



The Case for Anthropogenic Warming, II

Richard McGehee
School of Mathematics
University of Minnesota
Mathematics of Climate Seminar
September 17, 2019




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Anthropogenic Warming

Is the globe warming?
What determines the Earth's temperature?
What is the role of human activity?
How big is the problem?


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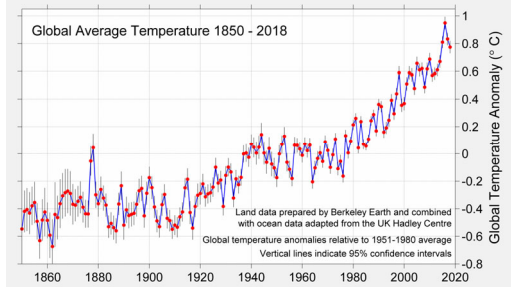
Anthropogenic Warming

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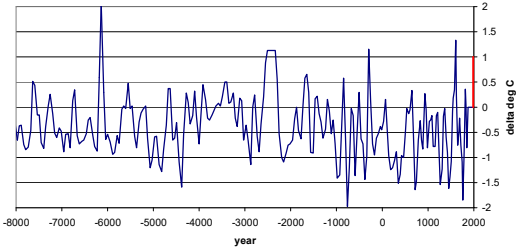
http://berkeleyearth.org/wp-content/uploads/2019/01/GlobalAverage_2018.png

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Anthropogenic Warming

Antarctic Temperature Data



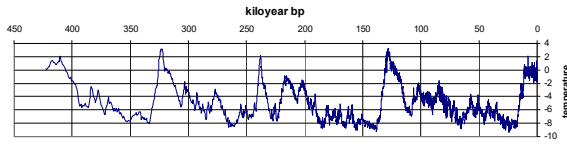
Petit, et al, *Nature* 399 (June 3 1999), pp.429-436

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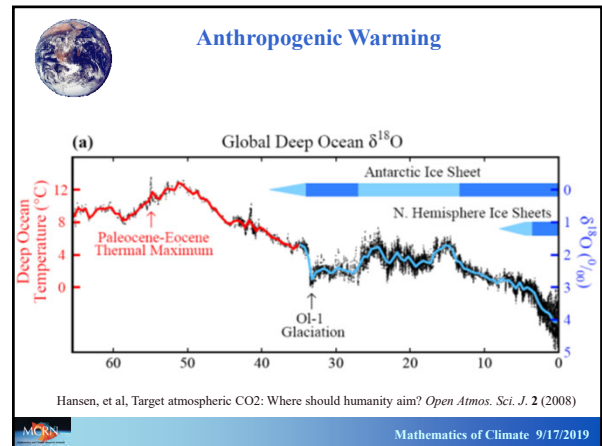
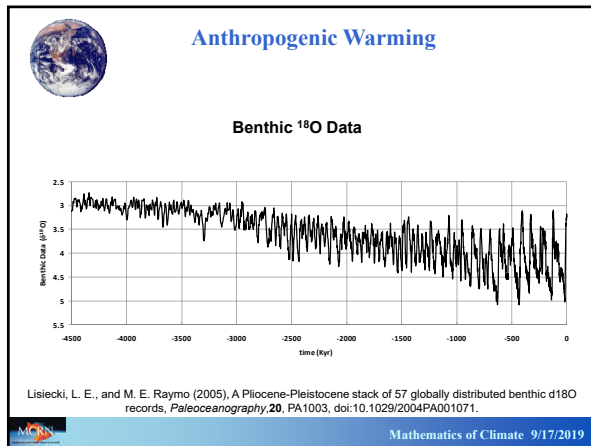
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Anthropogenic Warming

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Yes, but, from a geologic perspective, not so much.

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Anthropogenic Warming

Why isn't the Earth a Snowball?
The Greenhouse Effect!

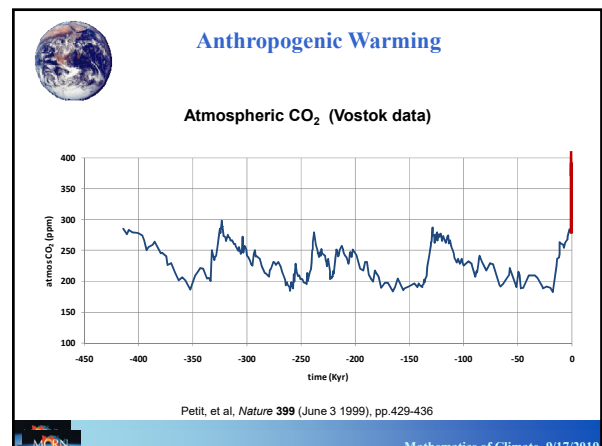
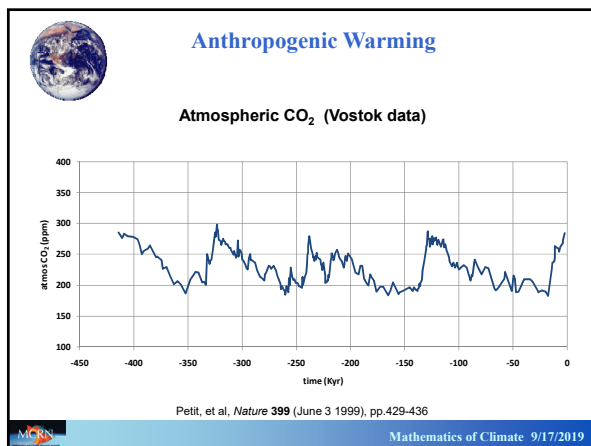
Joseph Fourier, *Mémoires de l'Académie des Sciences de l'Institut de France*, t. vii. 1827.

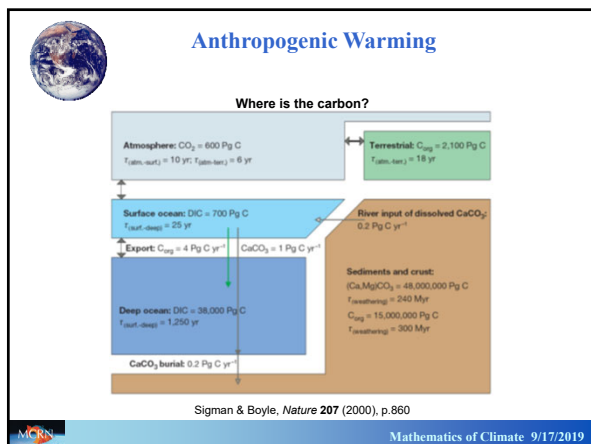
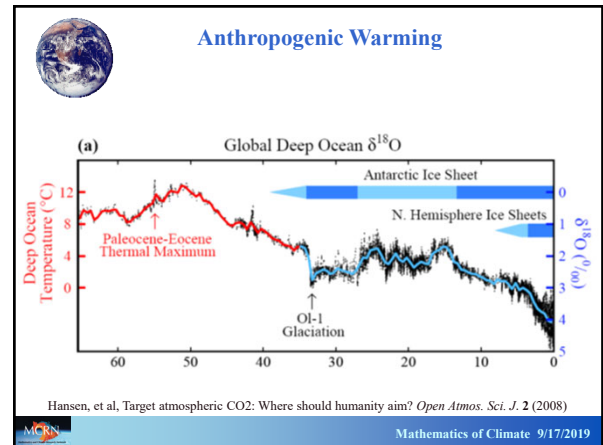
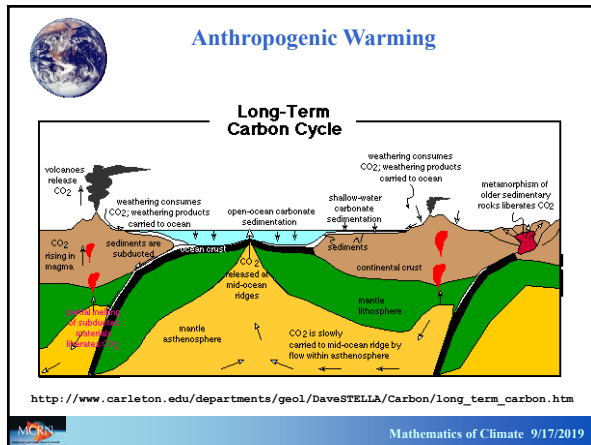
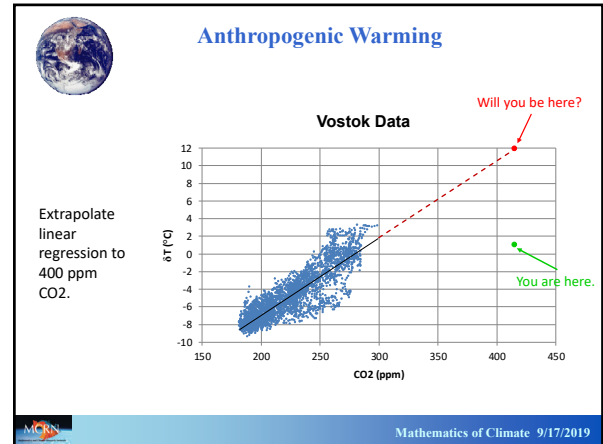
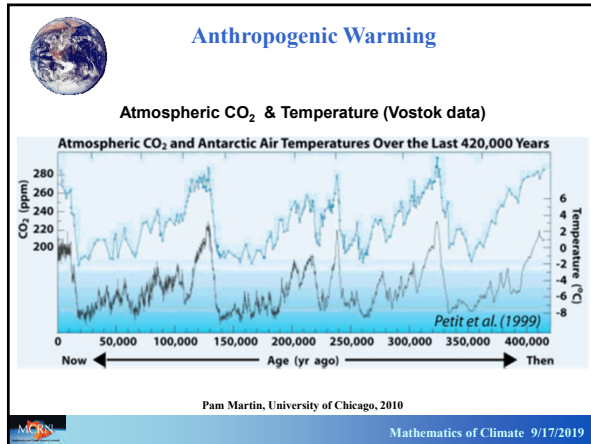


Svante Arrhenius, "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground," *Philosophical Magazine and Journal of Science (Fifth Series)* 41, pp. 237-276, 1896.



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Silicate Weathering

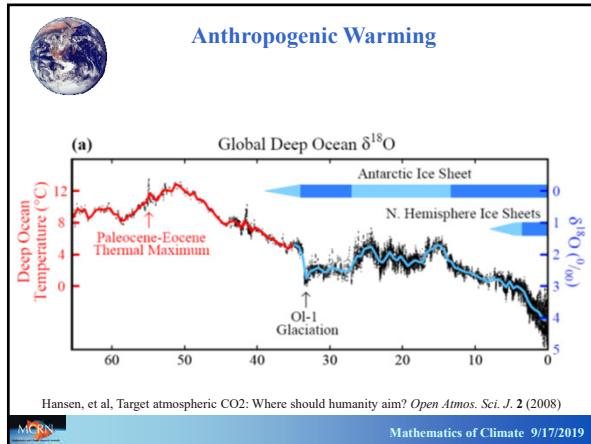
Rainwater containing dissolved CO₂ falling on silicate rocks replaces a silicon atom with a carbon atom, ultimately producing calcium carbonate (limestone) and silicon dioxide (quartz). For example, calcium silicate (Wollastonite):

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

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

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

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Anthropogenic Warming

Is the globe warming?

Yes, but, from a geologic perspective, not so much.

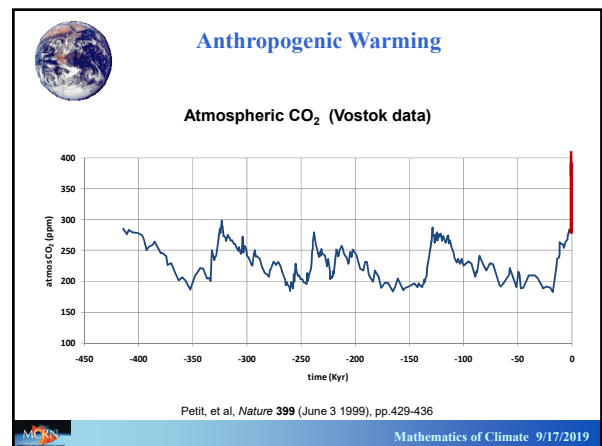
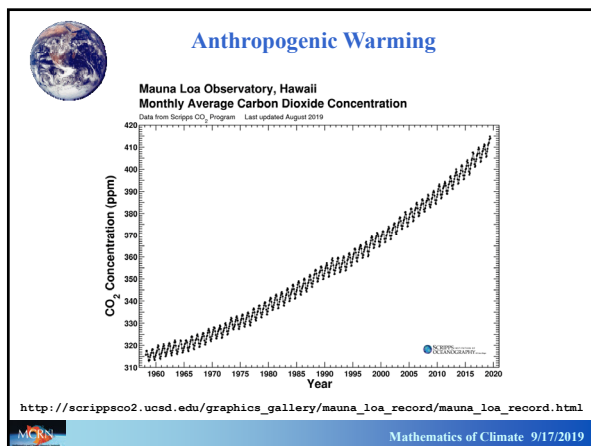
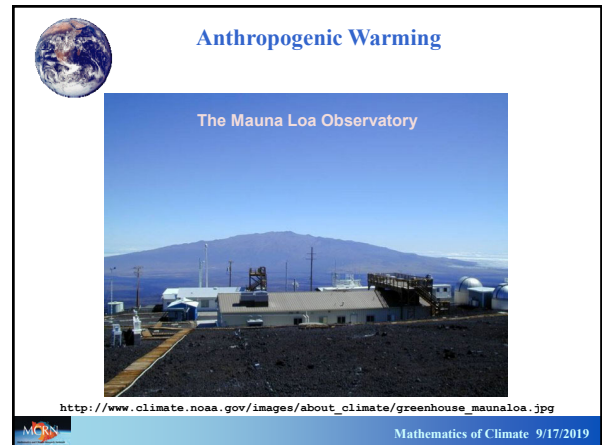
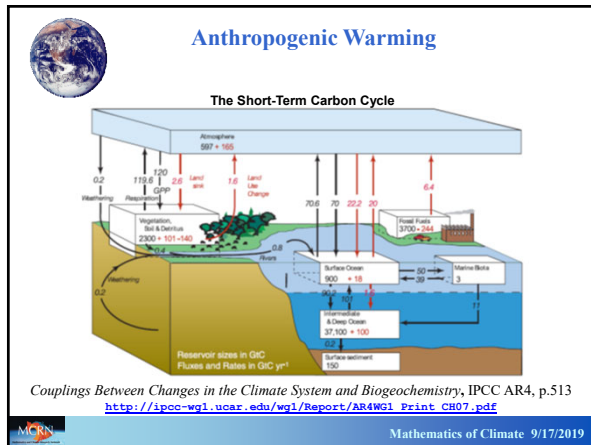
What determines the Earth's temperature?

Physics! Solar heating plus the carbon cycle.

What is the role of human activity?

How big is the problem?

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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-wg1.ucar.edu/wg1/Report/AR4WG1_Print_CH02.pdf

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Anthropogenic Warming

Is the globe warming?
 Yes, but, from a geologic perspective, not so much.

What determines the Earth's temperature?
 Physics! Solar heating plus the carbon cycle.

What is the role of human activity?
 We are adding CO₂ to the atmosphere.

How big is the problem?

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Anthropogenic Warming

The IPCC Fourth Assessment Report

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

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Anthropogenic Warming

Prediction Methodology

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

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Anthropogenic Warming

The IPCC Fourth Assessment Report

MULTI-MODEL AVERAGES AND ASSESSED RANGES FOR SURFACE WARMING

Global Mean Temperature Predictions

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

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Anthropogenic Warming


The IPCC Fourth Assessment Report

PROJECTIONS OF SURFACE TEMPERATURES

Surface Temperature Predictions

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

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Anthropogenic Warming


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

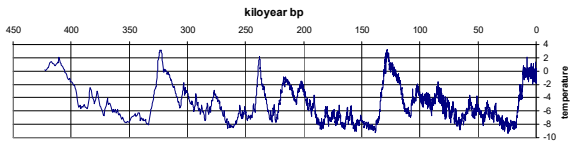


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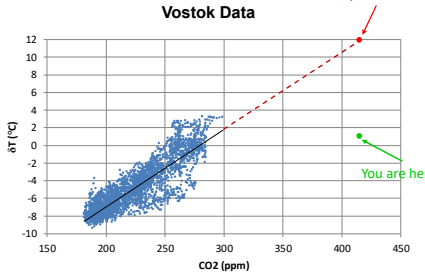

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Vostok Data


Will you be here?

You are here.

Extrapolate linear regression to 400 ppm CO2.

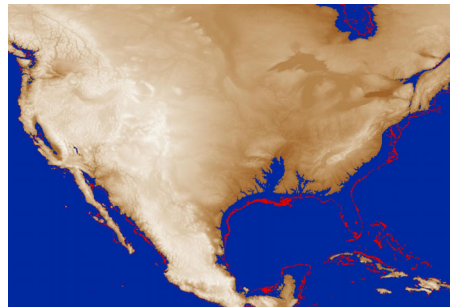



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Anthropogenic Warming


USA in the Ice Free Earth



Clarence Lehman, University of Minnesota, 2006



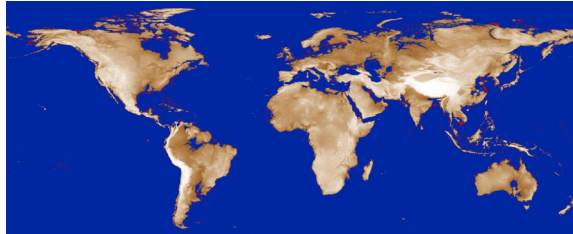
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Anthropogenic Warming

The Modern Ice Free Earth


Sea level rises 63 meters.



Clarence Lehman, University of Minnesota, 2006



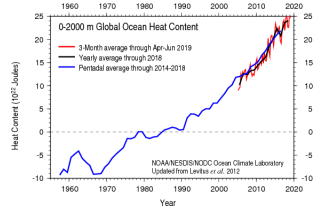
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Some energy comparisons:

- 1 megaton hydrogen bomb: 4×10^{15} Joules
- 1 day of an average hurricane: 5×10^{19} Joules
- Energy absorbed by the oceans since 1990: 25×10^{22} Joules
- = 5,000 hurricane-days
- = 60,000,000 H-bombs



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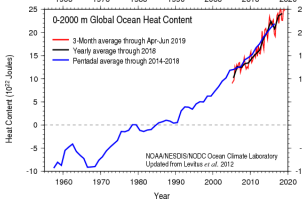
Anthropogenic Warming

Some energy comparisons:

Energy absorbed by the oceans since 1990:
 25×10^{22} Joules

*Energy required to raise sea level by 1 meter: 15×10^{22} Joules
 25×10^{22} J \leftrightarrow **+5.5 feet**


*Warm the atmosphere by 1°C:
 0.26×10^{22} Joules
 25×10^{22} J \leftrightarrow **+96°C = +173°F**



NOAA NESDIS/NOCC Ocean Climate Laboratory
 Updated from Levitus et al. 2012

*Hansen, et al, *Science* 308 (2005), p.1431

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Anthropogenic Warming

Summary


Is the globe warming?
Yes, but, from a geologic perspective, not so much.

What determines the Earth's temperature?
Physics! Solar heating plus the carbon cycle.

What is the role of human activity?
We are adding CO₂ to the atmosphere.

How big is the problem?
Huge!

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Anthropogenic Warming

What can mathematicians do?


Models
Minimal complexity, aka "conceptual", "simple", "toy"
Intermediate complexity
Maximal complexity, aka "GCM"

Data
Parameter estimation (statistics)
Data assimilation

Quantification
Uncertainty
Resilience


Join MCRN
mathclimate.org

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Anthropogenic Warming

What can mathematicians do?



Friday, Sept 20, St. Paul

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