



The Case for Anthropogenic Warming

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 Mathematics of Climate Seminar
 September 11, 2018




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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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Anthropogenic Warming


2017 Hurricanes



Harvey and Irma



Maria



Ophelia

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Anthropogenic Warming

2018 Wildfires



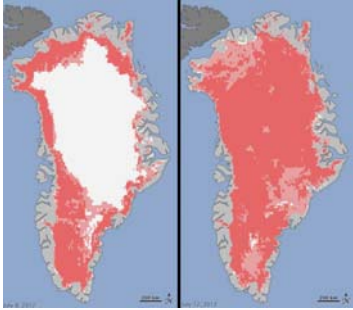
Carr Fire, California

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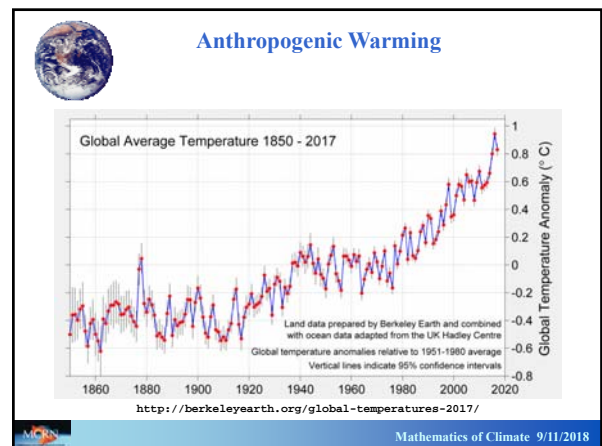
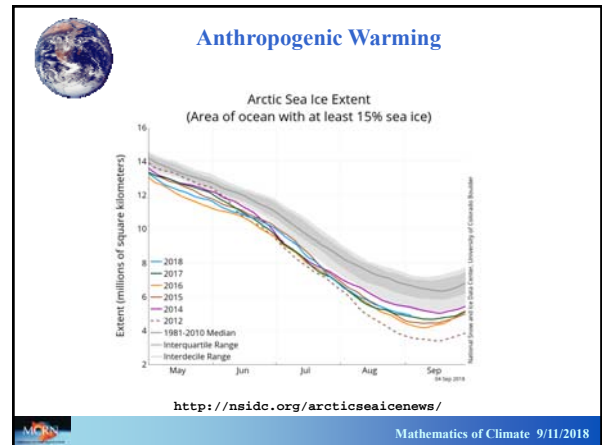
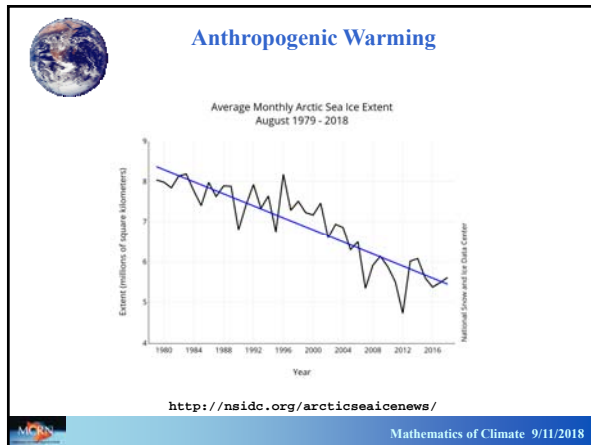
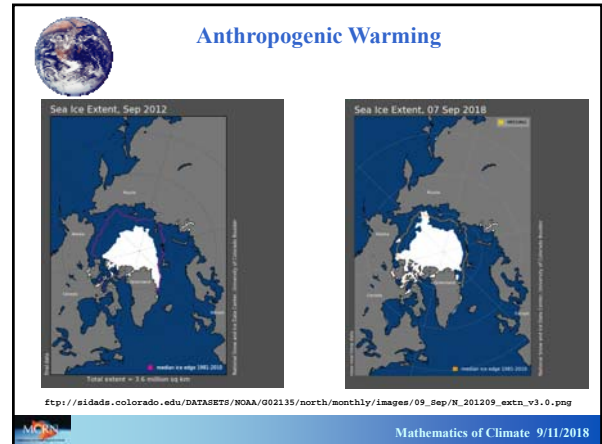
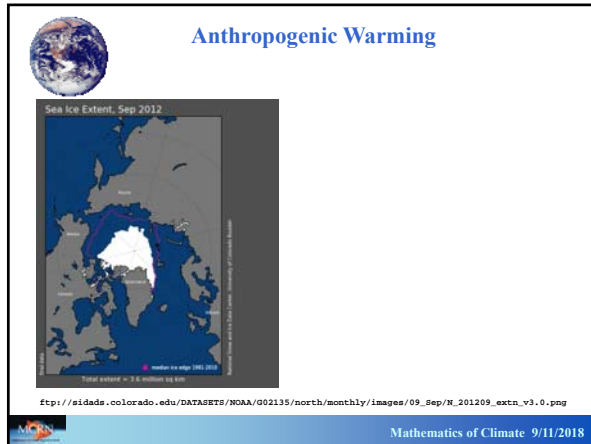
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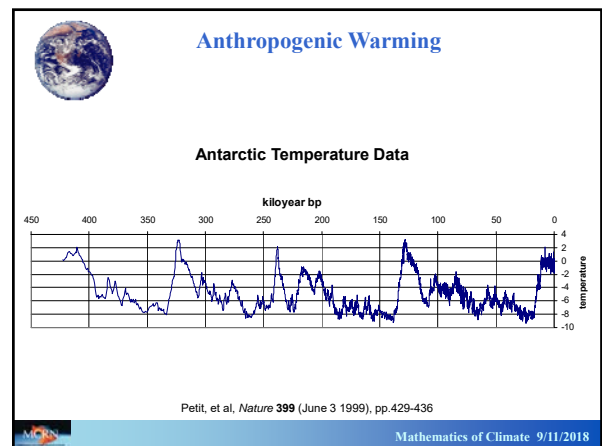
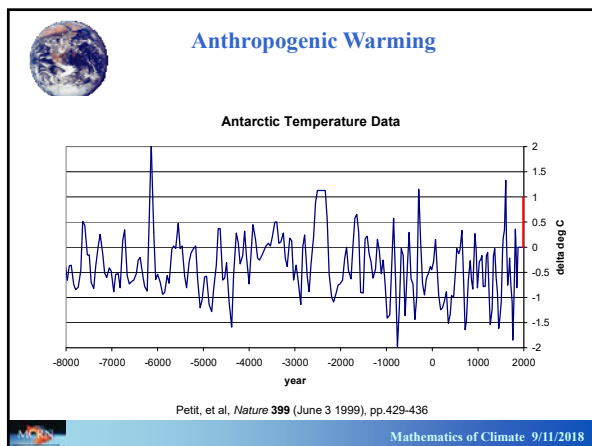
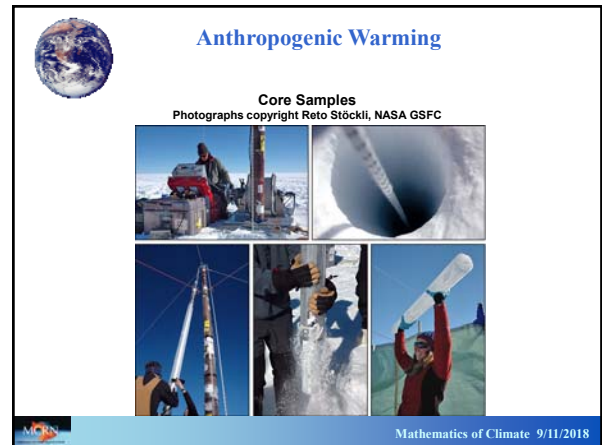
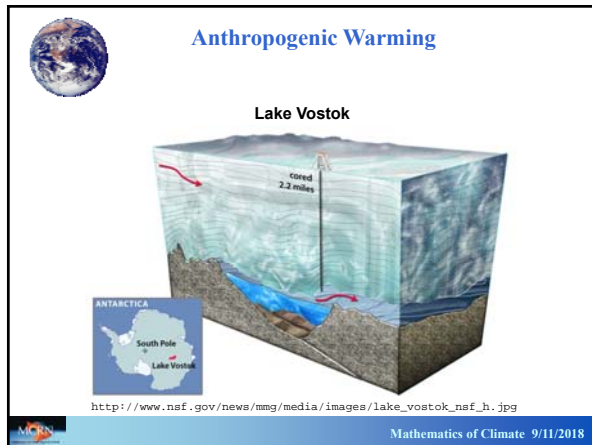
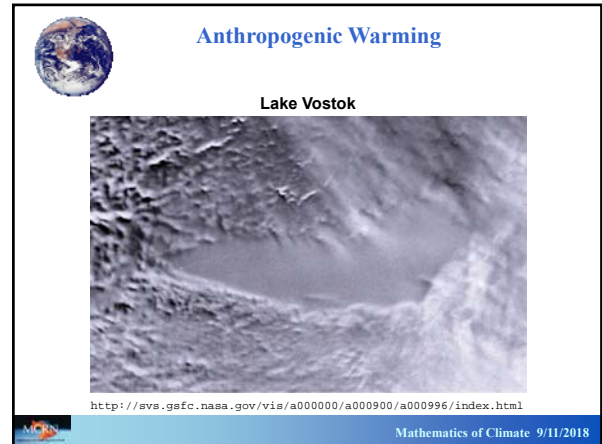
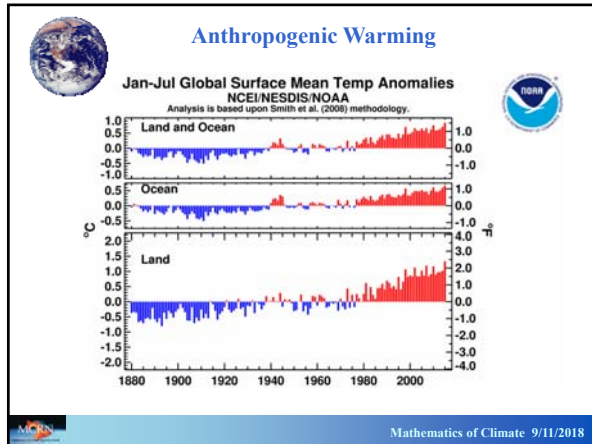
The Great Greenland Thaw: July 2012



<http://www.jpl.nasa.gov/news/news.php?release=2012-217>

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Ocean Sediment Cores

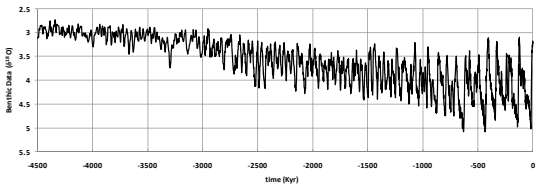


http://eo.ucar.edu/staff/russell/climate/paleoclimate/sediment_proxy_records.html

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Benthic ¹⁸O Data

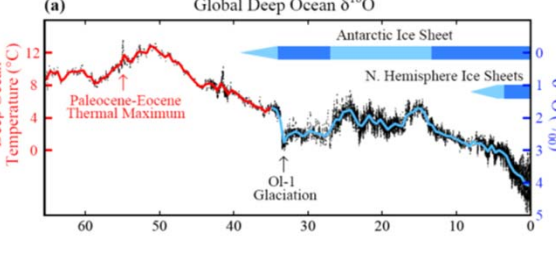


Lisiecki, L. E., and M. E. Raymo (2005), A Pliocene-Pleistocene stack of 57 globally distributed benthic $\delta^{18}O$ records, *Paleoceanography*, 20, PA1003, doi:10.1029/2004PA001071.

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Global Deep Ocean $\delta^{18}O$



Hansen, et al, Target atmospheric CO₂: Where should humanity aim? *Open Atmos. Sci. J.* 2 (2008)

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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?

What is the role of human activity?

How big is the problem?

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Heat Balance

outgoing (infrared) $\rightarrow \sigma T^4 = (1 - \alpha)S \leftarrow$ solar incoming (visible)

where T = surface temperature (Kelvin)
 S = solar influx (W/m^2)
 α = albedo (reflectivity)
 σ = the Stefan-Boltzmann constant

For current values, $T = 255K = -18^\circ C = [0^\circ F]$

Why isn't the Earth a Snowball?

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The Greenhouse Effect

Greenhouse gases (CO_2 , H_2O , CH_4) 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.

Who discovered the greenhouse effect?

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Who discovered the greenhouse effect?

Joseph Fourier (1827), *Mémoire sur les Températures du Globe Terrestre et des Espaces Planétaires*, *Mémoires de l'Académie Royale des Sciences*, t. vii., p. 569.



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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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GREENHOUSE EFFECT


A prerequisite for life on earth, the greenhouse effect occurs when infrared radiation [heat] is retained within the atmosphere.



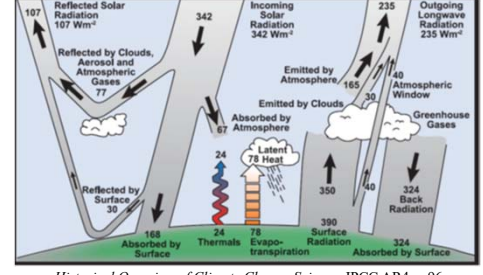
Gary Stix, *Scientific American* September 2006, pp.46-49

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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_CR01.pdf

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Remember Lake Vostok?



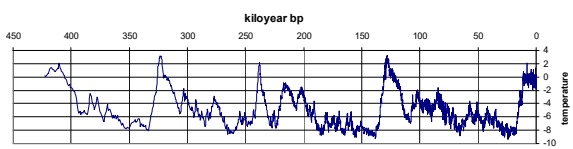
<http://svs.gsfc.nasa.gov/vis/a000000/a000900/a000996/index.html>

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Antarctic Temperature Data



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

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