

The Case for Anthropogenic Warming II

Richard McGehee



Seminar on the Mathematics of Climate Change
School of Mathematics
September 14, 2011



The Case for Anthropogenic Warming

Is the globe warming?
What determines the Earth's temperature?
Did human activity cause the problem?
How big is the problem?
What's at stake?



The Case for Anthropogenic Warming What Determines the Earth's Temperature?

Heat Balance

$$T^4 = kS$$

where T = surface temperature ($^{\circ}\text{K}$)

S = solar influx (W/m^2)

k = constant depending on reflectivity of the surface, emissivity of the surface, and the Stefan-Boltzmann constant.

For the current value of k , $T = 255^{\circ}\text{K} = -18^{\circ}\text{C} = 0^{\circ}\text{F}$

Why isn't the Earth a Snowball?

C.Lorius, The ice-core record: climate sensitivity and future greenhouse warming, *Nature* 347 (1990), pp.139-145



The Case for Anthropogenic Warming What Determines the Earth's Temperature?

Why isn't the Earth a Snowball?

The Greenhouse Effect!

Joseph Fourier, *Mémoires de l'Académie des Sciences de l'Institut de France*, t. vii. 1827.

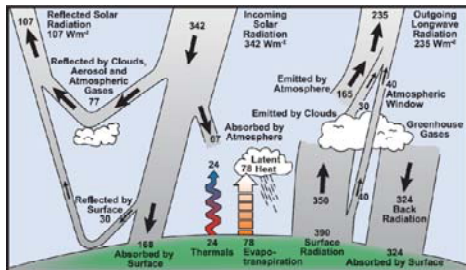


Svante Arrhenius, "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground," *Philosophical Magazine and Journal of Science (Fifth Series)* 41, pp. 237-276, 1896.



The Case for Anthropogenic Warming What Determines the Earth's Temperature?

Heat Balance

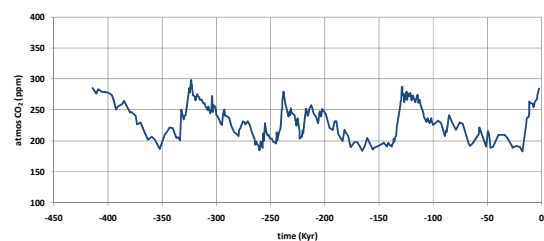


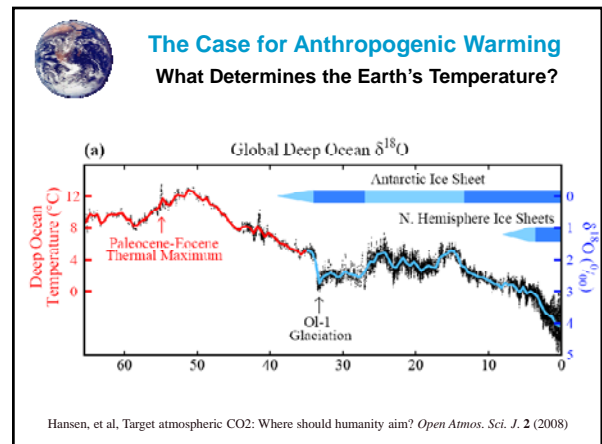
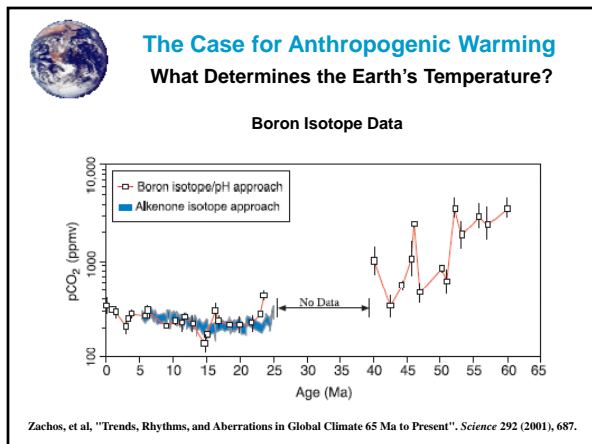
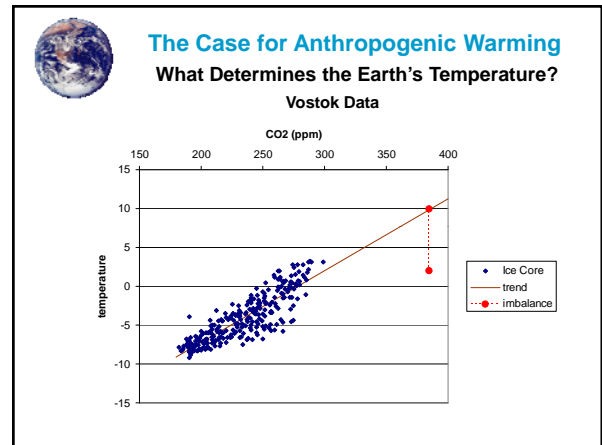
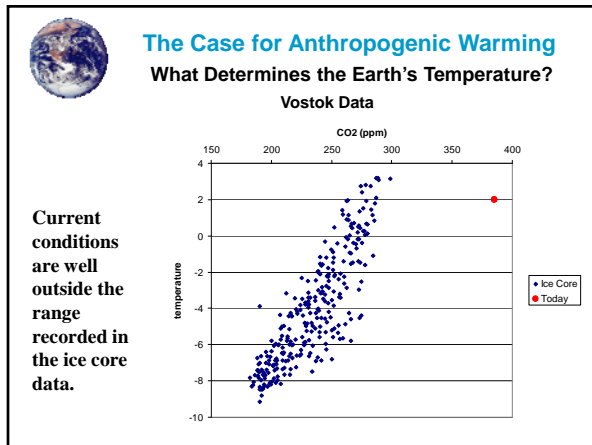
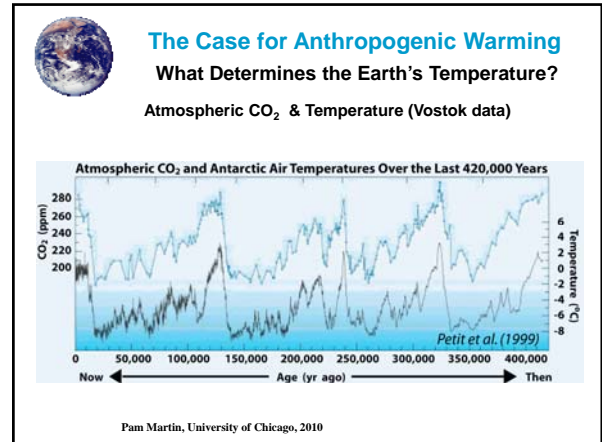
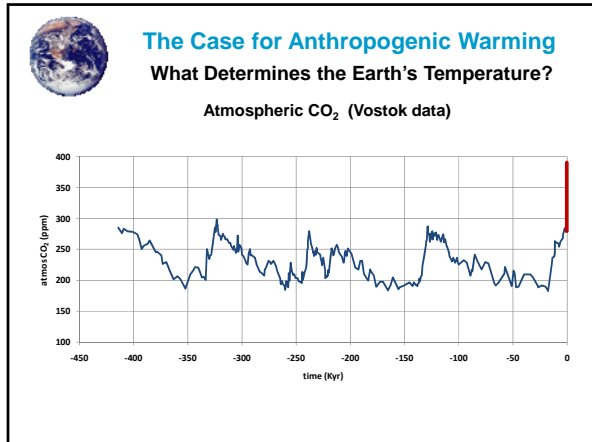
Historical Overview of Climate Change Science, IPCC AR4, p.96
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH01.pdf

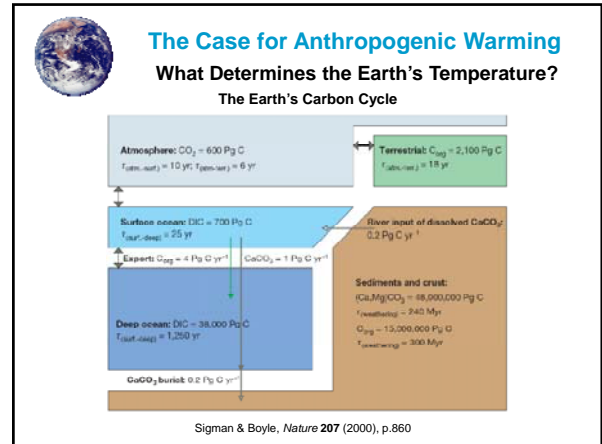
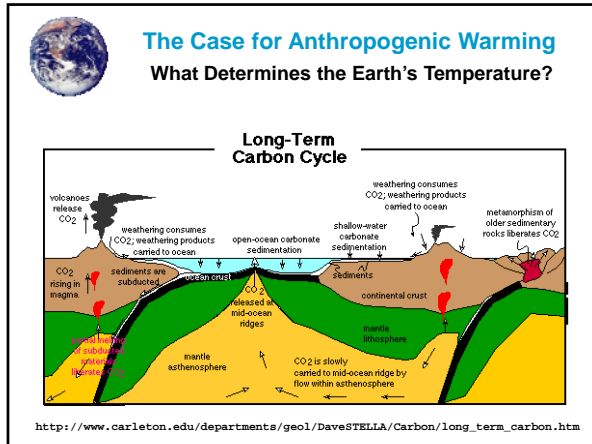


The Case for Anthropogenic Warming What Determines the Earth's Temperature?

Atmospheric CO₂ (Vostok data)







The Case for Anthropogenic Warming

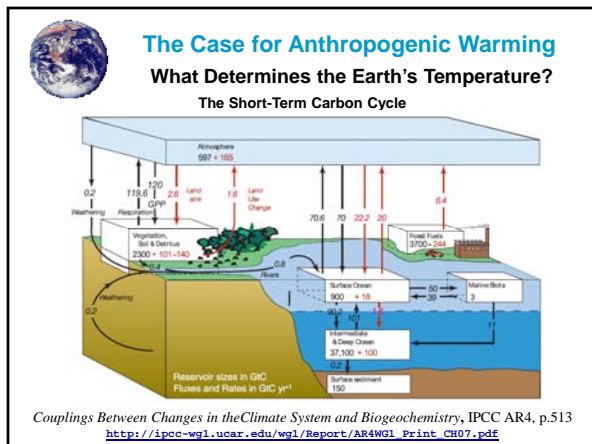
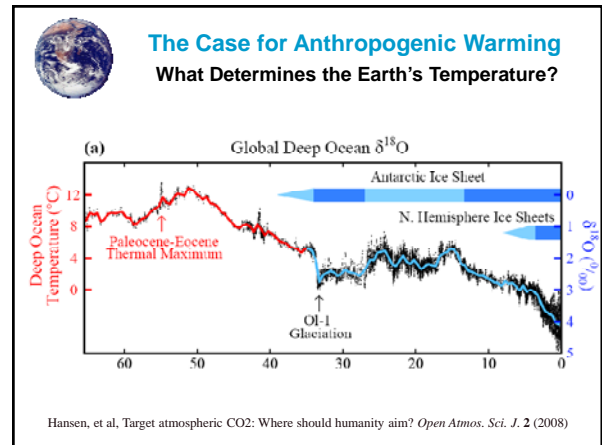
What Determines the Earth's Temperature?

Silicate Weathering

Rainwater containing dissolved CO₂ falling on silicate rocks replaces a silicon atom with a carbon atom, ultimately producing calcium carbonate (limestone) and silicon dioxide (quartz). For example, calcium silicate (Wollastonite):

$$CaSiO_3 + CO_2 \rightarrow CaCO_3 + SiO_2$$

Under volcanic conditions, the carbon atom is replaced by a silicon atom, completing the long term carbon cycle.

$$CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$$


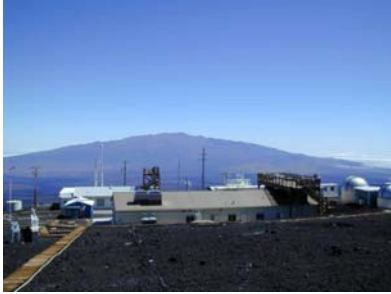
The Case for Anthropogenic Warming

Is the globe warming?
 What determines the Earth's temperature?
 Did human activity cause the problem?
 How big is the problem?
 What's at stake?



The Case for Anthropogenic Warming

The Mauna Loa Observatory

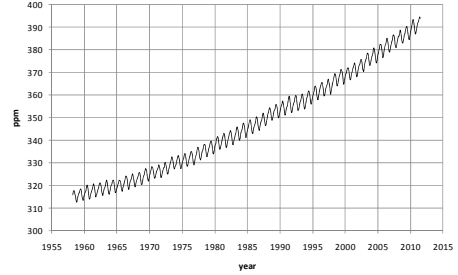


http://www.climate.noaa.gov/images/about_climate/greenhouse_maunaloa.jpg



The Case for Anthropogenic Warming

Mauna Loa Atmospheric CO₂

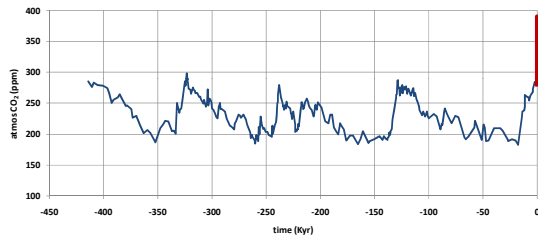


<http://scrippsco2.ucsd.edu/data/data.html>



The Case for Anthropogenic Warming

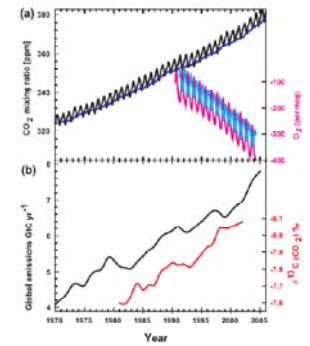
Atmospheric CO₂ (Vostok data)



The Case for Anthropogenic Warming

Did human activity cause the problem?

Carbon isotope ratios and atmospheric oxygen depletion indicate that the increase in atmospheric CO₂ comes from burning fossil fuels.



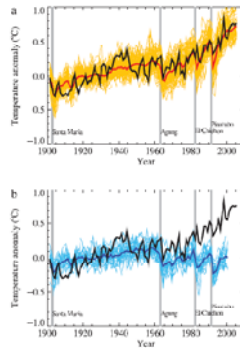
Changes in Atmospheric Constituents and in Radiative Forcing, IPCC AR4, Chap. 2, p.138
http://ipcc.org/wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH02.pdf



The Case for Anthropogenic Warming

Did human activity cause the problem?

Models with and without human activity.



Understanding and Attributing Climate Change, IPCC AR4, Chap. 9, p.684
http://ipcc.org/wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch09.pdf



The Case for Anthropogenic Warming

- Is the globe warming?
- What determines the Earth's temperature?
- Did human activity cause the problem?
- How big is the problem?**
- What's at stake?

The Case for Anthropogenic Warming
The IPCC Fourth Assessment Report

The Nobel Peace Prize 2007
For their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change"

Al Gore (US)
Nobel Peace Prize laureate 2007

http://nobelprize.org/nobel_prizes/peace/laureates/2007/

The Case for Anthropogenic Warming
The IPCC Fourth Assessment Report

Prediction Methodology

Comprehensive Climate Model

EMISSIONS → CONCENTRATIONS OF RADIATIVELY ACTIVE SPECIES → RADIATIVE FORCING → CLIMATE RESPONSE

Carbon Cycle Climate Interactions

observed → projected → observed → projected → observed → projected → observed → projected

Global Climate Projections, IPCC AR4, p.753
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf

The Case for Anthropogenic Warming
The IPCC Fourth Assessment Report

Global Mean Temperature Predictions
Multi-Model Averages and Assessed Ranges for Surface Warming

Global surface warming (°C)

Year

Legend: A2, A1B, B1, Year 2000 Constant Concentrations, 20th century

Summary for Policy Makers, IPCC AR4, p. 14
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf

The Case for Anthropogenic Warming
The IPCC Fourth Assessment Report

Surface Temperature Predictions
Projections of Surface Temperatures

Relative Probability

Global Average Surface Temperature Change (°C)

Technical Summary, IPCC AR4, p. 72
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf

The Case for Anthropogenic Warming
The IPCC Fourth Assessment Report

The Last Interglacial Period

Global average sea level was likely between 4 and 6 m higher during the last interglacial period, about 125,000 years ago, than during the 20th century, mainly due to the retreat of polar ice. Ice core data suggest that the Greenland Summit region was ice-covered during this period, but reductions in the ice sheet extent are indicated in parts of southern Greenland. Ice core data also indicate that average polar temperatures at that time were 3°C to 5°C warmer than the 20th century because of differences in the Earth's orbit. The Greenland Ice Sheet and other arctic ice fields likely contributed no more than 4 m of the observed sea level rise, implying that there may also have been a contribution from Antarctica.

Technical Summary, IPCC AR4, p. 58
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf

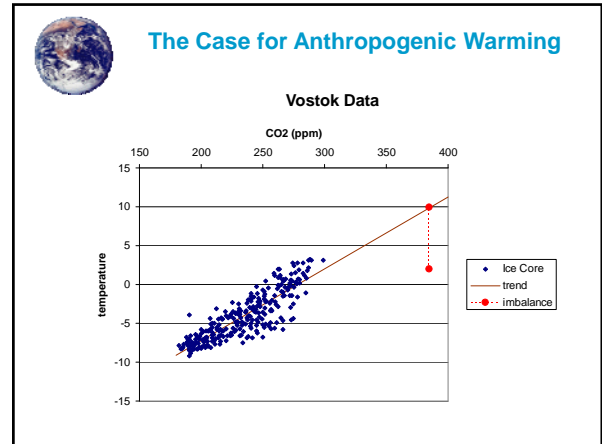
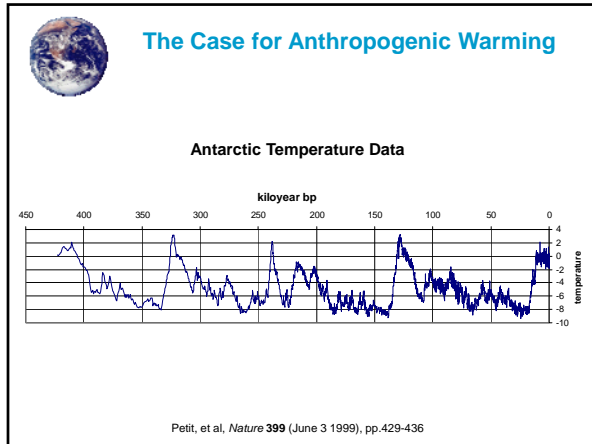
The Case for Anthropogenic Warming
The IPCC Fourth Assessment Report

The Last Interglacial Period
The Arctic and the Last Interglacial

Arctic Summer Surface Air Temperature Change (°C)

Annual Ice Thickness and Extent at Last Interglacial (m)

Technical Summary, IPCC AR4, p. 57
http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_SPM.pdf



The Case for Anthropogenic Warming

Summary

Is the globe warming?
Yes, but so far not much.

What determines the Earth's temperature?
Solar forcing plus the greenhouse effect.

Did human activity cause the warming?
The evidence is pretty convincing.

How big is the problem?
So far, not big. But ...

