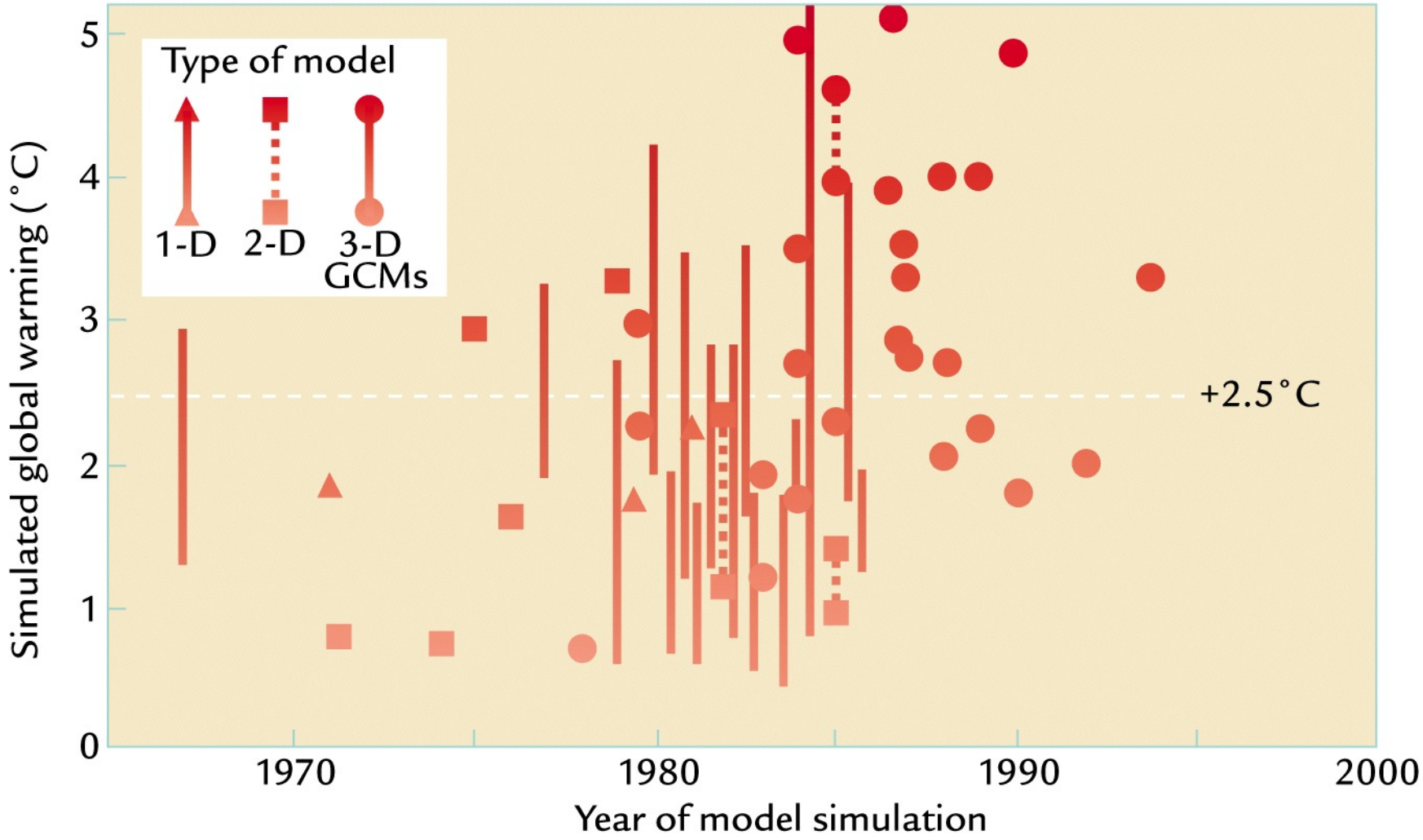


B Natural temperature changes

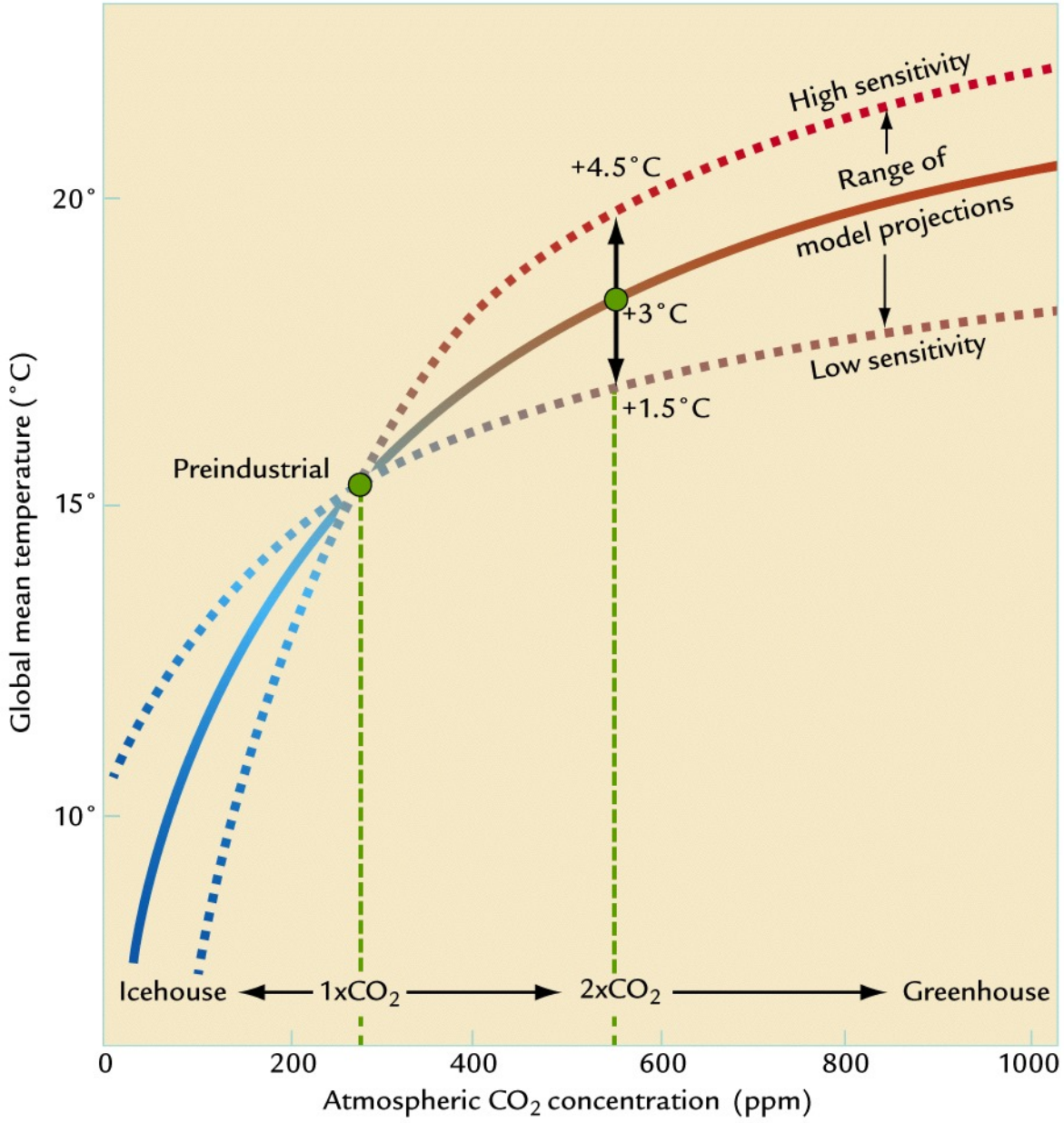
Components of 2 × CO_2 Warming



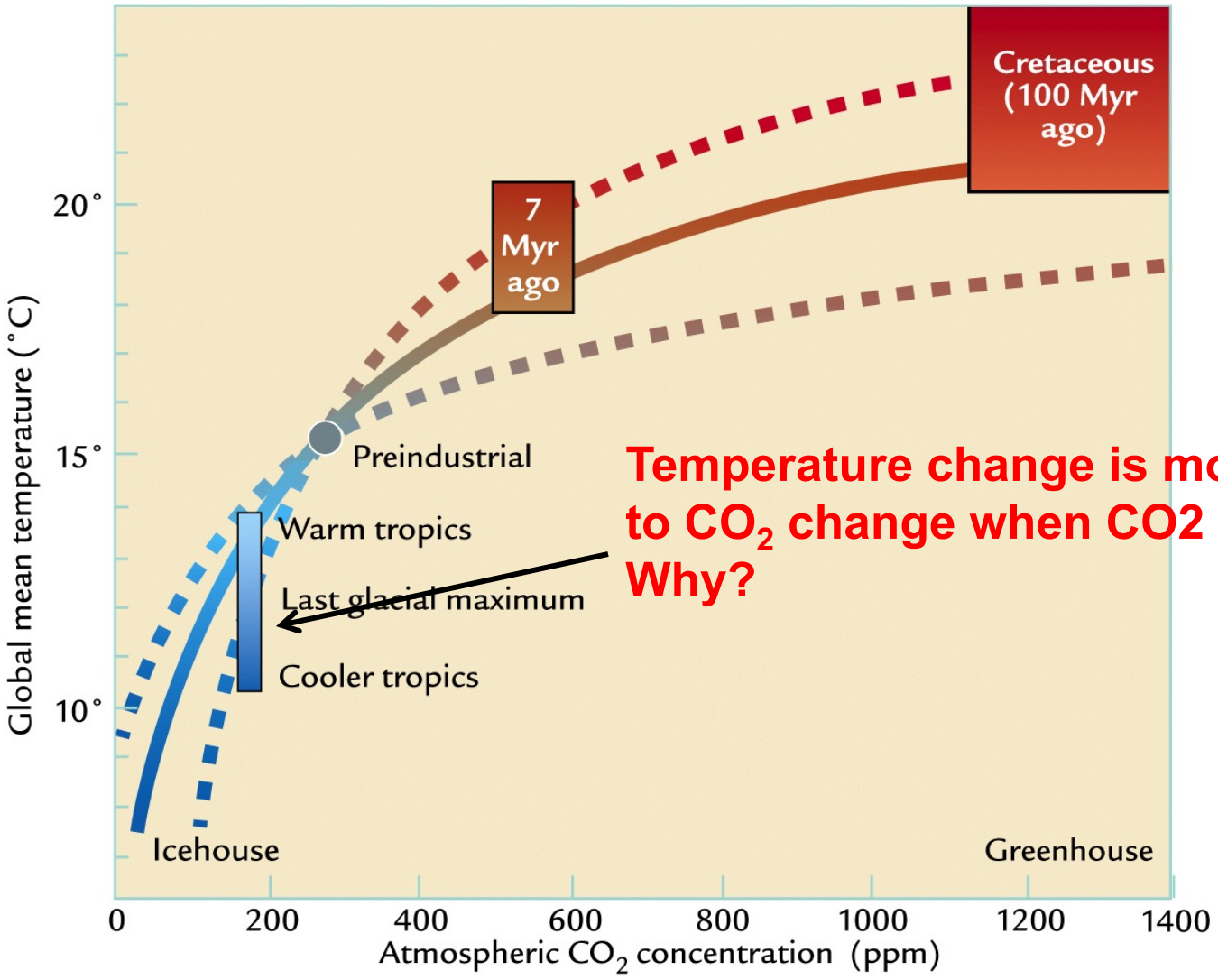
Model Simulations of 2 x CO_2 Sensitivity



Earth's CO2 Sensitivity from Climate Models

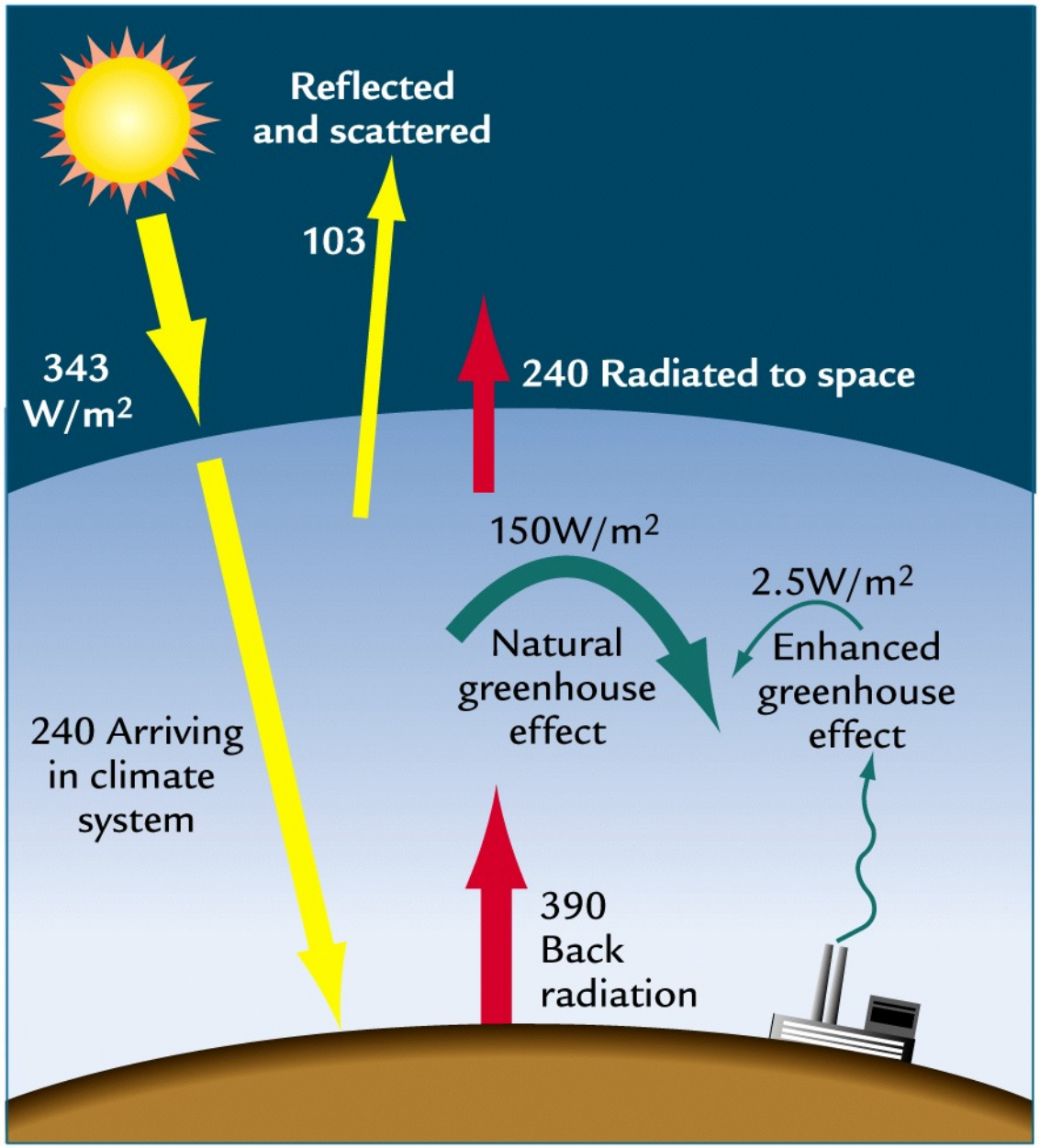


Earth's CO2 Sensitivity from Paleo-records:

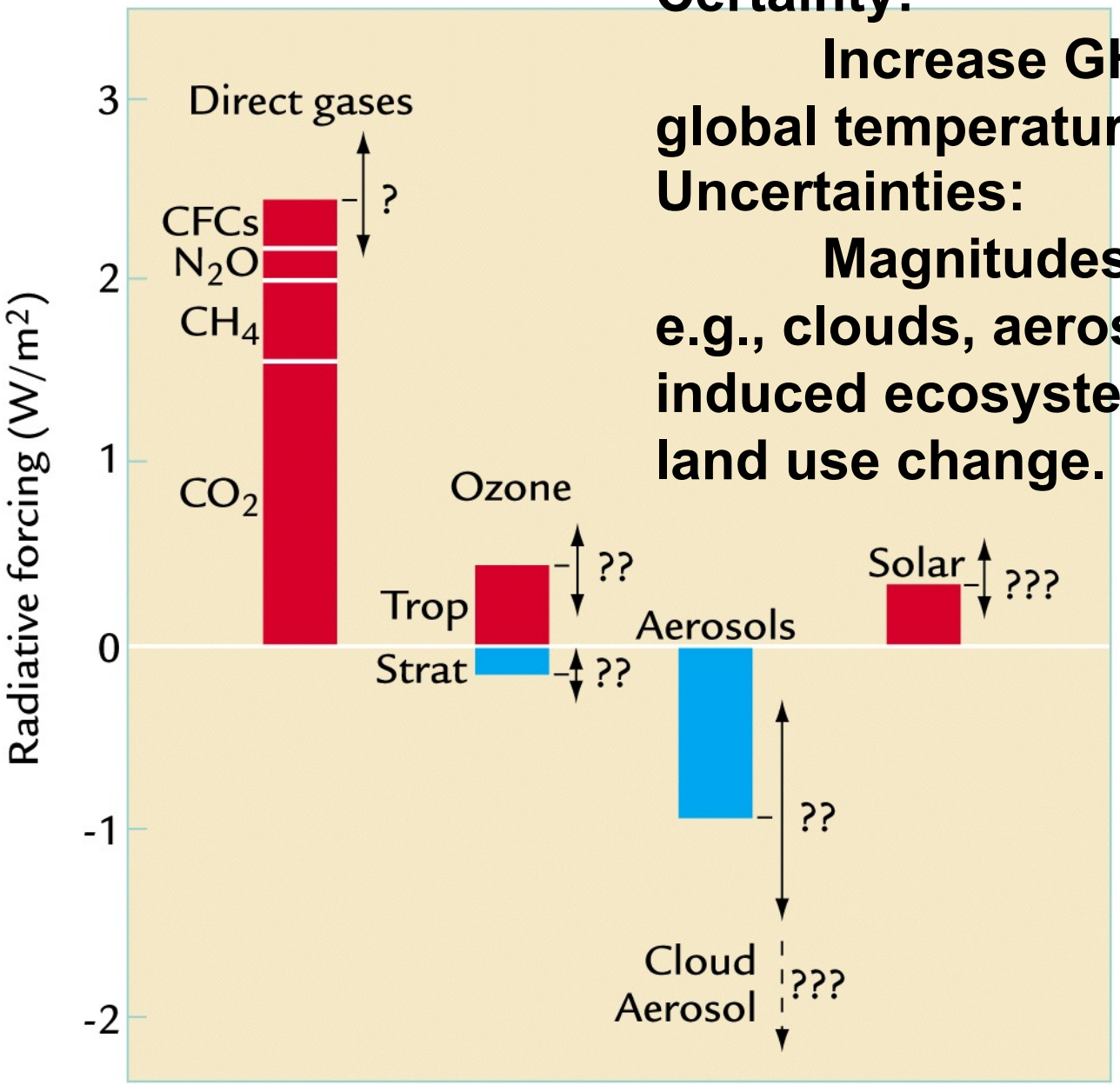


Temperature change is more sensitive to CO_2 change when CO2 is lower. Why?

Effects of Increases in Greenhouse Gases on Radiation



Radiative Effects of Greenhouse Gases



Certainty:

Increase GHGs will increase global temperatures

Uncertainties:

Magnitudes of feedbacks, e.g., clouds, aerosols, rainfall induced ecosystem feedbacks and land use change.

Summary-Discussion:

What are the main sources of human-caused increase of CO2?
How much human-emitted CO2 during the past century stays in the atmosphere?

Where did the rest of the CO2 go?

Do you expect the natural carbon sink to increase or decrease?

How do scientists reach conclusion that the observed warming in the last 100 years are mainly caused by human induced increase of greenhouse gases?

What are uncertainties and uncertainties in determining the future climate change?