

## The Case for Anthropogenic Warming

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Seminar on the Mathematics of Climate Change  
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## 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 ( $\text{W}/\text{m}^2$ )

$k$  = 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.

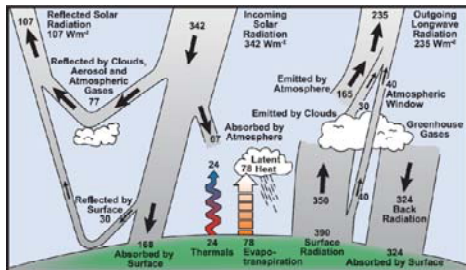


Svante Arrhenius, "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground," *Philosophical Magazine and Journal of Science (Fifth Series)* 41, pp. 237-276, 1896.



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### Heat Balance

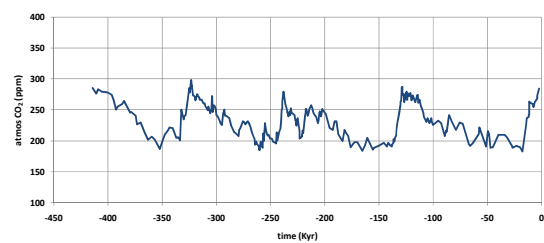


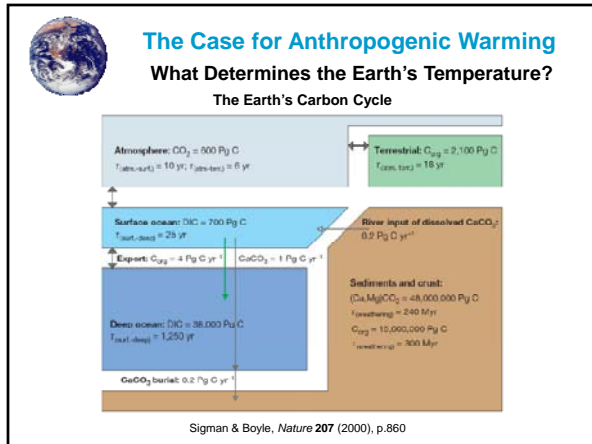
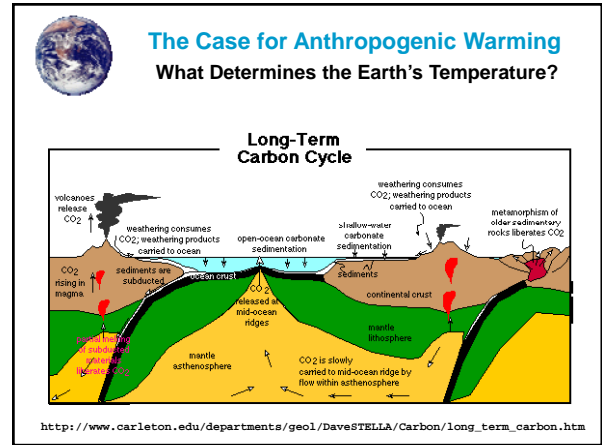
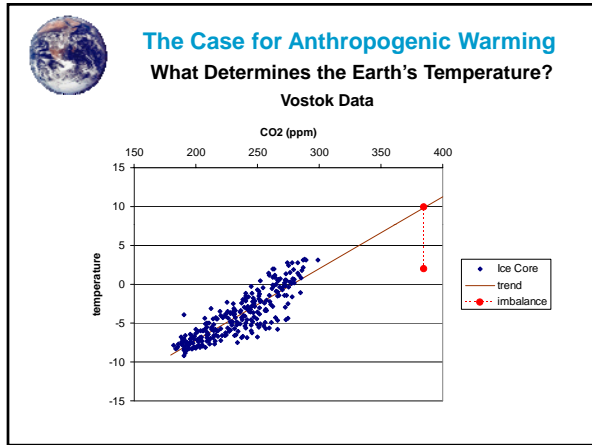
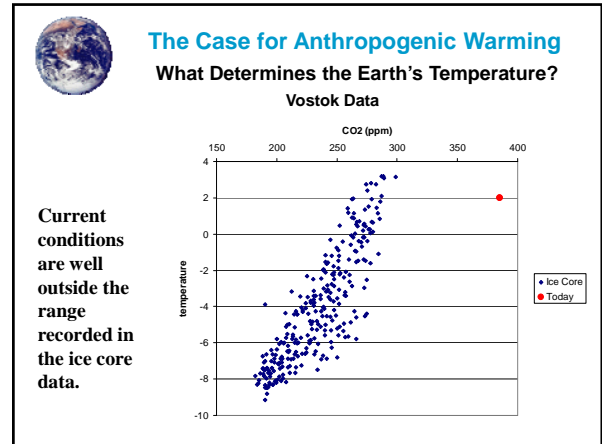
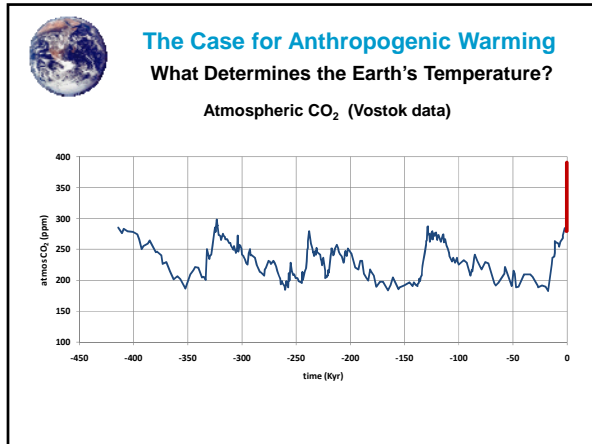
Historical Overview of Climate Change Science, IPCC AR4, p.96  
[http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1\\_Print\\_CH01.pdf](http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH01.pdf)



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### Atmospheric CO<sub>2</sub> (Vostok data)





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#### What Determines the Earth's Temperature?

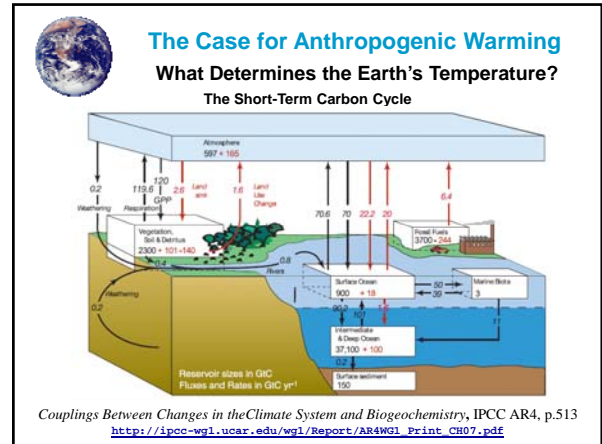
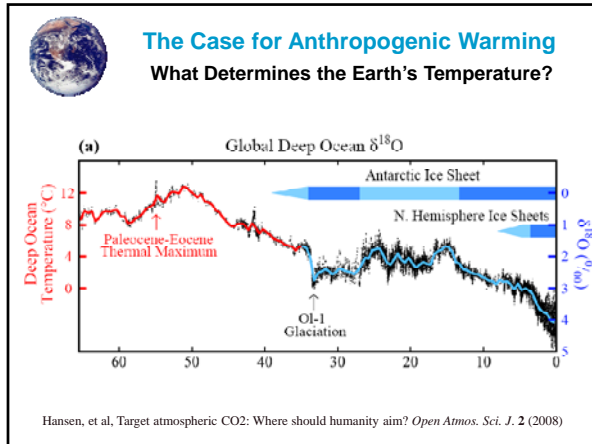
##### Silicate Weathering

Rainwater containing dissolved CO<sub>2</sub> 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):

$$\text{CaSiO}_3 + \text{CO}_2 \rightarrow \text{CaCO}_3 + \text{SiO}_2$$

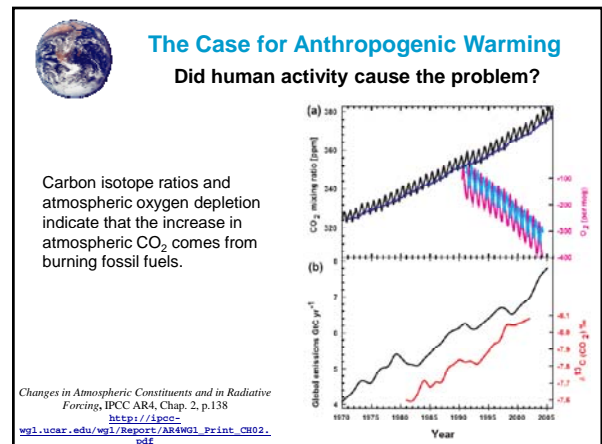
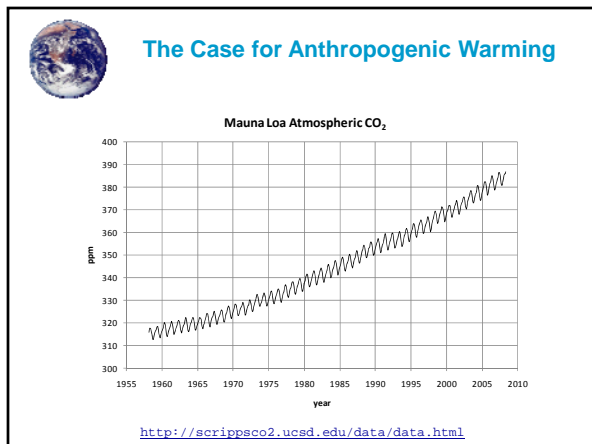
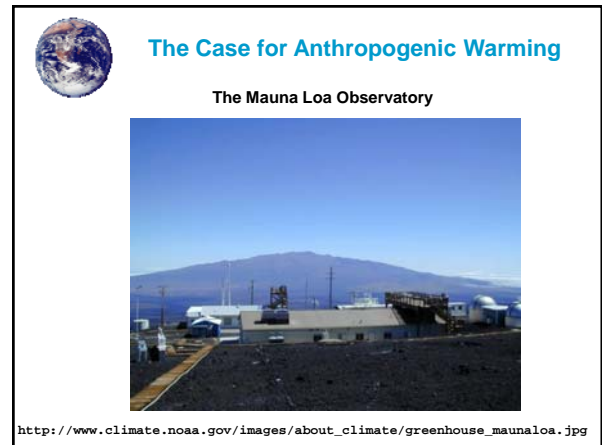
Under volcanic conditions, the carbon atom is replaced by a silicon atom, completing the long term carbon cycle.

$$\text{CaCO}_3 + \text{SiO}_2 \rightarrow \text{CaSiO}_3 + \text{CO}_2$$



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### 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-wg1.ucar.edu/wg1/Report/AR4WG1\\_Print\\_Ch09.pdf](http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_Ch09.pdf)*

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### The Case for Anthropogenic Warming

The IPCC Fourth Assessment Report

[http://nobelprize.org/nobel\\_prizes/peace/laureates/2007/](http://nobelprize.org/nobel_prizes/peace/laureates/2007/)

### The Case for Anthropogenic Warming

The IPCC Fourth Assessment Report

Prediction Methodology

*Global Climate Projections, IPCC AR4, p.753  
[http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1\\_Print\\_CH10.pdf](http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf)*

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Emission Scenarios

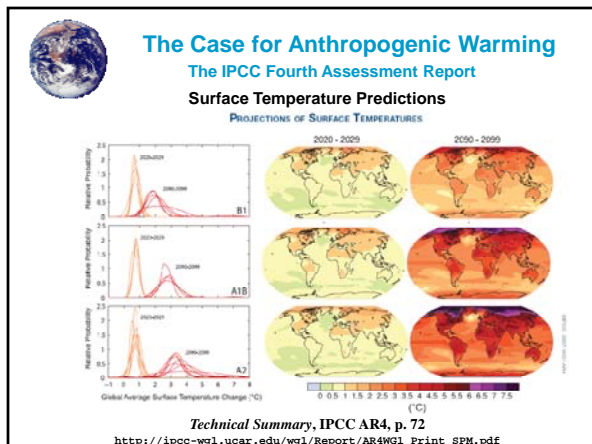
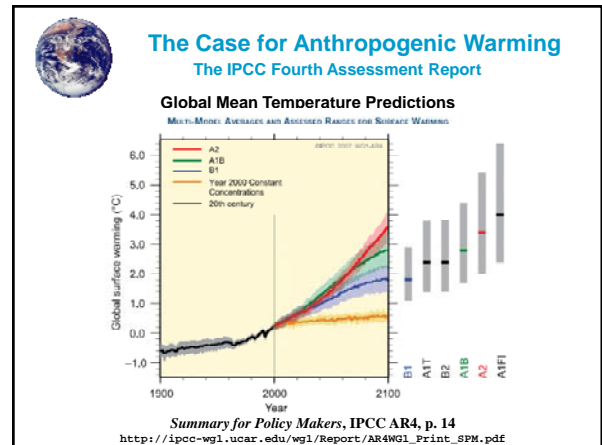
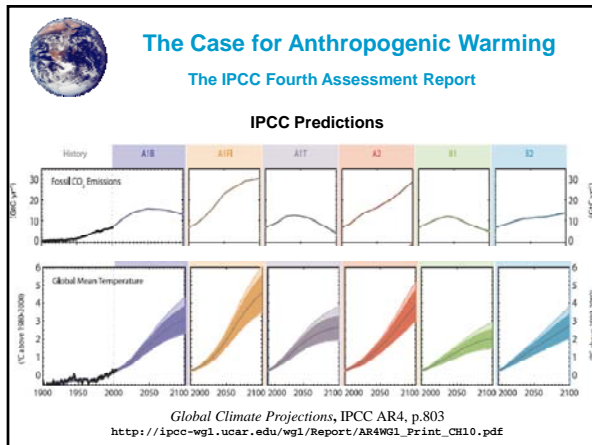
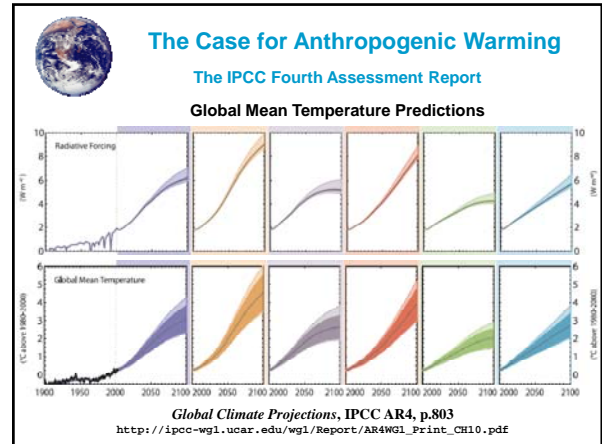
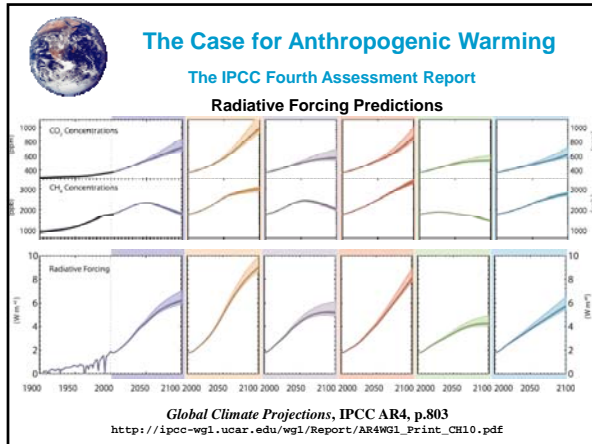
*Global Climate Projections, IPCC AR4, p.803  
[http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1\\_Print\\_CH10.pdf](http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf)*

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Greenhouse Gas Predictions

*Global Climate Projections, IPCC AR4, p.803  
[http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1\\_Print\\_CH10.pdf](http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH10.pdf)*



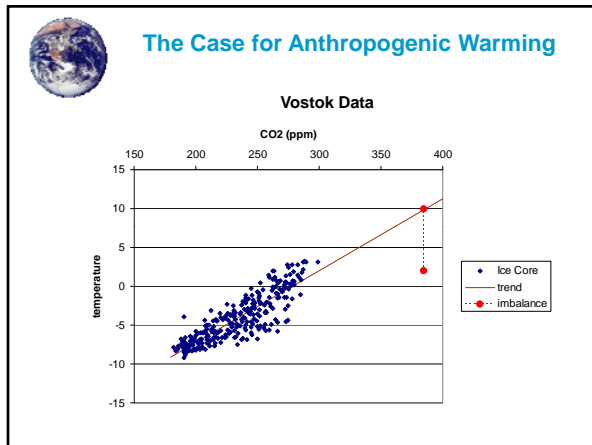
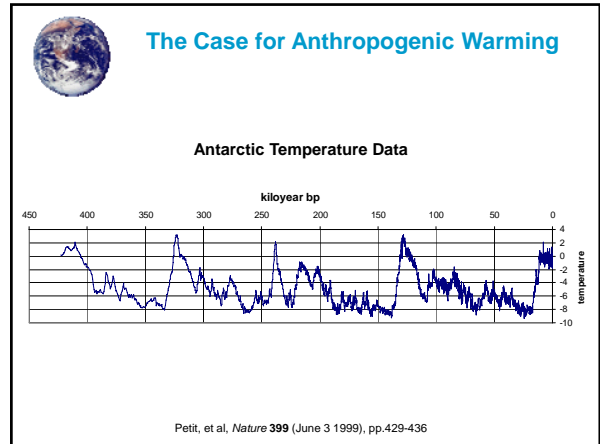
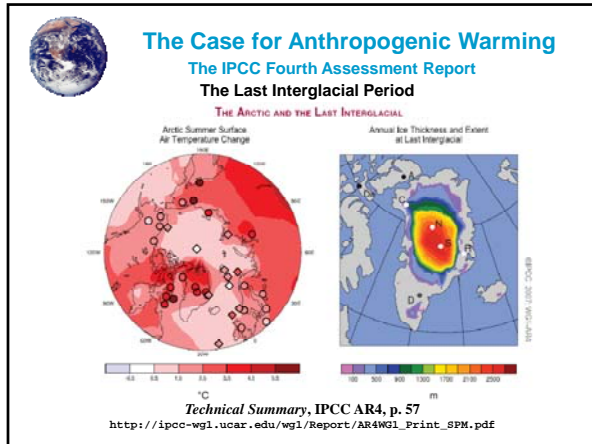
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#### The Last Interglacial Period

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](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 ...

