Global Warming for Scientists

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Temperature is Falling

Monthly Mean Global Surface Temperature

- Meteorological Stations
- Land-Ocean Temperature Index
Temperature is Falling

Temperature is Falling?

\[ \frac{dT}{dt} = (0.0105\pm0.0015) ^\circ C / year \]

(Okay, so not falling but it sure doesn't seem to be rising very fast)
Temperature is Falling?

Global Land-Ocean Temperature Index

Temperature is Falling

NOT!

It's easy enough to prove what you want to prove IF you can pick and choose the data you use (and DON'T use).

BUT

A scientist (a physicist, anyway) always wants to describe the LARGEST amount of data with the simplest possible explanation.

It is unfortunately the case that you need to know a person's motivations when assessing their argument. (Peer-review!)
So WHY is it Rising?

Ultimately, the Sun

The Sun is the only SOURCE of energy for the Earth (OK, except nuclear).

It is the energy from the Sun that warms the Earth.

(Without the Sun, we'd be about 3 K)
So *WHY* is it Rising?
But it's not the Sun alone

John Tyndall
(1820-1893)

Interested in electromagnetic radiation (light scattering, “ultra-red” radiation)

Interested in glaciology (and ice ages) (liked climbing around on glaciers)

The two became connected when he discovered that many gases (e.g., CO₂, CH₄, H₂O) were transparent to visible light, but opaque to “ultra-red”.

Such changes in fact may have produced all the mutations of climate which the researches of geologists reveal. However, this may be, the facts above cited remain; they constitute true causes, the extent alone of the operation remaining doubtful.
Changing CO$_2$ and H$_2$O will change temperature

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Interested in explaining glacial epochs (ice ages).

Noted that changing H$_2$O significantly not possible, so CO$_2$ the big issue.

Increasing/decreasing CO$_2$ by factor of 2 would increase/decrease temperature by 4-5 °C (increase not a bad thing if you live in Sweden)

So the question is, Did it? Did CO$_2$ concentration change enough to cause an ice age?

The answer is Yes.
(sort of)


Summarized in Arrhenius, 1896 (pp. 269-73)

“...The following calculation is also very instructive for the appreciation of the relation between the quantity of carbonic acid in the air and the quantities that are transformed. The world’s present production of coal reaches in round numbers 500 millions of tons per annum, or 1 ton per km.² of the earth’s surface. Transformed into carbonic acid, this quantity would correspond to about a thousandth part of the carbonic acid in the atmosphere. It represents a layer of

Noted that industrial activity increases atmospheric CO₂
(We've since figured out that CO₂ doesn't cause ice ages)
Heating by changing atmospheric composition called: “Greenhouse effect”

Up to a point, this is a good thing:
At equilibrium:
Solar insolation = Earth radiation
Power in = Power out

\[ S \pi r^2 = \sigma T^4 4 \pi r^2 \]

Solve for \( T \):

- **Mercury**: 436K (440K)
- **Venus**: 230K (737K)
- **Earth**: 254K (288K)
  - (stratosphere: 270K)
- **(moon)**: 278K (~270K)
- **Mars**: 210K (280K)
- **Jupiter**: 122K (165K)

Green house gases have increased significantly.

GHG have increased “suddenly”.

“Too much of anything, Lt., even [GHG] isn't necessarily a good thing.”

J. T. Kirk
Where do the GHG's come from?

Annually, the world burns roughly:
8 \cdot 10^9 \text{ tons coal},
5 \cdot 10^9 \text{ tons oil},
3.6 \cdot 10^{12} \text{ m}^3 \text{ natural gas}

Balance the equations – each mole of carbon in coal, oil, or NG produces one mole of CO$_2$.

Result: about 44 Gtons of CO$_2$.

Actual: about 34 Gtons of CO$_2$.
(Carbon Dioxide Information Analysis Center, Department of Energy, http://cdiac.ornl.gov/)
Humans produce a GREAT quantity of CO$_2$

- We've been pumping CO$_2$ into the atmosphere for about 150 years
- ESPECIALLY in the last 50 years
- If the spike in CO$_2$ in the atmosphere is NOT from human activity:
  A) What IS causing it?
  B) Where is the CO$_2$ humans produce going?

In short, human activity is increasing the GHG content of the atmosphere.
So what do we know?

- Humans increase atmospheric GHG, particularly CO$_2$
- CO$_2$ transmits visible light and absorbs infra-red light
- Energy is conserved (so that increased energy = increased temperature)
Anthropogenic Global Warming

- The Earth is warming
- Humans are causing it
- From **basic physics**, NOT complex modelling
  (models needed to understand the details - HOW much, HOW fast, what should we do)

AGW is as inexorable as gravity.
Most GHG's have a well defined atmospheric lifetime. CO$_2$ has no well defined lifetime (can be modelled by sum of exponentials).


Susan Solomon, Gian-Kasper Plattner, Reto Knutti, and Pierre Friedlingstein
“Irreversible climate change due to carbon dioxide emissions”
PNAS 2009 106:1704-1709
AGW – How Long?
will it stay hot?

Even if we stop immediately, about 40% of CO2 stays in atmosphere for >1000 years.

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So why do YOU care?

- “severe weather events”
- No clear evidence that AGW causes MORE hurricanes (which probably means that any effect is small)
- Hotter atmosphere means more turbulence so more TS formed BUT
- Hotter atmosphere means more ENSO and faster “winds aloft” which break up hurricanes (Josephine)
So why do you care?

But if a storm forms, it's likely to get stronger

Not MORE storms, but more POWERFUL storms

Satellite Images
Sea Surface Temperature of Gulf of Mexico
Coastal Ocean Observation Lab, Rutgers University
http://rucool.marine.rutgers.edu/
Effect of AGW on Hurricane Activity

TOP: Local Effect – Hurricanes depend upon Absolute Sea Surface Temperature

BOTTOM: NONlocal Effect – Hurricanes depend upon DIFFERENCE in Sea Surface Temperature (between the Atlantic and the Gulf)

Gabriel A. Vecchi, Kyle L. Swanson, Brian J. Soden,
“Whither Hurricane Activity?”

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Flooding in Alaska
(in November!)
Tornadoes in the US

www.spc.noaa.gov/wcm/adj.html
In Nepal and Bhutan, the receding glaciers have formed vast lakes that threaten to burst, devastating villages downstream. …
So what to do?

- Prevention
- Mitigation
- Adaptation

This ship has sailed......

This ship is setting sail...