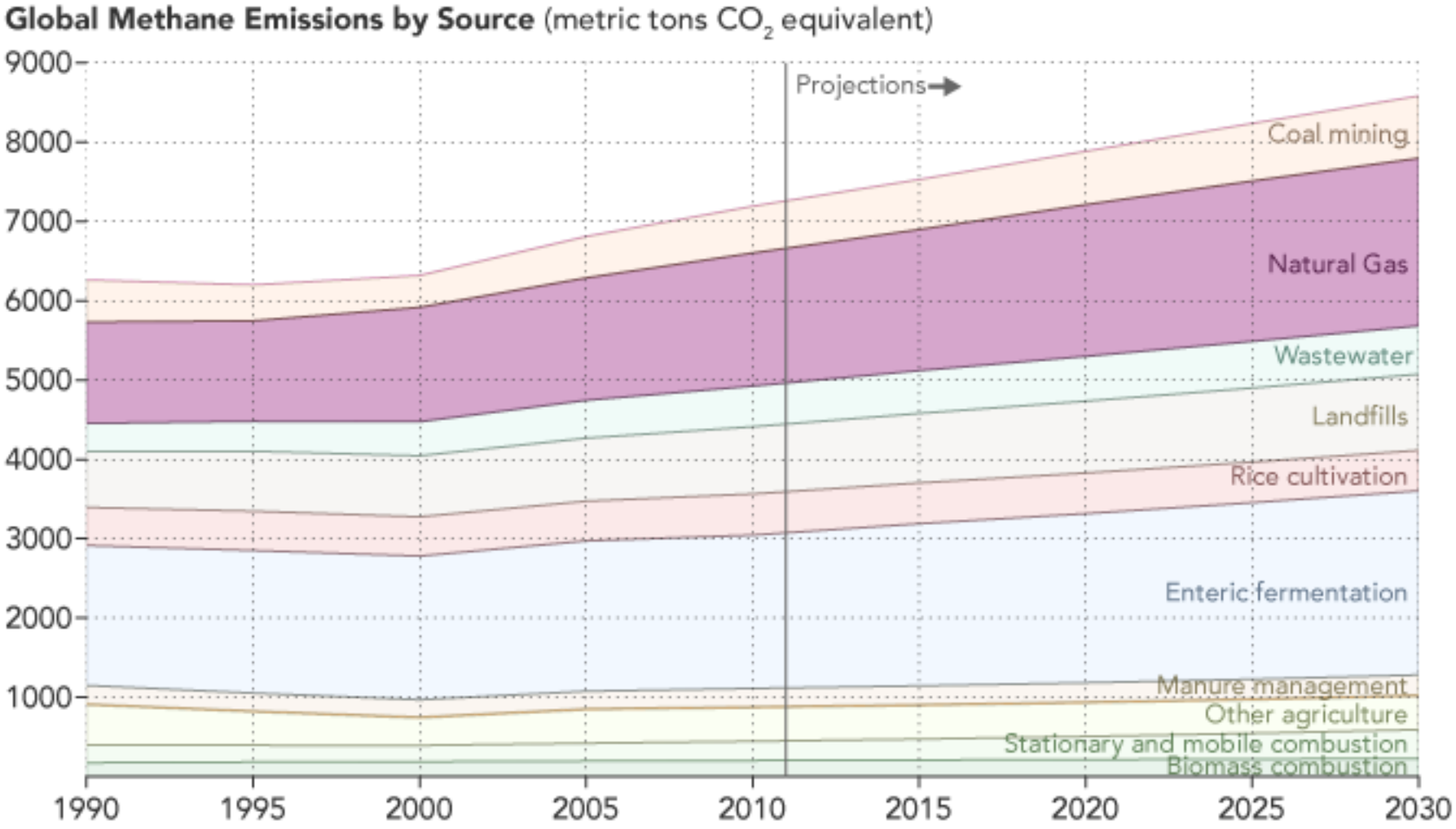
Methane – Climate and The Bigger Picture

Nov 8, 2019

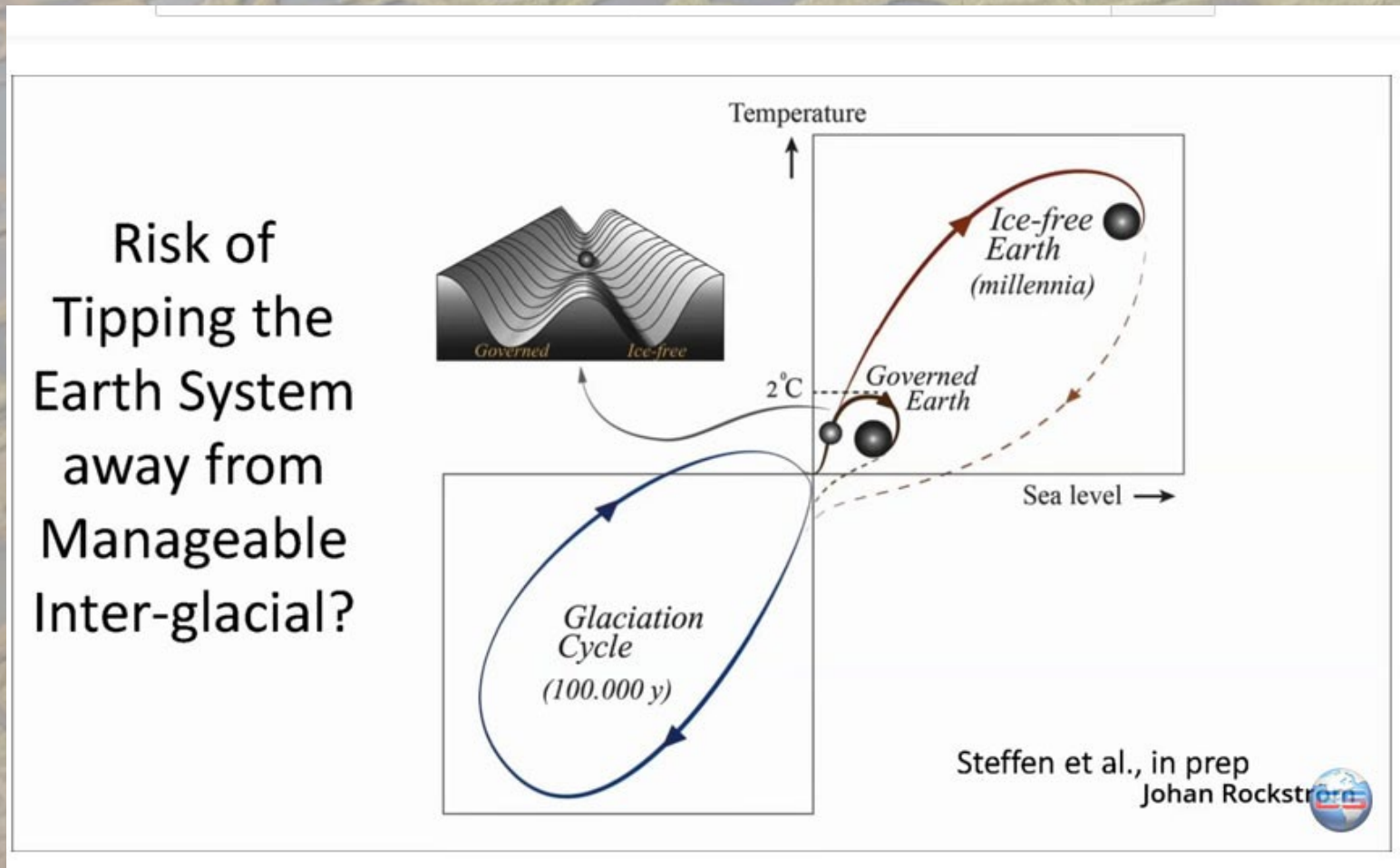
Richard Nolthenius, PhD

Cabrillo College Astronomy

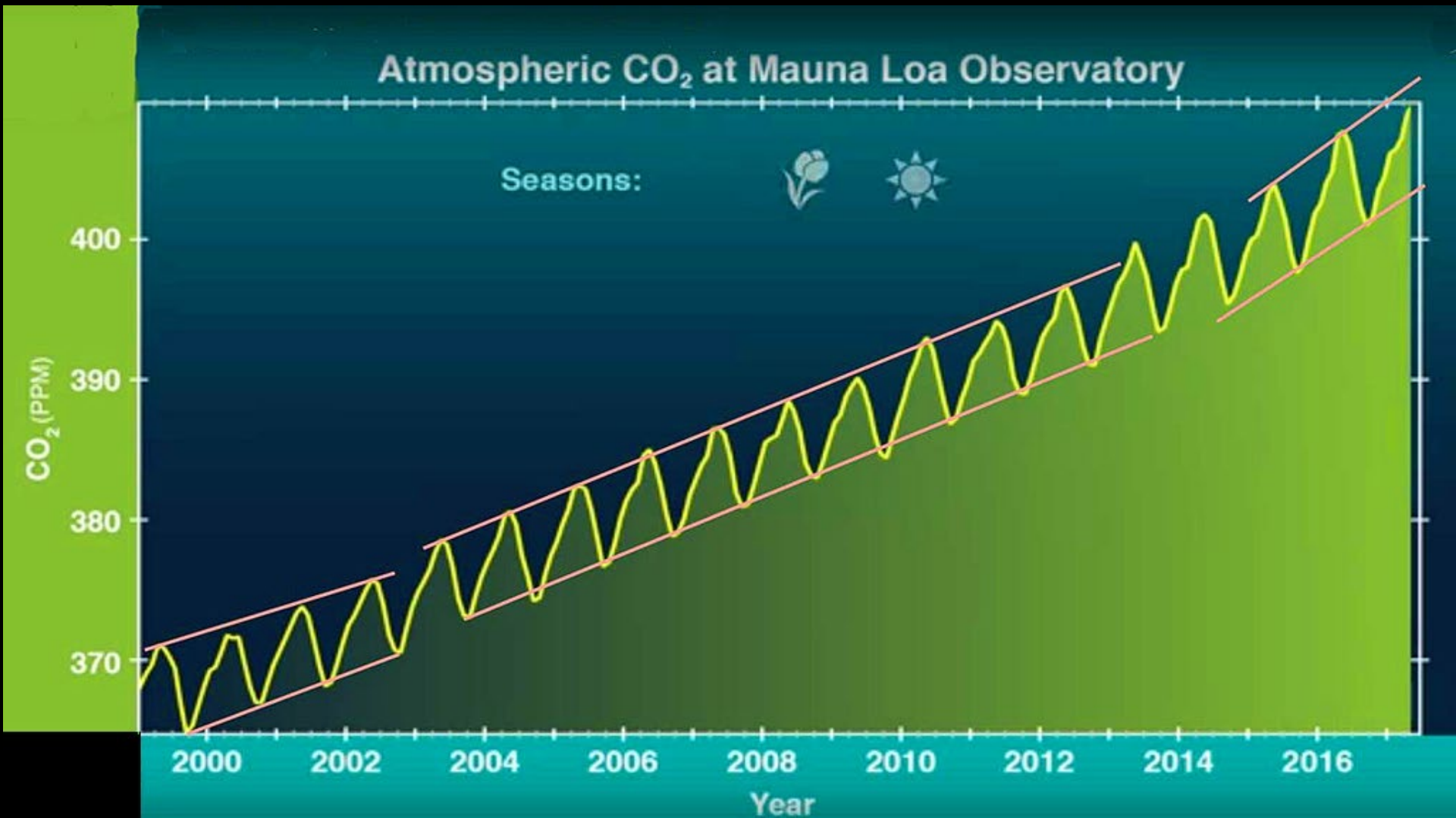
Direct Anthropogenic Global Methane Sources and Projections below. But the indirect human-triggered sources are the real future worry…



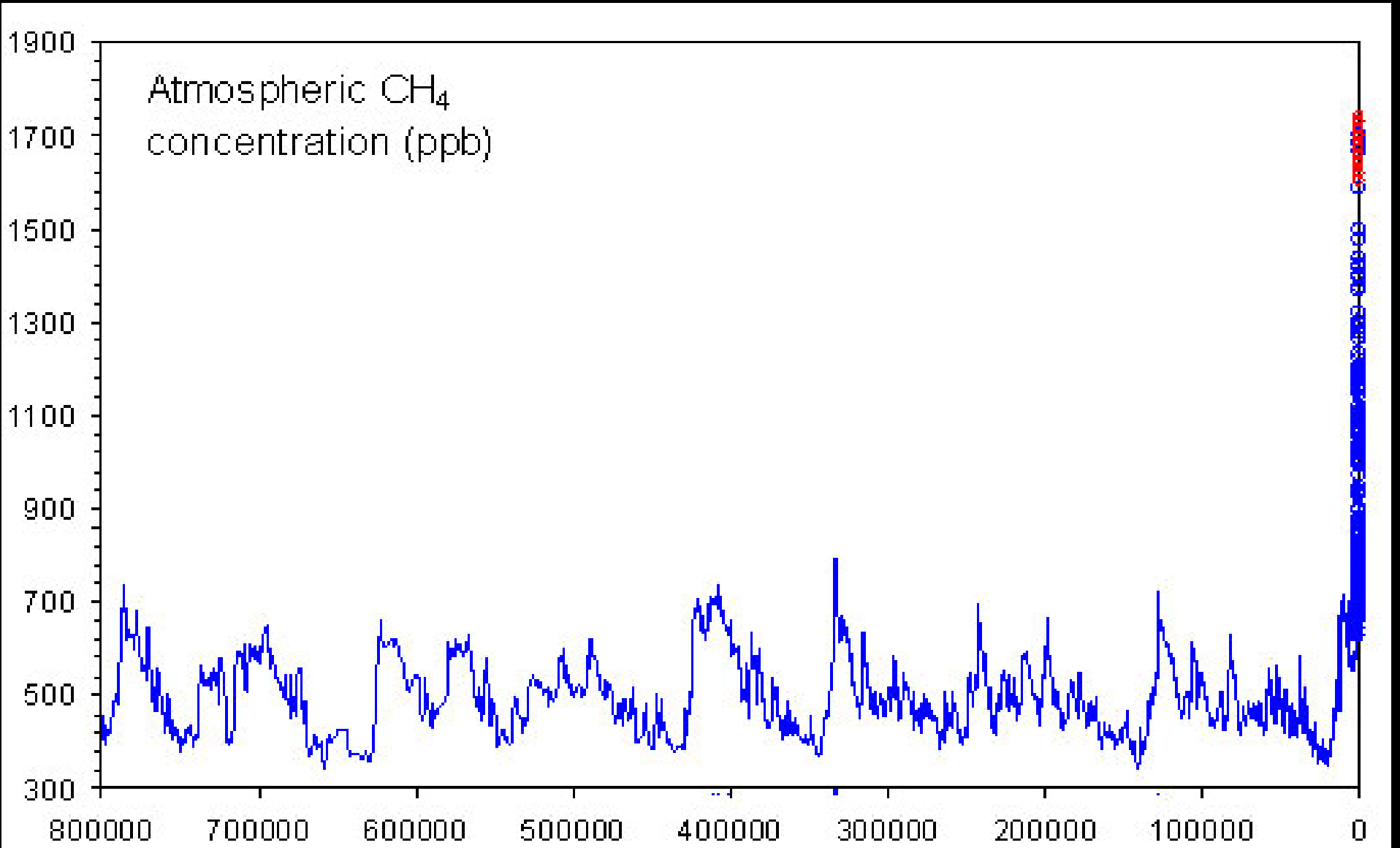
Methane forcing of climate was recently revised upward from ¼ of total (older IPCC) to 1/3 of total. Tipping Point Ahead?



Atmospheric CO2 Is Rising at an Accelerating Rate of 0.7% per year Today. It's 47% Above Pre-Industrial Levels in 2019



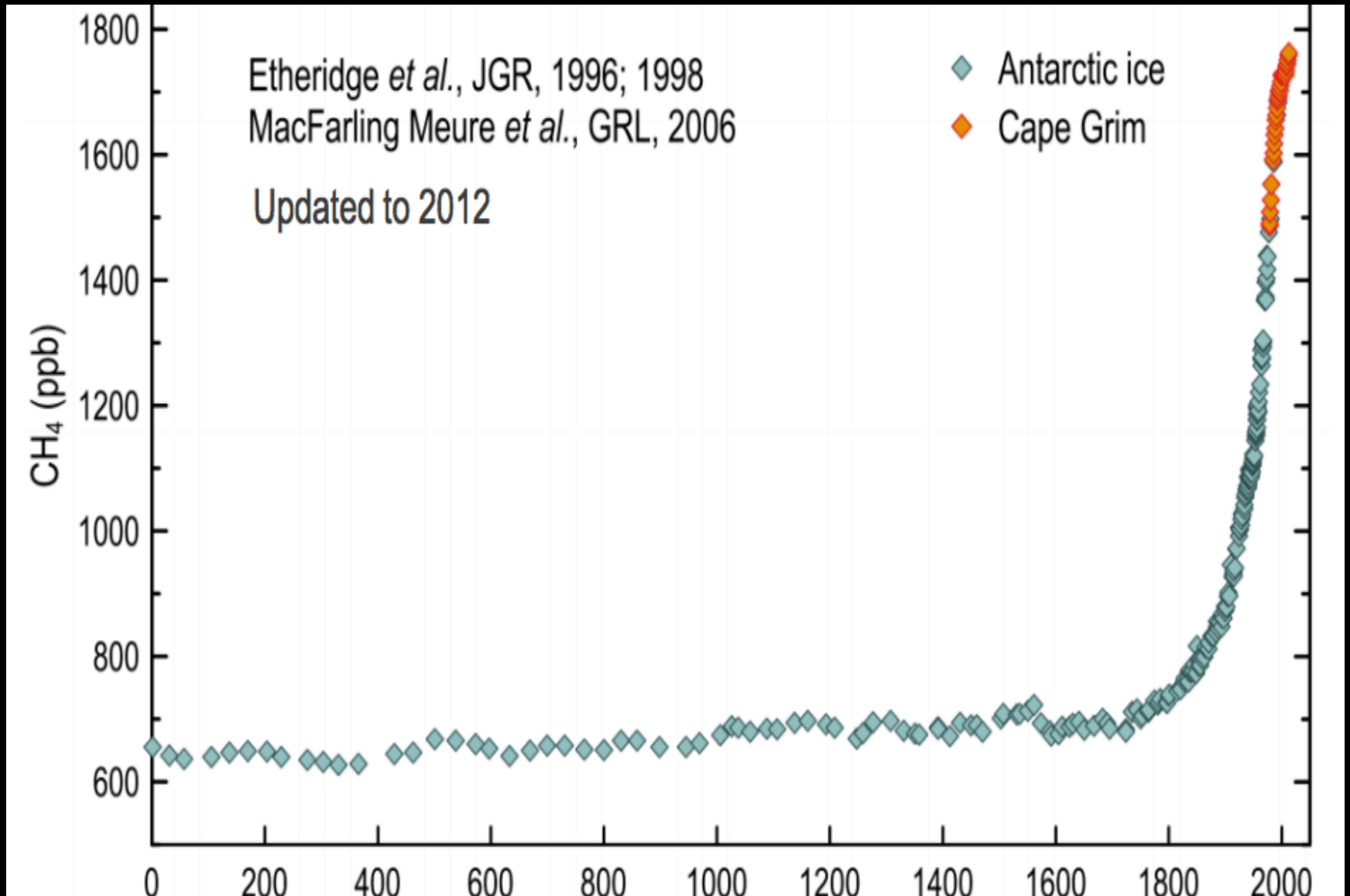
But Methane today is over 2,000 ppb, ***300%*** higher than Pre-Industrial Levels



This, despite the fact that CO_2 is a very tough molecule that will stay in the atmosphere for 10's of thousands of years…

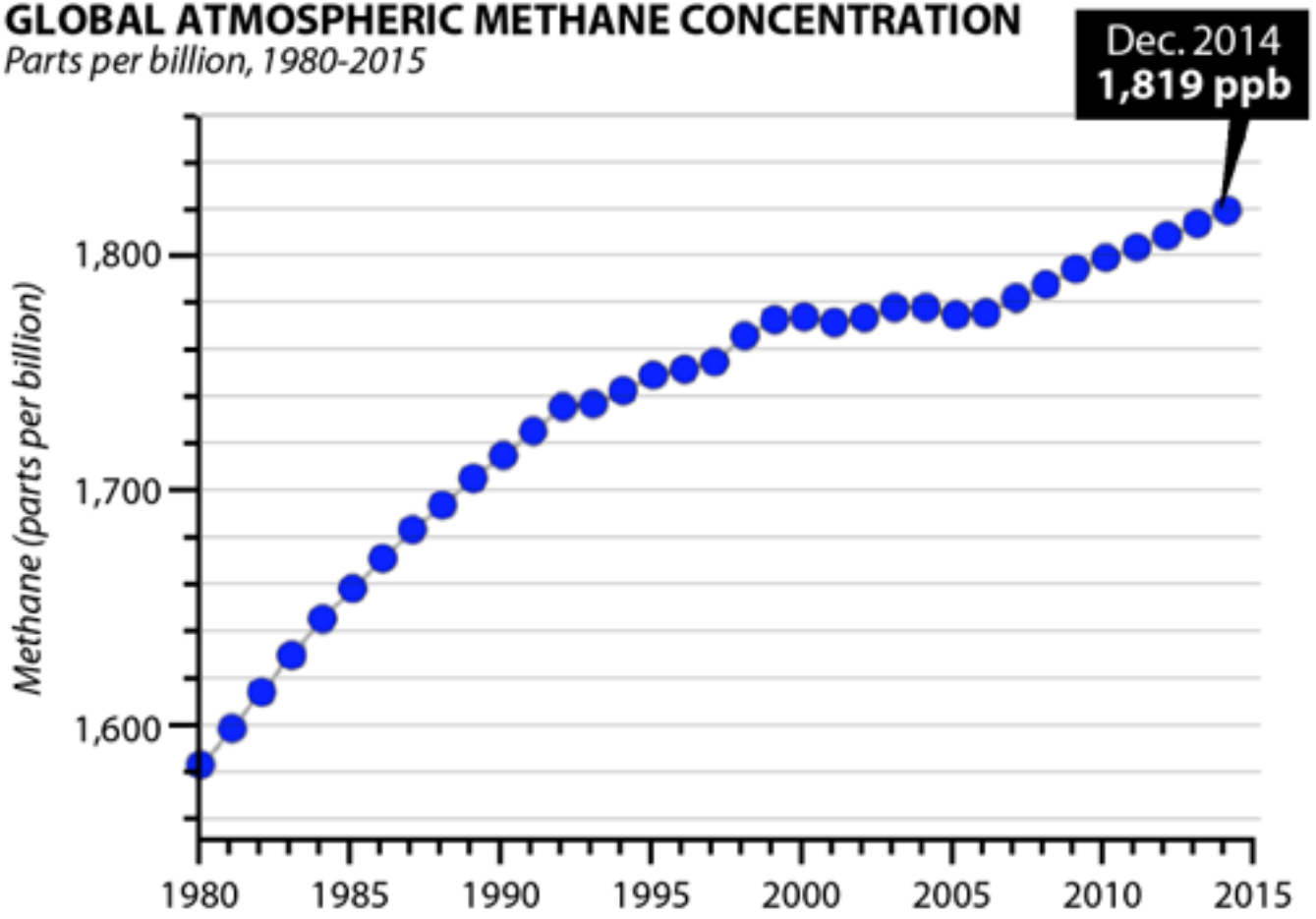
While methane oxidizes with a half life of only 12 years, to H_2O and CO_2 . Clearly, we're causing large ongoing emissions of methane to be forcing the system this strongly

Methane Levels: Stable for the Past Millennium – Until the Industrial Age



The Mysterious Rise of Atmospheric Methane

New study published Thursday in the journal *Science* points to agricultural growth in Asia for the increase in atmospheric methane, but the U.S. fracking boom could also be playing a role.



SOURCE: H. Schaefer et al., *Science* March 10, 2016

InsideClimate News

Rice fields, cattle, dead veg in reservoirs, and fracking all are involved

The IPCC assumed that atmospheric methane levels would decline by 37% in 2010->2050. Obviously a bad assumption.

Some Worry About a Planet-Killing "*50 Gt Burb*" of Methane "*at any time*"

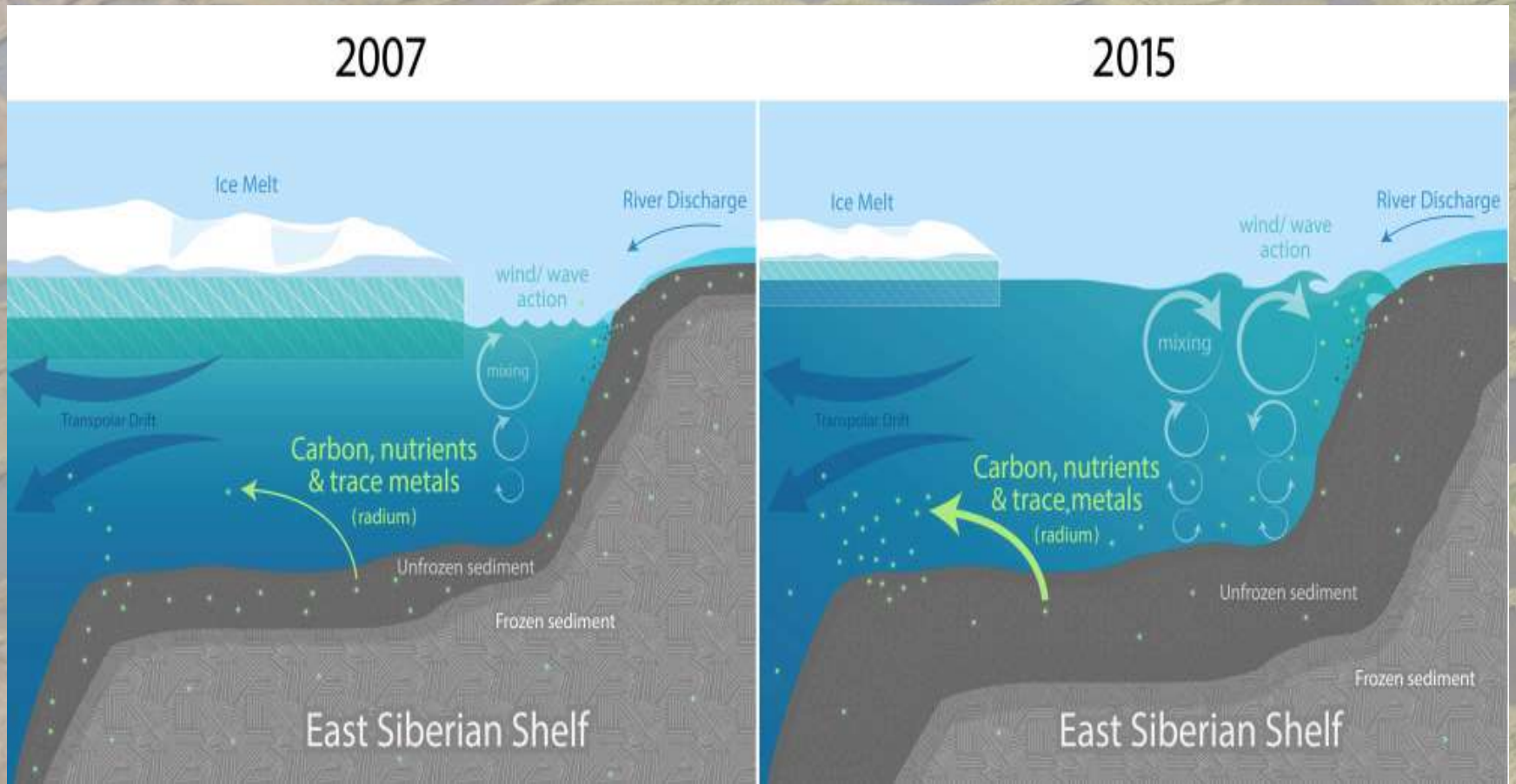
Is this a valid worry?

Methane Release from Sea Floor Methane Hydrates?

Sudden sharp release of only 10% of the estimated reservoirs would cause climate forcing 10 times that which CO2 is doing today.

- Is this possible? How stable? see **Archer, D. (2007)**
- **However: Nearly all researchers consider it unlikely that Arctic methane clathrate release can be abrupt, since the pressure necessary for clathrates is only found deeper than 350m and this is far below the sea bottom of the Arctic Ocean continental shelves where they may have formed in past Ice Ages, and where future warming is greatest.**
- **Heat conduction to these hydrates will take many centuries.**
- **We see no evidence of large Arctic methane release today, only low level leakage from the continuing thaw of shallow continental shelf which had frozen carbon during last Ice Age**

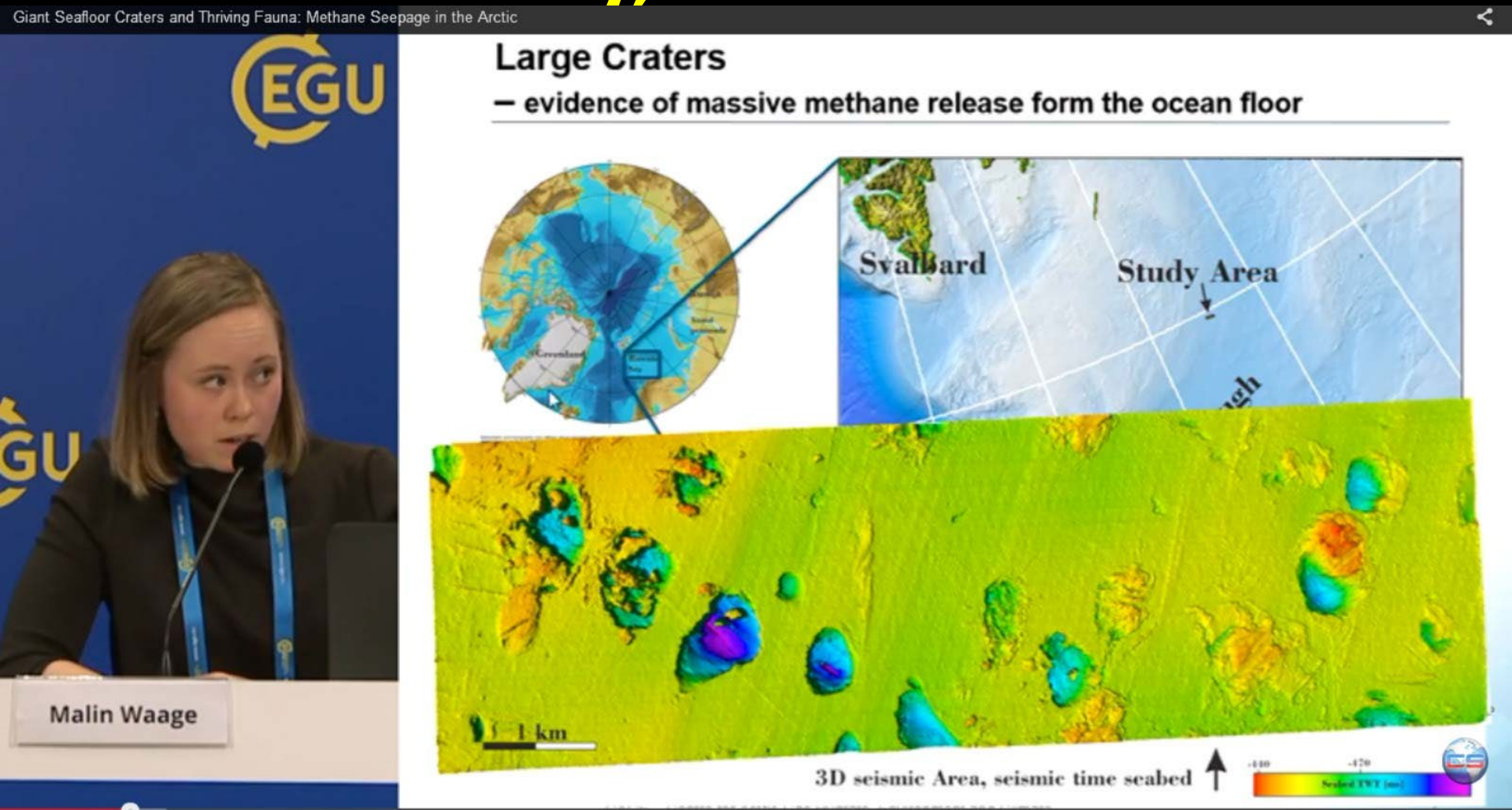
Still, some can argue: Arctic thaw is increasing river flows, amplifying mixing, heating sediments faster. Taliks can form, carrying heat deep into sediments. Metastable clathrates closer to sediment surface, where crack-able thawing undersea permafrost might give way? Still, summing up I feel "reassured, but nervous"

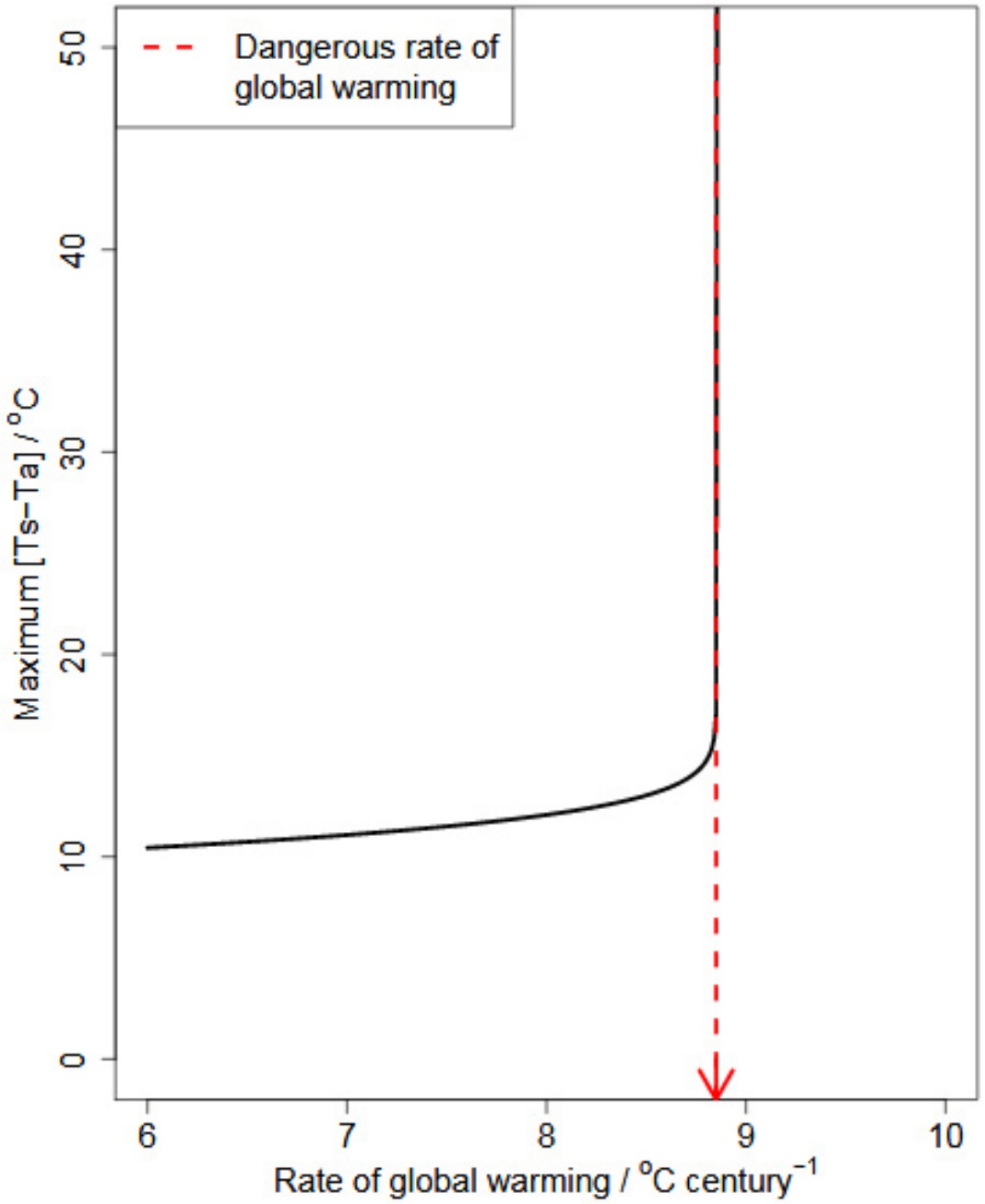


Nervous?

Explosive methane hydrate destabilization DID happen as the Earth began to warm at the end of the last Ice Age, 20,000 years ago, in areas off Svaalbard

Ocean floor (320m) craters 1 km in size, in hard rock. Still leaking methane today, albeit at a slow rate.





But **More Worrying is:**

The Compost Bomb Instability

PROCEEDINGS OF THE ROYAL SOCIETY A

Proc. R. Soc. A (2011) **467**, 1243–1269
doi:10.1098/rspa.2010.0485
Published online 24 November 2010

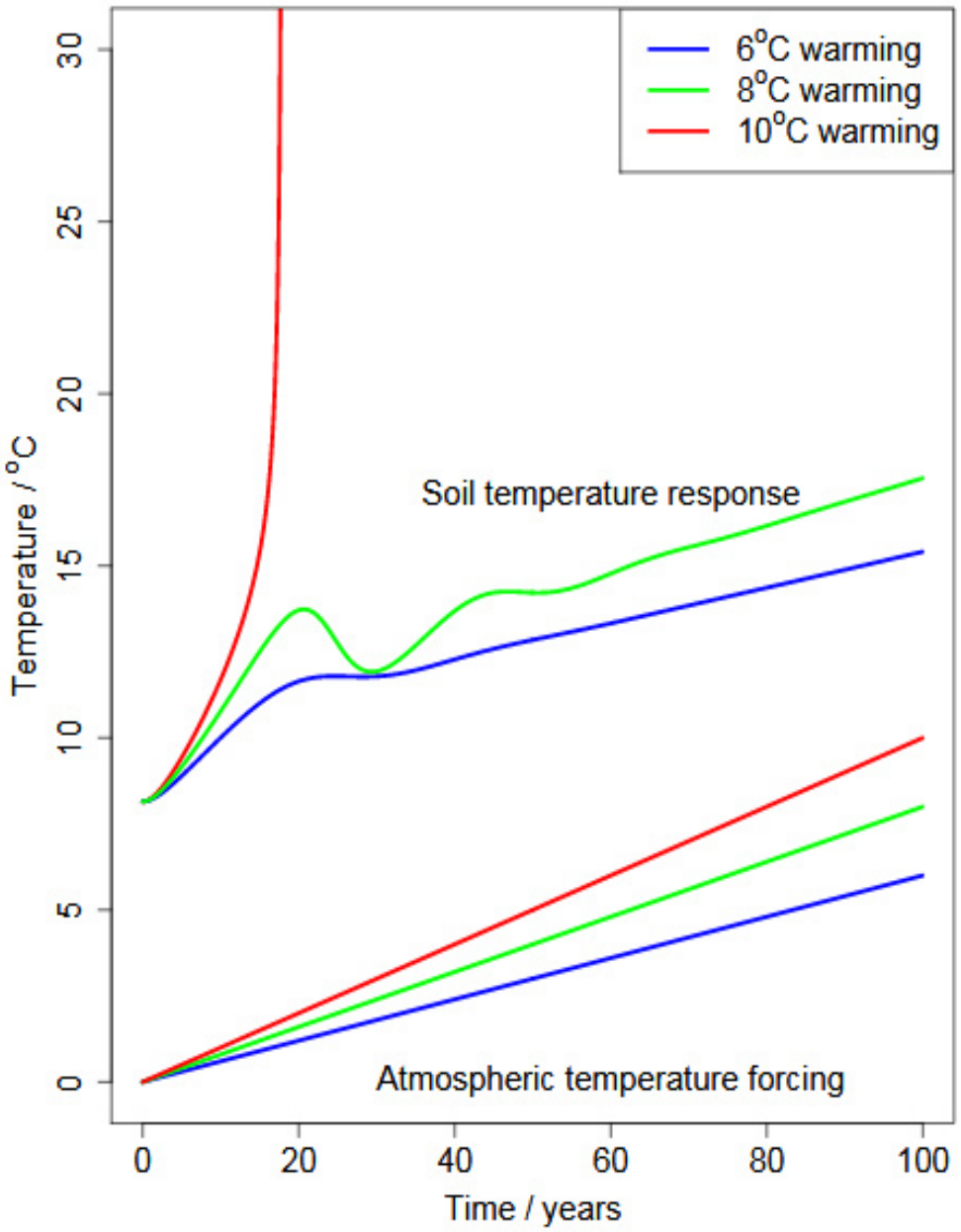
Excitability in ramped systems: the compost-bomb instability

BY S. WIECZOREK*, P. ASHWIN, C. M. LUKE AND P. M. COX

Mathematics Research Institute, University of Exeter, Exeter EX4 4QF, UK

The paper studies a novel excitability type where a large excitable response appears when a system's parameter is varied gradually, or ramped, above some critical rate. This occurs even though there is a (unique) stable quiescent state for any fixed setting of the ramped parameter. We give a necessary and a sufficient condition for the existence of a critical ramping rate in a general class of slow–fast systems with folded slow (critical) manifold. Additionally, we derive an analytical condition for the critical rate by relating the excitability threshold to a canard trajectory through a folded saddle singularity. The general framework is used to explain a potential climate tipping point termed the 'compost-bomb instability'—an explosive release of soil carbon from peatlands into the atmosphere occurs above some critical rate of global warming even though there is a unique asymptotically stable soil carbon equilibrium for any fixed atmospheric temperature.

Keywords: excitability; singular perturbation theory; climate tipping points; soil carbon; folded saddle; non-autonomous systems



When the atmospheric temperature rise rate exceeds 0.88C per decade, then within 15 years soil carbon in buried peat ignites, setting off the "Compost Bomb" and catastrophic carbon release to the atmosphere

"An explosive release of soil carbon from peat-lands into the atmosphere occurs above a critical rate of global warming, even though there is a unique asymptotically stable soil carbon equilibrium for any fixed atmospheric temperature"

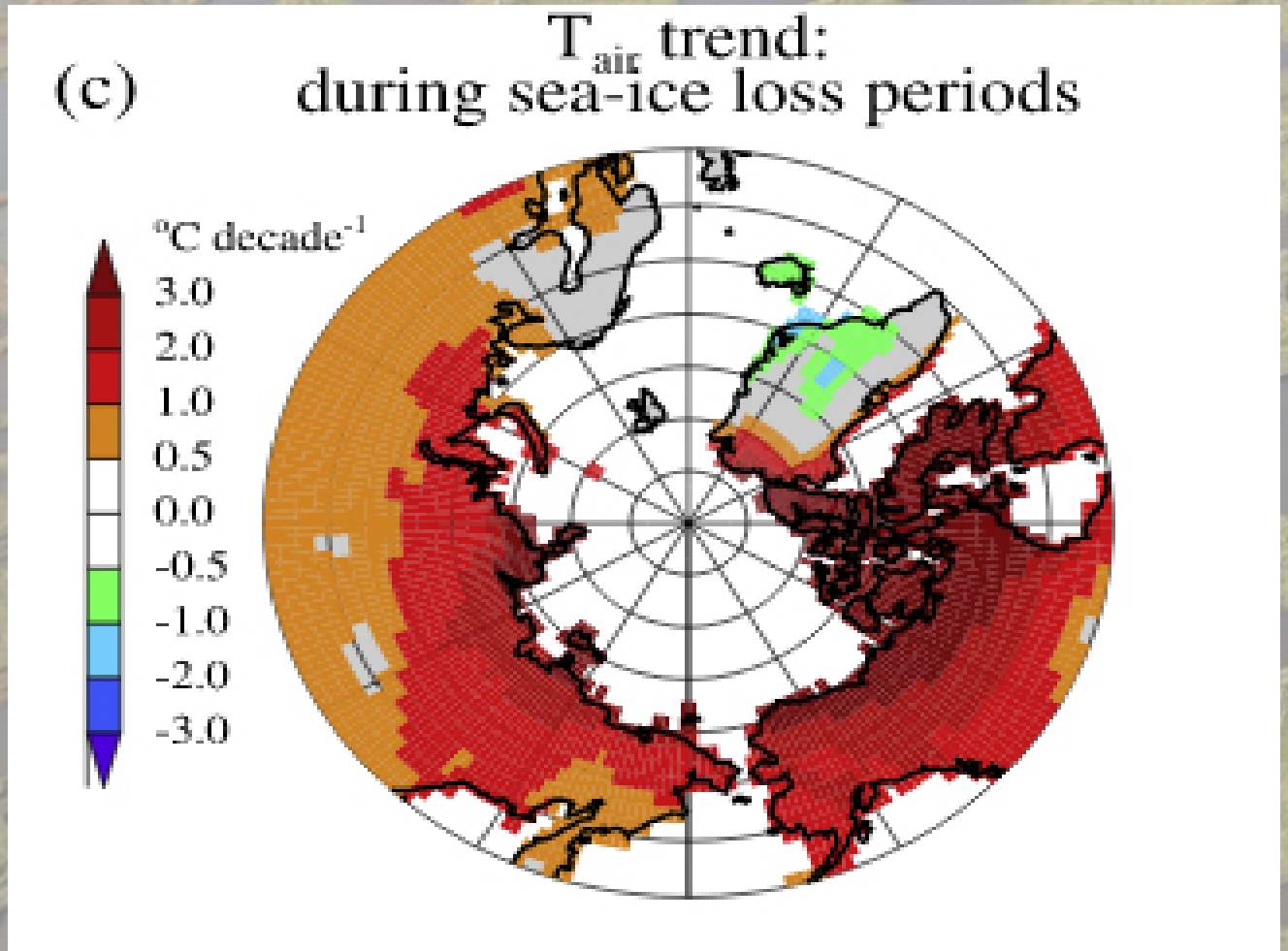
(Wieczorak *et al.* 2010)

Thawing, collapsing Arctic Coastlines are 34% of all global coastlines

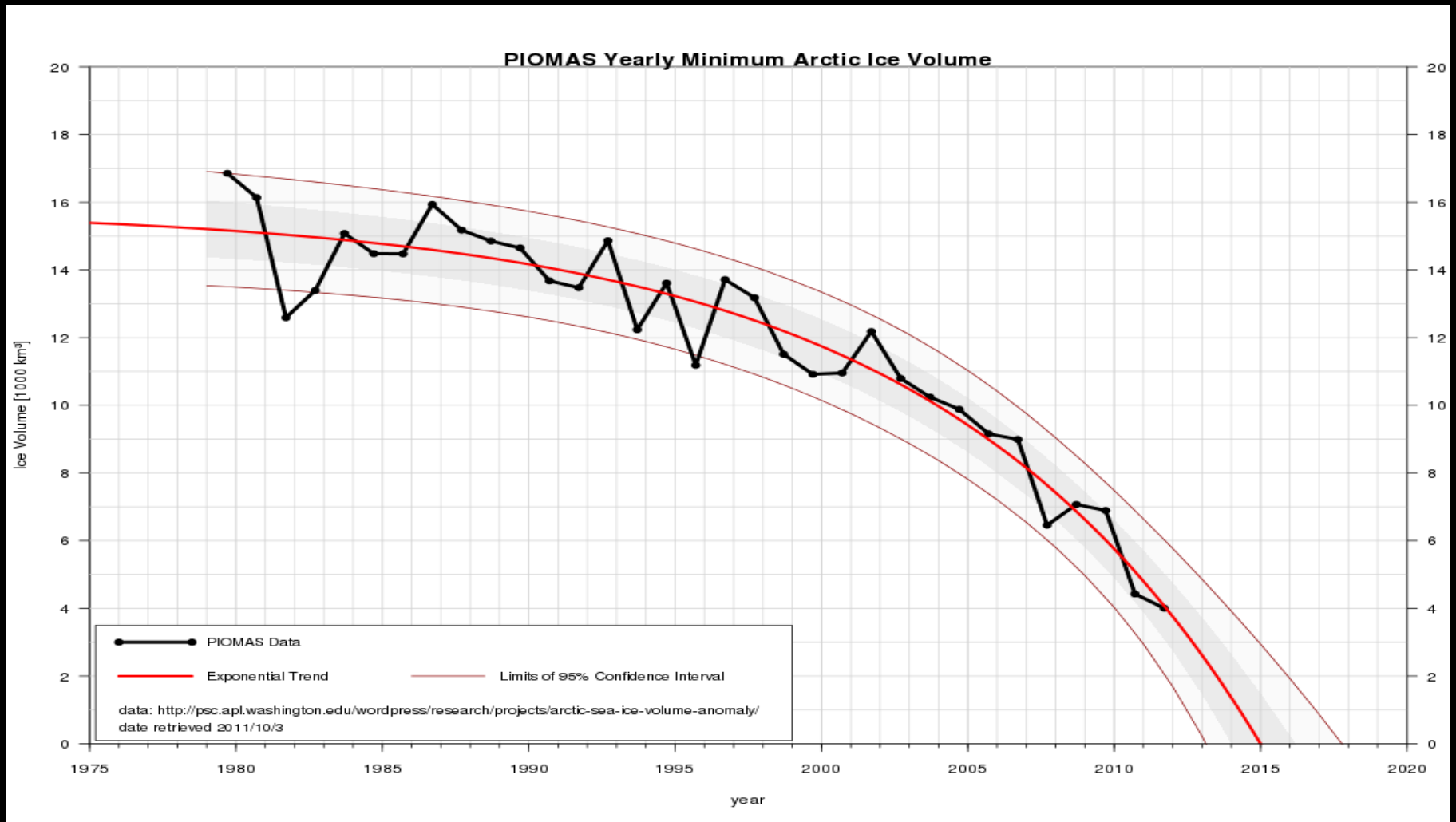
Arctic Coastline Collapse Liberating Carbon to Atmosphere

- **Tanski *et al.* (2019)** find that *"CO_2 was released as rapidly from thawing permafrost in seawater as it is from thawing permafrost on land."*
- The IPCC had simply assumed that carbon in coastal lands would go into the ocean and not the atmosphere… ***"Our results question the paradigm in current carbon budgets that OC (organic carbon) is entirely transported offshore, utilized for primary production or buried in shelf sediments (Bröder et al., 2016; Dunton et al., 2006; Vonk & Gustafsson, 2013).***

With sea ice loss, temperatures in the Permafrost rise from +1C to +3C per decade, and higher (Lawrence *et al.* 2008). This exceeds the "Compost Bomb Instability" limit. The Permafrost thaws above a tipping point at +1.5C above Pre-Industrial (Vaks *et al.* 2013). As of 2018 we're at +1.43C.



The Arctic Ocean is indeed only a few years away from losing all of its summer ice (Graph here is ice VOLUME).



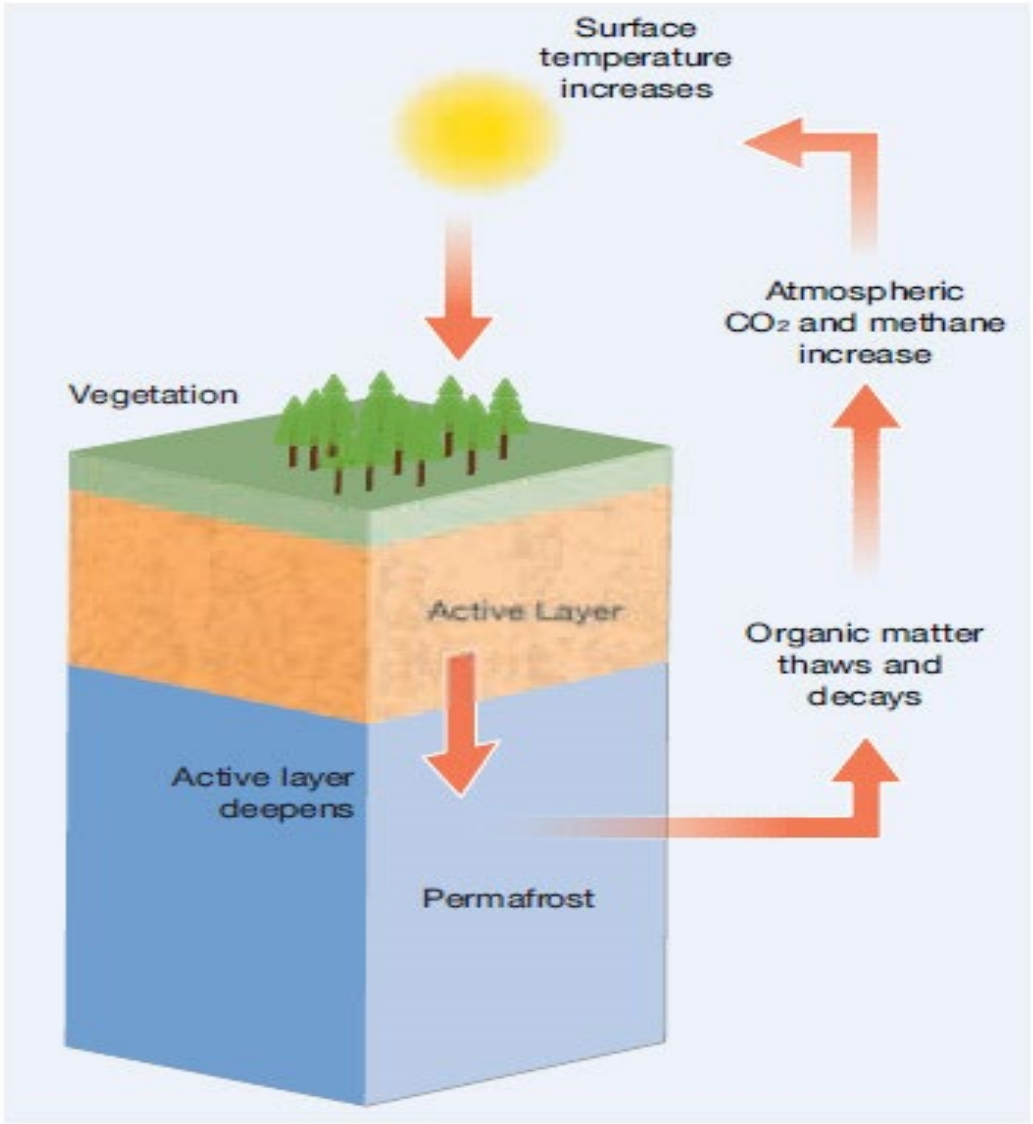
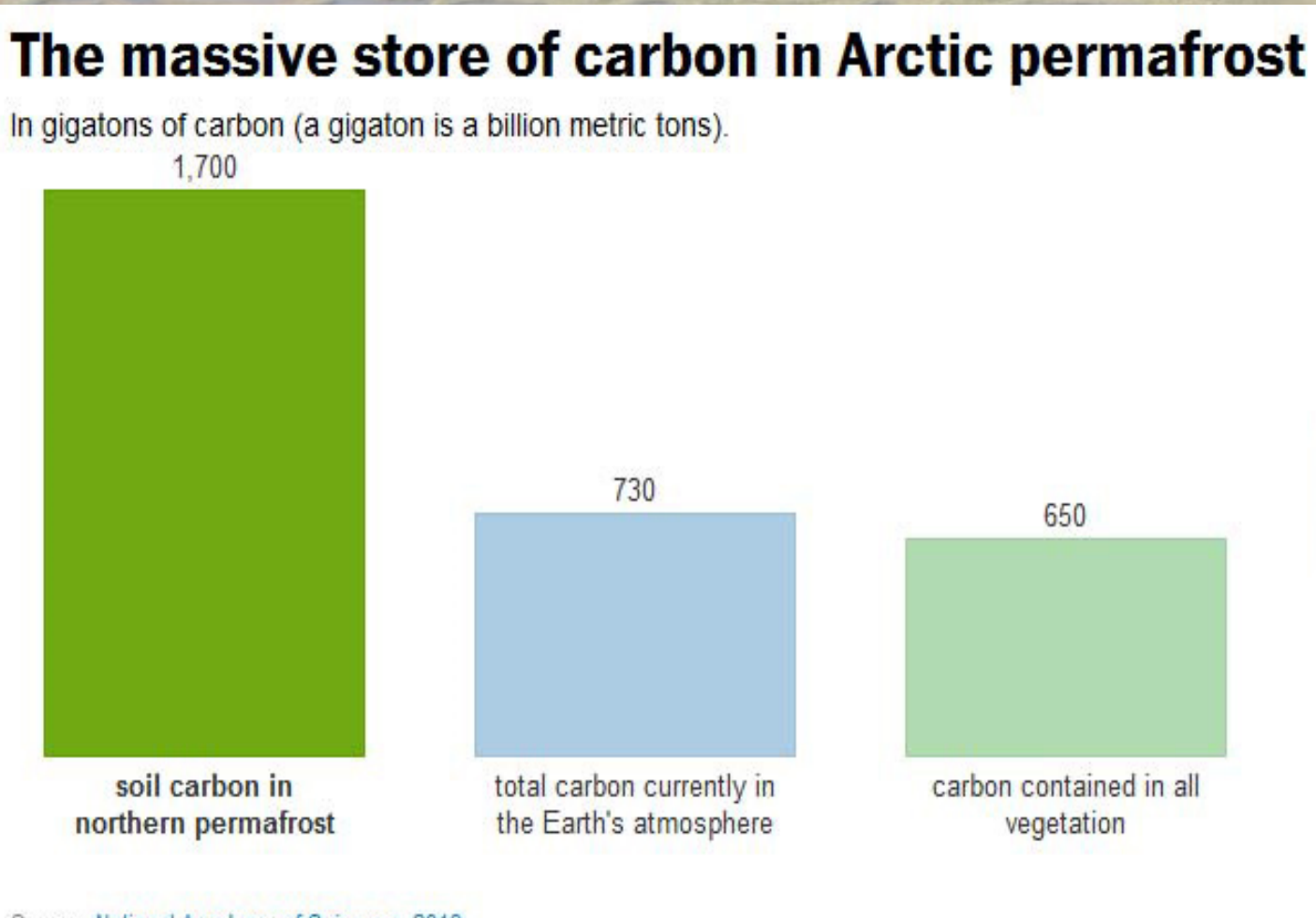


Figure 21: The permafrost carbon feedback is an amplification of surface warming due to the thaw of organic material currently frozen in permafrost, which will then decay and release CO_2 and methane into the atmosphere.

This is the trigger for the Permafrost Carbon Feedback tipping point

Northern hemisphere permafrost has more than double the carbon content of our atmosphere



Thermo-karst Arctic ponds are strong methane sources, not included by MacDougall *et al.*

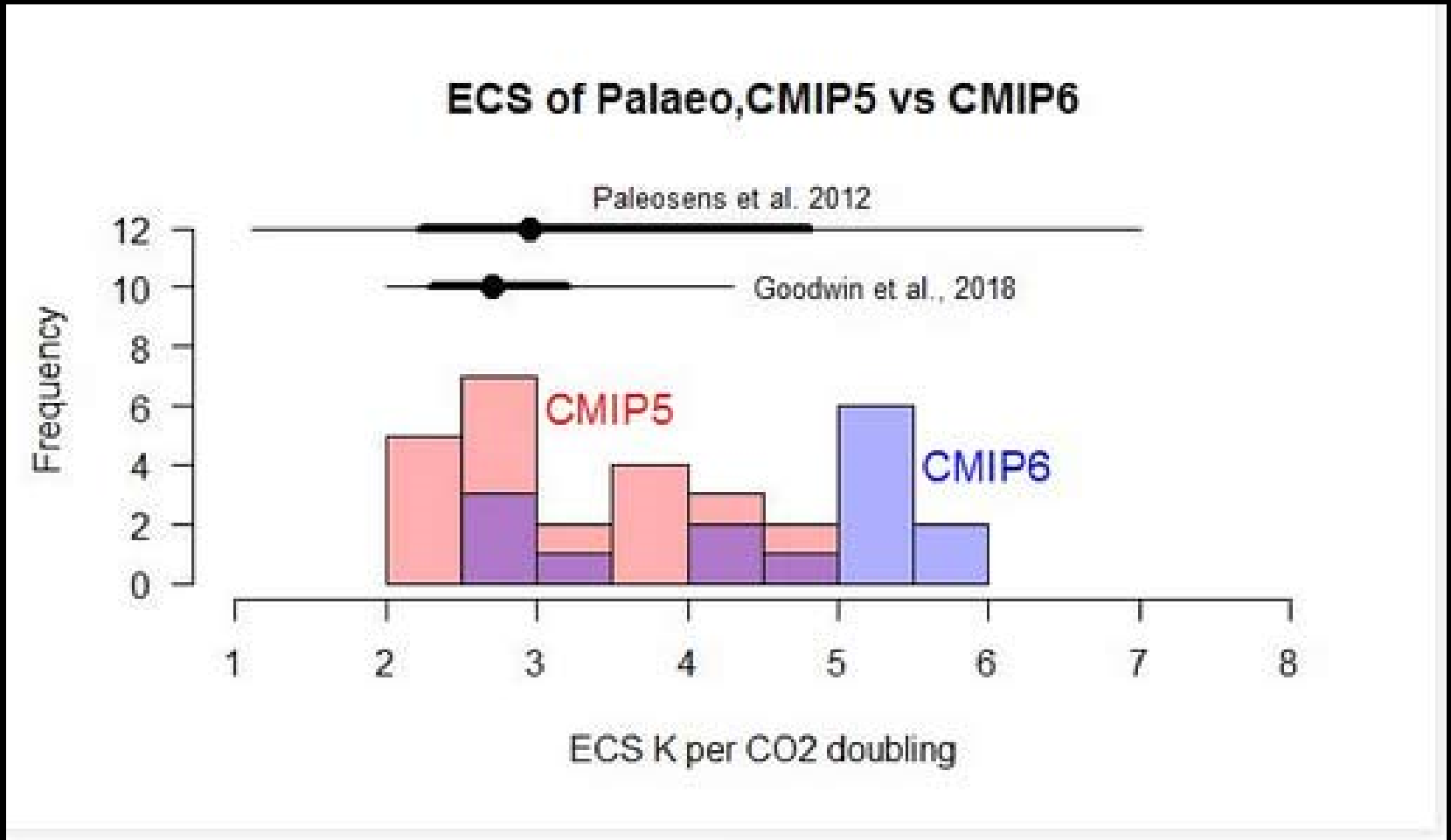
Methane Explosion Craters in Siberia

In 2017, scientists are discovering…

- …Over **7,000 new domes filled with methane** and *"are ready to explode"*, in the Yamal and Gydan Peninsulas alone

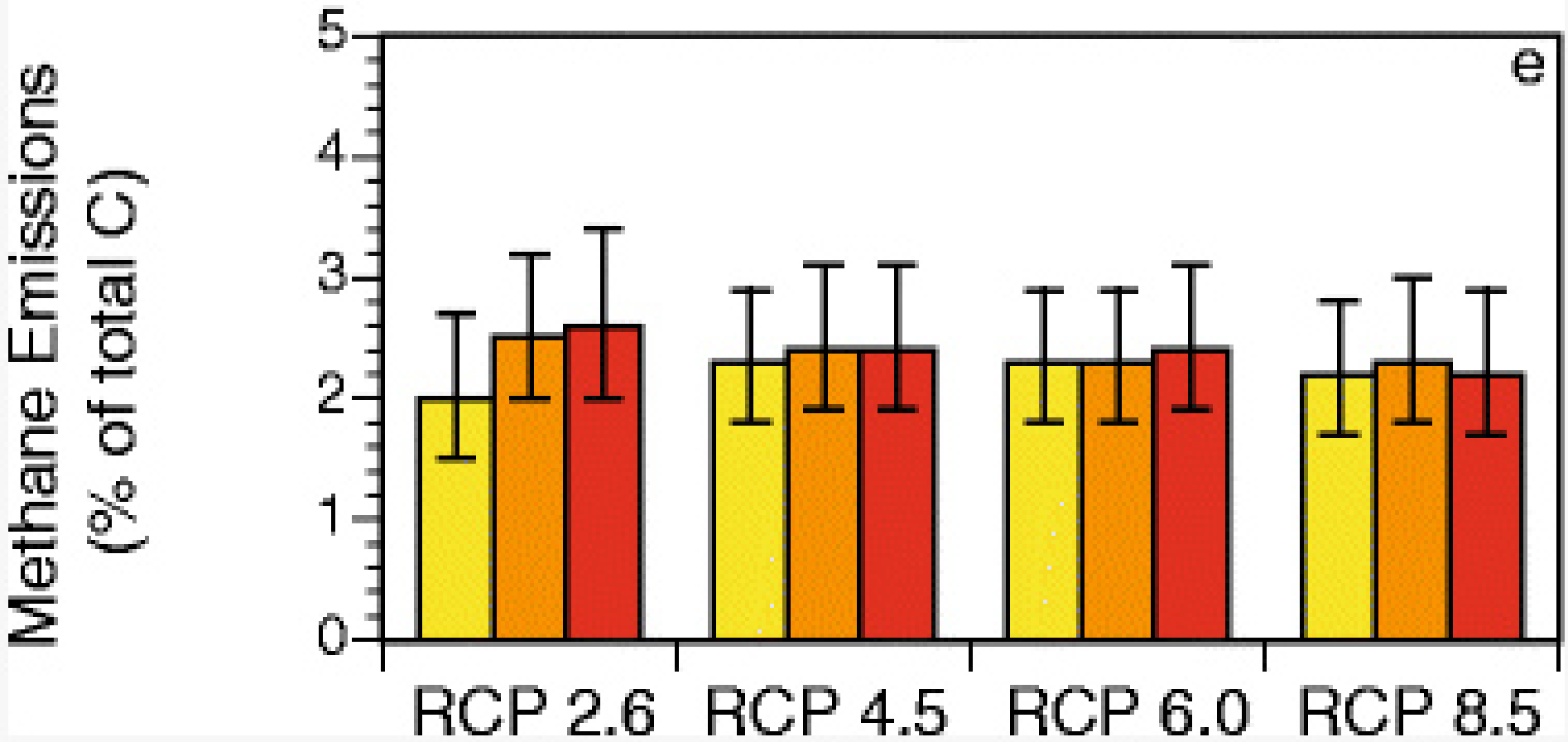
So if 97.7% of the carbon emerges in the form of CO2, but 2.3% as methane, what does that mean for greenhouse forcing?

The New CMIP6 Models Confirm Work of Friedrich *et al.* and Others: ECS Looks to be 5C, not the 3C Assumed in the Past



Schuur *et al.* 2013 , Review of experts:

2.3% of permafrost's carbon will emerge as methane - regardless of human emission scenario. That's 0.84% methane by mass



Methane Climate Forcing: 25% higher than IPCC Assumed, on 250 yr Time Scale

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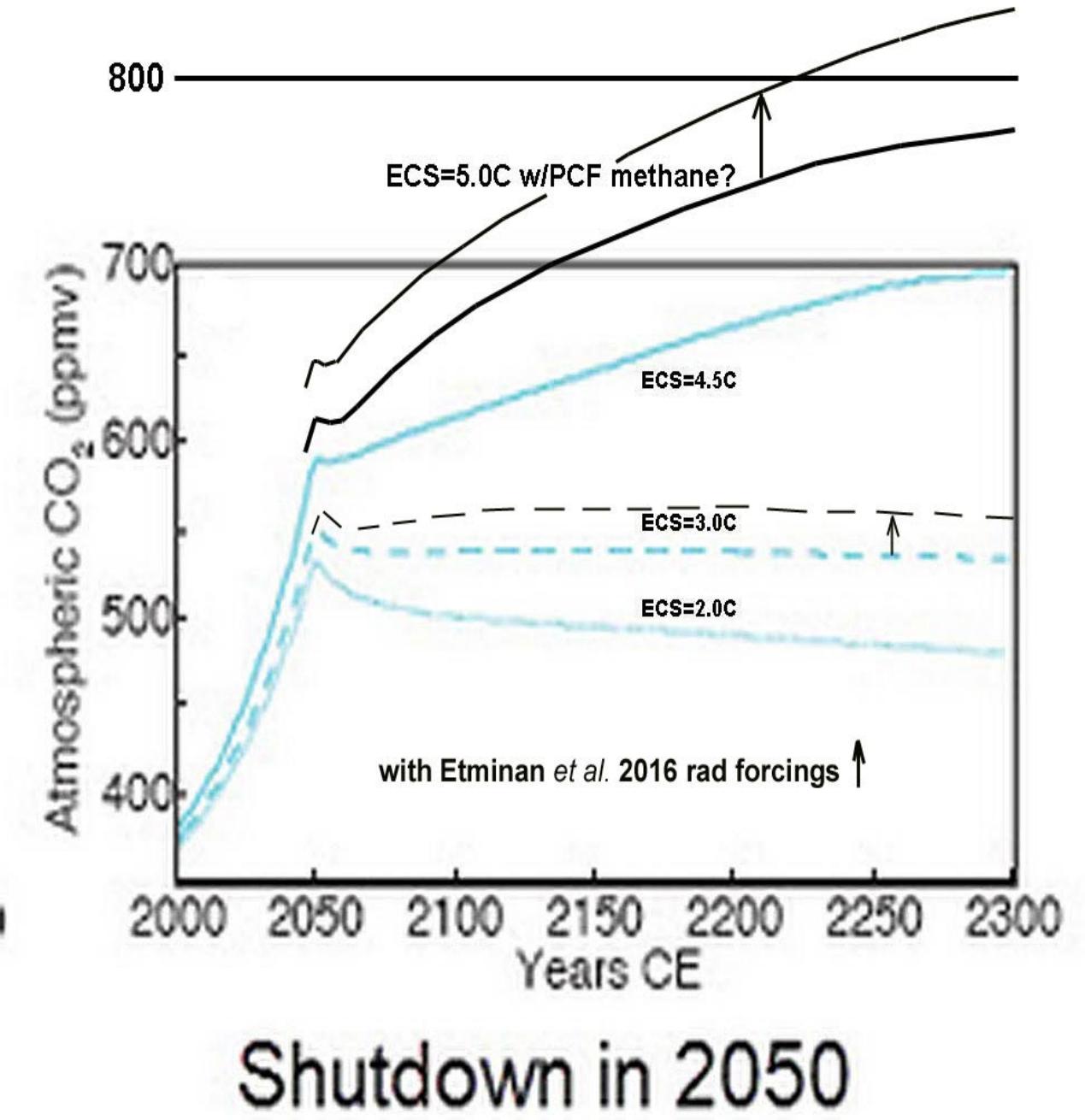
Radiative forcing of carbon dioxide, methane, and nitrous oxide: A significant revision of the methane radiative forcing

M. Etminan, G. Myhre, E. J. Highwood, K. P. Shine

First published: 27 December 2016 | https://doi.org/10.1002/2016GL071930 | Citations: 95

Abstract

New calculations of the radiative forcing (RF) are presented for the three main well-mixed greenhouse gases, methane, nitrous oxide, and carbon dioxide. Methane's RF is particularly impacted because of the inclusion of the shortwave forcing; the 1750–2011 RF is about 25% higher (increasing from 0.48 W m^{-2} to 0.61 W m^{-2}) compared to the value in the Intergovernmental Panel on Climate Change (IPCC) 2013 assessment; the 100 year global warming potential is 14% higher than the IPCC value. We present new simplified expressions to calculate RF. Unlike previous expressions used by IPCC, the new ones include the overlap between CO_2 and N_2O; for N_2O forcing, the CO_2 overlap can be as important as the CH_4 overlap. The 1750–2011 CO_2 RF is within 1% of IPCC's value but is about 10% higher when CO_2 amounts reach 2000 ppm, a value projected to be possible under the extended RCP8.5 scenario.



Shutdown in 2050

Starting from MacDougall *et al.* (2012) I've merely added 23% conservatively onto the ECS=3C and ECS=5C curves, neglecting nonlinear amplifying. Now, atmospheric CO2 is driven to 830 ppm and rising, by 2300. Temperatures would rise to likely +8C and beyond. All, without any human CO2 emissions starting just 30 yrs from now.

To Summarize My Estimation Technique for the Black Curves

- The blue curves are MacDougall *et al.,* while the black curves are mine, and are CO2e, adding in the forcing of methane (not other non-CO2 GHG's).
- I took the **difference** between the **Solomon *et al.* 2009** post shut-down curve for 550 ppm and the MacDougall curve for 550 ppm shutdown in 2050, and called that difference the PCF additional atmospheric CO2 contribution over time, after 2050.
- I then cut that difference to 60% due to the smaller active layer from **MacDougall and Knutti 2016**. (but see following slide)
- Then I took the remaining **difference** and multiplied it by 1.84 to account for the CO2e of MacDougall's neglected methane, which implies methane comprises 45% of permafrost climate forcing
- I did this for ECS=3C which is what both Solomon and MacDougall assumed. Then I scaled up this difference for ECS=5C to match proportionally higher curves for this ECS in the MacDougall *et al.* 2012 paper.

Note Added in Post-Script on Permafrost Methane Forcing

- If the active layer is only 60% as large as the original MacDougall assumption, this also means that the conductivity of surface heating through that layer is better, and since it is the conversion of permafrost into periodically thawed active layer that provides the emissions, it was, in hindsight, very likely more correct to make the revised CO2 curve significantly HIGHER, not assume 40% lower as I did.
- Also, climate modelling globally should ideally take account that the thaw of the Permafrost will be faster if there's a methane gradient due to this strengthening emission source. The effective GHG effect from the methane will be higher than assuming instantaneous well-mixed levels.
- On the other hand, the 12 yr half life of methan means the steady-state methane concentration relative to CO2 will be lower than assuming the concentration remains at its emission rate as I simply did.
- **These three effects compensate, so the net result of my black curve estimates is likely still not far off.**

Geo-Engineering the Earth to Save Climate – Kicking the can down the road, as we've done, means it's now necessary

- We've waited too long. And even with no direct **nor indirect** human-caused GHG emissions, temperatures will NOT go back down. ***~EVER.***
- **We're at +1.43C (Lowess smoothed GISTEMP) as of the close of 2018, and with 85% of global power still from fossil fuels, we'll sail far past +2C with system inertia alone.**
- **Stop-gap immediate cooling is needed.**
- **Enter - GeoEngineering**

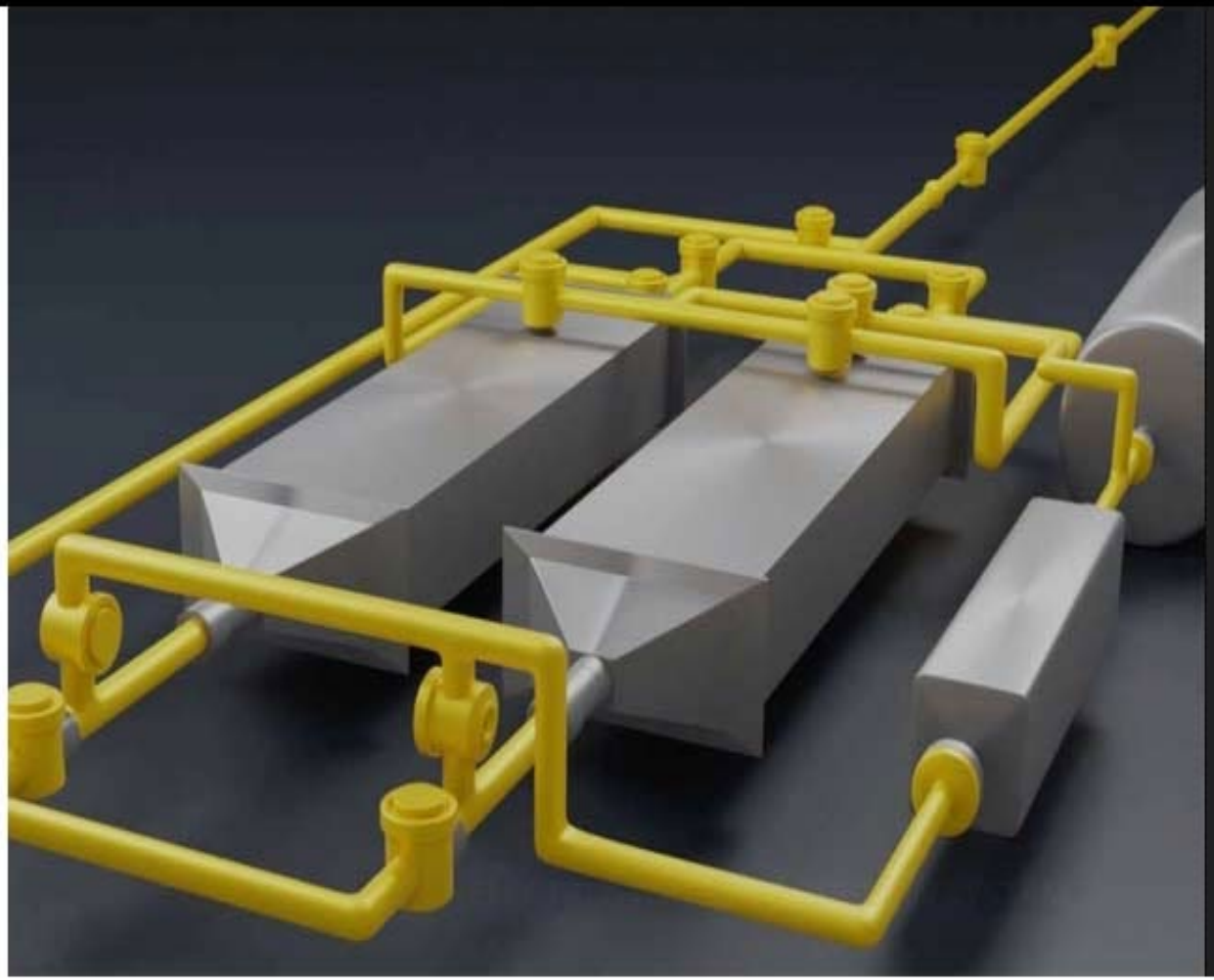
We have a Genuine Climate Emergency…

- But we all look around, see no one else panic'ing, and so we, like the social animals we are, we don't panic either.
- But those few who use their Nature-given ability to identify patterns, formulate and test principles of **How the World Works** from observations, project the future, and then seek to take actions that will meet that future… **are *more* than alarmed.**

Safe Ideas…

- **Safest-- Pull CO2 from the atmosphere**, pump it underground for permanent sequestration. In sedimentary oil-bearing cap-rock formations?
- Maybe combine 50:1 as carbonated water and pump into basalt formations?
- And/or into salt caverns such as near Gulf Coast.

- Also Excellent: re-icing the Arctic ocean using wind-powered pumps in winter (**Desch *et al.* 2017**).
- **See my Fall '18 talk** for more on **Strategies and GeoEngineering**, and my thinking on principles guiding the formulation of safe GeoEngineering ideas



FULL SCREEN

In this diagram of the new system, air entering from top right passes to one of two chambers (the gray rectangular structures) containing battery electrodes that attract the carbon dioxide. Then the airflow is switched to the other chamber, while the accumulated carbon dioxide in the first chamber is flushed into a separate storage tank (at right). These alternating flows allow for continuous operation of the two-step process.

Image courtesy of the researchers

MIT engineers develop a new way to remove carbon dioxide from air

The process could work on the gas at any concentrations, from power plant emissions to open air.

GeoEng: Safety Criterion #1

- **Leave the SURFACE of the Earth as untouched and compatible with existing Eco-systems as possible.**
- So… Capture, sequester CO2 underground? – **YES!**
- Paint everything white? **NO!**
- Re-Ice the Arctic? **YES!**
- Spread trillions of floating white beads over the Arctic Ocean (soon to disperse through ecosystems and all oceans)? – **NO!!**
- **BECCS**: Plant a U.S.-sized land area (where??) with weeds to repeatedly harvest and burn to capture/sequester the carbon, denuding the soil of nutrients? **NO!**

GeoEng Safety Criterion #2: No Hysteresis

- Means - take us BACK along the ~same Earth System Trajectory that got us here: **Examples**
- **--Reverse atmospheric GHG trends: Direct Air Capture and sequestration back down… "From Hell it Came" – so "Drag it to Hell" it should go!**
- --Re-freeze the poles
- --Re-grow tropical rainforests
- --Restore soils ability to store, means by ending current Big Ag practices

Porous oil/gas bearing sand, capped by shale, is how Nature sequesters Gas for millions of years. We're now destroying that cap rock to pull out another few years of Nat Gas.