A Climate Change Primer
The Case for Anthropogenic Warming

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Seminar on the Mathematics of Climate Change
School of Mathematics
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What’s at Stake?

- No ice fishing in Minnesota
- No polar bears in the Arctic
- No ice in Antarctica
- No Florida

The USA in the Ice Free Earth
Computer Simulation, Clarence Lehman, Univ. Mn. 2006

Sea level rises 63 meters.

Is the Globe Really Warming?

Gary Stix, Scientific American September 2006, pp. 48-49
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Is the Globe Really Warming?

http://www.ncdc.noaa.gov/paleo/globalwarming/paleolast.html

Antarctic Temperature Data


“Steven Milloy publishes JunkScience.com and CSRWatch.com. He is a junk science expert, and advocate of free enterprise and an adjunct scholar at the Competitive Enterprise Institute.”

http://www.foxnews.com/story/0,2933,289327,00.html
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What is the Competitive Enterprise Institute?

"CEI relies on donations from individuals, foundations and corporations. The most generous sponsors of last year’s annual dinner at the Capital Hilton were the Alliance of Automobile Manufacturers, Exxon Mobil, the Pharmaceutical Research and Manufacturers of America, and Pfizer. Other contributors included General Motors, the American Petroleum Institute, the American Plastics Council, the Chlorine Chemistry Council and Arch Coal."


http://www.washingtonpost.com/wp-dyn/content/article/2006/05/23/AR2006052301305.html

The temperature data indicate the globe is warming, but not dramatically compared to the last 10,000 years. Perhaps we are witnessing only a natural blip that has nothing to do with humans.

What Determines the Earth’s Temperature?

\[ T = S - k \]

where \( T \) = surface temperature (ºK)
\( S \) = solar influx (W/m²)
\( k \) = constant depending on reflectivity of the surface, emissivity of the surface, and the Stefan-Boltzmann constant.

For the current value of \( k \), \( T = 255ºK = -18ºC = 0ºF \)

Why isn’t the Earth a Snowball?

Why isn’t the Earth a Snowball?

The Greenhouse Effect!


Greenhouse gases (CO₂, H₂O, CH₄) are transparent to visible light, but opaque to infrared light. The energy from the sun passes through the atmosphere and heats the surface. The surface radiates energy at a lower temperature (infrared), which is absorbed by the atmosphere.

Gary Stix, Scientific American September 2006, pp.46-49
What determines the level of CO₂ in the atmosphere?

The Carbon Cycle

Short Term: Biology
Intermediate Term: Oceans
Long Term: Geology

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):

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

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

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

The rate of silicate weathering is temperature dependent. The temperature is a function of the atmospheric CO₂.

\[
\frac{dx}{dt} = f(x) - a - h(T(x))x
\]

where

- \(x\) = atmospheric CO₂ concentration
- \(T\) = surface temperature
- \(a\) = rate of CO₂ input from tectonics
- \(h\) = rate of silicate weathering

This model illustrates why the Earth’s temperature is relatively constant.

Limitations:

Perhaps \(a\) is a delayed function of \(x\).
Perhaps \(h\) is also a function of exposed silicate rocks and hence is a function of ice cover.
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Recent CO₂ Trends

http://www.esrl.noaa.gov/gmd/ccgg/trends/co2_data_mlo.html

The Mauna Loa Observatory

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

Lake Vostok

http://svs.gsfc.nasa.gov/vis/a000000/a000900/a000996/index.html

Vostok Core Sample Data

http://svs.gsfc.nasa.gov/vis/a000000/a000900/a000996/index.html

Core Samples


Atmospheric CO₂

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Core Sample Data
Plus Recent History

Atmospheric CO₂

Peter D. Ward, Scientific American October 2006, pp.64-71

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300 Million Year CO₂ Record


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Summary

There is a scientifically sound theory of the greenhouse effect.

There is a growing body of data linking CO₂ and temperature.

Human activity has produced huge amounts of CO₂.

The atmospheric CO₂ levels are heading for Eocene levels in the coming centuries.

The Eocene Earth was ice free.

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Where’s Florida?

But there’s hope ...

What about the oceans? They cannot absorb the CO₂ as fast as we are now producing it. But if we stop, can they return the atmospheric CO₂ to preindustrial levels?

Will we pass a threshold? Are we resetting the Earth’s thermostat to a higher temperature?

Can technology save us?

Come back next week for the continuing drama.