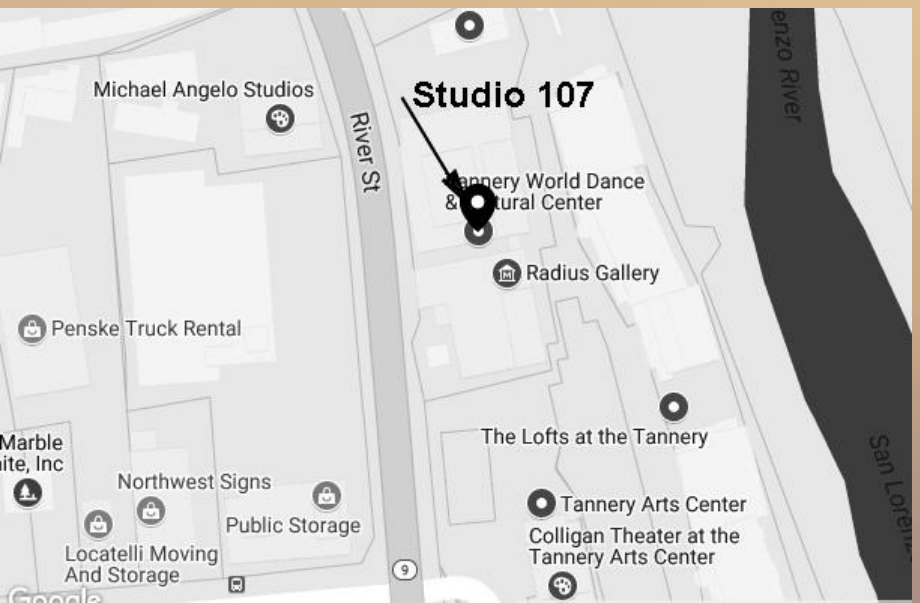
Our Climate Dilemma: The Political/Economic Agenda vs. the Straight Science

Richard Nolthenius, PhD

A Public Talk 6-8pm Thur Apr 19
at the Tannery Arts Center



Post-IPCC AR5 peer-reviewed science paints a much more dire future than policy-makers portray. We'll show the conflict, and look at proposed strategies for a long-term sustainable future. Q/A to follow.

Pot-luck! Bring some snacks!

My Background

- Chair of the Astronomy Department at Cabrillo College for 32 years
- Lecturer and visiting researcher in astronomy at **UC Santa Cruz**
- Masters Degree in Aerospace (U. Az) with specialty in computer code design for thermodynamics of fluid systems.
- 2 years in private industry as Thermodynamics Engineer at General Dynamics – Convair Space Division, designing and analyzing thermal systems for space craft and space payloads
- Thermal designer on General Dynamic's entry for the first round of what became the International Space Station
- Doctoral work at Stanford University in Applied Physics, finishing PhD in Astronomy and Astrophysics at UCLA
- Post doctoral fellowship at Steward Observatory, University of Arizona.
- Part of the Dark Matter team at UCSC led by Joel Primack, computer modelling of the evolution of Dark Matter cosmological simulation galaxies and comparison with real world galaxies
- Began Climate work in 2009, shifted focus from Astronomy to Climate in 2010

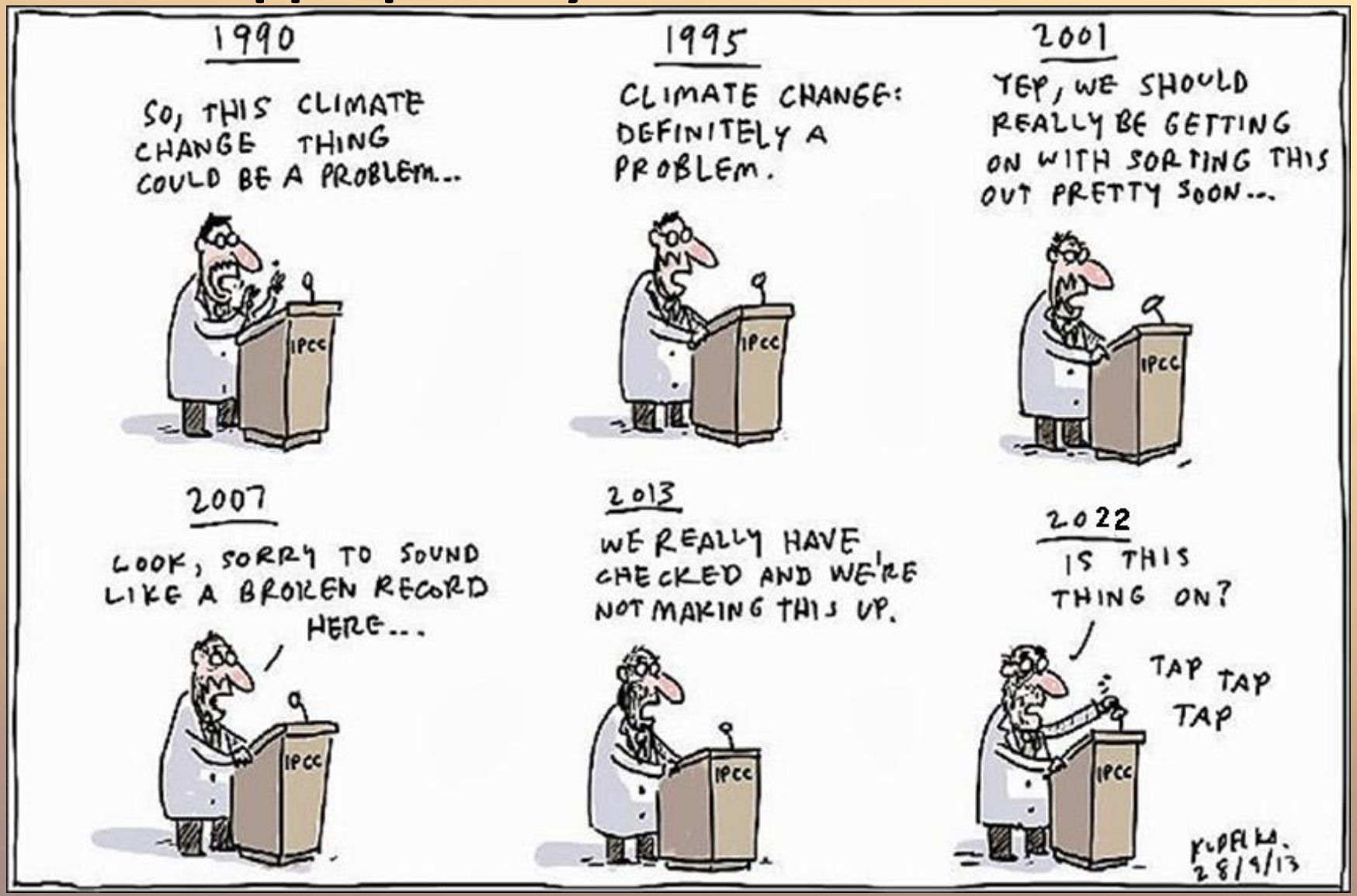
My Goals As a Climate Educator

- In my 9 years immersing myself in climate science and climate politics/economics, I've learned sobering things…
- **1.** Truth-telling in climate too often takes second-place to less admirable motives. On both the Conservative political/economic side, and also on the pro-environmental Liberal political side. Coming from Astronomy and Astrophysics, where this is much rarer, it's been painful.
- **2.** There are still too few scientists with the ability and willingness to digest the peer-reviewed journal science, unspun, synthesize it into the larger interdisciplinary picture, and convey it in an understandable way to the non-scientist.
- This is an arena where I feel I can make a positive contribution

I am a FIERCE defender of science

- I don't mean nerdy factoids. I mean the **essence** of science – honoring the sincere desire to KNOW and SHARE the **weight-of-evidence truth** above all else.
- Sincerity in **CARING, AS #1, TO DISCOVER and UNDERSTAND THE EVIDENCE, AND let your feelings about the science not get in the way**.
- You can spot it instantly, in their eyes, whether a person has this attitude. It is why I feel so comfortable around scientists, delight in my conversations with them, and usually not so much around others who don't respect this as #1.
- I have NO PATIENCE for those who - even nominally the "good guys" - would sully the name of science to serve their own agendas, whether it's to cheer you up, cheer themselves up, **$ell** you on their schemes, indulge in New Age magical fantasies, play politics, or anything else that doesn't honor REALITY above all else.

Alas, when the stakes are climate chaos and mass extinctions, the IPCC (with rare exceptions) hasn't had appropriately forceful communicators



Realize the Importance of Accurate, Truth-Driven, and Emotionally Connected Communication about Climate from Scientists

- Nowadays, most people know to "consider the source". Fabrications from politicians and Industry get heavy skepticism from anyone using their brain.
- But most people **don't** understand science, and so if someone postures as a big-shot scientist but does not exhibit the personality of ruthless fidelity to evidential truth, and share it as exactly that, they do profound damage to the cause. Far more damage than a climate denialist could do these days.
- They damage public trust in the word of scientists. They harm communication from genuine scientists, as people see manipulation from both sides and therefore decide to TRUST NO ONE.
- **People learn by example. Don't insult people's intelligence by being a mere pumper! Do your best to be a good example for the core meaning of Science!**

I've seen a lot of it!

- For example, I cringe far more when I hear scientists knuckle under U.N. pressure and **"bias to the side of Least Drama"** (in the words of the award winning communicator and climatologist Dr. Katherine Hayhoe, and others (**Nuccitelli 2013**), than the latest lies from the politicians.
- True in the other direction as well – The **Apostle of Apocalypse - Guy McPherson** gets paid to fly around the country telling people the entire human race will be DEAD in 8 years, from climate change. Outrageously false…
- That's beyond irresponsible, that's just plain cruel.

From Pulitzer Prize winning journalist and Princeton Professor Chris Hedges... *"This mania for Hope is a kind of sickness"*

- *"Of course, it's bleak. I'm sorry, the climate science reports are bleak… I'm not making it up. And **this mania for Hope is a kind of sickness**, because it prevents us from seeing how dire and catastrophic the situation is if we don't radically reconfigure our relationship to each other and to the ecosystem. And of course people don't want to hear it. We become entranced by the trivia that dominates the airwaves… We are fed this mantra, this fiction, that says we can have everything we want, that Reality is never an impediment to what we desire. It's given to us by Oprah, it's given to us by Hollywood... And it's not true"*
- *"The (mainstream) Democrats are as beholden to the Corporate Elite as are the Republicans"*
- ***Interview here***

"We got here according to the laws of physics and we are subject to those laws and must live within them. <u>We can't be guilty of magical thinking</u> in predicting our future."

- UCSC Astronomer and member of the National Academy of Sciences – Prof. Sandra Faber

"What I seek to accomplish is to serve, with my feeble capacity, truth and justice at the risk of pleasing no one"

- Albert Einstein

Tonight's Plan

- **1. Conflicts of Interest** and how they have affected the spin on the science you are told.
- **2. The straight science** of our future, especially since the last IPCC Summary: AR5 in 2013.
- **3.** How the **Thermodynamics of Civilization** constrains our options.
- **4. Strategies** for dealing with Climate: What's needed is far beyond and far more uncomfortable than any but scientists want to look at. (brief intro only).
- **5. Questions and Answers.**

1. Conflicts of Interest and how they have affected the spin on the science you are told

The U.N. Intergovernmental Panel on Climate Change (IPCC) is presented as the "Gold Standard" for Climate Scientists' Understanding of Climate

The last IPCC Assessment Report (AR5) digested the science from 2012 and before

That was 6 years ago, and a lot of science has happened since then.

But First, IS the IPCC's *"Summary for Policy Makers"* – which is the only document the vast majority of the press, the public, policy people, and legislators see – Is it really the unbiased Gold Standard?

…or has it been "spun up" by UN political agendas bent on not compromising competitive economic growth?

It's a Consensus Document

- Hundreds of scientists contribute to the writing of the IPCC documents. Quoted on the published purpose:
- *"Authors for the IPCC reports are chosen from a list of researchers **prepared by governments** and **participating organizations (RN: e.g. from industry)**, and by the Working Group/Task Force Bureau, as well as other experts known through their published work. The choice of authors aims for a **range of views**, **expertise** and geographical representation, ensuring representation of experts from developing and developed countries and countries with economies in transition." (**source**)*

…a “Range of Views”?

- As in, from hard-nosed science-based realism, all the way to profit-motived don’t-rock-the-paradigm, **Doubt-is-Our-Product** economics folks from Fossil Fuel and Right Wing organizations? You mean… **that** range?
- Vital, because – **ALL** scientists, industry representatives, UN officials, and policy people must sign off on a statement before it is approved and can appear in the final released documents.
- That means that **only the lowest levels of “alarm” can get approval**, despite what published climate research says, and yet the advertised purpose is digestion of published research relevant for climate policy formation. **It’s just not true.**
- **Could it even be that housing the scientists inside this U.N. structure was realized to be the most effective way to neuter the message of the science, dangerous as it is to the political / economic system that empowers the Economic Elite? (That’s a suspicion. I don’t know the answer.)**

Imagine the Spectrum of Possible Futures; from reasonably happy Pure White, to Near-Term-Human-Extinction Pitch Black

Here's how the game is played...

We Start with the Climate Deniers

Here's how the game is played...

Climate change is just a Chinese hoax!

Meanwhile, from the Apocalyptos...

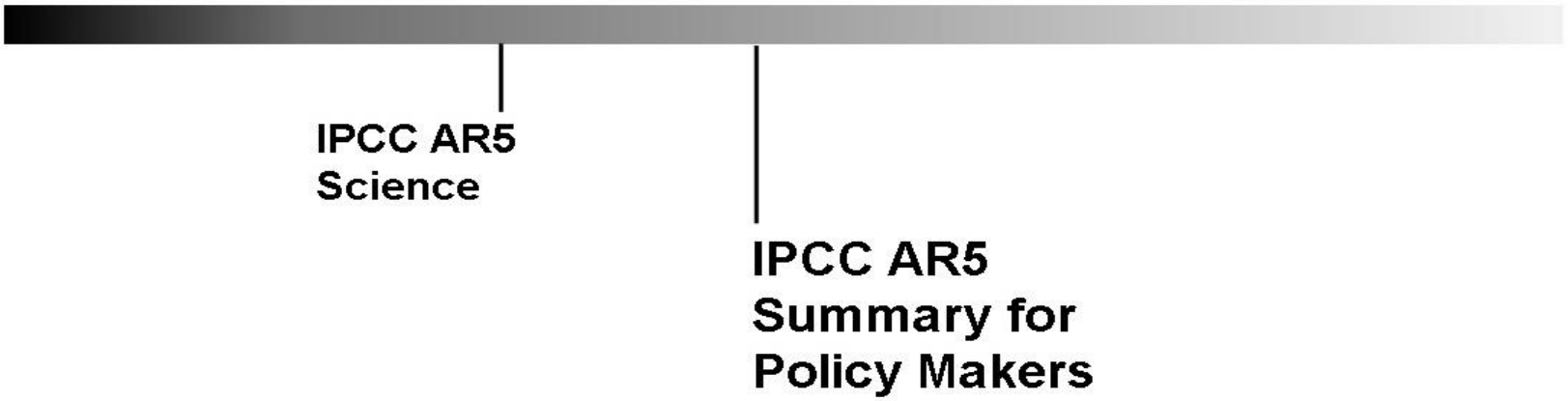
The entire human race, and nearly all species... DEAD! EXTINCT!
in 9 years!

This, too, is nonsense. The "Methane Apocalypse" is off the table

Getting More Serious: Start with the Dense, Almost-No-One-Reads Full Draft Prepared in Good Faith by the IPCC Scientists

The IPCC Scientists' digest of the 2012 and prior climate science, nearly unsullied by those few in the science teams who are industry sponsored. The future is a darkish shade of gray

Then the UN Political Representatives and Policy People go over every word, to neutralize anything which will harm prospects for their economic growth



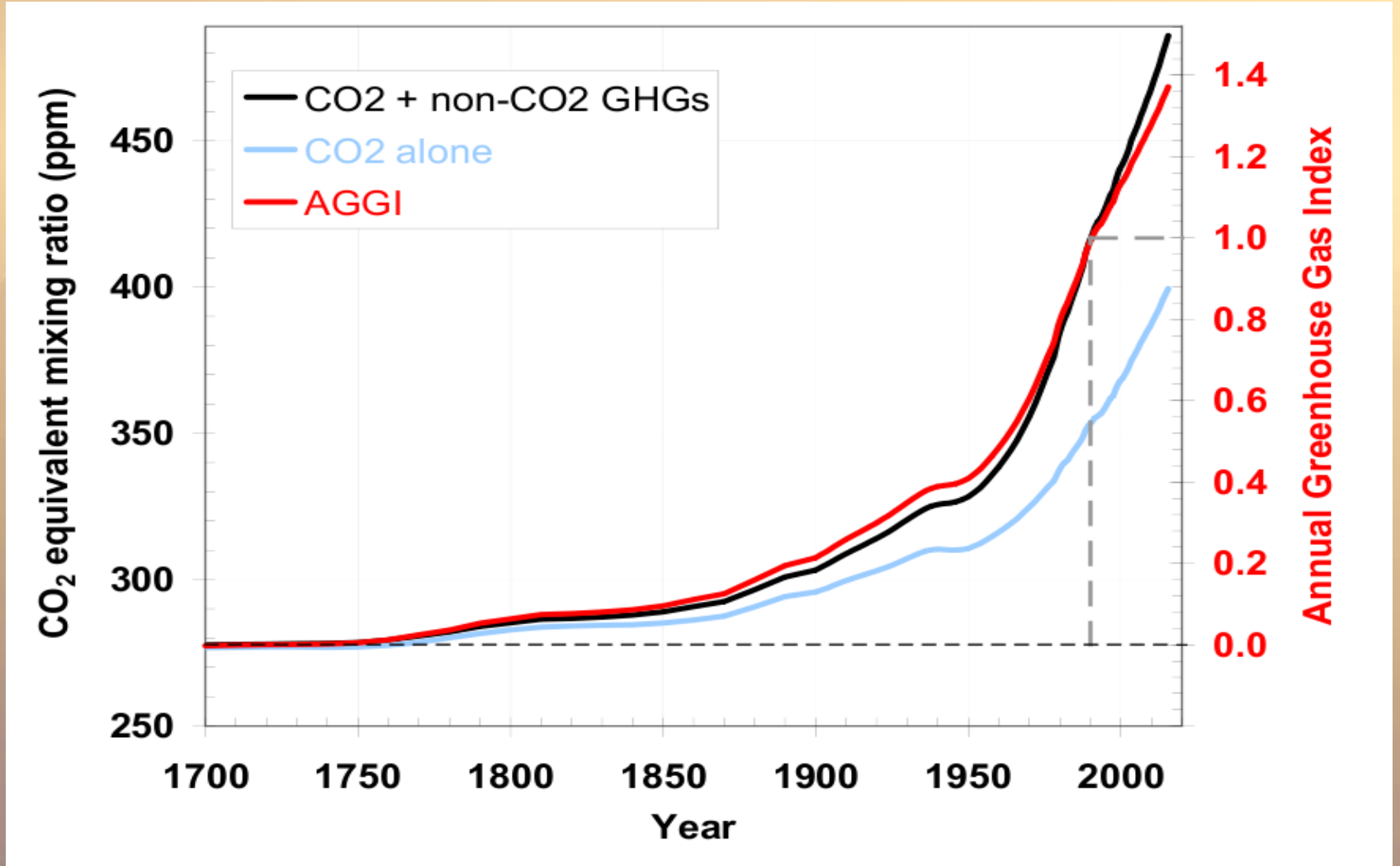
"A Document of Appeasement" – IPCC Prof. David Wasdell (source)

- *"Wasdell said that the draft submitted by scientists contained a metric projecting cumulative total anthropogenic carbon dioxide emissions, on the basis of which a 'carbon budget' was estimated – the quantity of carbon that could be safely emitted without breaking the 2 degrees Celsius limit to avoid dangerous global warming. He said that* ***the final version approved by governments significantly amended the original metric to increase the amount of carbon that could still be emitted. (and this is the version Policy people use)"***

The +2C "Carbon Budget" - Fundamental flaws

- **Wasdell:** *"The total carbon budget according to this estimate is about 1,000 gigatonnes of carbon (GtC) – although over 531 GtC was emitted already by 2011, leaving 469 GtC left. Applying the 'corrected non-linear function' reduces this available budget to just '280 GtC' – this figure does not account for the role of greenhouse gases other than CO2, including the potential impact of thawing permafrost or methane hydrates"*
- Note, **from Nobel Physics Laureate Steven Chu**, that the CO2 equivalent of all human GHG's (*i.e.* including CFC's, HFC's, methane, nitrogen oxides, etc.) is not 410 ppm **but 500 ppm today**.
- **That's 90 ppm CO2e higher (next slide). The IPCC simply assumes optimistically that we and Earth will stop emitting them and so they'll go away within a few decades.**

The non-CO2 GHG molecules: methane, ozone, CFC's, HFC's, N_x0 from agriculture, and others. The total CO2 equivalent = 500 ppm, not CO2's 410 ppm



If included, they would reduce the budget much further. Current emissions reduction pledges, therefore, still guarantee disaster.

- Wasdell's paper reads:
- *"… present levels of international contribution towards the reduction of emissions still led to a cumulative total of 2,000 GtC by the year 2100. That left an emissions reduction gap of some 1,097 GtC between promised reductions and the 903 GtC required to prevent temperature increase exceeding the policy goal of 2°C."*
- ***"The Summary for Policymakers is a document of appeasement, not fit for purpose. In reality, if my calculations are correct, we not only don't have much of a carbon budget left, we have already overshot that budget – we're in overdraft."***

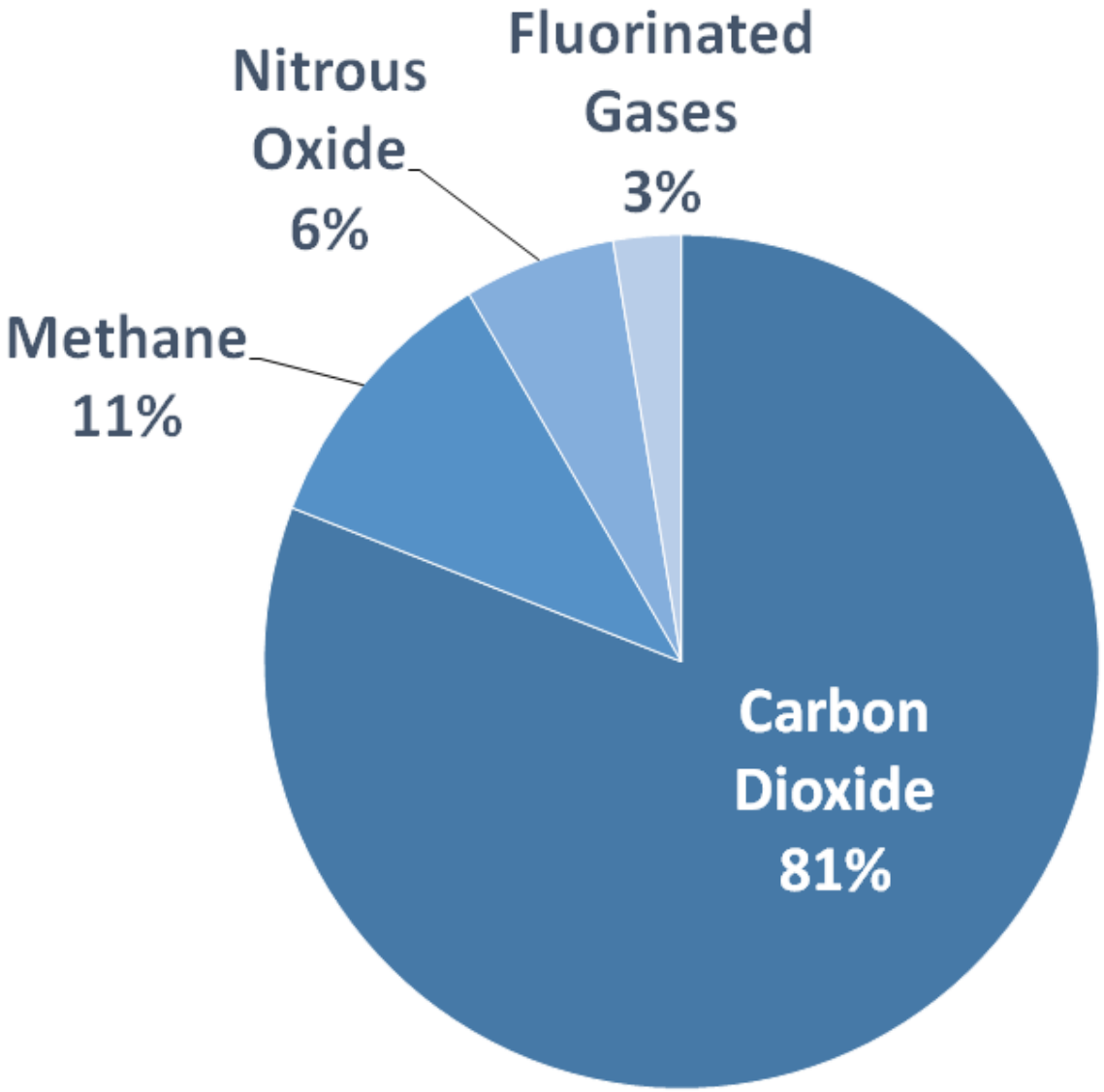
Yet to this Day - Every Promoted Techno-Fix Involving Fund-raising That I Have Seen Uses These Low-Bar Flawed Carbon Budgets

- **Why?**
- Apparently because they're a much easier goal to reach for their techno-ideas, hence easier to raise money from potential investors, the public, and granting agencies.

As Just One Example of the Hype – Agreement to Eliminate most HydroFluoroCarbon Refrigerants (HFC's)

- Here's some of policy people's hype*: **"the single most important step that the world can take to limit global warming."**,* and **from Sec of State John Kerry - *a "monumental step forward"***
- **Is it?** Consider: *"Between 2020 and 2050, 70 billion tonnes of CO2 equivalent, comparable to the emissions of nearly 500 million cars, will be prevented from entering the atmosphere thanks to a progressive reduction of HFCs."* (from ClimateHome)
- (note: a tonne is a metric ton = 1.1 tons = 2,200 lb)

U.S. Greenhouse Gas Emissions in 2014



Yet - HFC's "flourinated gases") are only ~3% of U.S. GHG emission (in CO2 equivalent measures

So, Is this Agreement Significant? Not Really

- Even assuming we halt global growth in CO2 emissions, and so for these next 30 years 2020 - 2050 it remains at 38 billion tons of CO2/year, and accepting for the moment the 70 billion ton CO2e value on the prior slide…
- Then, if there is no cheating (a problem for HFC and CFC's)… **…The agreement amounts to less than 6% reduction of CO2 equivalent emissions**, not counting the non-CO2 GHG's like N_2O and methane, and human-triggered natural GHG's from the melting permafrost and tropical wetlands.
- But wait - it's worse: we're **not** going to remove refrigeration from Civilization, so what will replace these HFC's?

There is No Mention of the Required Rise in Alternative Refrigerants

- Remember that **ALL molecules except symmetric diatomic molecules (N_2, O_2) are greenhouse gases**. Even simple ones like the older refrigerant ammonia
- Replacing current HFC refrigerants with the optimum lower GWP (global warming potential) alternatives, results in a reduction in net CO2 equivalent emissions by refrigerants of only about 1/3 (**Beshr *et al.* May 2017**). Said another way, **that wedge which is HFC's will still be 2/3 as large as it is now, once they are all replaced by their best-judged equivalent but safer refrigerants.**
- **And therefore, the REAL savings in total CO2e from the HFC ban agreement is not 6%, but less than 2%. And that assumes no cheating (which CFC's still suffer from, despite the 1989 Montreal Accords)**

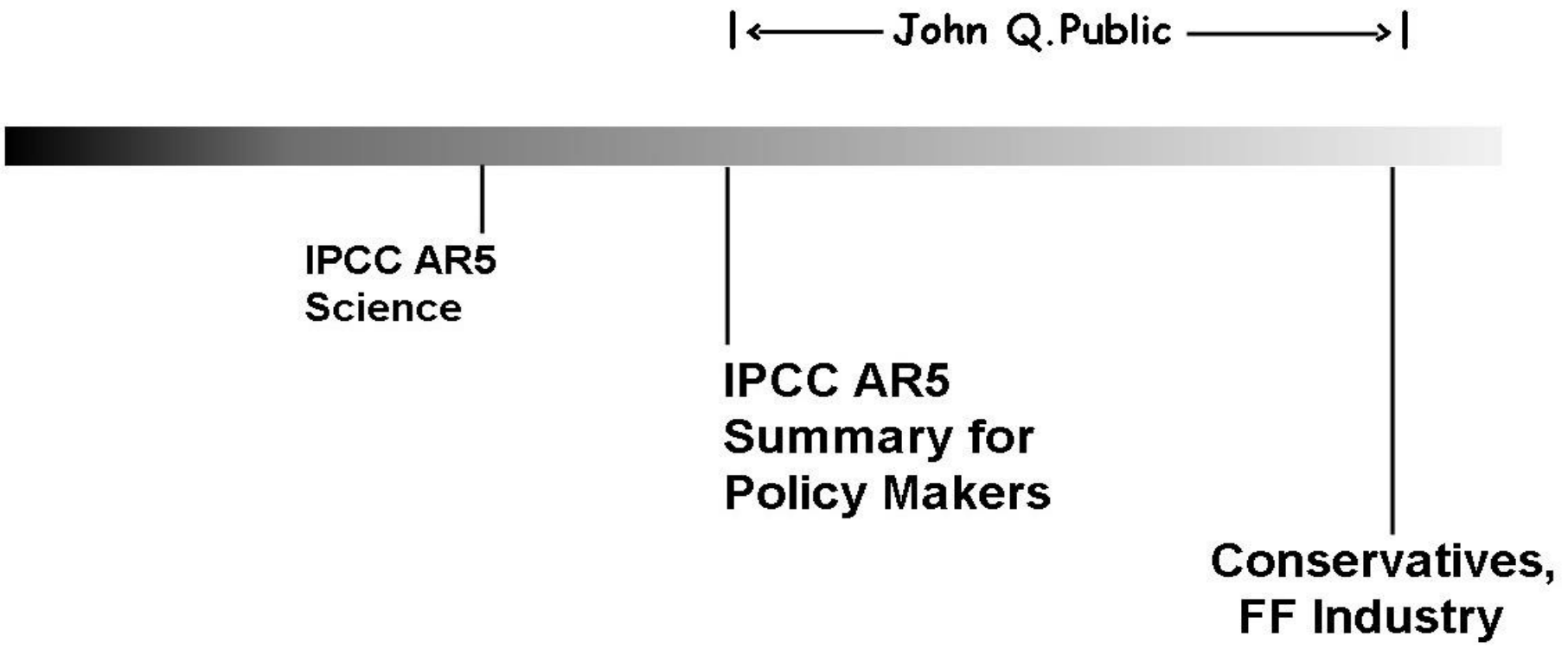
From this talk by the Director of UK's Tyndall Climate Research Centre, Prof. Kevin Anderson, in conversation with political climate policy senior people

- **Political scientist** (at request left un-named): *"Too much has been invested in +2C for us to say it's not possible – it would undermine all that's been achieved. It'll give a sense of hopelessness, that we may as well just give in"* – (30 min into **the talk**)
- **Anderson:** ***"Are you suggesting we have to lie about our research findings?"***
- **Political scientist:** *"Well, perhaps just not be so honest – more* ***dis****honest…"*

And What About that Presumed Safe +2C Limit. Where did THAT Come From?

- *"In his 1975 paper **Can We Control Carbon Dioxide?**, Nordhaus 'thinks out loud' as to what a reasonable limit on CO2 might be. He believed it would be reasonable to keep climatic variations within the 'normal range of climatic variation'. He also asserted that science alone cannot set a limit; importantly, it must account for both society's values and available technologies. He concluded that a reasonable upper limit would be the temperature increase one would observe from a doubling of preindustrial CO2 levels, which he believed equated to a temperature increase of about 2C." (**source**)*
- **Yes - A deeply flawed 43 year old paper… By an economist!**
- **Dr. James Hansen has shown that (his words) "+2C is a Prescription for Disaster". Worse, as we'll see later, a doubling of CO2 will yield a temperature more like +4.5C or higher:**

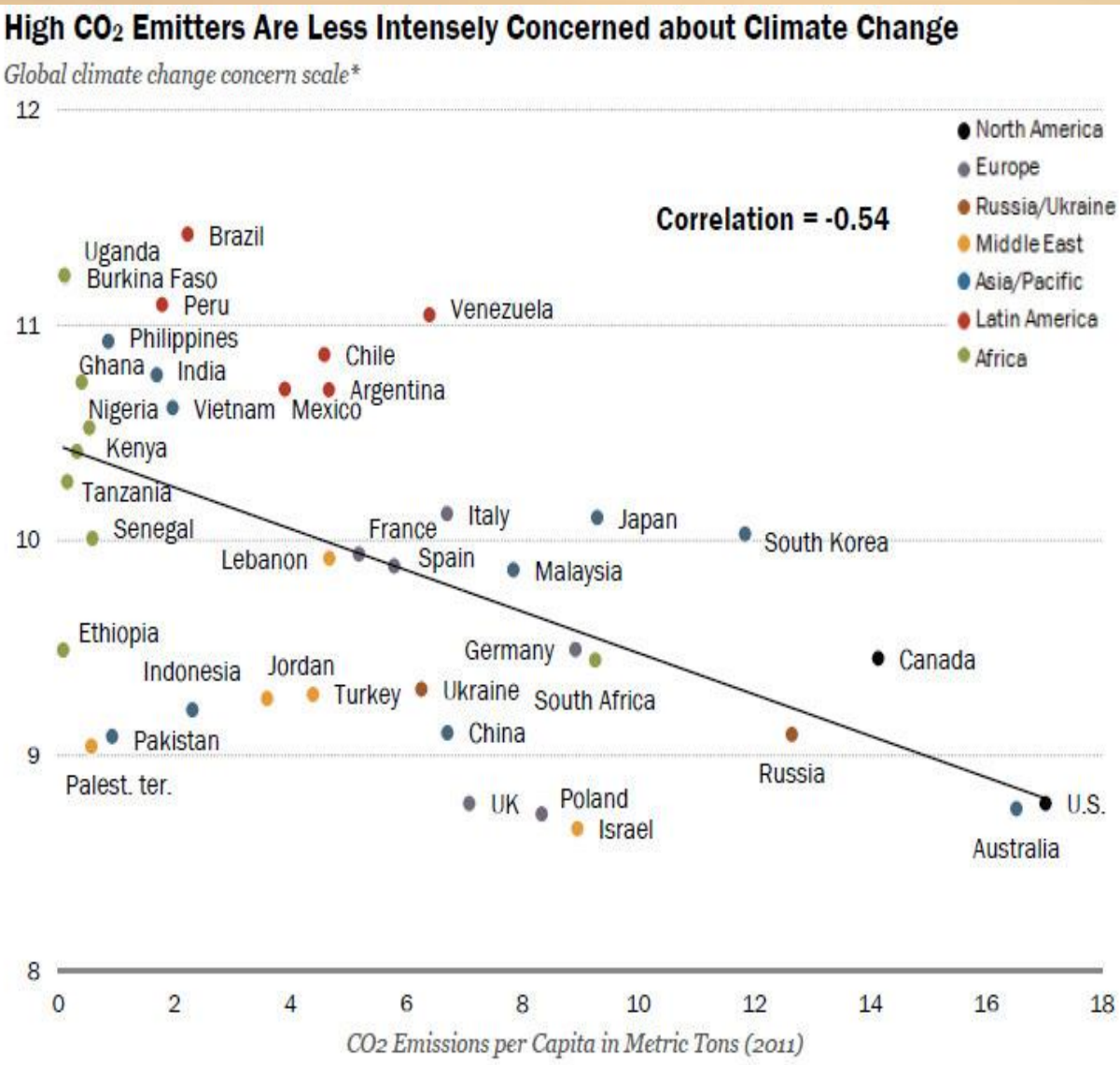
Continuing: Even this watered down version then becomes the target for right wing / fossil fuel interests to slander, calling them lies by "alarmist grant-grubbing scientists". Corporate media's "false balance" completes the mis-education of the public



The political manipulation of the science, in the IPCC's summary report is corroborated by other IPCC scientists...

*In a **letter** addressed to senior IPCC chairs dated 17th April, Prof Robert Stavins - a lead author for the **IPCC's Working Group 3** focusing on climate mitigation - complained of his "frustration" that*

The government approval process "built political credibility by sacrificing scientific integrity."



* Concern about global climate change is measured using a three-item index ranging from 3-12, with 12 representing the most concerned about climate change. Respondents were coded as 4 if they believe climate change is a very serious problem; if they think climate change is harming people now; and if they say they are very concerned that climate change will harm them personally at some point in their lifetime. The mean score for each country is used in this analysis. (See Appendix for more details.)

Source: Spring 2015 Global Attitudes survey. Q32, Q41 & Q42. Data for CO_2 emissions per capita from World Bank Data Bank, accessed August 5, 2015.

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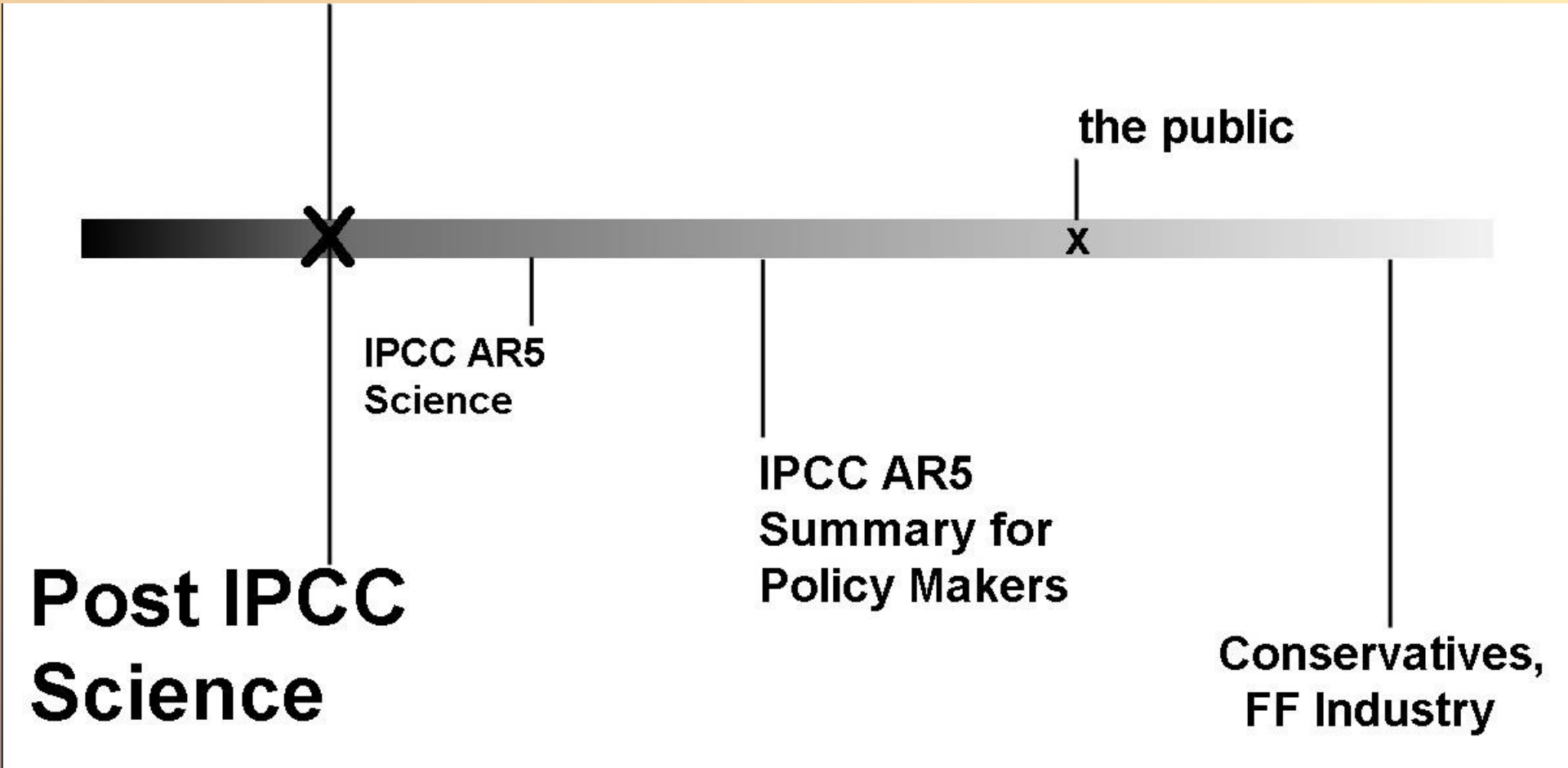
Indeed, The highest CO2 emitting countries are the most politically motivated to minimize the perception of climate danger. The U.S. (2015, pre-Trump), is the worst

But worse still - far from being "alarmist", even the largely good-faith IPCC AR5 main report is significantly too optimistic, based on the Post-IPCC Science which I'll summarize now…



From Climatologist Dr. Peter Cox, Commenting on the Paris COP21 and IPCC Scenarios…

- IPCC statement: *"Global Surface Temperature Change for the end of the 21st Century is likely to exceed +1.5C for all scenarios"*
- **Cox**: ***"…but this is the understatement of the century!…*** *and scientists are not allowed in the negotiations (at least not scientists like me, who might say something)…and I went there thinking 'we've got to TELL them; 1.5?? We're nowhere near +2, we're nearer +3C!'. And we all got side-tracked, as they put this shiny thing up (waving a key fob) '1.5 is over here, don't look at the 3, don't look at the 2'. There was an optimistic BUBBLE. But it needs to become…REAL."*

From Dr. James Hansen (2017, in the Discussion Section)

- *"This summary, based on real-world data for temperature, planetary energy balance, and GHG changes,* ***differs from a common optimistic perception of progress toward stabilizing climate.***"

- *"Although the scenarios employed in climate simulations for the most recent IPCC study (AR5) include cases with rapidly declining GHG growth,* ***the scenarios do nothing to alter reality, which reveals that GHG growth rates not only remain high, they are accelerating.***"

During the Eemian – the Prior Ice Age Interglacial Warm Period (We're in an interglacial right now)…

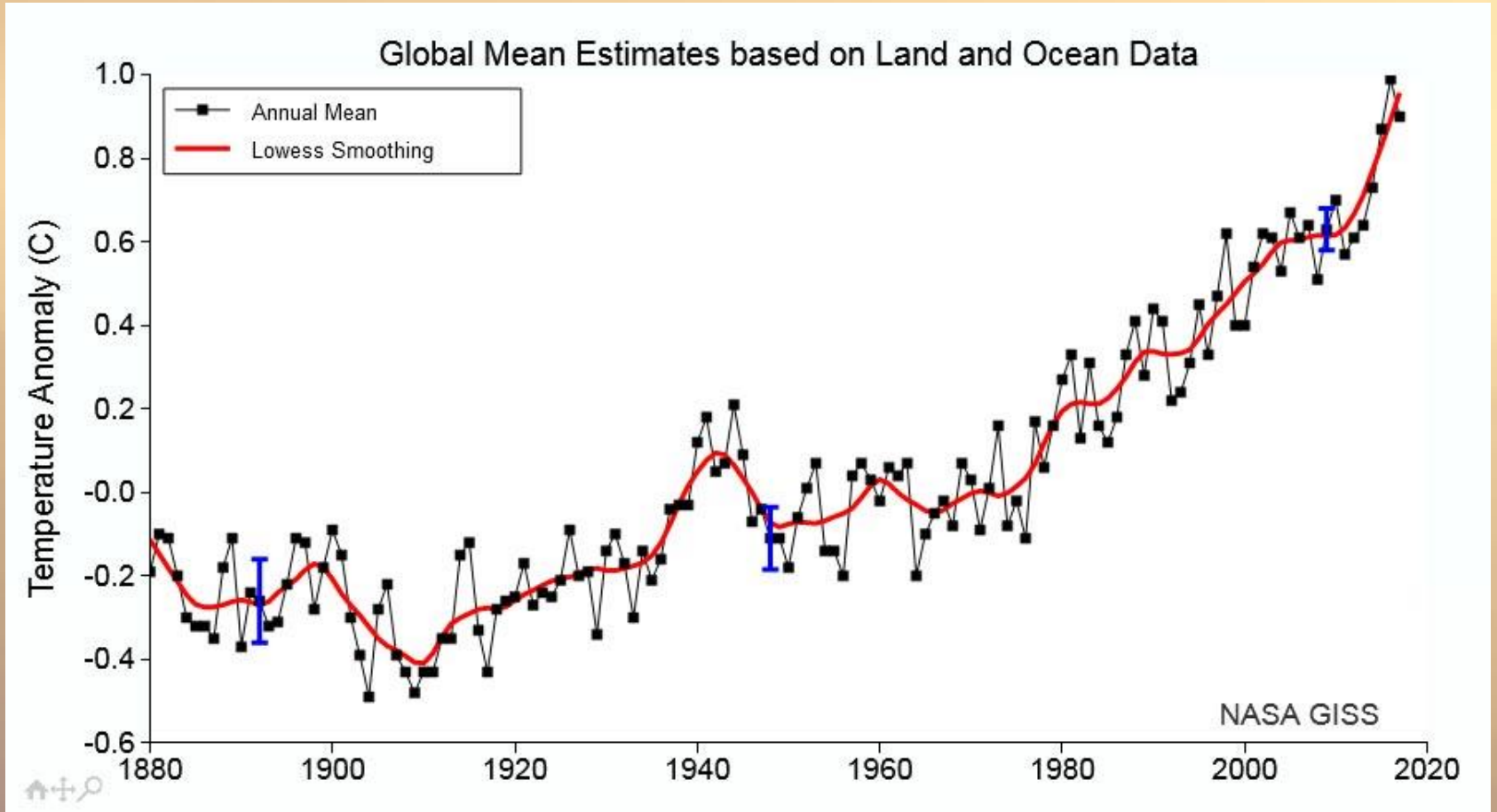
- **…Sea level was 6-9 meters higher than today. <u>That's 25 feet.</u>**
- **Yet global average temperature was only +1.0C above "pre-industrial" levels, and we'll see we're already HOTTER than that now.**
- Unless we rapidly bring temperatures back down to pre-industrial levels, something possible only with massive Geo-Engineering or massive CO2 removal from the atmosphere - beyond what the ocean and land can accomplish… then our coastlines are doomed in the century ahead (linked in **Hansen *et al.* 2017**)

If We're Serious About Preserving the Stable Climate and Sea Levels Human Civilization Evolved in…

- *…"It's not enough to pull the excess that's in the atmosphere at that time — we'd also have to pull out what went into the oceans," he said.* ***"If we want to undo this, we would have to artificially pull out all of the cumulative emissions since preindustrial times."*** *– **Dr. Pieter Tans** at NOAA's Greenhouse Gas Reference Network (**source**)*

- ***Looks like at a minimum, 350.org needs to be re-purposed and re-named as 280.org***

The Spin Continues… the average person looks at the early 2018 NASA GISS Global Average Temperature Graph and says to himself…



Land-ocean temperature index, 1880 to present, with base period 1951-1980. The solid black line is the global annual mean and the solid red line is the five-year lowess smooth. The blue uncertainty bars (95% confidence limit) account only for incomplete spatial sampling. [This is an update of Fig. 9a in Hansen et al. (2010).]

"Well… OK - it's going up… But hey! We're not even +1C hotter yet, and they keep saying +2C is a safe limit. Looks we got decades to figure this out."

- ***"What? Me worry*? Carry on!"**
- ***"Smart people in a lab somewhere will figure it out and fix things!"***

But look again, at the tiny print at the bottom. The reference baseline is the 1951-1980 average, NOT the Pre-Industrial baseline that is appropriate for correlating with models and Paleo evidence.

- If GISS had used the conventional "Pre-Industrial" baseline, namely the first 3 decades of good quality global data: 1880-1910 average, then they must **add +0.254 C** to all points on that curve.
- **But wait** – In that period we were already in the go-go "Gay 1890's" of rapid coal and oil burning and CO2 emissions at a rate fully 10% of what we are doing today. So even that baseline is not appropriate. **Then why have we been using it? Because 1880 is the beginning of easily accessible good modern global temperature records, that's why!**
- **Schurer *et al.* have a better answer for the baseline…**

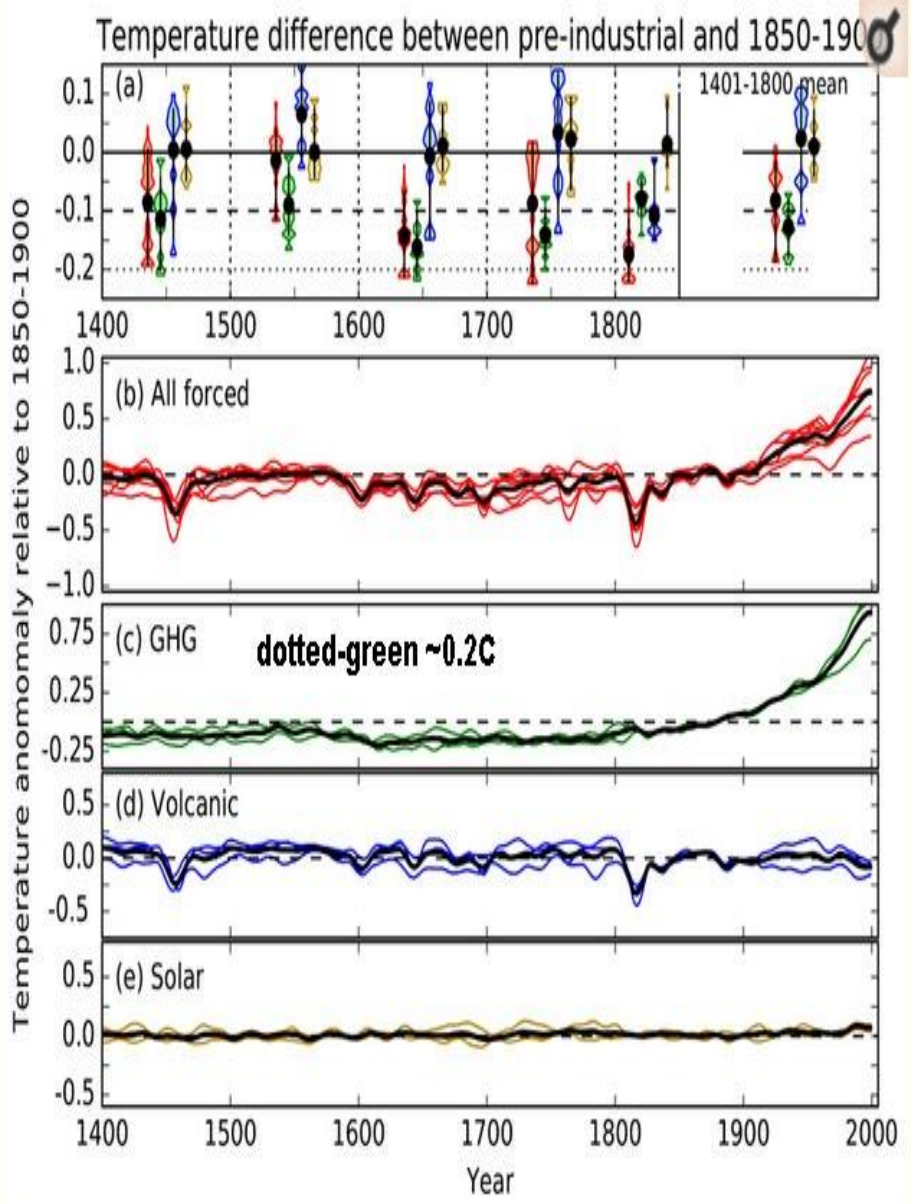
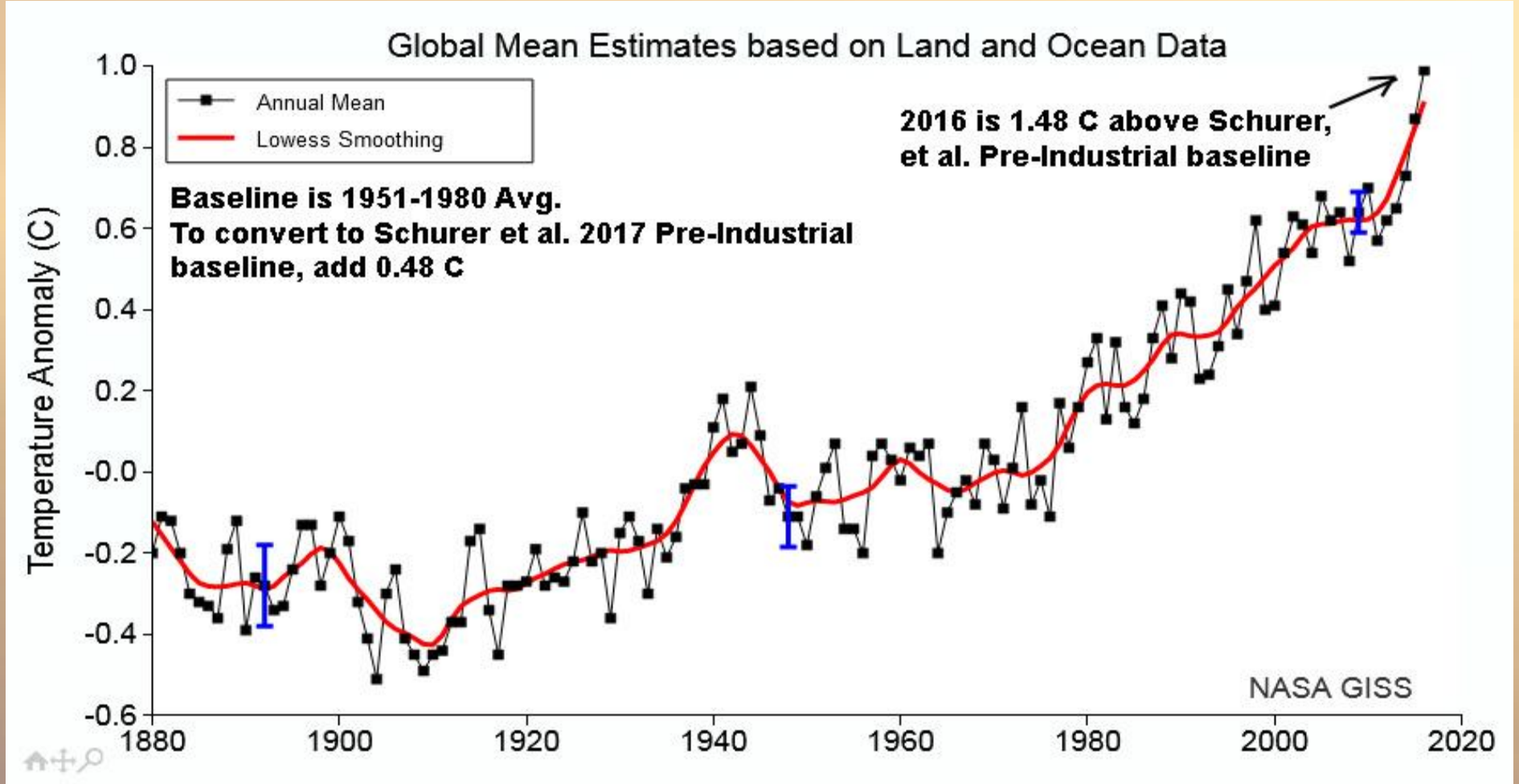


Fig 2

Model simulated difference in global mean temperature between different pre-industrial periods and 1850-1900.

The last 600 years of climate forcing. GHG baseline (green) is **another 0.2C** below the 1880-1910 dotted line conventional "Pre-Industrial" baseline, argue **Schurer, Mann *et al.* 2017, and therefore:**

…our ACTUAL temperature at the close of 2016 = +1.48C above the best-estimate Pre-Industrial Baseline. This makes a mockery of the COP21 Paris Climate promises



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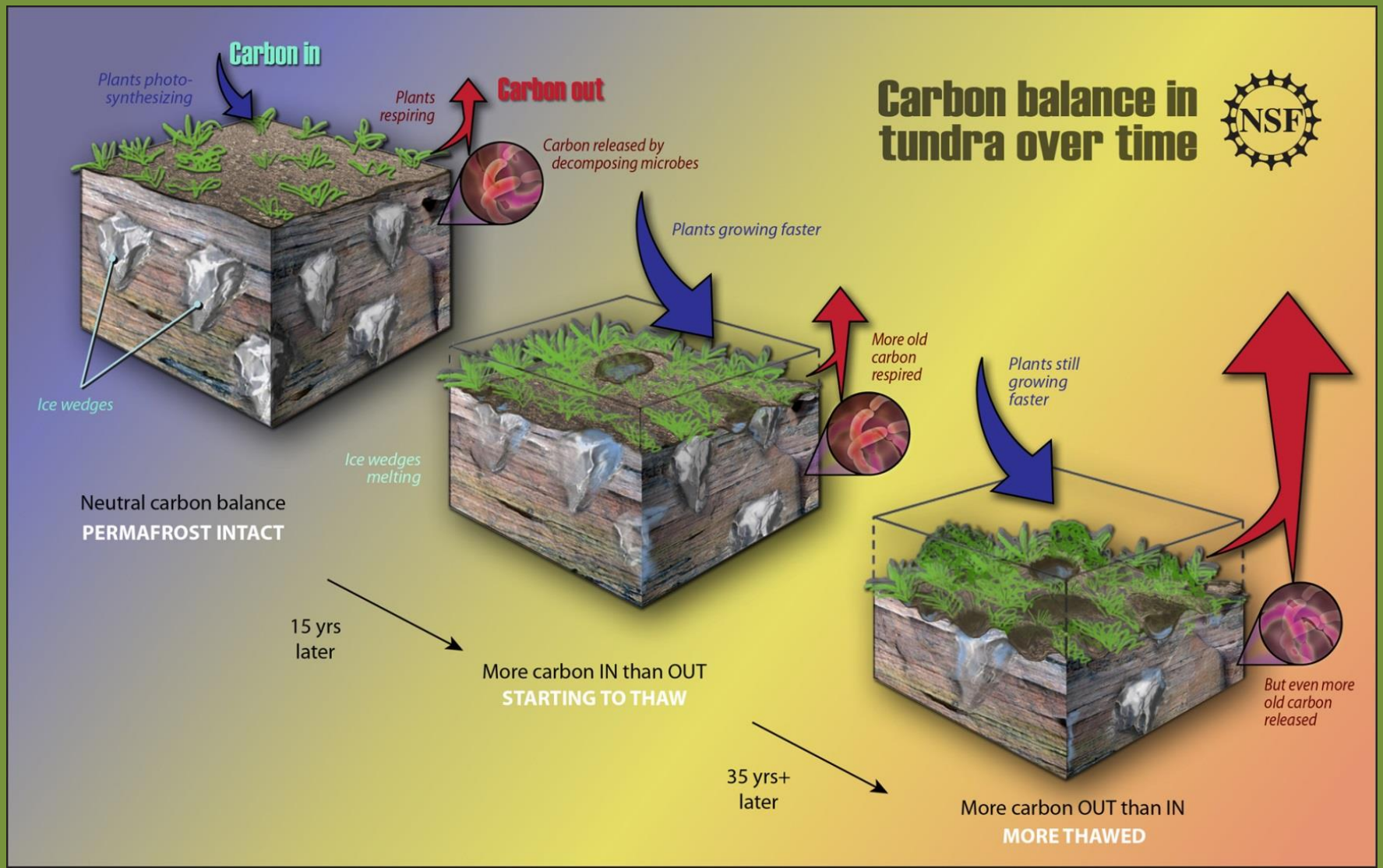
Whether it's bad communication, patronizing pandering to your supposed *"You can't <u>HANDLE</u> the Truth!"*, or to protect pro-growth interests, the outcome is the same – <u>Anesthetized Complacency</u>

2. The Straight Science



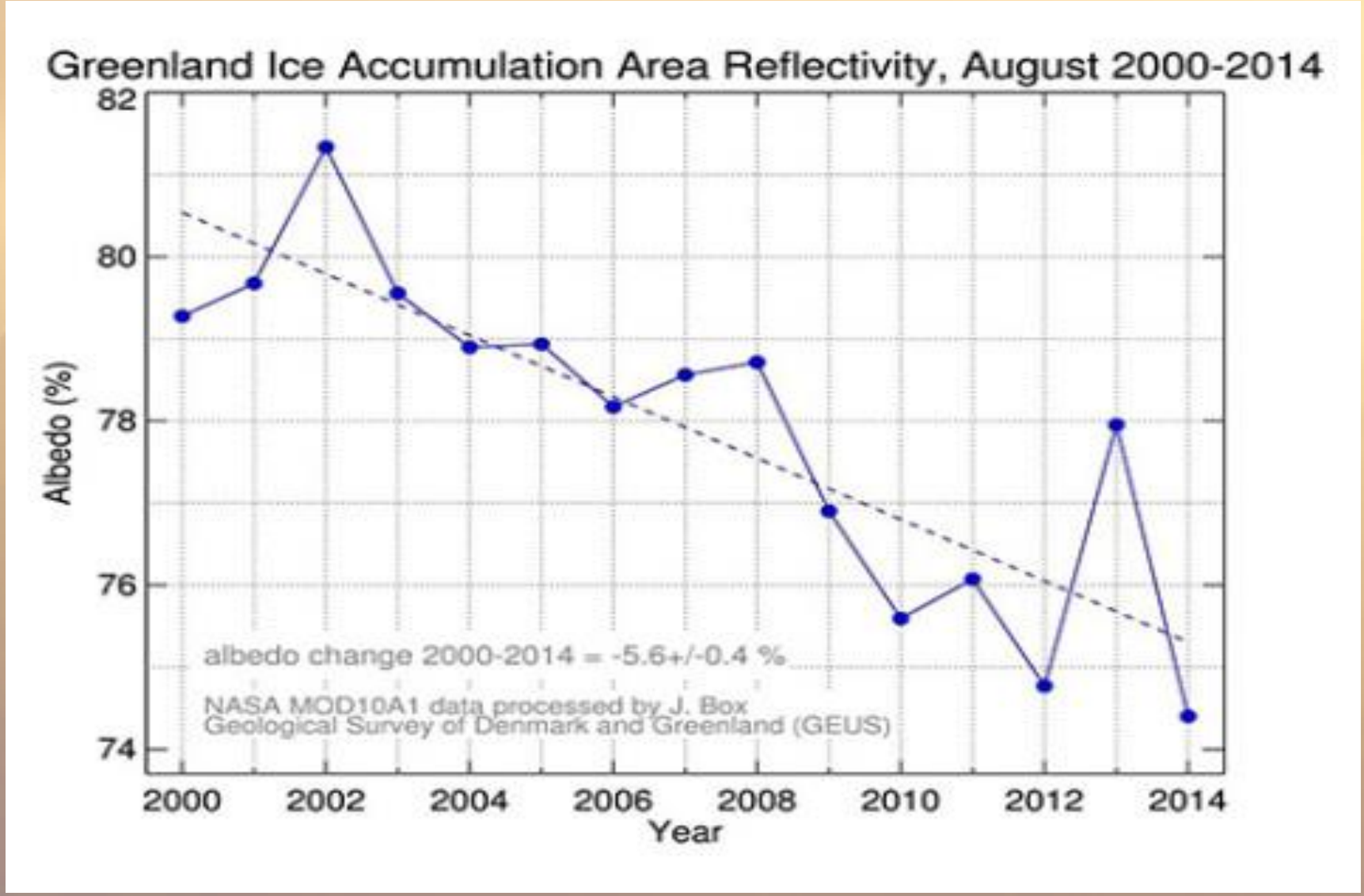
Beyond Temperature Baseline Shennanigans… More Serious, is the Missing Physics from the IPCC Modelling…

IPCC Models Do Not Include: Increasing wildfires and their smoke (80+% are human-caused: Balch *et al.* 2016)

IPCC Models Do Not Include: Ice surface meltwater generates algae and other microbe colonies which further darken the ice, absorbing more sunlight

Yes, that's Summer Greenland ice below.

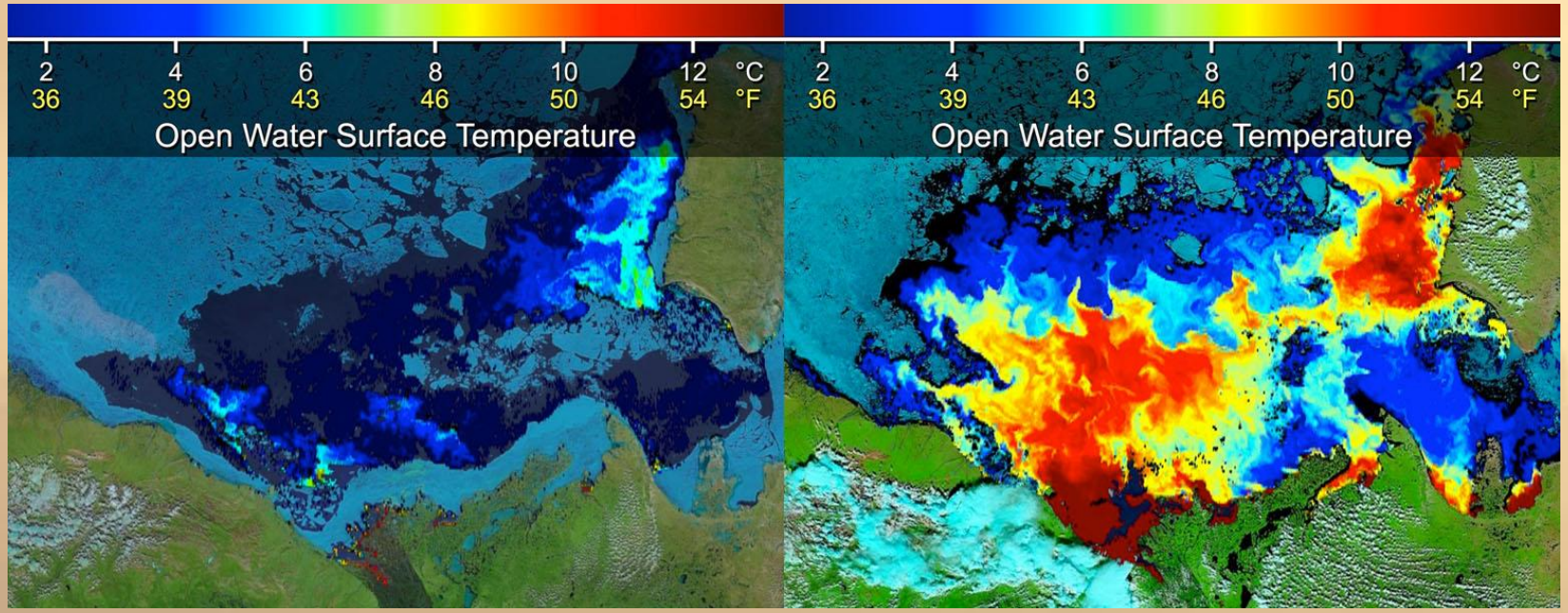
And So: IPCC Models Don't Include Summer Albedo dropping in Greenland



IPCC Models Do Not Include:

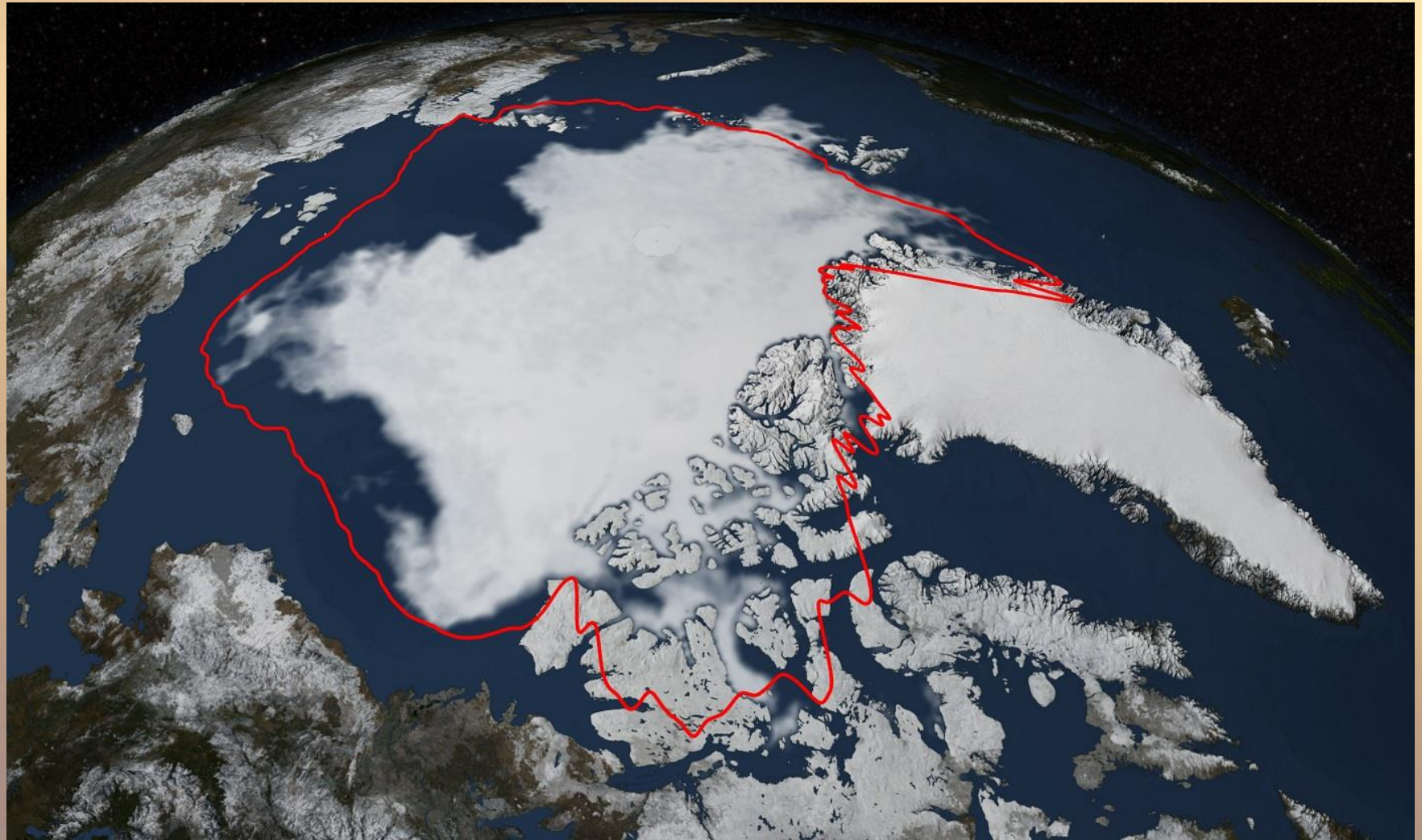
Surface melt on Greenland generating rivers of water causing hydro-fracturing, driving heavier water through lighter ice, generating moulins – taking water miles deep, softening the base of the ice sheet, accelerating glacier speed

IPCC Models do not include: The large heat influx from warm river water into the Arctic Ocean (Ngheim *et al.* 2014, described here)



The Arctic Ocean, with warm water (reds and yellows) from the MacKenzie River in Canada Scientists saw an increase of 11.7 degrees Fahrenheit **(+6.5 degrees Celsius)** in the surface temperature of the open water, which enhanced sea ice melt.

IPCC Models Do Not Include: Non-linear breakup of thinning Arctic sea ice, driven by wind and waves as more open water wind fetch appears, and subsequent iceberg drift south past Greenland.



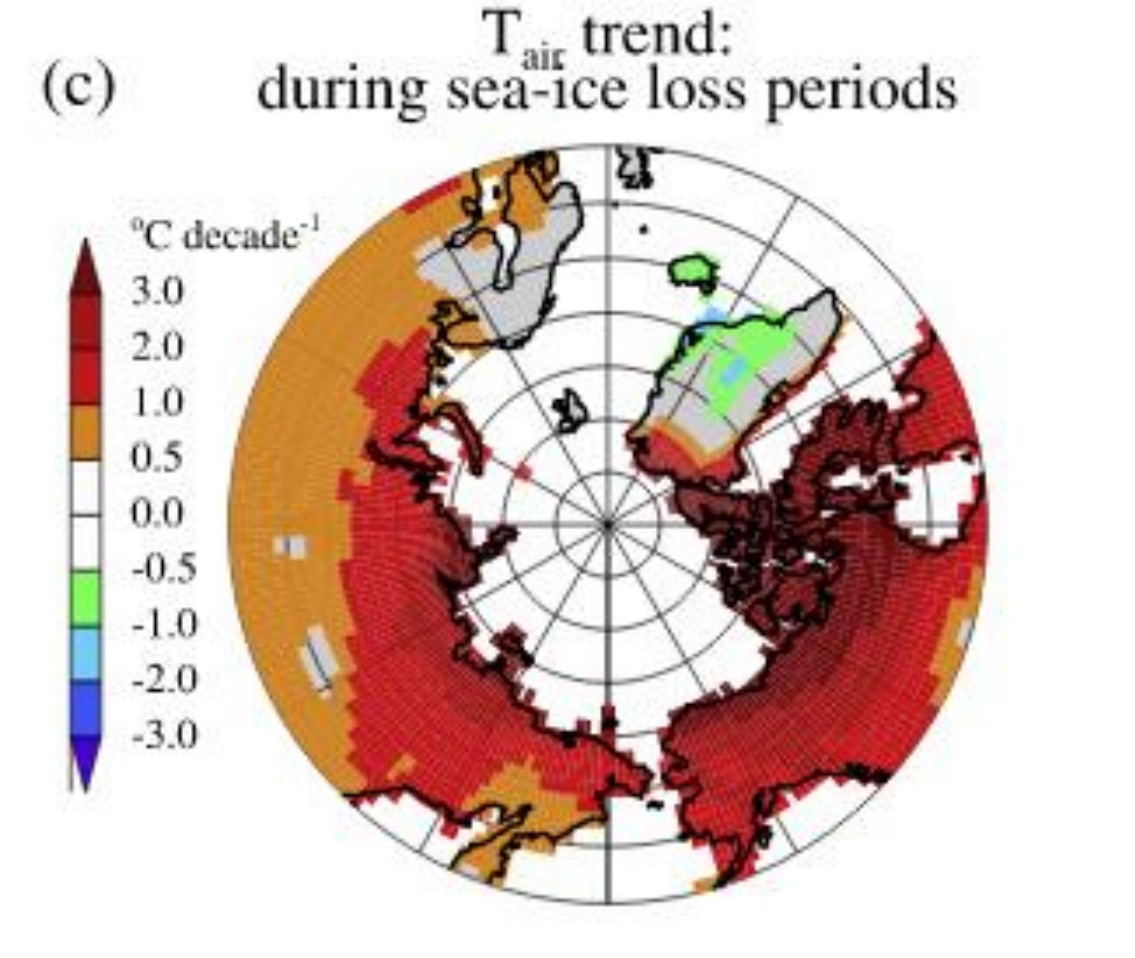
ALL of these contribute to their dramatic under-estimation of sea ice loss. Implications? …

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/

This Loss of the Arctic Ocean's Ice …sends a pulse of heat 1500 km south of the Arctic shorelines (Lawrence *et al.* 2008), across the Permafrost.

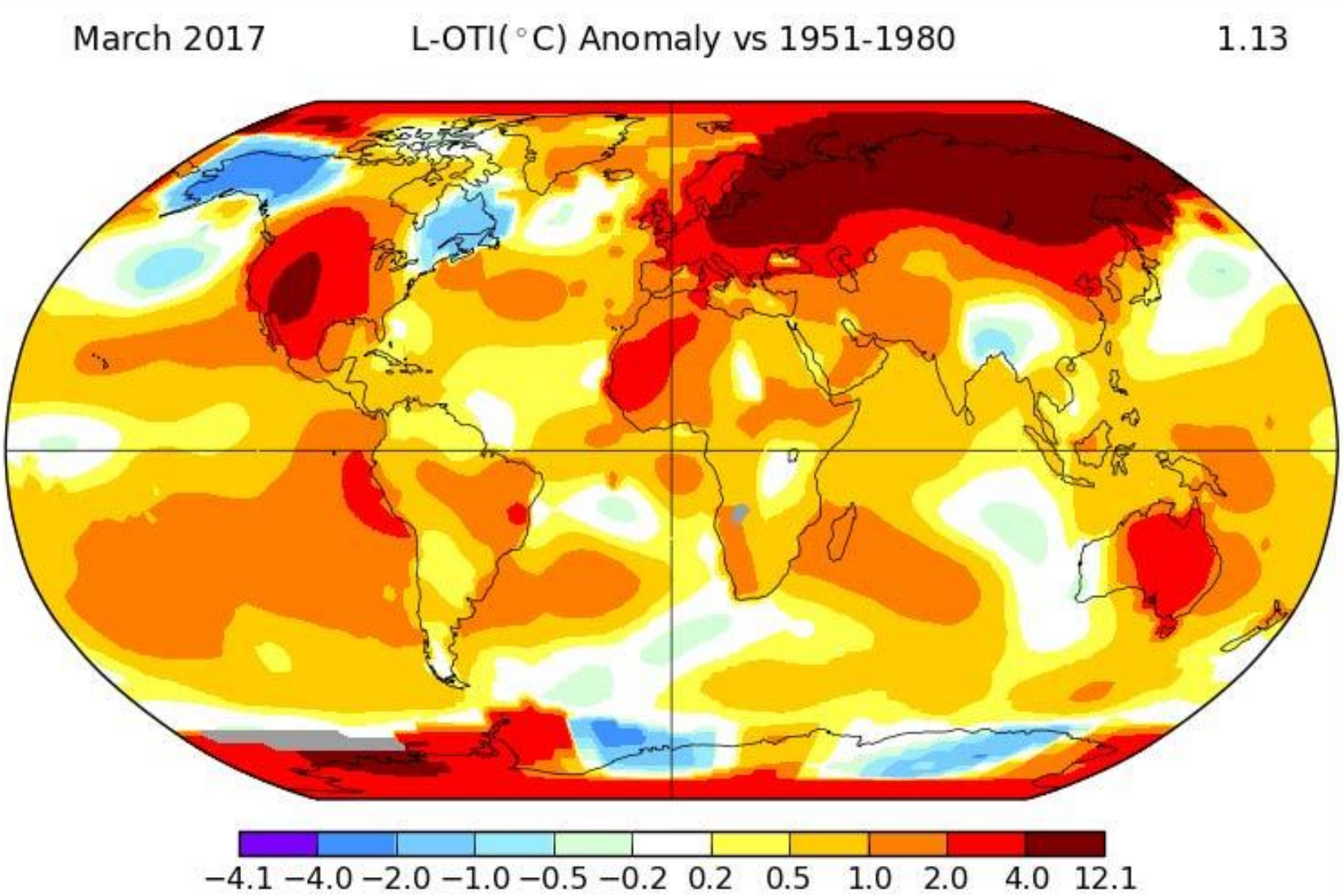
Below: temperature trend map. Hot in Siberia, but even hotter in North America. So if Siberia melts, North America will as well, and likely sooner



Vaks *et al.* 2013, showed from Paleo data that the tipping point for the melt of ~all Siberian permafrost (and therefore all global permafrost), occurs at +1.5C above pre-industrial temperatures.

- From the paper's conclusion section: *"Warming of ~1.5°C (i.e., as in MIS-11) causes a substantial thaw of continuous permafrost as far north as 60°N…(near the Arctic coastline) Such warming …can potentially lead to* ***substantial release of carbon trapped in the permafrost into the atmosphere****." (see* ***interview on YouTube****)*

So How Close Are We to +1.5C…? As we Just Saw – We're Already There

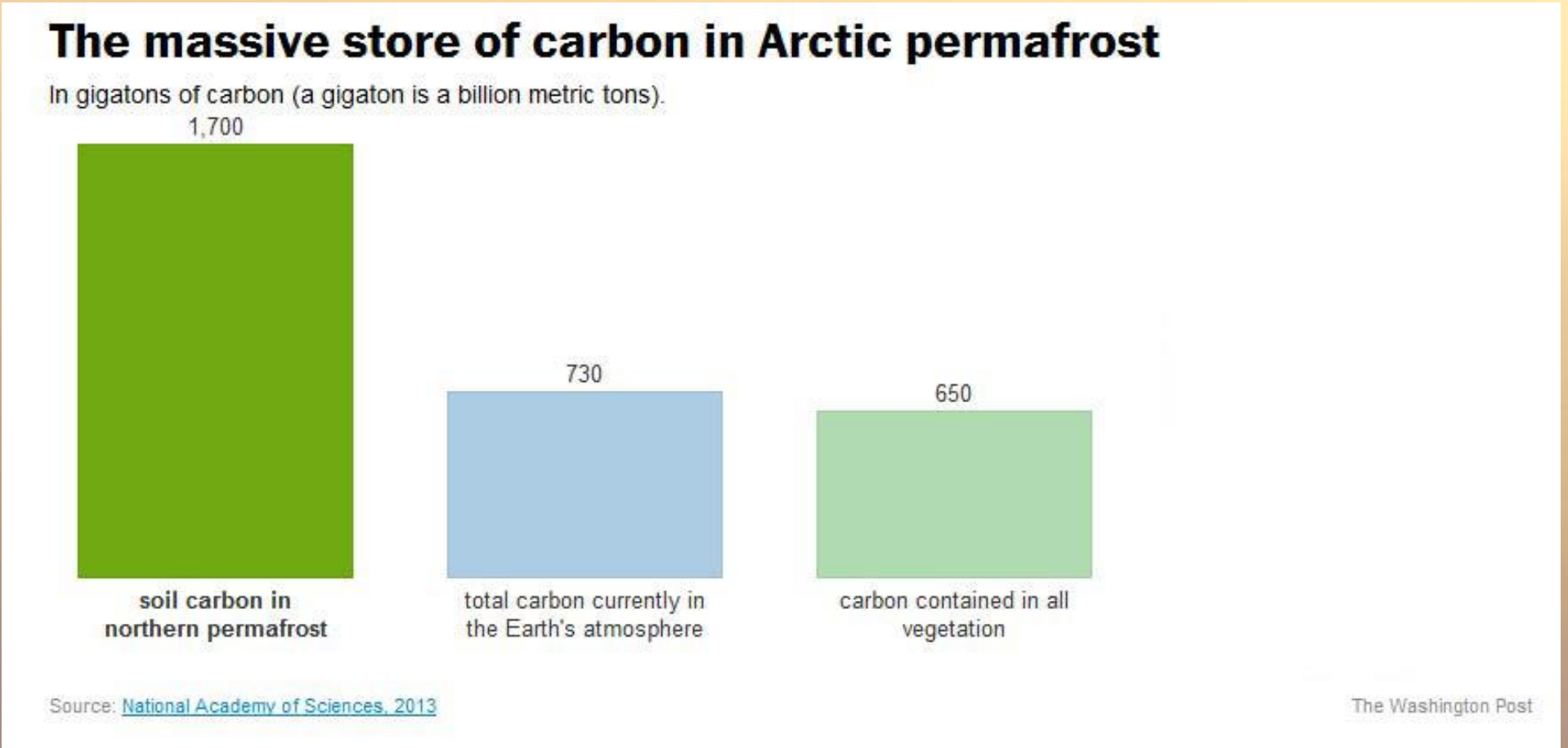


Indeed, the Permafrost is Now Melting

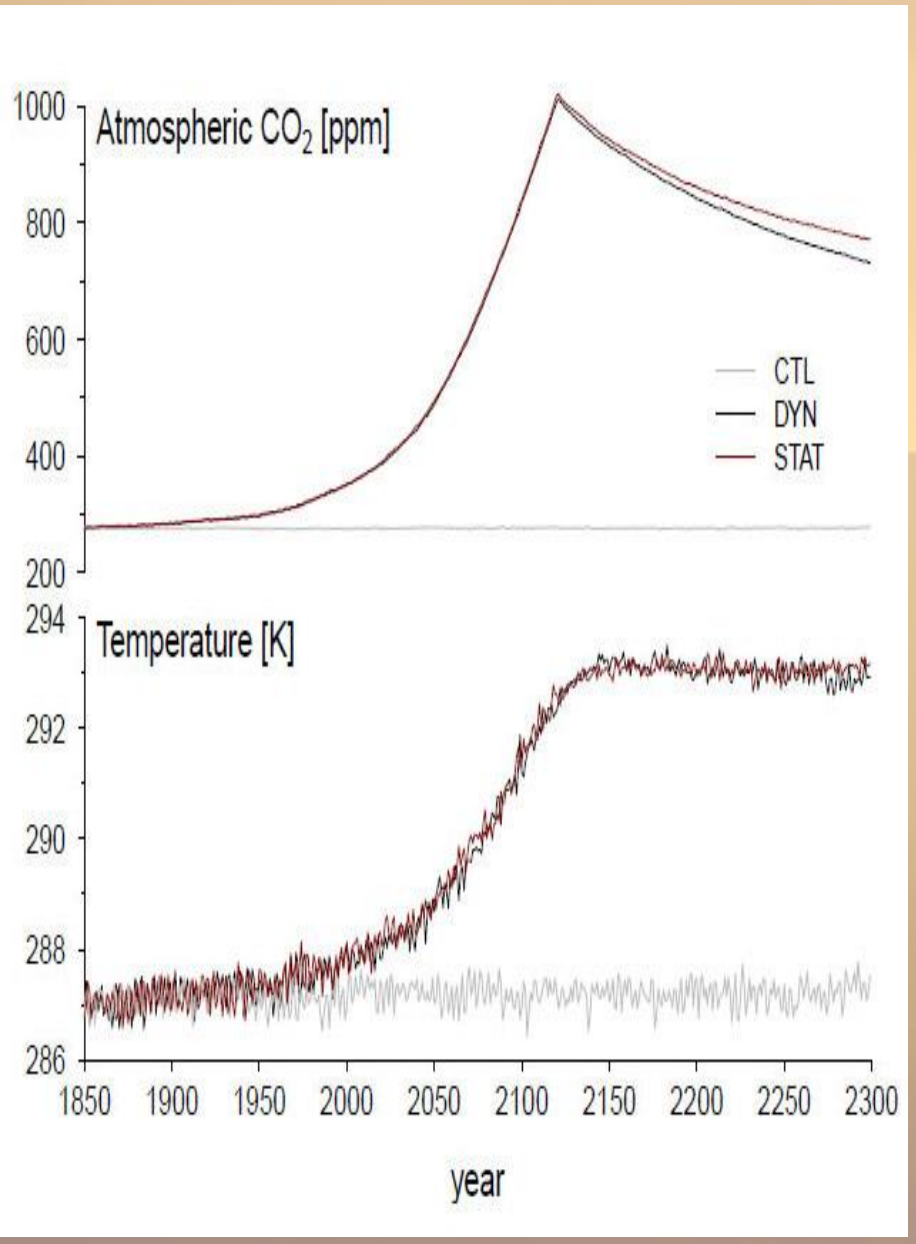
Is the Carbon Release in Thawing Permafrost Incorporated into the IPCC Assessment Reports and Projections?

- **No.**
- *"The concept is actually relatively new,"* says Dr. **Kevin Schaefer** of the **National Snow and Ice Data Center** at the University of Colorado in Boulder. *"It was first proposed in 2005. And the first estimates came out in 2011. Indeed, the problem is so new that it has not yet made its way into major climate projections",* Schaefer says.

Could this be significant? Yes! There's more carbon in the permafrost than in the entire atmosphere plus all of Earth's vegetation… combined



How Will This Thawing Permafrost - Neglected in IPCC Models - Affect Atmospheric CO2 and Methane Levels?

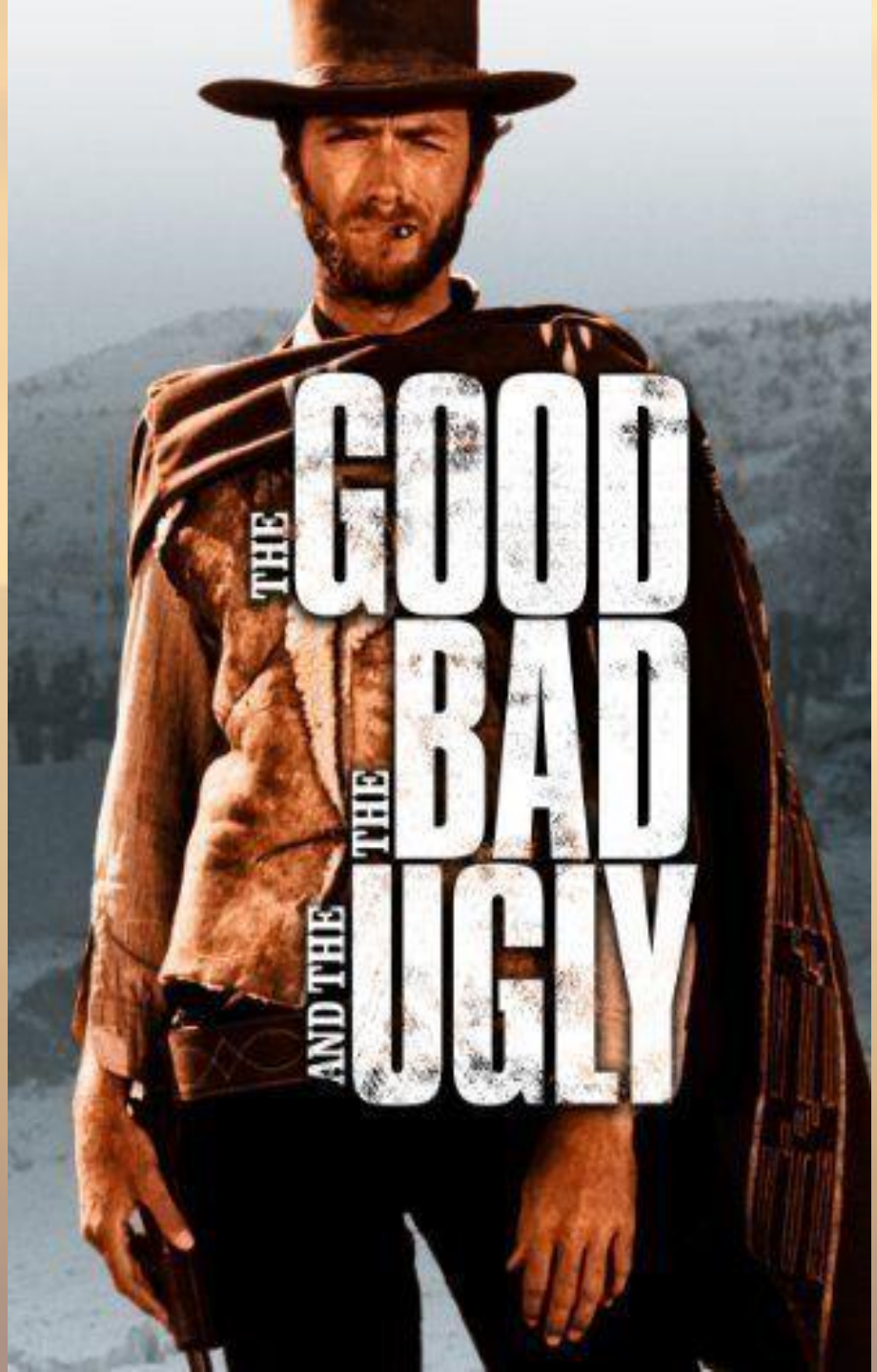


The IPCC had been using the work of Solomon *et al.* 2009 , Mathews and Weaver 2010, and others, who assumed no permafrost or other additive GHG sources, so ending human-caused emissions (here, at year 2100) lets ocean and land absorb atmospheric CO2 (top graph).

But Global Temperature does NOT drop (bottom), due to the ocean's thermal inertia and the fact the Earth hasn't heated up enough to reach radiative balance.

Now Let's Include the Permafrost Carbon Feedback…

- THE GOOD
- THE BAD
- AND THE UGLY



First, We Need to Introduce a Convenient Number: ECS= Equilibrium Climate Sensitivity

- Take pre-industrial atmospheric CO2 levels of 280 ppm, and double it to 560ppm, and then wait for global temperatures to rise until they reach “equilibrium” (equilibrium for fast climate feedbacks only, the slow ones take a few THOUSAND years and make ECS higher)
- **That temperature rise is called ECS. Averaged over the past few million years, it’s about ECS=3C (+- ~1.3C)**

MacDougall *et al.* 2012 re-calculated atmospheric CO2 assuming an immediate end to all human CO2 and sulfate emissions, but including the Permafrost Carbon Feedback . Assuming ECS = 3.0C, we see that CO2 does not fall, instead flattening, as permafrost emissions fully compensate for ocean/land absorption. And this was assuming 2012 temperatures, which were 0.3C below today in 2018

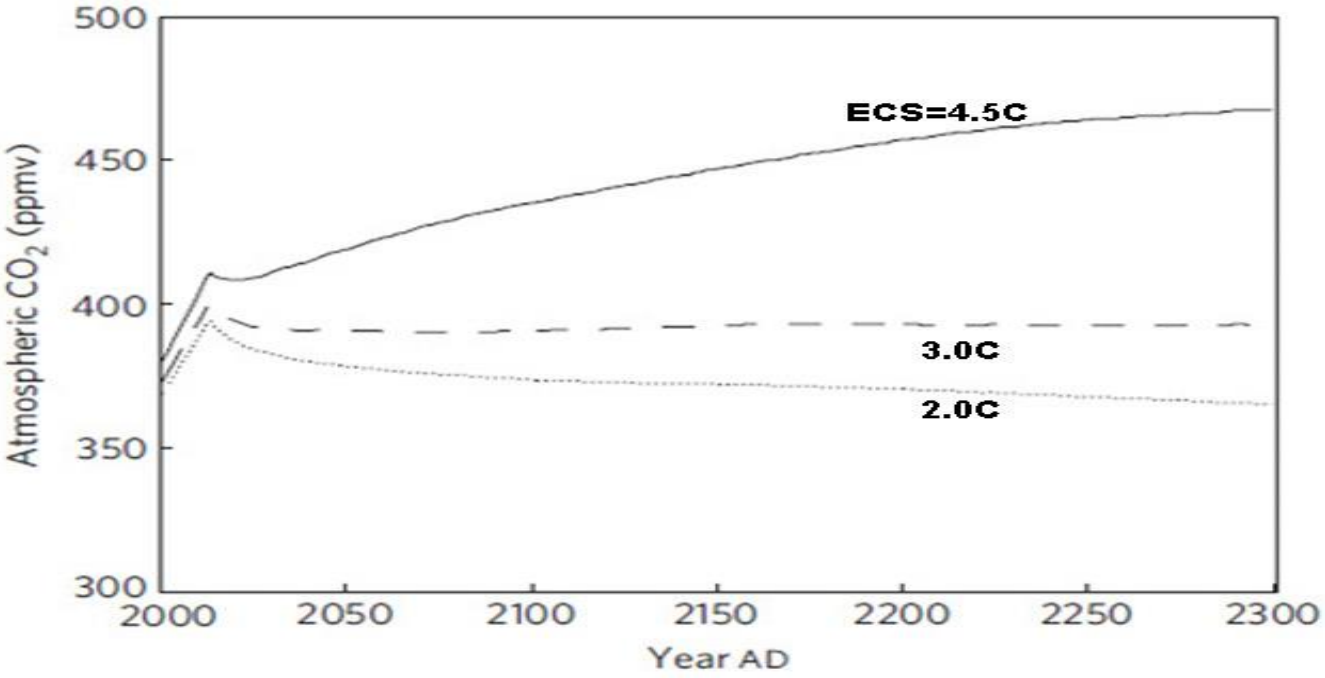
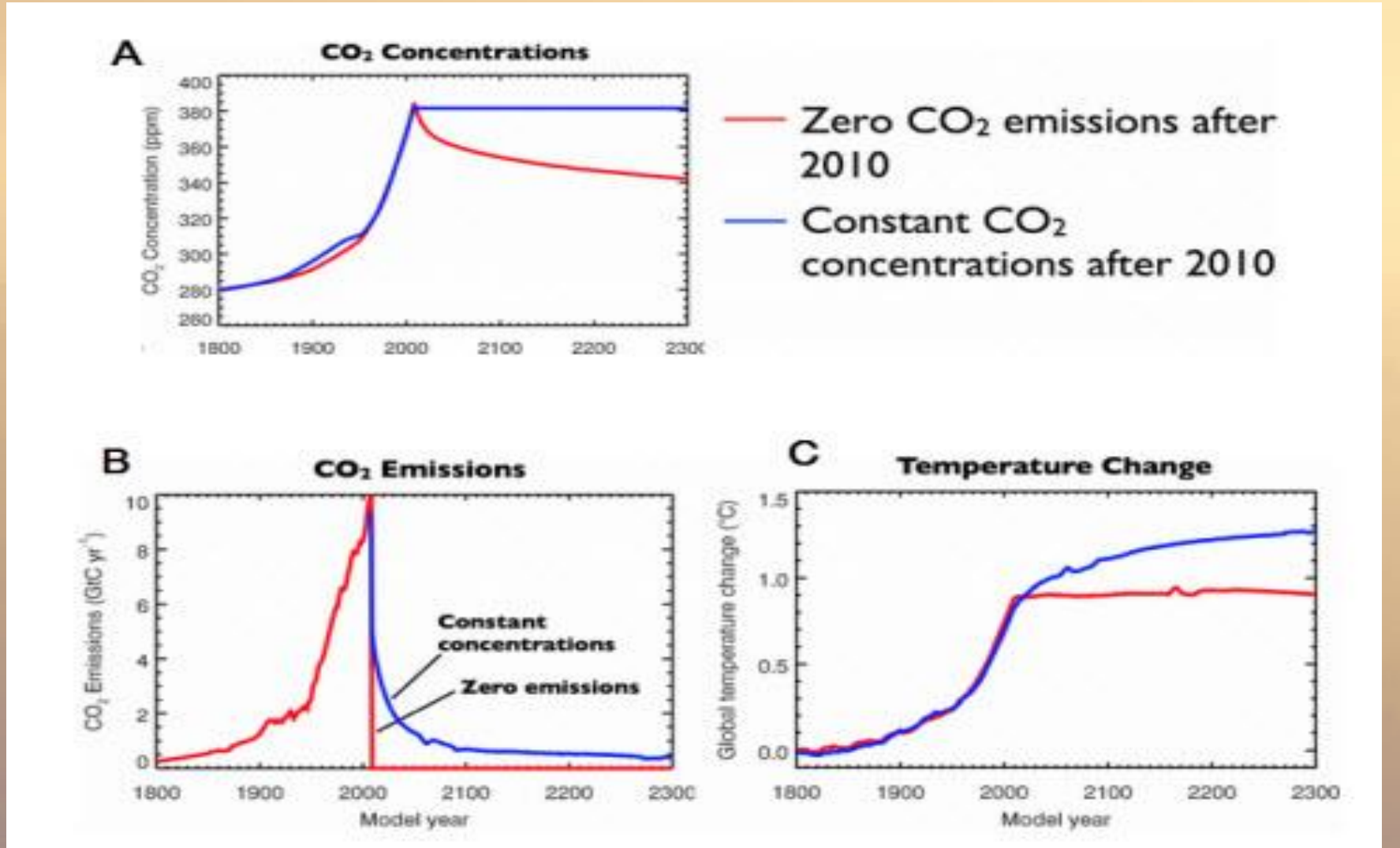


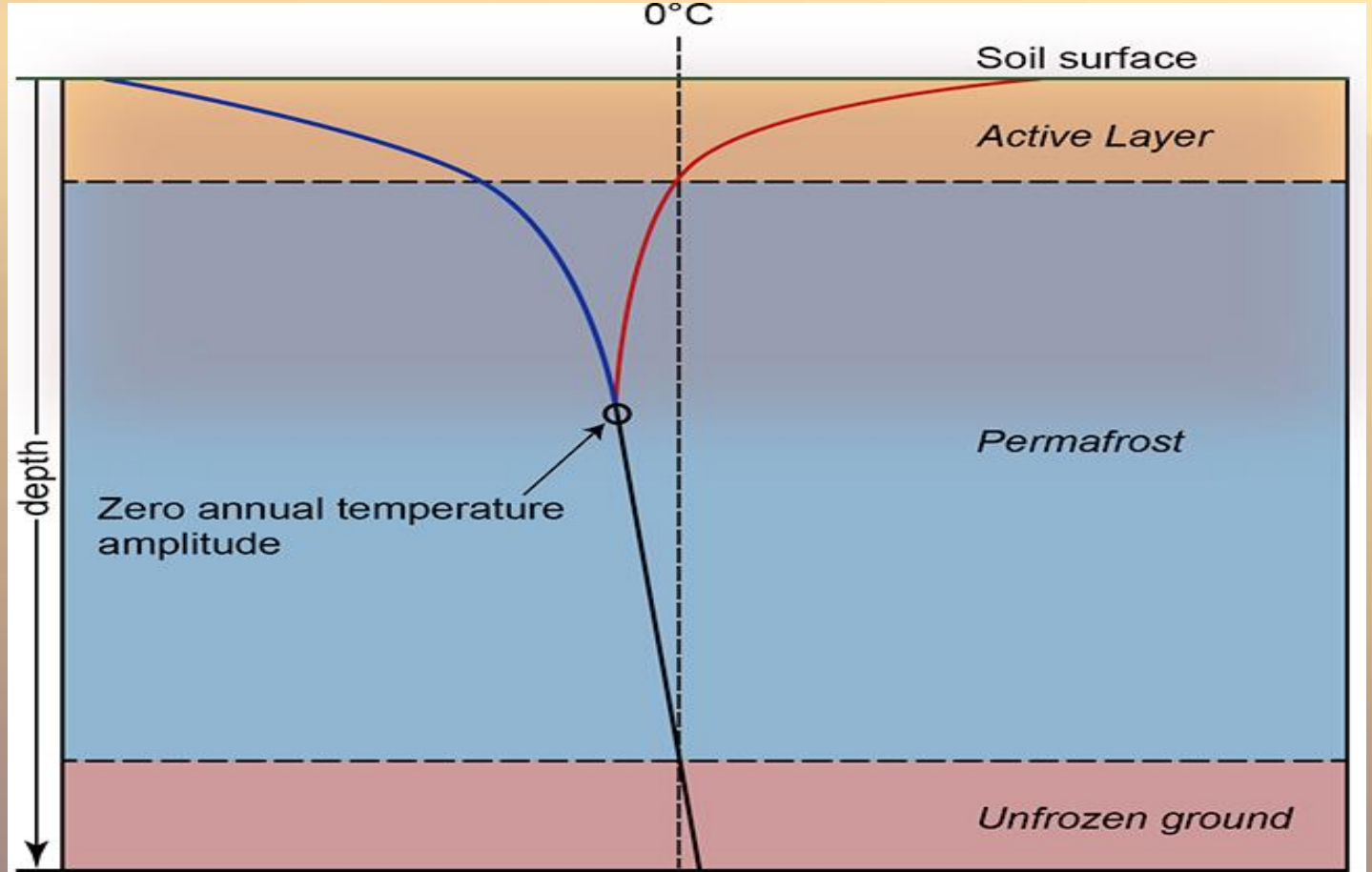
Figure 3 | Evolution of atmospheric CO_2 concentration in response to a cessation of anthropogenic CO_2 and sulphate emissions in the year 2013. The dotted line represents the response for a climate sensitivity (to a doubling of CO_2) of 2.0 °C, the dashed line a climate sensitivity of 3.0 °C and the solid line a climate sensitivity of 4.5 °C.

Yet flat (Constant concentrations – blue) atmospheric CO2 leads to continued rising temperatures (bottom right) (*e.g.* Matthews and Weaver 2010 here), because of the existing 0.6 W/m^2 of radiative imbalance (recently upped to ~0.75?)

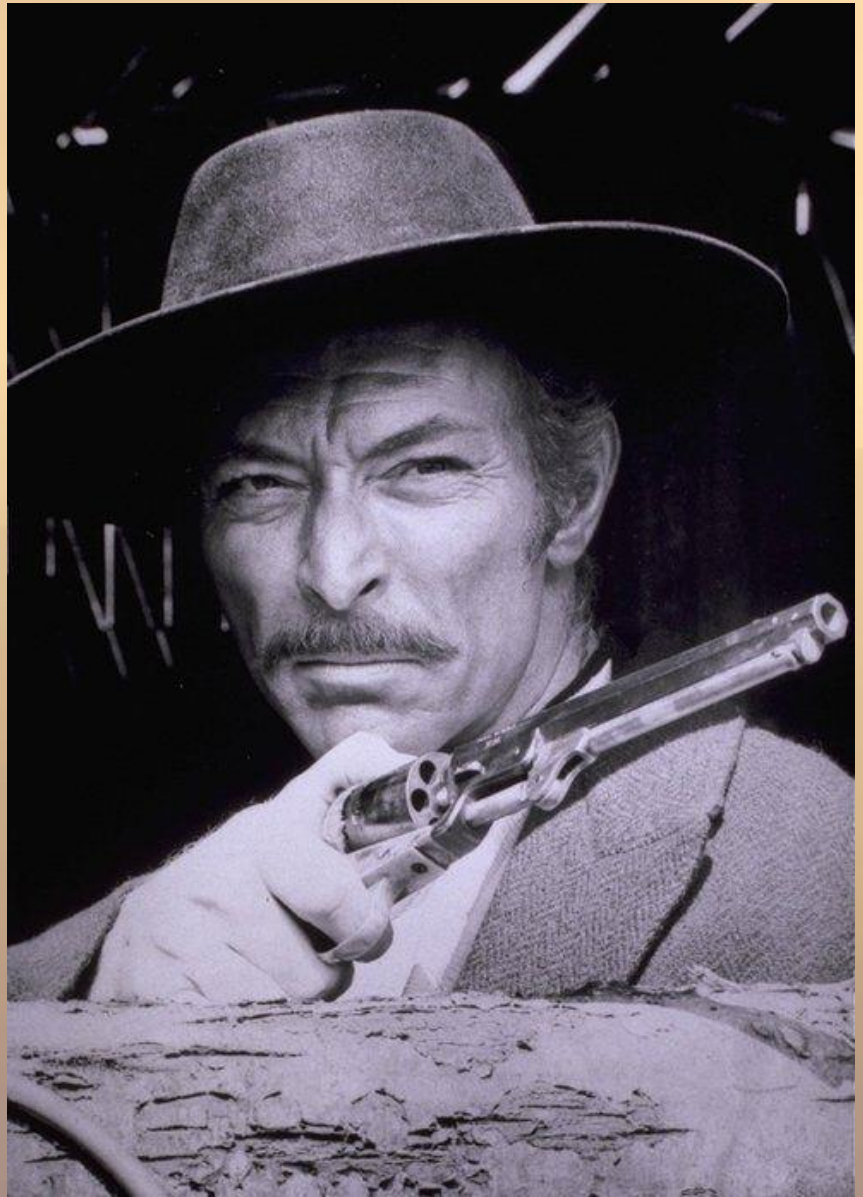


A Closer Look: THE GOOD

Schadel *et al.* 2014 finds the depth of the active layer (the annual freeze/thaw layer near surface) is 40% smaller than the earlier estimate used by MacDougall's 2012 work.



THE BAD

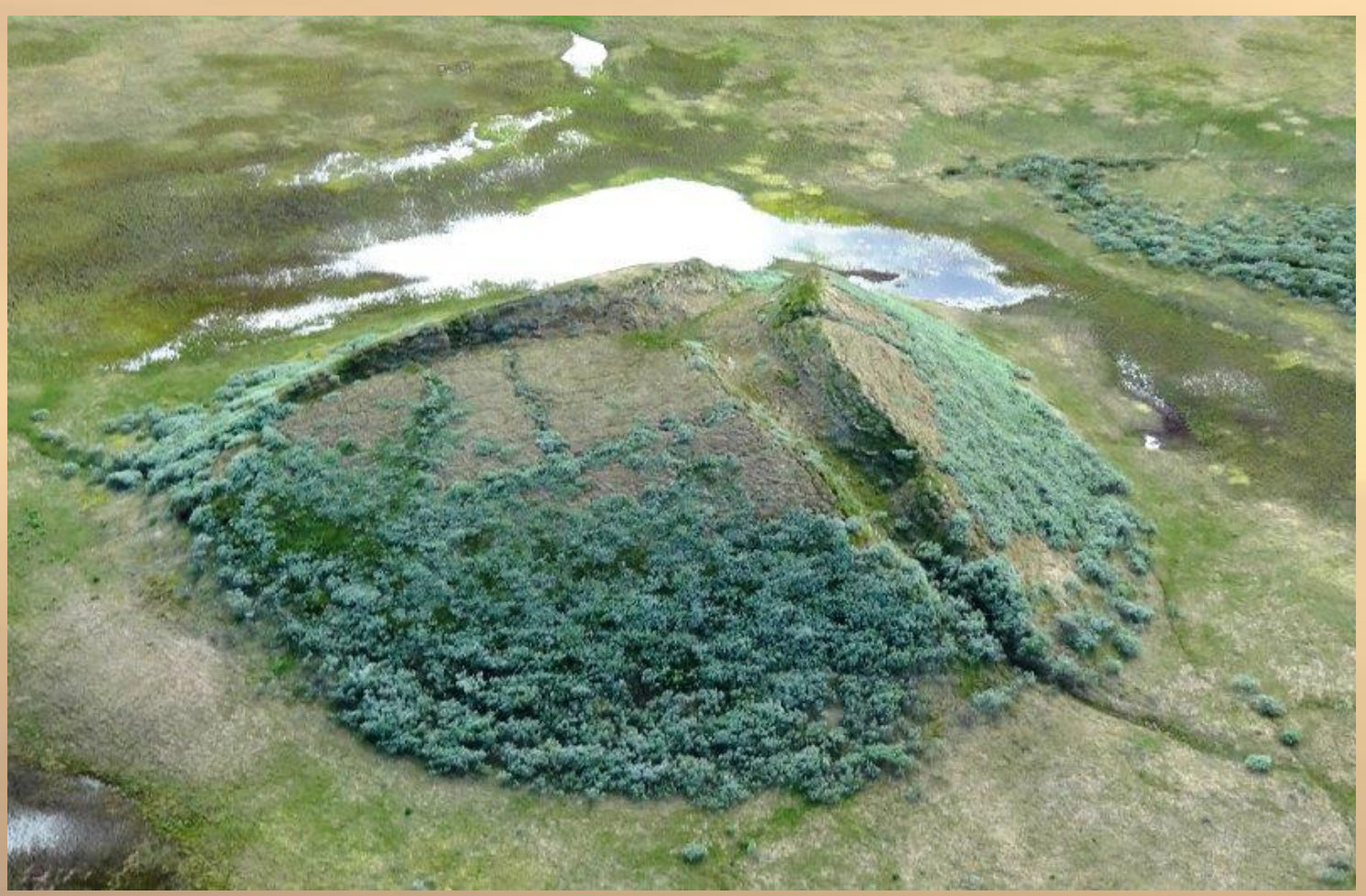


<u>IPCC Models Don't Include</u>: trapped methane in frozen Arctic lakes, which is quickly lost when the permafrost thaws

IPCC Models Do Not Include: Pingos melting and filling with deep methane, then exploding and leaving large craters. While it would take many thousands of such craters to be a significant force in climate…

… more are being discovered all the time

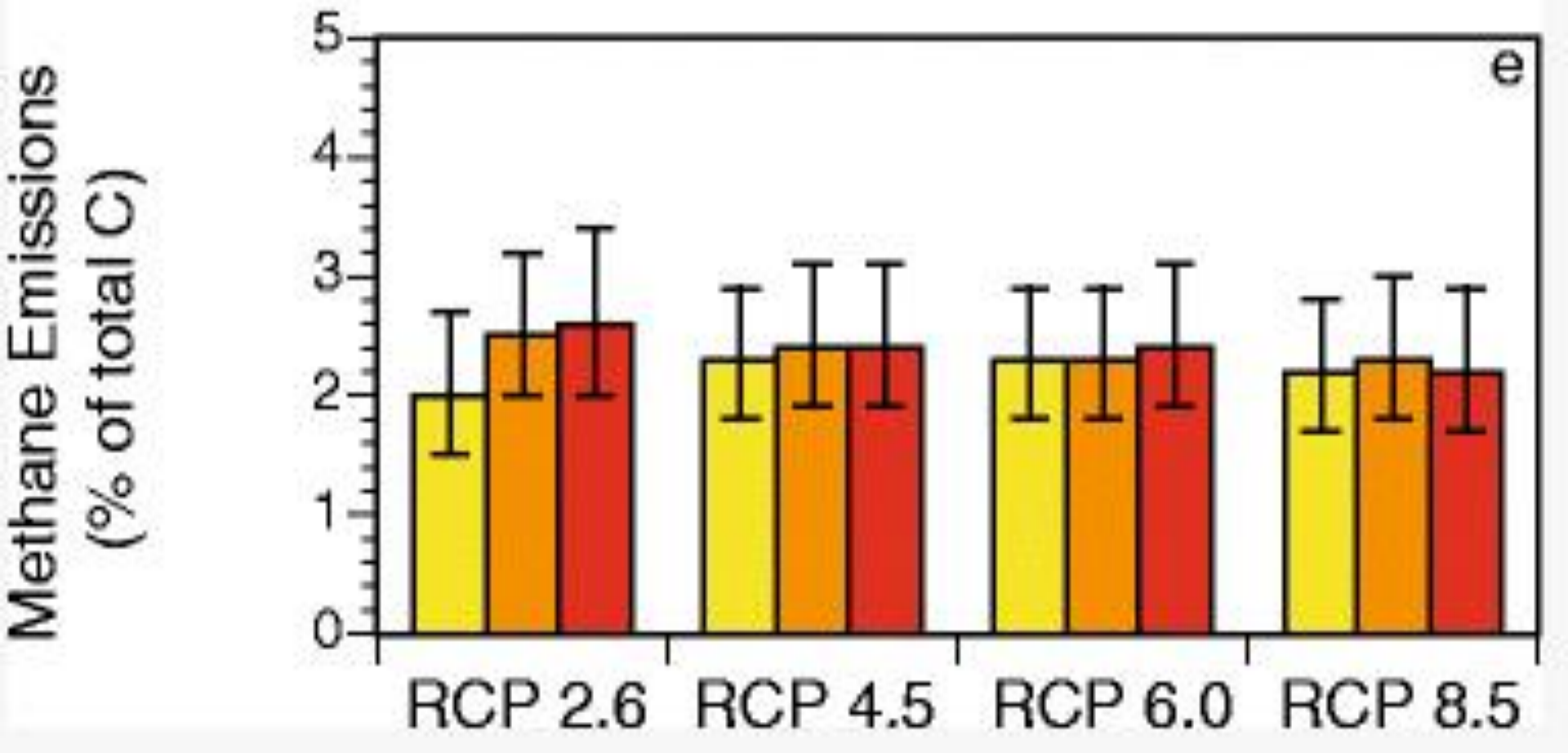
New in 2017, scientists are discovering…



- …Over **7,000 new domes filled with methane** *(link above)*, in the Yamal and Gydan Peninsulas alone

So How Much Methane is there, in melting Permafrost?

Consensus from permafrost experts: 2.3% of emerging carbon will be in the form of methane (Schuur *et al.* 2013, review paper) - regardless of human emission scenario. (bar colors are for years 2040, 2100, 2300)



This is BAD

Because there's NO methane in the MacDougall *et al.* 2012 predictions curves

- …The climate model used by **MacDougall *et al.* 2012** (the **UVic model**) makes the simplifying assumption that all permafrost carbon emissions are simply CO2.
- **So the missing Methane must be added in to their published predictions.**

Methane's a far more powerful GHG than CO2: So what does this mean for greenhouse forcing?

"If just 1% of the permafrost carbon released is methane, it will have the same greenhouse impact as the other 99% that is released as carbon dioxide."

- …explains Dr. Charles Miller, Principle Investigator of NASA's **C**arbon in the **A**rctic **V**ulnerability **E**xperiment (**CARVE** 2013).
- **2.3% of tundra carbon atoms emerging as methane means 2.3%/2.75 = 0.84% by mass as methane, *vs.* CO2**
- **If 1% methane (by mass) doubles the warming force of pure CO2, then 0.84% almost doubles it**

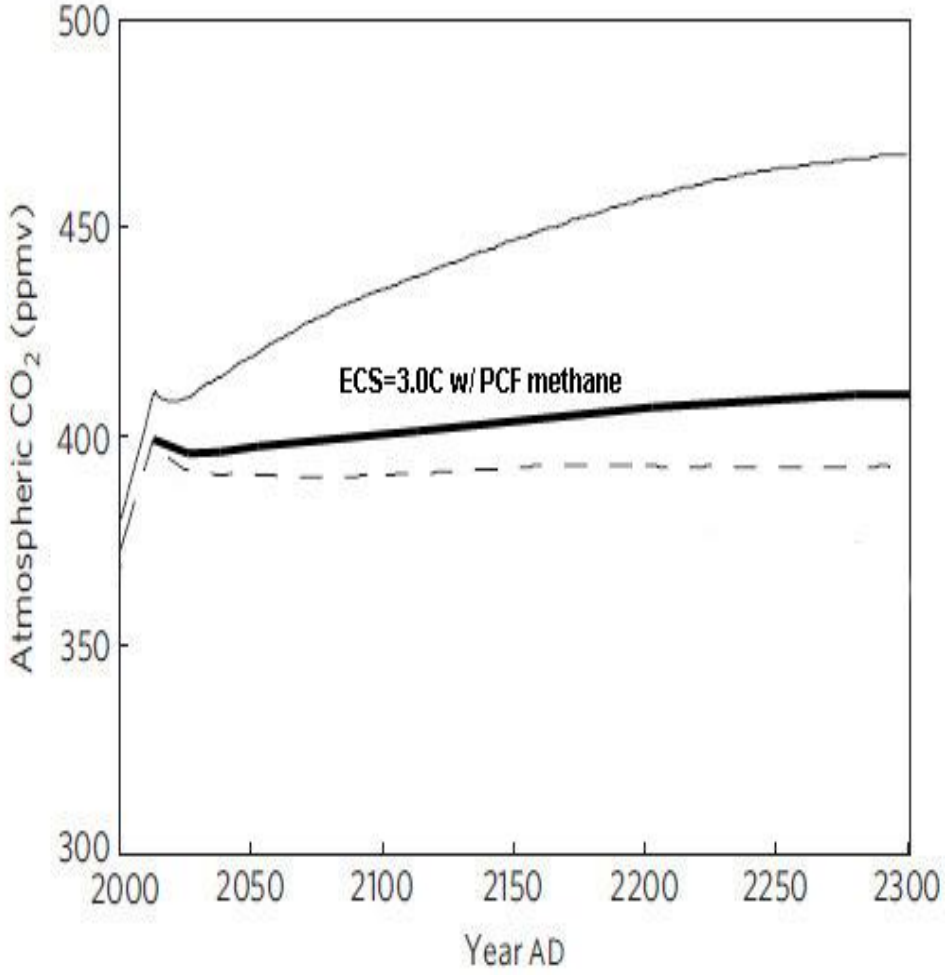


Figure 3 | Evolution of atmospheric CO_2 concentration in response to a cessation of anthropogenic CO_2 and sulphate emissions in the year 2013. The dotted line represents the response for a climate sensitivity (to a doubling of CO_2) of 2.0 °C, the dashed line a climate sensitivity of 3.0 °C and the solid line a climate sensitivity of 4.5 °C.

Result? Here's that MacDougall *et al.* 2012 graph for ECS=3C, with added (dark) curve after correcting for smaller active layer but now including methane. Not horrific, but it's still rising.

But again, this is after turning off ALL human emissions in 2013). Note we're already at 410 ppm in 2018

But wait …

The MacDougall *et al.* modelling neglects…

* …permafrost loss from **stream and coastal erosion**

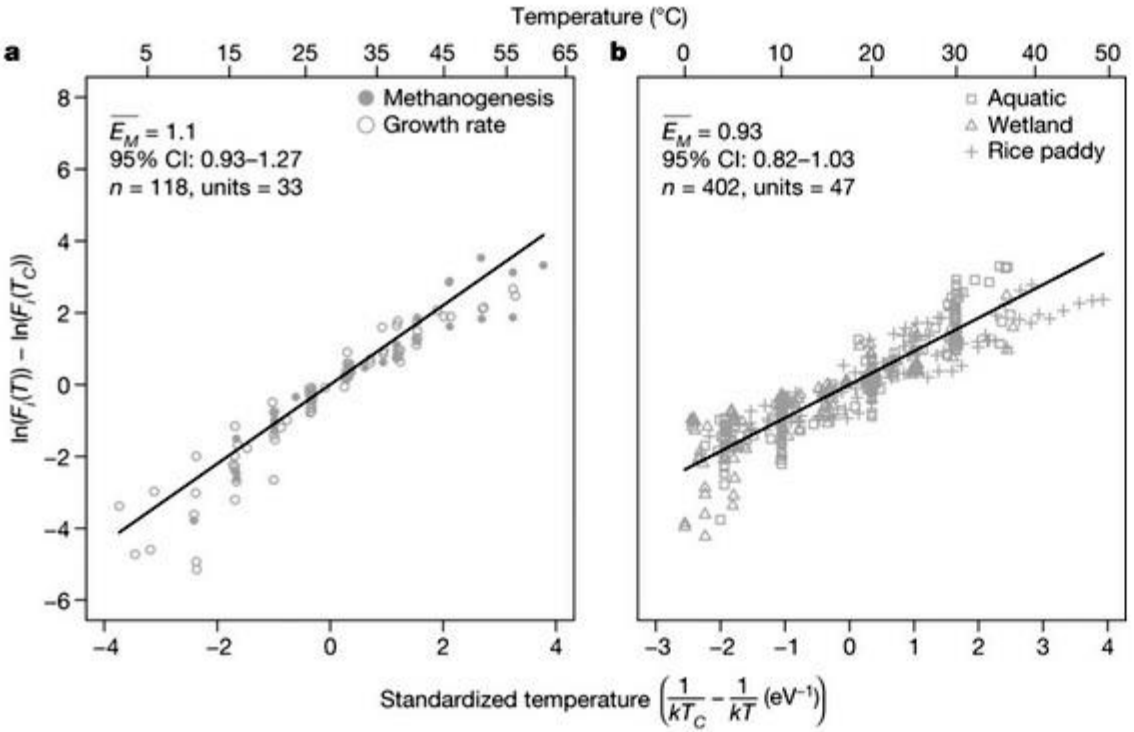
* …**thermokarst degradation**, which may **double** the actual release rate. A new study (**Anthony *et al.* 2018**) confirms this doubling, yet not included in this presentation.

* …any **active layer melting below 3.3m depth**, yet melting will gradually deepen the active layer

* Much of the Alaskan and Siberian permafrost soil is fine-grained **Yedoma** permafrost, which releases its CO2 very rapidly to the atmosphere when thawed. Even, within weeks (**Spencer *et al.* 2015**).

- **None of this is included in any projections yet.**

MacDougall *et al.* also does not include non-Arctic methane, and IPCC Models Do Not Include the newly discovered strong temperature dependence of methane emissions across ~all ecosystem size scales (Yvon-Durocher *et al.* 2014)



Caption

Figure 1: Temperature dependence of CH_4 production and related processes at population and community levels. Temperature dependencies for methanogen populations in culture (a) and anaerobic microbial communities from natural sediment samples (b) are separately characterized using mixed-effects models by fitting Boltzmann-Arrhenius functions with experimental-unit-level random effects on the apparent activation energy and rate at fixed...

0 Recommendations

- **Methane emission rates from natural systems go up a strong "57 fold from 0-30C" or 14% per 1C temperature rise**

Methane fluxes show consistent temperature dependence across microbial to ecosystem scales

Gabriel Yvon-Durocher[1], Andrew P. Allen[2], David Bastviken[3], Ralf Conrad[4], Cristian Gudasz[5,6]†, Annick St-Pierre[7], Nguyen Thanh-Duc[8] & Paul A. del Giorgio[7]

Methane (CH_4) is an important greenhouse gas because it has 25 times the global warming potential of carbon dioxide (CO_2) by mass over a century[1]. Recent calculations suggest that atmospheric CH_4 emissions have been responsible for approximately 20% of Earth's warming since pre-industrial times[2]. Understanding how CH_4 emissions from ecosystems will respond to expected increases in global temperature is therefore fundamental to predicting whether the carbon cycle will mitigate or accelerate climate change. Methanogenesis is the terminal step in the remineralization of organic matter and is carried out by strictly anaerobic Archaea[3]. Like most other forms of metabolism, methanogenesis is temperature-dependent[4,5]. However, it is not yet known how this physiological response combines with other biotic processes (for example, methanotrophy[6], substrate supply[3,7], microbial community composition[8]) and abiotic processes (for example, water-table depth[9,10]) to determine the temperature dependence of ecosystem-level CH_4 emissions. It is also not known whether CH_4 emissions at the ecosystem level have a fundamentally different temperature dependence than other key fluxes in the carbon cycle, such as photosynthesis and respiration. Here we use meta-analyses to show that seasonal variations in CH_4 emissions from a wide range of ecosystems exhibit an average temperature dependence similar to that of CH_4 production derived from pure cultures of methanogens and anaerobic microbial communities. This average temperature dependence (0.96 electron volts (eV)), which corresponds to a 57-fold increase between 0 and 30 °C, is considerably higher than previously observed for respiration (approximately 0.65 eV)[11] and photosynthesis (approximately 0.3 eV)[12]. As a result, we show that both the emission of CH_4 and the ratio of CH_4 to CO_2 emissions increase markedly with seasonal increases in temperature. Our findings suggest that global warming may have a large impact on the relative contributions of CO_2 and CH_4 to total greenhouse gas emissions from aquatic ecosystems, terrestrial wetlands and rice paddies.

cultures of methanogens, laboratory incubations of anaerobic sediments, and seasonal field surveys of CH_4 emissions) that correspond to three distinct levels of biological organization (population, community and ecosystem). In particular, we assess whether ecosystem-level CH_4 emissions exhibit temperature dependencies similar to those of the underlying methanogenic process. To do this, we first established the magnitude and variability of the temperature dependencies of key rate processes for populations of methanogens in culture (methanogenesis, growth) and laboratory incubations of anaerobic microbial communities from natural sediment samples (CH_4 production). We then assessed whether these temperature dependencies differ from those observed in an ecosystem-level analysis of the seasonal temperature dependence of CH_4 emissions from aquatic, wetland and rice-paddy ecosystems.

To characterize the temperature dependencies of physiological rate processes for methanogens, we fit the Boltzmann–Arrhenius function (which describes the exponential relationship between metabolic rate and temperature, assuming a single enzyme-catalysed reaction is rate-limiting[22]), separately, to the data compiled from the population and community-level experiments using linear mixed-effects models (see Methods).

The population-level analysis reveals that the average temperature dependencies for the rates of methanogenesis and growth are similar. Specifically, the improvement in model fit going from a null model, which assumes a common average activation ($\overline{E_M}$ in equation (1), see Methods) energy for both rate processes to an alternative model, which assumes a distinct average activation energy for each rate process, is not statistically significant (likelihood ratio test: $\chi^2 = 0.39$, d.f. $= 1$, $P = 0.53$). Thus, the average temperature dependencies for both rate processes (methanogenesis and growth) can be characterized using the same average apparent activation energy ($\overline{E_M} = 1.10$ eV, 95% confidence interval of 0.93–1.27 eV; Fig. 1a).

The community-level analysis of CH_4 production rates from anaerobic sediment incubations produces a similar value for the average acti-

Put on your reading glasses to read the abstract !

Newer Work - Even Worse: Zona *et al.* *2016* show, contrary to assumptions, that methane emissions do not end when the Arctic autumn freeze sets in, but instead stay high through December and beyond, thus ~DOUBLING the Arctic methane emissions. Does this mean we double AGAIN the calculations we just did? (won't do in this talk)

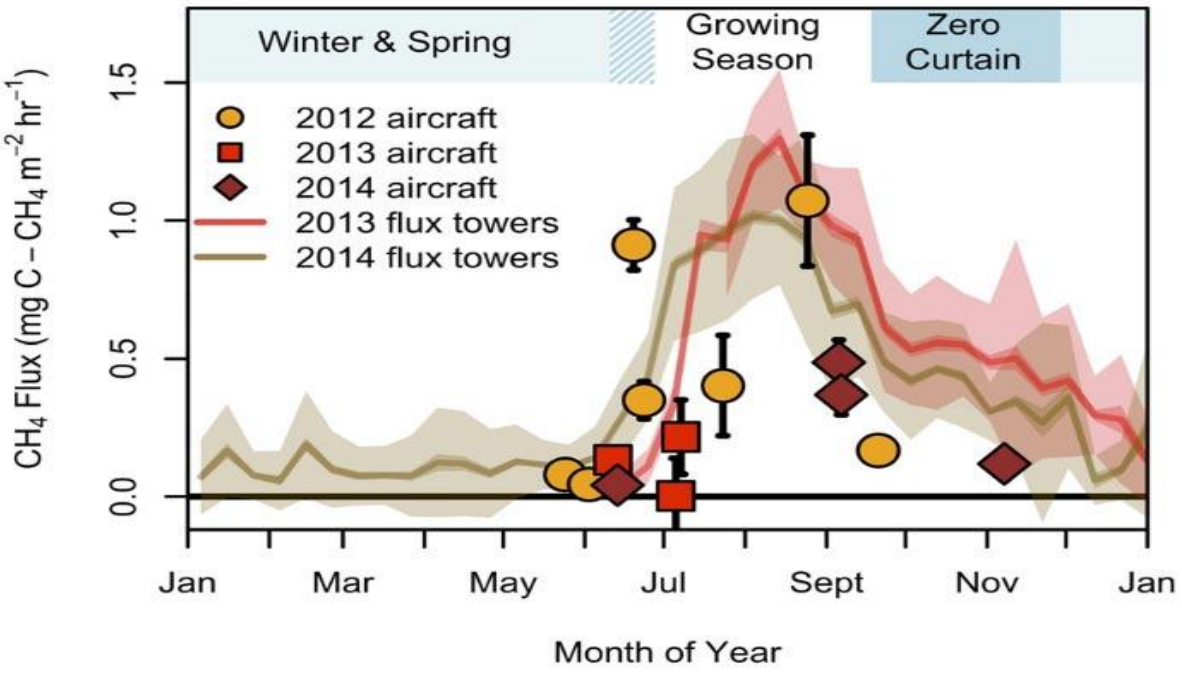


Fig. 4. Ten-day block average of the five EC flux towers over a 300-km transect across the North Slope of Alaska (shaded bands) for 2013 (red) and 2014 (brown), with the mean (solid line), 95% confidence intervals (darker shade), and SD in the CH_4 data (lightest shade). The regional fluxes of CH_4 calculated from the CARVE aircraft data for the North Slope of Alaska are shown for 2012 (yellow circles), 2013 (red squares), and 2014 (brown diamonds). The mean dates for the onset of winter, the growing season, and the zero curtain are indicated in the band on top. Regional scale fluxes of CH_4 (mg C-CH_4 m^{-2} h^{-1}) showed similar seasonal pattern to the EC flux towers across multiple years.

What is atmospheric methane actually doing today? Data below: Rising even faster than CO2, and re-accelerating in the past decade.

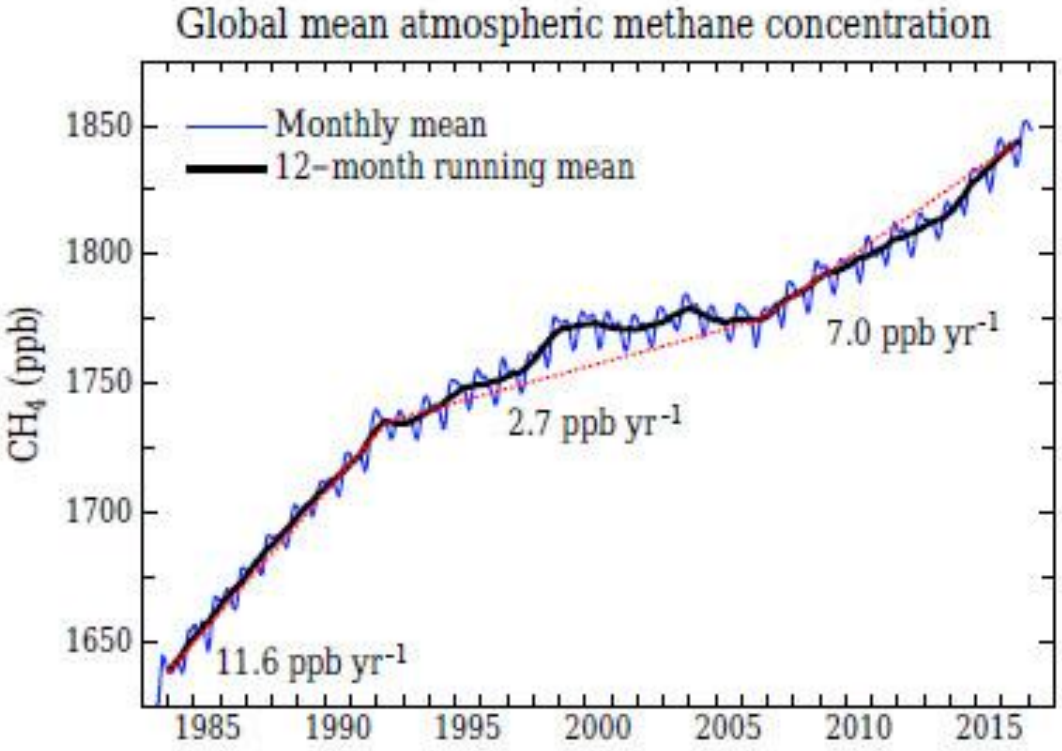
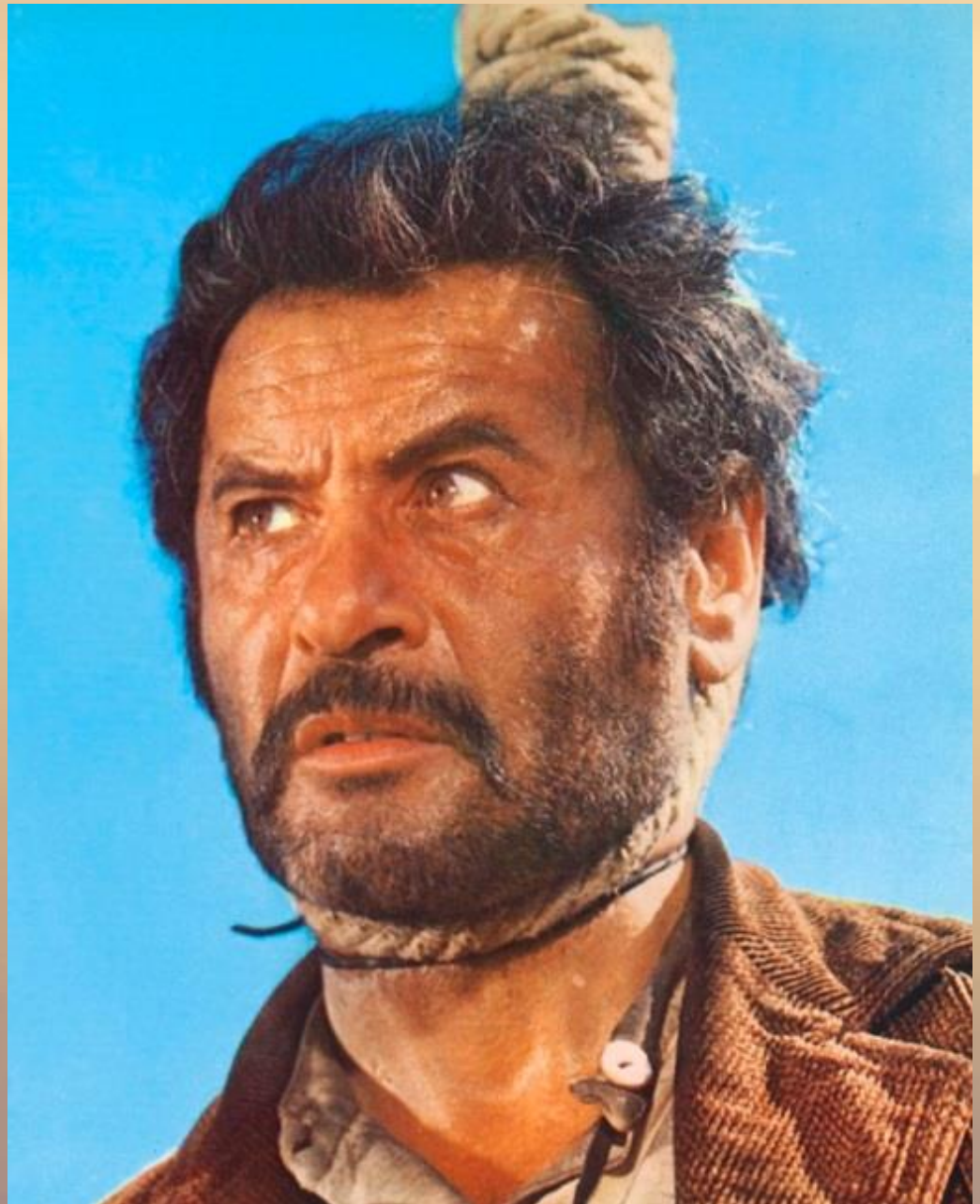


Figure 7. Global CH_4 from Dlugokencky (2016), NOAA/ESRL (http://www.esrl.noaa.gov/gmd/ccgg/trends_ch4/). End months for three indicated slopes are January 1984, May 1992, August 2006, and February 2017.

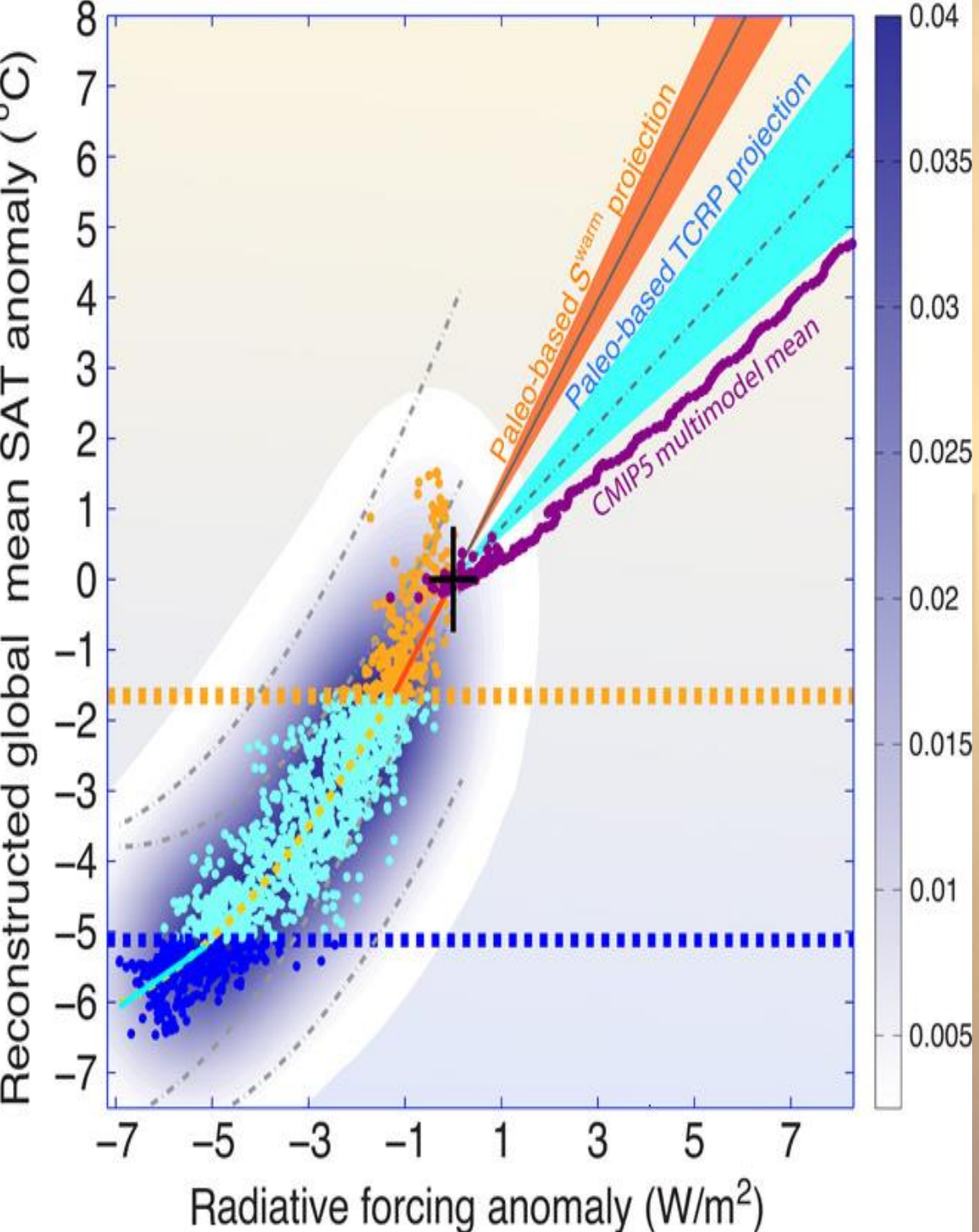
That was the BAD, Now… the UGLY



What if ECS is not +3C per CO2 Doubling, but is actually higher?

While ECS=3C fits well with past paleo data for the Ice Age cycles averaged as a whole, new work is in fact showing that …

ECS is HIGHER in HOTTER climate states



The best study is the most recent – by [Friedrich *et al.* (2016)]

who find strong upward curvature in climate forcing *vs*. global temperature; This says **higher ECS applies during interglacials' higher temperatures.**

Their (orange) fit is ECS=4.88C for the interglacial warm periods

Other Post-IPCC studies agree (from review paper: von der Heydt *et al.* 2016). Within ALL of these studies you'll see HIGHER ECS in HOTTER climate states. This is NOT in the IPCC projections.

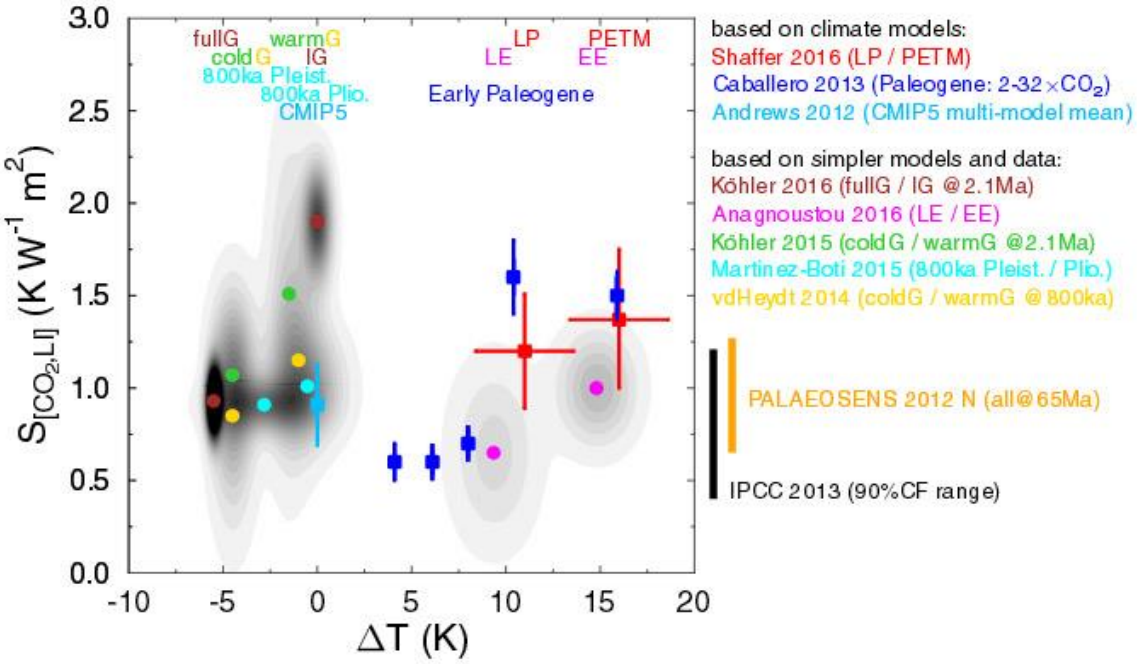


Fig. 1 Published paleo-based values of $S_{[CO_2,LI]}$ (specific equilibrium climate sensitivity parameter caused by CO_2 radiative forcing and corrected by variations in land-ice (LI) feedbacks) indicating its state dependence. Only studies published after the PALAEOSENS review paper [21] are considered. For comparison, the state-independent values from PALAEOSENS, and from the IPCC report [3], and the CMIP5 multi-model mean for present day [41] are also shown. All values of $S_{[CO_2,LI]}$ were given as mean (*or most likely*) $\pm 1\sigma$, apart from IPCC, which is the 90 % confidence (CF) range. Climate background states are given by ΔT from pre-industrial and are marked as estimated ranges (or $\pm 2\sigma$). In [42], further corrections for other slow feedbacks have been calculated, which has been ignored here, leading to different values of ΔT than published. To increase the clarity of the figure, the data-based results are visualised by *colour-coded circles* (mean values), while their uncertainties are combined in a cumulative probability density distribution (*grey shading*) assuming normal distributed values. Results based on climate models are shown by *colour-coded squares* (mean) including their uncertainties (*bars*). *G* glacial, *IG* interglacial, *LE* late Eocene, *EE* early Eocene, *LP* pre-PETM/late Paleocene, *PETM* Paleocene-Eocene thermal maximum. Reference numbers of the given citations: IPCC 2013 [3], PALAEOSENS 2012 [21], Andrews 2012 [41], Caballero 2013 [43] vdHeydt 2014 [20], Martinez-Boti 2015 [44] Köhler 2015 [32], Anagnoustou 2016 [42], Köhler 2016 [45], and Shaffer 2016 [46]

The ECS We Care About is the One that Applies NOW, for Our Rising CO2 Future

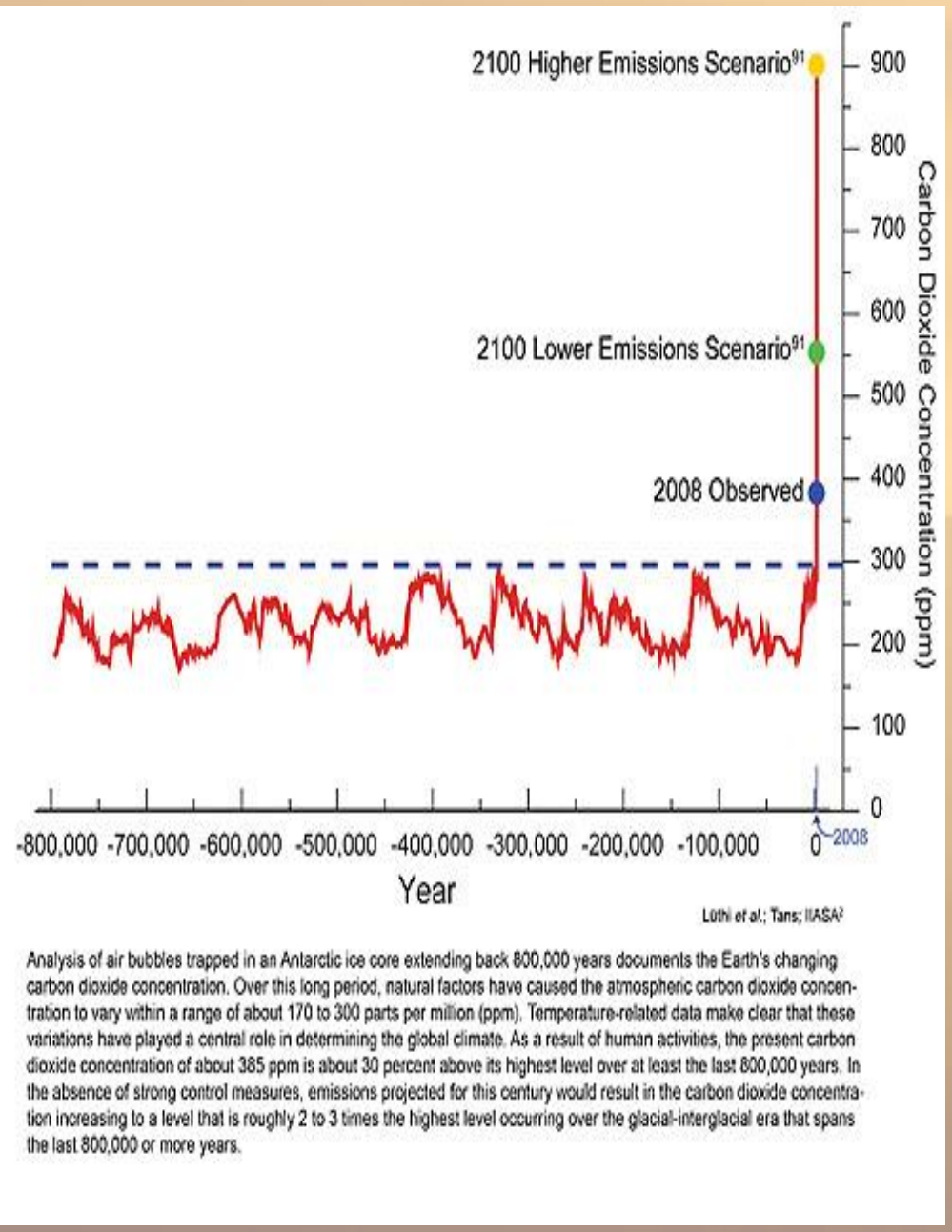
- Let's do a simple estimate of what's happening now – CO2 is at 410 ppm, which is 46% of the way to a full 2x CO2 = 560 ppm.
- Our global average temperature, smoothed, from the GISS data (which includes Arctic warming and which his NOT in the IPCC temperature figures which instead used the NOAA data, which neglects Arctic warming) is **+1.39 C (2017)** above the **Schurer et al. 2017** Pre-industrial baseline.
- Even just a linear extrapolation to this trend gives T Rise = **1.39/0.46 = 3.02C** at the moment we hit 560 ppm.

Proistosescu & Huybers 2017 Confirm High ECS

- But holding CO2 at 560 ppm means temperatures continue higher by ~0.4C, as we saw, giving **ECS**=3.4C as closer to what should be expected just based on the simple modelling.
- **But wait** – that neglects the added effects of uniquely HUMAN non-CO2 warming – deforestation, darkening of the Arctic ice. And most important, it neglects the confirmed NON-linear trend in **ECS** with climate state we just saw by **Friedrich *et al.* 2016, which is…**
- …curvature confirmed by **Proistosescu & Huybers 2017 and discussed here, who find that model and paleo data are now in agreement about the higher ECS operating over "decades and centuries" *i.e.* the "Fast ECS" at issue (the "slow ECS" (continuing for a couple thousand years) is much higher still, as all agree).**

It thus appears that the simplified assumptions of Hansen *et al.* (2017) giving a fast ECS of 3C may be too low

- They do not use the newly published Schurer *et al.* baseline, and simply make a linear fit to temperature rise and thereby remove the recent sharp rise which is likely real and ~permanent, due to the ending of the prolonged cool period in the Pacific Decadal Oscillation in 2015 and the rapidly disappearing Arctic Ocean ice.



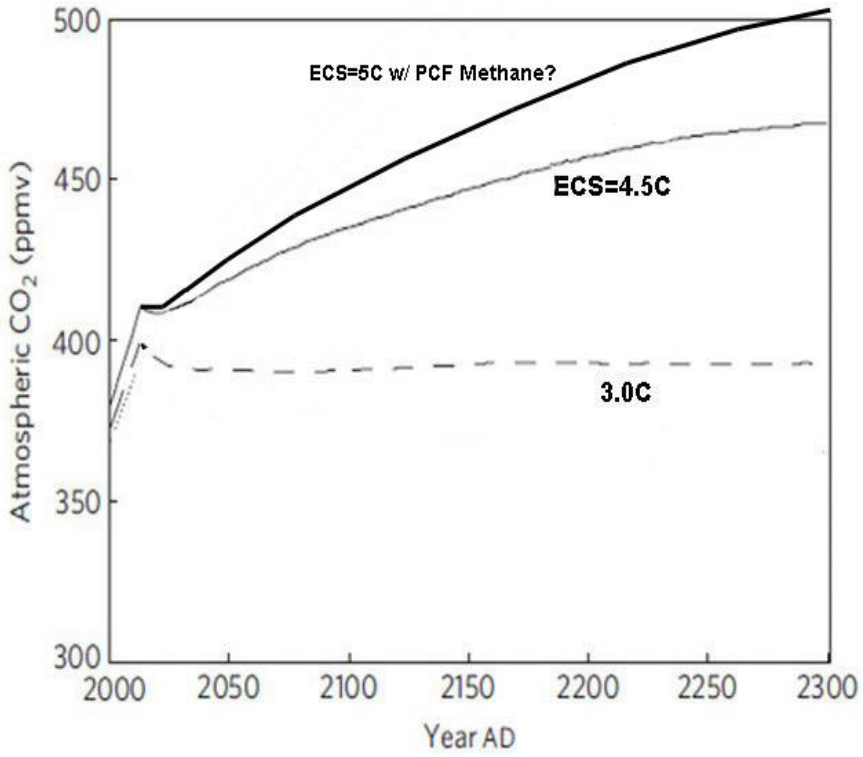
Analysis of air bubbles trapped in an Antarctic ice core extending back 800,000 years documents the Earth's changing carbon dioxide concentration. Over this long period, natural factors have caused the atmospheric carbon dioxide concentration to vary within a range of about 170 to 300 parts per million (ppm). Temperature-related data make clear that these variations have played a central role in determining the global climate. As a result of human activities, the present carbon dioxide concentration of about 385 ppm is about 30 percent above its highest level over at least the last 800,000 years. In the absence of strong control measures, emissions projected for this century would result in the carbon dioxide concentration increasing to a level that is roughly 2 to 3 times the highest level occurring over the glacial-interglacial era that spans the last 800,000 or more years.

Even this ECS=4.9C from past interglacials may be too conservative

…Since during the past Ice Age interglacials, atmospheric CO2 never rose above 280 ppm. **But we're at 410 ppm now,** and accelerating.

Because of this, Hansen (2016) warns that although his work showed +3C a good match to Ice Age cycling as an average, we should not necessarily assume ECS=3C for the future

560 ppmv = doubling of pre-industrial CO2



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UGLY!

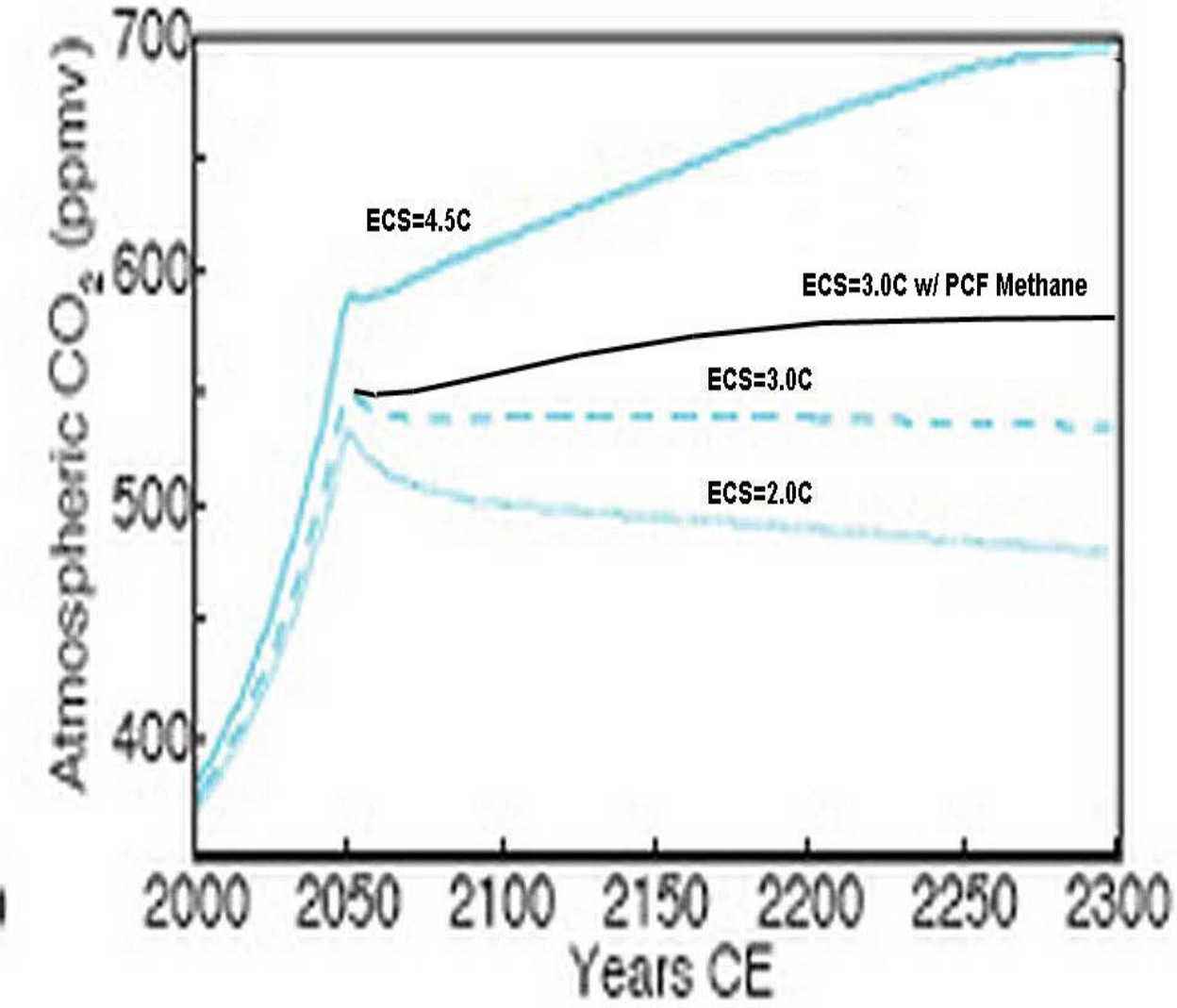
ECS=+4.9 C leads to atmospheric CO2 +methane rising to over 500 ppm by year 2300 (not including other GHG's)

That's after ending all Fossil Fuel burning in 2013

But, of course… We Didn't shut down carbon-based Civilization in 2013. So NOW what?

Assume we work HARD, and end ALL global fossil fuel burning and GHG emissions, even in the most rapidly developing 3rd World countries, by late in this century, as many energy analysts think is the best–case scenario

- MacDougall *et al.* approximates this scenario with a simple assumption of "Business as Usual" emissions till 2050, then 100% shutdown.
- 2050 is just 31 years from now.



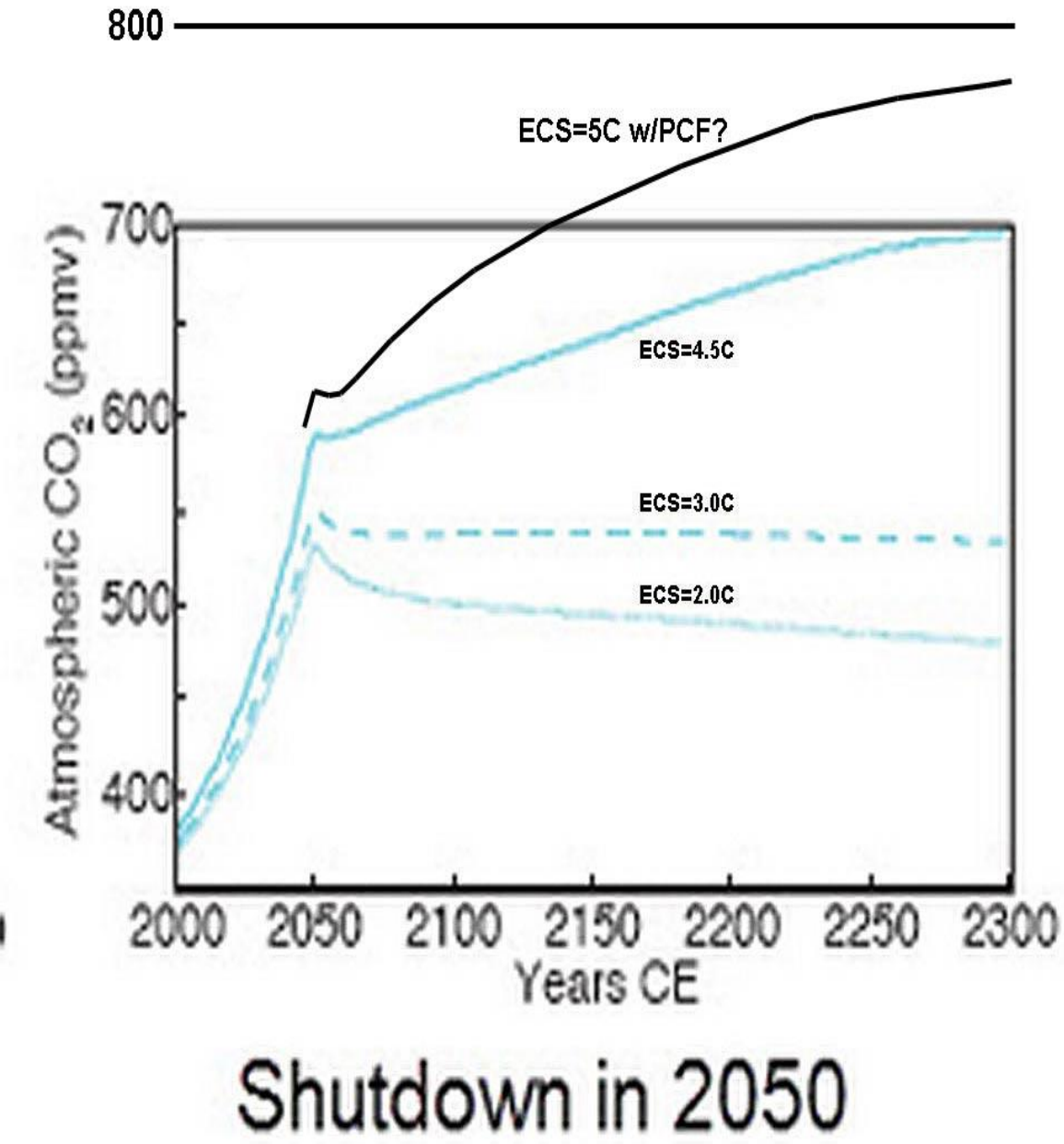
Shutdown in 2050

Then, be optimistic - take the mild assumption of ECS=+3C. Result is that CO2+methane still doubles, hence global temperatures pass +3C above pre-industrial.

As the award-winning website "**SkepticalScience**"'s **summary** of this work says… ***"Unfortunately, there are several good reasons to consider the outlook in MacDougall et al. as rosy; as the authors themselves make clear."***

- These effects are just from triggered permafrost CO2 and methane thaw alone, and are missing thermo-karst methane, coastal/stream erosion carbon, *Zona et al.'s* doubled methane from cold season emissions, new tropical wetland methane production temperature dependence, and more…

Even UGLIER! If instead ECS=+5C as some of the newer studies suggest…



Shutdown in 2050

Then permafrost melt drives atmospheric CO2+methane close to 770 ppm.

This corresponds to a global ECS-induced temperature rise of ~6.9C. This would be manifestly incompatible with "organized society" ("ungovernable" in James Hansen's measured tone)

Again, this is including hard work to eliminate all anthropogenic carbon emissions in coming decades

Even +4C Rise Is Judged *"Incompatible with an Organized Global Society"*

- Tyndall Climate Centre head Prof. Kevin Anderson summarizes… ***"a 4 degrees C future is incompatible with an organized global community, is likely to be beyond 'adaptation', is devastating to the majority of ecosystems, and has a high probability of not being stable."*** (meaning, it continues hotter).
- Think this is doomsday poppycock? Nobel physicist and former Secretary of Energy under Obama – Dr. Steven Chu – entirely independently, finds it **highly likely** that we'll exceed 550-600ppm CO2 equivalent
- **The path we're on, is sheer madness**

More Consequences…

Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2 °C global warming could be dangerous

James Hansen[1], Makiko Sato[1], Paul Hearty[2], Reto Ruedy[3,4], Maxwell Kelley[3,4], Valerie Masson-Delmotte[5], Gary Russell[4], George Tselioudis[4], Junji Cao[6], Eric Rignot[7,8], Isabella Velicogna[7,8], Blair Tormey[9], Bailey Donovan[10], Evgeniya Kandiano[11], Karina von Schuckmann[12], Pushker Kharecha[1,4], Allegra N. Legrande[4], Michael Bauer[4,13], and Kwok-Wai Lo[3,4]

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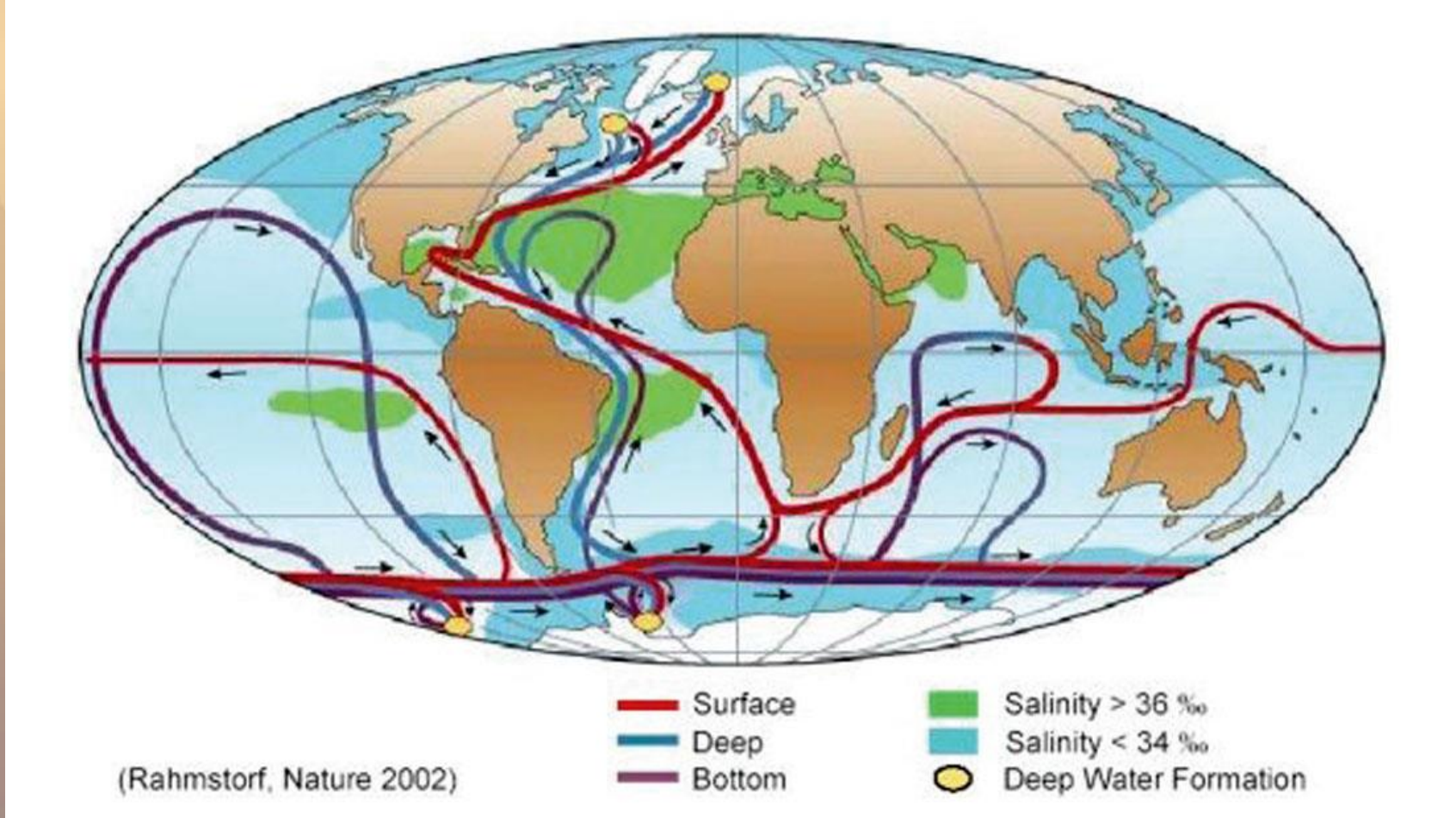
The Global Ocean Current Can Only Exist if the 4 Drop Points Remain Intact; where surface water can plunge to the ocean bottom (two near Greenland, two near Antarctic Peninsula). Can they?...



IPCC Models Did Not Include: Surface melt of Greenland, causing cold, low density, low salinity sea surface waters (Hansen *et al.* 2016) at those 4 points

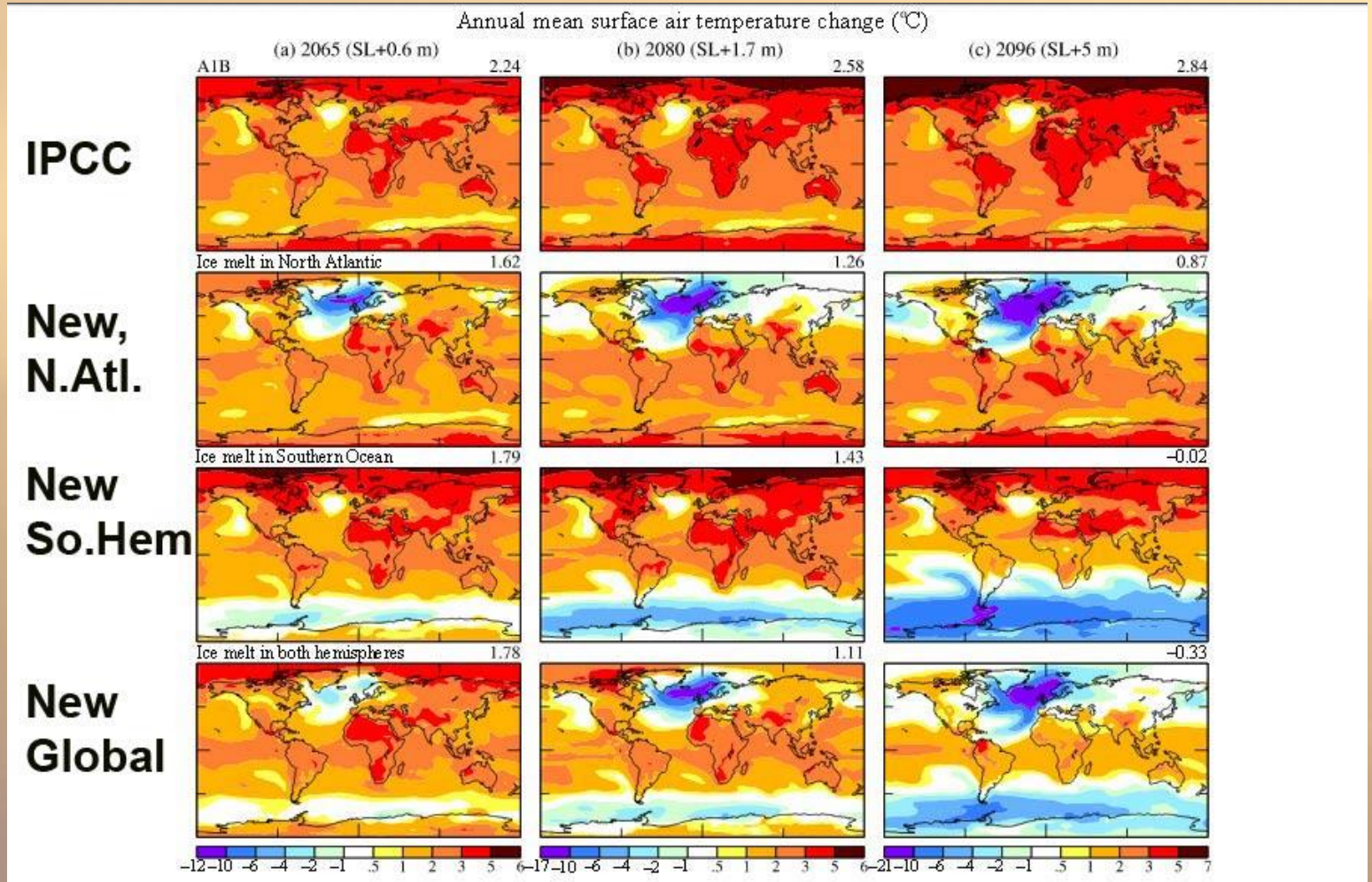
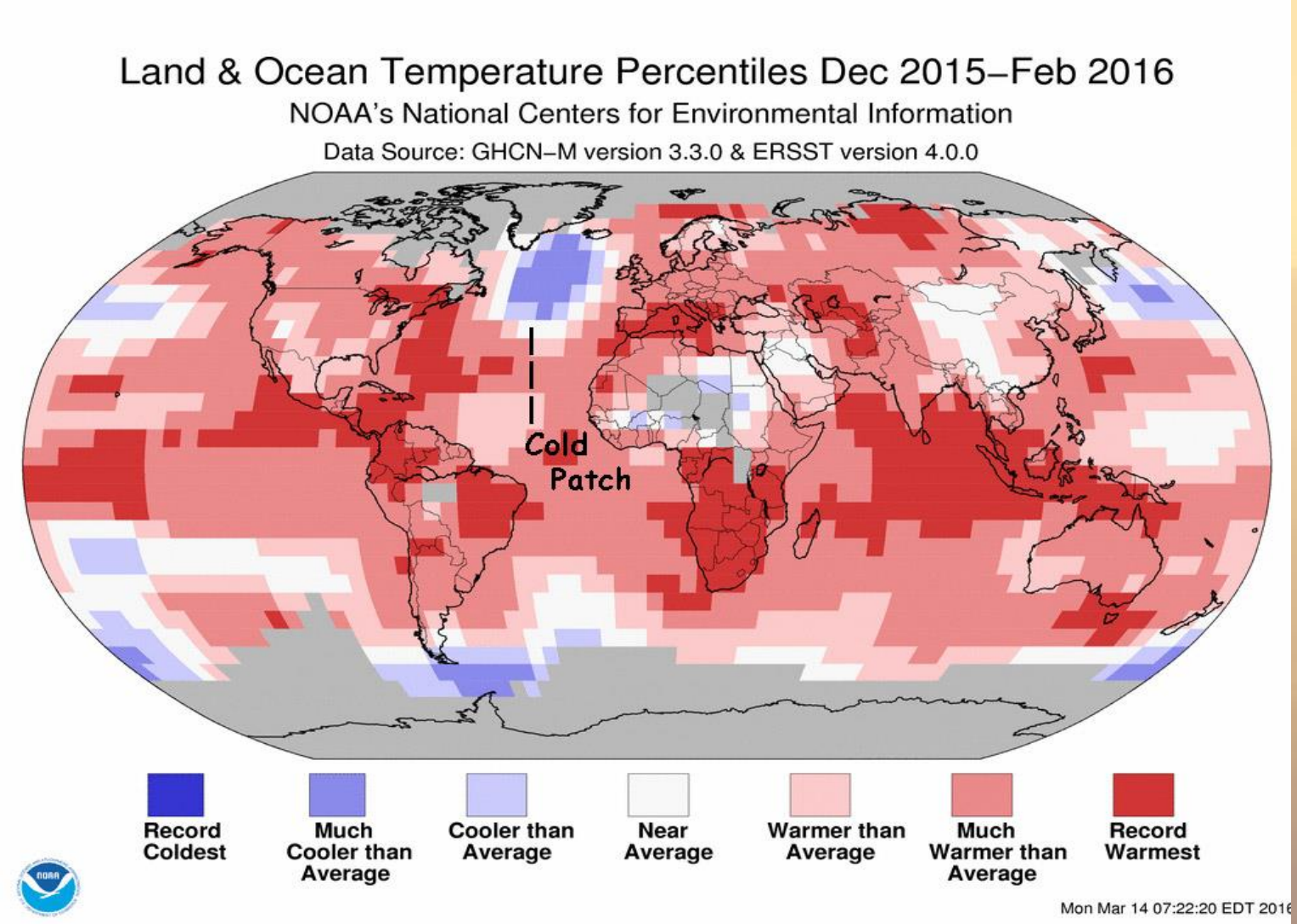
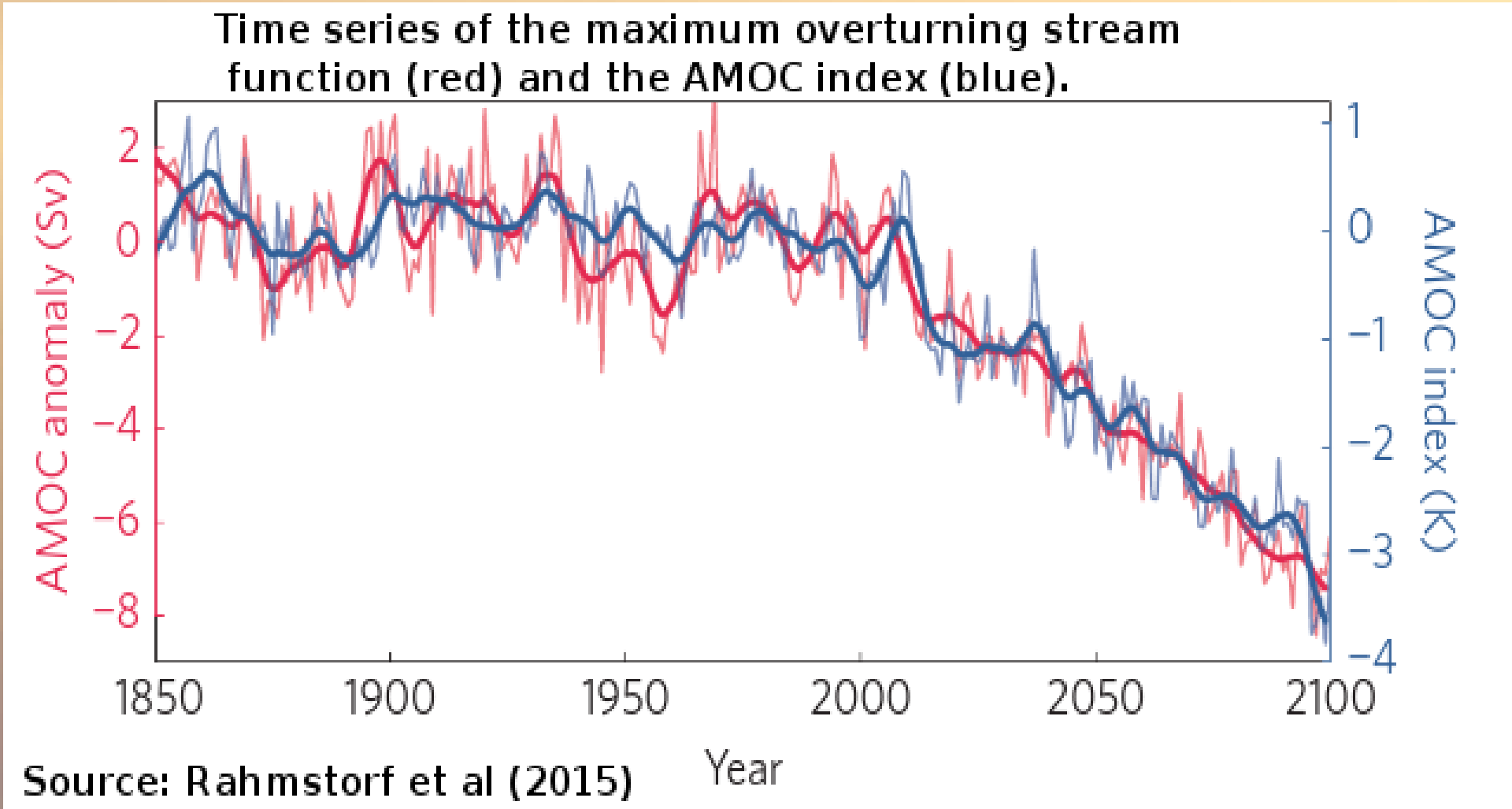


Figure 6. Surface air temperature (°C) relative to 1880–1920 in **(a)** 2065, **(b)** 2080, and **(c)** 2096. Top row is IPCC scenario A1B. Ice melt with 10-year doubling is added in other scenarios.

Today's real-world data below. Note the Cold Surface Melt Waters forming off Greenland, and the Antarctic Peninsula. Greenland melt flow in 2018 equals the flow of the entire Mississippi River.



The strength of the AMOC is indeed declining, and predicted to continue declining (Rahmstorf *et al.* 2015). It's already dropped 15% since 1950: a flow rate equivalent to that of all the rivers in the world, times 3.



Source: Rahmstorf et al (2015)

Independently, Liu *et al. (2016)* identify fundamental flaws in models of the AMOC; and fixing them shows…

- … **the AMOC passes the tipping point and collapses** even if we merely double CO2e (to 560 ppm) and hold it there (**Liu *et al.* 2016**, linked **here**)
- **Yet, we saw that the new ECS work indicates we could very well sail far past CO2e of 560ppm even if we work very hard to end all anthropogenic emissions by mid-century (yet so far, we've done nothing).**

Liu *et al*: Correcting erroneous prior modelling shows 560 ppm CO2 leads to collapse of the AMOC, complete within ~200 years

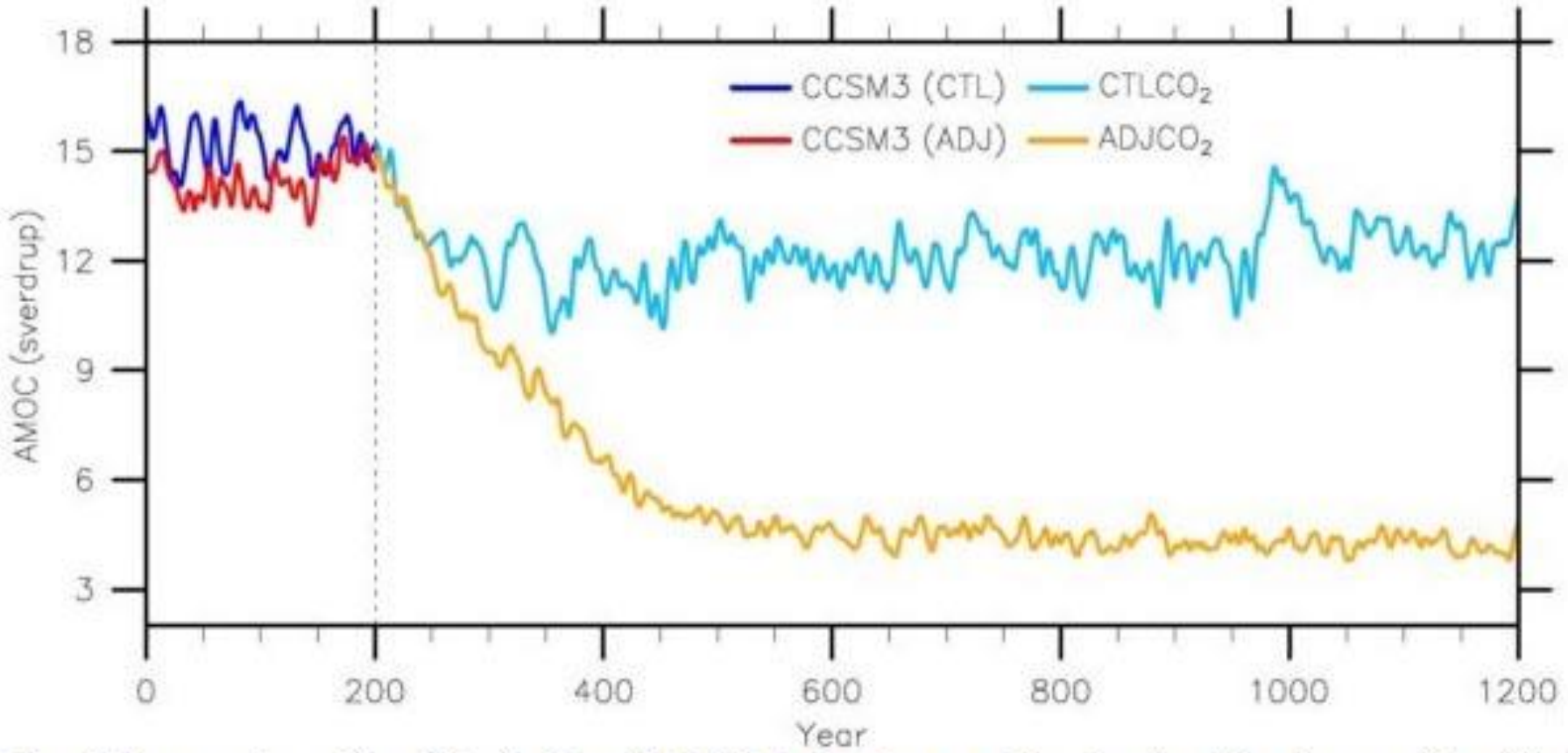
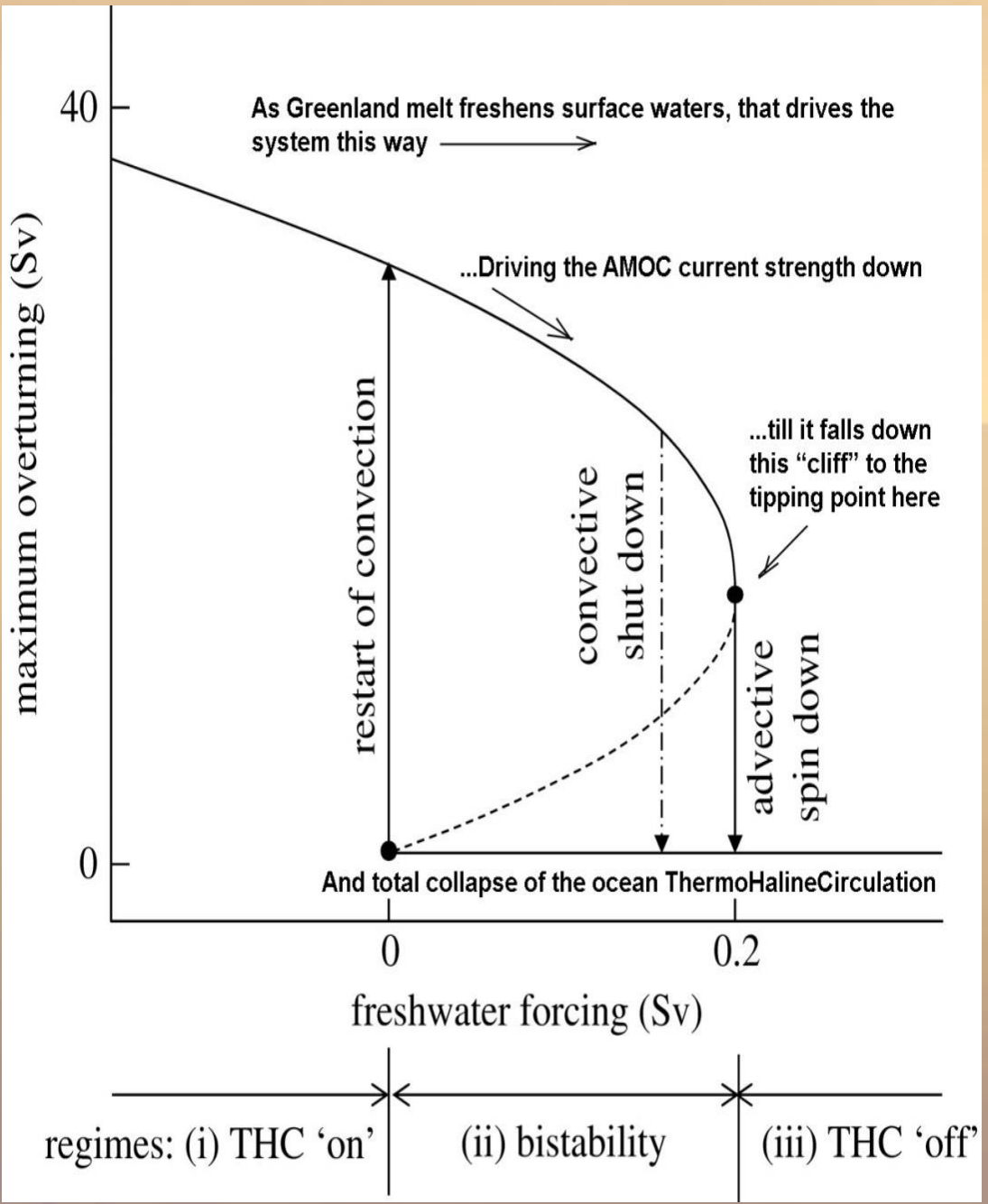


Fig. 2 *Time series of the Atlantic flow (AMOC) in the two model variants: without correction (blue) and with correction (orange). In model year 201, the CO_2 concentration in the model is doubled and then left at this level. Source: Liu et al., Science Advances 2016.*

The latest studies in 2018 confirm the AMOC now looks to be close to the tipping point of shut down

- Studies discussed **here**, and in more detail in **RealClimate.org** , but *Nature* papers are behind a paywall.
- **Prof. Michael Mann notes the AMOC weakening is happening a century ahead of model predictions.**
- Dr. Peter Ward (U. Washington) warns that shutdown of the global ocean circulation due to rapid rise of CO2 induced by massive volcanism is **implicated in 4 of the Earth's 5 great Mass Extinctions**, when the resulting anoxic deep oceans generated deadly hydrogen sulfide which rose to the surface and into the atmosphere and killed most life on Earth.



Tipping Point Soon… Shutdown of the Thermohaline Circulation of the Ocean would be extremely bad

Ocean Thermohaline Circulation Shutdown: Consequences

- Heat transport from equator to poles drops dramatically, causing much steeper pole-equator temperature gradient.
- This would drive **“SuperStorms”** (later slides)
- Stagnant oceans would lose oxygen, causing death to many or most fish and other oxygen-breathing organisms. Note that phytoplankton provides half the world’s oxygen.
- Hydrogen sulfide generating microbes thrive, could drive H_2S into the atmosphere, where **even just 200 parts per million (prof. Peter Ward) is enough to kill mammals, including humans. Implicated in the worst mass extinctions in Earth history.**

Massive volcanic basalt flows, carrying CO2, driving global warming sufficient to shutdown the Thermohaline Circulation, driving anoxic oceans, promoting H_2S - generating microbes, killing most life on Earth. Implicated in all but one past Mass Extinction. However – here's a bit of hope… the Eemian interglacial experienced AMOC shutdown, w/o leading to a Mass Extinction.

The "Big Five" Mass Extinctions identified since the Cambrian		
Extinction Event	Date of Extinction	Massive Volcanic CO2-driven THC shutdown and H2S Death
End of Ordovician	443 Million years ago	x
Late Devonian	375 Million years ago	x
End of Permian	251 Million years ago	x
End of Triassic	200 Million years ago	x
End of Cretaceous	65 Million years ago	asteroid impact

These ~1,000 ton boulders were tossed up from the shallow ocean offshore during the Eemian interglacial in the Bahamas by Super-Storms, powered by the same AMOC shutdown we may, by the evidence, have initiated with our Fossil Fuel burning. Caption includes "chevron ridges" … (next slide)

Fig. 1. Two boulders (#1 and #2 of Hearty, 1997) on coastal ridge of North Eleuthera Island, Bahamas. Scale: person in both photos = 1.6 m. Estimated weight of largest boulder (#1, on left) is ~ 2300 tons.

Enormous boulders tossed onto an older Pleistocene landscape (Hearty, 1997; Hearty et al., 1998; Hearty and Neumann, 2001) provide a metric of powerful waves at the end of stage 5e. Giant displaced boulders (Fig. 1) were deposited in north Eleuthera, Bahamas near chevron ridges and runup deposits (Hearty, 1997).

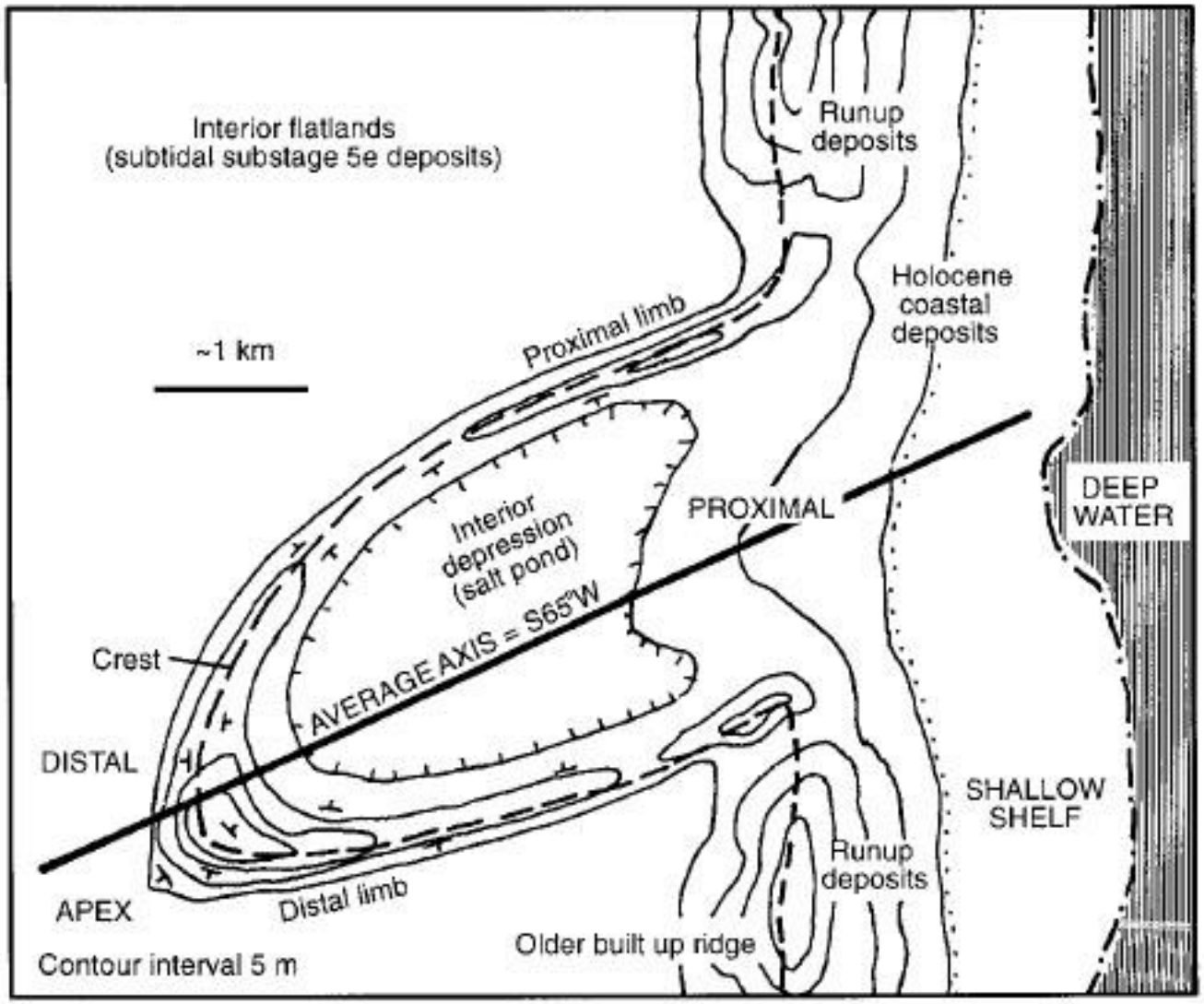
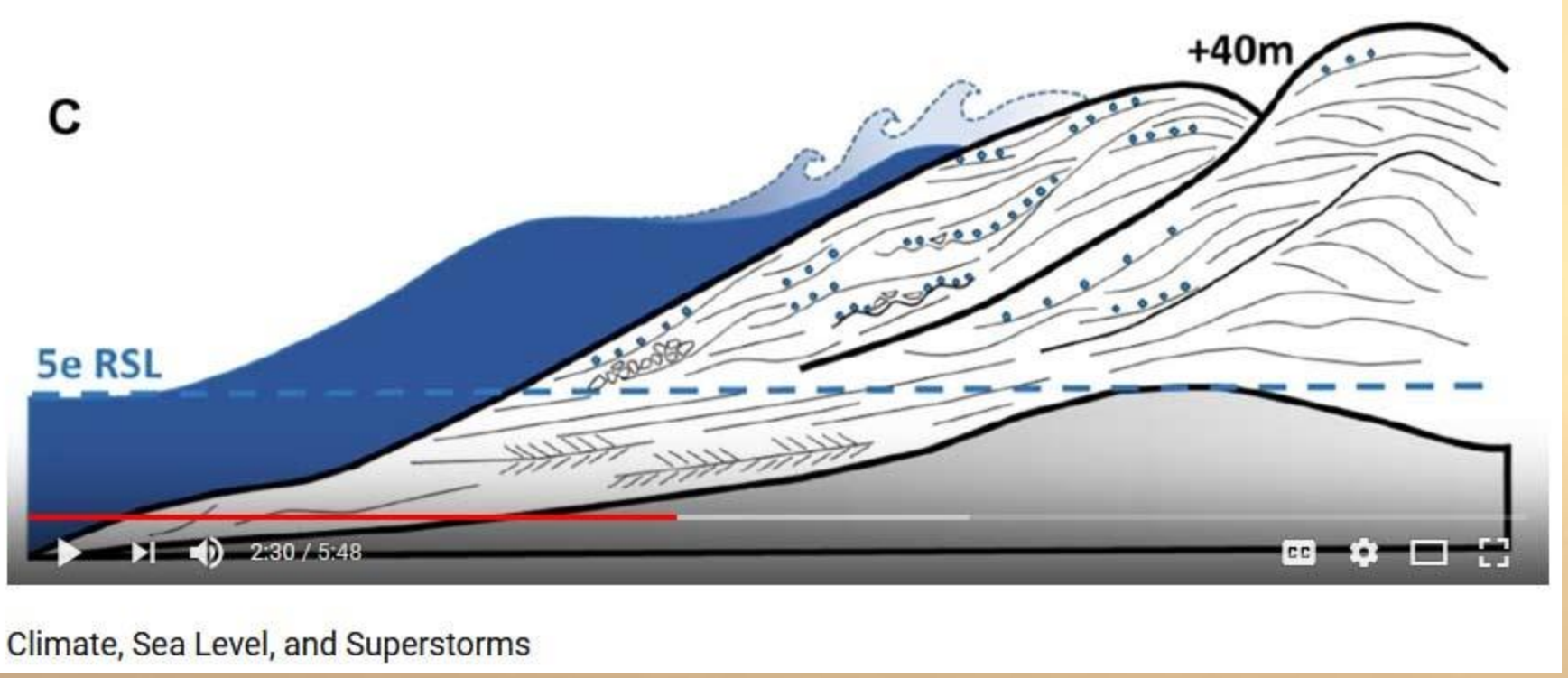


FIG. 1. Schematic map of chevron beach ridge.

Giant Super Storm Waves of the Eemian created chevron deposits 50 ft high and 2 miles long, when washing back to sea. These are all along the shorelines of the Bahamas. Some run-up deposits are as high as 43m, requiring waves nearly ~200 ft in height to create them.

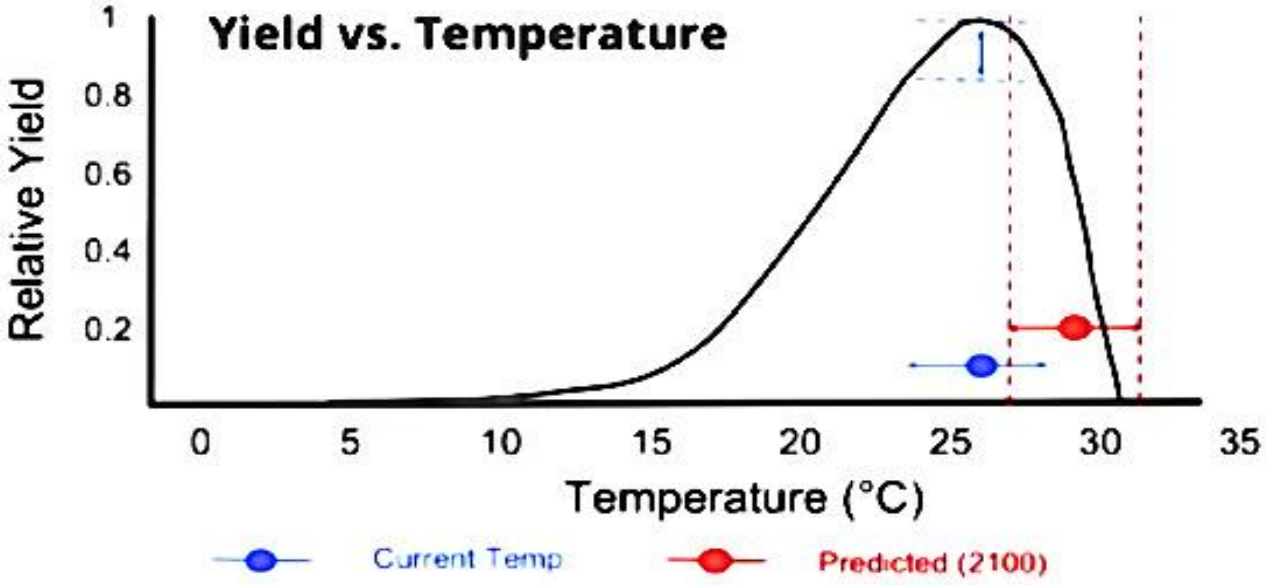
Here is a recent 6 min video on this, from Yale Climate Connections



The waves required for such 43m high run-up deposits… are as tall as a 17 story high-rise(!). These would scrape clean many smaller Caribbean islands, and the U.S. East Coast

As temperatures rise, even mid-latitude crop yields plummet and also carbon sequestration in soil. Note that one heat wave can completely kill vast areas, later this century, since staple crops are already above their optimum temperature range when grown in the tropics

Higher Mean Temperature Increases Volatility in Mid-Latitude Yields



After Tewksbury et al 2008; see also: Urban et al. 2012, Climatic Change 112: 525-533

3. Before We Can Consider What to Do About This, We Must Consider the Thermodynamics of Civilization Itself

- The **Laws of Thermodynamics** govern energy flow in physical systems, and new work is finding that analogous thermodynamic principles are obeyed for the system called Human Civilization, constraining the track of future atmospheric CO2 unless repressive and Draconian measures are taken.

"Visualize yourself not dying and then be that reality."

Get past the '70's New Age Books and their pandering; Human Nature follows its own inherent rules

The Thermodynamics Obeyed by Civilization Itself

Cloud physicist **Prof. Tim Garrett** had the insight to investigate civilization as a thermodynamic system - creating order (civilization) out of disorder by the utilization of energy. (**Garrett 2014**)

Civilization is a constant battle against the Second Law of Thermodynamics – the increase in entropy (disorder) in all closed systems. We fight it by imposing order on part of that global system (the "civilized" part) at the cost of continuous energy expenditure and greater disorder on the remaining part of the system

This is, and must be, a **global relation of the system.** You can't consider individual countries alone, because of economic and material flows across borders…

Thermodynamic Principles Predict…

The current rate of global civilization's primary energy consumption ("Power")…

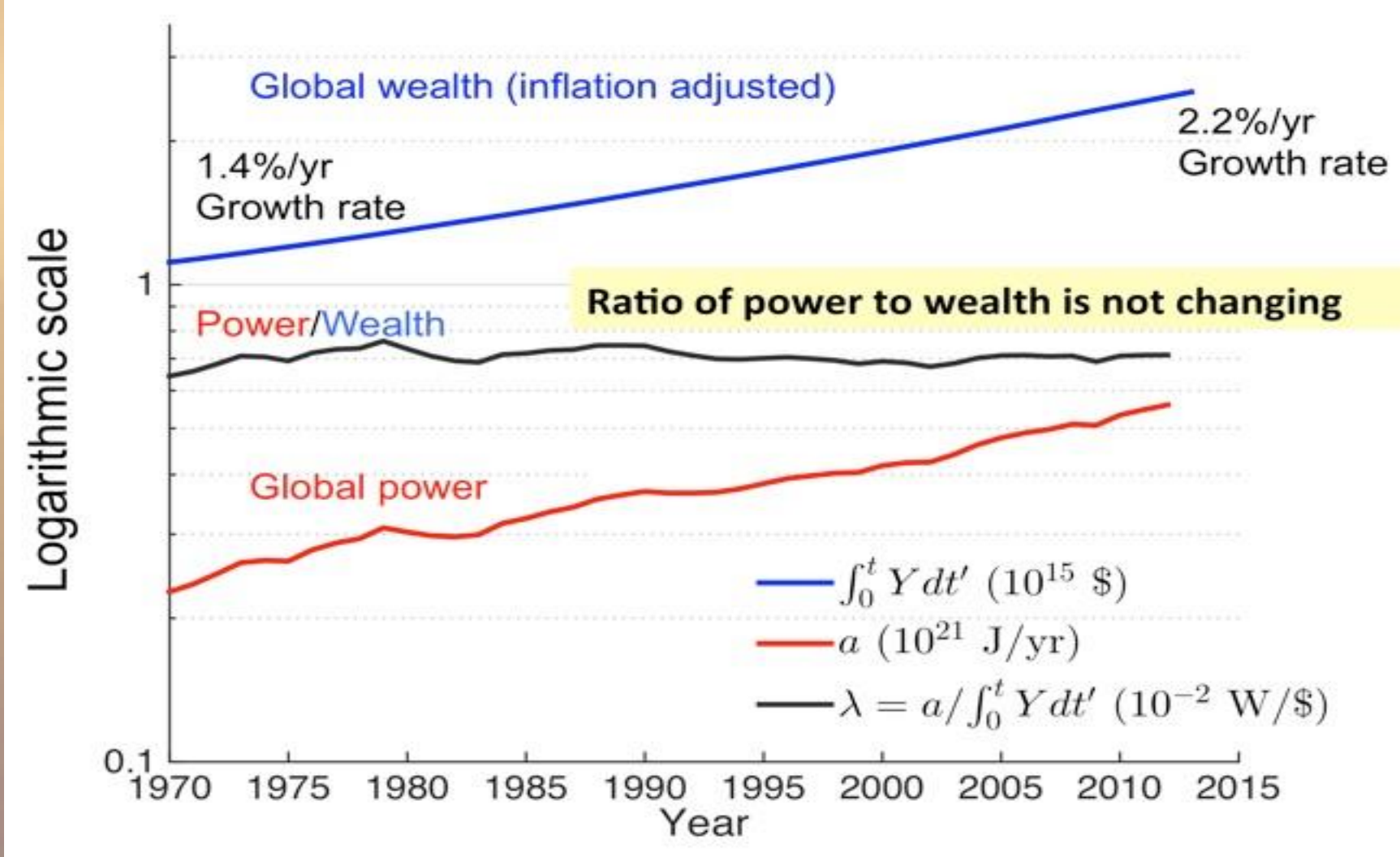
<u>is directly proportional to</u>

…The total integrated, inflation-adjusted <u>G</u>ross <u>W</u>orld <u>P</u>roduct summed over all countries and over all of time (="Wealth")

Grasp the Meaning…

- Every spending ever done, was done to create products and networks of relationships to enhance civilization. Bringing order out of disorder. Fighting entropy. Flows of material and energy along these networks dissipate energy continually.
- Every action of the past carries a ghost of itself into the future, embodied by the vast civilization we have today.
- ALL of it can only be supported by continual energy consumption. And the larger it is, the higher the rate of that consumption.
- It is thermodynamics applied to the ordered system we call HUMAN CIVILIZATION

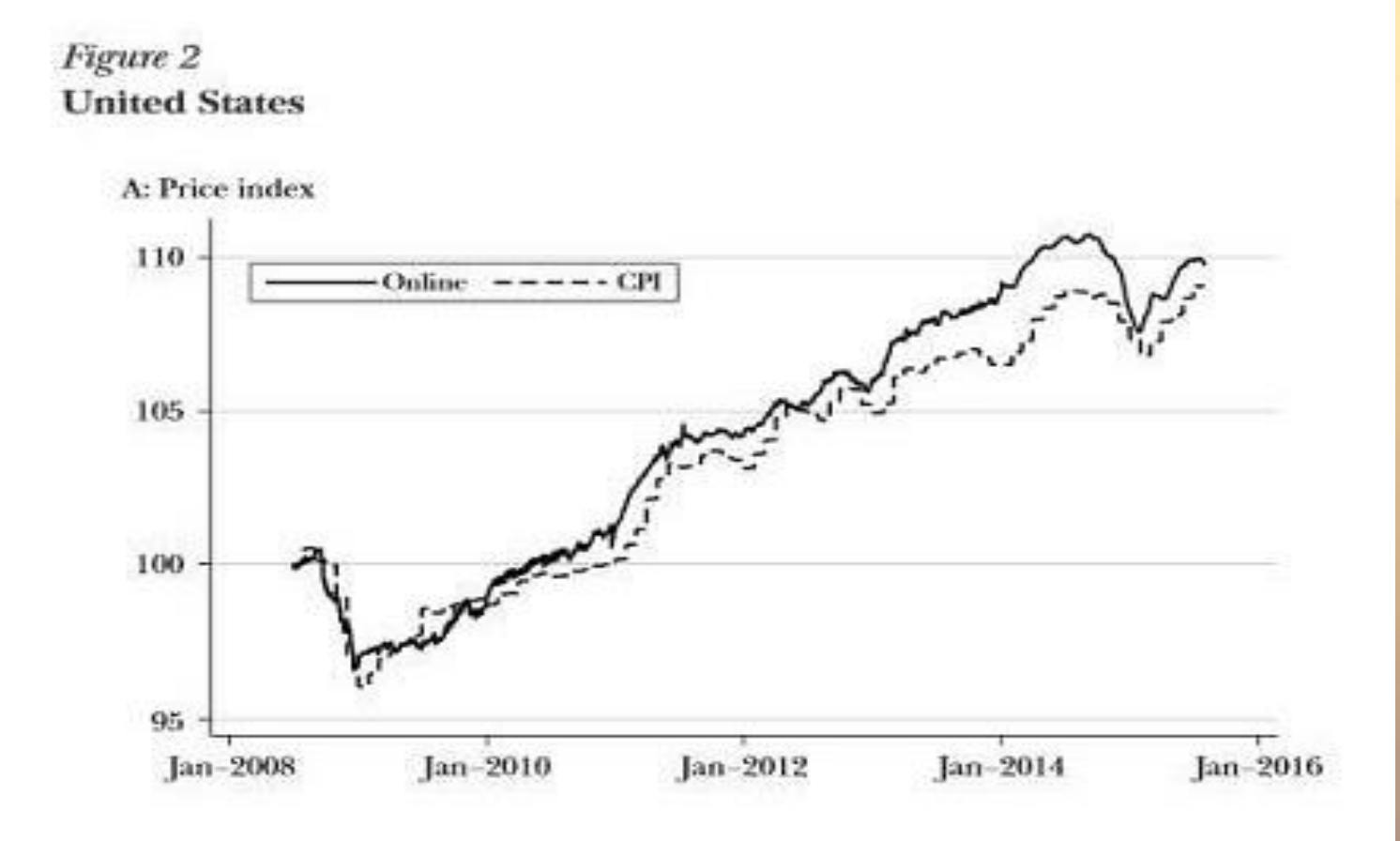
The Garrett Relation Confirmed: 7.1milliwatts of continuous power needed to support every (inflation-adjusted to 2005) global GDP dollar ever spent (Garrett 2012)



My Own Work on The Garrett Relation

- This relation is **Fundamentally Important** to our future. So, it is vital to know…
- **Is the Garrett Relation Really True?**
- **Are there considerations that may invalidate it? I've become a bit obsessed with answering this question. So…**
- **Inflation correction? Examined ShadowStats, Kitov, BillionPrices Project…**
- **GDP or TOTAL spending? Should use TOTAL spending, hence we should add in the "Shadow Economy". How does that affect the GR?**
- **Global calibration across individual countries' currencies: Purchasing Power Parity (PPP) *vs.* Market Exchange Rates (MER)? Which to use and why?**

MIT's BillionPrices Project (BPP) uses a much wider range of global online prices to compile a more complete CPI. They find official annual CPI understated, but by a much smaller amount than ShadowStats: Official CPI since 2009 has averaged 1.567%; BillionPrices CPI averaged 1.826%



Purchasing Power Parity *vs.* Market Exchange Rate. Which to Use?

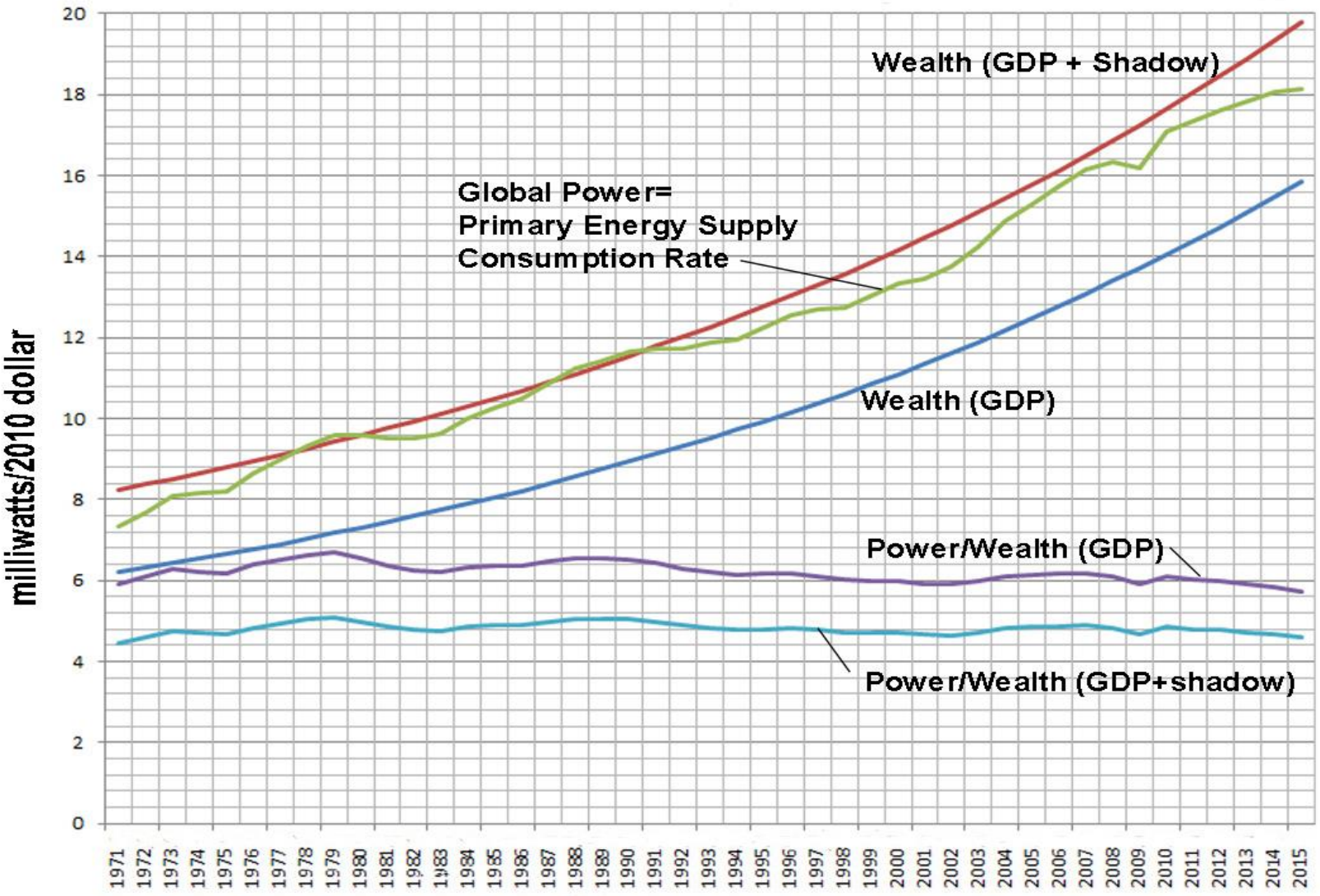
Arguments in favor of MER Accounting Method

- Well-determined by large frequent trading
- Measures much wider realm of economy than consumer prices
- Available for longer time series
- Economists agree it's the better measure when international trade is a strong component of what is desired to be measured. Certainly true for our ThermoCiv purpose.
- PPP only determined for consumer goods
- PPP very difficult to determine equivalencies between products; *e.g.* a loaf of bread in South Sudan is a very different thing than a loaf in France
- PPP only available for a minority of countries, and only measured every ~6 years. Measures standard of living perhaps better than MER, but so what? We care about the energy consumption encumbered by the future from today's spending to enhance Civilization. Not the same thing

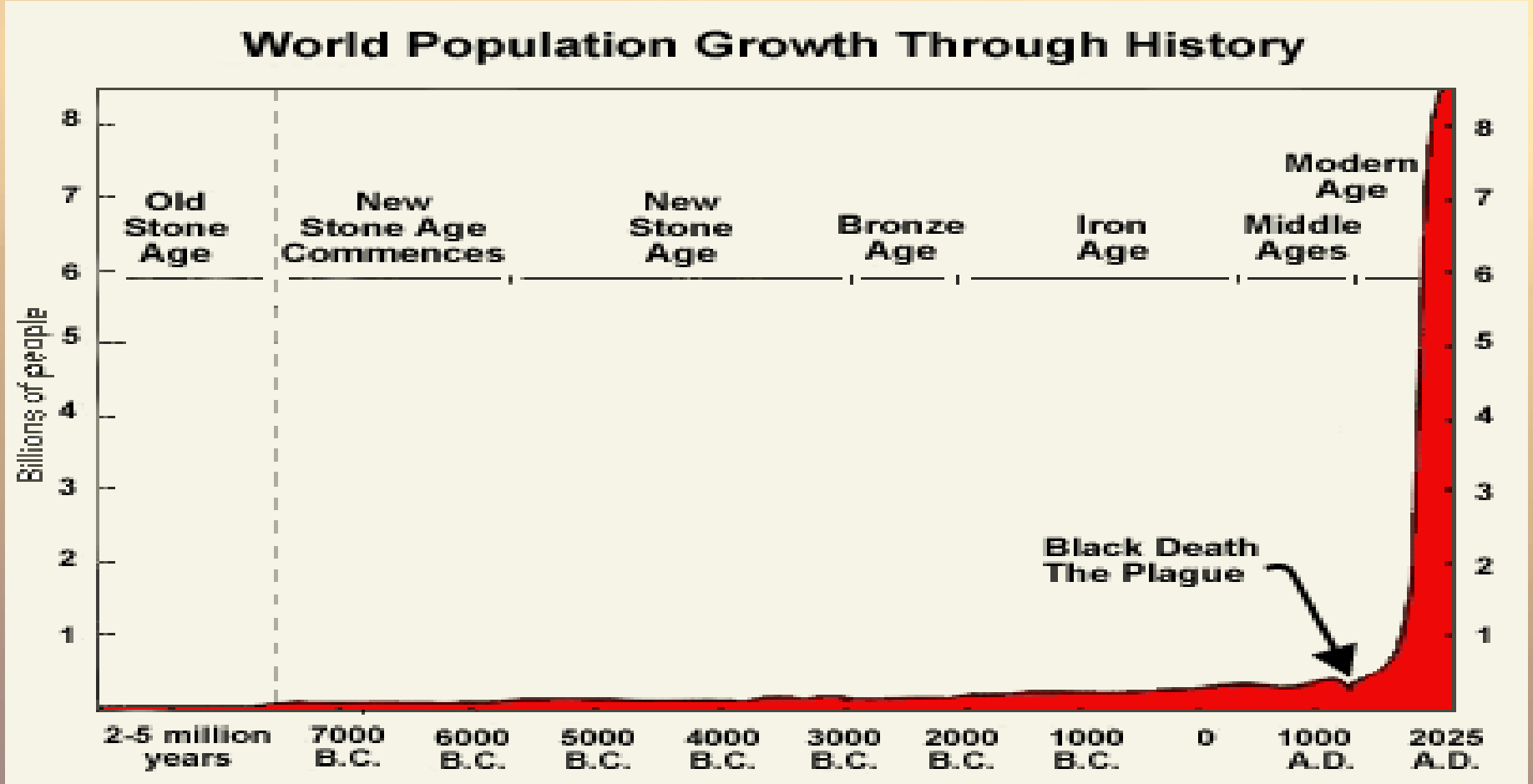
My Conclusion: Garrett is Correct in Using Market Exchange Rates (MER) instead of Purchasing Power Parity (PPP) to Calibrate GDP Across Countries

- Using PPP would give higher global GDP rise.
- Not large; Consider the difference in global GDP % rise from 1970 to 2015, using the period over which we have data for both PPP and MER. Using PPP instead of MER would only lower the slope of the Garrett Ratio (next slide) by a few percent.
- On the other hand, calibrations of GDP by night illumination monitored by satellite data argue that "autocrat"-ruled countries' official GDP's are overstated by 15-30% (Martinez 2018). Including this (not done on the next slide), would ~eliminate the remaining slight downward slope of the Garrett Relation.

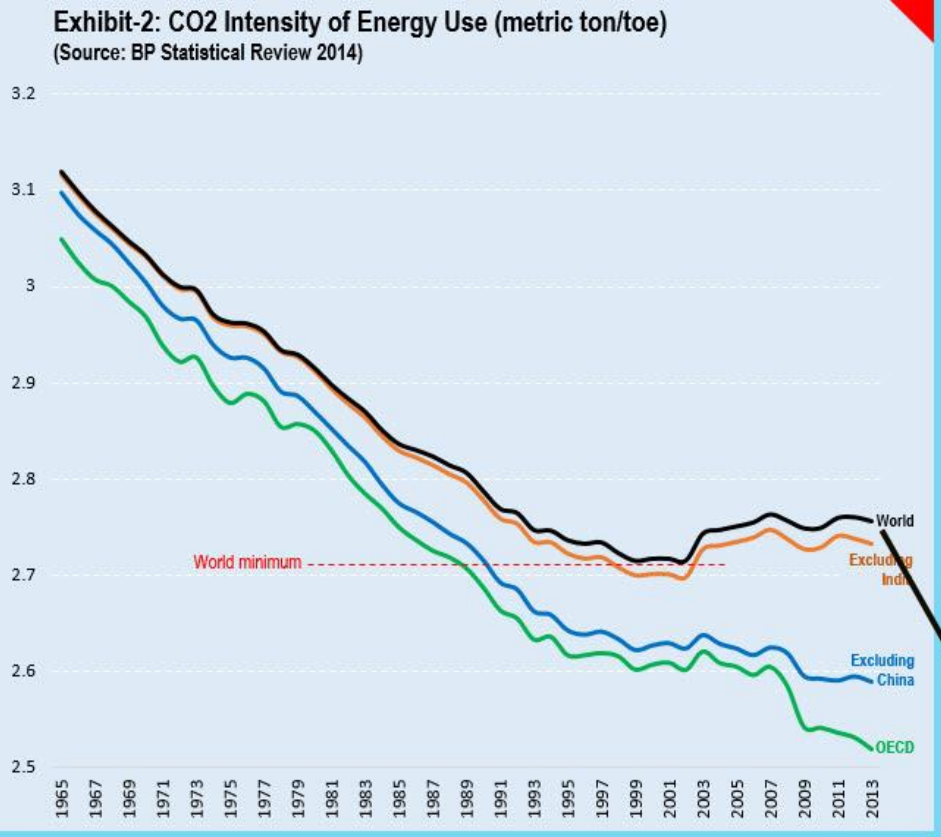
The Garrett Relation (GR) Strengthened. Using Total Spending and wider inflation measure (BPP), GR is even Flatter (light blue) *vs.* Using Just GDP (purple)



Energy discovery allowed us to multiply ourselves, our Civilization. Now; we're stuck with supporting that bloated Civilization. That population is IN PLACE. That Wealth is IN PLACE. That infrastructure is IN PLACE, all needing constant feeding of more energy to just to maintain it. Short of apocalypse, that is a FACT of our LIVES. We've dug a very deep hole: our power needs. That manna from heaven – fossil carbon – is killing our planet. Yet we're more than addicted to it. It is IN PLACE as our energy source supporting the massive Civilization that it created, and we can't get off of it fast enough to avoid the planetary disaster it is creating. History of World Population in 1 minute



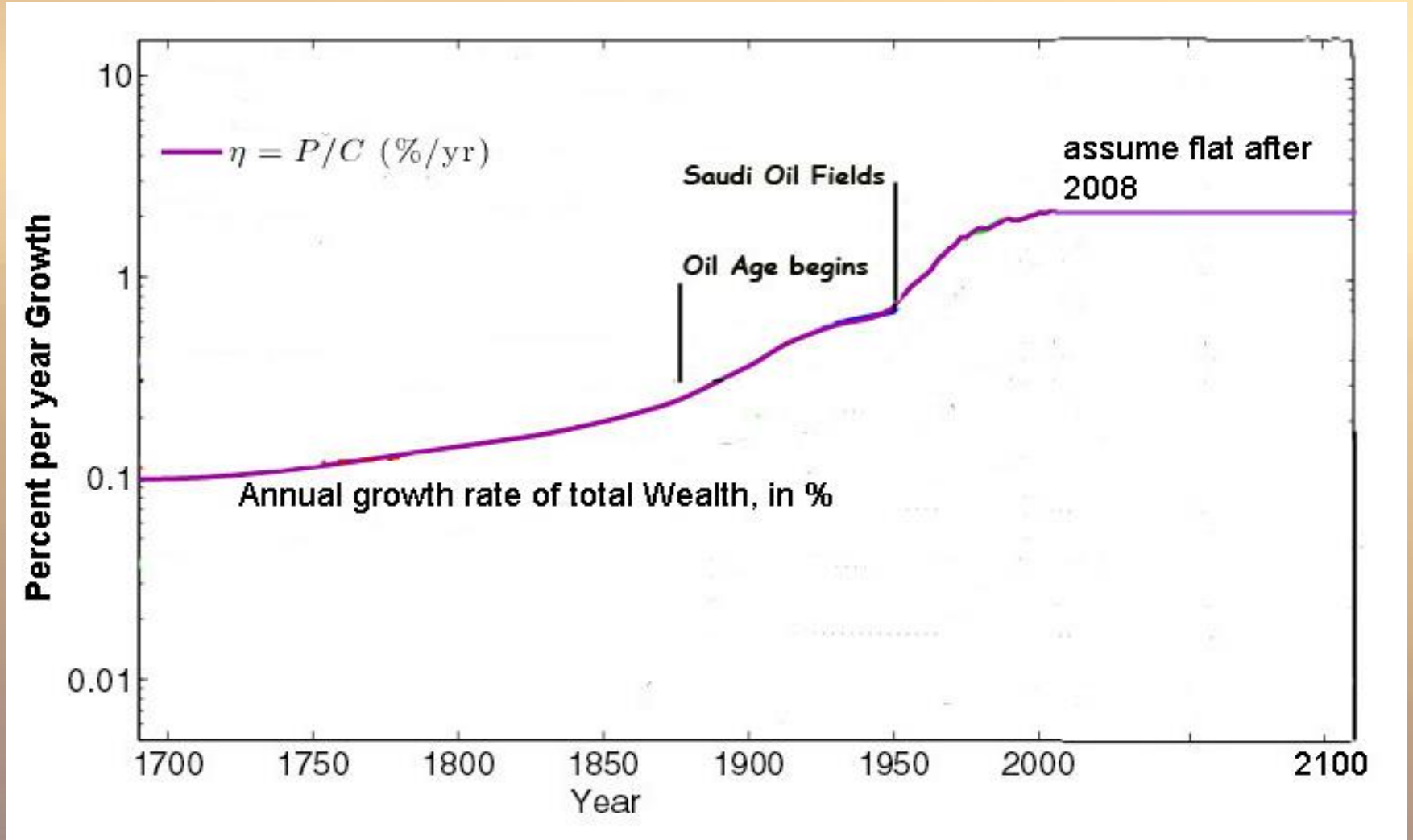
What Does the Garrett Relation Imply, when we include it in Calculations of the Future of Atmospheric CO2 Concentrations?



trend of linear approximation to exponential halving time of 50 years

Let's assume we de-carbonize our energy sources at an exponential rate, with halving time of 50 yrs – very steep by historical standards…

Further Assume: Annual Growth Rate of "Wealth" (Wealth=sum total of all Civilization spending over all time), no longer grows (not likely, given our new solar and wind power coming online)



Even these conservative assumptions lead to significantly more dire Atmospheric CO2 (Red Curves) when the Garrett Relation is included: Atmospheric CO2 Relentlessly Rises. And higher civilization resiliency means faster economic growth and higher CO2 at year 2100. Only in the most crippled case, with growth in decline, does CO2 stabilize (and inflation reaches 73%/yr in 2100!). IPCC eco-friendlier SRES scenarios were naively pie-in-sky, not including how civilization actually operates

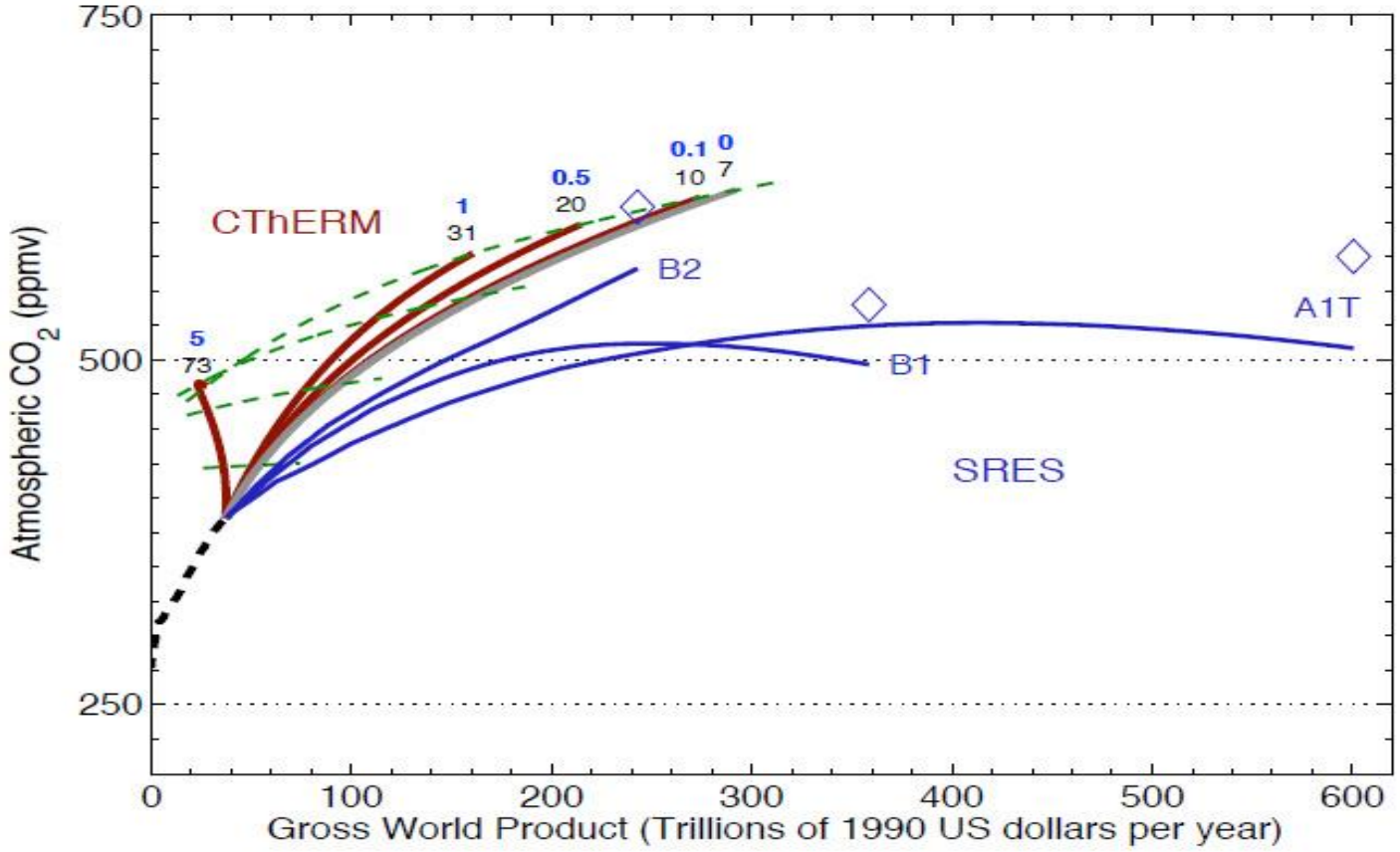


Fig. 7. As for Fig. 6 except that it is assumed that the value of carbonization c has an assumed halving time of 50 years. For comparison, the IPCC SRES trajectories that are considered are the A1T, B1 and B2 scenarios.

Why So Hard to Reduce CO2?

- **"Jevons' Revenge"! Increasing Energy Efficiency causes HIGHER, not LOWER energy consumption rates**
- **Improving energy efficiency has been going on for centuries. That efficiency leads to savings, and those savings are SPENT.**
- SPENT, to expand civilization further, and therefore by the Garrett Relation, expand its energy consumption rate.
- **By itself, increasing efficiency will not save us from a CO2 climate disaster unless we forbid ourselves from expanding civilization with those savings, and decarbonize much faster than is now considered.**
- **It's like walking 5 mph down, on an up-escalator going 10 mph**

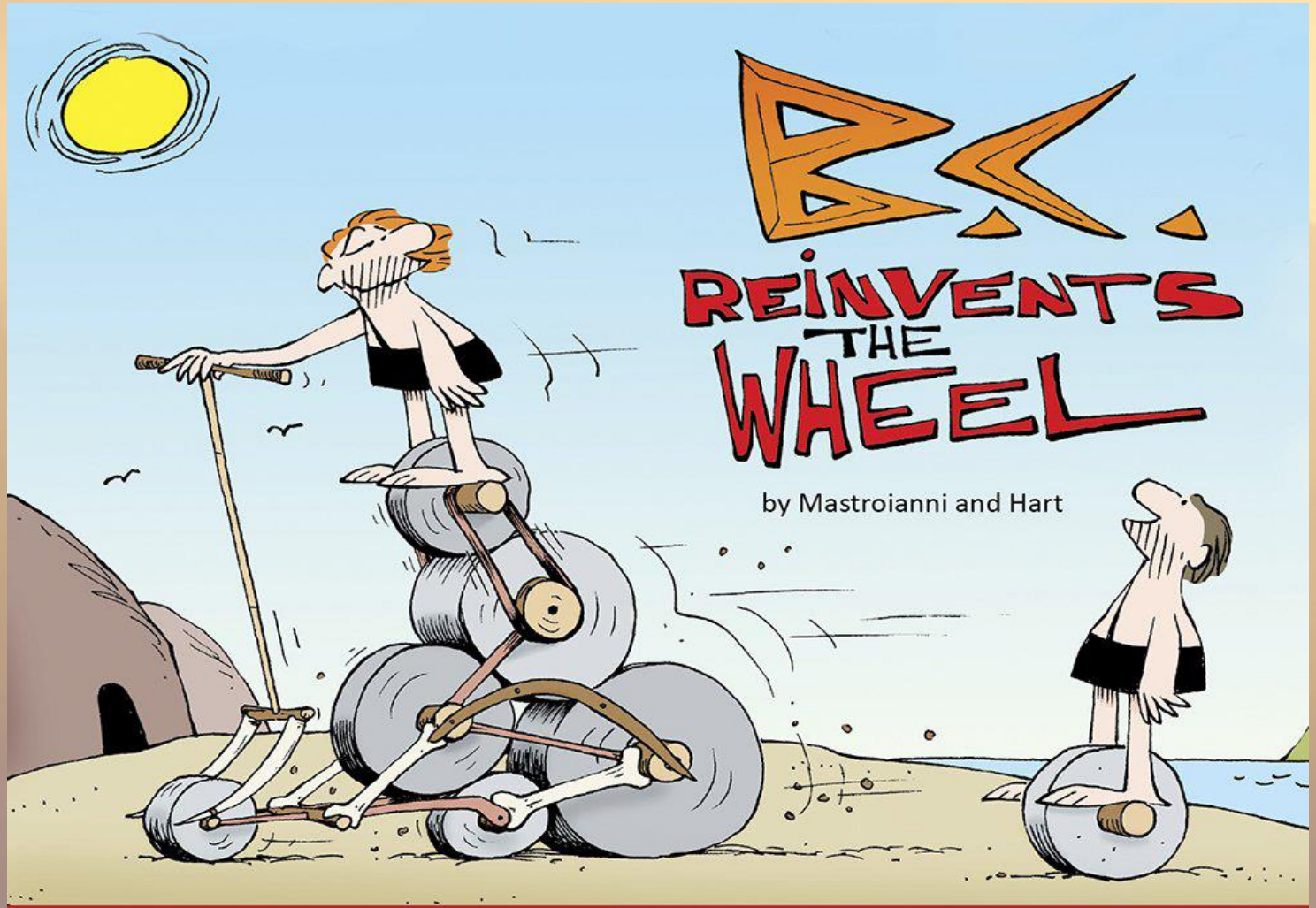
Efficiency Gains Lead to FASTER Energy Consumption Rates, not slower

- This key fact (**Garrett 2012**) is simply missed, ignored, or distorted into a "straw man" by policy "white papers" and promotional publications and speeches.
- They misunderstand what humans actually DO with efficiency gains in energy production – we do not destroy those "dollars", we do not get happy with a static lifestyle that costs less. Instead, we plow those savings to grow further, and that means higher energy consumption rates.

We've All Heard the Urgings from the Eco-friendly Progressives…

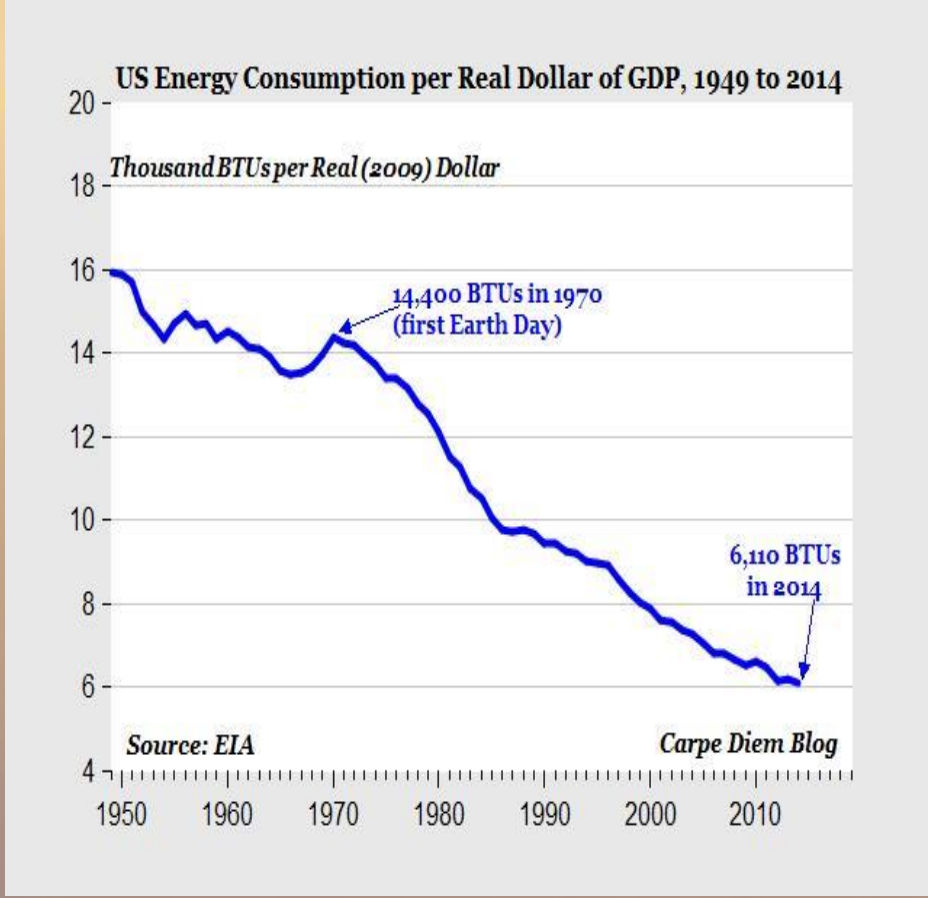
- … if only we can mandate lighter vehicles instead of those heavy steel cars of old!
- … if only we would raise our mandated mileage standards for vehicles!
- … if only we can eliminate those darn "vampire power" losses in our appliances!
- … if only we would outlaw incandescent light bulbs and go to all compact fluorescent bulbs!
- ….if only we would outlaw those compact flourescents and go to all LED lights!
- …if only we can eliminate cars and go to personal rapid transit (PRT) community vehicles!

Yet – we've been dramatically increasing energy efficiency ever since the invention of the wheel! We're "optimal foragers", as are all other animals, seeking to lower our energy spent per unit of economic utility

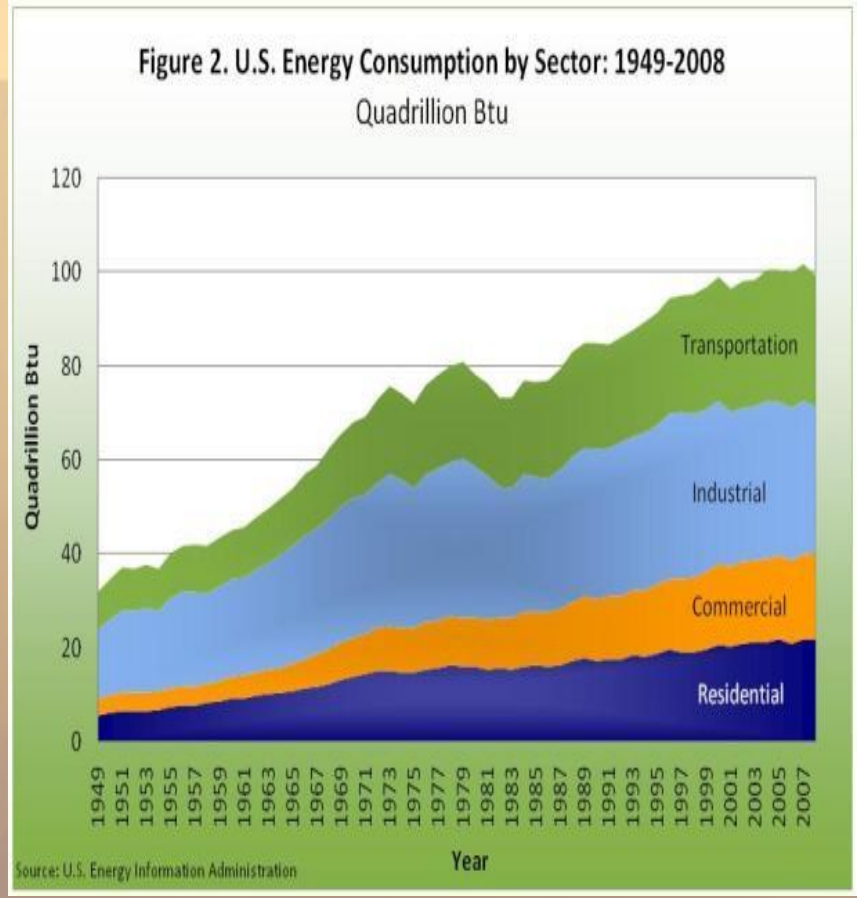


Increase energy efficiency? – we've ALWAYS been raising energy efficiency!

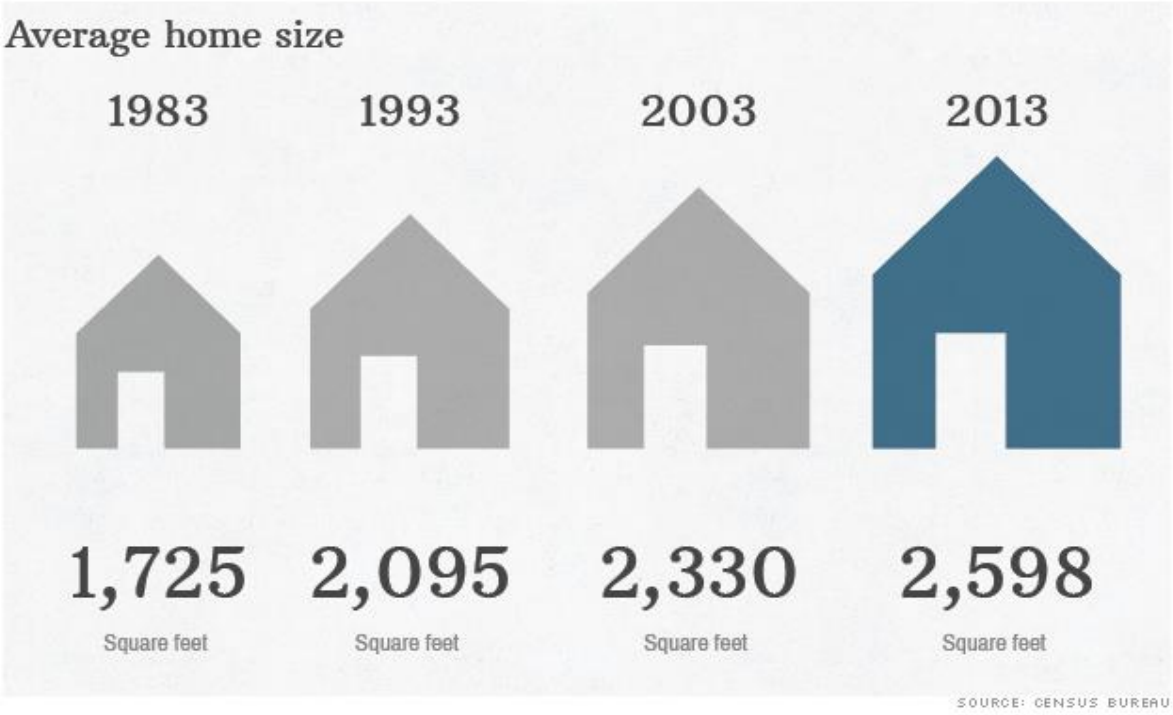
70 yrs of spectacular increases in U.S. Energy Efficiency! Has it lowered energy consumption?...



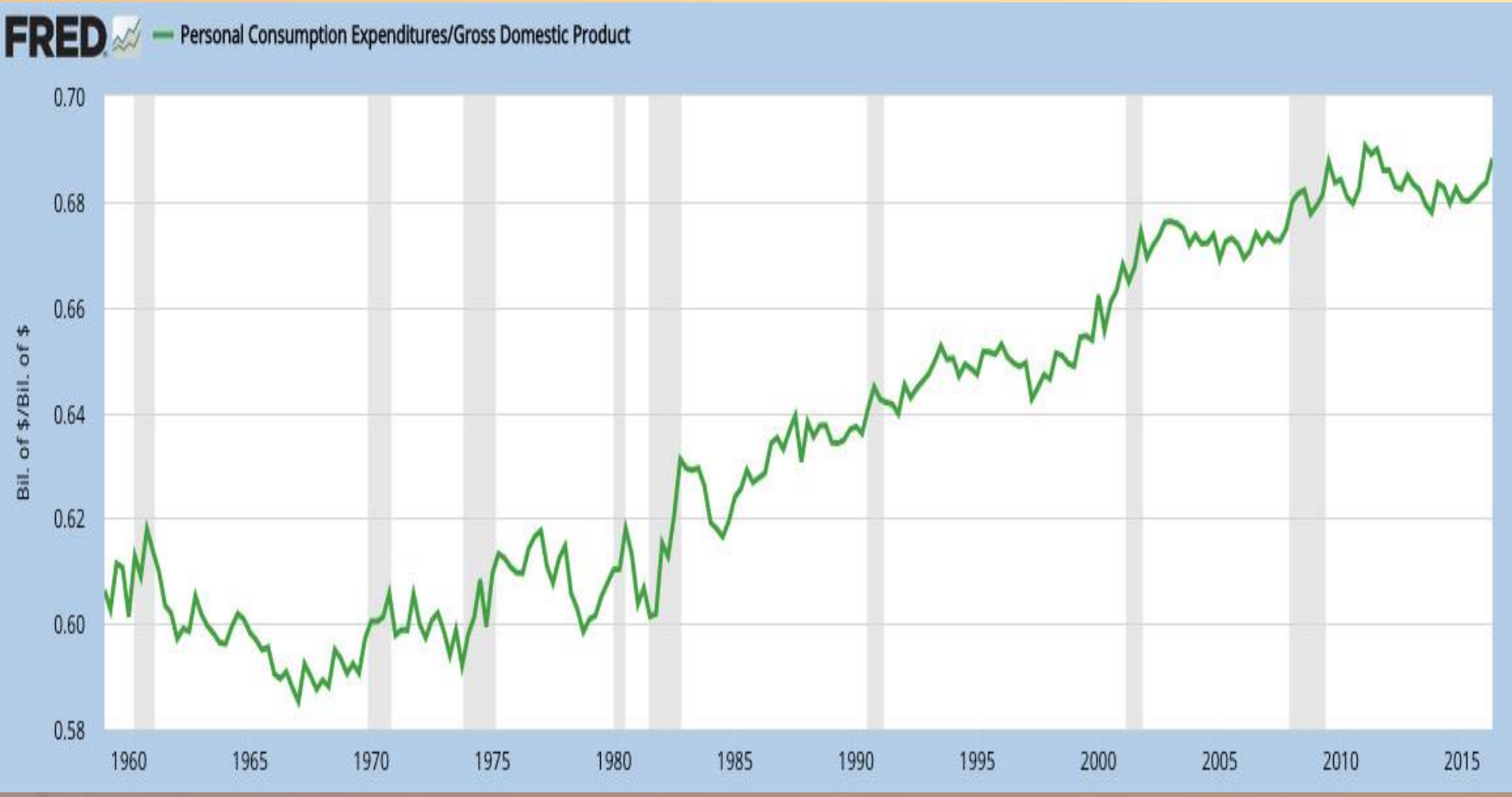
No! Energy consumption continues to rise, even given our off-shoring of much manufacturing to Asia



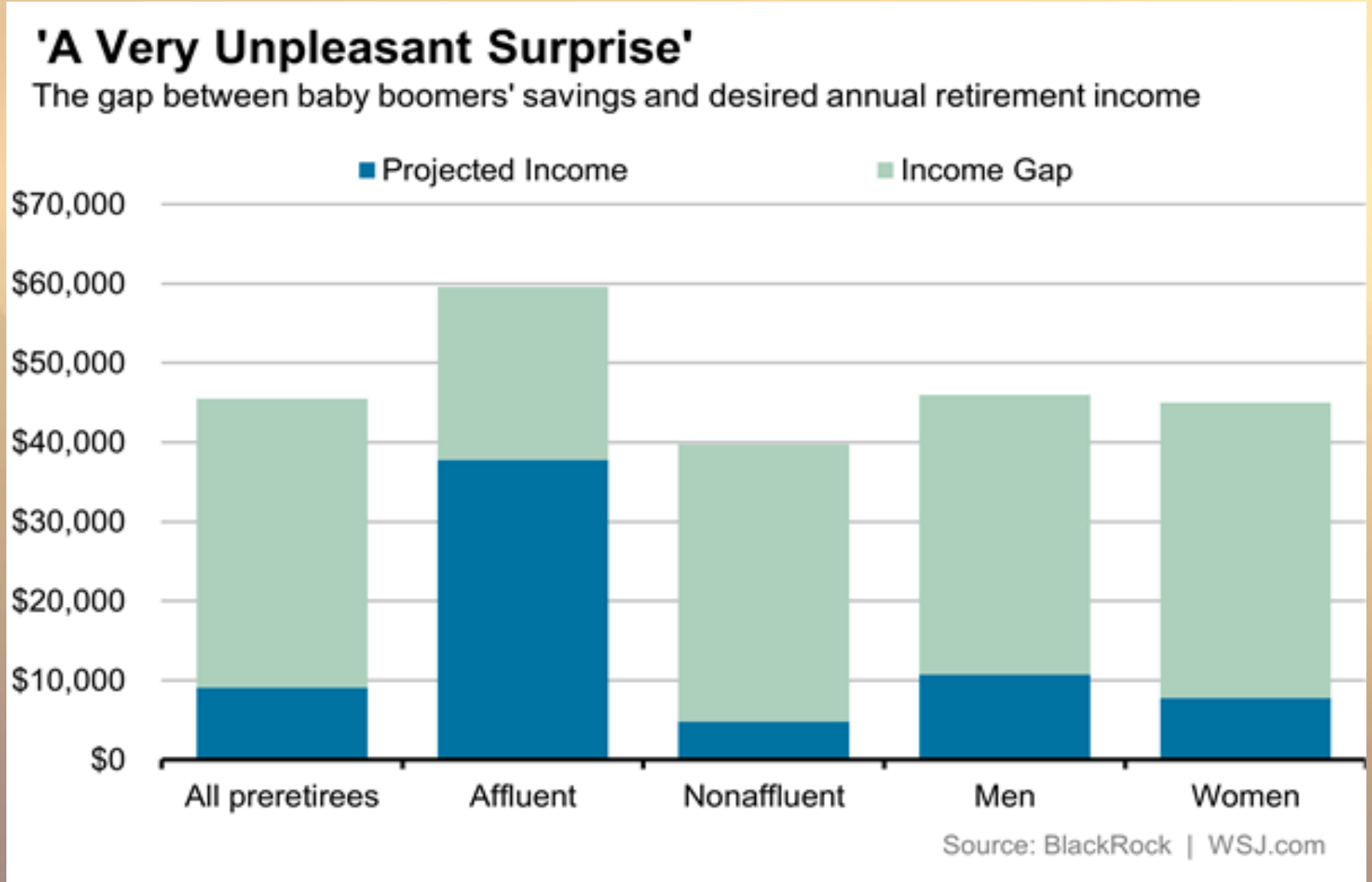
Even in the wealthy U.S. …We do NOT save our efficiency gains. We SPEND them; on Bigger Homes…



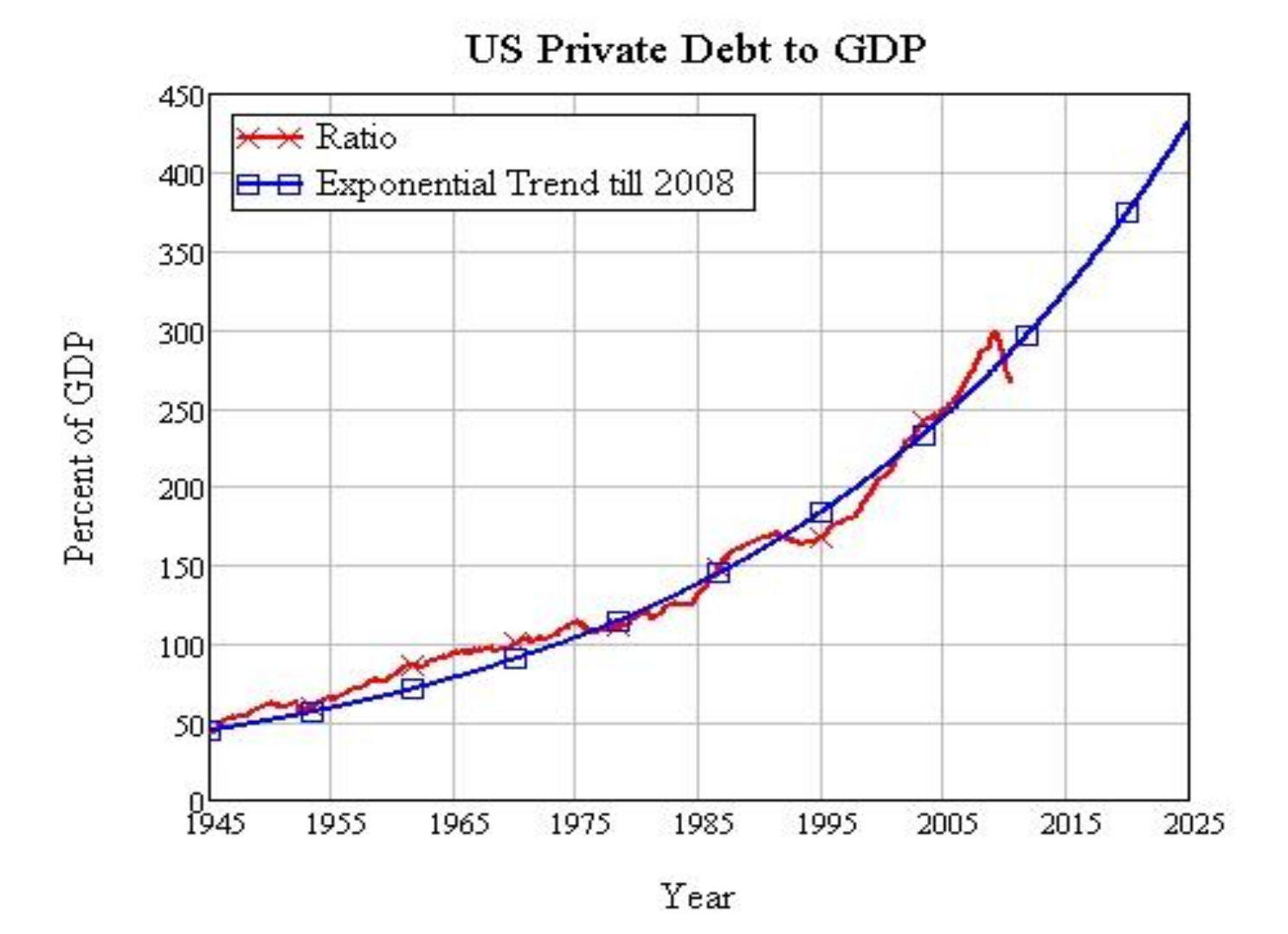
…on more consumption spending per $ of GDP



We're NOT Saving… even for our own retirement



We SPEND. Not stopping with bankrupting ourselves, we go on to spend our children's and grandchildren's inheritance: Debt/GDP is exponentially increasing



"Being able to falsify a result lies at the core of the scientific method. It must be possible to set up a test that could lead to a model being discarded." – Tim Garrett

- The above is from Garrett's article with the blunt and provocative title **"Macroeconomics is not a Science"**
- Integrating physics (thermodynamics) with civilization's economic aspects, on the other hand, does qualify in this regard (*i.e.* scientifically testable)…
- **"Current global rates of energy consumption growth and global GDP growth can be accurately predicted based on conditions observed in the 1950's, knowing only the key thermodynamic civilization relations and without appealing to any observations in the interim, with skill scores >90%.** (Garrett - from same article).

- For a more detailed study of Garrett's work, see key papers linked **near the top of this page** of mine. The latest and most mathematically detailed paper is **Garrett 2014**

Well, what if I just leave my energy efficiency savings in the bank?

- Even if you simply leave your savings in the bank, the bank uses those dollars as an asset base, enabling them to lend out a multiple of those dollars (newly minted money out of thin air) to others who will spend them. So that's also a no-win. (We all live, globally, within a fractional reserve banking system)
- Thus, if you're going to avoid expanding energy consumption rates, you have to "destroy" the dollars saved through efficiency gains.
- (Or else, convert them to non-productive assets like gold, and literally bury it, waiting for a day when the Earth can afford your spending it.)

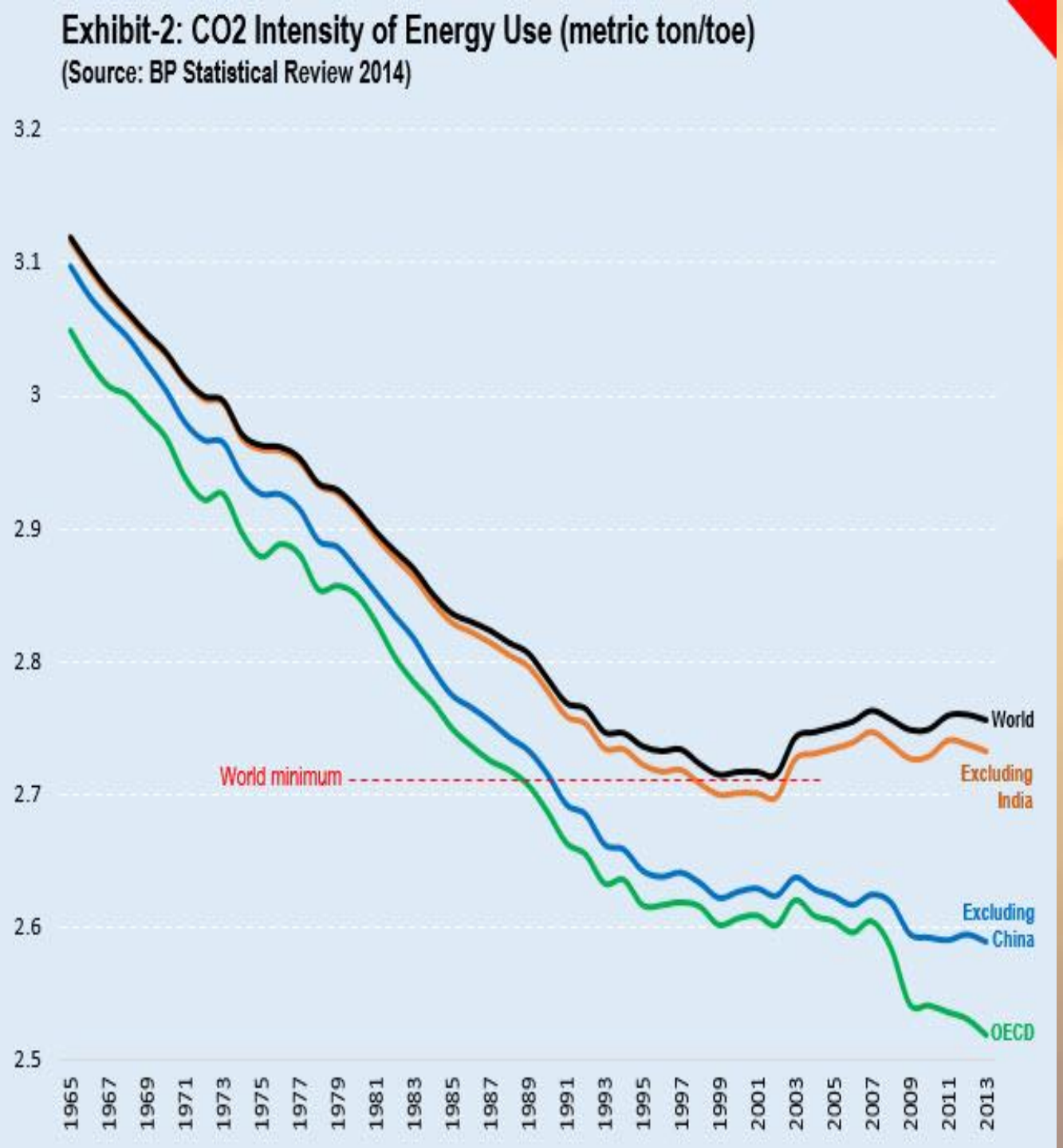
So, we have to essentially BURN our piles of efficiency-gained cash??

I Wish it Were That Easy…

- The cash only denominates wealth, and if the wealth remains, the upkeep it requires and the ability it enables - that of further growth in energy consumption - remains.
- Burning the cash only makes for “negative nominal inflation” after it’s burned. It doesn’t help our dilemma – our dilemma being to LOWER Civilization’s total energy consumption.
- We need to actually cripple civilization’s ability to grow, or else voluntarily halt that growth by policy action or (impossibly hard) universal and continually summoned human will power, against our desires.
- In a competitive world, this would seem ***extremely*** unlikely

To avoid Generalized Jevons' Paradox, improved energy efficiencies cannot be spent elsewhere. Even spending them on de-carbonizing will require energy, and will raise CO2 emissions in the present (but better spent on decarbonizing than not)

- **This last observation may help explain the next graph, which many of you will find surprising…**



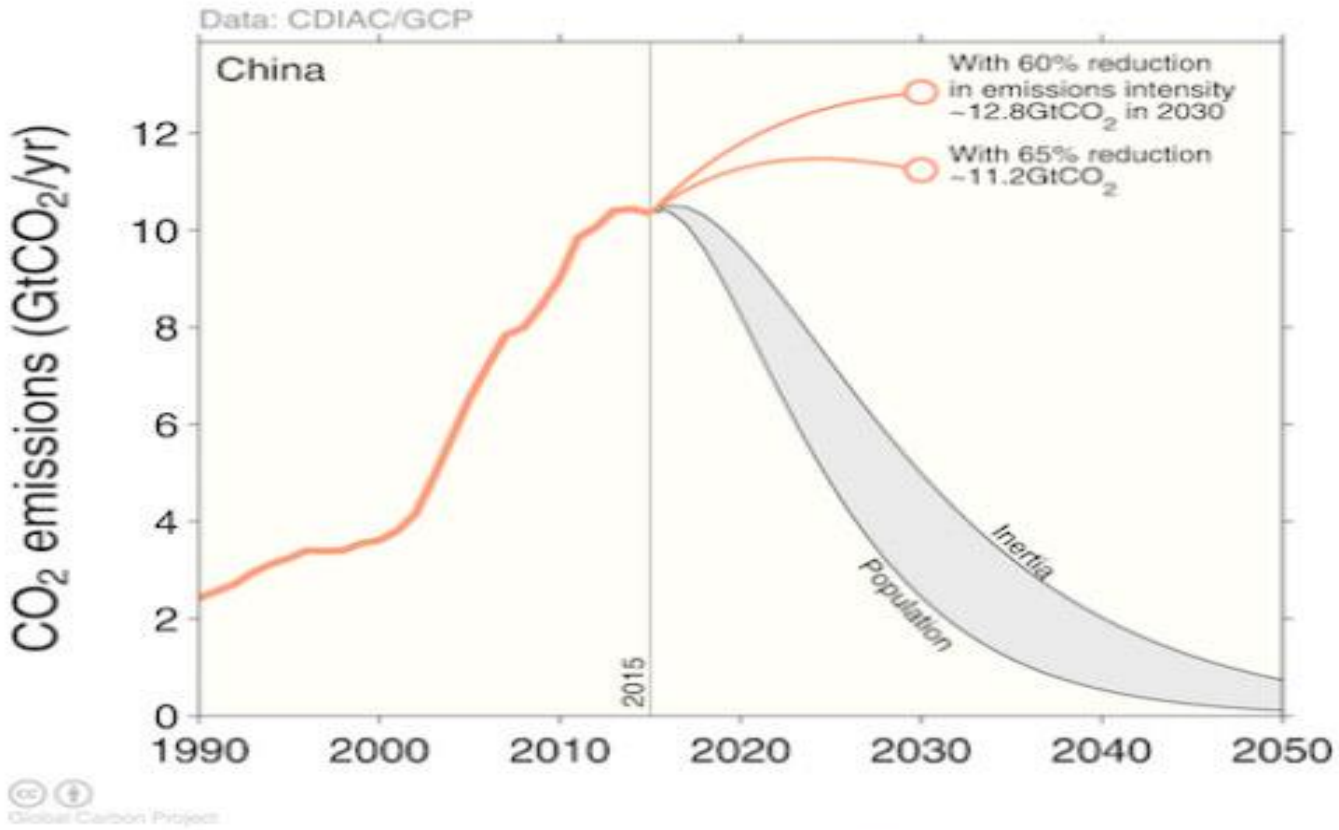
Plotted is CO2 intensity per unit of energy generated. Strong growth from China (coal) halted decarbonization this century. Even the non-China world (blue) has slowed its de-carbonization, although it's still decarbonizing. Developed world (OECD green) is doing better. The current (2016) global economic slow-down may see these curves resuming downward, is my guess. But *Climate cares ONLY about the World (black) curve!*

Note: The exponential halving time of carbonization 1965-2001 is **180 years**

While Much Press has been made of China's Recent Commitments to Lower CO2 Emissions…

- Glen Peters of ClimateChangeNews (2017) looks deeper and **advises strong skepticism** based on under-reporting, boom/bust construction, and the unique way the numbers are reported.
- *"A recent **study** estimated that a decline in construction activity explained about three-quarters of the decline in coal use. This is since construction requires energy-intensive inputs of products such as cement and steel.*
- *"Economic woes are behind the recent slowdown in Chinese coal consumption and emissions, but growth in renewables and concerns about air pollution contributed."*

China's pledge of 60-65% reduction in CO2 emissions intensity by 2030 sounds planet-savingly dramatic!… until you convolve with their growth. Do the math and see what it means: Even Emissions RATES Keep Rising (red circled), 15-30% above 2015 emission rates. That means further steepening acceleration in atmospheric CO2



The Chinese emission pledge (orange lines after 2015) is inconsistent with the recent slowdown in emissions growth (orange lines before 2015). The grey band shows where Chinese emissions need to go to remain consistent with a 2°C temperature limit. (Source: Cicero)

Let's Make Sure You Understand That Last Slide

- A promised 60% reduction in carbon intensity of energy (per unit of economic activity) by 2030 corresponds to an exponential halving time $\mathbf{t_{1/2}}$ of only **14 years.** Impressive! – perhaps impossibly so.
- We'll see how strikingly rapid that is, and certainly impossible without decommissioning perfectly working fossil fuel fired power plants; so be highly skeptical.
- It's dramatically rapid compared to historical decarbonization rates, and yet **– at China's growth rate it still results in annual CO2 emissions RISING in 2030 by a further 30% above today's.**

The Conclusion is Inescapable: Economic Growth is the Enemy of Climate.

And so – The climate forcing due to our GHG's is not only rising, the growth rate of rising is itself rising! (from Hansen *et al.* 2017 fig 14). Climate forcing rise rate by GHG's has risen by 50% in just 13 years, and accelerating. This is dramatic exponential growth

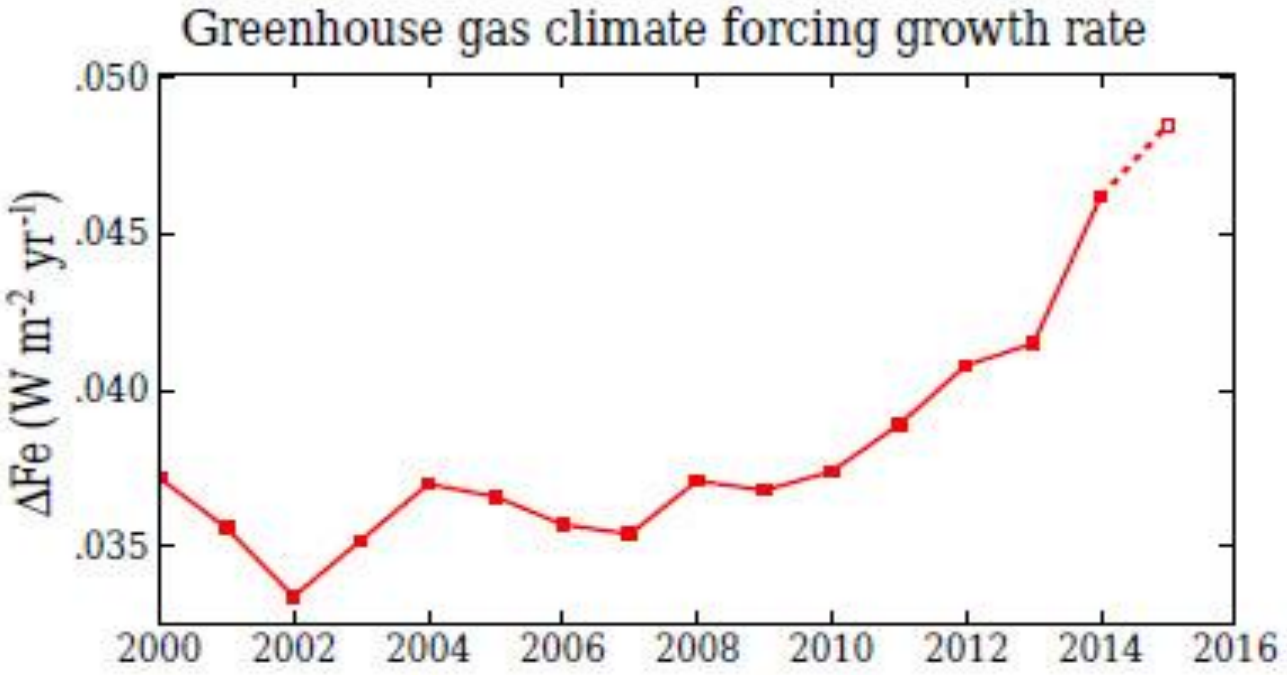
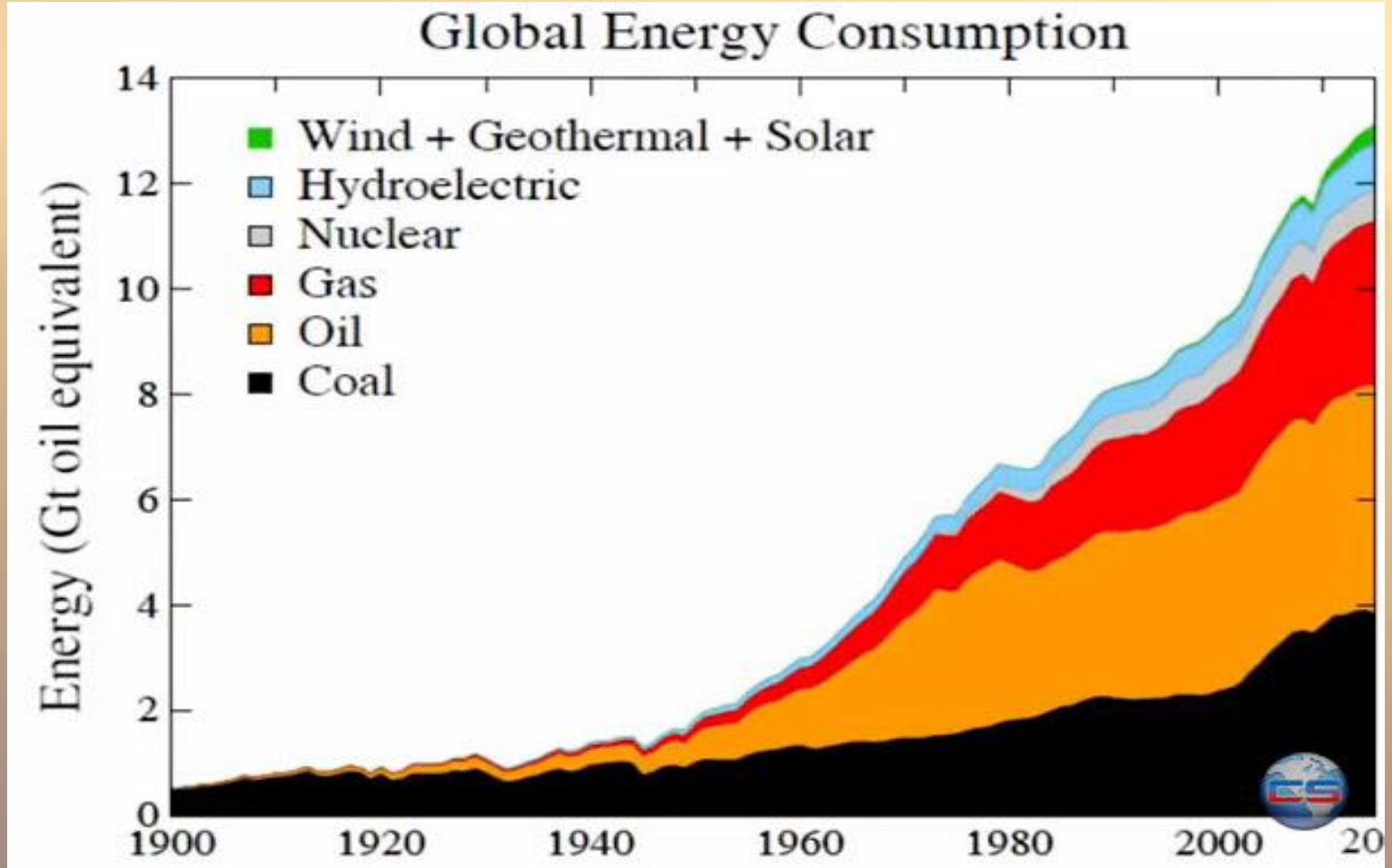
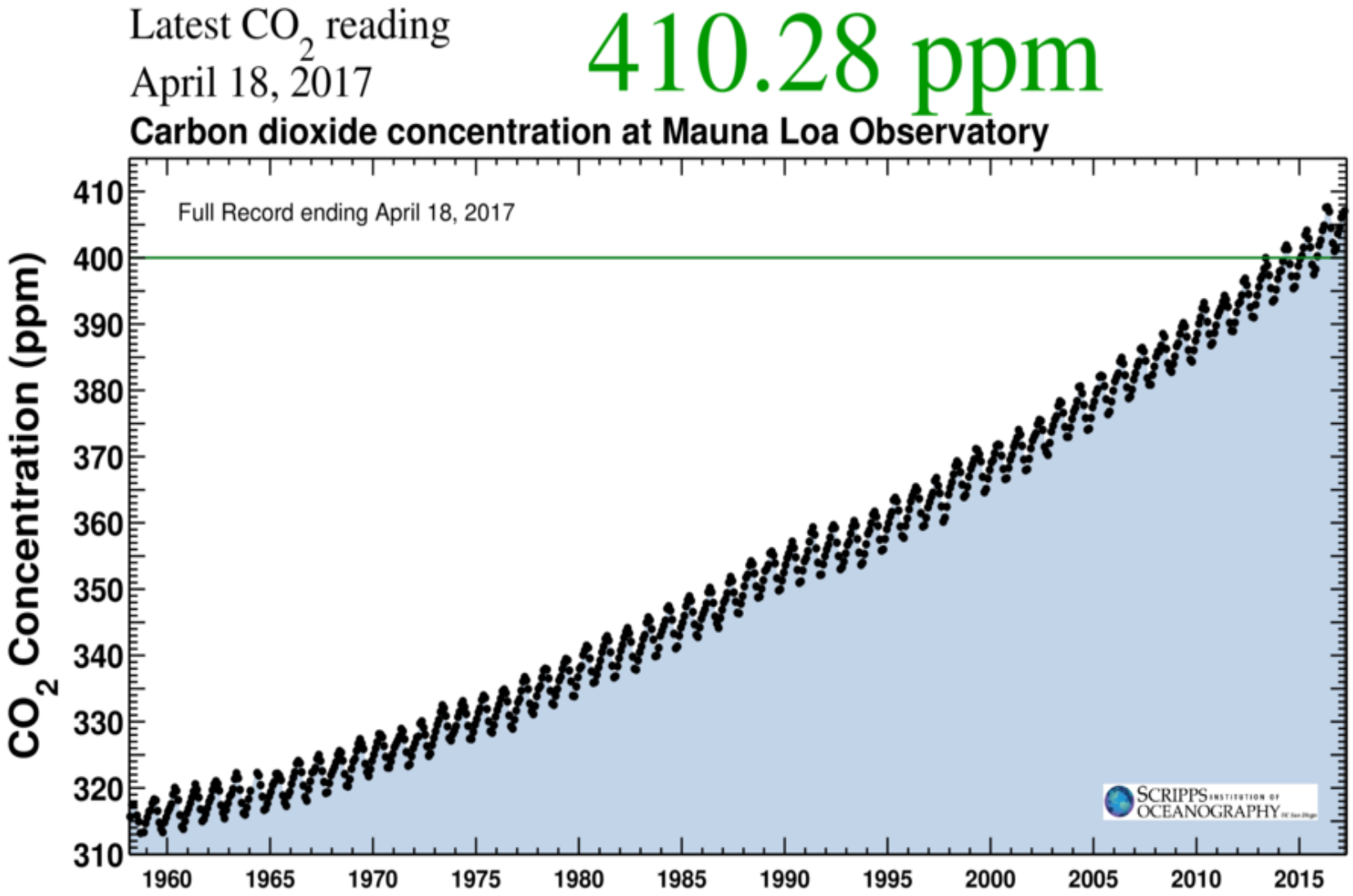


Figure 14. Recent growth rate of total GHG effective climate forcing; points are 5-year running means, except for 2015, which is a 3-year mean. See Fig. 8 for individual gases.

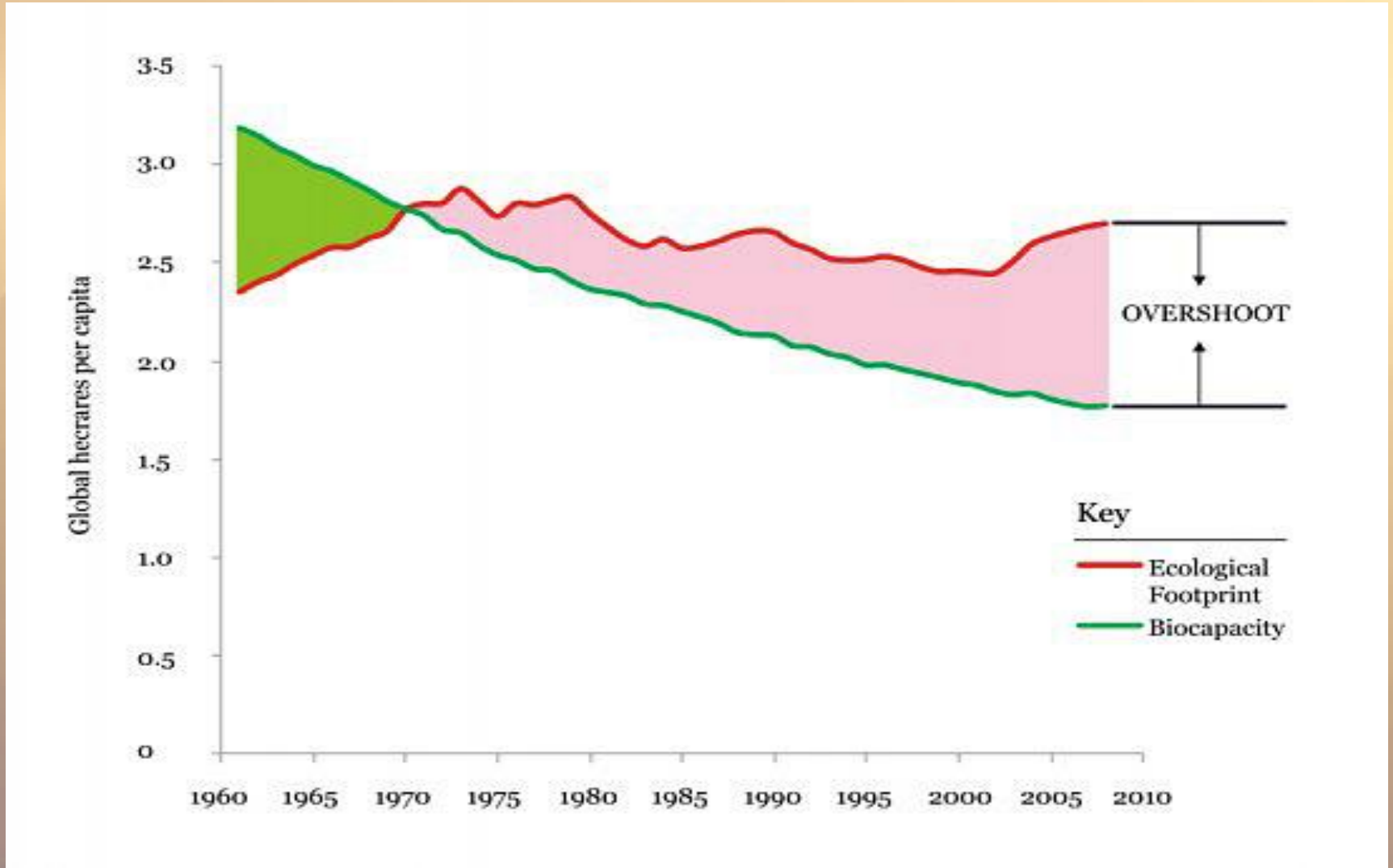
Civilization will exploit ANY and ALL energy it can lay hands on. Yes, new power plants are increasingly solar and wind, <u>when cheaper</u>, but only in part, and older FF plants will not be unplugged just to save the planet, they'll be unplugged at the end of their natural lives… The tiny blip of green is non-hydro renewables, on top of rising fossil fuels underneath. Hydro and Nuclear have grown little for decades



So: in the Real World: CO2 Continues to Accelerate with no break



<u>Sustainability on a finite Earth requires an end to the growth paradigm</u>, and that won't happen without painful globally enforced policy, because it runs against the grain of our genetic inherited desires.



You May Be Grumbling…

- …that my talks are “negative”, a “downer” and no one wants to hear that sort of thing. Right. Got it…!

Yes. We instead want…


Powerful Affirmations
to Attract & Manifest
WEALTH
powerfulmoneyaffirmations.com

But Mother Nature does not care about your desires. Her laws will be obeyed. Period. End of Negotiations

- And the numbers don't pencil out. Resist the temptation to complacency induced by those who want to "sell" you on "hope", and pamper their popularity along the way. "Hope" - that smart people in a lab somewhere will let us have cake/eat too.
- We're passing tipping points right now. Not in 20 years… NOW. If your house was on fire, and the smoke alarms blared, would you complain and grumble that the smoke alarm is "a downer" and you don't want to hear it?

Our Massive Climate System Changes Direction Like the Titanic. But so does the massive civilization in which we live. We need to act as if this is the emergency that it actually is, even though it's playing out in slow motion.

- Consider WW II. We complacently "hoped" for the best for years, But meanwhile, Europe was doomed to ruins, and Indo-China raped, before effective action happened. We only roused ourselves when attacked by Japan.
- I expect we'll only consider doing UNcomfortable things for climate when the disasters come too thick and fast to ignore. But by then, our hot, humid future will be too far along to avoid without REVERSE climate change, which will be very painful and likely dangerous in many ways.
- **Nolthenius' First Law: People Learn the Hard Way**


Sorry!
The lifestyle you
ordered is currently
out of stock

Garrett's work, however, includes no permafrost thaw

- So the reality will very likely be worse than those red curves.
- My extensions to this work involve the inflation term, and have important implications. No time to elaborate here, alas. See **this talk**
- **I also plan to extend the work to more drastic assumptions of decarbonization.**

4. What do we DO About This?

So What Do We Tell Our Students to Do?

- Encouraging voluntary individual conservation has psychic value, **but ~no climate value**. The entire U.S., in fact, is a minor contributor to additional CO2 now. Asia is #1.
- **Only GLOBAL actions can affect LOCAL climate** – unlike almost any other environmental problem. Even inspiring 1 billion of the high-carbon wealthy nation people to somehow cut their carbon footprint in HALF, only cuts annual CO2 emissions by a negligible 13%.
- **Techno-fixes are essential, but highly unlikely to succeed in a civilization committed to growth.**
- **We need to create and enforce Global Governmental Policy. It is the Policy and Education Environment that needs our Efforts. Techno-fixes without that, are doomed**

Restate for Emphasis: Even if you Inspire 1 Billion People to Voluntarily Cut their Total Carbon Footprint by 50%

- You lower our CO2 emissions globally by only 13%, almost negligible compared to the problem we face
- Of course, your efforts WON'T inspire a billion people to voluntarily cut their footprint in half…
- **Why?**

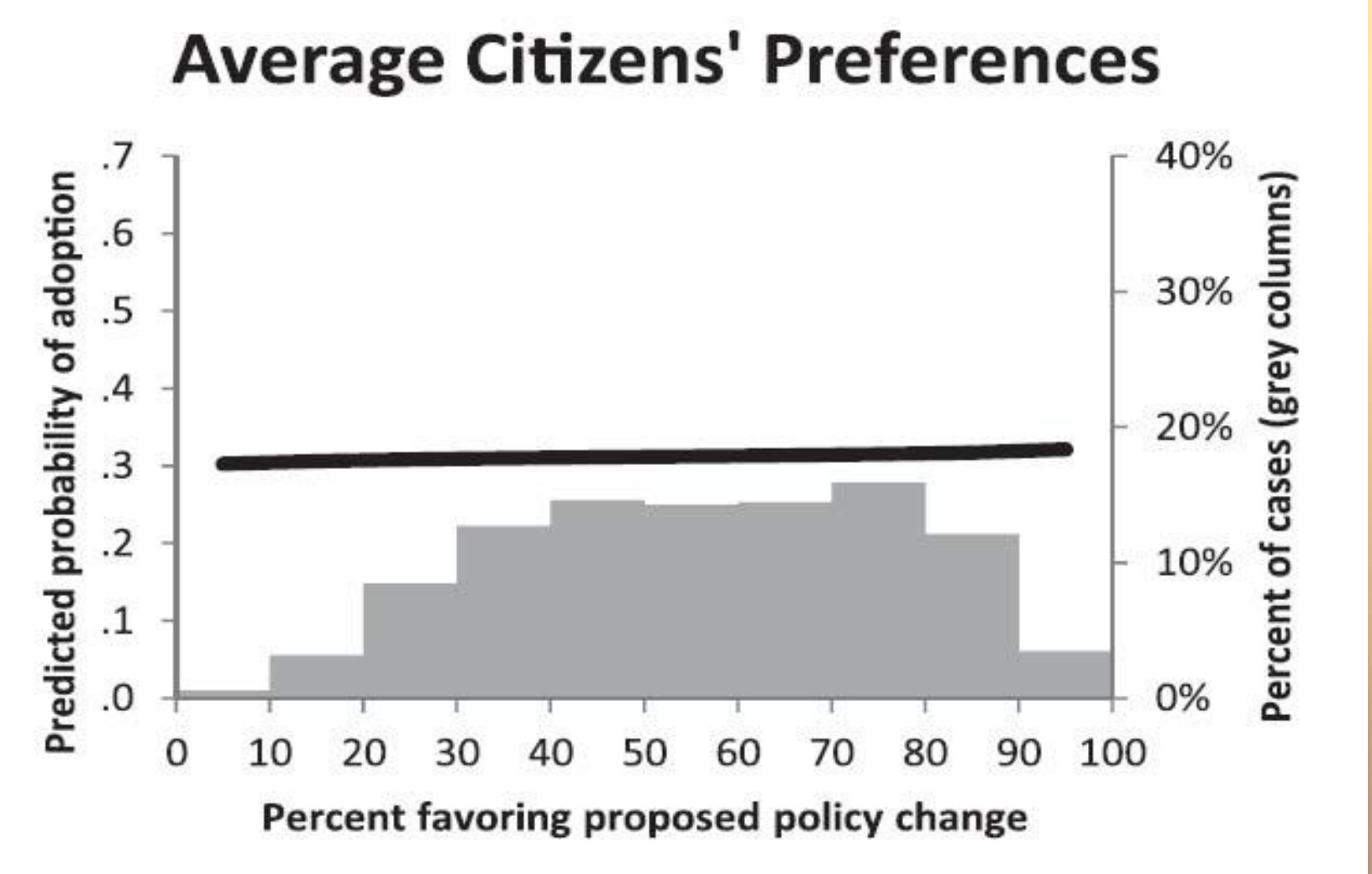
Econ 101: Because People Make Their Economic Decisions "On the Margin"

- Facing decision X, we compare what will be our situation if we **DO X** *vs.* if we **DON'T do X**. And we do NOT control others, only ourselves.
- Seen this way, all individual voluntary carbon footprint changes are negligible for climate and will not motivate us to do them**, especially if they entail financial sacrifice for ourselves and those that depend on us. We're sheepish to say it out loud, but we all know the truth of this.**
- The actual motivating value to an individual for making noble sacrifices is in their perceived noble stature, their relative status, their believed increased worth as a person as seen by others. This does move some to better actions, but only a tiny minority.

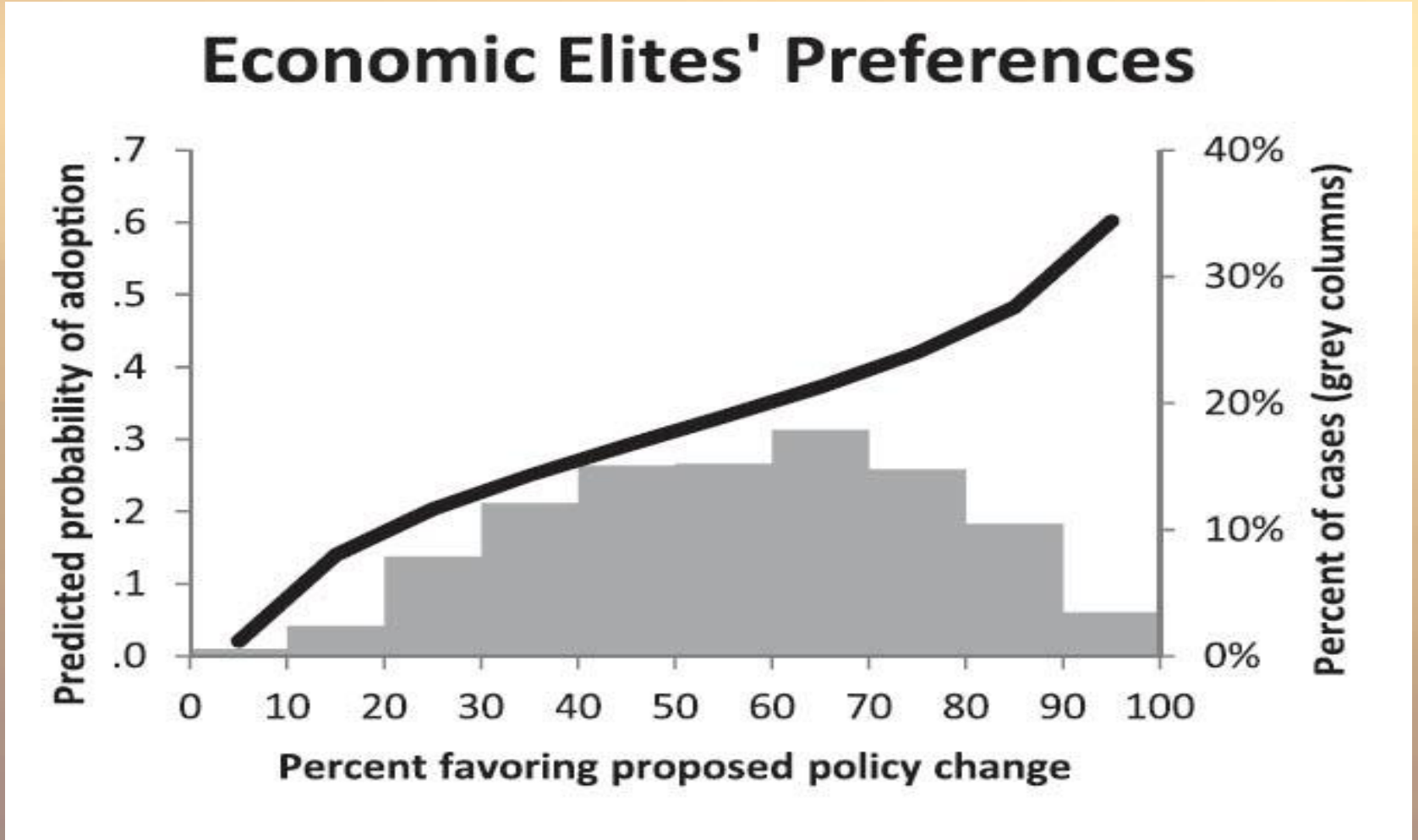
But many have already sold off their self respect to the highest bidder.

- Their perceived status comes from ostentatious displays of money as substitute for virtue, and display of personal power over others.
- For them, the additional marginal cost of one more betrayal is small, while the "juice" of money and power and all that comes with it, is all they can now hope for in the way of rewards in this life
- **So, Shall we Write our Congressman Earnest Letters Urging Better Laws? It won't help. Why?...**

Because there is ZERO correlation (=flat) between what legislation is desired by average citizens, and what actually gets adopted (Princeton research Gilens and Page 2014), when corrected to measure independent influence



…<u>but Near-Perfect correlation between what the Economic Elites want and what gets adopted</u>. True over 20 years of both Republican and Democratic Governments. This is a deep <u>systemic</u> dysfunction. Note their perfect batting average at killing legislation they hate (bottom left)



Yikes! Well, but… Can we Trust the Economic Elites?

Alas, No…

- …fully **21% of corporate CEO's fit the diagnosis as Psychopaths, the same fraction as found in prisons.** (Brooks *et al.* 2016, published in ***The European Journal of Psychology***)

- **In the general population, using their criteria, the rate is only 1%, as they point out.**

Your Political Influence is *ZERO!*

It is not noble to "HOPE" that banging your head against a brick wall will break the wall before it breaks your head… and your heart

"We Are What We Repeatedly Do" – Aristotle

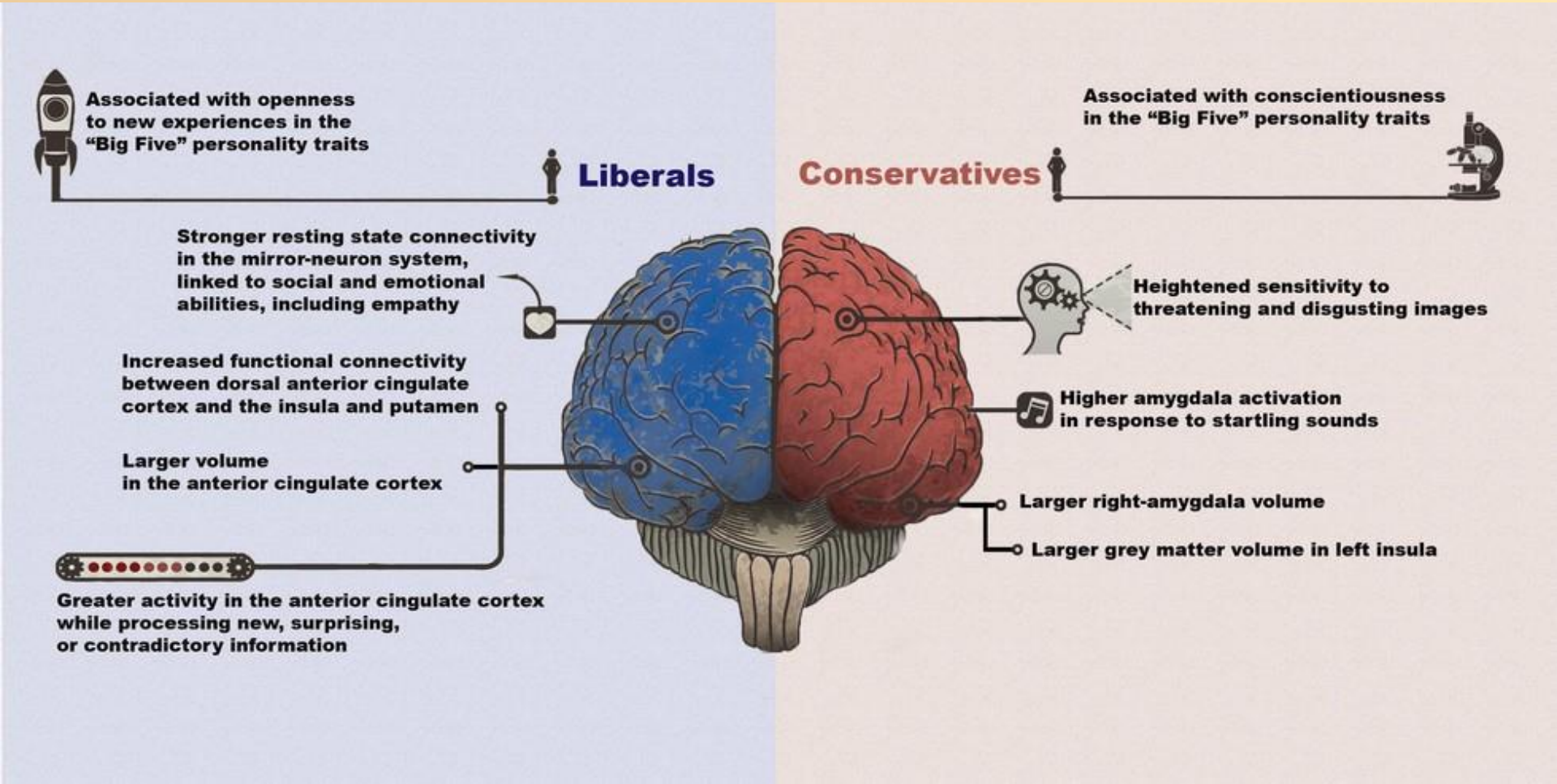
What does that say about our Congress's Integrity?

Congress Makes the Laws that Control Congress

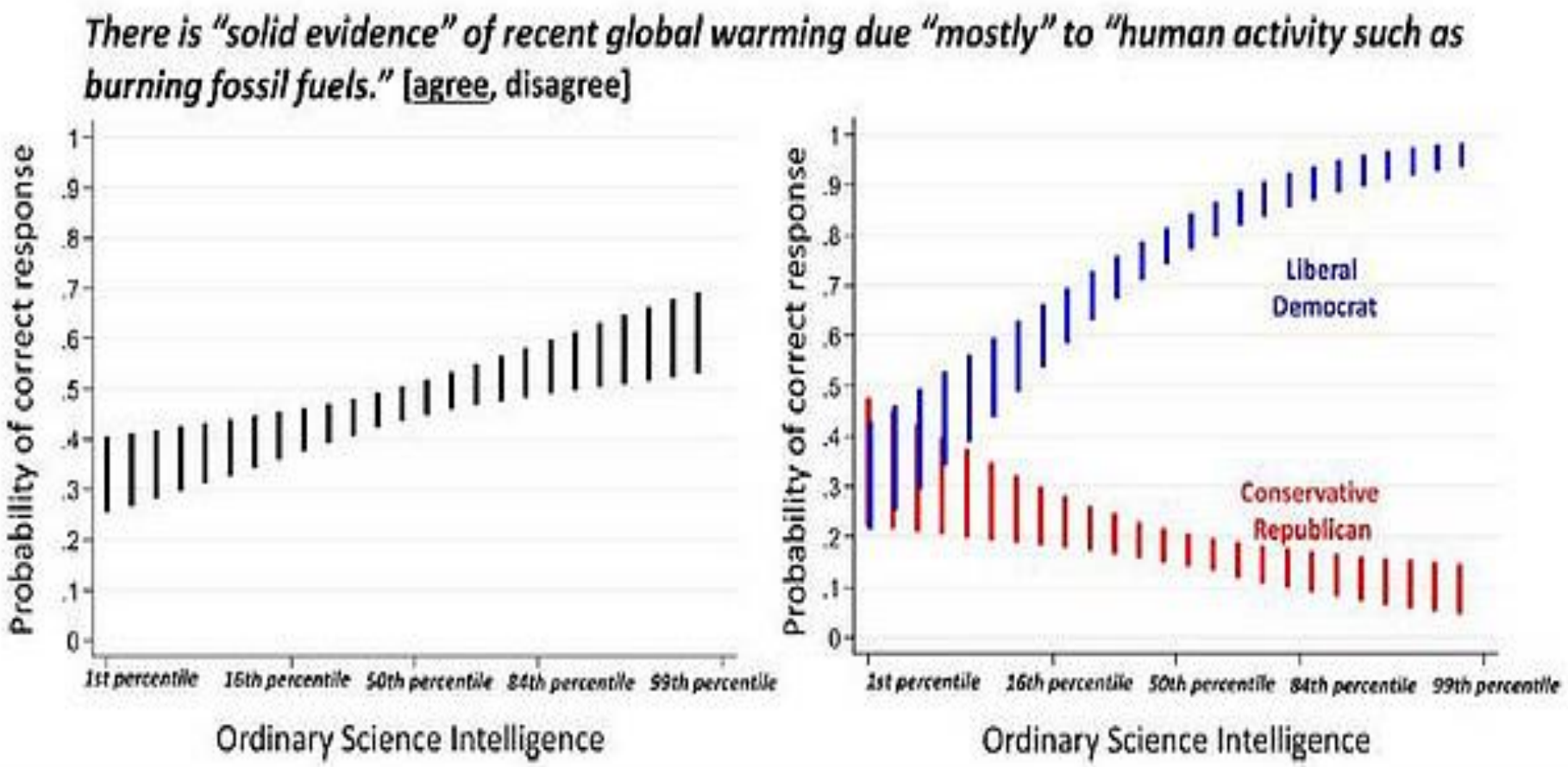
- Including laws for campaign financing, “dark pool” money sources, influence peddling, slap-on-wrist punishments, and everything else.
- So it’s a closed loop. An air-tight system which **has not** and **will not** change by politely asking “please?”.
- **It’s a closed System**.
- **THEY** are on the inside. **YOU** are on the outside.
- ***Sorry!***…… **Deal with it!**
- It’s really simple. If you find it hard to accept, perhaps study up on **Stockholm Syndrome**

On Political Action: I Sometimes I feel like Sarah Connor in *"Terminator 2"*, in the nightmare scene at the playground, shouting to her younger naïve self *"<u>Wake</u>! <u>Up</u>!!"*

Conservatives Run Our Country… They Exhibit Psychopathologies, backed up by numerous brain studies



The more scientifically intelligent, then the more convinced Liberals are of human-caused global warming. But it is the opposite for Conservatives (Kahan *et al.* 2015 , discussed here). Trying to reason with Conservatives makes them LESS Rational. We must route AROUND them, not WITH them.



- **Realize – the Gilens and Page 2014 Dataset is** …BEFORE The new Trump era
- …BEFORE "**Citizen's United**" allowed dark money to flow where it increasingly flows – attacking climate scientists
- So have things gotten better?
- Not likely.

…And for the Executive Branch…?

Can We Trust *Laissez Faire* Capitalism to Solve Our Climate Situation?

- The mantra from market economists is ETERNAL ECONOMIC GROWTH.
- **On a finite planet, this is suicide.**
- To Infinity! To the Asteroids, and Mars… !
- **No**, we'll soon likely be too crippled to have the money for such foolishness. Better prove they can steward OUR planet before invading others.

- **To Hammer Home the point…. Continue!**

My Best Analogy for *Laissez Faire* Capitalism, is -"The Terminator"

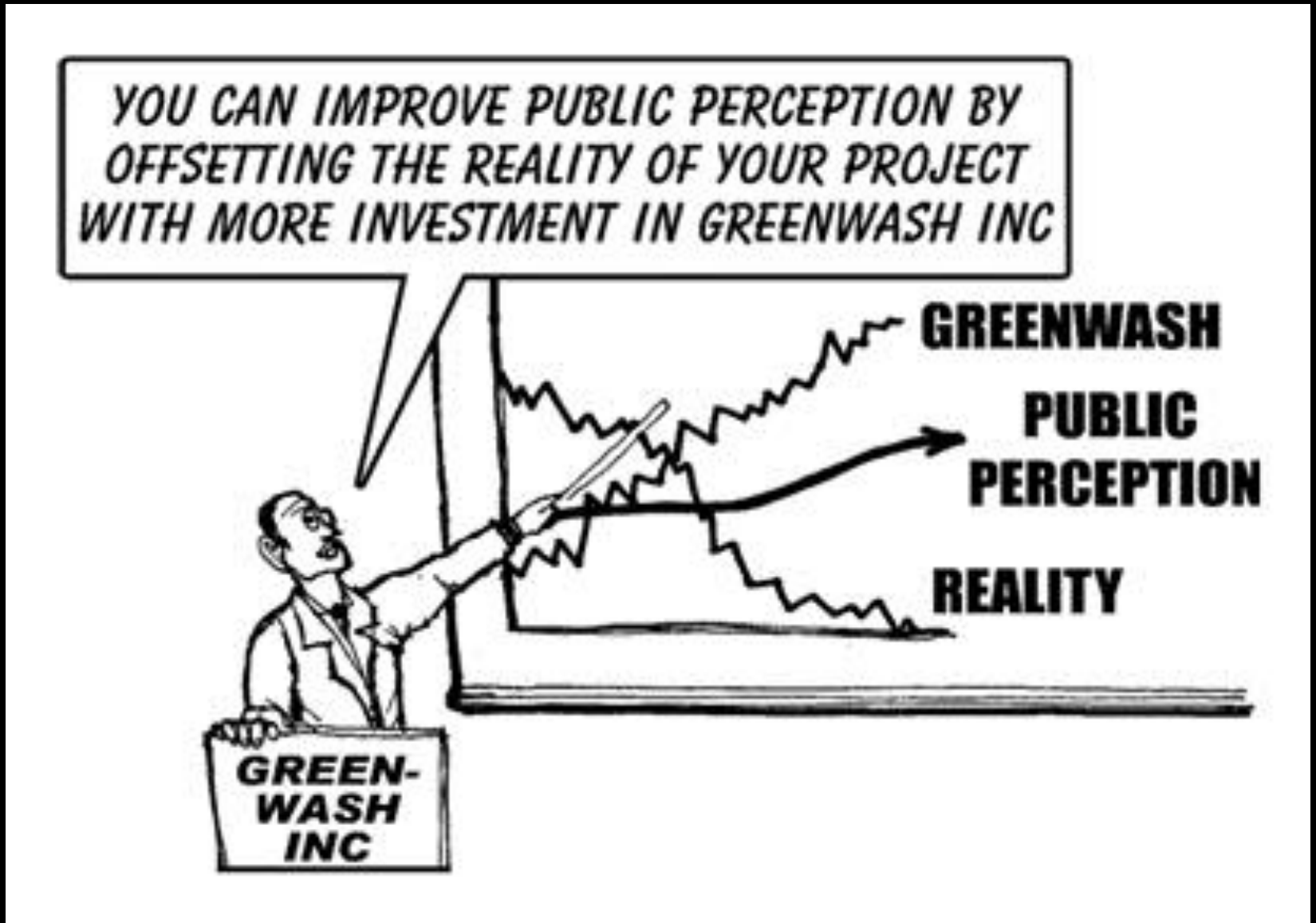
“Listen, and Understand…”

- ***“…that Terminator is <u>out</u> there! It can’t be bargained with! It can’t be reasoned with! It doesn’t feel pity! Or remorse! Or fear! And it absolutely WILL not STOP. <u>EVER</u>! Until you are <u>DEAD</u>!” (video)***

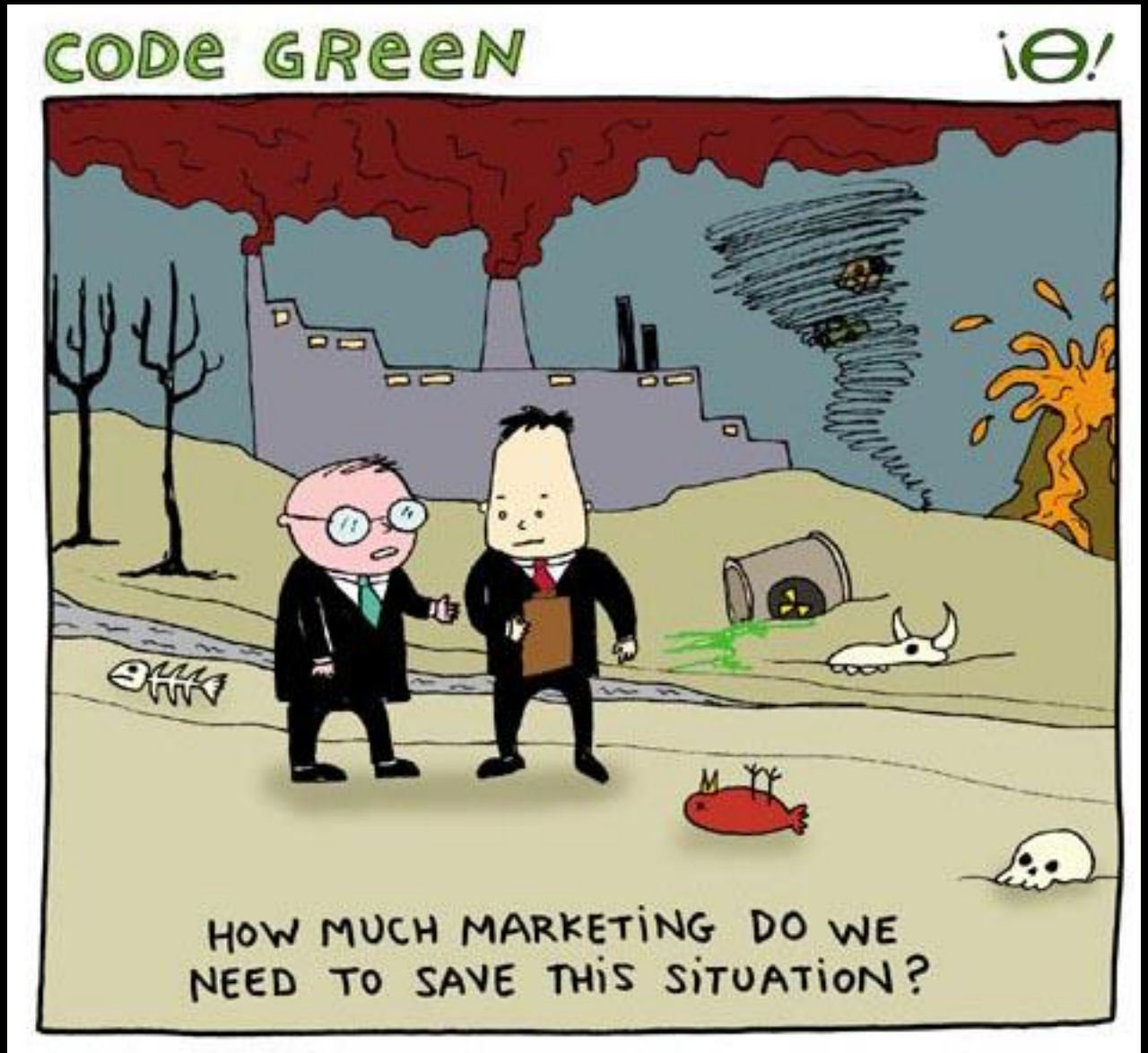
To Paraphrase for Capitalism…

- It doesn't **CARE** for your well-being
- It doesn't **CARE** what is good for Earth's future!
- It doesn't **CARE** about future generations of humans or other species!
- It doesn't **CARE** what laws you want! (see Gilens and Page 2014)
- It **doesn't feel pity** for the poor it may impoverish!

It doesn't feel remorse for its lies,



It doesn't feel remorse for its phony salesmanship



It doesn't feel remorse for its outrageous violations of science

Independent Science Shows Harmful Effects from BPA, while Industry Science Shows None

A recently-published review of scientific studies shows that, in the last 7 years (through November 2005), 151 studies on the low-dose effects of BPA have been published.(37) None of the 12 studies funded by the chemical industry reported adverse effects at low levels, whereas 128 of 139 government-funded studies found adverse effects. These many studies were conducted in academic laboratories in the U.S. and abroad. Even the 12 industry-funded studies have flaws, however. Of the industry studies, two had their positive controls fail—an indication that the entire experiment had failed, not that BPA had not caused an adverse health effect.

	Adverse health effect	*No effect*
Plastics Industry funded	*0*	*12*
Government funded	*128*	*11*

Another industry study concluded BPA caused no adverse effect, but an independent analysis of the experiment's data by scientists convened by the National Toxicology Program of the U.S. Department of Health & Human Services concluded that in fact there was an adverse effect. Industry scientists had misreported their own results. The chemical industry relies on an incomplete review of scientific studies by an effort funded by the American Plastics Council at the Harvard Center for Risk Analysis. The panel funded by the American Plastics Council only considered 19 studies in concluding in 2004 that the weight of the evidence for low-dose effects of BPA was weak.(38) As of November 2005, there were 151 published studies on the low-dose effects of BPA.

It doesn’t feel pain for what it does to the Earth

It will fund dis-information campaigns

It will Slash the Budgets to, and Duct-Tape the Mouths of, its Own Scientists

EXXONKNEW

1979

Major fossil fuel companies met regularly as part of a task force to discuss the science and implications of climate change.

1982

Roger Cohen, director of the Theoretical and Mathematical Sciences Laboratory at Exxon wrote a memo stating "Temperature increase of this magnitude would bring about significant

1983

Exxon cut funding for climate research from $900,000 per year to $150,000. Exxon pivoted from the cutting edge of early climate change science to the forefront of climate denial.

1996

Mobil engineers noted that "An estimated rise in water level, due to global warming, of 0.5 meters may be assumed" in their planning for exploration and production facilities

It will buy Politicians

Whether it produces valuable products good for the long term health of people and the Earth…

Or irreparable scars generating poisons that pollute the entire Earth... It does not matter. <u>There is ONLY ONE PRIORITY</u>

Its Singular Priority is: to ACCRUE MONEY to the Corporations and the Major Shareholders

"It's What it DOES!

It's ALL, it DOES!"

– Reese, from "The Terminator"

Reminder, so I don't get BLASTED…

- *Laissez Faire* Capitalism **isn't** Immoral, **it's Amoral,**
- **In other words, morality just doesn't enter the equation of free and unfettered capitalism.**
- **It enters only if Governments enact moral laws forbidding what would otherwise be bad behavior.**
- Still, there ARE a few companies trying to both make money, and do good for people and the Earth.
- Paul Hawken, Elon Musk come to mind. There are others of course.

But making money is still PRIORITY #1. Anything that gets in the way… then something gets TERMINATED!

Sustainability Needs a New Rebel Alliance

(led by **Our Students. Oldsters** got them INTO this mess and resist reconsidering strategies)

I Offer This: Occupy DC with ½-1 million Strong, and Not Leave Until They…

- **Pass a 28th Amendment to the Constitution, guaranteeing unspoiled commons to future generations (oceans, air, great forests…)**
- **Pass a Carbon Tax and Dividend, at ~$300/ton CO2 level just for starters**
- **End subsidies to Fossil Fuel interests (5% of global GDP!)**
- **Institute 1-child-per-family, globally**
- **Support lawsuits against governments for discriminatory failure to protect the most vulnerable among us**
- **End "Citizens United"**
- **Fund research and deployment of CO2 air capture and other climate interventions which safely trace us backwards along the system trajectory we followed to get here.**
- See my ***.pdf* on "Policy"** for much more…

Why Would "Occupy DC" Work?

- A small weekend march is soon forgotten
- A determined march by a few gets more attention, but soon they're arrested, dispersed, or otherwise "disappeared"
- **But a half million cannot be arrested** – there's not enough jail cells.
- "Business as Usual" cannot continue to function, yet the citizens are only exercising their 1st Amendment right to peaceably assemble and present redress to their government – entirely constitutional.
- So any police violence committed against marchers would galvanize action from the best among the millions of Americans watching it on the news.
- Corporate news downplays and ignores many small climate skirmishes, but they could not ignore the media ratings THIS occupation would promise!

Most important: While your congressmen may be corrupt at this point…

- …somewhere there may yet be an honorable bone in their body, or at least a real desire to be a better person, buried somewhere in their unconscious.
- But they will not poke their individual head out of the foxhole of corporate sponsorship only to get it shot at by their corporate paymasters.
- However if ALL legislators are confronted with "Occupy DC", they now have the perfect excuse to disobey, and begin the long road back to some sort of self respecting behavior.

Suing Governments for Gross Negligence

- A **Dutch court has ruled** that the national government has a legal responsibility to protect its citizens against climate change, and ordered faster cuts in greenhouse gases in that nation.
- However, in America, it's different. **Kivalina, Alaska sued Exxon-Mobil** in Federal court over sea-level rise threatening their town. It was dismissed.
- One of the key bases for the law suit was that Exxon-Mobil deliberately lied to the affected people about the science of CO2 and climate. But the court decided to dismiss the case without getting to this interesting question, so it provides no legal basis for later suits. Such is the System, in the United States.
- **13 U.S. cities are defying Trump** and posting on their own city websites the climate science that was deleted from the EPA's web page at the Trump Takeover of the U.S. Government.

Prosecuting Exxon-Mobil, and Big Oil

- The State of New York, (and **now California as well**) is attempting to prosecute Exxon-Mobil for funding dis-information campaigns long AFTER **their own scientists told them of the disastrous climate implications of their business**, using existing shareholder disclosure laws
- In July 2017, Marin County, San Mateo County, and the City of Imperial Beach – all in California, are **suing 37 Big Oil companies over gross misconduct in the issue of climate change**. It's encouraging to see entire counties joining this effort, with the financial ability to stand up to oil company lawyers.
- And 3 months later, the cities of **San Francisco and Oakland are now suing Big Oil as well**, for causing climate change and then lying about it.

A 2015 Lawsuit Submitted to U.S. District Court of Oregon to Force Climate Recovery

- In November 2015, by 21 young people (ages 8-19), to force the U.S. government to reduce CO2 and institute a "science-based climate recovery plan"
- The lawsuit is opposed by the Fossil Fuel Industry (not surprising). They include the **American Fuel and Petrochemical Manufacturers** -- which represents **ExxonMobil, BP, Shell, Koch Industries and more** -- the **American Petroleum Institute** and the **National Association of Manufacturers. They are all arguing for dismissal of the case**
- The lawsuit (I'll call it the "Oregon Case") is also opposed by the U.S. Government, (also not surprising) which enacts legislation according to corporate lobbies' wishes (see **Gilens and Page 2014**)

In April 2016 – The Federal District Judge Denies Dismissal of the Oregon Case

- **This has the potential to be quite important and even historic**
- Judge Coffin wrote: *"The debate about climate change and its impact has been before various political bodies for some time now. Plaintiffs give this debate justiciability by asserting harms that befall or will befall them personally and to a greater extent than older segments of society. It may be that eventually the alleged harms, assuming the correctness of plaintiffs' analysis of the impacts of global climate change, will befall all of us. But the intractability of the debates before Congress and state legislatures and the alleged valuing of short term economic interest despite the cost to human life,* ***necessitates a need for the courts to evaluate the constitutional parameters of the action or inaction taken by the government****. This is especially true when such harms have an alleged disparate impact on a discrete class of society."*
- (above emphasis mine)
- **The next step:** Judge ordering Federal Govt to cease jeopardizing global climate? No doubt this will be appealed with great vigor, and we'll have to see how fair are judges further up the line.

The Plaintiffs, on hearing the Judge's Decision in the Oregon Case

A New Example of Victorious Young People

- From the Apr 29, 2016 Huffington Post: **Judge agrees to force Washington State** to create, by the end of 2016, policies to substantially reduce GHG emissions state-wide, after the usual foot-dragging and placations we're used to.
- This group is part of the James Hansen inspired **"Our Children's Trust"** organization
- Young people here, take note of the **Bill Moyers interview of plaintiff Kelsey Juliana.**
- Hansen, former head of the **Goddard Institute for Space Sciences** and the long time dean of climate science, resigned after much soul-searching, and thinking of his granddaughter and her future. He decided his new activism would be best accomplished unfettered.

Landmark Case Goes Forward

- The Federal **district court in Oregon has ruled that this case (the "Oregon Case") has merit and will go to trial**
- This time, it may not be hyperbole to call this the most important court case of the century.
- Trump has been **added to the list of defendants**, and his new Secretary of State, former Exxon CEO Rex Tillerson, it has been ruled, can be deposed.
- In March 2017, the **Trump forces are doing everything they can to keep this case from going forward.**

- **Another victory for Children's Trust, reversal of an outrageous interpretation of Colorado law that is demands a "balance" between safety and economic development in an anti-fracking suit. That case goes forward now, too. Part of the plaintiffs demands is access to Rex Tillerson (aka "Wayne Tracker" pseudonym in many relevant correspondence) and his emails.**
- Unfortunately, the Trump version of the Supreme Court is now in power, and so the ultimate future of appeals is not promising.

Federal District Court Judge Allows "Climate Necessity" Defense in Tar Sands "Shut it Down" case

- In Oct 2016, a coordinated action by activists commandeered valves shutting off some of the flow from the tar sands processing operation.
- They were arrested, of course, but the **Federal Court has allowed, for the first time, the defense to base their case around "Climate Necessity"**, thereby allowing testimony of scientists on climate and legal scholars on the historic place for activism in changing bad laws, and for the jury to be instructed to consider this testimony (in the past judges have instructed juries to disregard this defense).
- Trials begin in late '17 and into '18.

Techno-Strategies

- First I emphasize: ANY strategies which seek to simply "kick the can" of ending growth further down the road… ANY strategies which try to "techno" our way out of short-term trouble while ignoring the real enemy – ECONOMIC GROWTH on a FINITE PLANET…
- …Is ultimately DOOMED, and so are we.
- ONLY if techno strategies are paired with **a rapid de-growth paradigm**, might we hope to return to the climate that our current ecosystems and civilization was adapted to thrive in.
- But ANY spending means GROWTH in energy requirements (The Garrett Relation), so it's a **double bind**. **We must climate-"afford" the spending on techno strategies by cutting spending on all else.**

Strategies Ranked by Paul Hawken's Book "Drawdown"

- **Acknowledges there's no "silver bullet" for climate. "We need to do it ALL"… dozens of little slivers of ideas to fill out the whole pie.**
- **#1 is Population reduction.** Must be dramatic to make a real difference. Educating women, as he advises, is a start. But it's not enough, Paul!
- Even if we eliminate all unwanted pregnancies worldwide, population still grows further, and remains beyond what sustainability can support all during this century (next slide)…

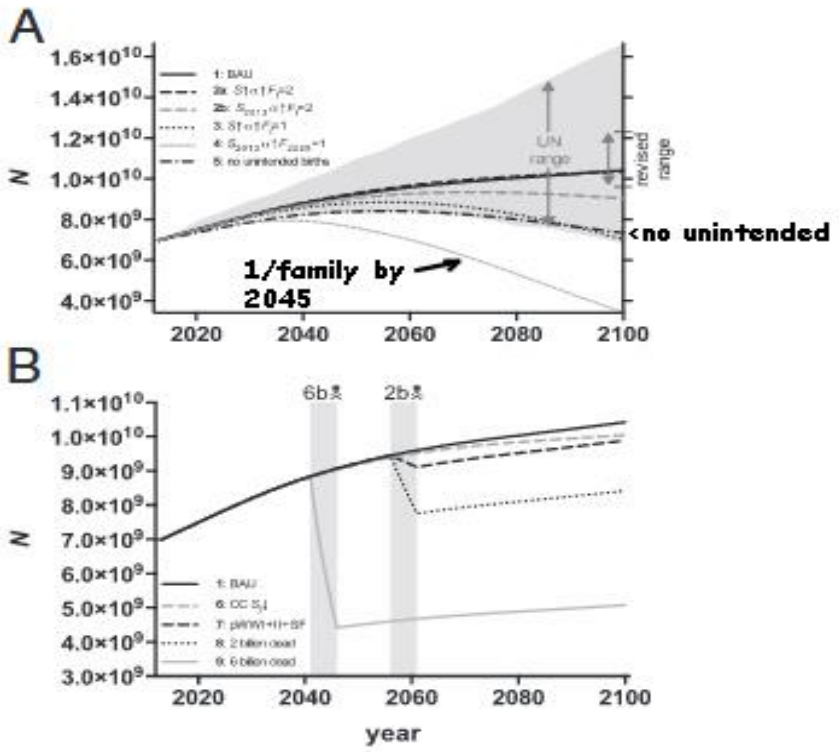
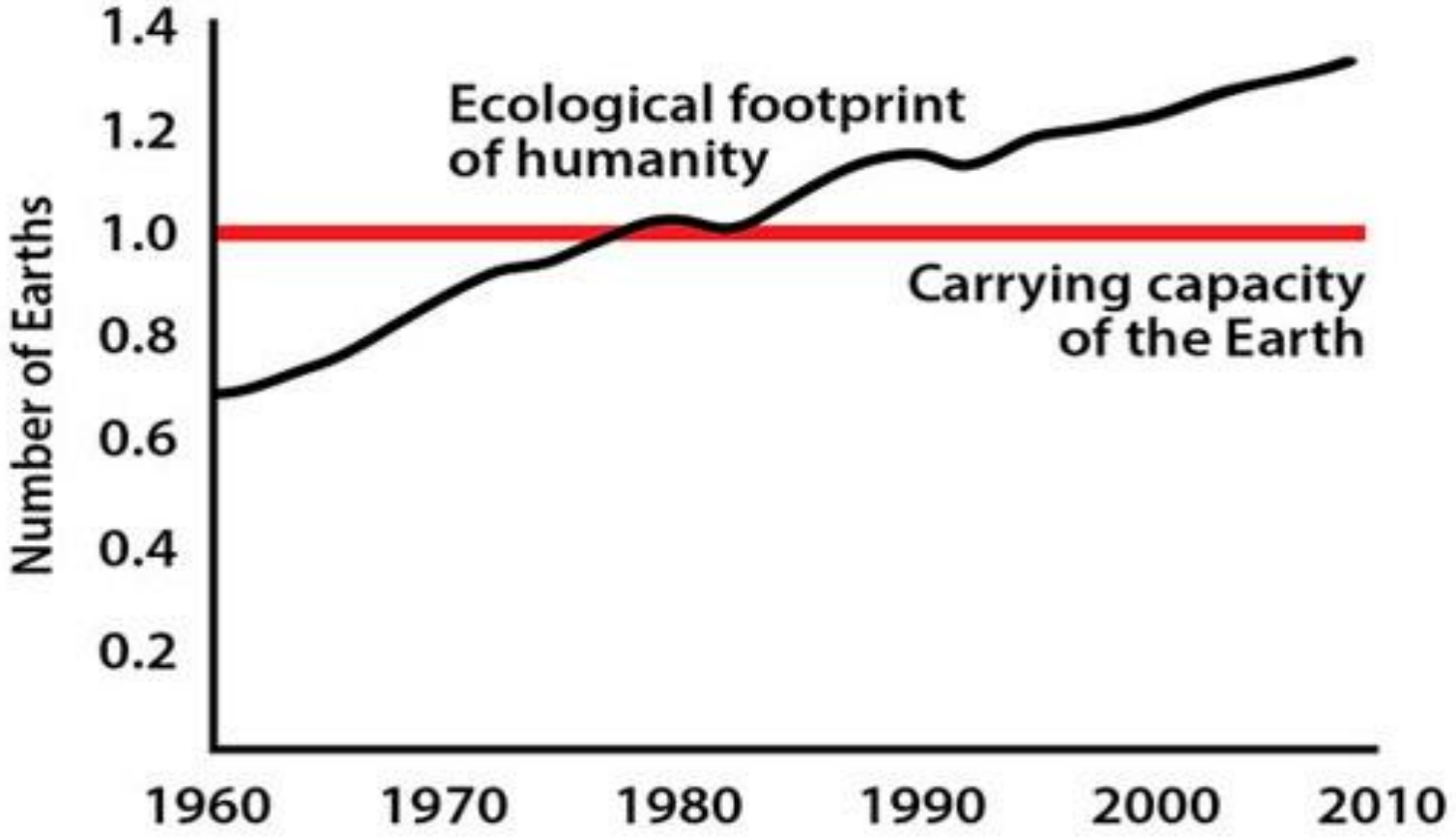


Fig. 1. Scenario-based projections of world population from 2013 to 2100. (*A*) Scenario 1: BAU population growth (constant 2013 age-specific vital rates); Scenario 2a: reducing mortality (M), increasing age at primiparity (α), declining fertility to two children per female ($F_t = 2$) by 2100; Scenario 2b: same as Scenario 2a, but without reduced mortality; Scenario 3: same as Scenario 2a, but $F_t = 1$; Scenario 4: same as Scenario 3, but without reduced mortality and $F_t = 1$ by 2045 and thereafter constant to 2100; Scenario 5: avoiding all unintended pregnancies resulting in annual births. High and low projections by the United Nations (12) are shown as a grayed area, and the revised range for 2100 (13) is also indicated. (*B*) Scenario 6: elevated childhood mortality (M_j) from climate change (CC); Scenario 7: mass mortality event over a 5-y period starting 2056, equal to the proportion of combined number of deaths from World War I, World War II, and Spanish flu scaled to the mid-21st century population; Scenario 8: 2 billion people killed because of a global pandemic or war spread over 5 y, starting midway (i.e., 2056) through the projection interval; Scenario 9: 6 billion people killed because of a global pandemic or war spread over 5 y and initiated one-third of the way through the projection interval (i.e., 2041). The mass mortality windows are indicated as gray bars.

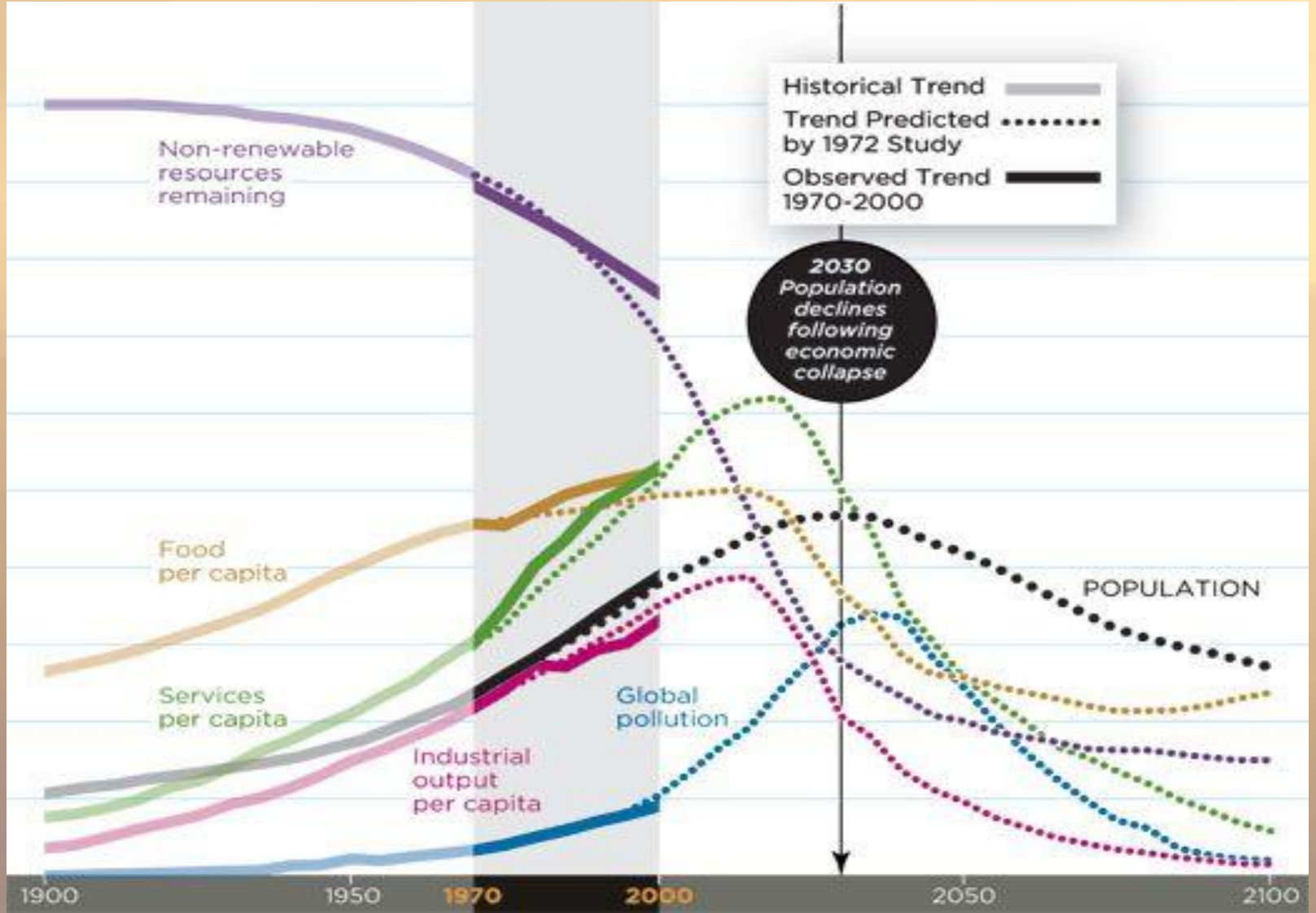
Bradshaw and Brook (2014) show that even eliminating all unintended pregnancies worldwide, still population continues to grow until mid-century. 1-child per family eventually gets us down to 4 billion by 2100, which will not be sustainable by then, considering degradation rates

Latest Estimates are 1.7 Earth's to Support 2018's Population Sustainably



Humanity's ecological footprint and the carrying capacity of the Earth. Adapted from *Limits to Growth: The 30 Year Update*.

Predictions from the 1972 Study "The Limits to Growth" are on track – We're on "Overshoot and Crash" trajectories



Organic Farming and Carbon Sequestration in Soil

- Soil can hold more carbon in roots, but only until the topsoil has a climax community above it
- Claims that organic farming can sequester enough carbon to halt CO2 rise (**Rodale white paper**), neglect this key fact and are at strong variance with nearly all authoritative studies cited by the IPCC.
- Note: *Rising soil temperature increases carbon oxidation* and *returns soil carbon to the atmosphere as CO2*, and cooler soil temperatures do the opposite (**Post *et al.* 1982**)**.** Note the rich carbonaceous soils of the rain forests of the Pacific Northwest, for example, and the famously poor soils of the tropics.
- Therefore global warming will be taking carbon OUT of the soil INTO the atmosphere, independent of soil management. We're seeing this, strongly, in 2015-2016

Potential Carbon Uptake with Best Ag Management Practices ? Small…

- A good review paper (**Stockmann *et al.* 2013**) with comprehensive links on soil organic carbon (SOC) and soil carbon sequestration (SCS)
- Returning cropland to forest or pasture has the most potential for increasing SCS (**Post and Kwon 2002**) (but then, where to grow crops?)
- *The IPCC (**Smith et al., 2007**) AR4 digestion finds an annual sequestration potential of 1.4–2.9 Gt of CO_2-equivalents through global agricultural soils, where soils would reach C saturation after 50–100 years.* (sec. 5 of Stockmann *et al.* 2013)
- **This is only ~5% of global anthropogenic CO2 emission rates**

Best Organic and "No Till" Soil Practices: Potential Soil Carbon Sequestration Rates are Still Small *vs.* Human Emissions, says the latest IPCC Review.

- **Stockmann *et al.* 2013** sec. 5 continued.... (NT="no tillage of soil")
- *"In contrast, a recent publication by **Chatterjee and Lal (2009)** suggests a sequestration potential of agricultural soils of up to 6 Gt of CO_2-equivalents per year by 2030 (*=about 15% of human emissions*). In this regard, **Table 7** summarizes potential rates of SOC sequestration by adoption of best management practices for principal biomes whereas **Table 8** compiles actual measured rates of SOC sequestration.*

Limited Help in Soil Organic Carbon (SOC) from No-Till, says Earlier Studies

- *For instance, most meta-data analysis (Table 8) suggest that if NT farming is adopted, there is a slight overall increase in SOC in the surface soil compared to full-inversion-tillage (FIT) and that this increase improves with time (Angers and Eriksen-Hamel, 2008, Luo et al., 2010a and Virto et al., 2012). However, when considering the whole soil profile, there seems to be a limited effect of NT on SOC stocks (Luo et al., 2010a). Virto et al. (2012) found that some of the variability (up to 30%) in response to NT can be attributed to differences in yield and C inputs. As seen in Table 8 there are some case studies where NT does not increase SOC (e.g. Loke et al., 2012) or where NT results in SOC increase at very great depth (Boddey et al., 2010).”*

So, No-Till helps SOC, but amounts are relatively small and in dispute; "White Papers" *vs.* the Peer-Reviewed Papers looking at the big picture. And…

- …Can we, and still feed 7 billion people affordably? We have put our soils "on steroids", stripping them of natural nutrients and force-feeding nitrogen chemical fertilizers, and used today's massive monoculture Ag practices **because this is the most cost-effective way** to get crops out of the soil with the least **labor** cost.
- Selling price minus cost means everything to a farmer. We see riots when basic staple crops rise in price even by just 20-30%, (e.g. "Arab Spring" revolutions)
- **Worse, modern Ag practices are causing topsoil loss of 1%/year, leading to estimates we have only ~60 years of topsoil left at current trends. So, costly or not, we need to do everything we can to treat our soils sustainably!**

Multiple Problems With Trying to Get More from Our Soils

- We NEED to do it, but it'll be harder than rosy-white paper promoters tell you…

Competing weeds grow ~3x faster than food crops in global warming conditions

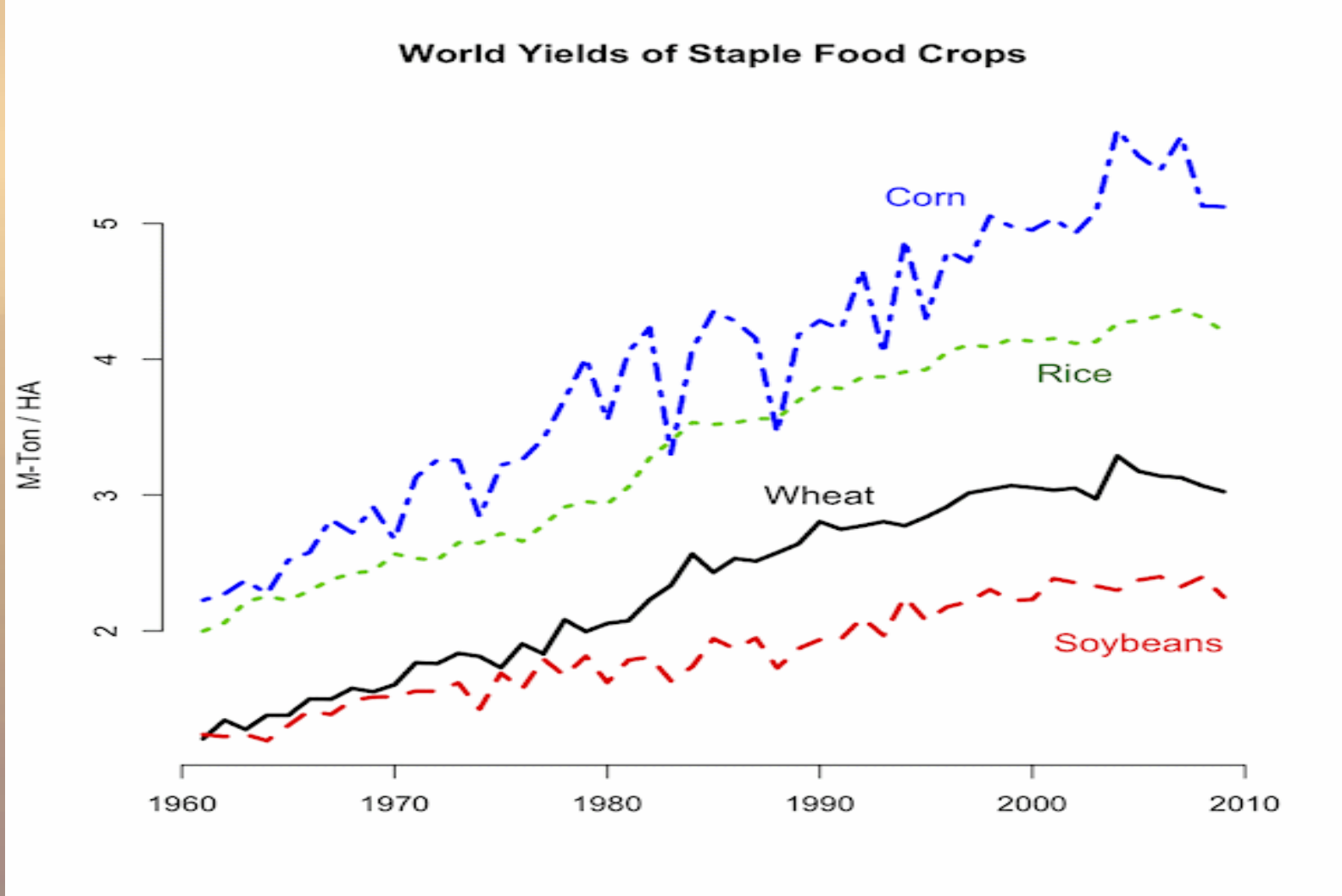
A Contradiction for BECCS

- The most promoted of carbon capture and sequestration schemes in the IPCC AR5 is BECCS – biofuel energy with carbon capture and sequestration.
- But forests sequester carbon too slowly and would take **~4x India's in area (!)**
- Weeds grow up to 4x faster. Still, that's **An entire India worth of weeds. Do we have a spare India's worth of fertile land for weed-growing? Obviously not.**

Expect increased use of Monsanto's *Round Up* and its carcinogenic glyphosate (already at high levels in American food)

- A worrying situation – but the FDA in the Trump Era has implemented a "solution" (…to the **worry, that is**): **Stop testing crops** for the herbicide(!)

Already, yields of the staple crops which feed most of the world are showing signs of halting their improvements (Long *et al.* 2015)

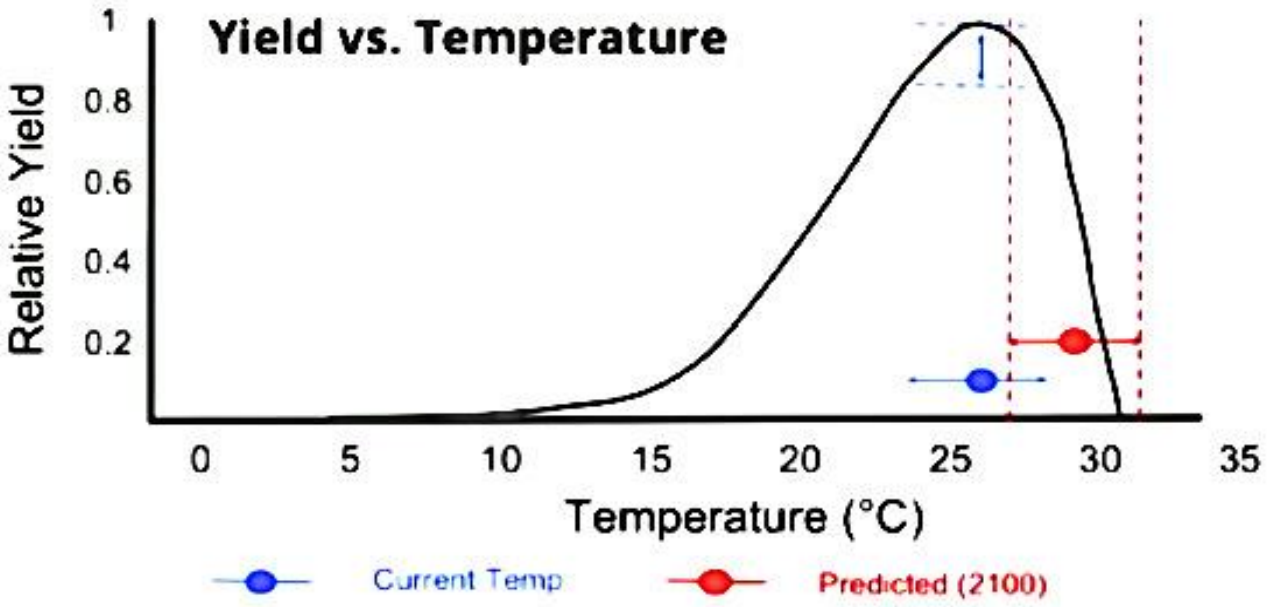


Can’t we just GMO some tougher crops?

- We’ve had some success with breeding more drought-tolerant plants.
- But biology is extremely temperature dependent, and despite 30 years of major efforts, there has been NO success at breeding heat-tolerant staple crops (**1:04:50 into this talk by atmospheric scientist Dr. David Battisti in 2016**)

As temperatures rise, even mid-latitude crop yields (and also carbon sequestration in soil), plummet. Note that one heat wave can completely kill an entire region's yield, with temperatures later this century

Higher Mean Temperature Increases Volatility in Mid-Latitude Yields

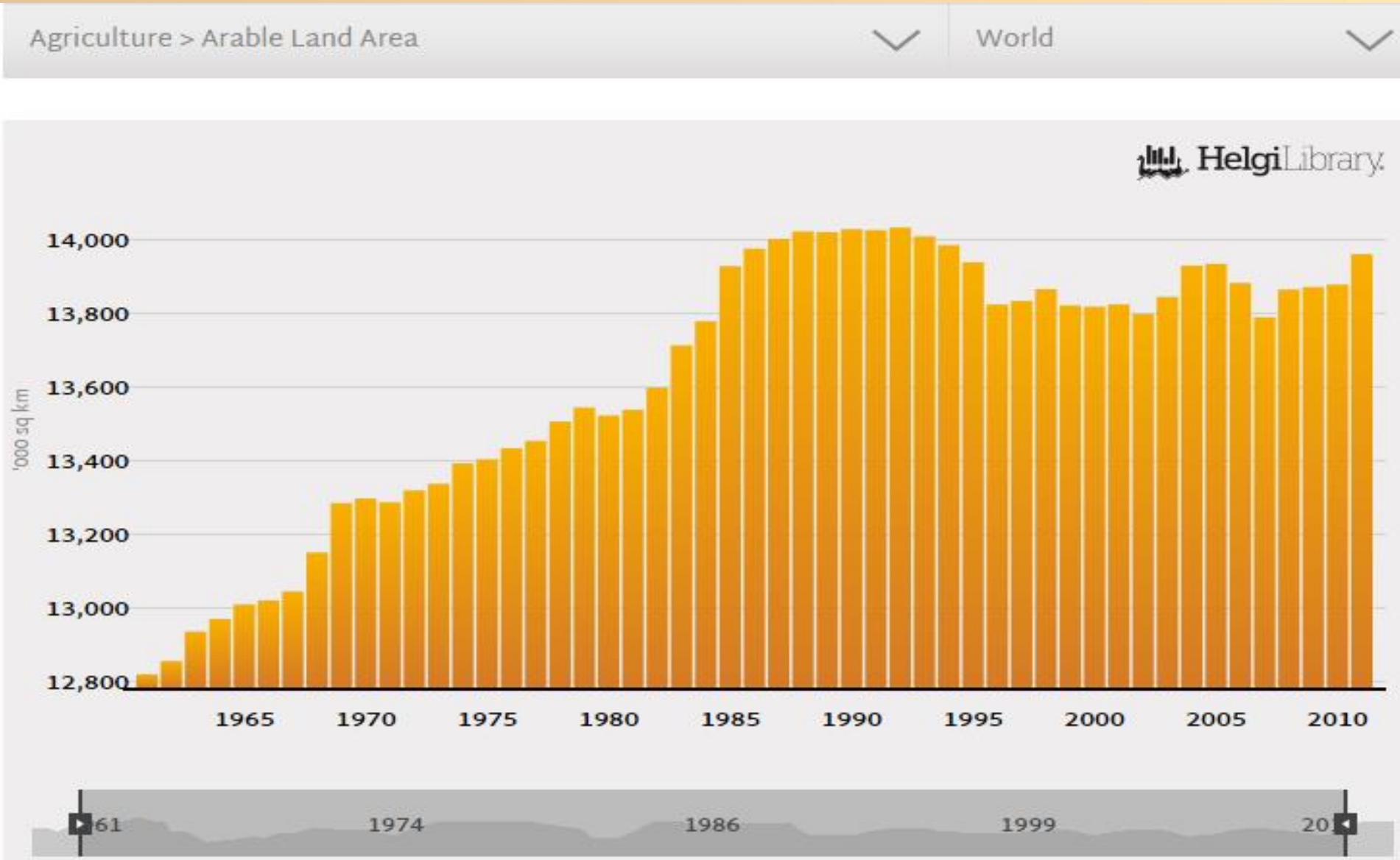


After Tewksbury et al 2008; see also: Urban et al. 2012, Climatic Change 112: 525-533

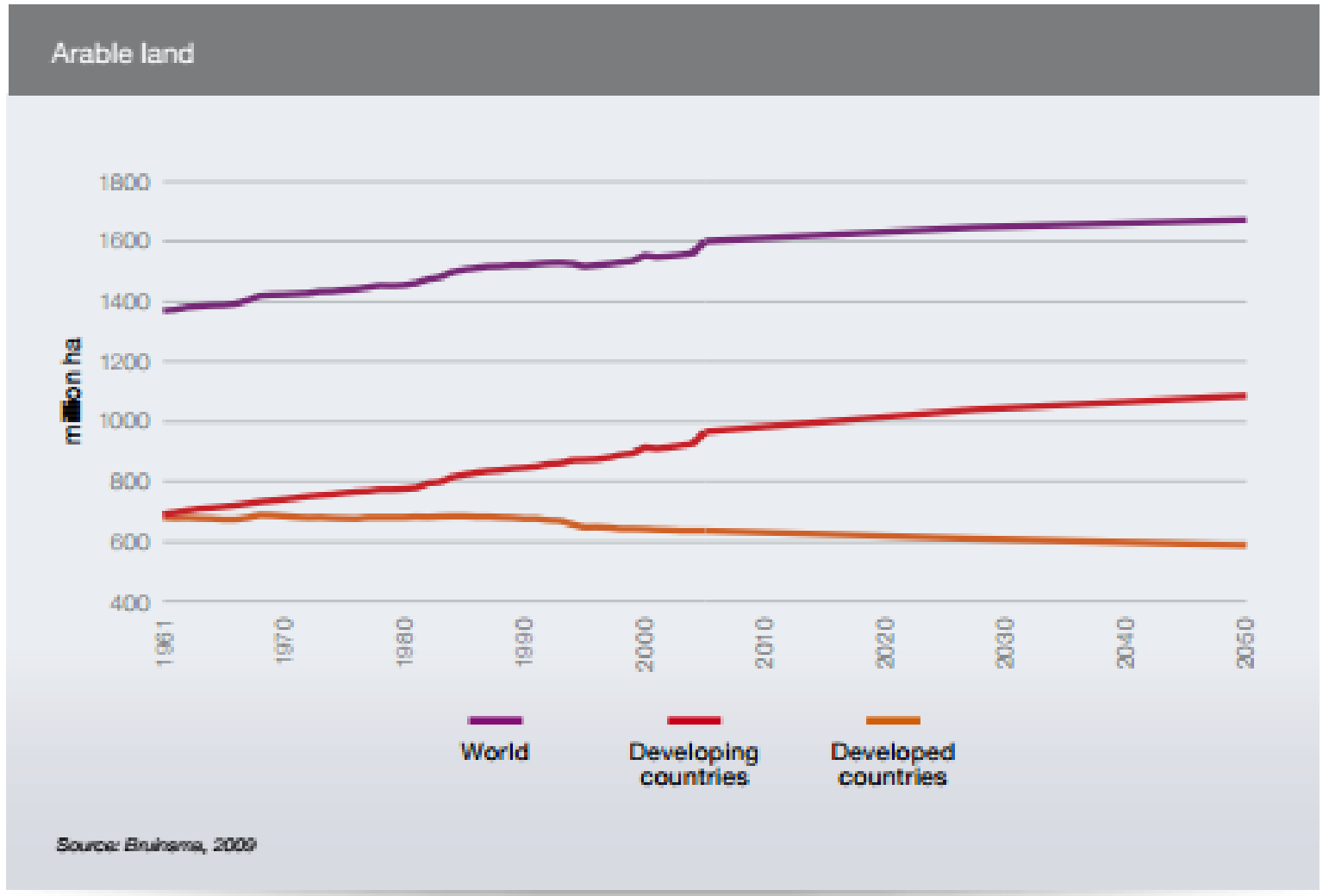
These Only Consider the Effect of Drought and Temperature on Crops – What about on Soil?

- **Existing arable land topsoil is being washed away at a rate of almost 1% per year, because large-scale disc'ing of land which needs little labor. This robs soil of roots and other organic holds. It also releases N_2O (a greenhouse gas) from mass use of nitrogen fertilizers (which also minimize costs *vs.* labor-intensive organic methods). Cost rules the decisions, as always.**
- Topsoil replacement rate is only ~1 cm per 1,000 yrs by geological forces, (but even that assumes healthy plant cover). In deep soil locations, more carbon can be stored deep, however.
- With current commercial agriculture techniques which strip soil of nutrients and prevent "weeds" from holding soil in rain storms. At this rate, **farming might survive for only another 60 years.**

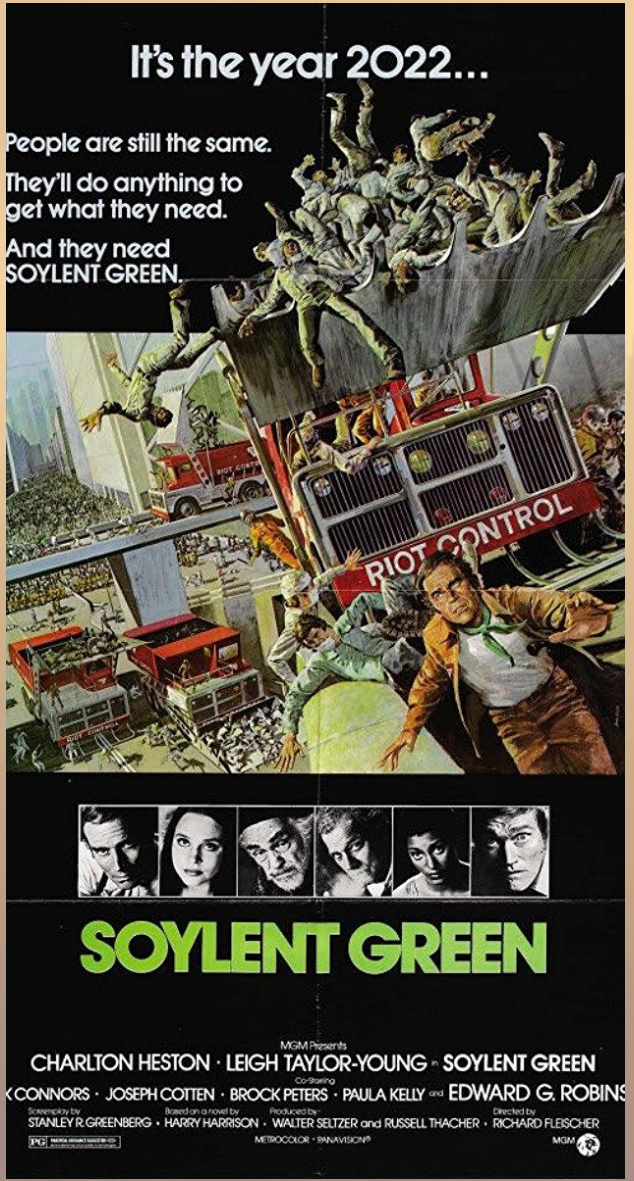
Total area of arable land has plateaued. While depth of topsoil continues to erode



This source below is more optimistic: bringing on-line more crop land (but, to be similarly washed away??). Additional convertible land is very scarce, especially in developed nations, who are losing arable land the fastest (in orange)



By 2050, the amount of arable land per person will drop to only ¼ of what it was in 1950



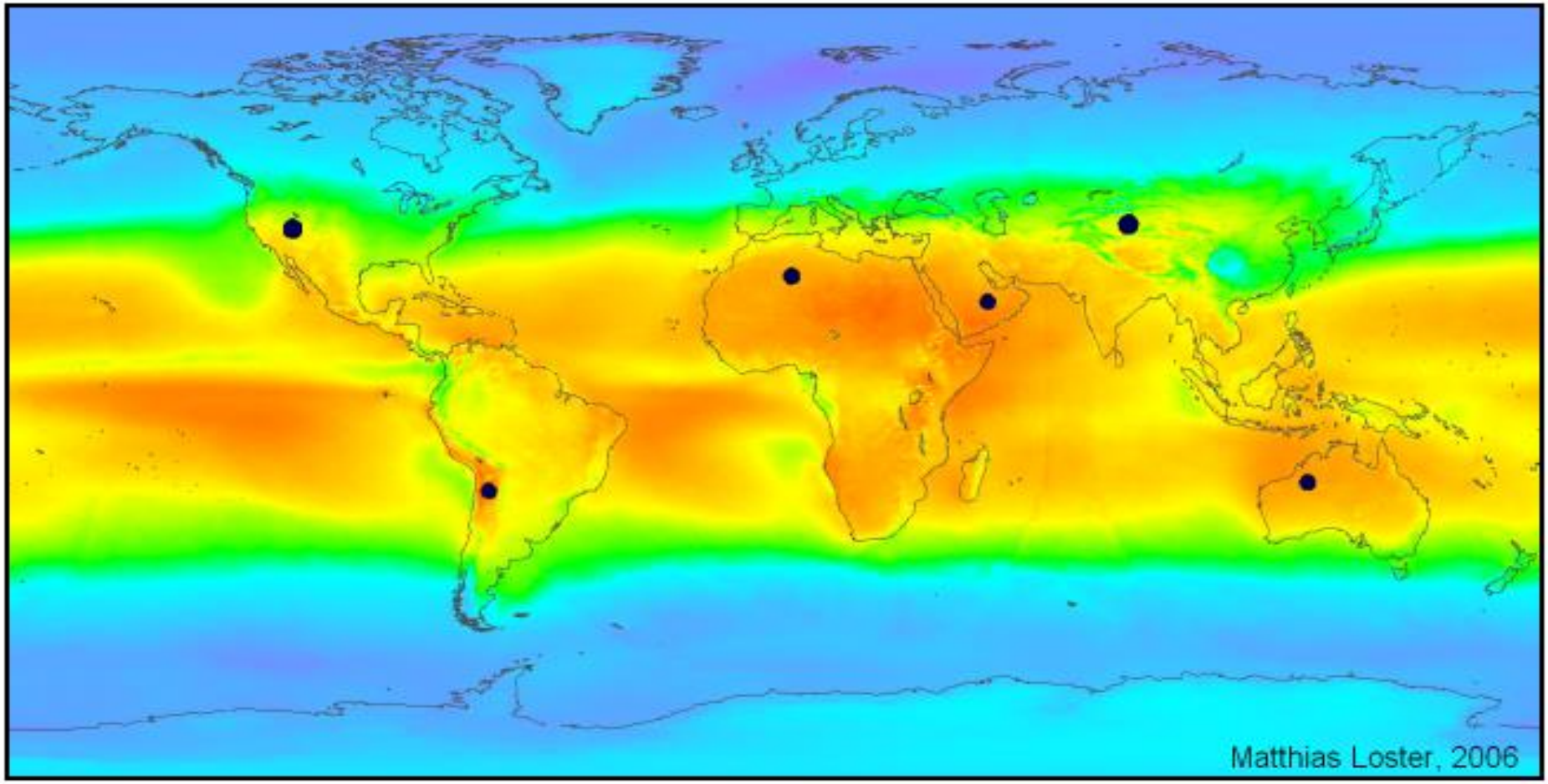
- So what will we eat then?
- Large fish in the ocean are down ~90%
- At the base of the food chain; Phytoplankton abundance is dropping.
- Most shellfish as well, both from warmer surface waters and growing acidity, especially off the West Coast of the U.S, where reproductive failure of shellfish has been happening for several years now due to growing acidity.
- **Considering overpopulation problems, perhaps Soylent Green? I volunteer our political "leadership" as first into the chipper!**

Highlights from Battisti's Talk: "*Climate Change and Global Food Security*"

- **(start 8:50 into the talk to skip the pre-lim's)**
- **We need to double our staple crop yields in the next 35 yrs. The prior facts make this highly unlikely to happen.**
- Requires increasing yields at a rate we have only accomplished once, near the end of the "green revolution" some years ago, and we have to do it continually for a much longer period of time. And yet…
- ~all agro land is already in use, and we're losing it at 1%/yr due to erosion, salt intrusion, wind/dust bowls

- Water? Already in short supply and dropping, opposite to what we needed during the "Green Revolution"
- Only 50-300 yrs of global supply of phosphorus (K) is all that remains. K and N (nitrogen) are both essential to plants.
- 50% of the food for the tropical populations is the staples: rice, wheat, maize, which are in trouble because in the tropics they are already above their optimal temperature range. Expect steeply falling yields as temperatures continue to climb

Solar PV Accessible Power Potential, Including Cloud Cover. Sum of black dot areas = total global power needs



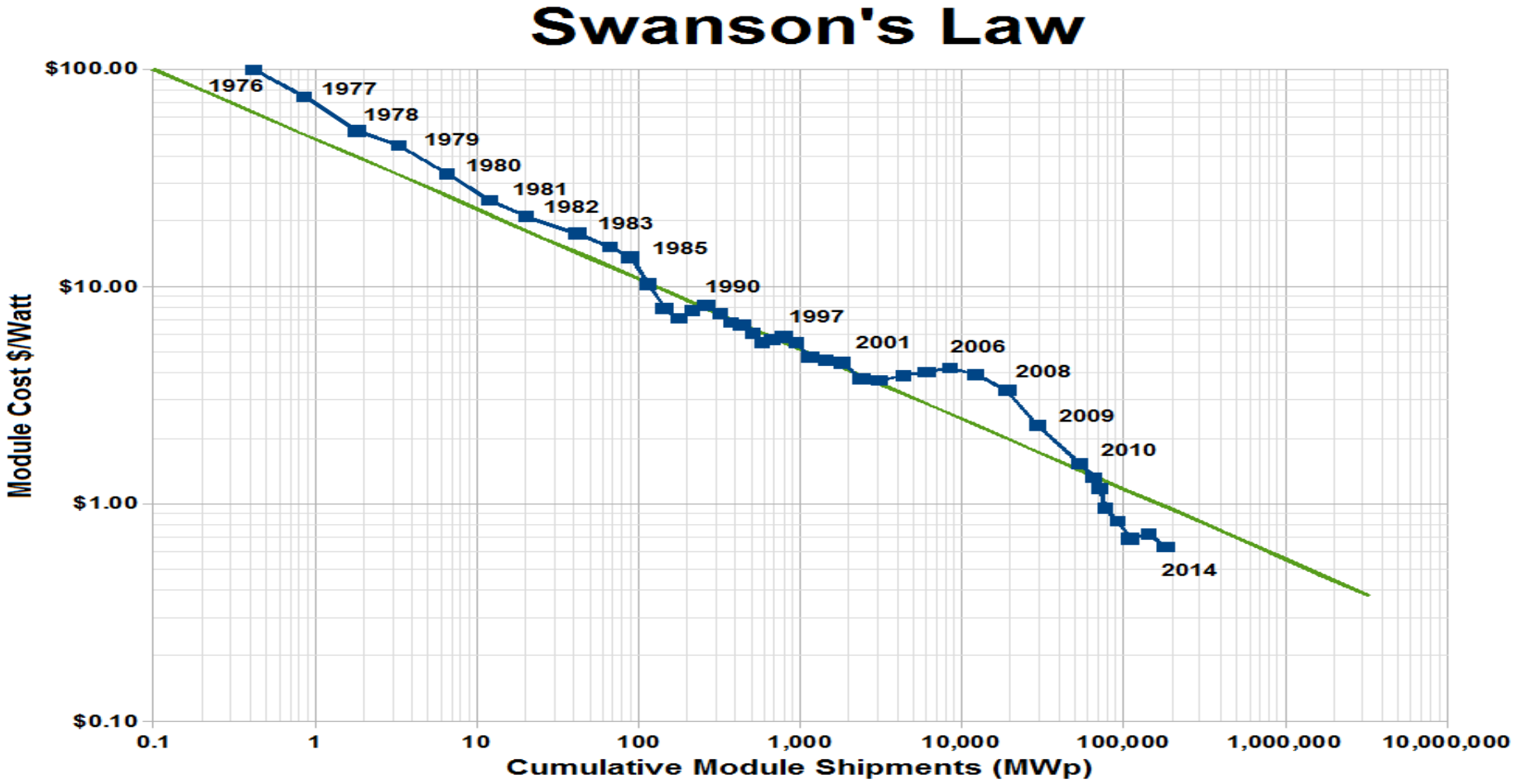
To get off CO2-generating Fossil Fuels

- Solar PV promising, and has been growing
- Solar arrives free, although very dilute, and puts stress on land area and other species use of incoming solar.
- Utility-scale solar has been cheapest
- Rooftops – use ‘em! But not enough of them.
- Solar roadways? Maybe, if they prove out.
- Solar building sides – sure.
- But before going too euphoric over Solar…

More important for cost…

- The technological gains in cell efficiency are mostly already accomplished, as are the gains due to economies of manufacturing scale.
- Solar is already a significant industry, with scaling cost reductions mostly accomplished, especially by the Chinese
- Gains will perhaps continue, but be slower
- BEWARE of promoters who simply extrapolate past curves into the future, ignoring the true, evolving source of future costs (next slides)

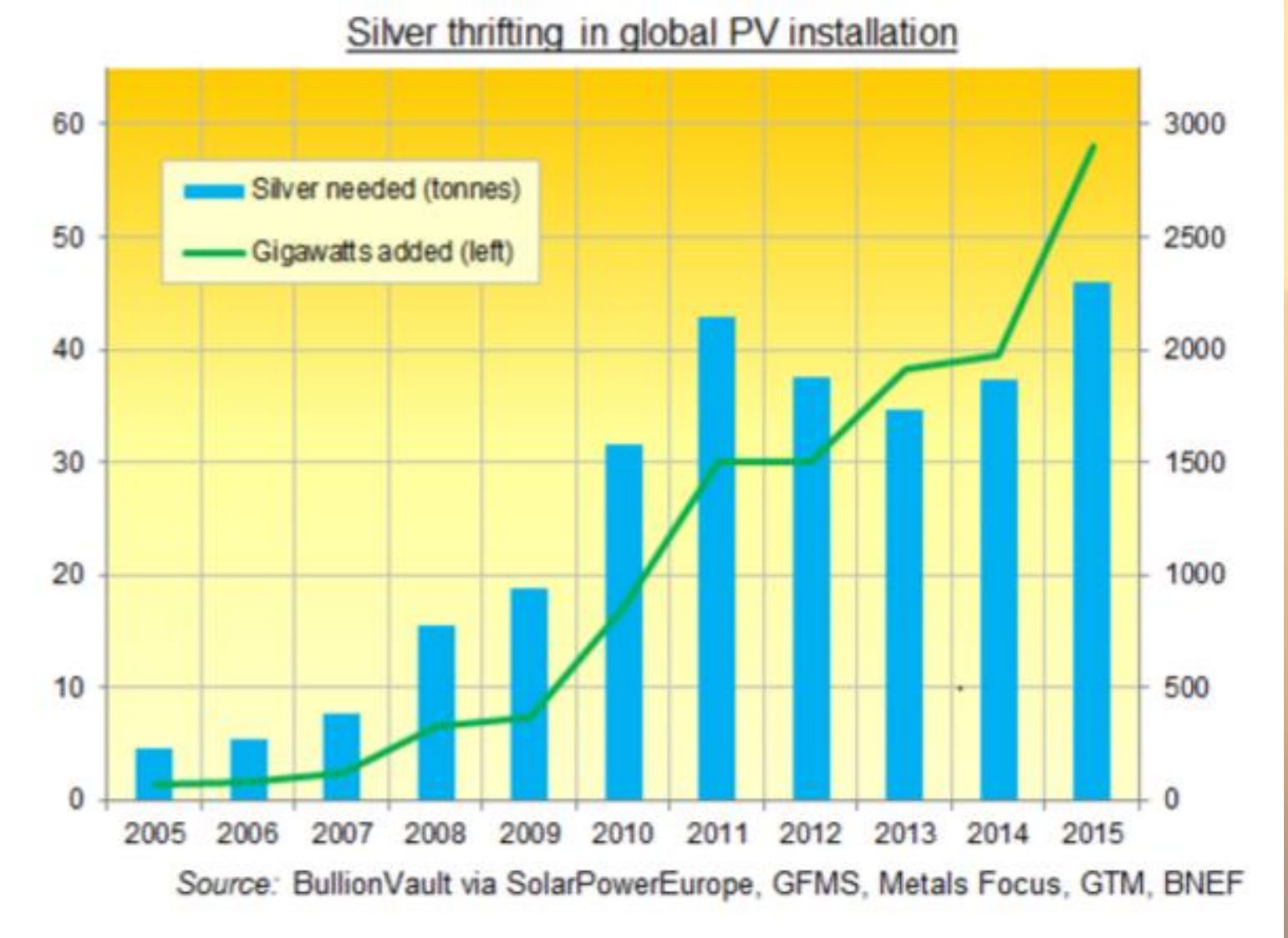
This is also seen in the past decade's deviation from Swanson's Power Law, note the steepening lately – falling module costs are not leading to increased shipments at same rate as earlier, as more of the costs are not in the modules, but other costs which are not falling so much…



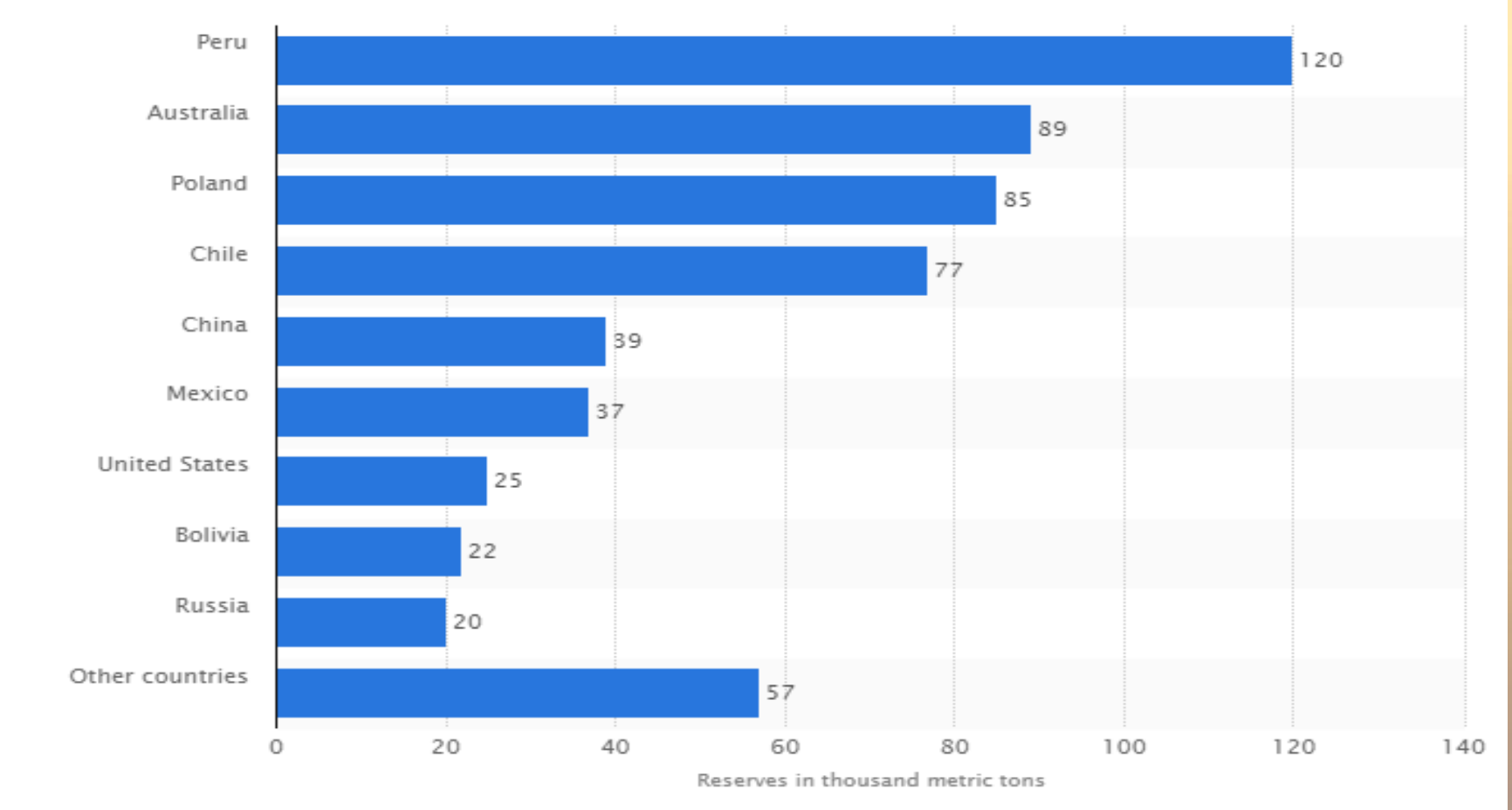
There's Potentially Another Problem: Available Silver

- Current solar panels (1.8 m^2) require 20g of silver.
- That's 11.1 tons of silver for 1 square km of solar PV panels.
- **In order to power the world with current solar PV panels, it would take 5.62 million tons of silver.**
- **Even assuming silver per GW of power will drop to only ¼ of today's), that's still 1.4 million tons of silver.**
- Today's panels already use far less than they did 10 years ago, motivated by high silver cost. So this hypothetical drop may not be easy – it's been an issue for years and the easy solutions are already done

While silver needed per unit of power is falling at 5%/yr, the total silver required keeps rising as solar deployment continues



The problem is, what's required is more than twice the estimated silver reserves on Earth. While above-ground stores (*e.g.* old coins) can be put to use here, only at sufficiently higher prices and on only a small fraction of it.

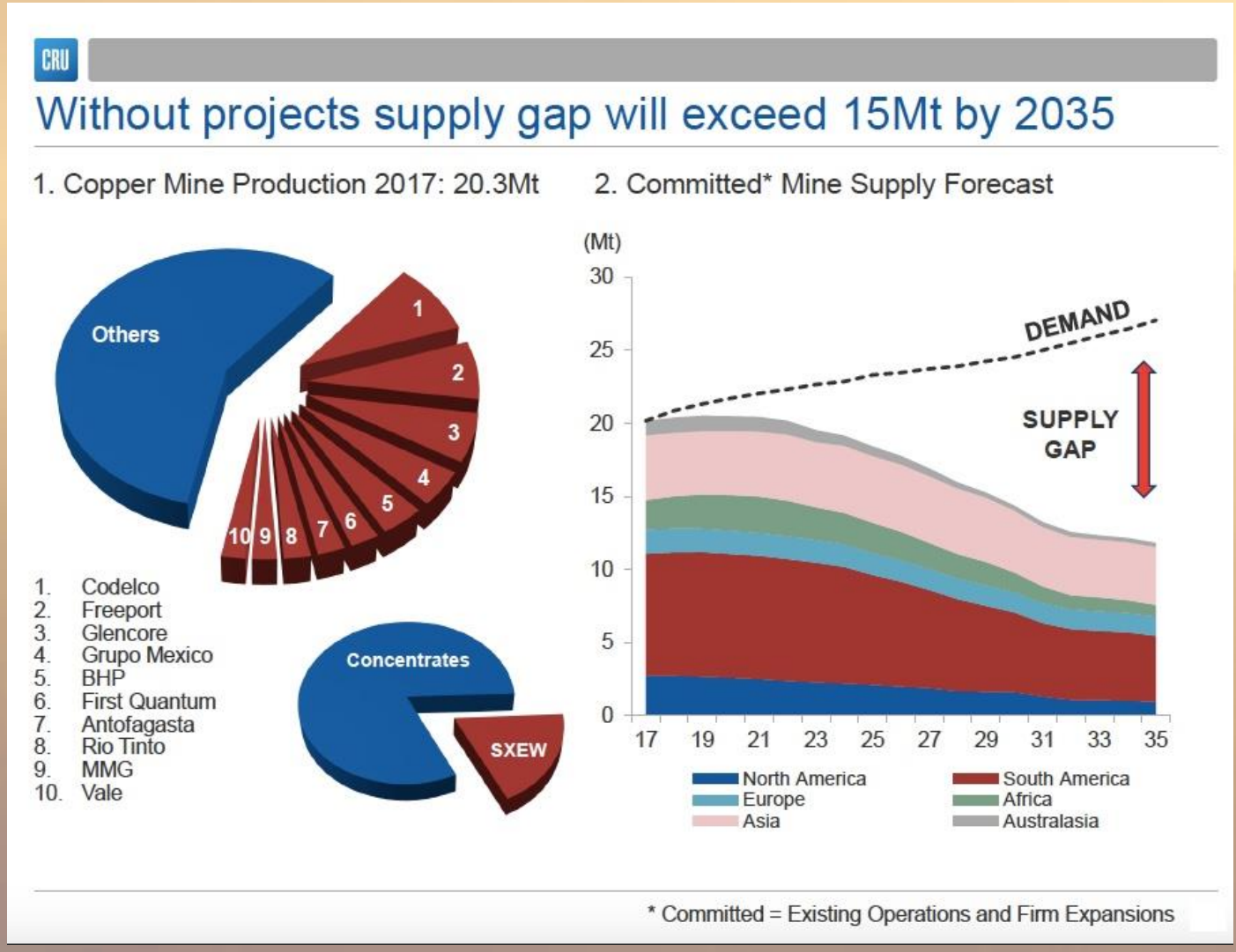


- Solar panels lose efficiency at a rate of 0.2% to 1% per year, requiring ongoing new silver even at constant global solar power use (even with recycling).
- Other industrial processes require silver, which would then not be available for solar panels.
- Merely adding to energy needs at standard global 2% growth rates would consume almost double the current rate of silver mining today, yet this is after consuming the more than double all known reserves to reach solar PV powering the world.
- I've seen a lot of pro-solar rosy projections and promotions… but this issue never seems to be highlighted, hardly ever even mentioned.

Can’t we just replace silver with aluminum or copper, in solar PV panels?

- Some makers are already starting to use copper, but copper prices are rising too.
- However, silver has the highest reflectivity and the highest conductivity of any available metal, so price compromises will also become panel efficiency compromises.
- Lower efficiency means more solar panels to do the same job, accelerating the amount of required silver which is still used. Substitution is not necessarily a killer, but an inconvenient problem almost never mentioned.

Worse – [demand/supply will tip over by 2020](), according to new estimates, spiking prices. Existing mine production will fall to barely over 50% of today, by 2034. All the while China and Asia expect to be skyrocketing their demand.



This issue was just one contributor to … solar panel prices stopped falling and indeed rose significantly in the U.S. in 2017. Module costs rose 23%

2.5 U.S. Polysilicon, Wafer, Cell and Module Prices, Q4 2016-Q4 2017

	Q4 2016	Q1 2017	Q2 2017	Q3 2017	Q4 2017
Polysilicon ($/kg)	$14.98	$16.93	$14.39	$16.69	$18.03
Wafer ($/W)	$0.15	$0.15	$0.14	$0.15	$0.15
Cell ($/W)	$0.21	$0.21	$0.21	$0.23	$0.22
Module ($/W)	$0.39	$0.38	$0.40	$0.45	$0.48

Source: GTM Research

We'll Just Have to Embrace the "Circular Economy" – That'll Save us!?

- Sounds wonderful – recycle everything!
- But the **2nd Law of Thermodynamics** has **something to say about that**, and it only "kicks the can" down the road a while further, at best.
- …Making the ultimate cost to the future harsher.
- *"In order to reconcile the circular economy with the **Second Law** we have to apply not only changes to the way we use materials, but how we consume them. Moreover, that implies such a large reduction in resource use[29] by the most affluent, developed consumers, that in no way does the image of the circular economy, portrayed by its proponents, match up to the reality[30] of making it work for the majority of the world's population."*
- It does make us feel less guilty, though… and that's what counts after all… Right?

Beam me up? *"As is so often the case with feel-good eco-stories, the 'Today' programme's[1] interviewer was all light and fluffy; and obviously flummoxed because they did not have the confidence to ask any basic, challenging questions of the interviewee"*

How To Judge Geo-Engineering Ideas You'll See Advertised

- **1. All EFFECTIVE strategies must either**

* **A.** Reflect additional sunlight back to space, or

* **B.** Enhance Earth's ability to radiate its heat to space

- **2. All SAFE strategies should have no hysteresis**
- In other words - take us BACK along the ~same Earth system trajectory that got us here: Examples - reverse atmospheric GHG's, re-freeze the poles, re-grow tropical rainforests, let soils recover carbon-sequestering capability by ending current Big Ag practices.

Safe Strategies…

- **…Should NOT** involve global changes to weather and eco-systems in ways significantly different than any we have seen. Highly dangerous!
- There are millions of species, and ecosystem interactions have been studied for only a few, and even those - incompletely.
- **When you discover you're in a mine field – you carefully retrace your steps. You don't run in new directions!**

To Be SAFE: They must Take the Earth Systems back along the ~same Trajectory that GOT us here

- **Dangerous failures** of this criterion: iron seeding of the surface oceans, sulfate aerosols into the stratosphere, many others.
- **Safer ideas:**
- --re-icing the Arctic ocean using wind-powered pumps in winter.
- -- Pull CO2 from the atmosphere, pump it underground for permanent sequestration. In salt domes? In sedimentary oil-bearing clay-capped formations? Combine 50:1 as carbonated water and pump into basalt formations?

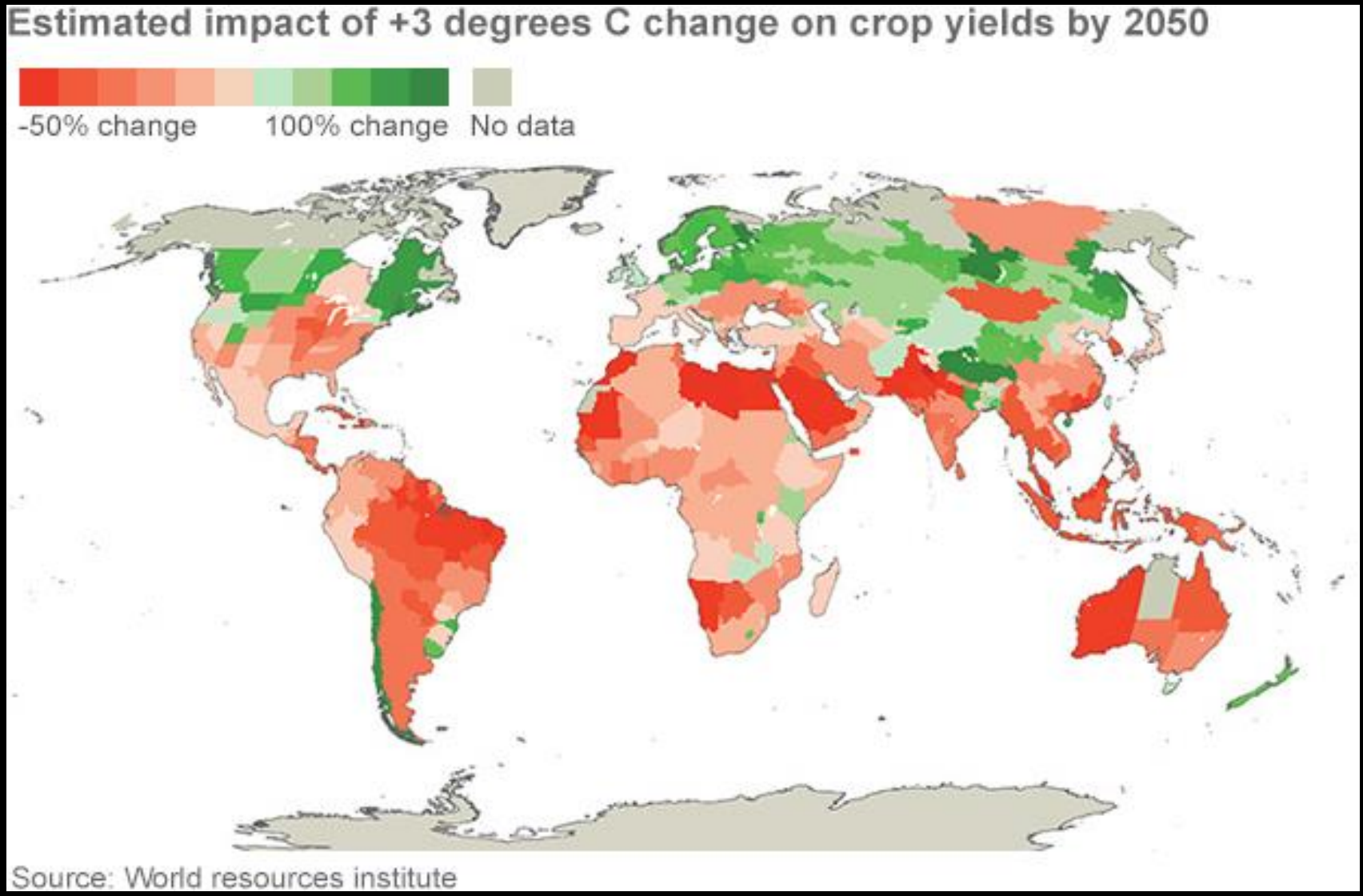
THE Worst Idea I've Heard… OTEC Pipes to Cool Earth

- OTEC ("ocean thermal energy conversion") Pipes to pump cold ocean water from 1km down, beneath the thermocline, to the surface to cool the atmosphere.
- This radically violates the "safe" criteria for ecosystems, ocean currents, weather patterns... Just about everything.
- Worse, it traps ocean heat which MUST be allowed to escape or it will build up and overheat the future. Several studies out of Stanford University and elsewhere demonstrate this, at all scales big and small.
- OTEC Also out-gases CO2 for most ocean locations, especially the most thermally useful ones, in the tropics.
- If you hear anyone trying to attract money to pay him and others to study such a scheme, get educated (**GeoEngineering pdf) and counsel others to hold on to their wallets!**

Politically Impossible to Halt Climate Change?

- Any global program affecting climate strongly will almost certainly have to be subject to UN approval, and among the select few who make up the UN Security Council **is Russia**. Any single UN Security Council member can veto a proposal.
- Will Russia sign on for halting and reversing climate change?
- **No. Here's why…**

Russia and Canada are relative crop yield winners from climate change, and thawing permafrost also helps Russia access frozen oil, gas fields, Siberian Shelf carbon



And Burke *et al.* 2015) Use Past Climate Data to Correlate GDP (Gross Domestic Product) to Temperature

- For a +4C world by the year 2100 (easily possible and even probable based on what we've now seen, even with massive climate efforts) there are only two significant GDP possible winners: Canada and Russia.
- The entire tropical belt descends into economic collapse and chaos, with their GDP plunging by 70-80% with no sign of halting. **They essentially exit the world system**.
- The game of competitive national advantage is how global politics has always worked, and NO country embraces this strategy more than Russia.
- Any attempt to re-freeze the Arctic, fly aerosol-dispensing planes, or other ideas accessible to their missiles may be doomed. **Attempting it may even initiate war.**

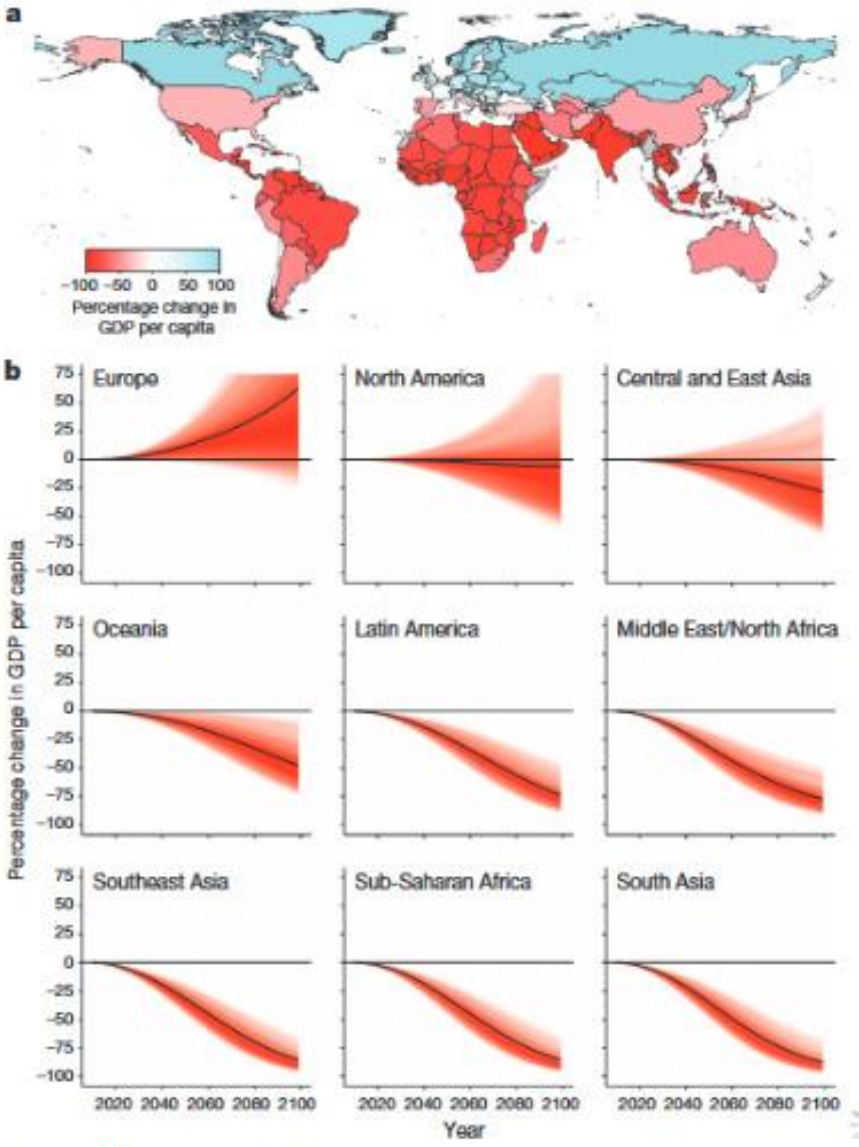


Figure 4 | Projected effect of temperature changes on regional economies. **a**, **b**, Change in GDP per capita (RCP8.5, SSP5) relative to projection using constant 1980–2010 average temperatures. **a**, Country-level estimates in 2100. **b**, Effects over time for nine regions. Black lines are projections using point estimates. Red shaded area is 95% confidence interval, colour saturation indicates estimated likelihood an income trajectory passes through a value[27]. Base maps by ESRI.

Russia is the big "winner" in global warming. The tropical countries utterly collapse, essentially leaving the system, and Russia's main competitors – the U.S. and China, both suffer relatively more. This study (Burke *et al*. 2015), however, can't include the unpredictable outcomes of global wars and trade collapse, so it's likely too optimistic about all countries tropical or not. Yet still, the point is made.

For More on All of These Considerations – Scientific, Sociological, Political, Economic, and Psychological…

- …See my list of PowerPoints inside my **“Planetary Climate Science” PowerPoint list, and note they are in *pdf* format as well**

To Summarize: Techno-Fixes Will NOT Save Us. Not with Human Nature and Thermodynamics as We've Seen

- We Need Technology, but only wedded to a complete Re-Thinking of Our Relationship to Nature.
- Nature bred in us the compulsion, the desire, the lust for the brain chemicals that go for competitive **growth**. **"Grow or Die".**
- To out-compete for your place in the ecosystems.
- To beat back the wilderness and other species and make your place.
- To duel for choice mating opportunities!

You May Think the Tragedy is if Your Species Loses This Struggle

But no – the Real tragedy is when you WIN.

- If you lose, only **your** species perishes.
- But with the power humans have amassed and the ruthless efficiency of *Laissez Faire* market economics…
- **…When HUMANS win it is the entire planet which loses. And then, humans too.**
- **We are at that point now. Today. After 6,666 generations of Homo Sapiens. How will we transform our very impulses and political/economic Systems to avoid catastrophe? Will we? I see no evidence of this yet.**

“The most difficult thing is the decision to act. The rest is merely tenacity”

- Amelia Earhart

Is This Going to Be Our Bottom Line?

"Yes, the planet got destroyed. But for a beautiful moment in time we created a lot of value for shareholders."

“There’s No Fate But What We Make”

Consider my Fall '18 "Planetary Climate Science" Course, by far the most complete exploration of Climate Change at Cabrillo College