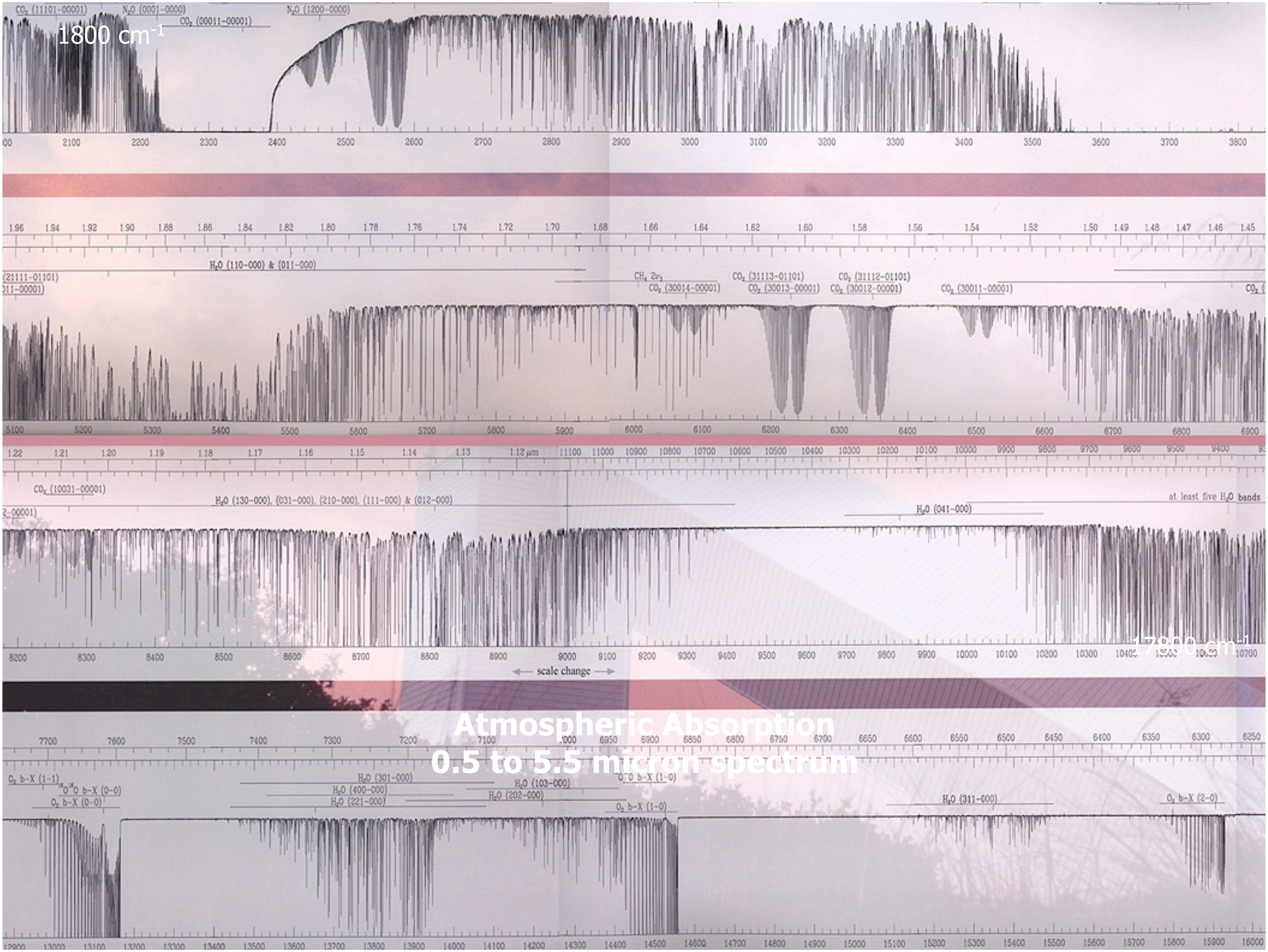
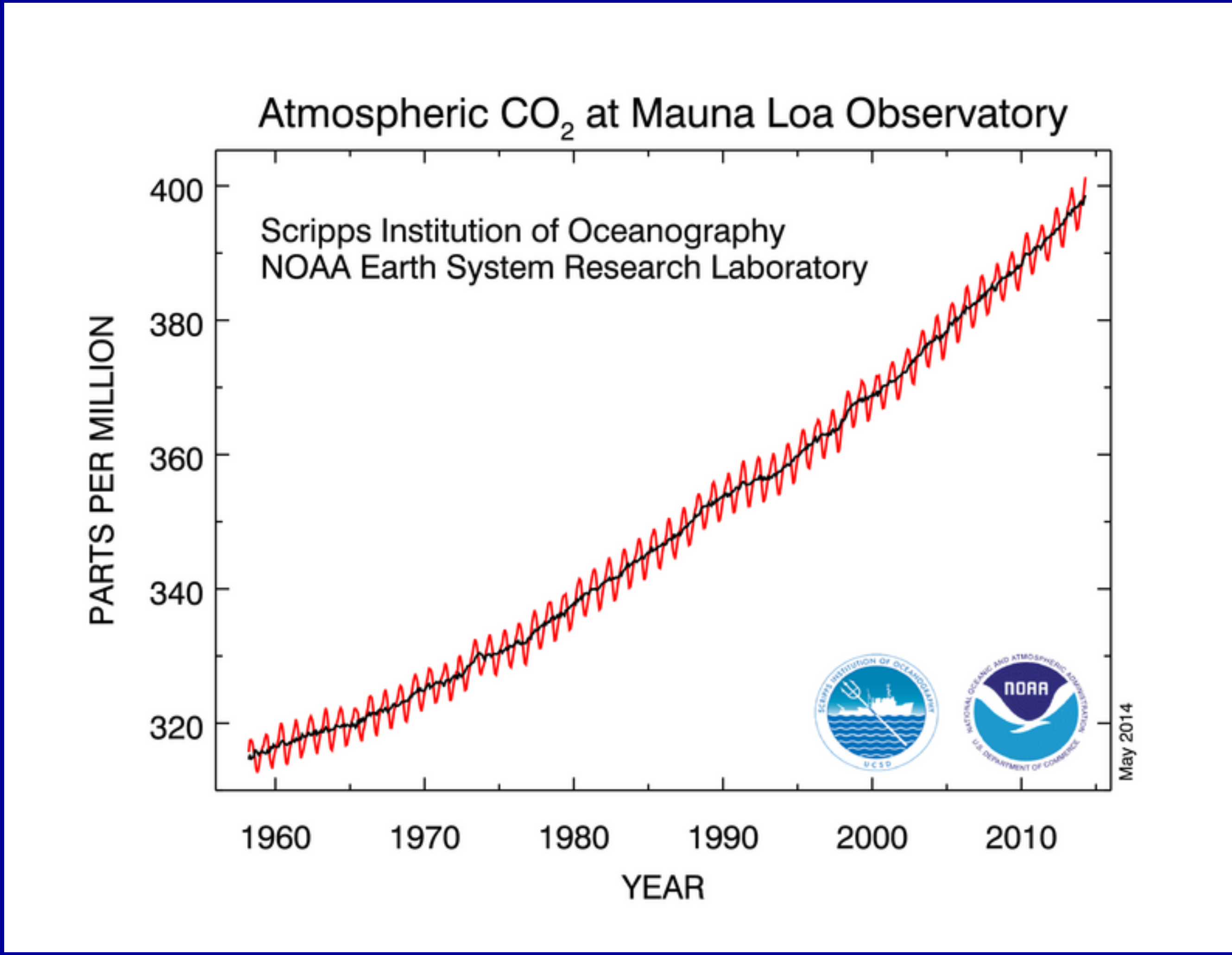


Atmospheric Absorption
0.5 to 5.5 micron spectrum
1800 cm-1
17800 cm-1
CO2 (11101-00001)
N2O (0001-0000)
CO2 (00011-00001)
N2O (1200-0000)
H2O (110-000) & (011-000)
CH4 2ν3
CO2 (30014-00001)
CO2 (31113-01101)
CO2 (30013-00001)
CO2 (31112-01101)
CO2 (30012-00001)
CO2 (30011-00001)
CO2 (10031-00001)
H2O (130-000), (031-000), (210-000), (111-000) & (012-000)
H2O (041-000)
at least five H2O bands
scale change
O2 b-X (1-1)
O2 b-X (0-0)
H2O (301-000)
H2O (400-000)
H2O (221-000)
H2O (103-000)
H2O (202-000)
O2 b-X (1-0)
H2O (311-000)
O2 b-X (2-0)

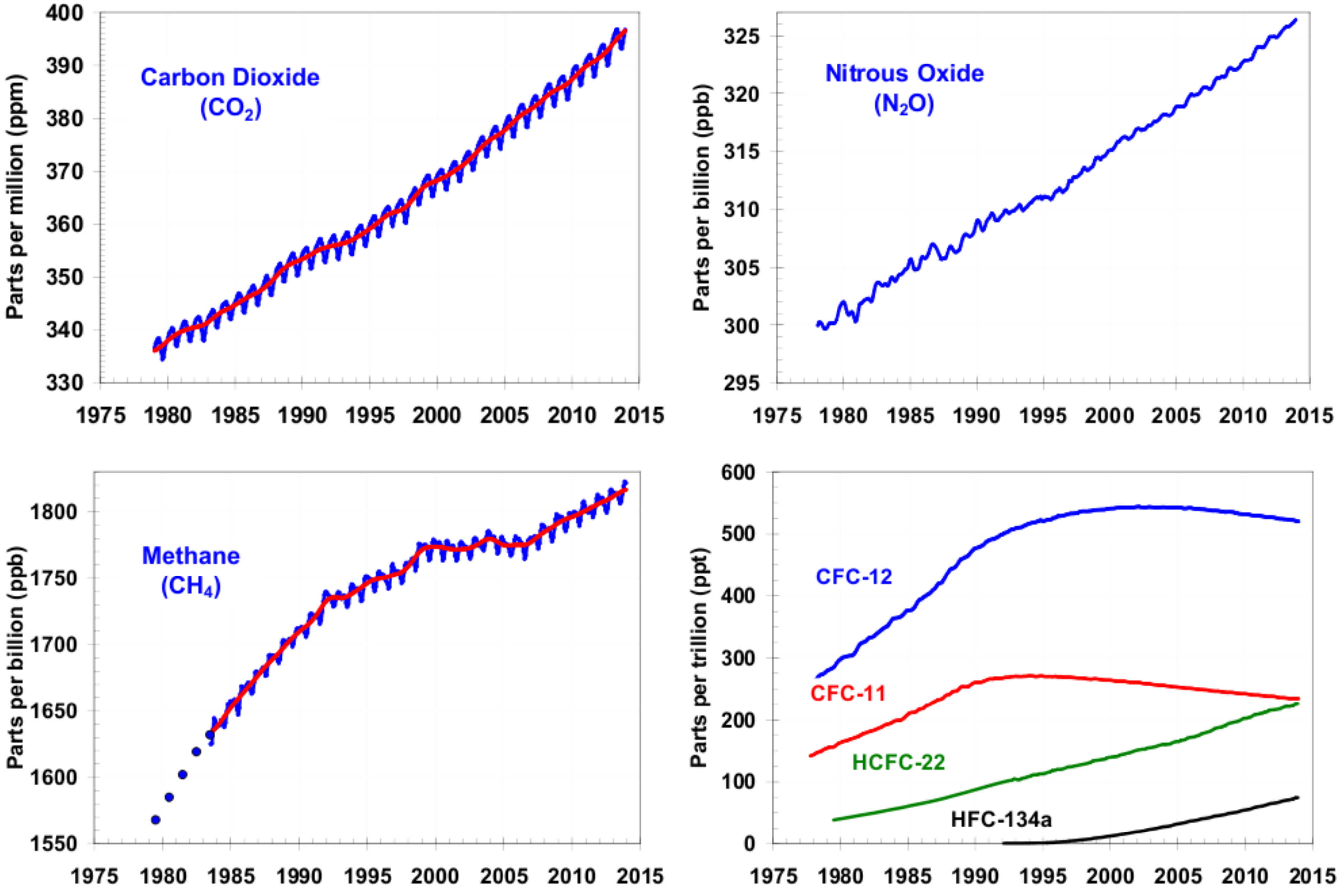
The Keeling curve

Charles David Keeling



Mar 20:405 ppm (goes up until May then draws down as plants come alive in spring)
https://www.co2.earth/daily-co2?how-co2-is-measured_html

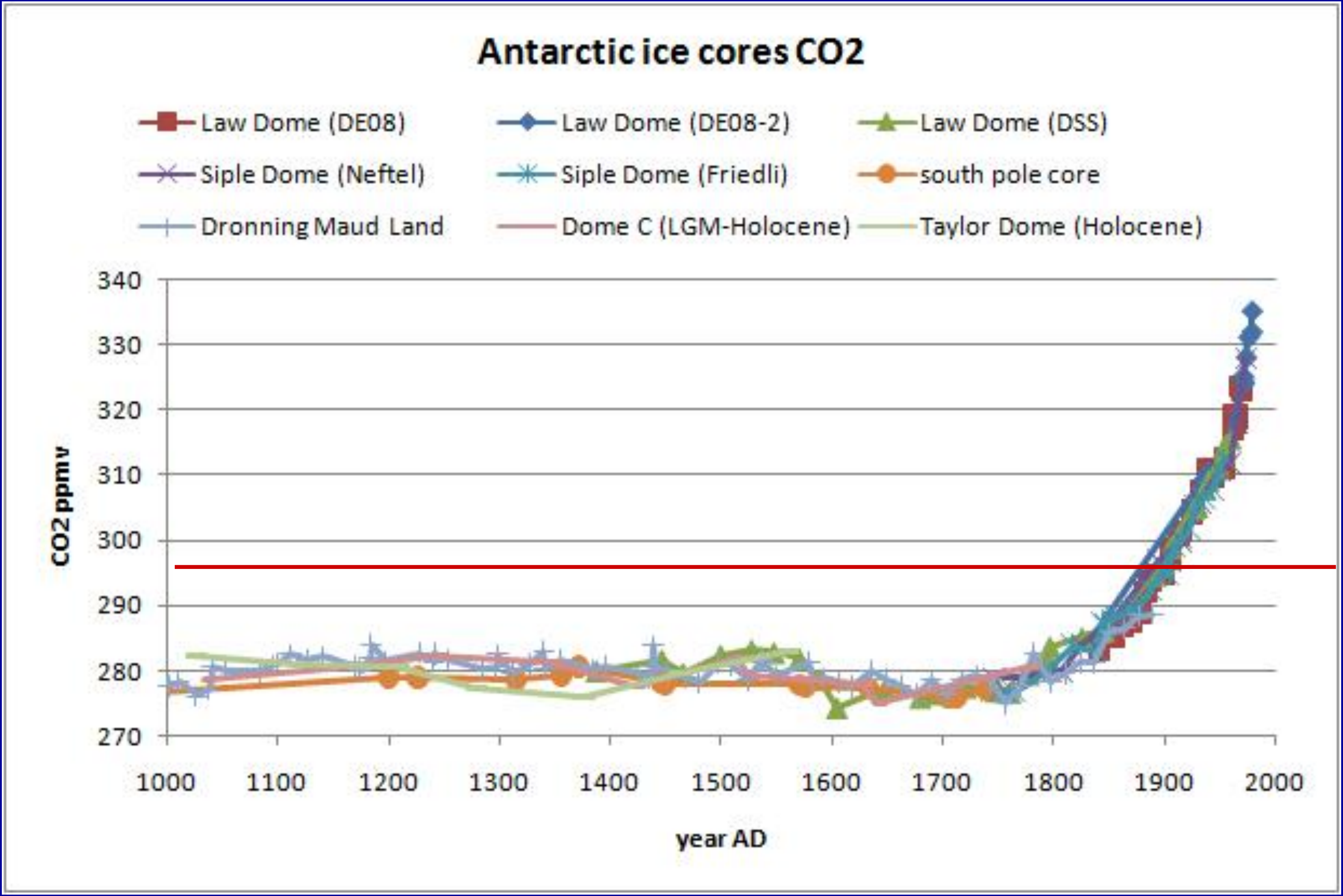
Greenhouse gas (GHG) trends



Atmospheric CO_2 rates
Volcanoes: 0.13 to 0.44 billion tons per year
Human activities: 35 billion tons (2010)

Volcanoes are a minor contributor!

The fraction of *new* atmospheric CO_2 is currently above 30% and rising.



red lines indicate maximum for last ½ million years

CO_2 is a greenhouse gas.
It is released by burning fossil fuels.

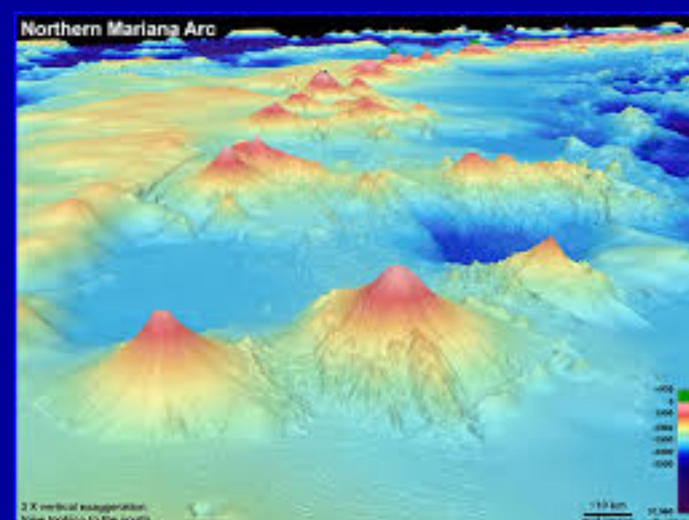
Fossil fuels have driven an extraordinary period of human expansion and prosperity. We have all benefitted greatly from inexpensive energy. Is the piper is asking to be paid?

Volcanic contribution

Well known that volcanoes contribute gas and dust to the atmosphere that cools the planet on the short term – 2-5 years.

CO_2 from volcanic eruptions cannot be seen in Keeling plots. Uncertainty comes from undersea eruptions.

Atmospheric CO_2 rates:
Volcanoes: 0.13 to 0.44 billion tons per year
Human activities: 35 billion tons (2010)

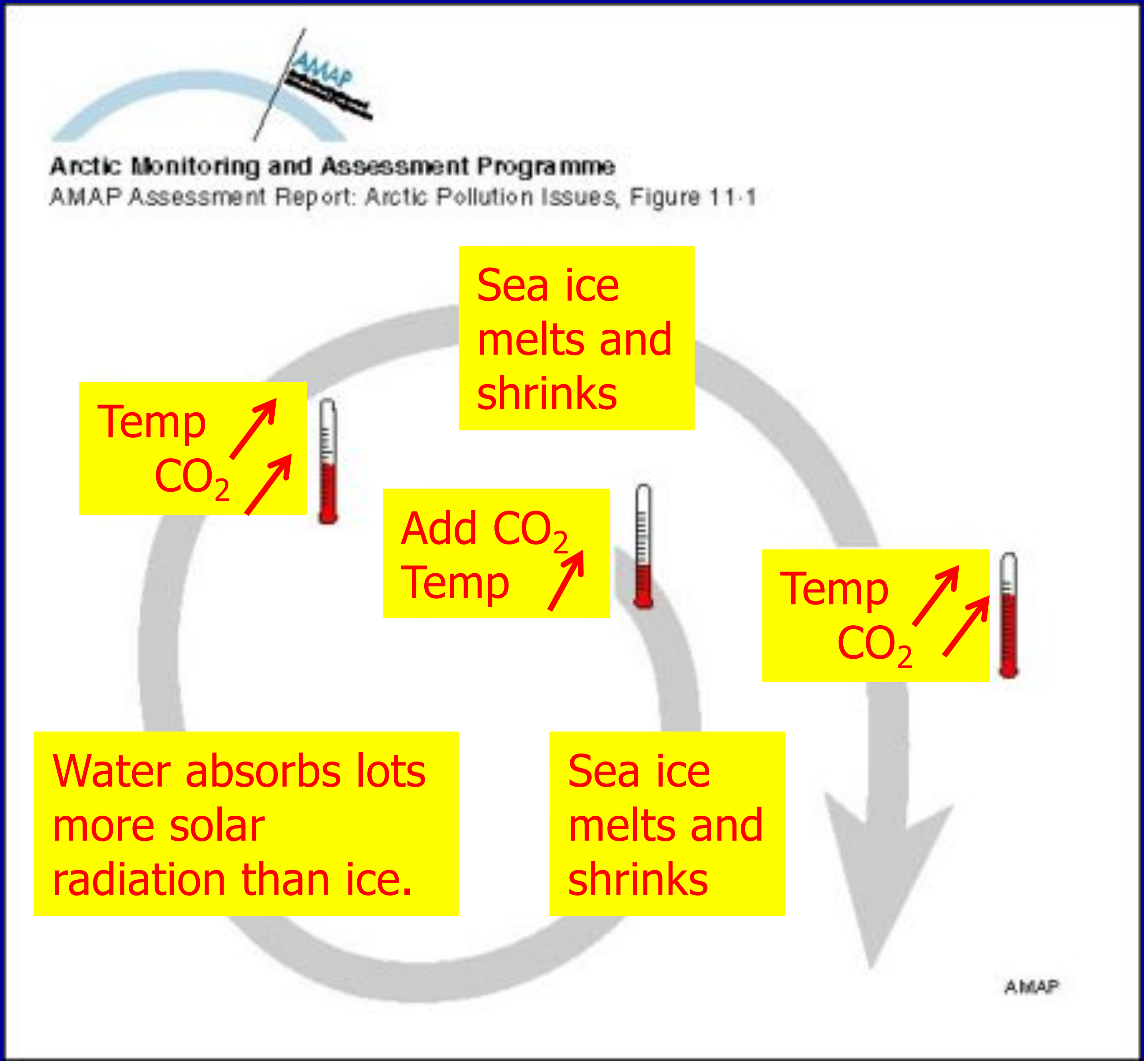


Climate Feedback

Given a climate forcing (e.g. CO_2 increase) → initial warming

- Amplifying loops (positive feedback) magnify the warming
- Diminishing loops (negative feedback)

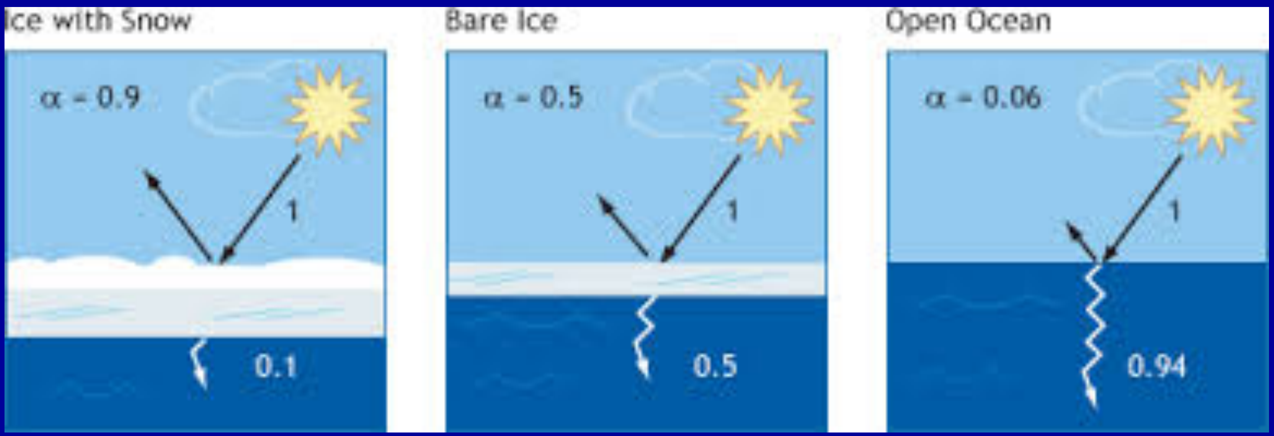
Positive Feedback is most serious in the Arctic.



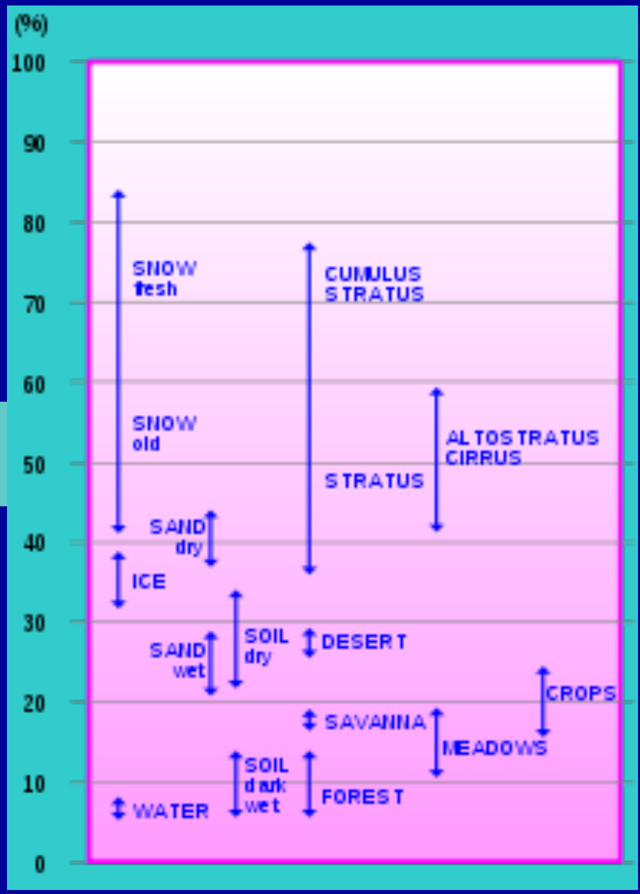
We call it "albedo", but it is really the coefficient of reflectivity

Albedo, α, is the ratio of <u>reflected radiation from the surface</u> to the incident radiation upon it.

The word comes from the Latin word albedo (whiteness).

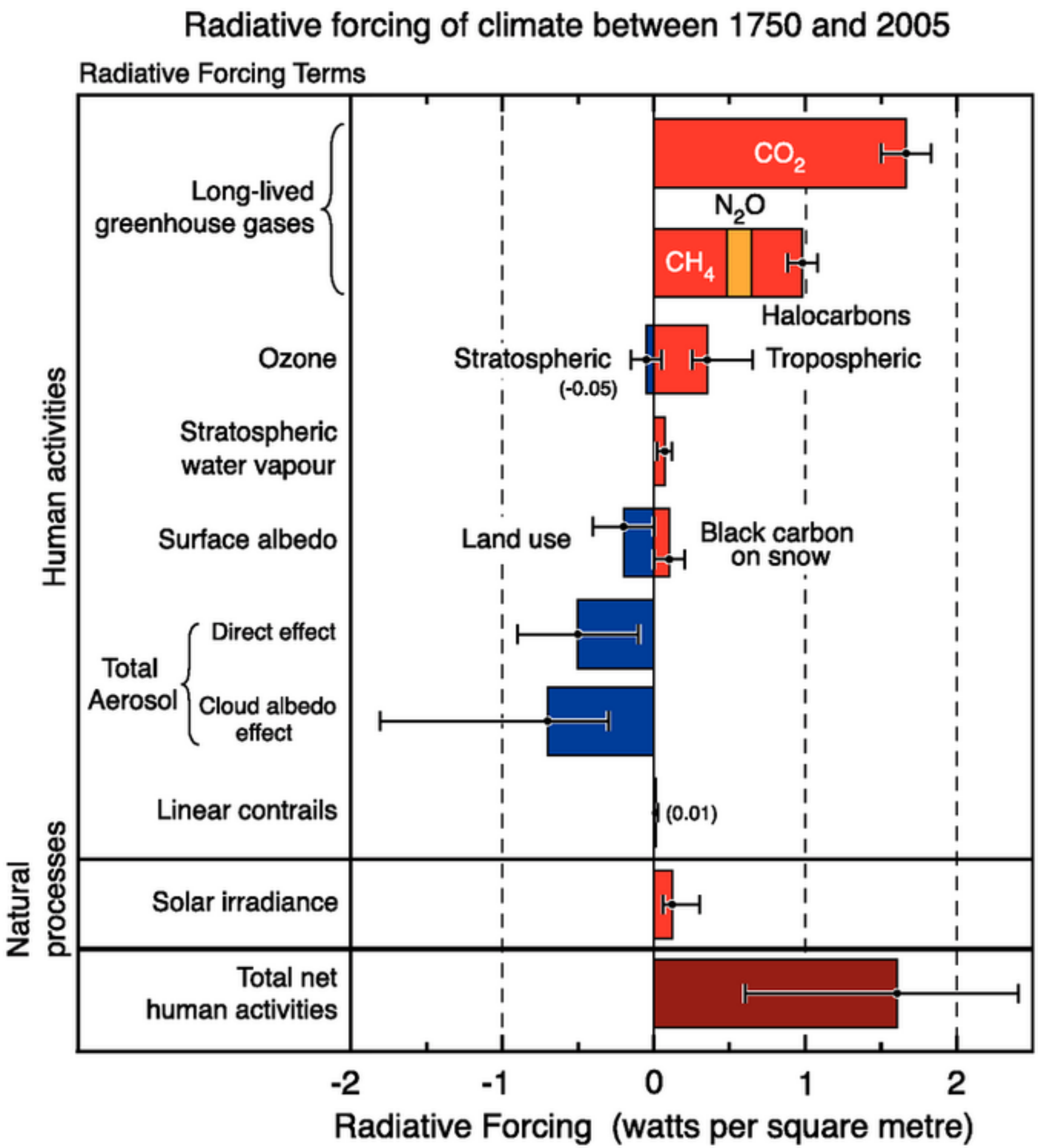


α



Global and temporal average
α = 0.31 for the Earth

Weather or Climate

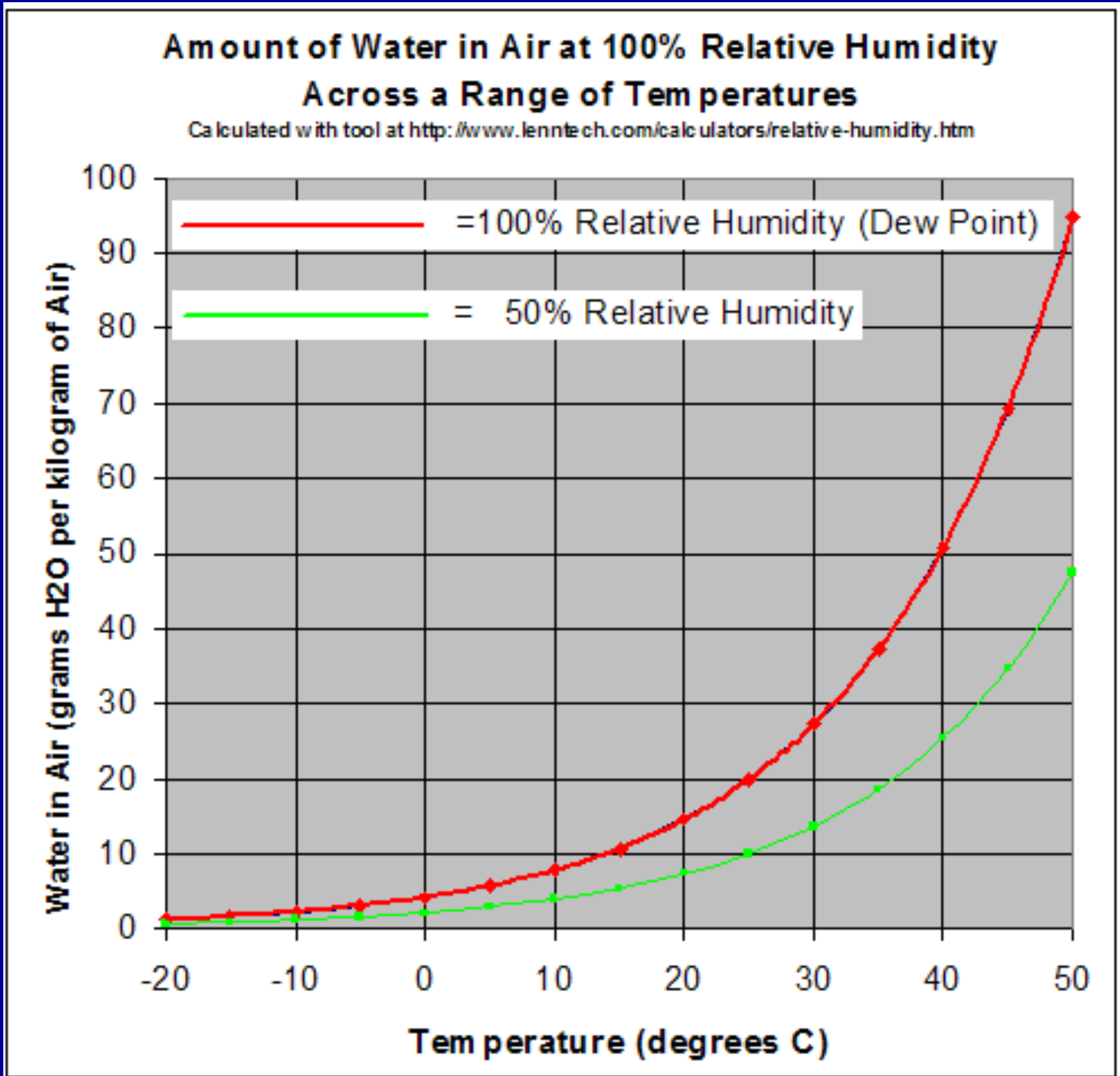


What is the relative contribution of human-induced and natural variations?

Another way is to compare the driving forces.

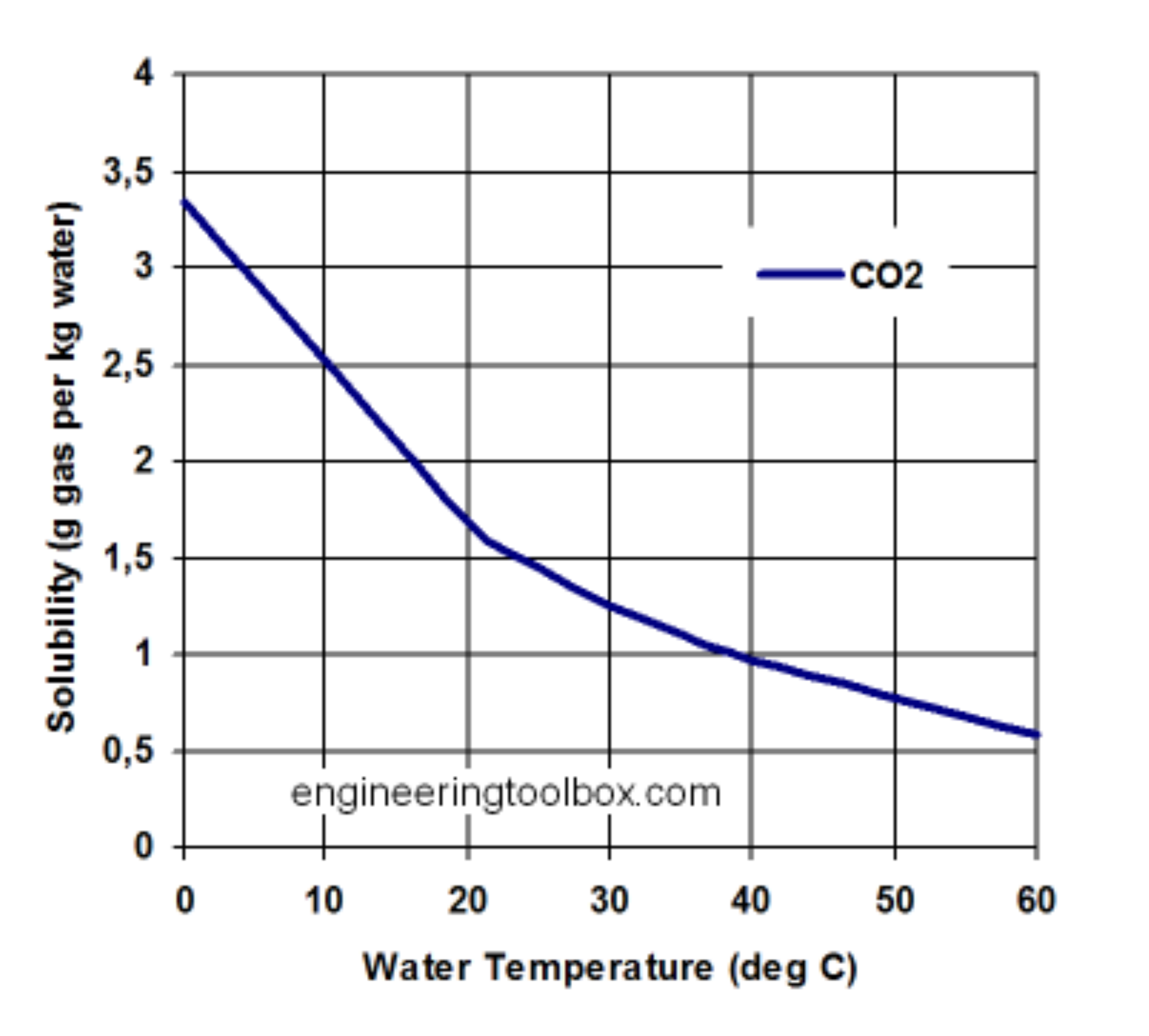
10:1 CO_2:solar

10 net human/1 solar with large uncertainty



Warmer air holds more H_2O

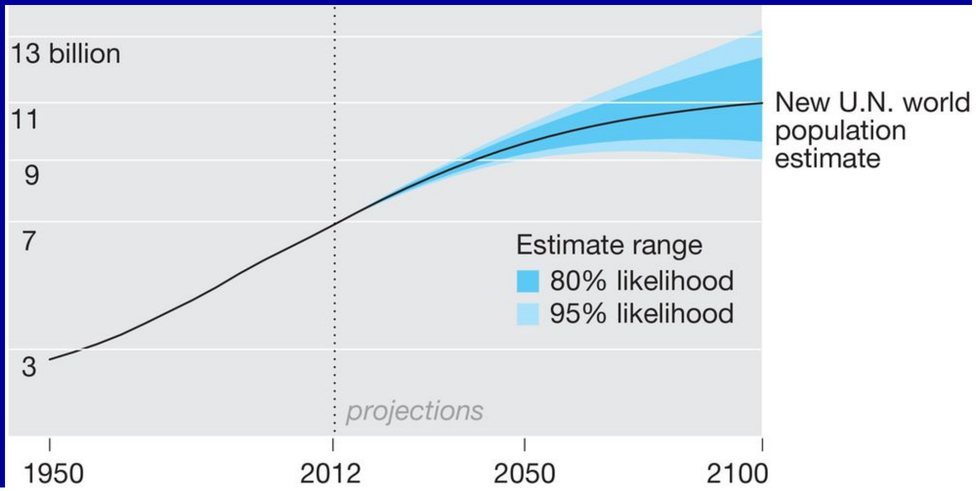
Carbonating our oceans



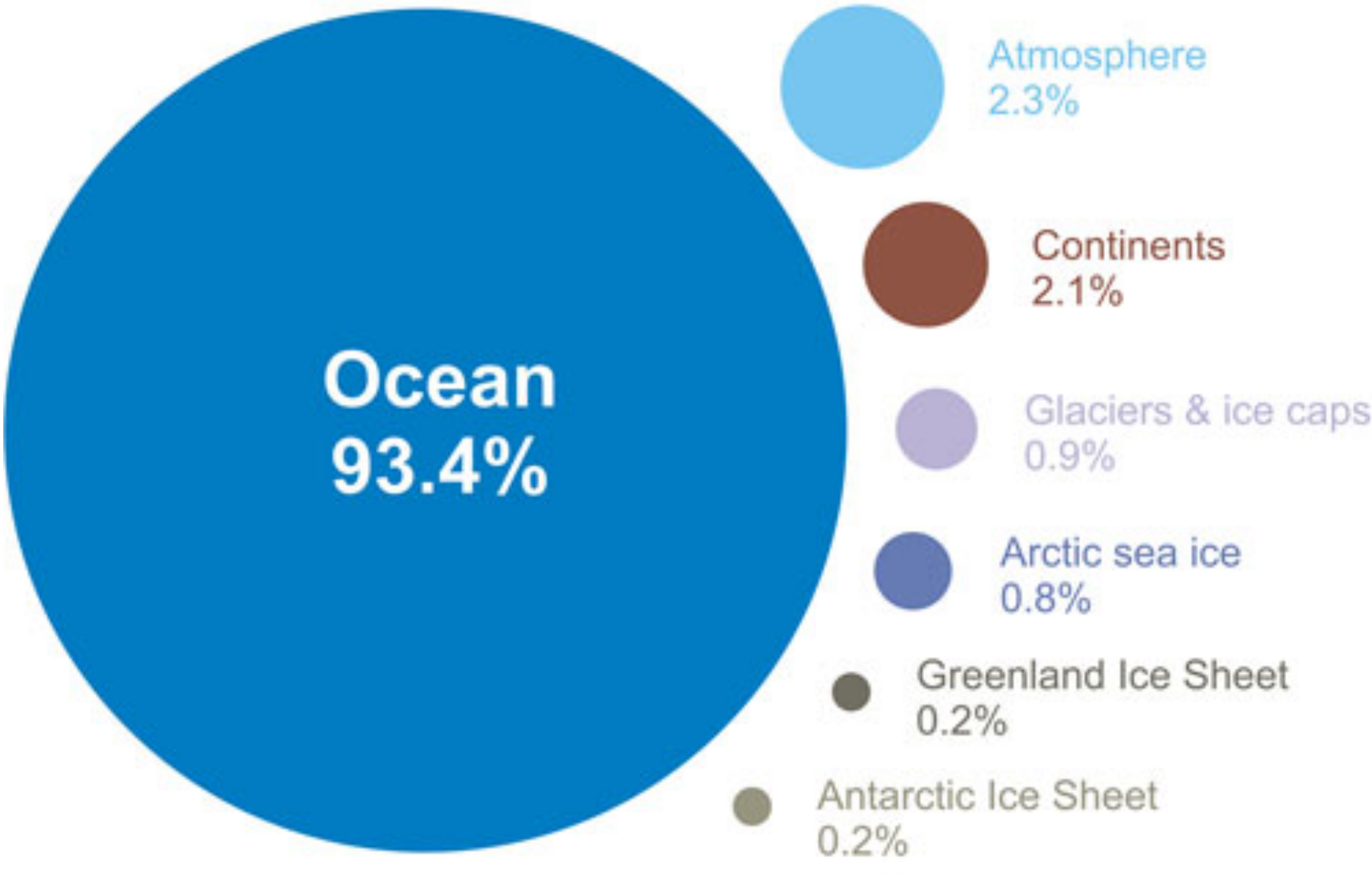
http://www.engineeringtoolbox.com/gases-solubility-water-d_1148.html

Background

- Population and affluence are drivers on energy use
  - Population growth rate is declining (ZPG by 2100??)
  - Per capita energy use is growing
  - Energy use => fossil fuels => global warming
- Carrying capacity of Earth
  - How many people can we feed
  - Land and water as resources
- Human impact on biosphere



Where is global warming going?

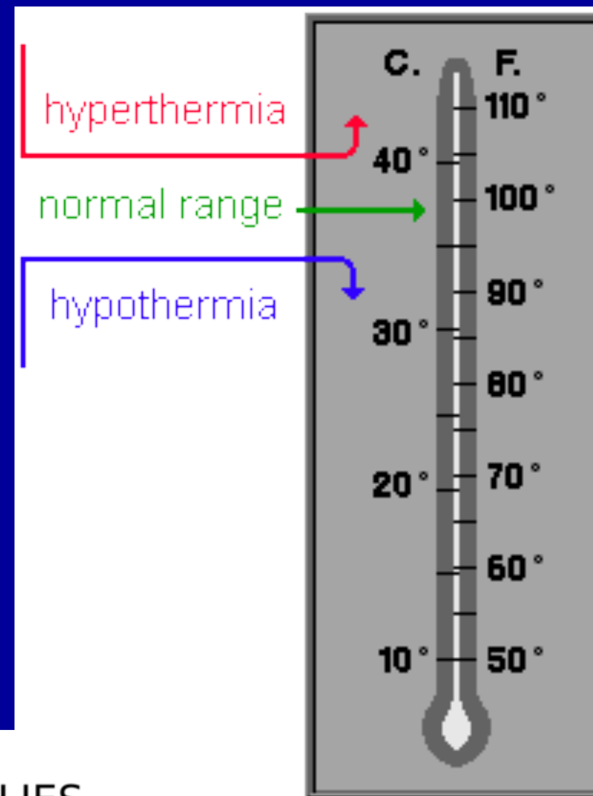


Consequences

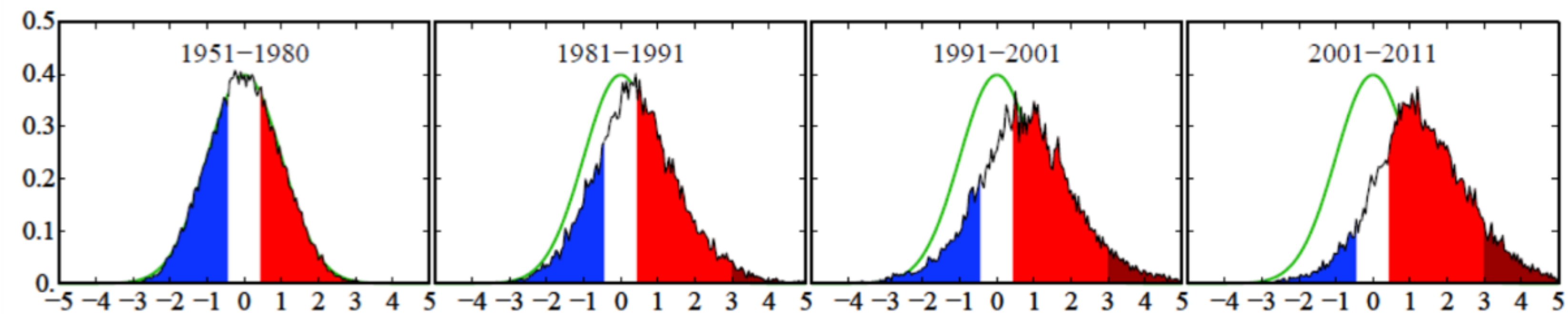
Alpine Flower season is expanded by 1 month

Danger to human life?

- E.g. Heat wave Europe 2003
- health crises; death toll at 70,000
  - heat
  - crops/drought
- Among most lethal weather



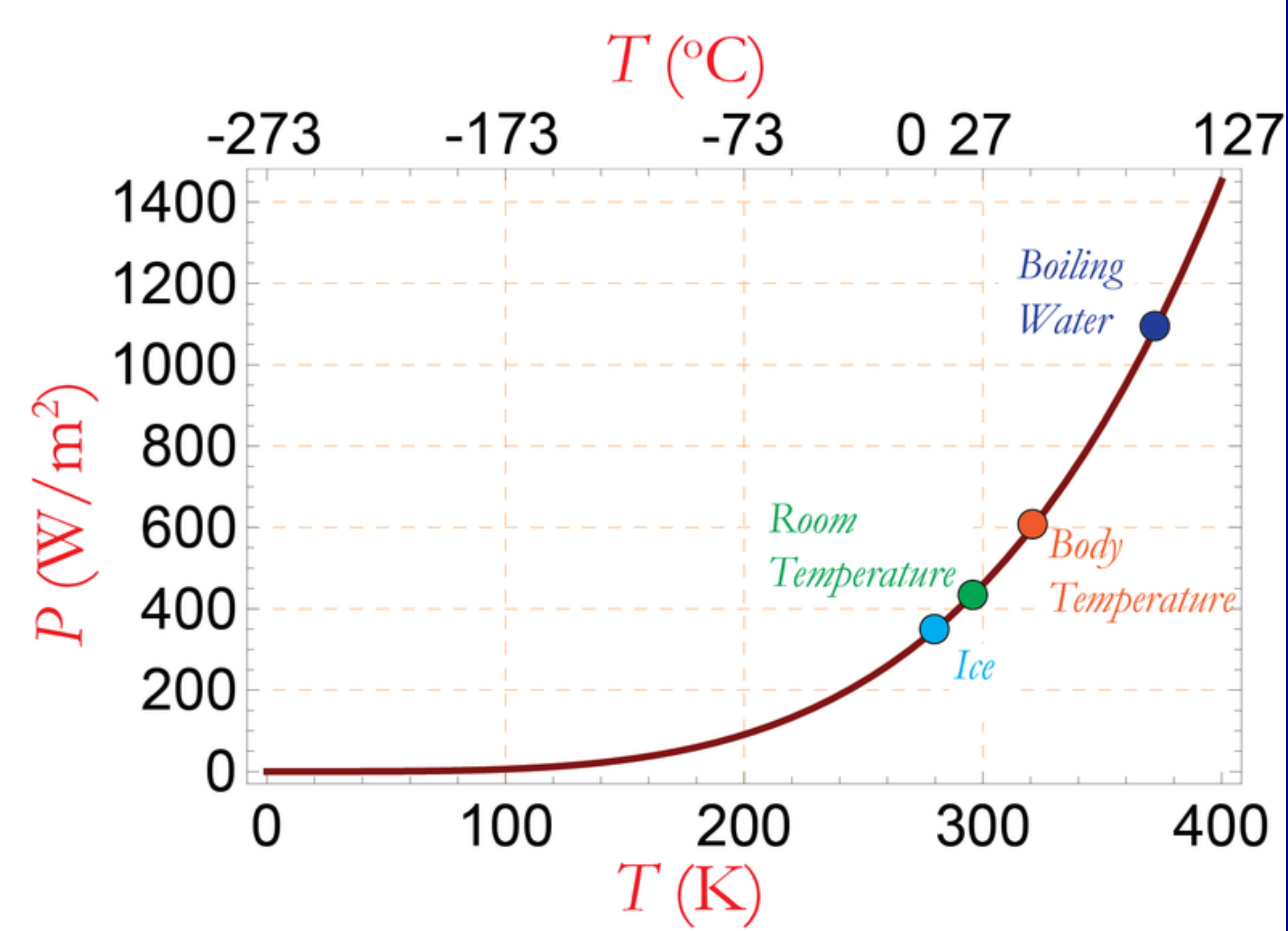
SHIFTING DISTRIBUTION OF SUMMER TEMPERATURE ANOMALIES



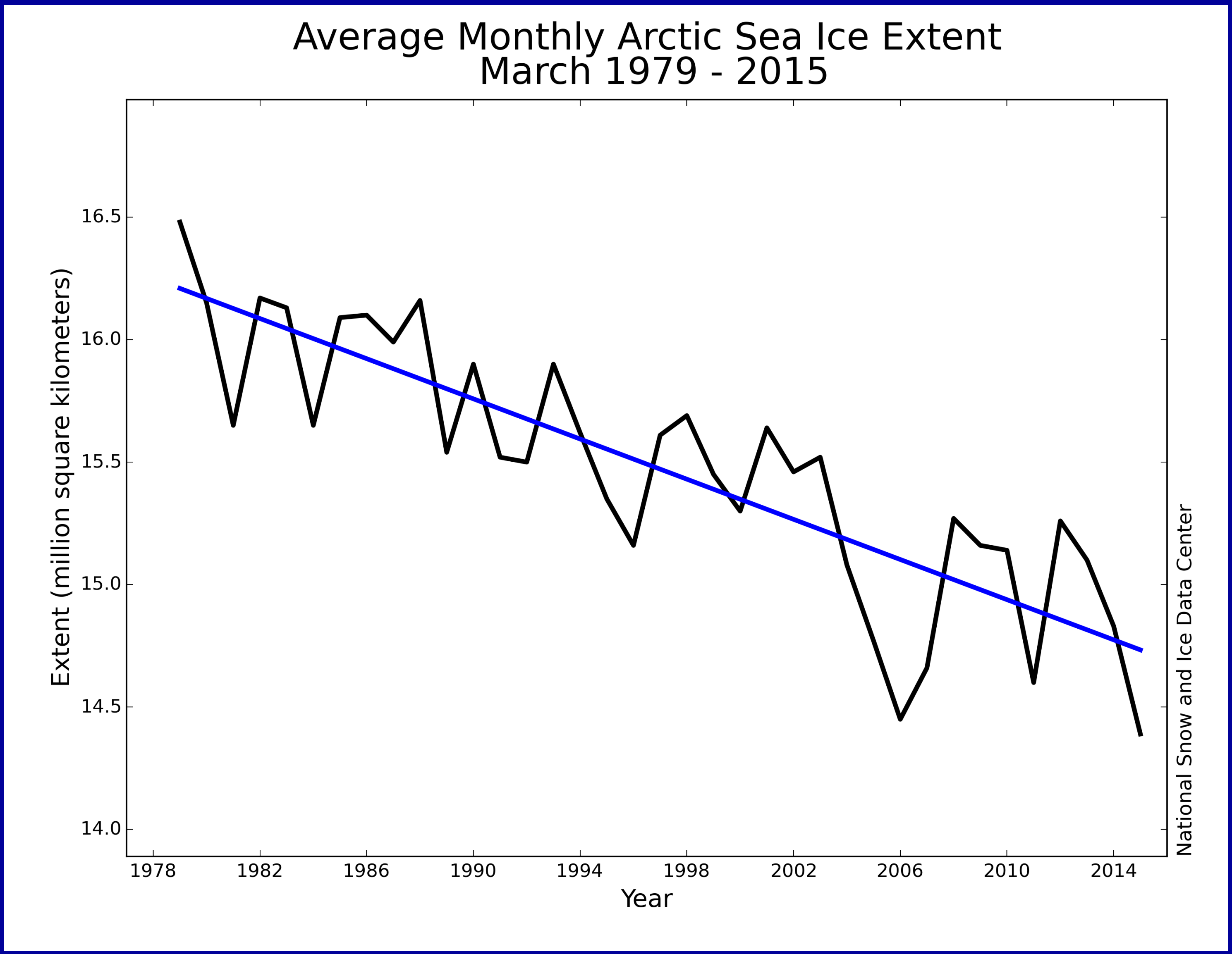
Credit: James Hansen, NASA Goddard Institute for Space Studies

The human zone

Power emitted = σT^4



Arctic Sea Ice Extent




Arctic Sea Ice Age
Every Week Since 1990

Why worry?

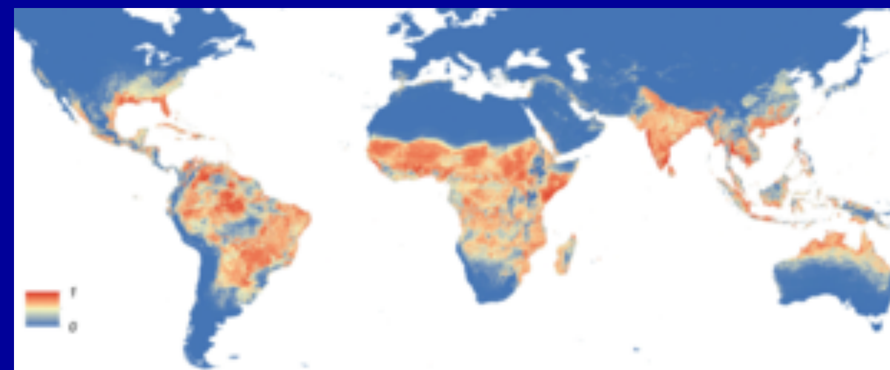
I'm worried because of the consequences the rapid rise in temperature on us and future generations.

heat -> instability
&
instability -> problems

- Health
- Sea level rise
- Species extinctions
- More violent storms
  - Wildfires, heat waves, drought

Effects of instability

- Water
  - Flooding
  - Rising seas
- Loss of biodiversity
- Stresses to food production
  - Fish
  - Topsoil
- Infectious disease propagation (temp dependent)
  - malaria, dengue fever, diarrheal diseases, tic borne encephalitus
  - foodborne salmonella, vibrio parahaemolyticus



Predicted distribution

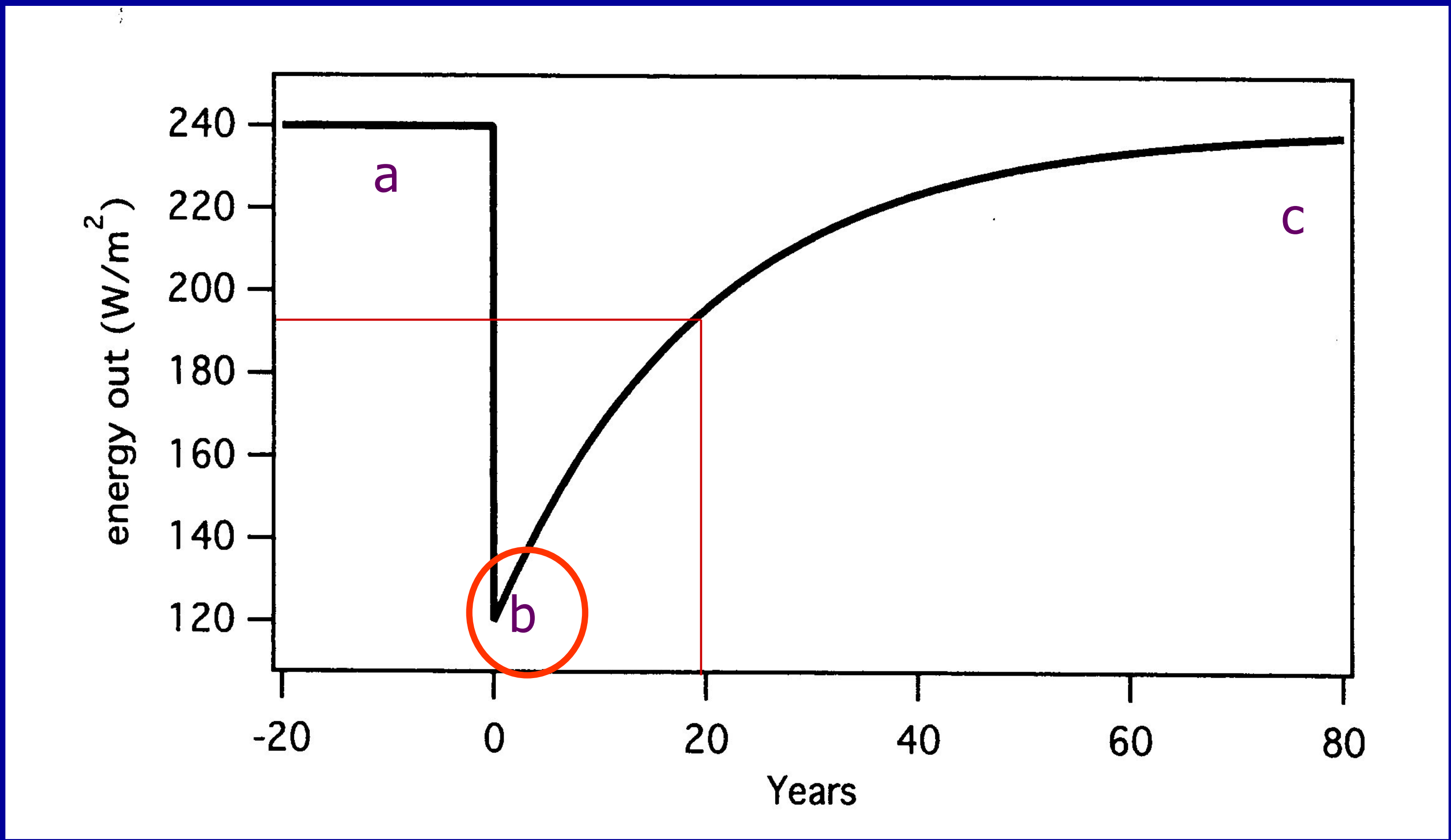
zika virus

“Climate’ s changed before”

- Climate reacts to whatever forces it to change at the time; if not humans, what is now the dominant forcing?
- Natural climate change in the past proves that climate is sensitive to an energy imbalance. If the planet accumulates heat, global temperatures will go up. Currently, CO_2 is imposing an energy imbalance due to the enhanced greenhouse effect. Past climate change actually provides evidence for our climate’ s sensitivity to CO_2.

A disequilibrium leads to a "recovery curve" like that shown here.
The recovery follows an exponential.

Where the "recovery" time τ is about 20 years as shown.



This recovery or equilibration time is not well understood and is the subject of current study. It depends on the heat capacity of the ocean

The precipitation paradox

As global temperatures rise, both drought and heavy rains are increasing.
How can this be?

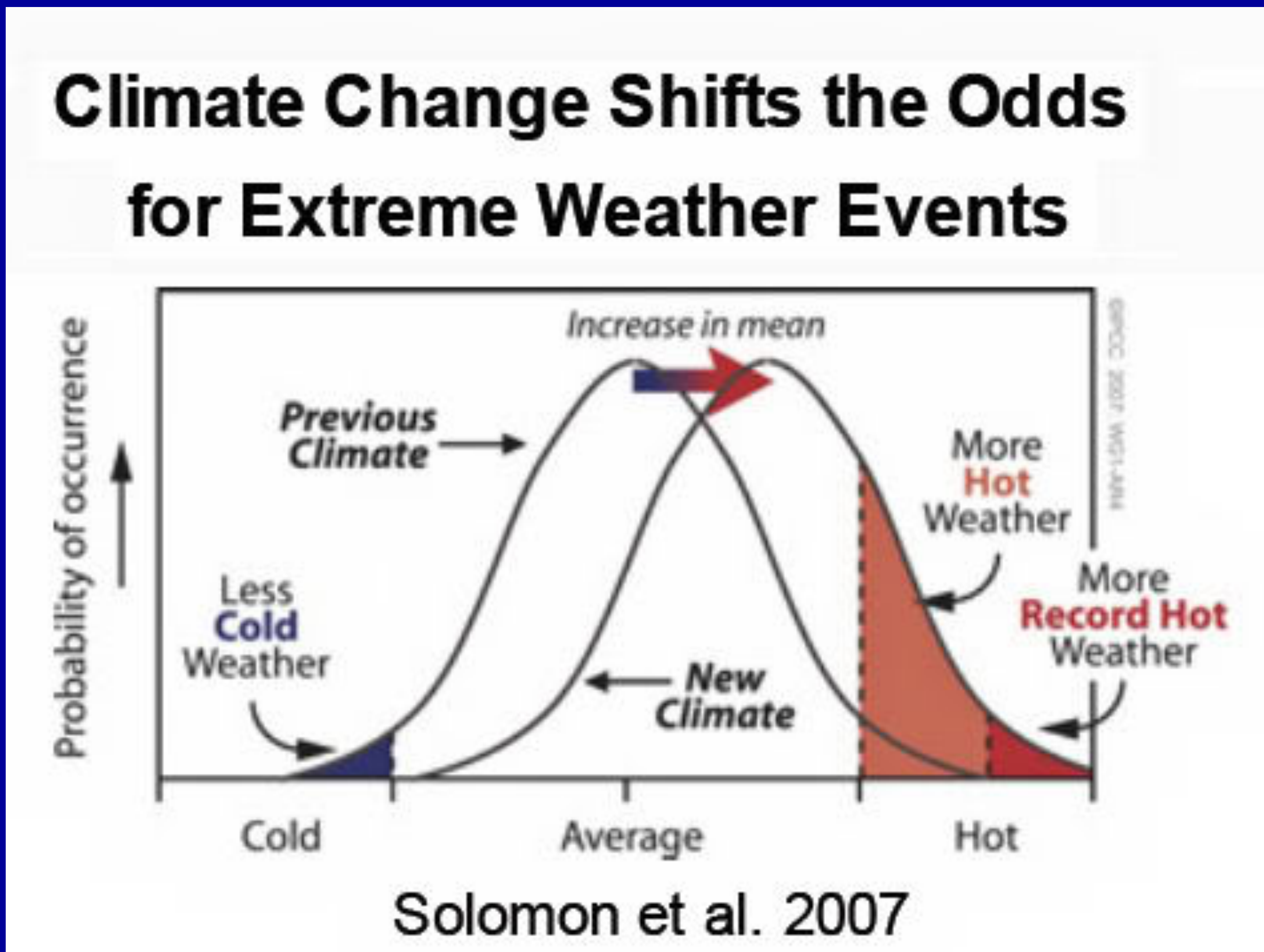
Over land: warmer air rises, sucking moisture from dry land, intensifying drought

UCAR

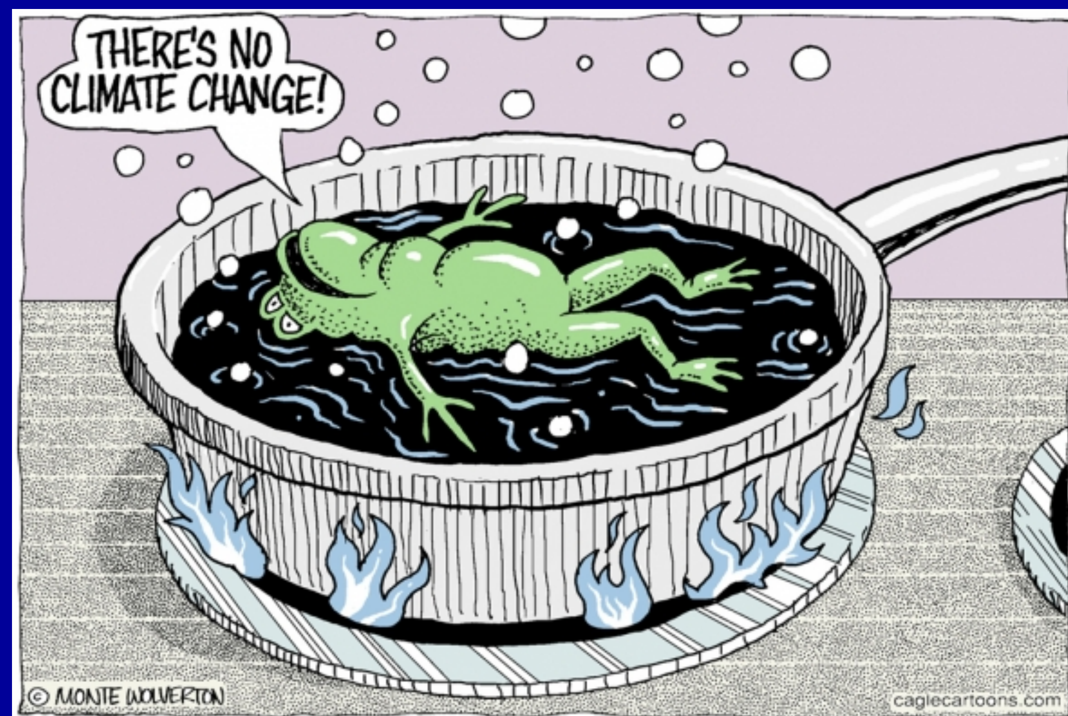
Over the oceans: more water evaporates into warmer air, helping increase precipitation intensity worldwide

UCAR

Global warming cannot be “blamed” for any individual storm.
Weather happens.
However, we can blame warming for shifting the distribution and increasing the probability of storms of a specific intensity.

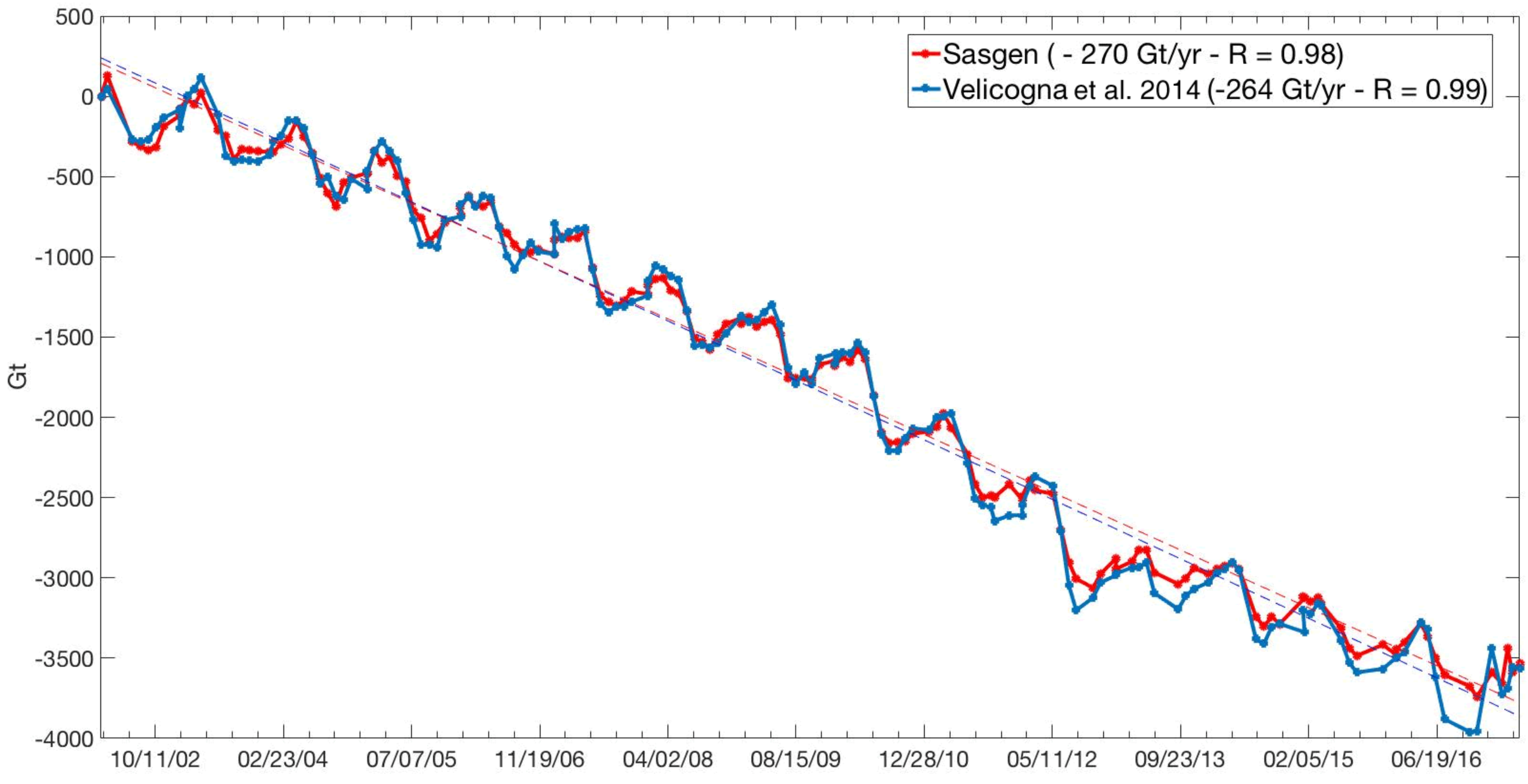


The climate denier's mascot?



Mass loss on Greenland

It takes about 360 billion tons of ice to produce one millimeter of global sea-level rise.



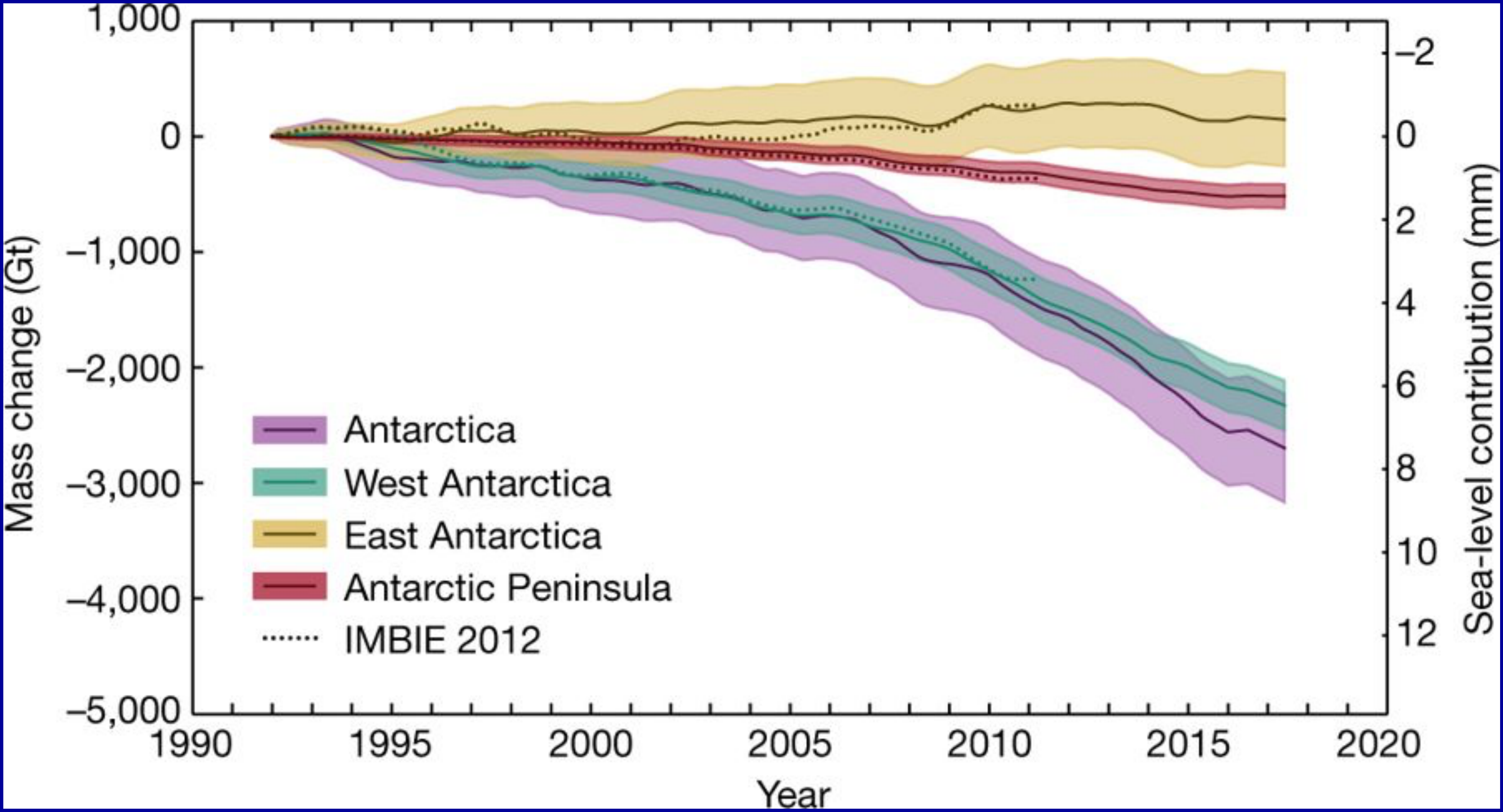
The ice sheet in Greenland is now contributing on average about 1mm/year to global sea level rise.

47 +/- 21 GT/y	1972-1980
-51 +/- 17 GT/y	1980-1990
-41 +/- 17 GT/y	1990-2000
-187 +/- 17 GT/y	2000-2010
-286 +/- 17 GT/y	2010-2018

Greenland, the world's biggest island, appears to have hit a tipping point around 2002-2003 when the ice loss rapidly accelerated, said lead author Michael Bevis, a geoscientist at Ohio State University. By 2012 the annual ice loss was "unprecedented" at nearly four times the rate in 2003, Bevis said in an interview.

National Geographic January 21, 2019
From *Proceedings of the National Academy of Sciences*

Antarctica is complicated



Current rate: -20Gt/yr to +5Gt/yr

End here
Go to Human Causation