

# Climate Change – A Few Key Facts You Probably Don't Know



A brief talk at Santa Cruz High School to  
the Central Coast Coalition of  
Environmental Clubs

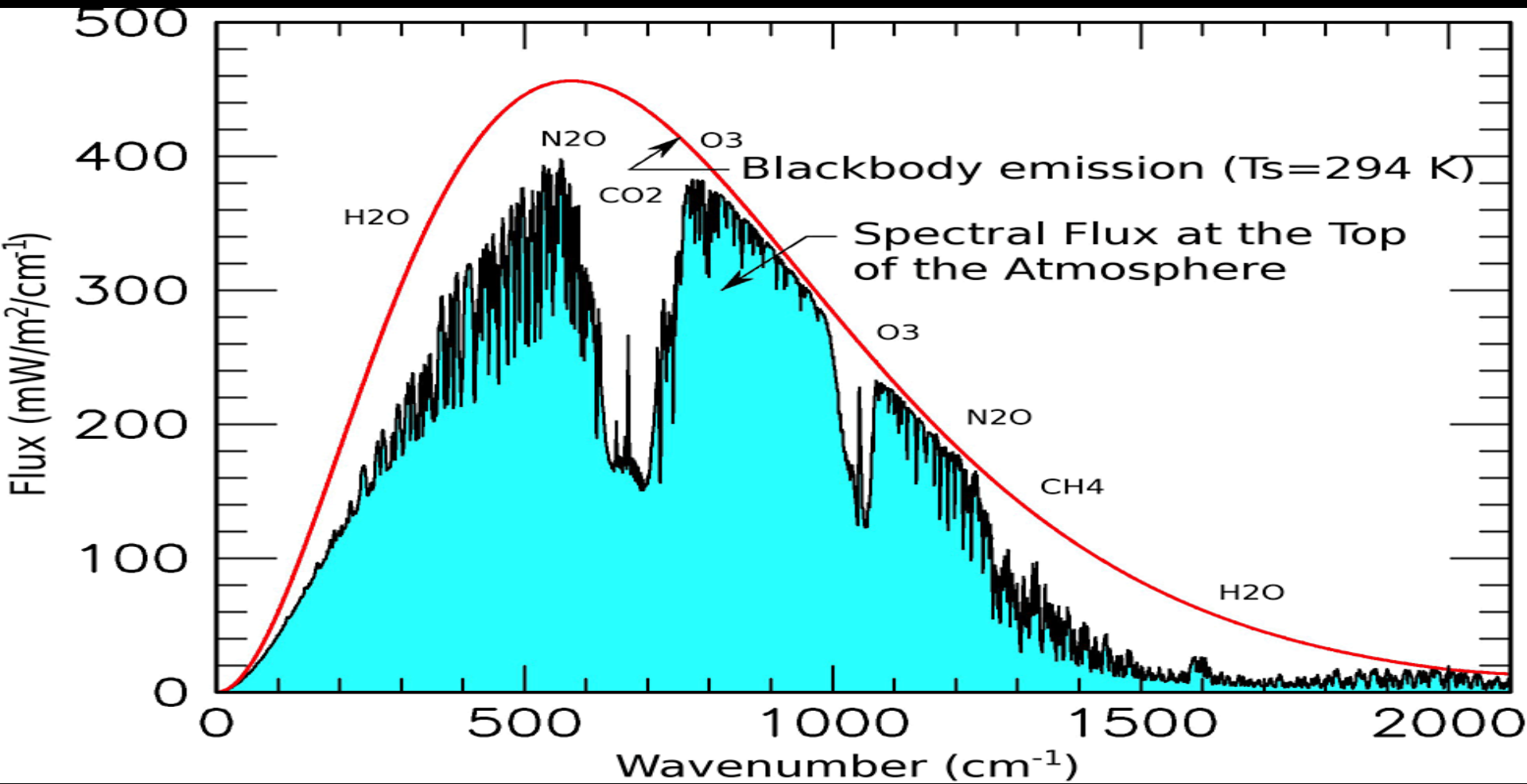
May 20, 2017

# First, Who am I?

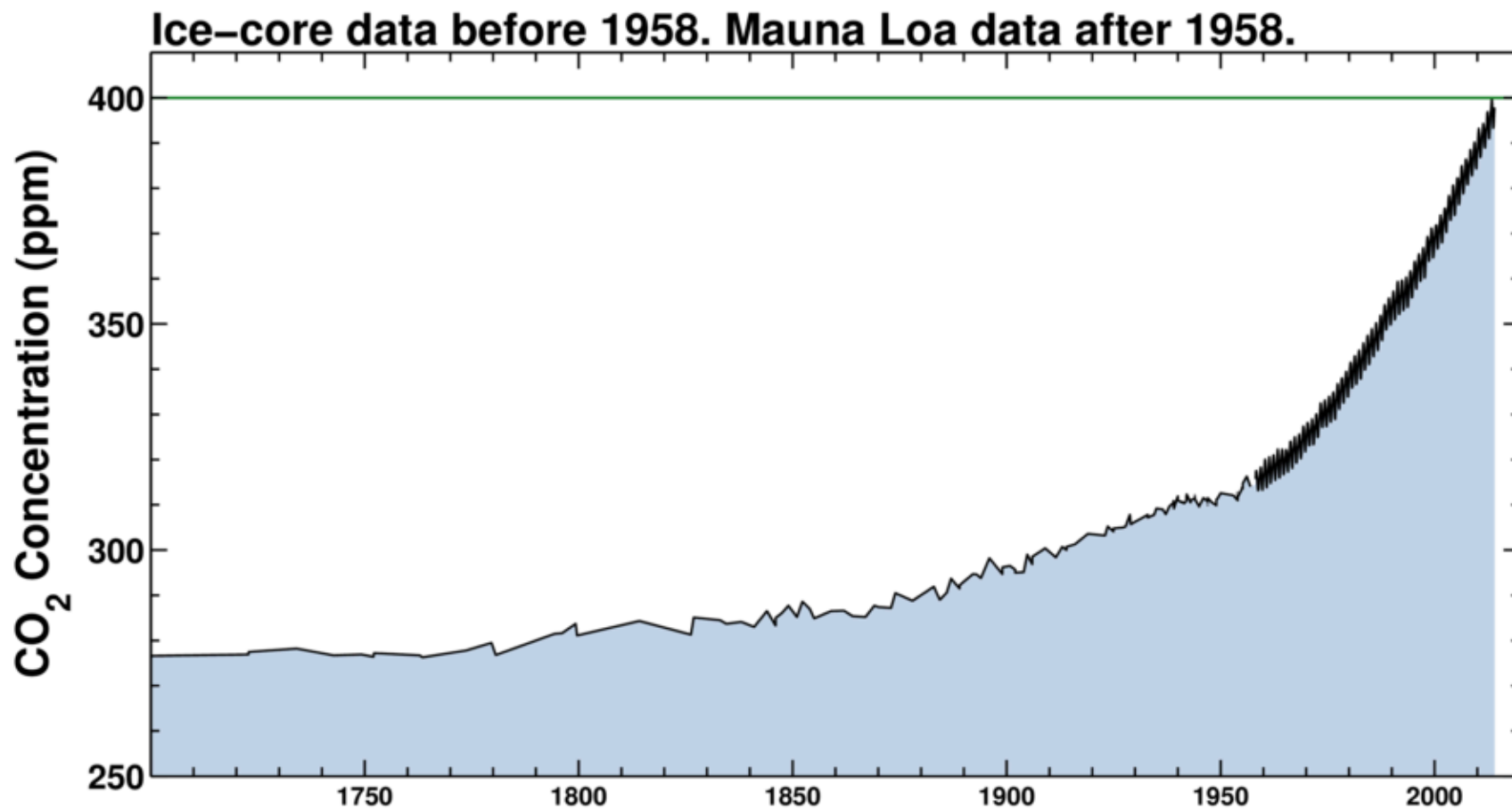
Rick Nolthenius – Chair of the Astronomy Department  
at Cabrillo College

- M.S. Aerospace from U. Arizona
- PhD Astronomy and Astrophysics from UCLA
- Thermal analyst and designer in the Atlas/Centaur Rocket Program at General Dynamics – Convair Space Division
- For the past 7 years, my prime focus has been investigating and teaching planetary climate and especially current Earth Climate Change

**The Greenhouse Effect: Sunlight comes in at short wavelengths. The warmed Earth tries to radiate back to space to reach equilibrium temperature, but GHG's absorb those long wavelengths. CO2 is the Prime Driver of Climate Throughout Geologic History**



**Atmospheric CO<sub>2</sub> is 46% higher than pre-industrial levels – driven by human industrial emissions. Now at 410 ppm**



# Pop Quiz!

**If we could magically turn a key and end the entire planetary industrial civilization's GreenHouse Gas (GHG) emissions, What would Global Average Temperature Do?**

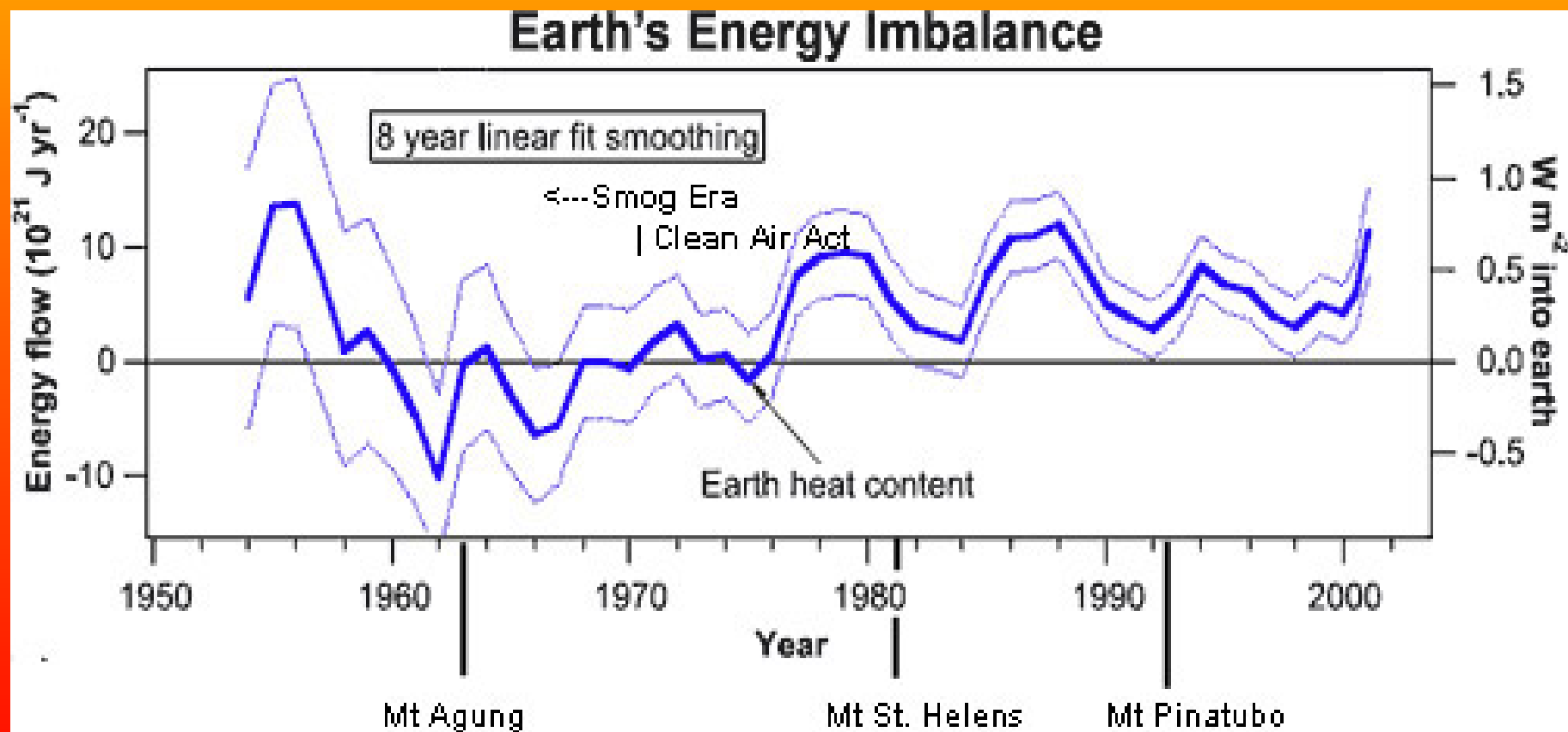
- A) continue to rise, for centuries, albeit at a slower rate than today, for centuries or longer
- B) stop rising, but instead stay constant at today's value
- C) Slowly decline. The Earth would heal, slowly
- D) Temperatures would reasonably quickly go back down, and would be back to pre-industrial temperatures by the end of the century

**Answer: (A)**

**Temperatures will  
continue to rise, for  
centuries or longer**

**Why?**

**1. The Earth hasn't yet caught up to be in equilibrium with the GHG's we've ALREADY emitted; so every square meter of Earth is able to radiate to space through our existing CO2 by fully 0.6 watts less than that square meter GETS from the sun.**



Picture every man, woman and child on the planet having not 2 hands, but 44 hands! And in every hand there is a 1000 watt hairdryer blowing hot air, running 24/7/365! That's how much heat we're adding to Earth, constantly because of our radiative disequilibrium. It's also = 4 Hiroshima Bombs per second

# 4 GLOBAL WARMING AT HIROSHIMA ATOMIC BOMBS PER SECOND

**GET THE WIDGET FOR BLOGS**      **UNDERSTAND THE SCIENCE**      **USE THE FACEBOOK APP**

Our climate is absorbing a lot of heat. When scientists add up all of the heat warming the oceans, land, and atmosphere and melting the ice, they find our climate is accumulating 4 Hiroshima atomic bombs worth of heat every second.

This warming is due to more heat-trapping greenhouse gases in the atmosphere. The burning of fossil fuels means we are emitting billions of tonnes of carbon dioxide every year. This is the main contributor to global warming.

To communicate the sheer amount of heat our planet is accumulating, we have created this widget, embeddable on blogs and also available as a Facebook app. To help get the word out on just how much global warming our planet is experiencing, add the widget to your own blog or use the widget on Facebook, like it and share it.

**GET THE WIDGET FOR YOUR BLOG**      **USE THE FACEBOOK APP**

Our climate has accumulated **2,037,065,708** Hiroshima atomic bombs of heat since 1998

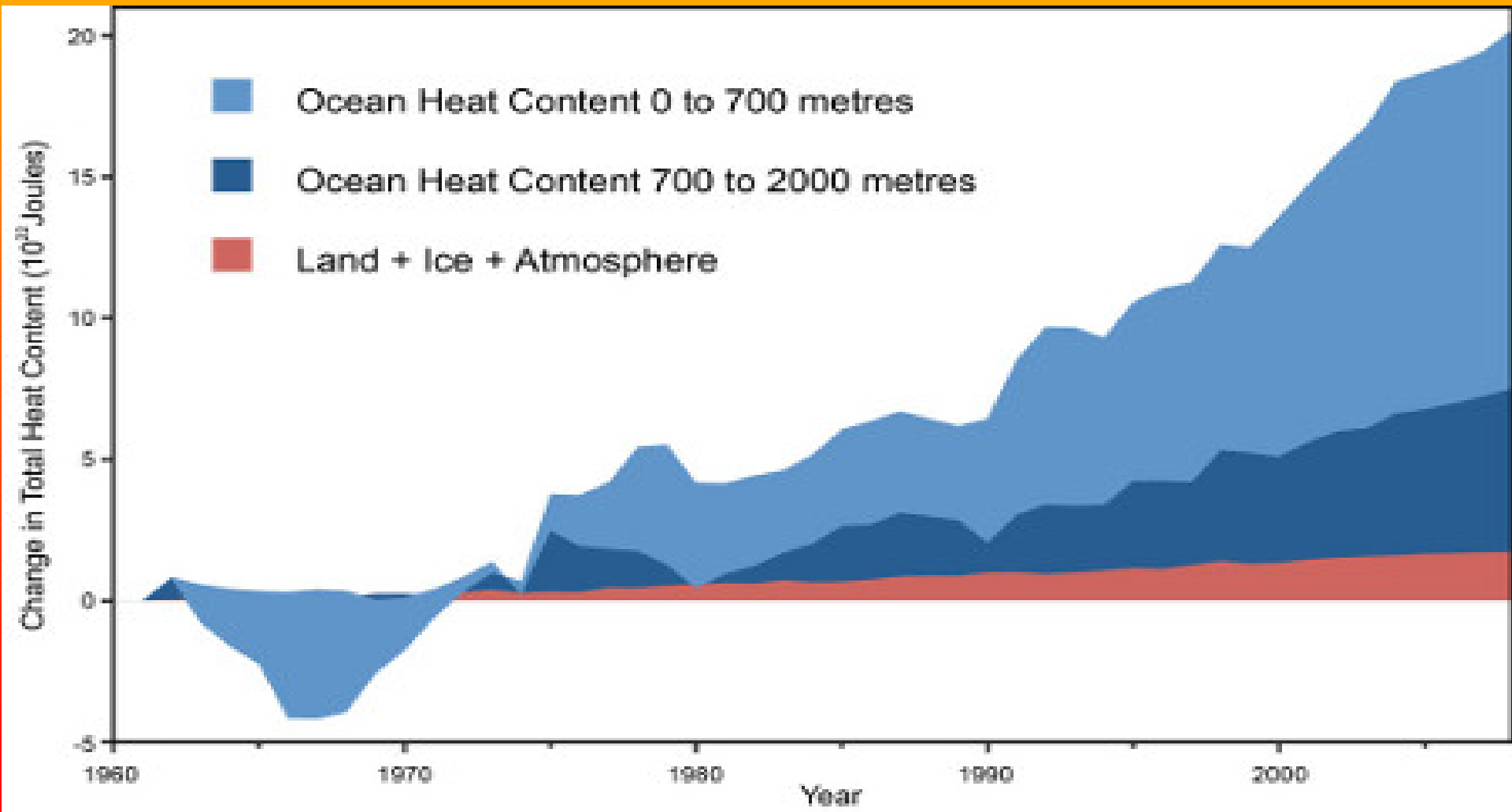
Year	Billion A-Bombs
1998	0.0
2003	0.5
2008	1.0
2012	1.5

<http://sks.to/heat>

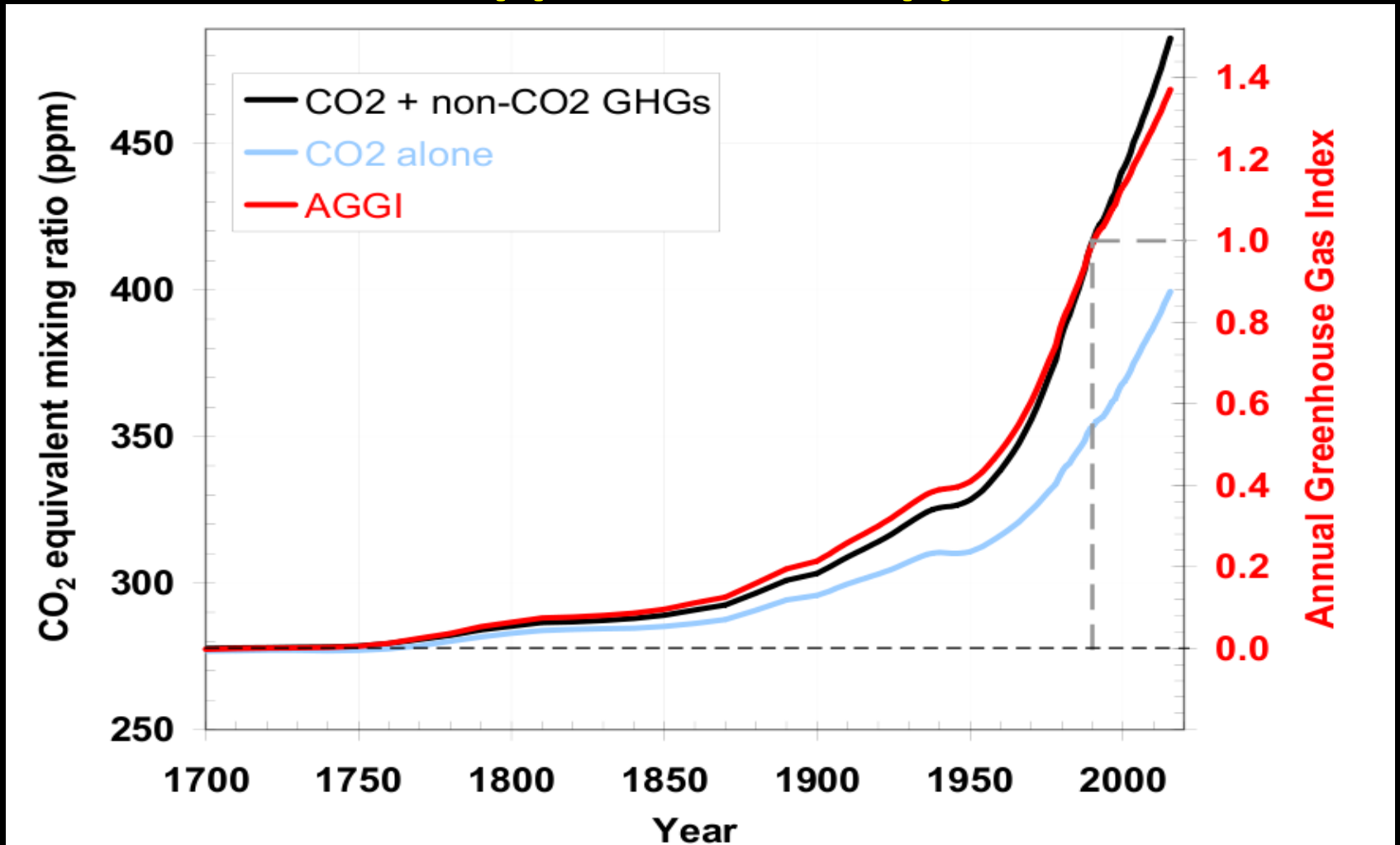
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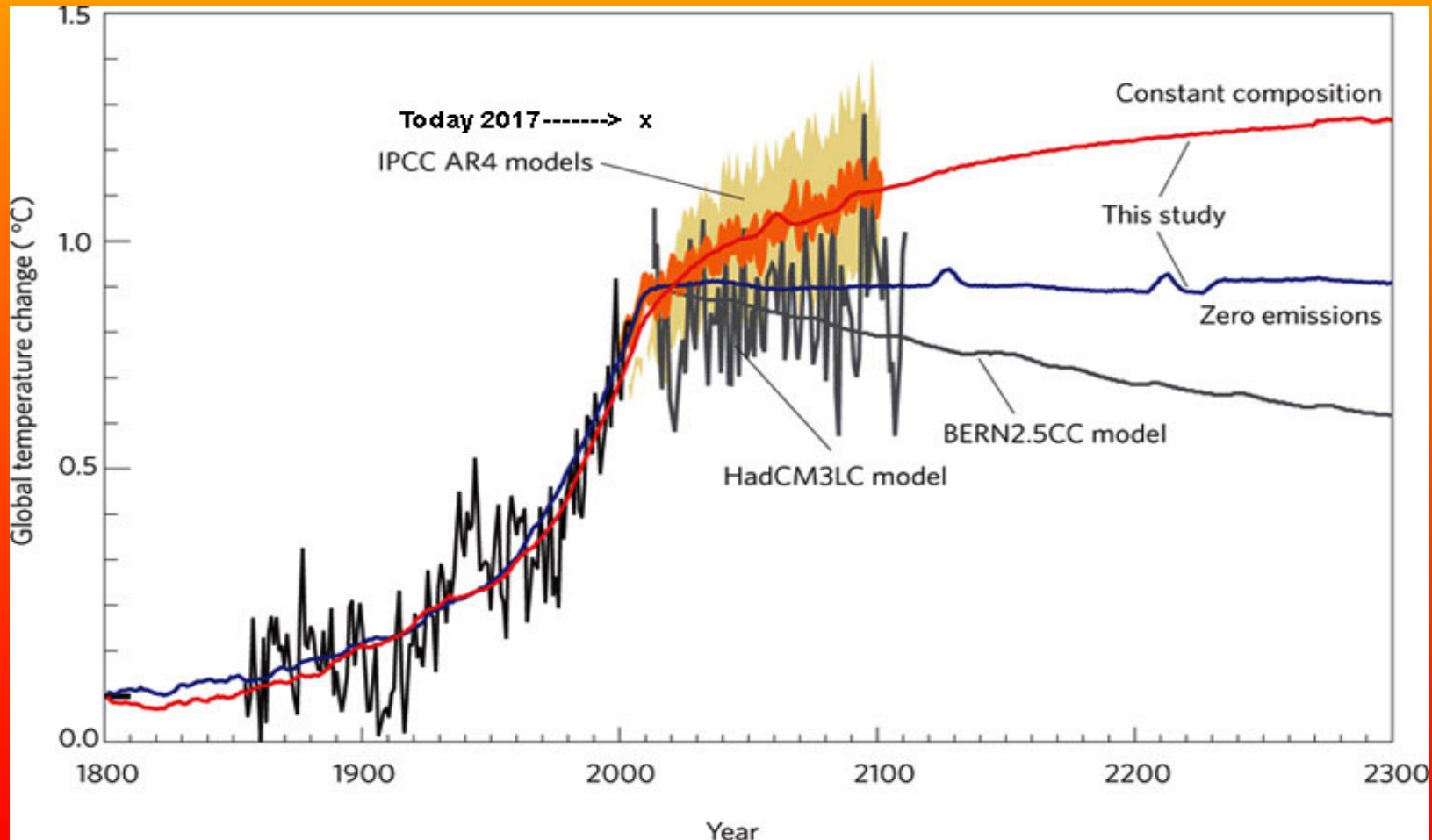
**2. The Ocean has absorbed 93% of our greenhouse heat. It will give it back** to the extent we attempt to cool our atmosphere, therefore preventing atmosphere cool down (the ocean has 700x more thermal capacity than the atmosphere! – picture a BB trying to cool while sitting on a giant hot iron skillet that won't change its temperature quickly).



**But its worse – we're also emitting other industrial GHG chemicals: methane, CFC's, HFC's, N<sub>2</sub>O from agriculture, and others. The total CO<sub>2</sub> equivalent = 500 ppm, not 410 ppm**



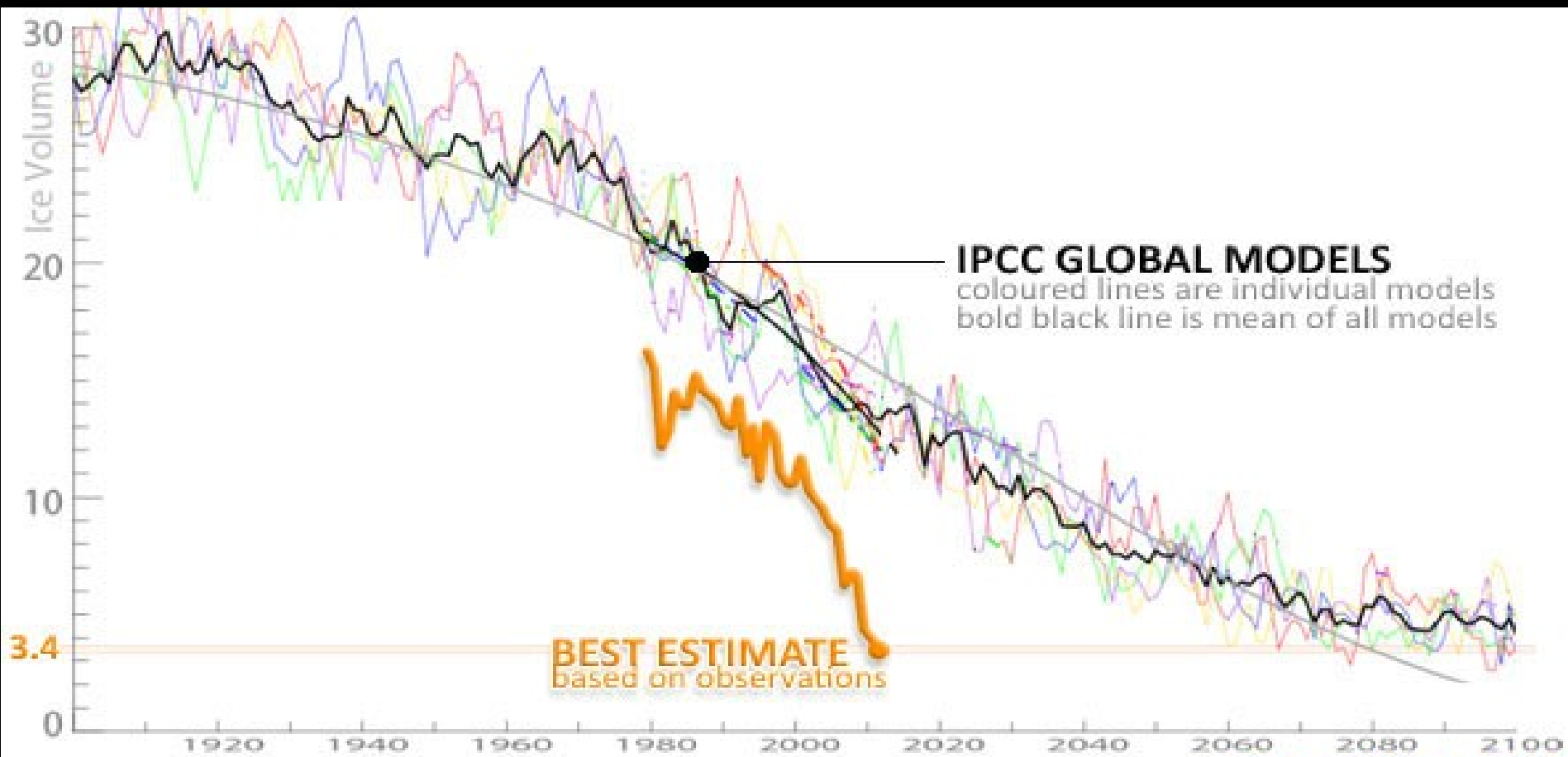
**Even with all this, we HAD thought that ending all human GHG emissions would lead to no worse than CONSTANT temperatures... but we were wrong (as I'll show)**



# **Question: How long before temperatures are TOO high and we're past key tipping points?**

- **Answer:** We're ALREADY crossing those tipping points now...
- And +2C is, in the words of Professor James Hansen, former head of NASA Goddard Institute for Space Science, "a prescription for disaster"

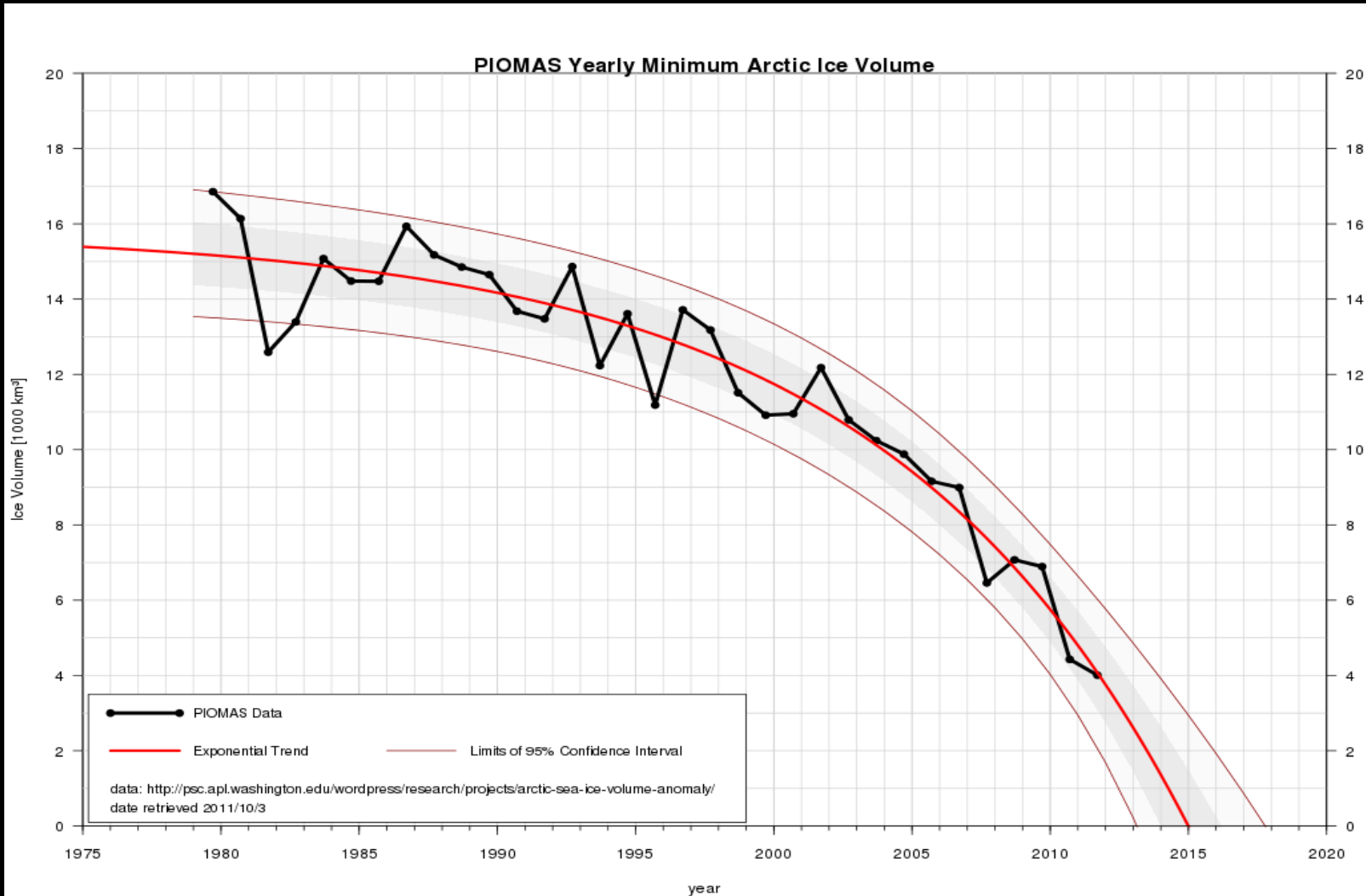
# IPCC climate models did not include many key ice and permafrost dynamics, leading to their dramatic underestimation of sea ice loss



## MINIMUM ANNUAL ARCTIC SEA ICE: IPCC MODELS VS OBSERVATIONS

base chart: <http://www.realclimate.org/index.php/archives/2012/04/arctic-sea-ice-volume-piomas-prediction-and-the-perils-of-extrapolation/>  
modified by Barry Saxifrage (VancouverObserver.com and VisualCarbon.org) to include orange line showing PIOMAS volume data in 1,000s of km³ from <http://psc.apl.washington.edu/wordpress/research/projects/arctic-sea-ice-volume-anomaly/data/>

# The nearly melted Summer Arctic Ocean has turned it from reflective cool white, to heat-absorbing dark blue



# This is Initiating the Melting of the Permafrost

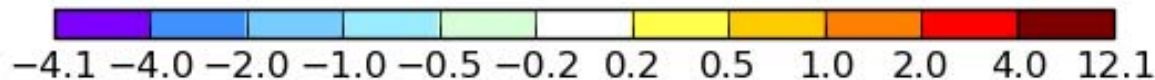
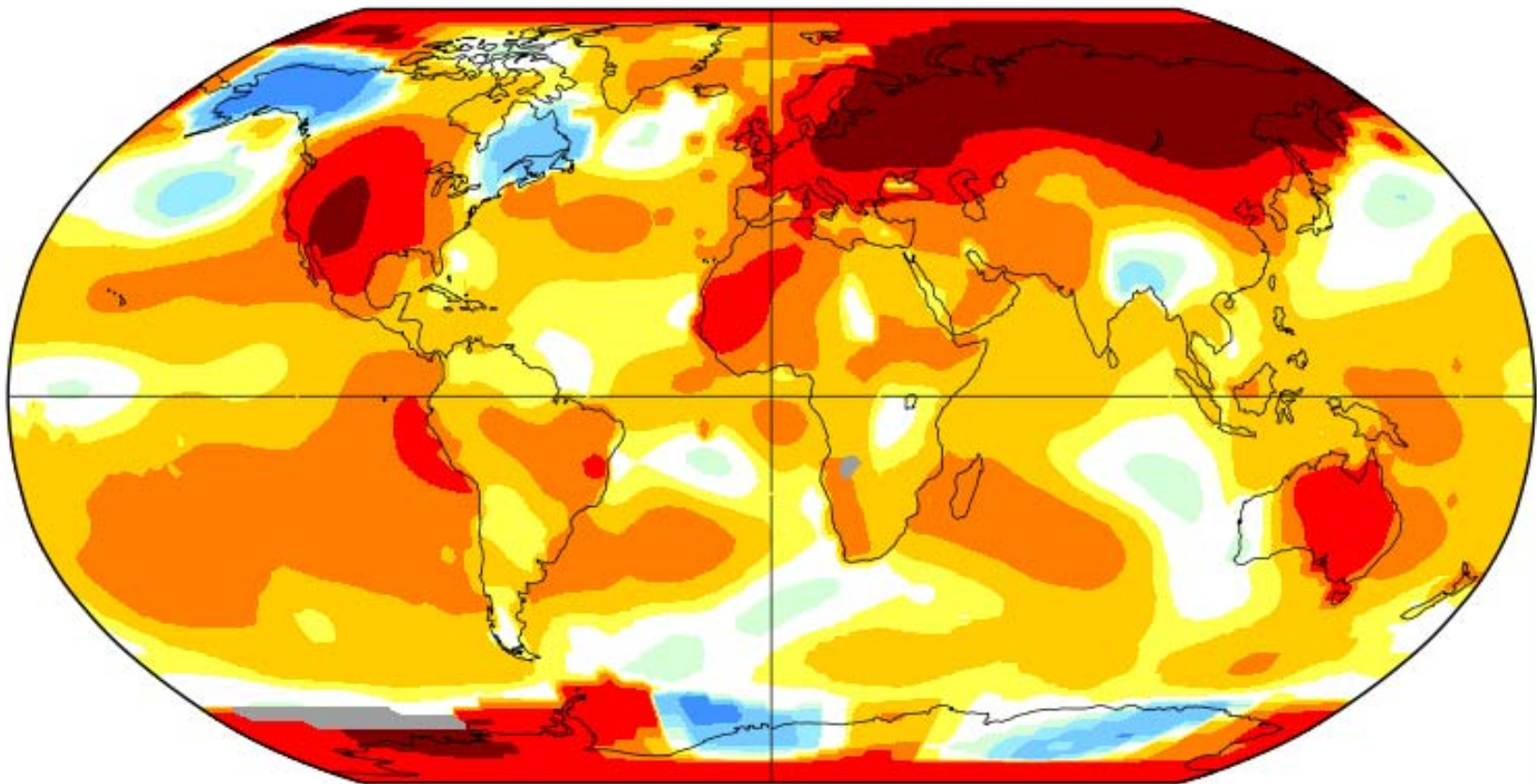
- Vaks *et al.* 2013 show that by **+1.5C** above pre-industrial temperatures, after equilibrium is reached with a couple of centuries, essentially all of the permafrost melts within a couple of centuries
- The Permafrost contains **TWICE** the carbon as there is in the atmosphere + all global biomass combined
- Once it gets going, the permafrost melt may be unstoppable without dramatic geo-engineering action to immediately cool the planet

**We're at +1.4C (1.13C + 0.254C to convert 1951-80 back to Pre-Industrial baseline), and rising very rapidly. The Permafrost - much hotter still**

March 2017

L-OTI(°C) Anomaly vs 1951-1980

1.13



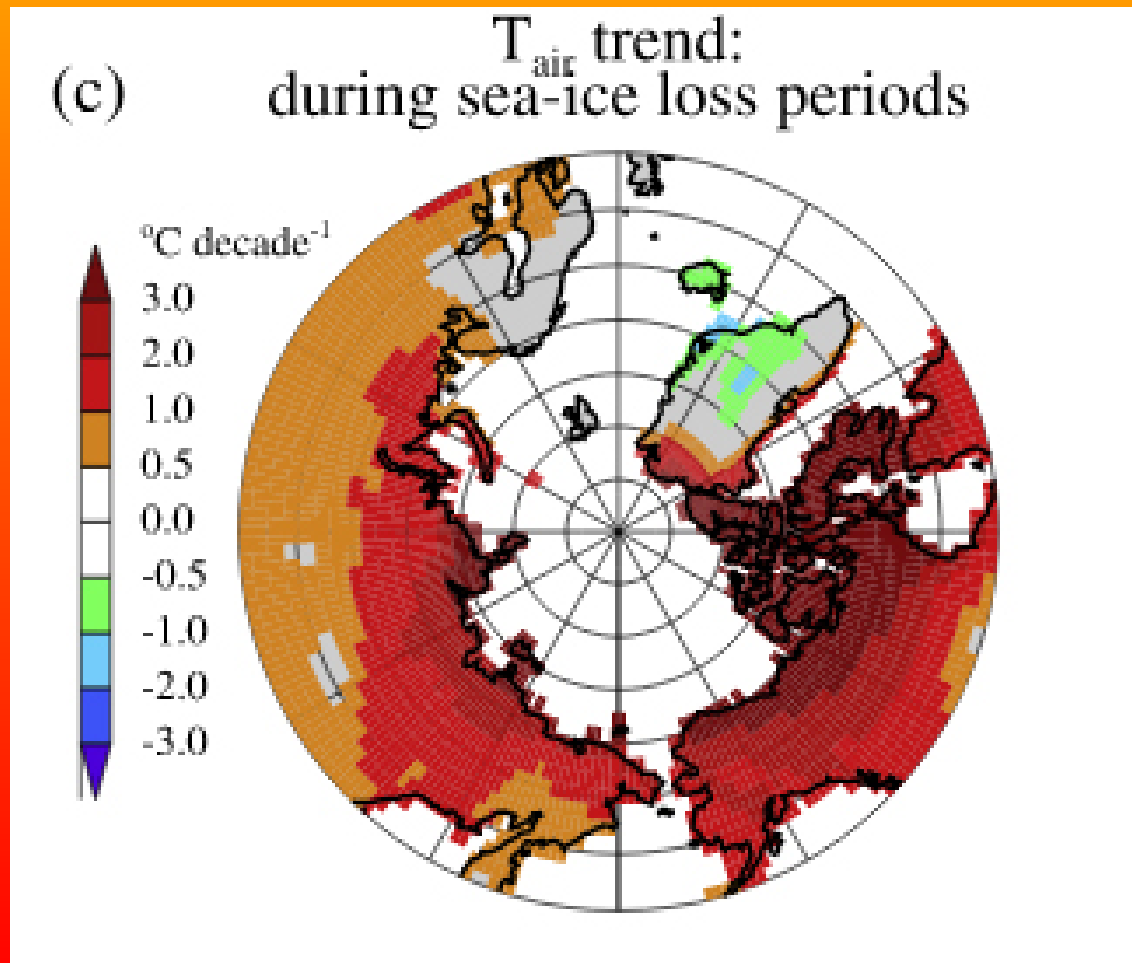


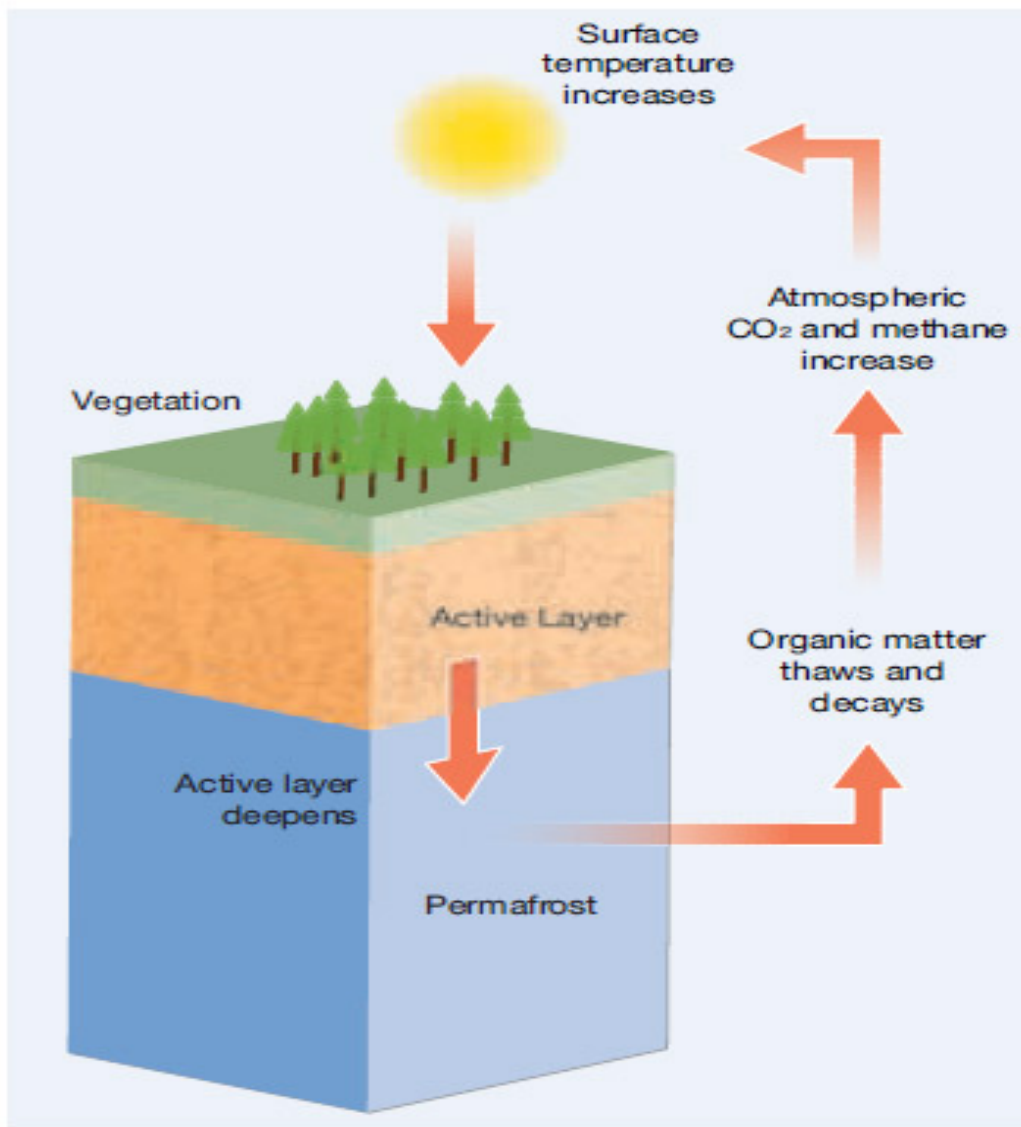
# It is the Loss of the Arctic Ocean's Ice ...Ice which once

REFLECTED ~90% of sunlight, turns to open ocean which now ABSORBS ~90% of sunlight. Lawrence *et al.* [2008](#) show this sends a pulse of heat

1500 km south of the shorelines throughout the Arctic Permafrost.

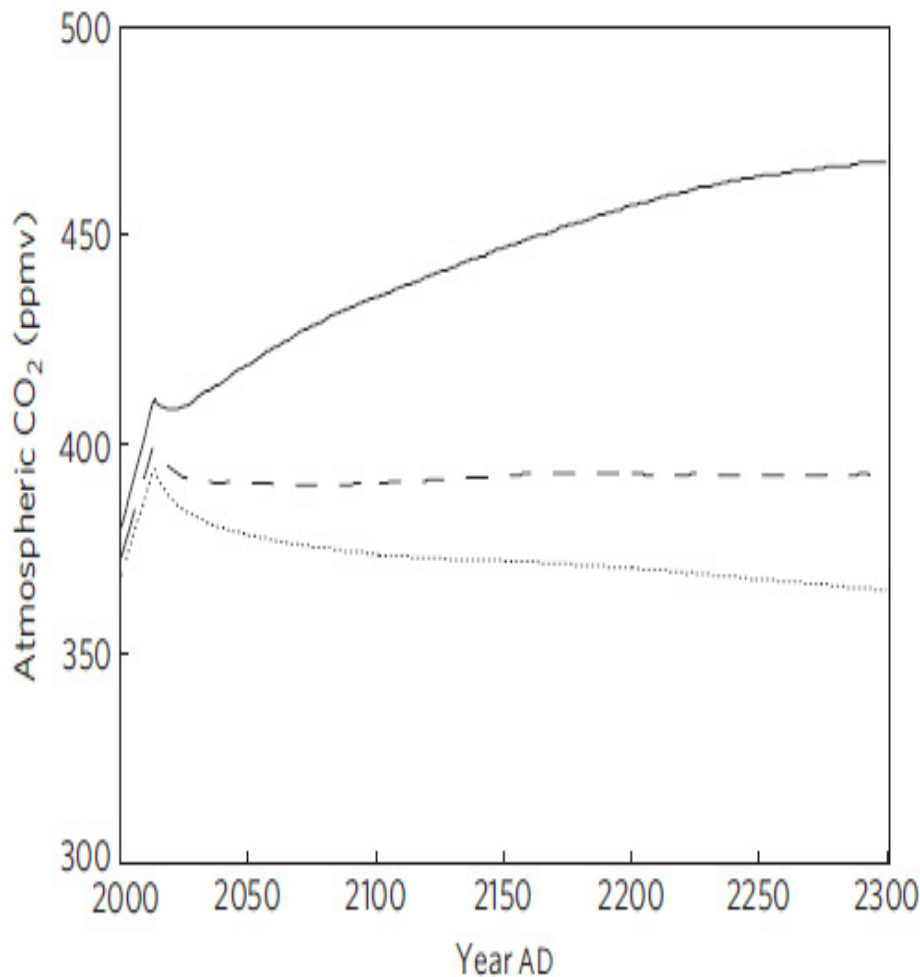
Below: temperature trend map. Sharp in Siberia, but even sharper in North America. So if Siberia melts, North America will as well, and likely sooner





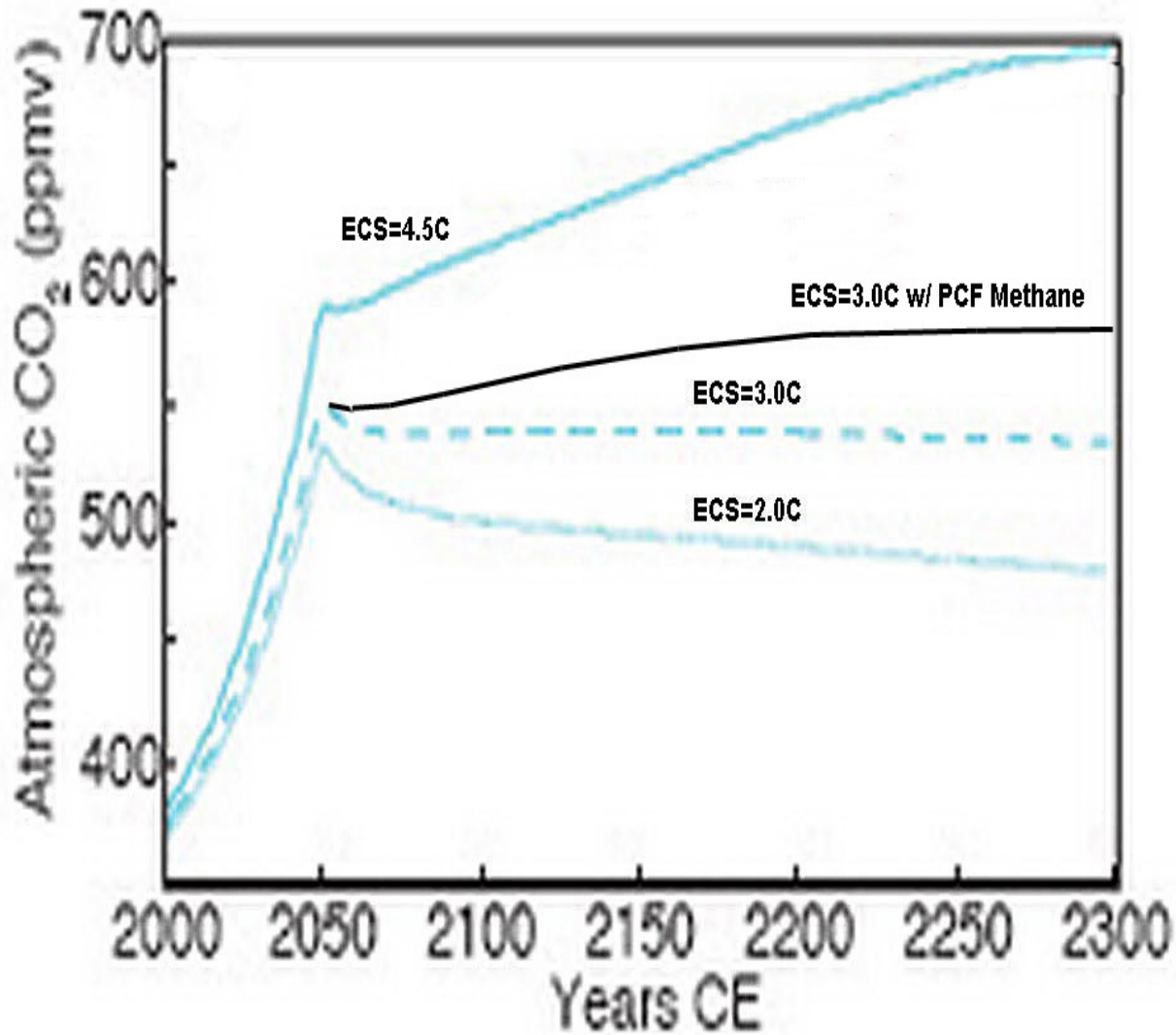
# The Permafrost Carbon Feedback (PCF)

**Figure 21:** The permafrost carbon feedback is an amplification of surface warming due to the thaw of organic material currently frozen in permafrost, which will then decay and release CO<sub>2</sub> and methane into the atmosphere.



**Figure 3 |** Evolution of atmospheric CO<sub>2</sub> concentration in response to a cessation of anthropogenic CO<sub>2</sub> and sulphate emissions in the year 2013. The dotted line represents the response for a climate sensitivity (to a doubling of CO<sub>2</sub>) of 2.0 °C, the dashed line a climate sensitivity of 3.0 °C and the solid line a climate sensitivity of 4.5 °C.

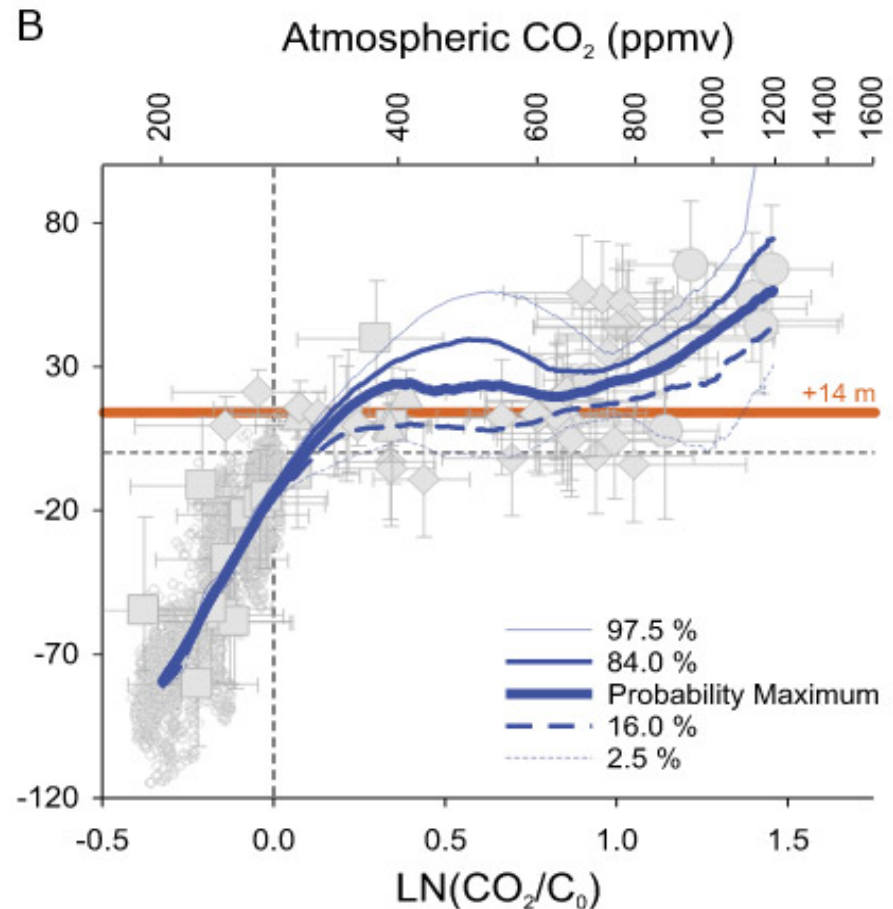
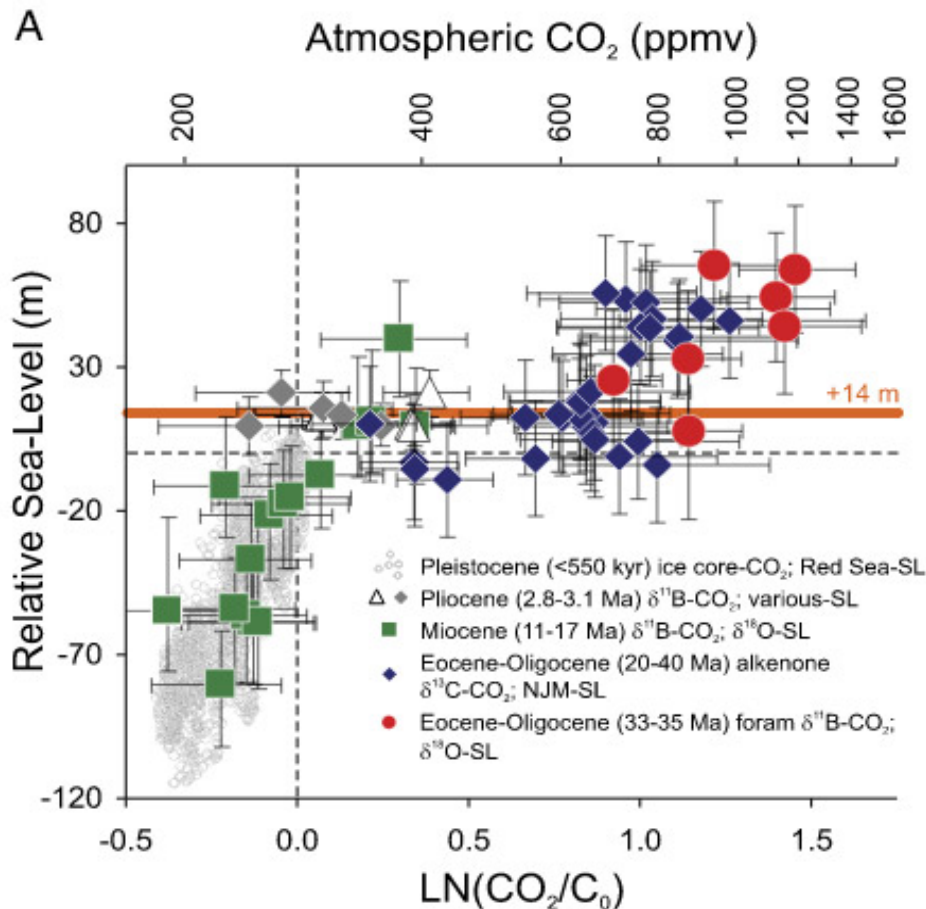
**If Equilibrium Climate Sensitivity ECS = 4.5C, as Friedrich *et al.* 2016 now show evidence for - then even ending all humann-generated GHG emissions in 2013... still CO<sub>2</sub> continues to rise, due to the permafrost carbon feedback (MacDougall *et al.* 2013, discussed [here](#)) . This causes sharply rising global temperatures for many centuries more.**



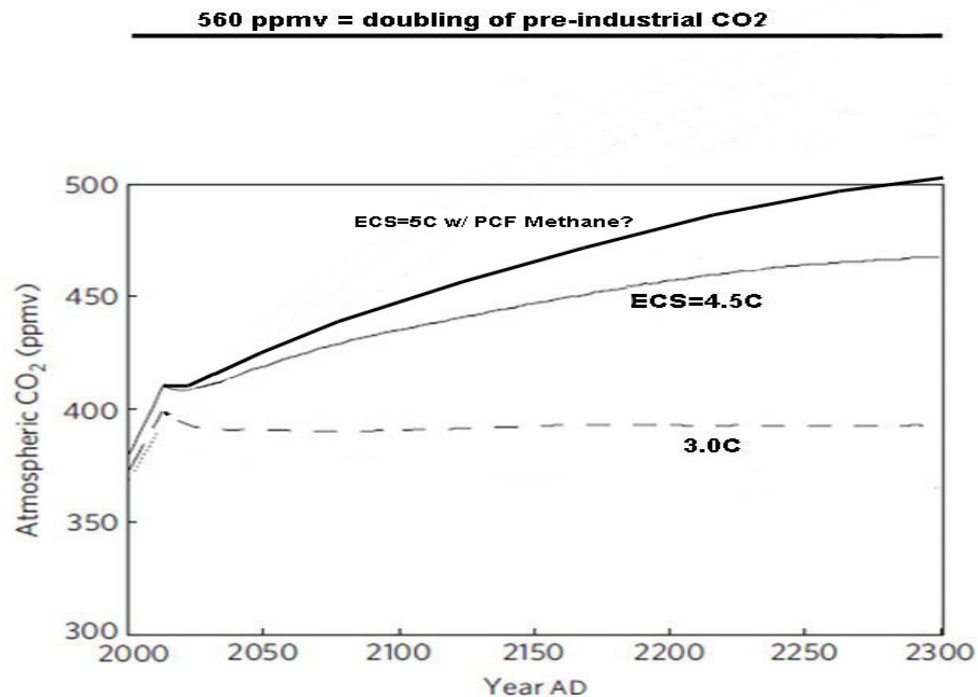
Shutdown in 2050

What if we DON'T end human GHG emissions tomorrow?  
 (hint – we won't).  
 Here, MacDougall *et al.* approximate gradual ending of GHG emissions by following “business as usual” till 2050, then complete end of human GHG emissions, but now including the PCF.  
**Result: CO<sub>2</sub> equivalent more than doubles pre-industrial, even for low ECS=3C. Thus, global temperature rises at least 3C, more likely ~7-9C**

**Foster & Rohling 2013** - Paleo Climate shows that 400 ppm CO<sub>2</sub> leads to final sea level rise of ~24m (**80 ft**) above today's, and conclude "Our results imply that to avoid significantly elevated sea level in the long term, atmospheric CO<sub>2</sub> should be reduced to levels similar to those of preindustrial times." (That's 280 ppm, vs. today's 410 ppm). 350.org's original goal of 350ppm is **NOT NEAR ENOUGH**



**Add in Arctic methane, which was NOT included in these studies. Then CO<sub>2</sub>-equivalent warming faster. We're facing the real possibility of +5C global temperatures even if we turn off all human GHG emissions tomorrow. This would lead to a civilization in steep collapse and fatalities in the hundreds of millions, and more if societal collapse**



**Figure 3 | Evolution of atmospheric CO<sub>2</sub> concentration in response to a cessation of anthropogenic CO<sub>2</sub> and sulphate emissions in the year 2013. The dotted line represents the response for a climate sensitivity (to a doubling of CO<sub>2</sub>) of 2.0 °C, the dashed line a climate sensitivity of 3.0 °C and the solid line a climate sensitivity of 4.5 °C.**

**So: Unlike many of Earth's  
environmental problems – merely  
stopping our hurting of the Earth...  
will not be enough to permit the  
Earth to heal.**

**Not for 10's of thousands of years**

# So What Do We Do?

- It's clear now – we have waited far too long.
- Too many are still living in the '90's, thinking that voluntary carbon-limiting like more efficient cars, changing light bulbs, eliminating “vampire” appliances, etc, will let the planet heal.
- ***It won't***
- Still, Paul Hawken (talks at Bookshop Santa Cruz May 25), has a new book – [“Drawdown”](#) - ranking ideas for addressing climate change. Population control ranks high

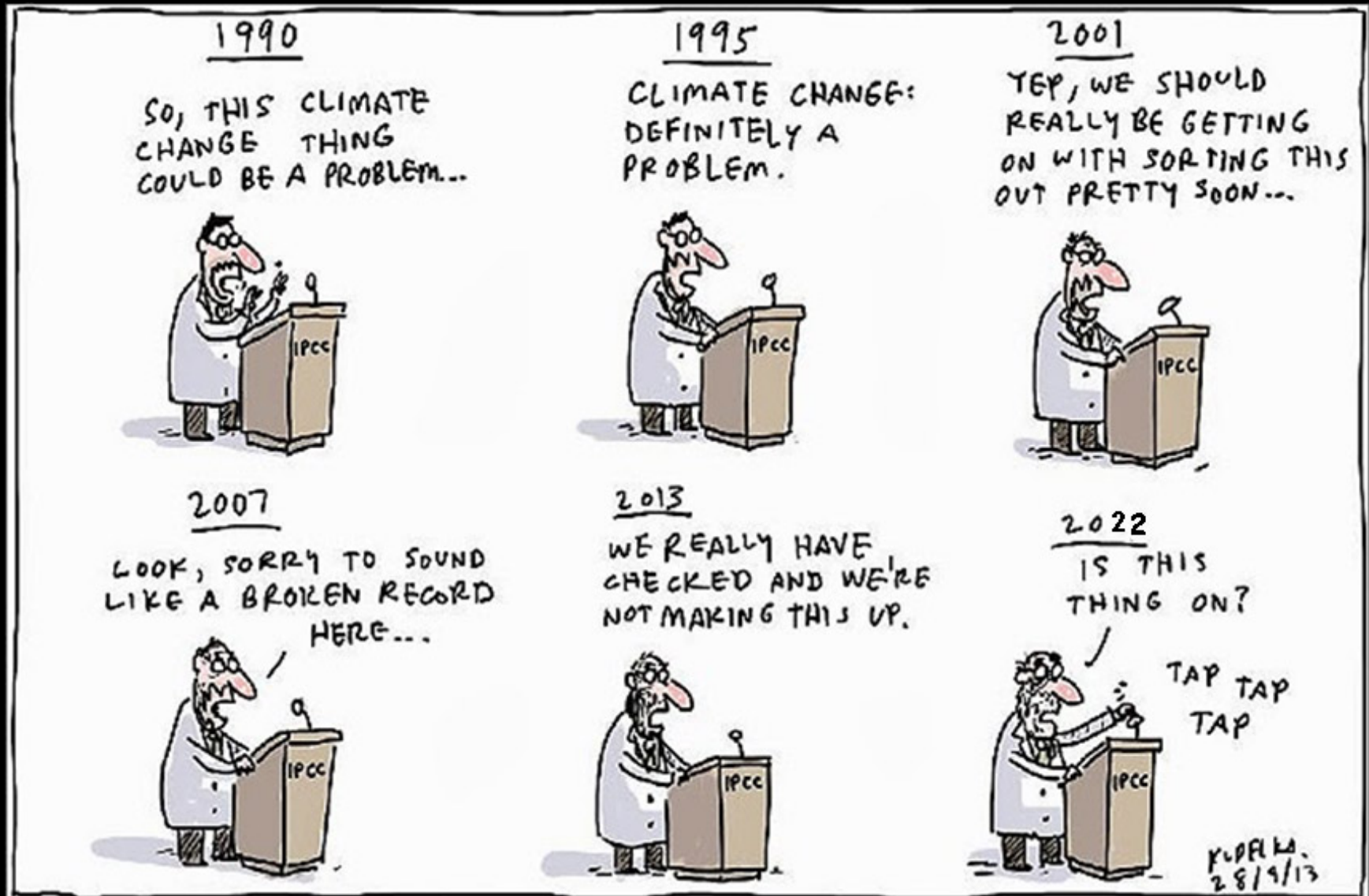


# Inspiring Voluntary Actions?

Even if you convinced 1 billion of the richest most carbon-using people on Earth to voluntarily cut their carbon footprint in half (tough to do that even if you wanted to), you would still only cut global CO2 emissions by ~13%, which is making only a tiny dent in the problem

And GHG's are globally well-mixed. Climate is GLOBAL and can ONLY be fixed by a GLOBAL effort. Today, most GHG's are coming from Asia

# When the stakes are climate chaos and mass extinctions, the IPCC scientists (with rare exceptions) haven't been appropriately forceful communicators



**We Need a New Rebel Alliance.  
That's YOU!**

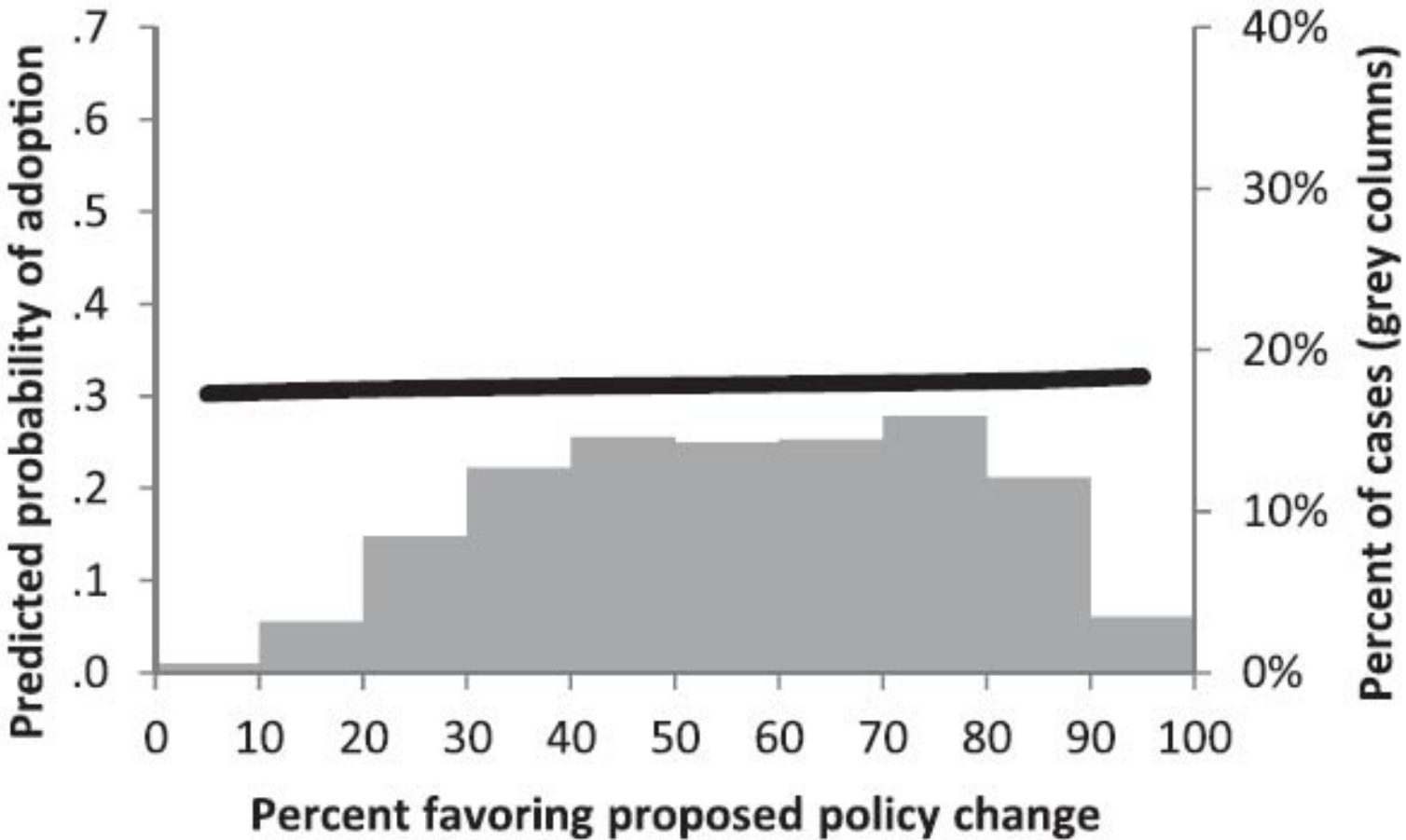


# You... Doing what? Write your Congressman?

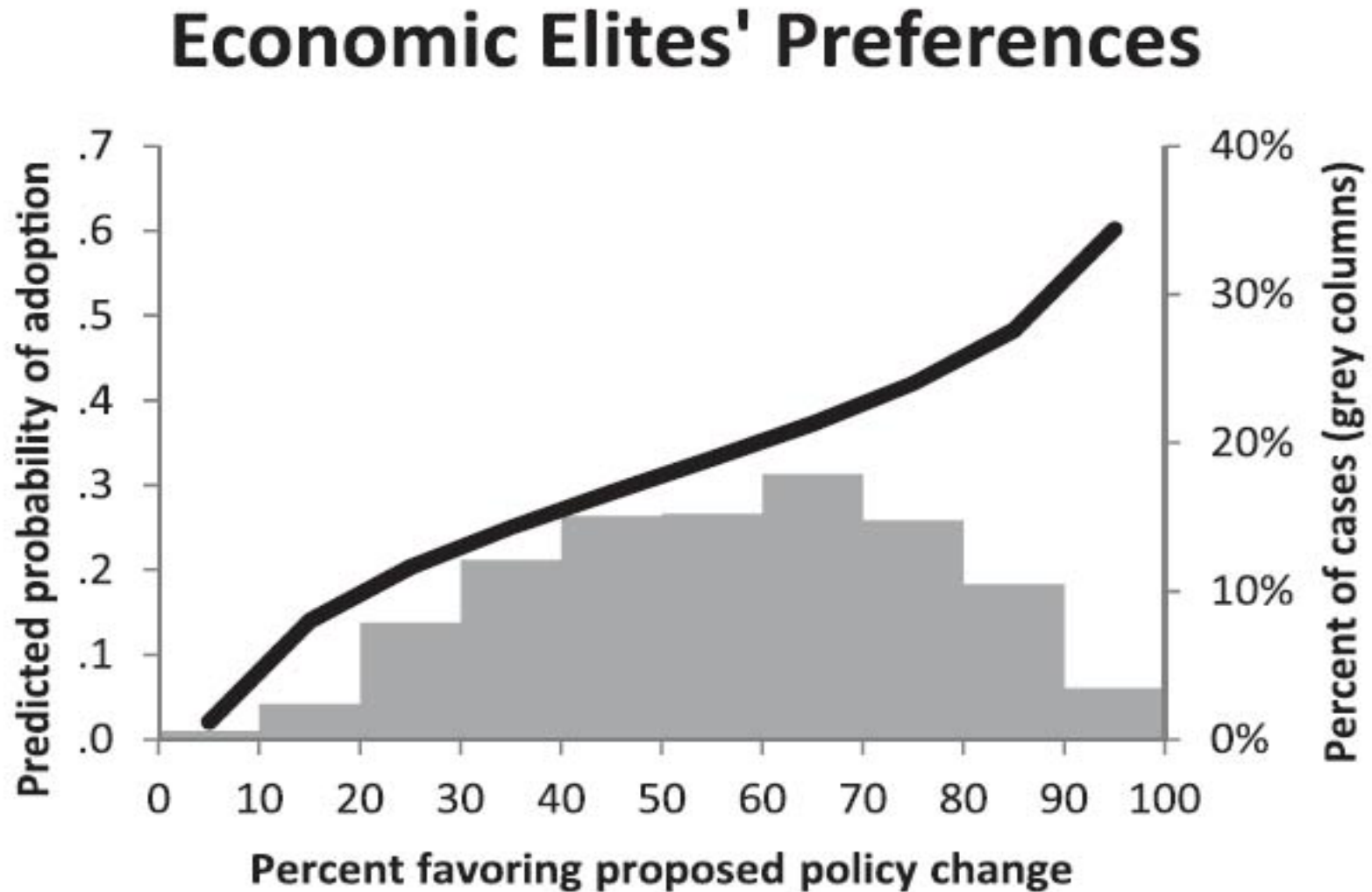
- Alas, two Princeton researchers, [Gilens and Page](#), published a landmark paper in 2014.
- It broke our population into 5 categories
- 1. Average citizens like you and me
- 2. Mass-based lobbies (like Sierra Club, etc)
- 3. Business lobbies
- 4. the Economic Elites, and their lobbies
- Then they studied all legislation from Congress for the past 20 years – This covered both Democrat and Republican majority in each of the 3 branches of government and correlated with the stated desires of these 4 groups by a set of criteria

**They found: There is exactly ZERO correlation between what legislation is desired by average citizens, and what legislation actually gets enacted ([Gilens and Page 2014](#))**

## Average Citizens' Preferences



And near-Perfect correlation between what the Economic Elites and their lobbies want, and what gets adopted. This is a deep systemic dysfunction.



**I'll Close with Just 5  
Key Thoughts on  
“What to Do” ...**

# #1 Tax-and-Dividend Policy

- **1. Somehow (Occupation of DC with One Million Citizens?)** institute stiff “Tax-and-Dividend” policy. Tax carbon where it enters the U.S. (wellhead, or ports), and return tax receipts to the citizens directly via monthly checks
- This would raise the prices of anything requiring carbon energy (most everything today), disincenting carbon use. Price rises would be less on low-carbon energy uses, incenting their adoption further
- **CCL: Citizen’s Climate Lobby** – grass roots organization whose sole purpose is to try to get such legislation passed. [Santa Cruz CCL](#) very active



# #2: A New Amendment to the U.S. Constitution

- I propose a 28<sup>th</sup> Amendment to the Constitution...
- *Congress shall permit no law denying the rights of present and future citizens to safe commons, including air, ground water, river water, and natural forest. Congress shall permit no laws which interfere with the existence of a natural environment in harmony with the right to life and the pursuit of happiness by future as well as present citizens.*
- These policies incentivize the high costs of technological initiatives needed

## #3. An ESSENTIAL Emergency Stop-Gap

- We MUST prevent further melting of the Permafrost, and therefore we MUST cool the Earth enough to bring back the Arctic Ocean's permanent ice cap, which is the cause of Permafrost melt
- How? The fastest, safest (?), cheapest and most-do-able strategy is...

# Inject reflective sulfate, calcium carbonate aerosols into the stratosphere continually. "SunShade"

## Cool tech: an experiment in atmospheric control

Scientists are aiming to discover whether the climate could be deliberately cooled using the controversial technique of 'geoengineering'

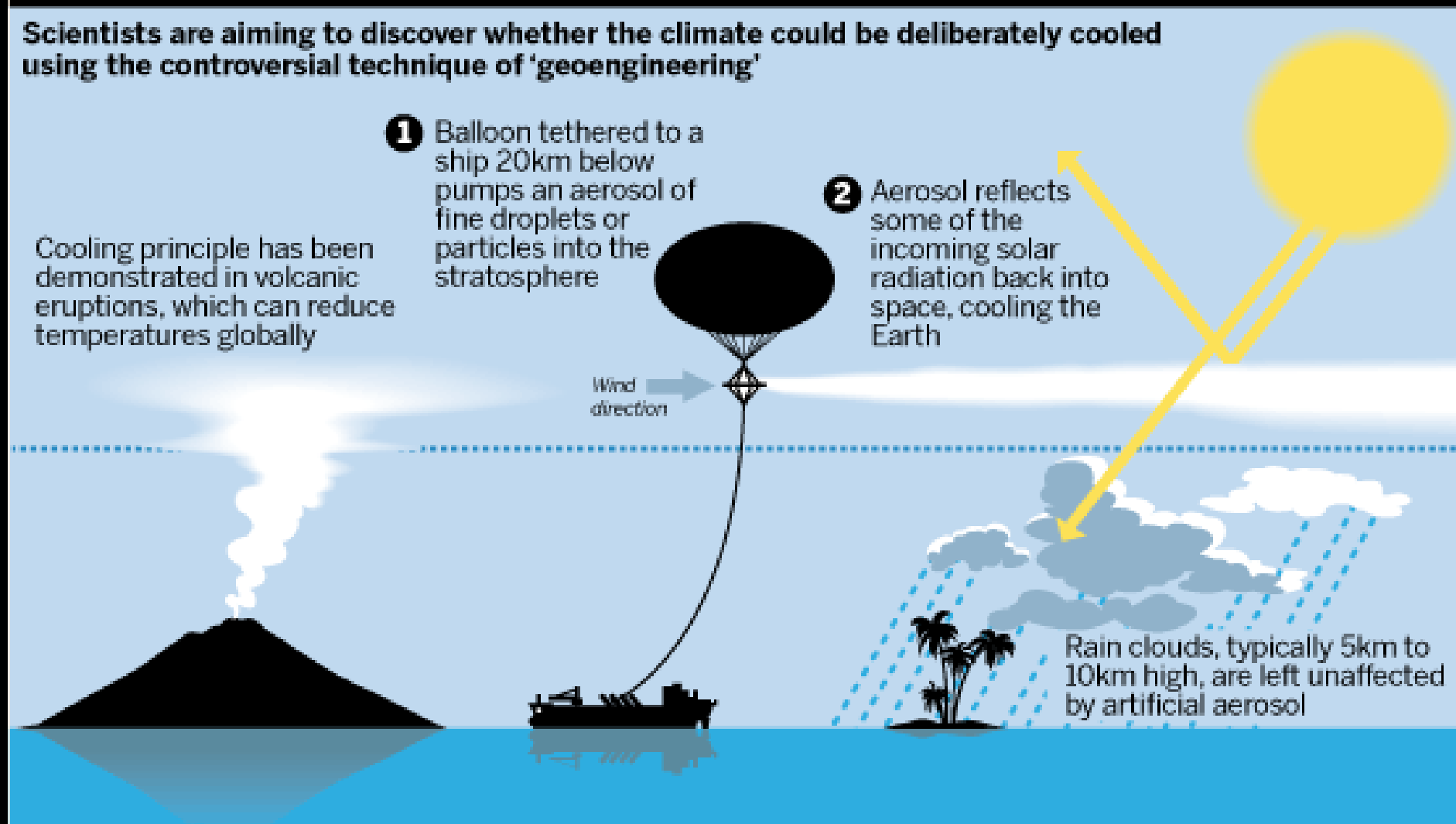
Cooling principle has been demonstrated in volcanic eruptions, which can reduce temperatures globally

**1** Balloon tethered to a ship 20km below pumps an aerosol of fine droplets or particles into the stratosphere

**2** Aerosol reflects some of the incoming solar radiation back into space, cooling the Earth

Wind direction

Rain clouds, typically 5km to 10km high, are left unaffected by artificial aerosol



## #4. Longer Term: Must pull our CO<sub>2</sub> back out of the atmosphere

- Capture (somehow), liquify, and inject underground?
- Combine with limestone to make bicarbonate and dump into the ocean?
- Inject into basalt formations and let it form carbonate underground?
- Highly energy intensive, expensive. Technologically uncertain. We have much to learn here. But – what's our planet worth? Shall we start the bidding at INFINITY?

# Techno Strategies – How To Judge Ideas Which You'll See Advertised

- **ALL EFFECTIVE strategies must either**
  - \* (A) Reflect additional sunlight back to space, or
  - \* (B) Enhance Earth's ability to radiate to space
- **All SAFE strategies should...**
  1. NOT involve novel, global modifications to ecosystems to manipulate them in pulling out CO<sub>2</sub>. Millions of species and interactions known for only a few, and poorly. Highly dangerous!
  2. Take Earth BACK along the system trajectory that got us here (i.e. ONLY reduce atmospheric CO<sub>2</sub> and other GHG's, and re-freeze the poles.

# #5. Take Cabrillo College's "Astro 7: Planetary Climate Science" Class

- It is the **ONLY** dedicated course in Planetary Climate, and has far more detail than the brief mention given in the Environmental Science class or the Meteorology class.
- Offered every semester
- This Fall, it's 2:45-5:50pm, once-a-week on Tuesdays
- No Prerequisites. High school students welcome!
- I tell you explicitly in class exactly what questions I'll ask for the quizzes and final exam (all are Mult Choice, for objectivity)
- Most students earn "A" grades if they attend and listen to every lecture. That's my goal and so that's my motivation for this generous policy!

# What's Covered in Astro 7?

- Principles of clear thinking and Scientific method
- modes of heat transfer, light and interactions with molecules, the Greenhouse Effect
- climate for other planets
- Paleo climate of Earth, atmosphere structure, carbon cycles, clouds/aerosols
- **Current/future Earth Climate Change is most of the course:**
  - Causes, proofs of human-origin
  - Climate modelling, radiative forcings
  - Ocean/atmosphere connection
  - Changes: temperature, ice sheets, ocean acidification, deforestation, sea level rise, storms, other effects...
  - Psychopathologies of climate denial, political aspects
  - Debunking climate denialists bogus claims
  - Future climate - the post-IPCC science is much more dire
  - The Thermodynamics of Civilization itself and how constrains solutions
  - Strategies: Govt Policy, economics
  - Strategies: Technological

# Astro 7: Planetary Climate Science



**Cabrillo College Rm 806 Tuesdays 2:45-5:50pm**  
**A non-mathematical UC/CSU transfer course for the intelligent layman on planetary atmospheres, especially Earth climate and current climate change: the science, the politics, the future. Civilization and its limitations. Strategies - Policy, Economics, and Technological**