

Introduction to Climate Change

Climate Change: What to do? How to Fix it?

Academy for Lifelong Learning

September 29 - November 17, 2016

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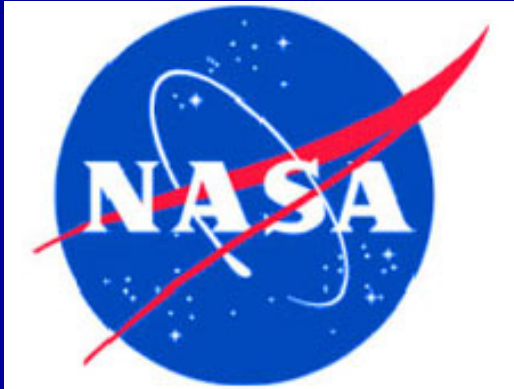
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Stanford University

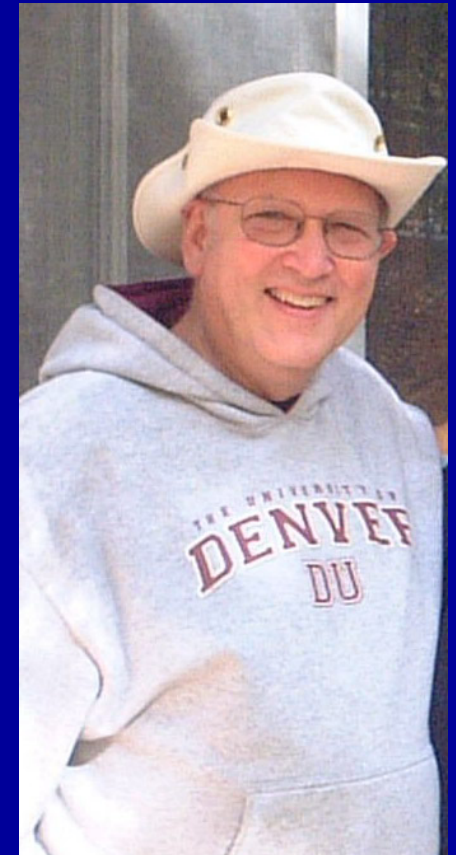
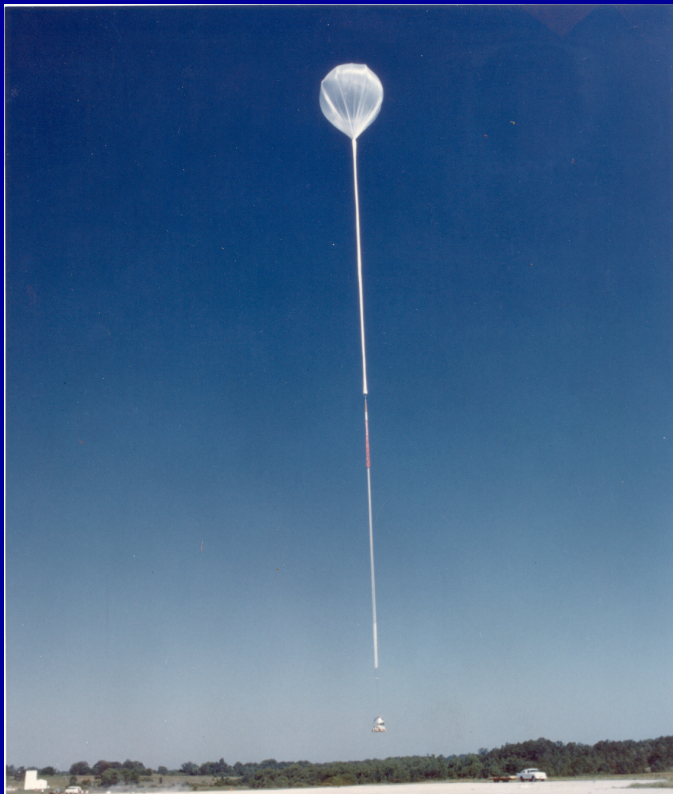


UNIVERSITY OF MINNESOTA





Director of Space Sciences 2000-2004



Public Announcement

Presentation slides and handouts can be downloaded from either the link at the Academy's web site or directly from this Web site at DU:

<http://portfolio.du.edu/OurClimate>

The site is public.
You do not need to create an account.
Search for "[OurClimate](#)".

The Academy also has a link to my page there.
Click on **Courses** and then on the last item on the scroll down menu
Course Materials

<http://www.academyll.org/course-materials/>

Handouts for today

1. Overview of course
 - How to get copy of my presentations
 - Bibliography
2. Instructions for NICL tour (Oct. 27)
3. Energy units (dealing with big numbers)
4. Glossaries of terms (download from web site)

Visit NICL (Oct 27th)



This from Richard Nunn regarding access to the NICL.

Denver Federal Center
One Denver Federal Center
Building 810, Entrance E-11, MS 975
Denver, CO 80225-0046

**Bring warm coat,
gloves and hat.**

Take 6th Avenue to the Kipling Avenue south exit. Take Kipling Avenue south to the second light at **Gate 1** of the Denver Federal Center. Turn right into Gate 1. Be prepared to show picture identification at the gate. After clearing security, drive through the gate straight ahead (the road curves somewhat to the left) to the second stop sign. Turn left. As you turn you will see the first in a series of blue and white signs that will guide you around Building 810 to NICL. Follow these signs to Door S25. Parking is unrestricted.

Everyone will need to have some form of ID such as a **drivers license**.

Non-US citizens, must have their **green cards or passports** for identification.

Outline

- Greenhouse effect
 - A Tale of Carbon Dioxide (CO₂)
- The role of coal, oil and natural gas
 - Planet has a fever
- Alarm – Call the Dr.
 - Melting ice caps
- Hope
 - Take medicine to save biosphere
 - Planet will be fine

Climate: Long-term Average Weather

- If you don't like the weather, go indoors and wait
 - Icelanders say: "There is no such thing as bad weather, only bad clothing."
- If you don't like the climate, move

**“Climate is
what you expect;
weather is
what you get.”**

Climate must average over

- **Day-night**
- **Seasons**
- **Multi-year, even decades long,
Atmospheric and oceanic
oscillations**



www.extremeinstability.com

“The atmosphere is a *global commons*.”

Climate vs. Weather

Welcome to the anthropocene!

Can we adapt fast enough?



What's the difference between weather and climate?



You can't weather a tree, but you can climate.



How do hurricanes see?

A series of seven horizontal teal-colored bars of varying lengths, stacked vertically, serving as a template for text input.

You all know about the Greenhouse Effect and infrared radiation



I have had a window blown out of my car left at an airport parking lot.



Earth's biosphere temperature is controlled
by a very thin layer of atmosphere!



The Greenhouse Effect keeps the planet warm and habitable.

The Earth's atmosphere is gas

- nitrogen (78%), oxygen (21%), argon (1%),
- trace amounts of carbon dioxide, neon, helium, methane, krypton, hydrogen, nitrous oxide, xenon, ozone, iodine, carbon monoxide, and ammonia.
- Lower altitudes also have quantities of water vapor.

Remember the periodic table?

Atomic mass: H: 1, C: 6, N: 7, O: 8

N_2 : 14

O_2 : 16

CO_2 : $6+16 = 22$ heavier than air

H_2O : $2+8 = 10$ lighter than air

One of our dilemmas

CO₂ is a good thing

Plants breath it and give back oxygen in exchange
Keeps the planet warm

CO₂ is a bad thing

Supreme Court ruled CO₂ can be regulated as a
pollutant under the Clean Air Act.

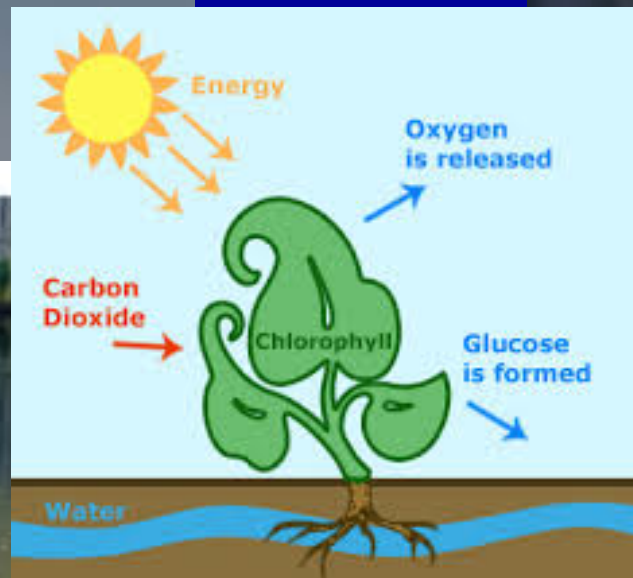
Examples of “too much of a good thing” are part of our lives:

A glass or two of wine at dinner is a good thing; a whole bottle
of wine might get you killed in an accident on the way home.

Proverbs 23:31-32

Do not look at wine when it is red, when it sparkles in the cup and goes
down smoothly. In the end it bites like a serpent and stings like an adder.

CO₂ is a natural gas.
It is released by breathing fauna and taken
up by plants during photosynthesis.
All life depends on it.



CO₂ is a colorless, odorless gas

How the heck can it control the climate?



Frozen CO₂ is dry ice



It is not “clear” or colorless to infrared radiation.

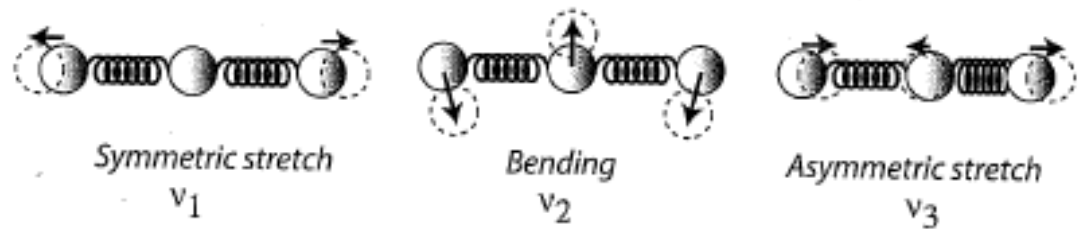


Aliso Canyon gas leak

Diatomic (N_2 , O_2 , CO)



Linear triatomic (CO_2 , N_2O)



Nonlinear Triatomic (H_2O , O_3)

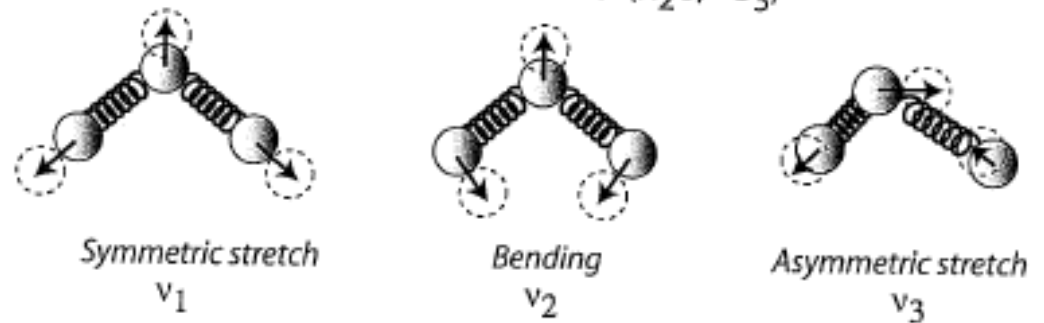


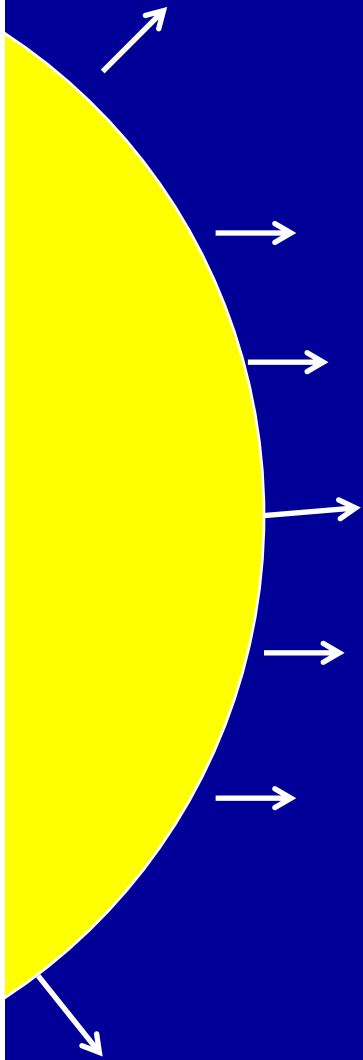
Fig. 9.4: Illustration of normal modes of vibration for simple molecules.

Molecular structure and oscillation modes

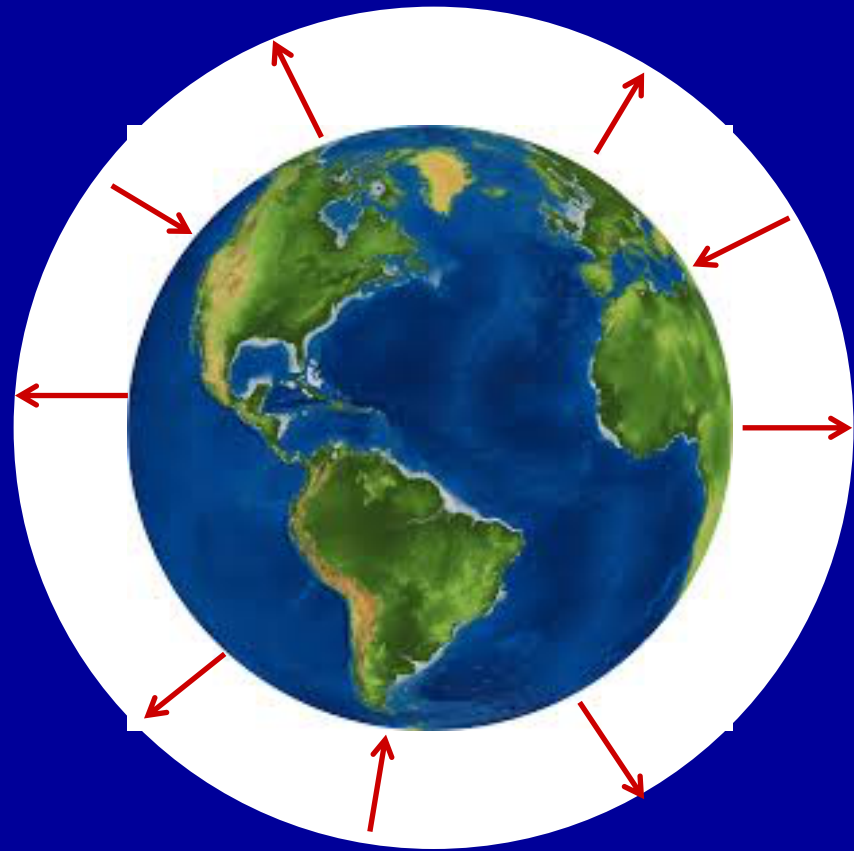
The “Global Warming”
is based on
straightforward science

not computer models ...
not recent temperatures ...
not complicated!

Sun radiates energy to the Earth's surface.



Earth's surface radiates energy to space.

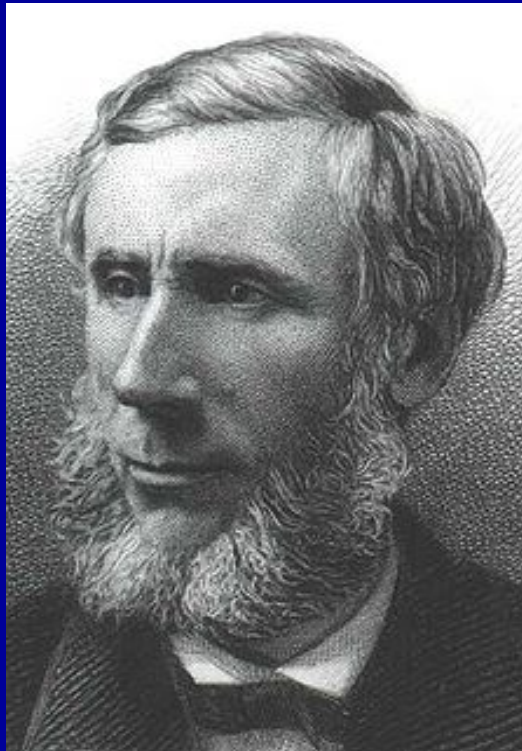


H₂O and CO₂ absorbs some of that energy and radiates it back to Earth.

Greenhouse gases keep the planet warm



Joseph Fourier computed that the Earth should be much colder than it is (1824, 1827)



John Tyndall, January 1863

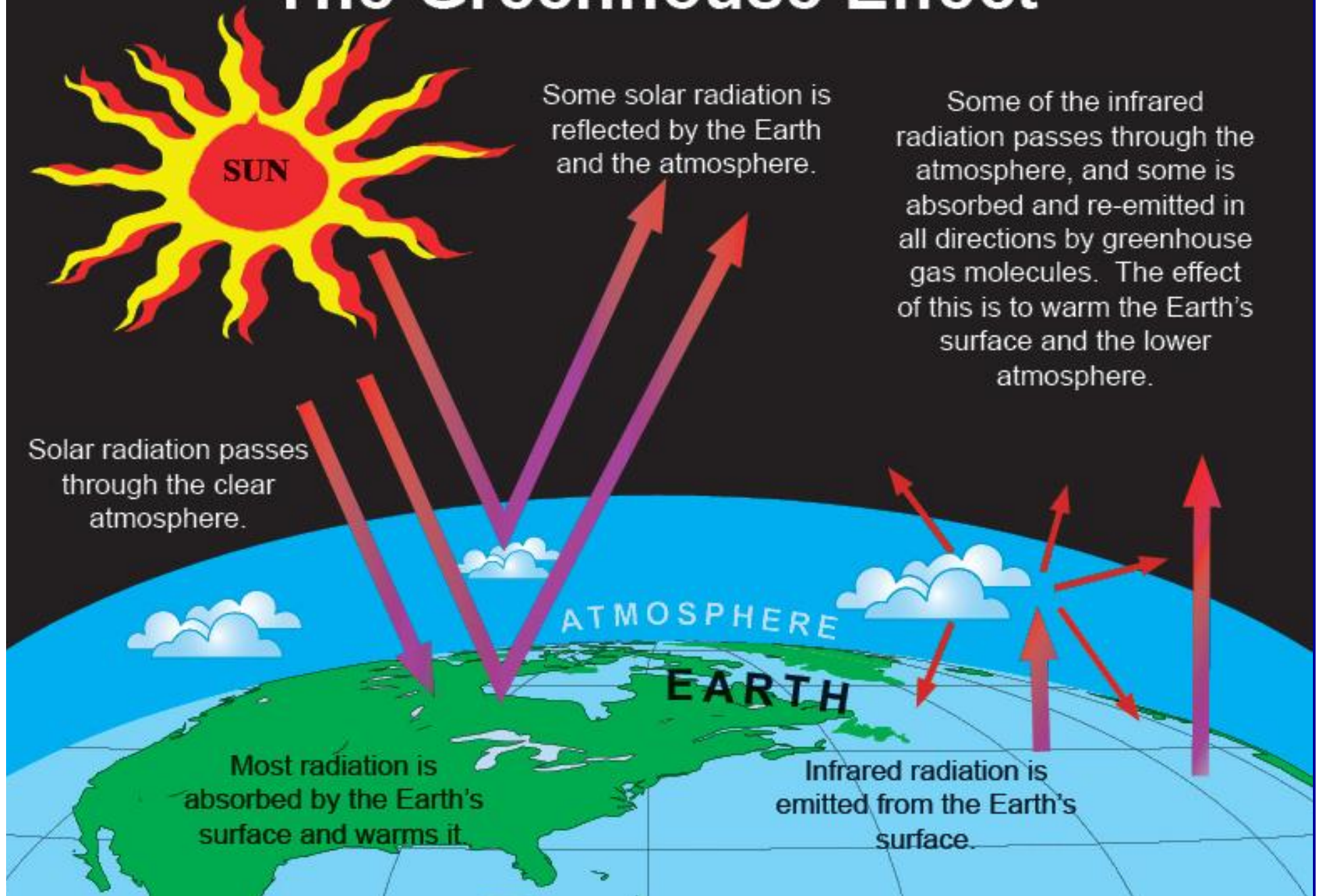
Measured the absorption and emission of heat radiation by CO_2 in air (made the measurements of the physics.)



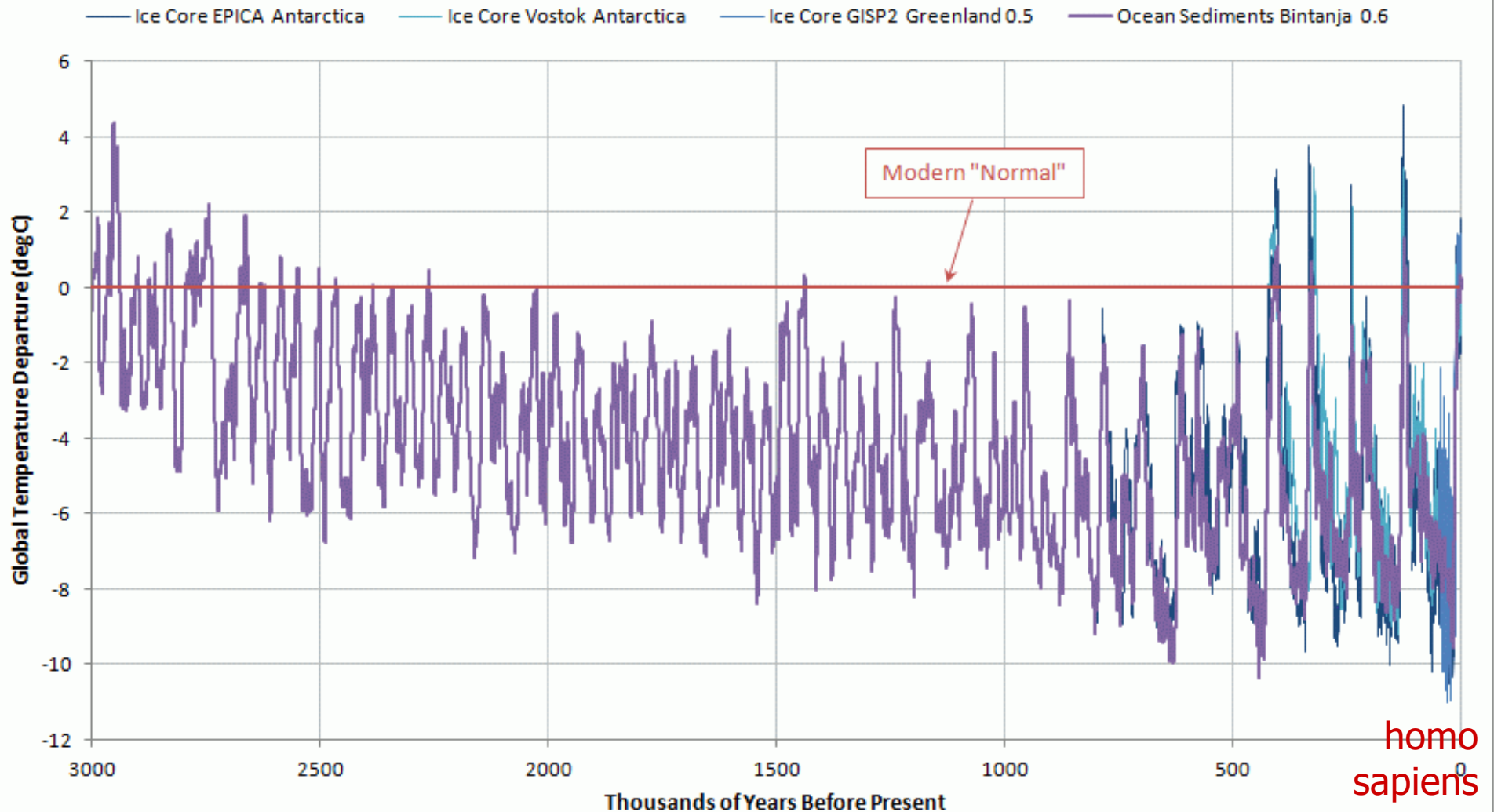
Svante Arrhenius, 1896

Calculated in detail effect of CO_2 on Earth's temperature.

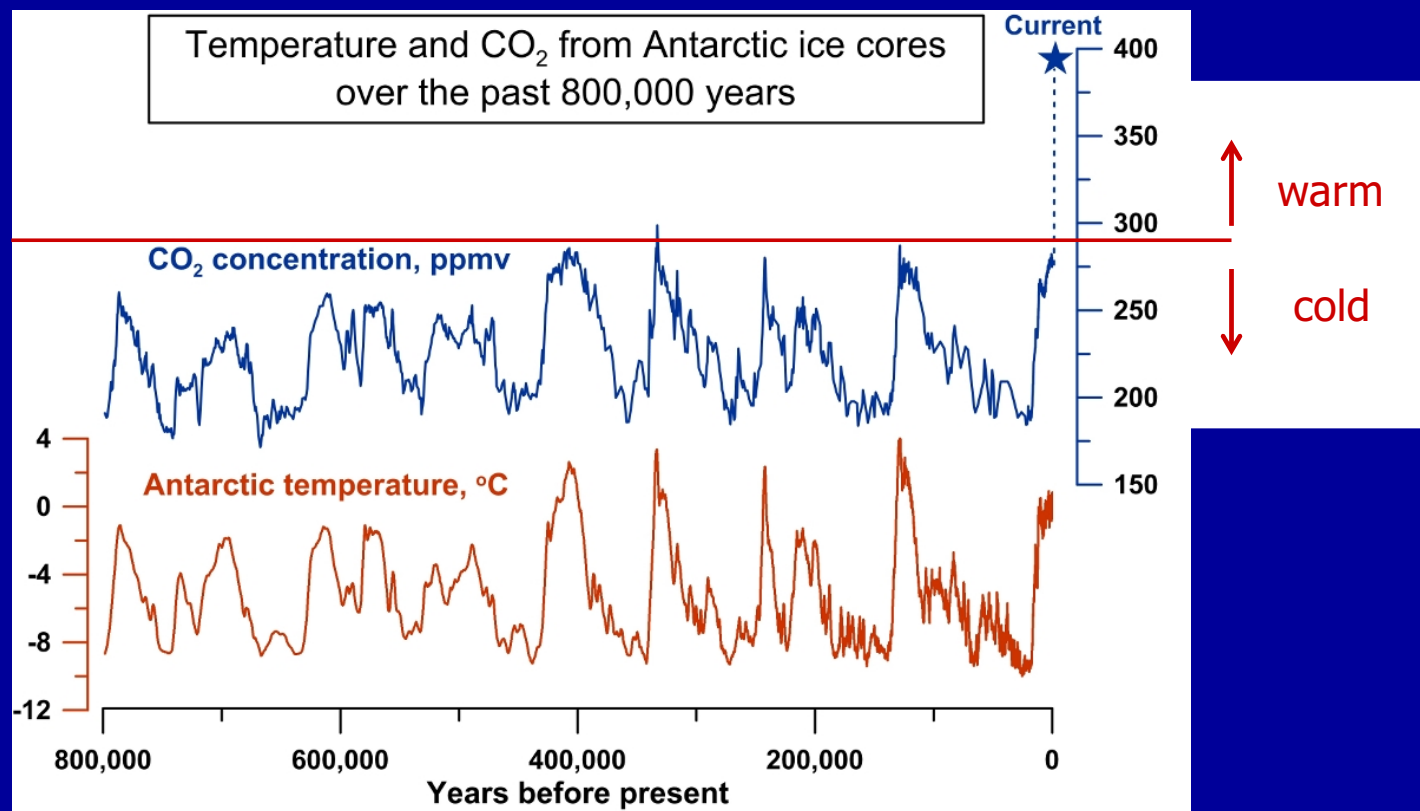
The Greenhouse Effect



The climate changes all the time.
The plot shows average planetary temperature
for the last 3 million years.



This plot compares temperature and CO₂ abundance for the last 0.8 million years. Now it's way higher than this (400 ppm) and rising very fast.



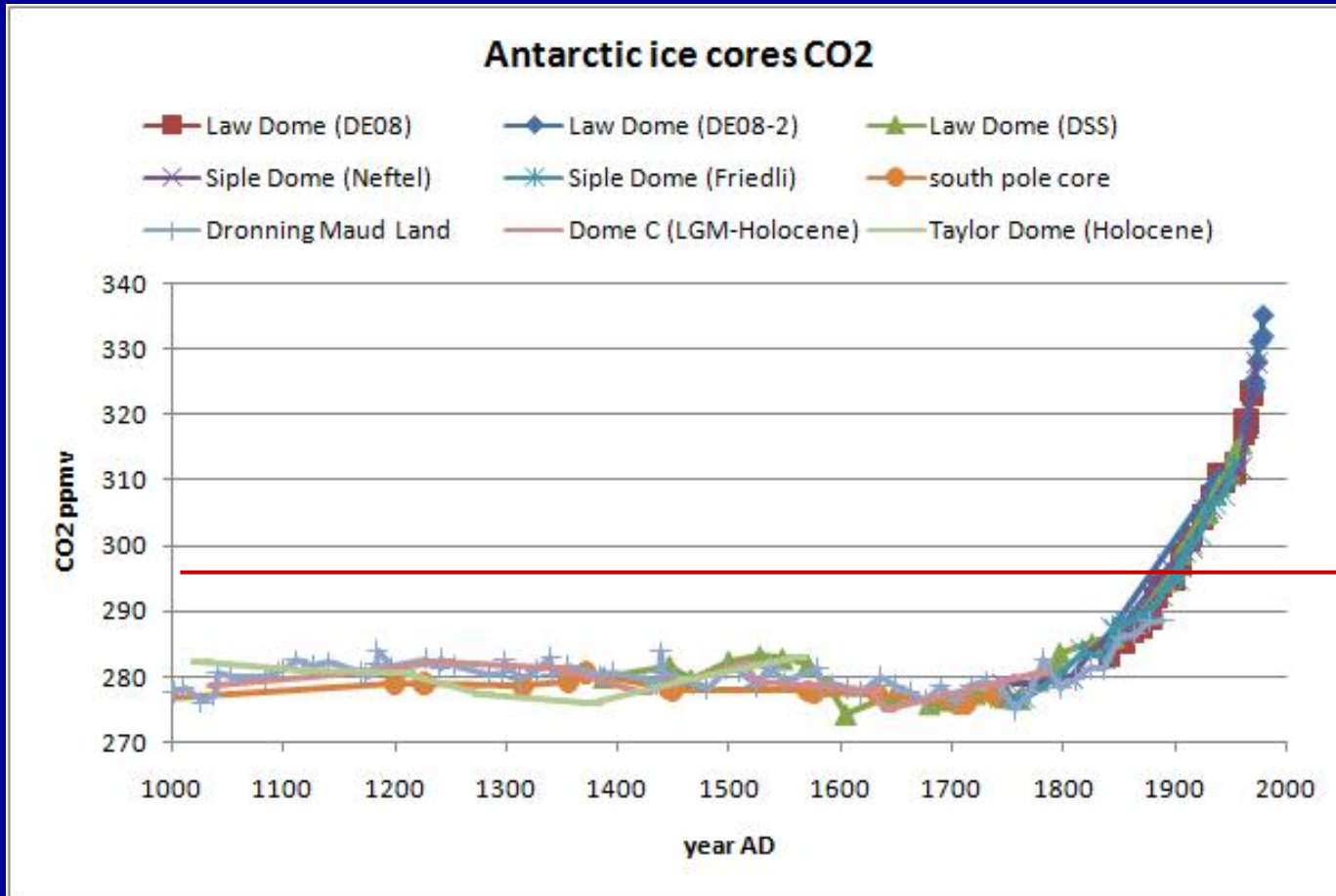
Way too much CO₂!!

Atmospheric CO₂ rates

Volcanoes: 0.13 to 0.44 billion tons per year

Human activities: 35 billion tons (2010)

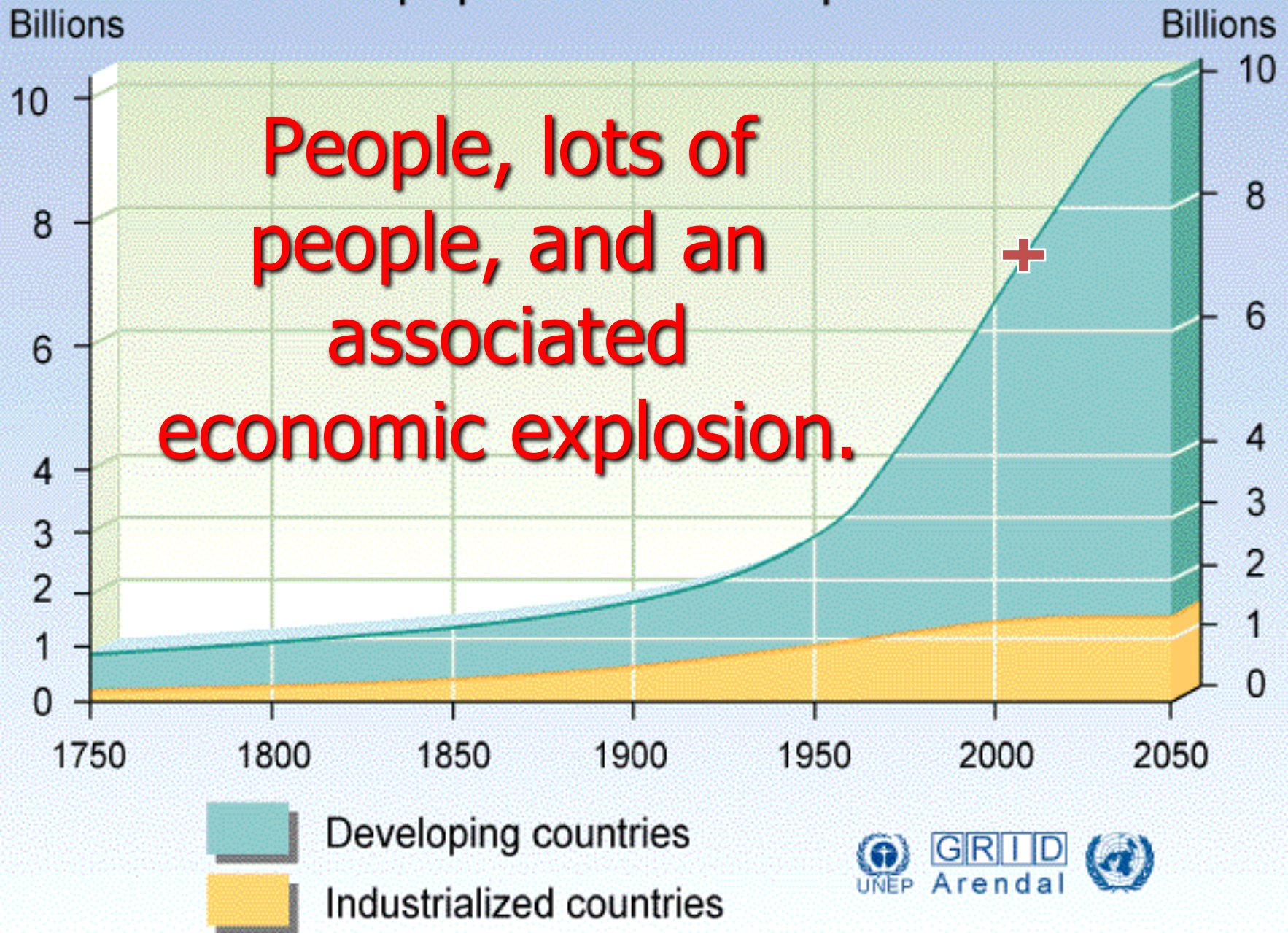
It's not volcanoes!



red lines indicate
maximum for last
1/2 million years

Who is doing the burning? Apes, ants, elephants?

World population development



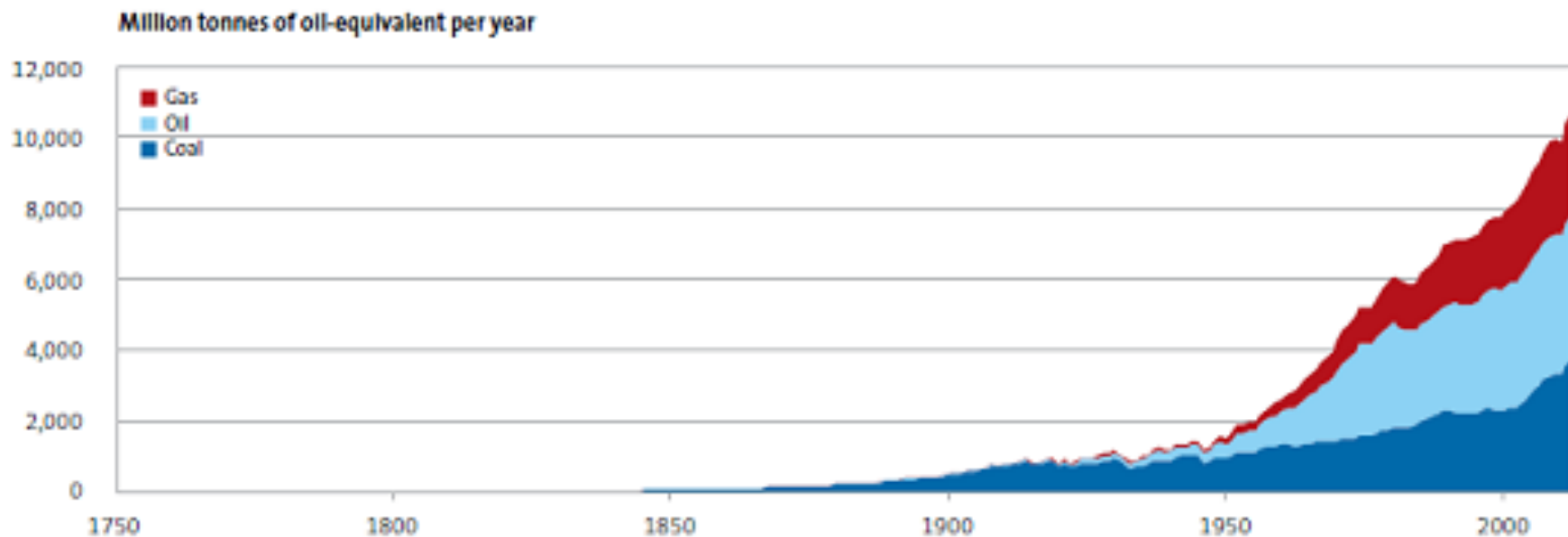
Coal and oil drove an amazing expansion of human possibilities



We have all benefitted greatly and don't want to lose what we have gained.

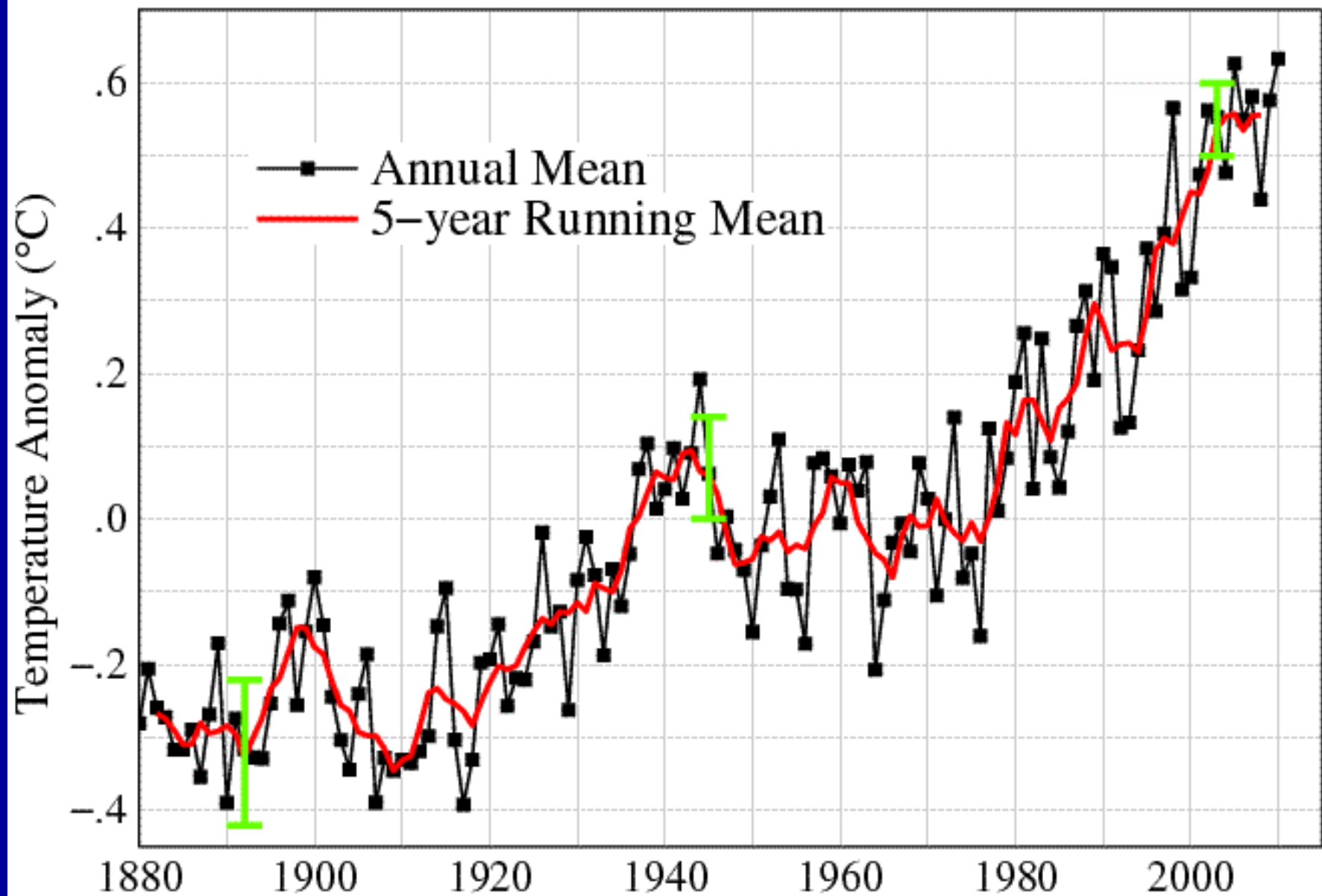
The use of energy is a good proxy for economic development since we discovered fossil fuels and weaned ourselves off of whale oil.

Fig. 5.1: World fossil fuel consumption since 1750*



* Source: Tullett Prebon calculations and estimates from various sources

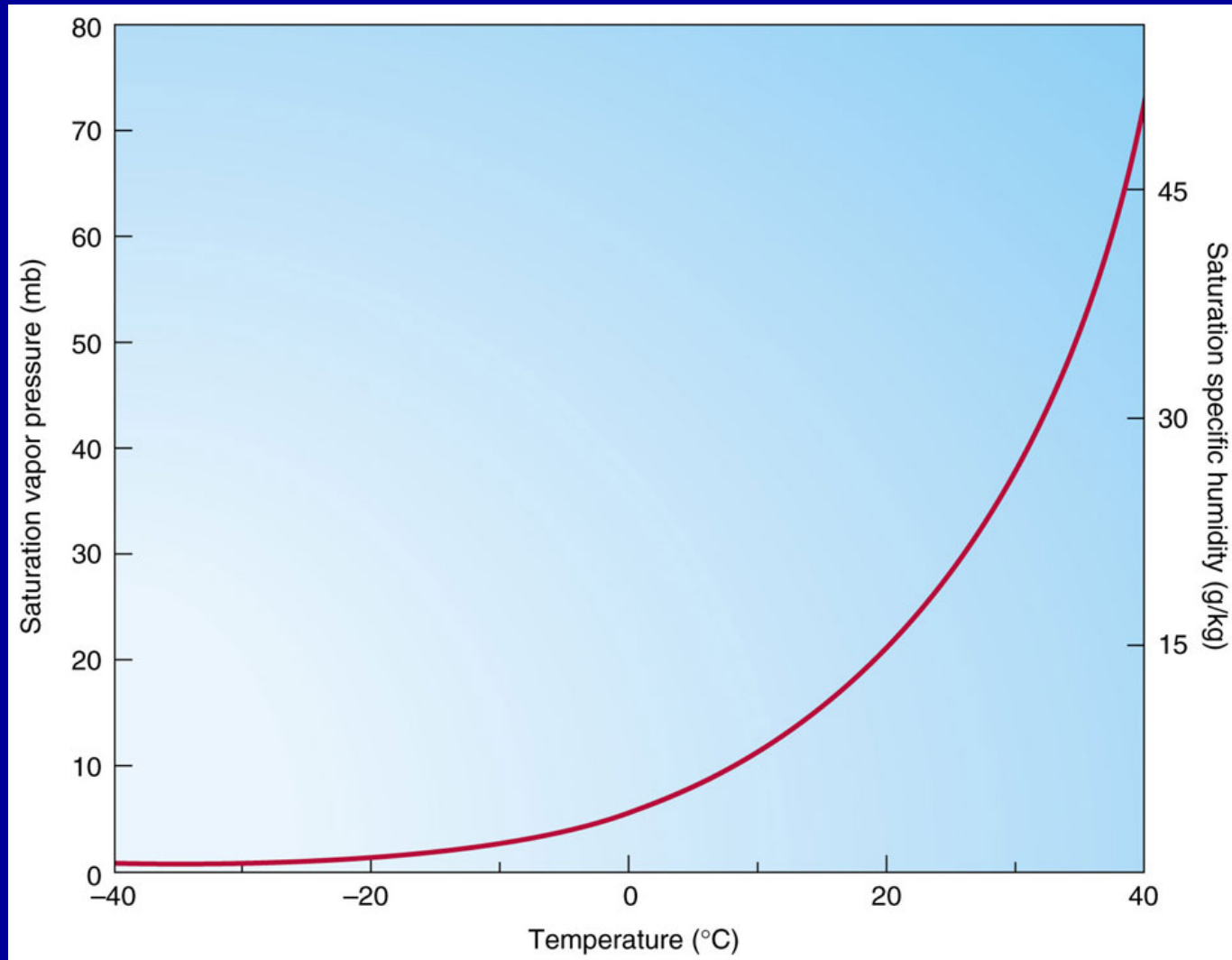
Global Land–Ocean Temperature Index



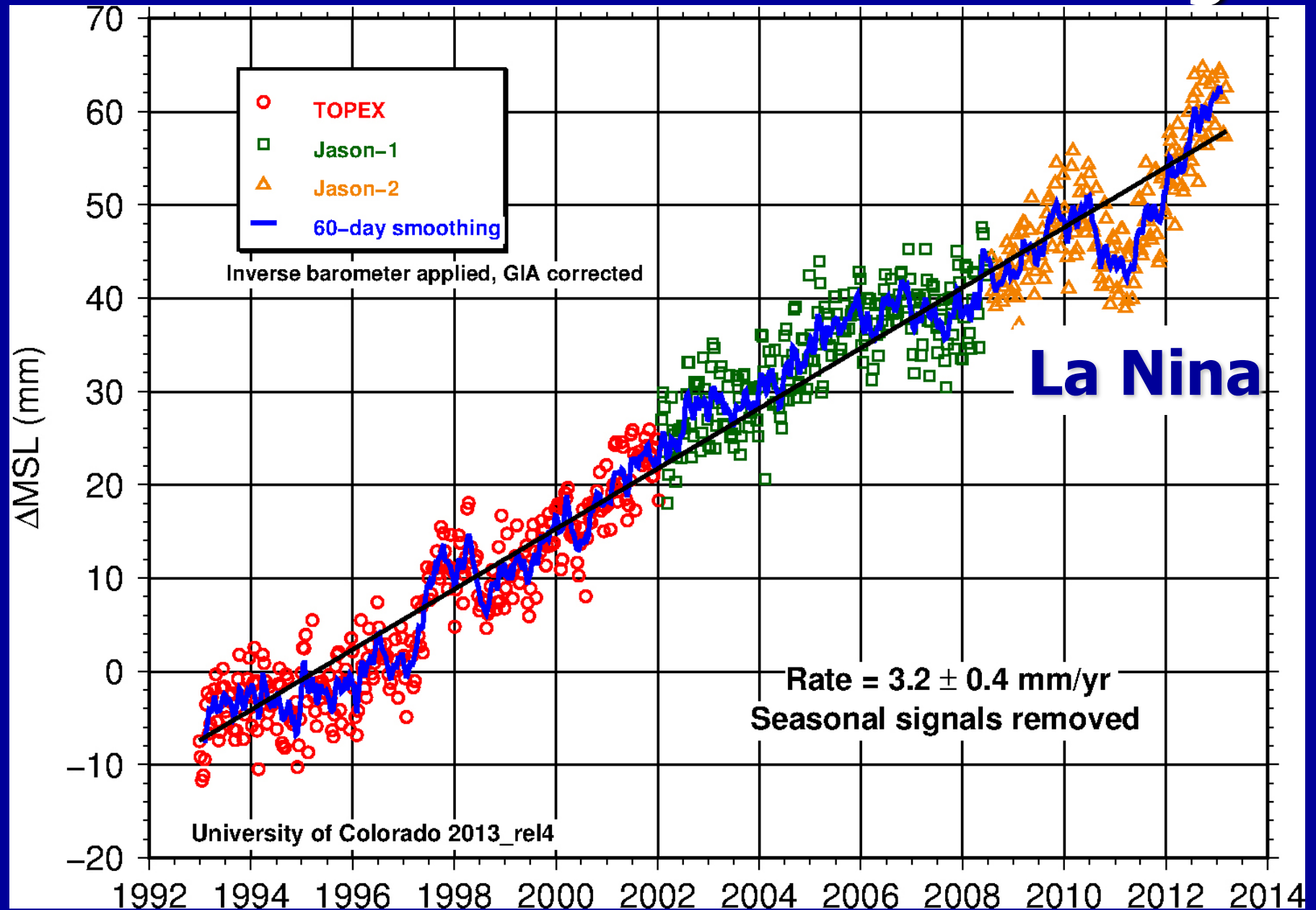
More energy – more instability

- Expect climatic instability
 - Droughts and floods
- Expect rising sea levels (time to adapt)
 - Sandy, Katrina
- Expect heat waves
 - France 2003 - 70,000 deaths
 - Dehydrated the grapes
 - Tropical diseases
 - Fires (Australia now typically above 40 °C in summer – 104 °F)

Water vapor vs. temperature



This measurement is amazing



Where did the water go?

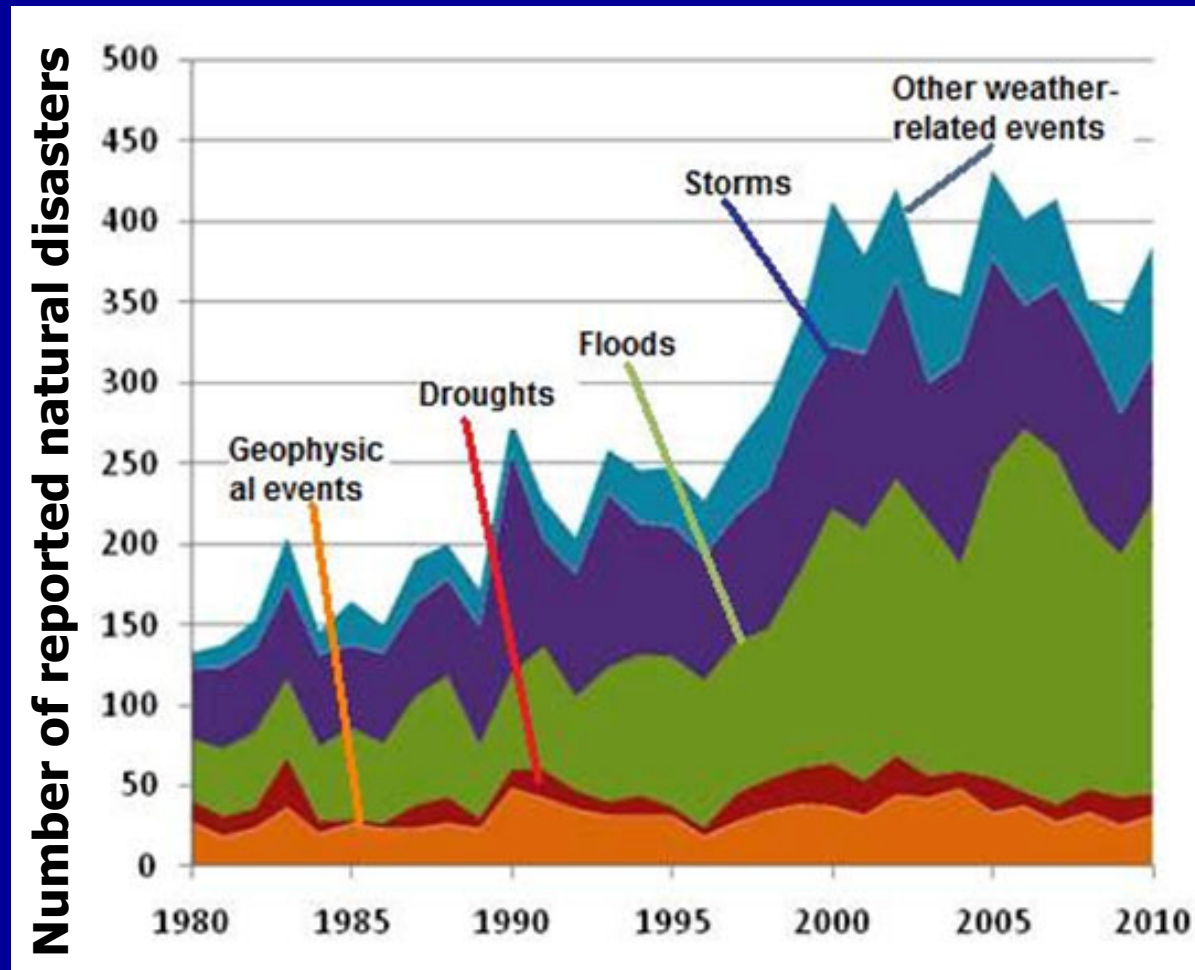


Bangkok, Thailand



Australia

Too much water



Trends in number of reported natural disasters

World meteorological organization:

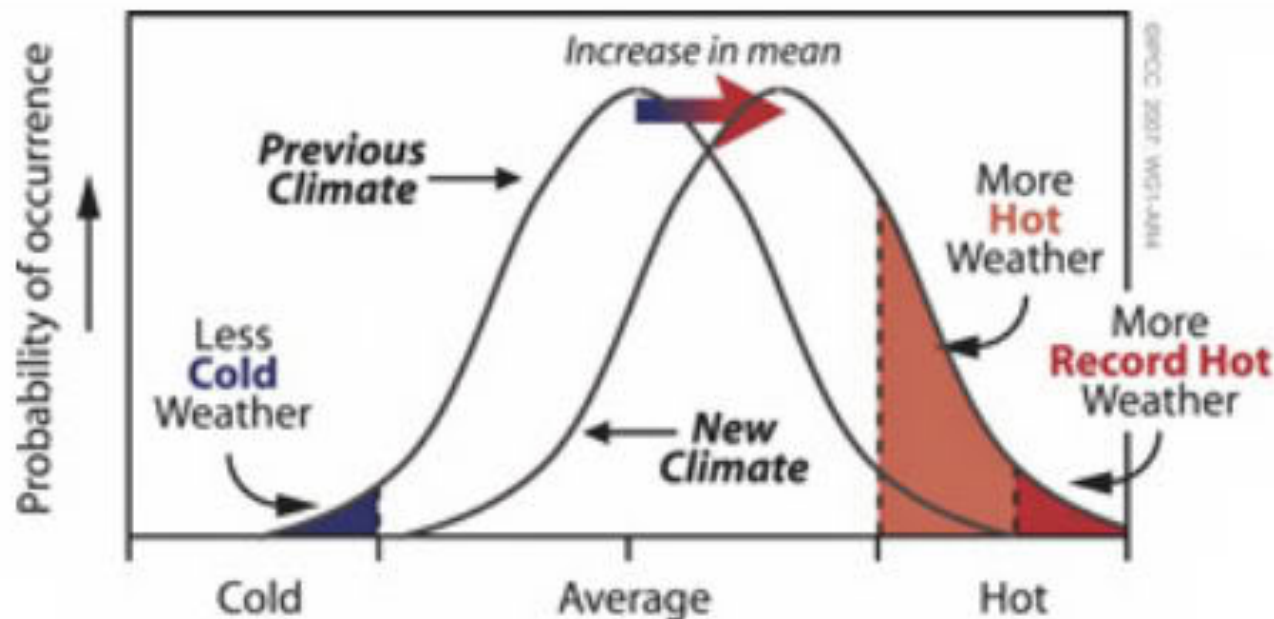
http://www.itu.int/net/newsroom/wrc/2012/features/natural_disasters.aspx

Global warming cannot be “blamed” for any individual storm.

Weather happens.

However, warming can be indicted for shifting the distribution and increasing the probability of storms of a specific intensity.

Climate Change Shifts the Odds for Extreme Weather Events



Solomon et al. 2007

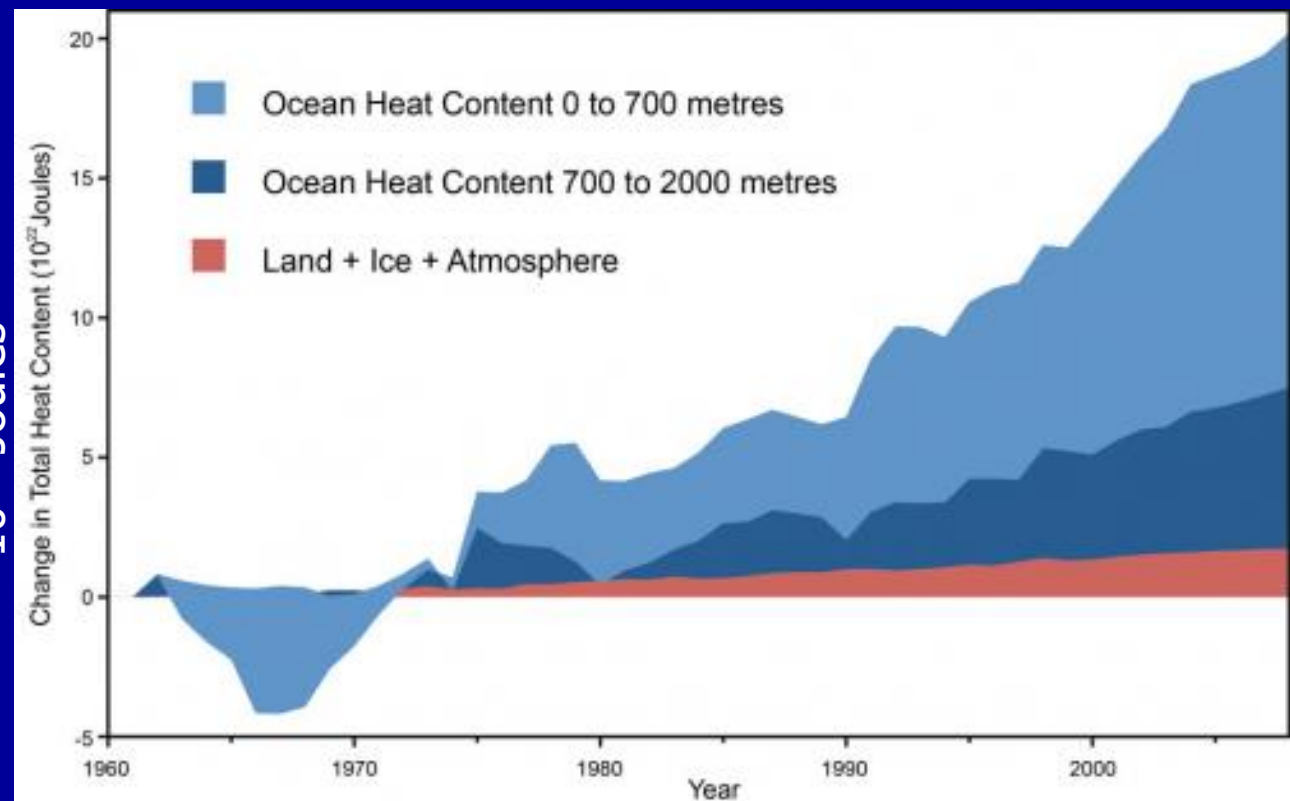
Excess heat is prodigious

Our climate is accumulating
4 Hiroshima atomic bombs
worth of extra heat every second.

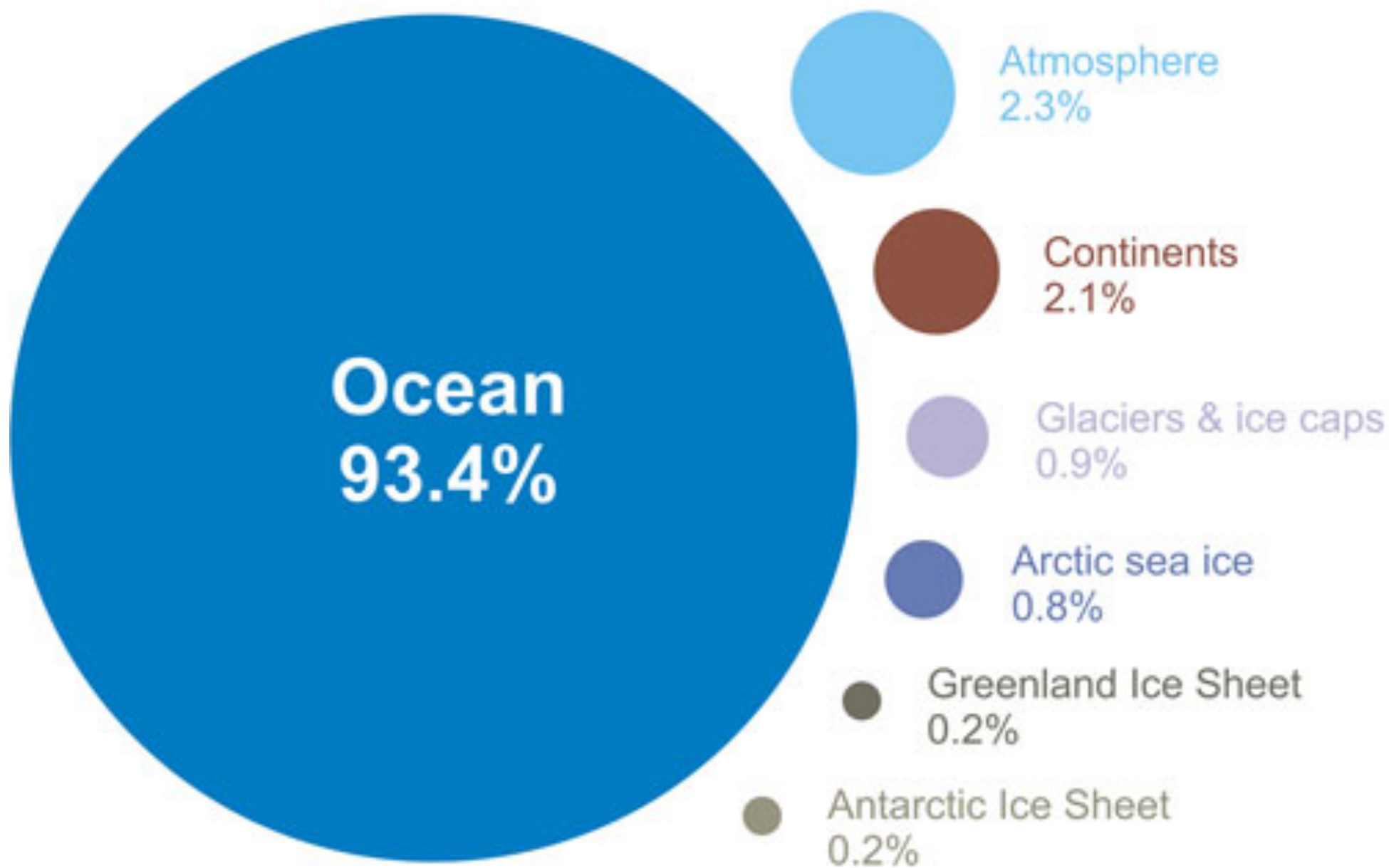


90% of the
energy is
going to heat
the oceans;
the rest
heats the
land and air.
A few % is
melting ice.

10²² Joules



Where is global warming going?



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



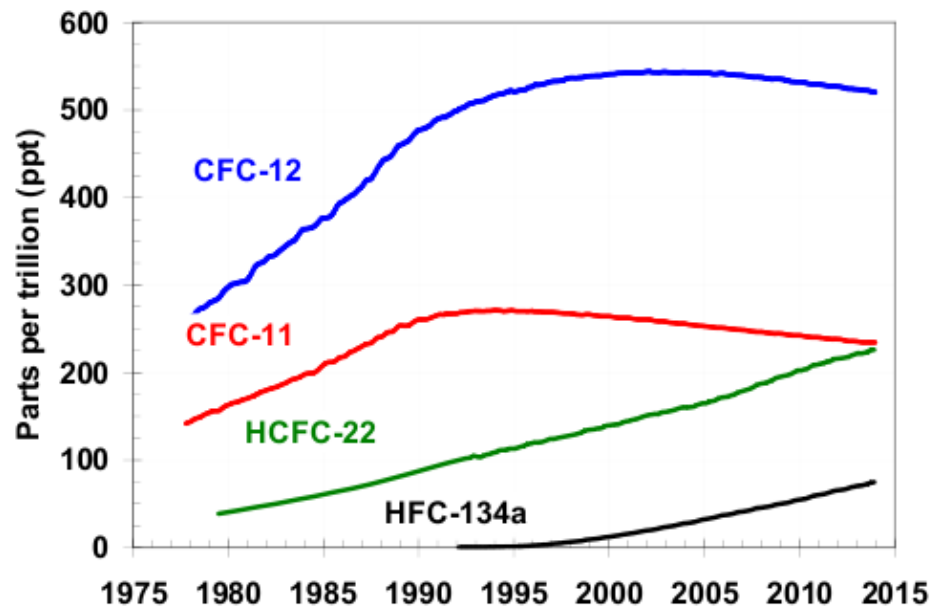
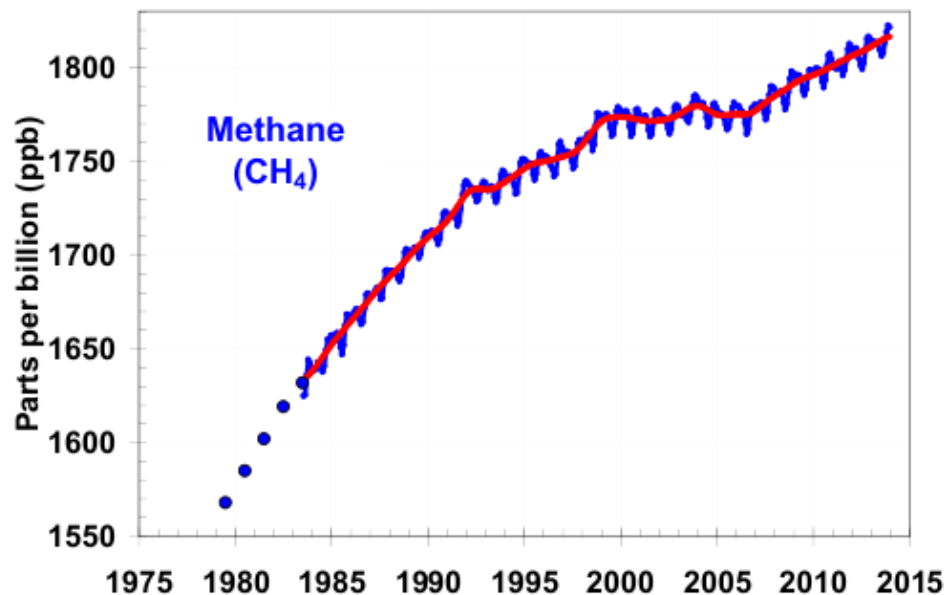
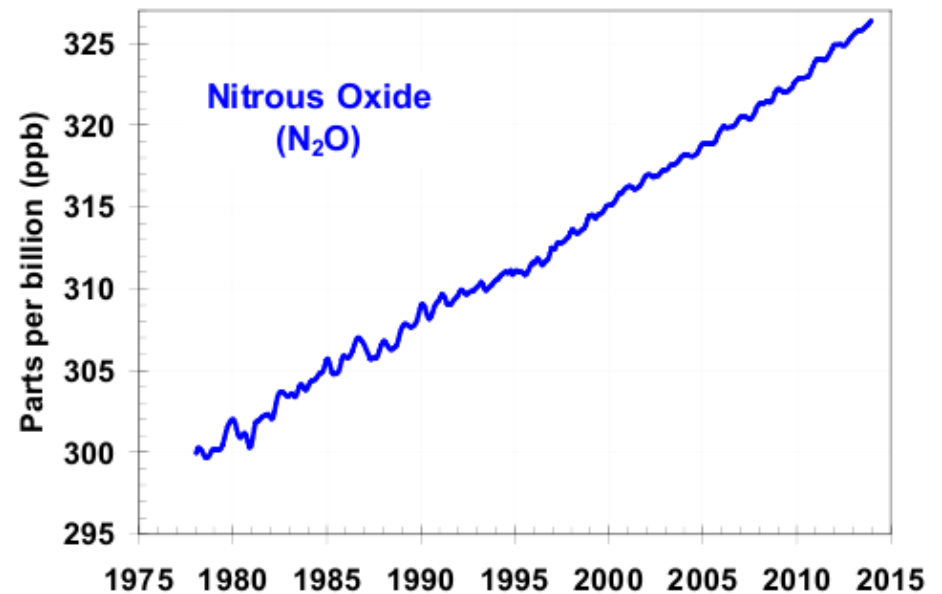
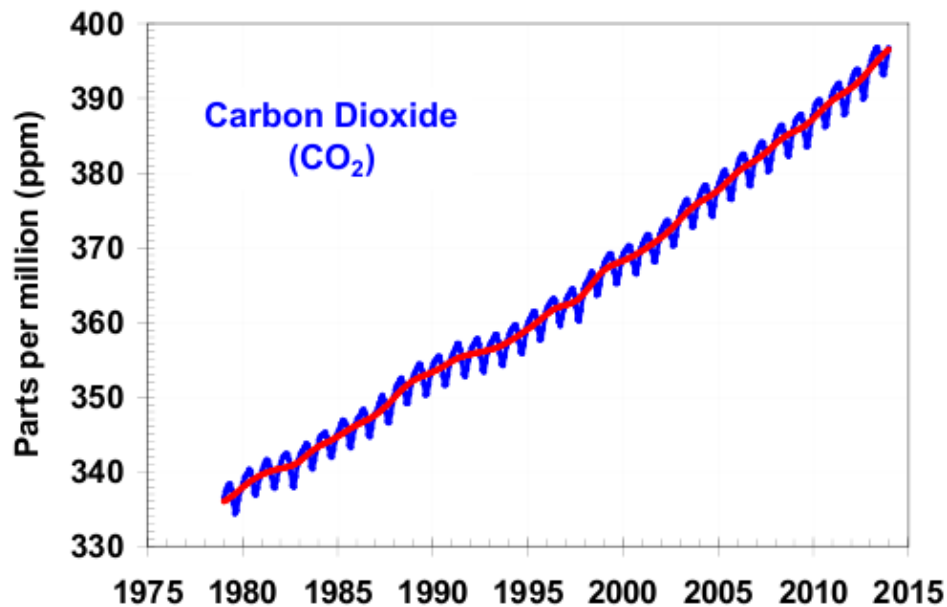
UCAR

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

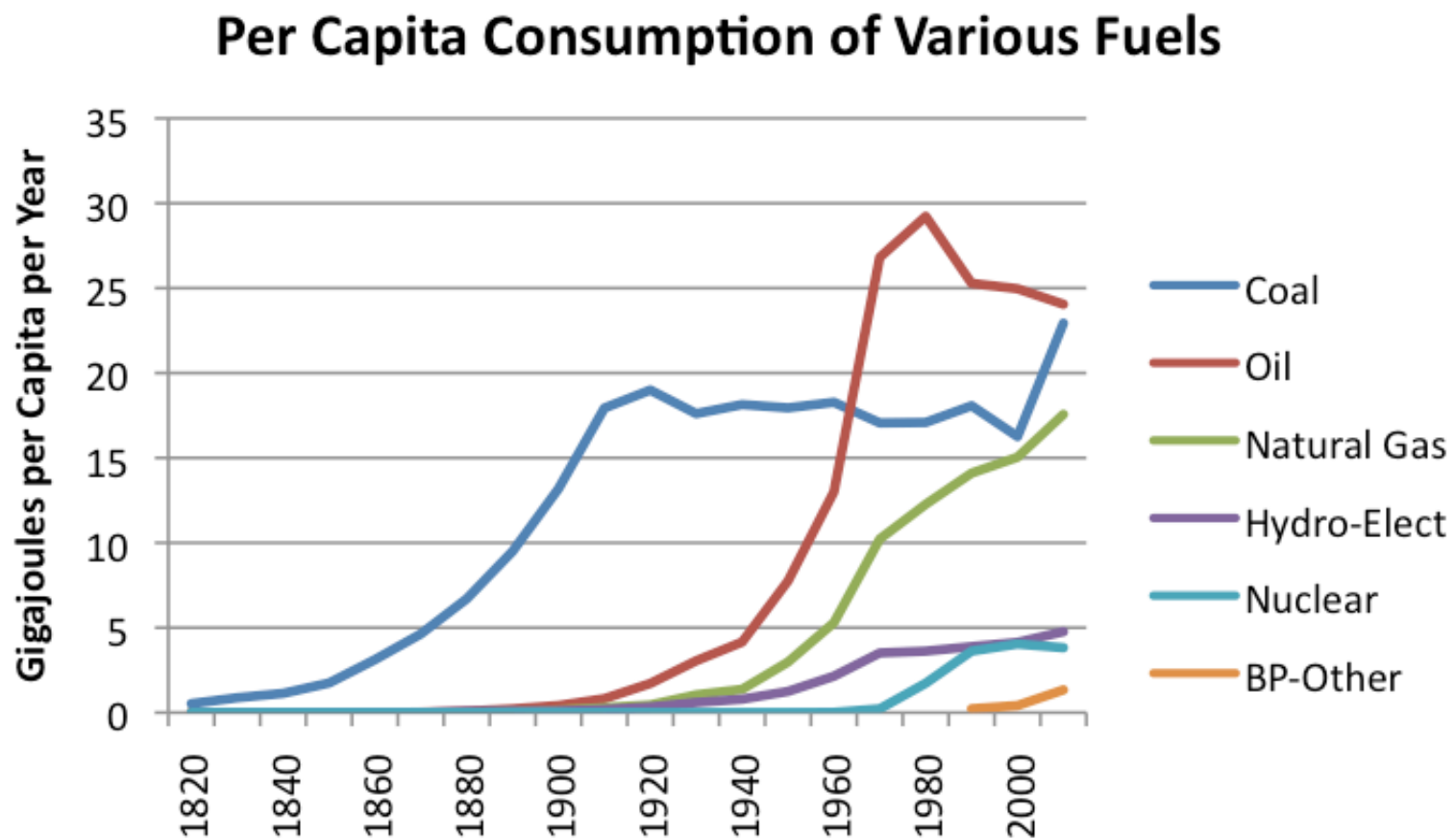


UCAR

Greenhouse gas (GHG) trends

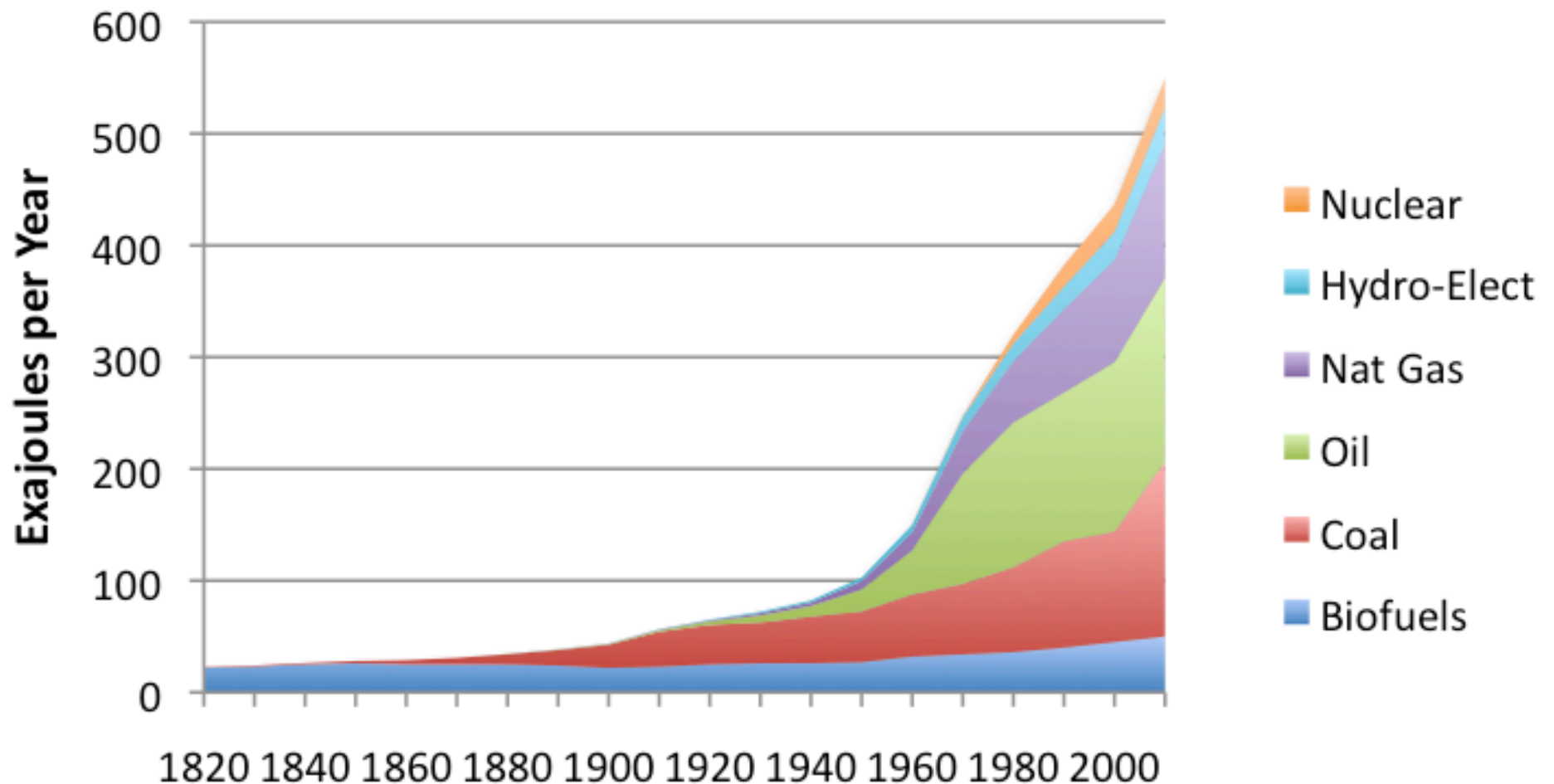


Energy footprint



Energy consumption rises

World Energy Consumption



It's a complex business

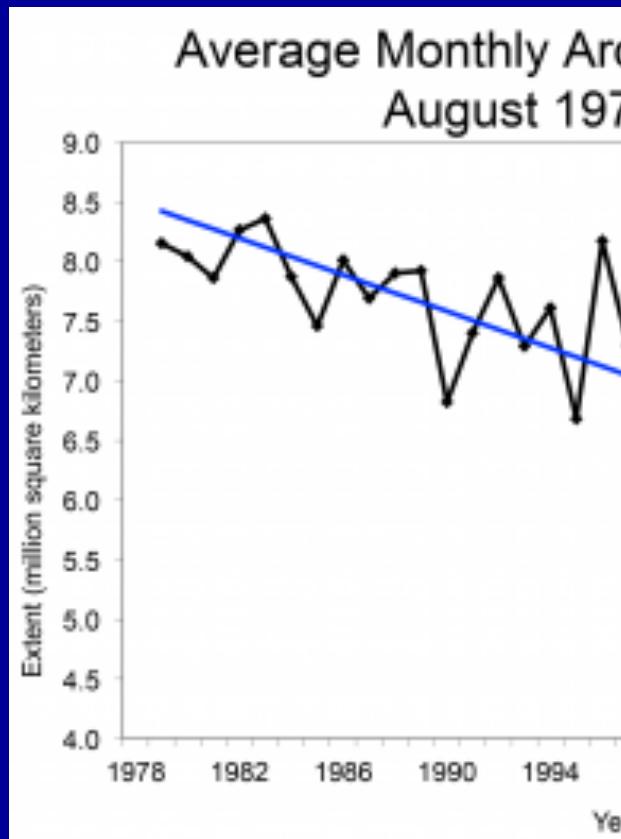
- Climate science is multi-disciplinary
 - Astrophysics, physics, chemistry, geology, fluid dynamics, etc.
- Now add the human social and geopolitical aspects of the problem etc.
- It's an interesting complex problem keeping the mind of an old man active.

What to do?

Save and conserve ancient hydrocarbons - priority uses!

- Convert to renewables: (wind, solar, tides, nuclear)
- Price carbon, incentivize markets
 - Citizen's Climate Lobby (CCL) Carbon Fee and Dividend
- Use less energy (your favorite here)
 - LED bulbs
 - Eat vegan, eat local, grow local
 - Recycle
 - Plant trees
- Develop sustainable economics

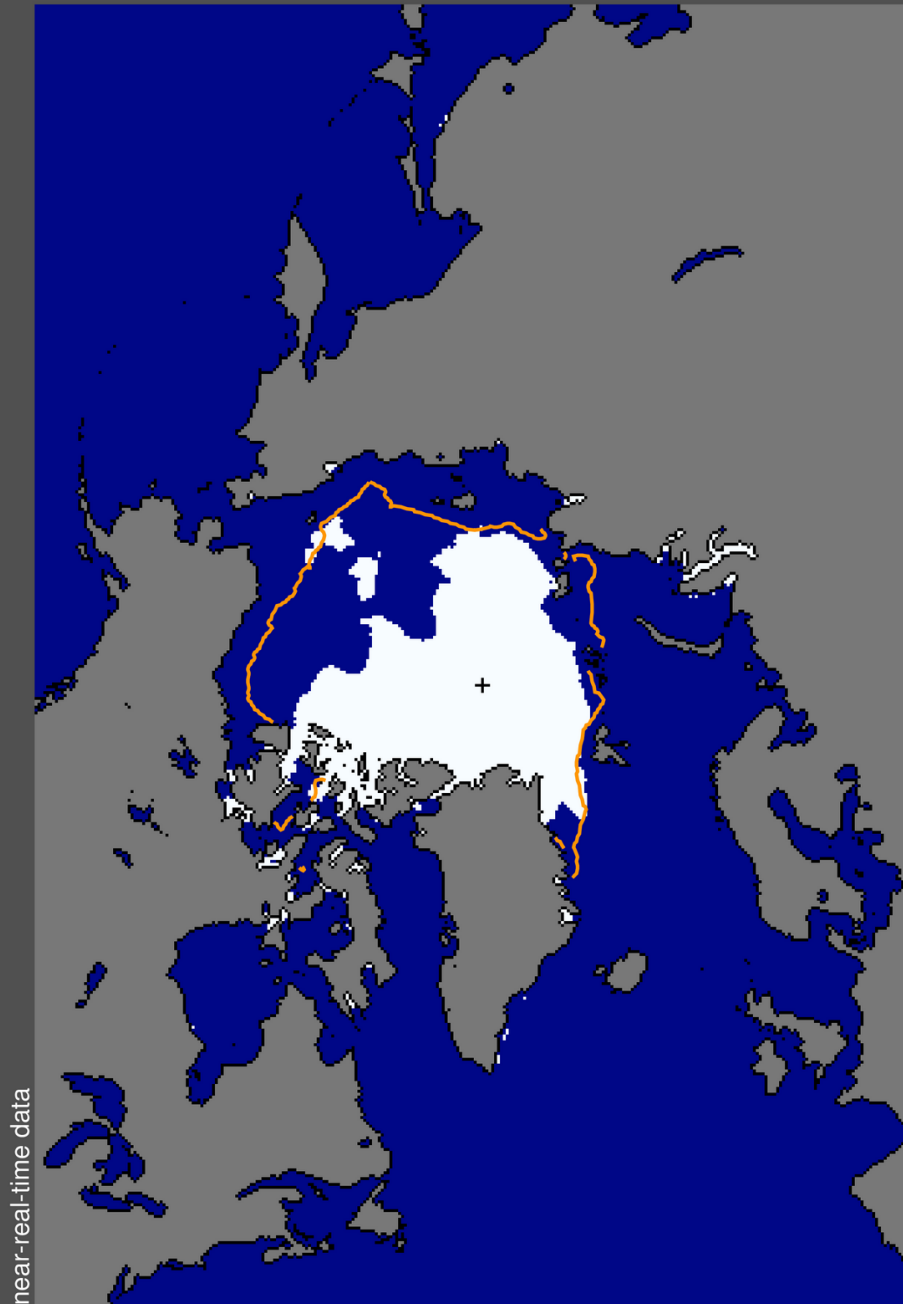
Here is t



From the National

<http://nsidc.org/a>

Sea Ice Extent
09/10/2016

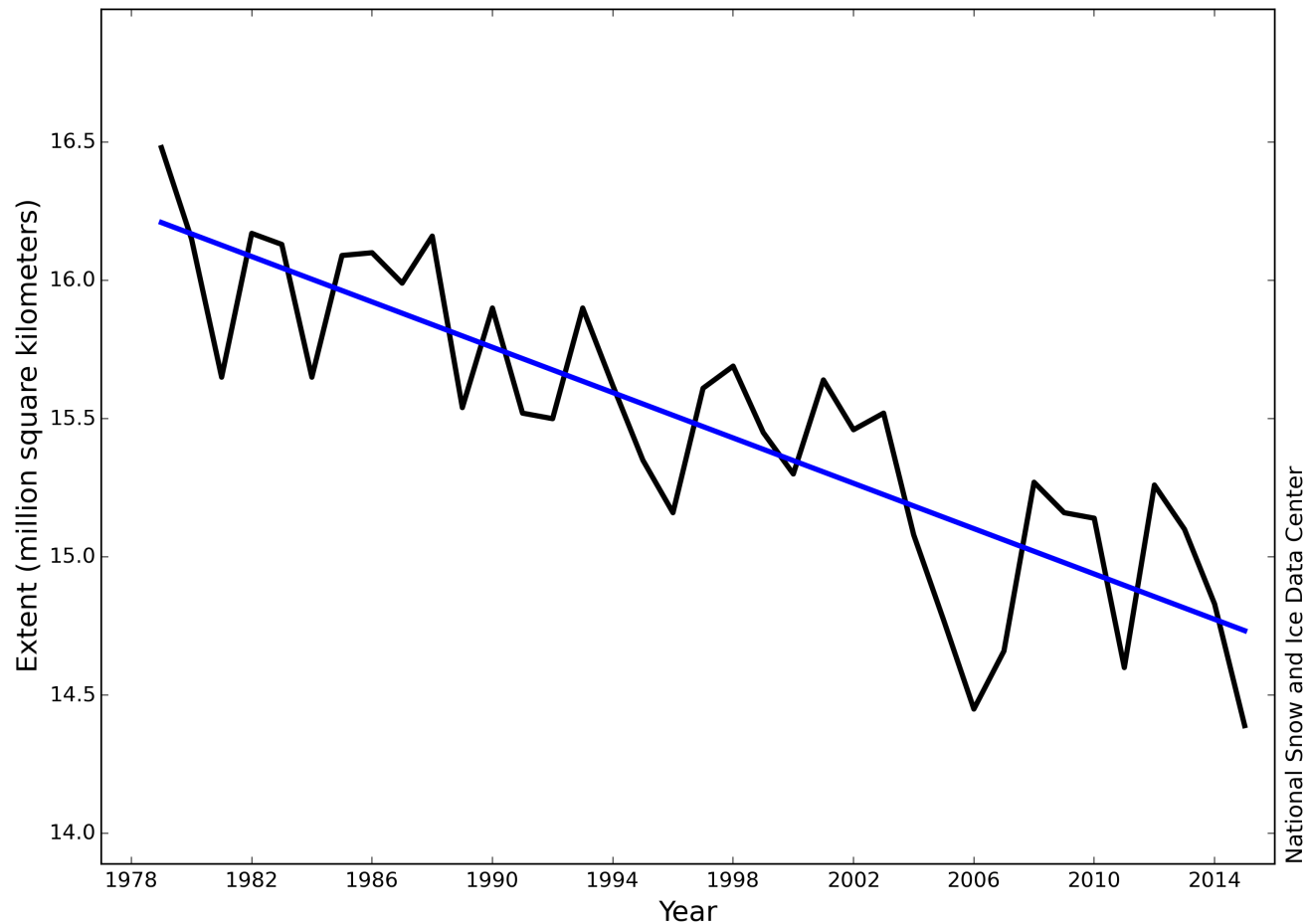


National Snow and Ice Data Center, Boulder, CO

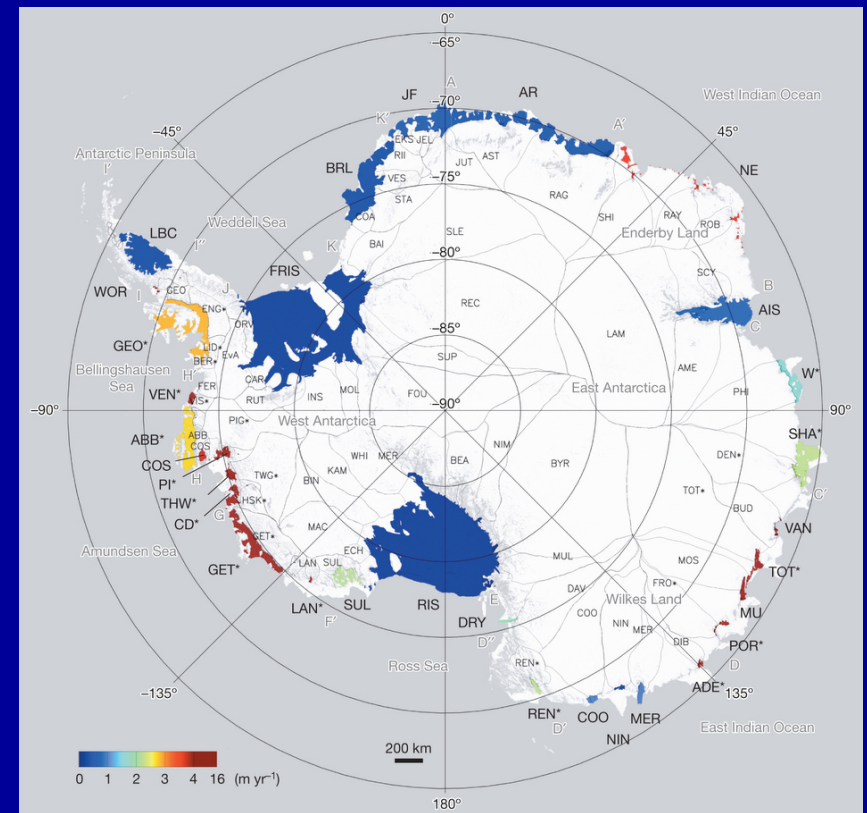
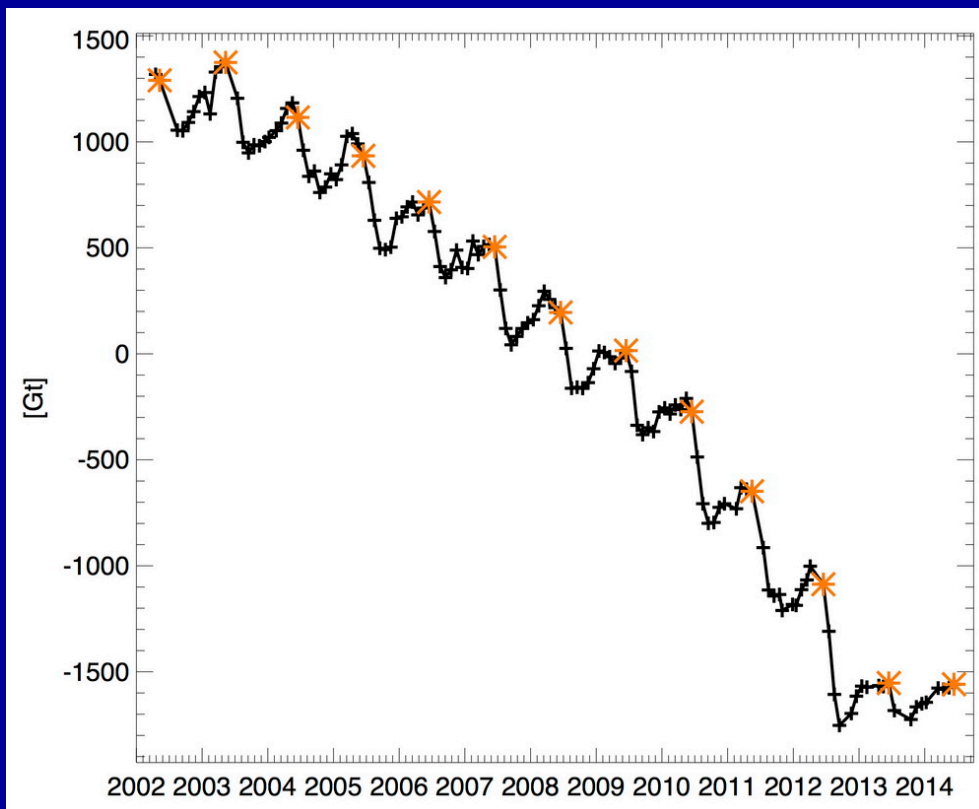
median
1981-2010

Arctic Sea Ice Extent

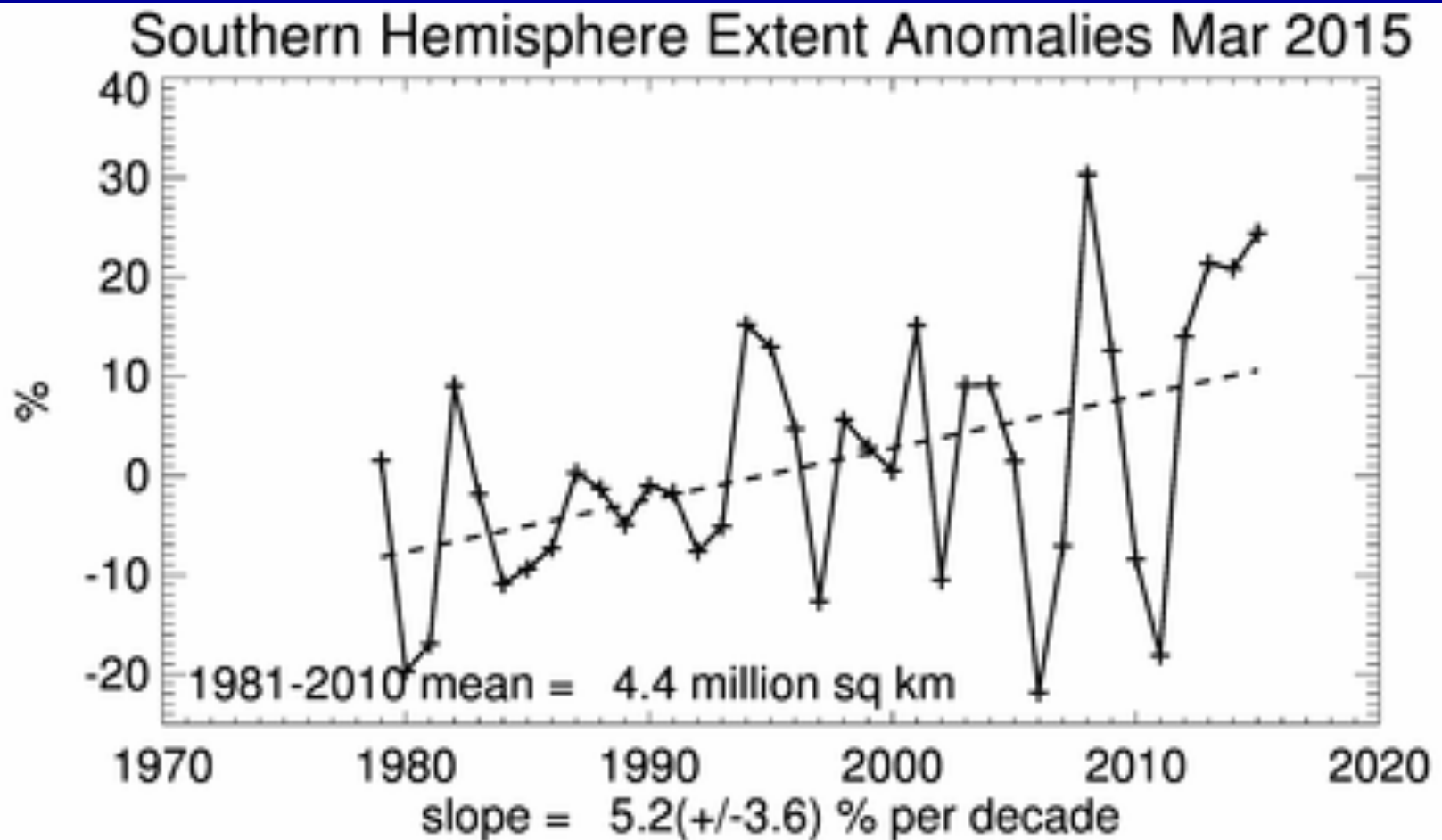
Average Monthly Arctic Sea Ice Extent
March 1979 - 2015



Antarctic land ice



Antarctic sea ice extent??



Antarctic Sea ice grows, and sea surface temp increases

Why? The simple explanation is that fresh water from melting ice freezes more easily than salty water. So as the continental ice melts, it goes into the surrounding sea and freezes.

Therefore:

More continental melt -> growing sea ice.

Complex interactions of land, sea and air: increasing melt adding fresh water, increasing winds forcing surface currents around the continent, faster currents, larger Coriolis effect, role of eddies, overturning convection currents, etc. combine to make this beyond the ability of current models.

The Bottom Line

- Global warming is real.
- It's caused by us (burning ancient hydrocarbons, cutting down forests, land use changes, etc.)
- It's bad; temperature has risen & will keep rising.
 - We don't know exactly how bad but we do know the CO₂ stays around for hundreds of years!
- This science is simple and well understood.
 - Scientists really do agree about this!
- There's hope.
 - We can and must do something about it.

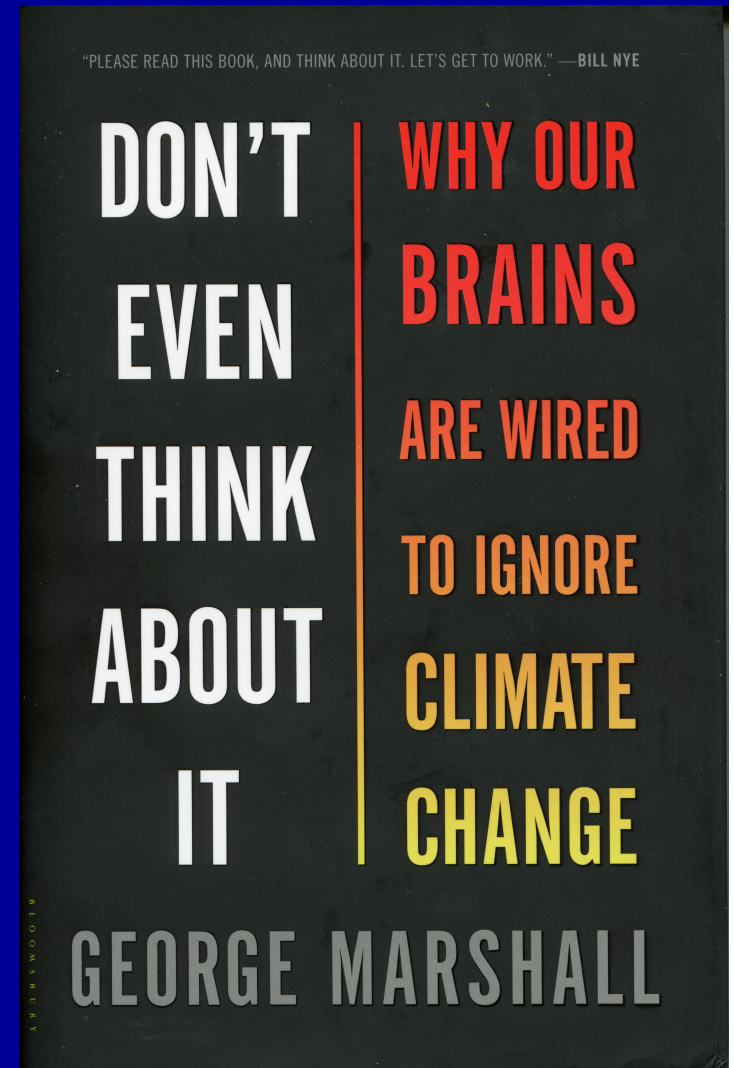
Why can't we convince everyone about climate change?

For this see the book

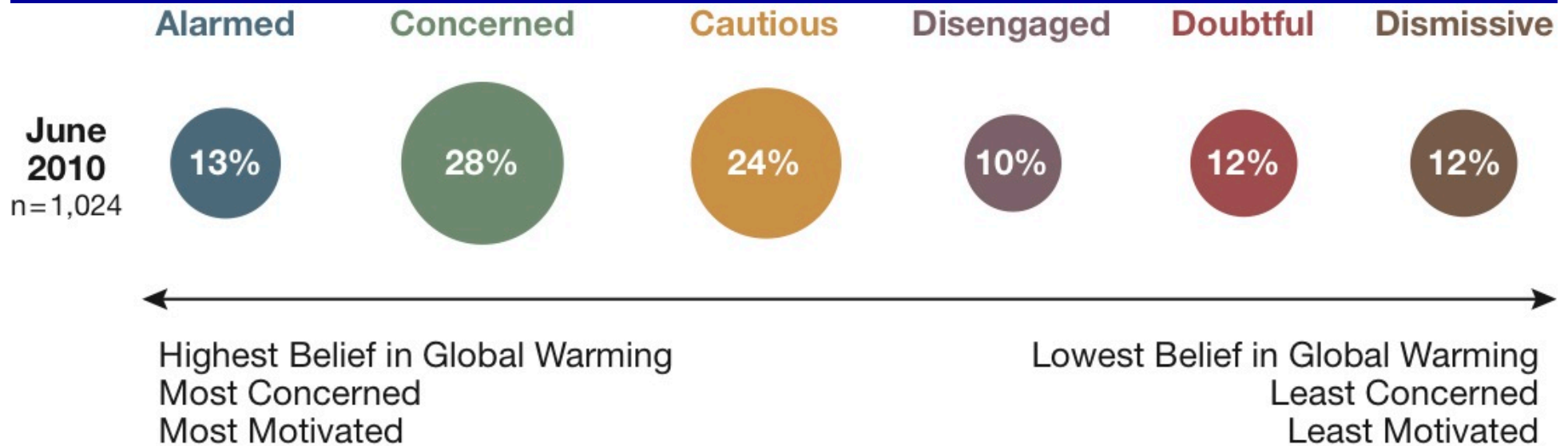
*Don't Even Think About It;
Why Our Brains Are Wired
to Ignore Climate Change*

by George Marshall
(2014, Bloomsbury)

It's a fascinating read and
sociologically important.



Where are you on this scale?

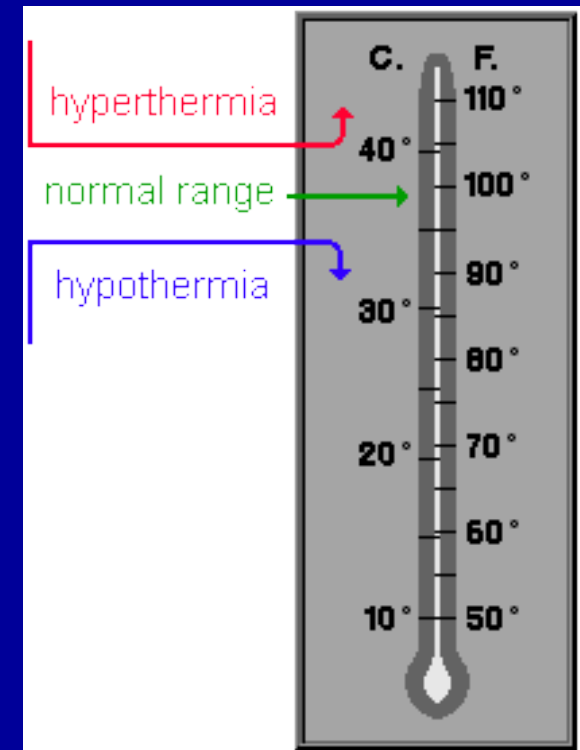


Proportion represented by area

Source: Yale Project on Climate Change Communication

What is the point?

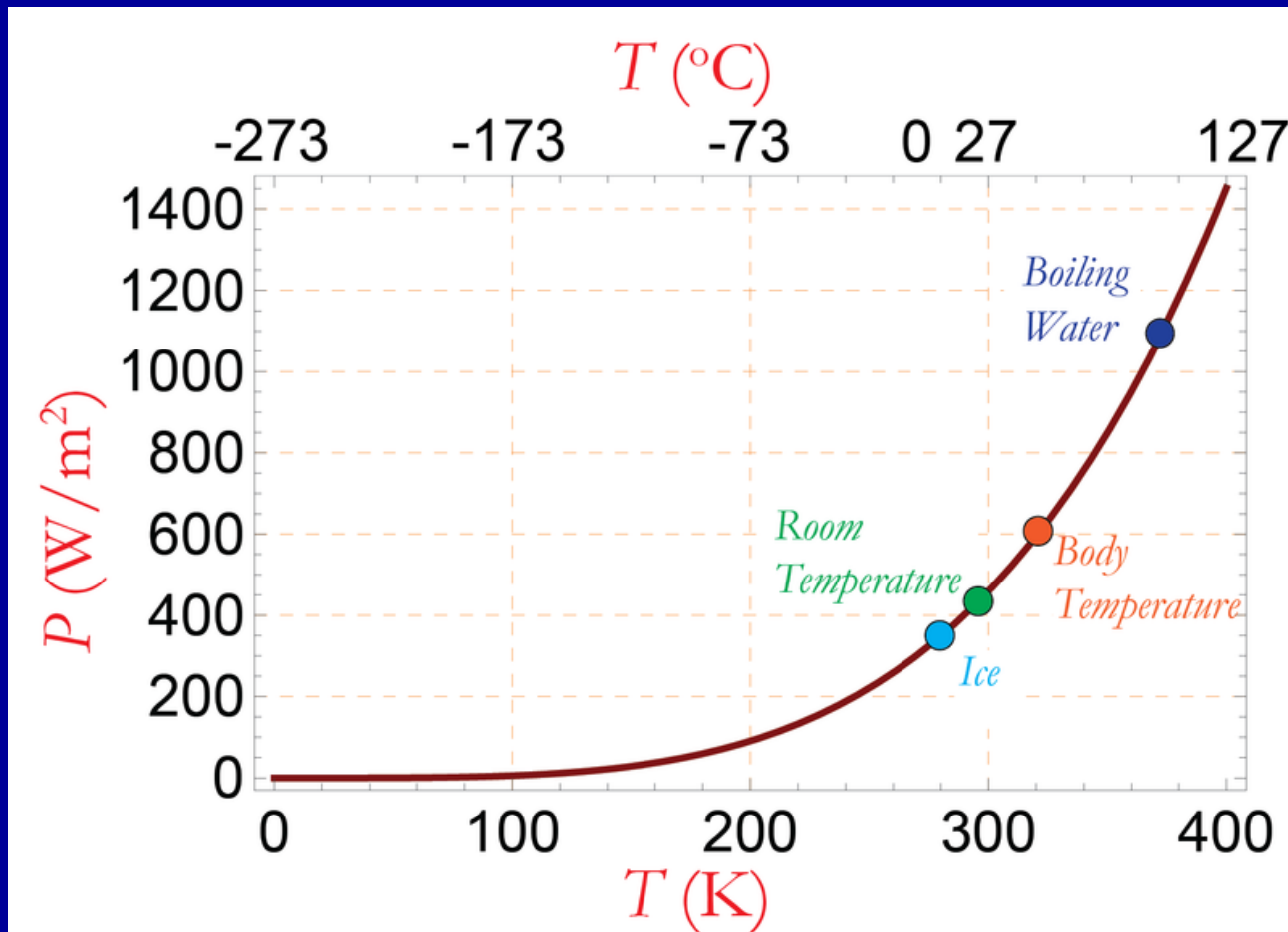
- Make people feel guilty?
- Make people reduce their lifestyle?
- Stop the poisoning of the atmosphere?



Unite humanity in a common cause.

The human zone

$$\text{Power emitted} = \sigma T^4$$



- Awareness of Earth from the 1960s

- Almost 50 years
- Earthrise photo 1968
- Earth Day 1970



- People may feel threatened, hopeless, anxious, guilty, avoidant, thoughtful, challenged,

- When did you first become aware climate change?
- What do you think now?
- What are your feelings?

Reasons for optimism?

- Impacts are probably manageable
- There is time to do something
- Change is happening (cost of solar panels)
- The human species is not at risk (at least from climate change directly)
 - All species go extinct eventually
- Mass migrations have happened before
- We have an incredible ability to adapt