THE ECONOMICS OF CLIMATE DAMAGE: A CRITIQUE OF WILLIAM NORDHAUS AND NEOCLASSICAL ECONOMICS IN LIGHT OF 21ST CENTURY CLIMATE SCIENCE

PART 1

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CRITIQUE OF NEOCLASSICAL ECONOMICS OF CLIMATE CHANGE AS EXEMPLIFIED BY NORDHAUS' WORK:

3 LINES OF ATTACK…

- Flawed economic modelling
- Poor climate science
- Missing, flawed ethics in valuing future generations and other life on Earth

1. REACTIONS OF CLIMATE SCIENTISTS AND ECONOMISTS TO NORDHAUS' WORK

CLIMATE SCIENTISTS' REACTIONS (AS *QUOTED HERE* IN 2020)

- *"For **Michael Mann**, director of the Earth System Science Center at Pennsylvania State University, Nordhaus' 'heavy social discounting inappropriately down-weights devastating impacts that fall disproportionately on future generations, arguably violating basic ethical considerations'.*
- Mann says: *"Frankly, such claims absurdly underestimate true costs & damages of business-as usual. They are based on a linear extrapolation of a coupled physical-politico-societal response that is highly non-linear and admits collapse. There IS no economy after civilization collapse..."*

FROM **POTSDAM INSTITUTE CLIMATOLOGIST** JOHAN ROCKSTROM…

- *"It is simply not aligned with climate science," said **Johan Rockstrom**, director of the Potsdam Institute for Climate Research in Germany; "It is an unequivocal finding in the natural sciences that a +3C warming is a disastrous outcome for humanity", Rockstrom told AFP.*

- *“Many climate scientists are now calling for the focus on economy efficiency and incremental change that economists have taken to global warming to be abandoned.*
- *In a subsequent academic paper based (1991) on this lecture, (Nordhaus) stated that (cumulative to year 2100) “damages are estimated to be 2 percent of output at a 3°C global warming and 8 percent of output with 6°C warming”. This is a trivial level of damage, equivalent for the 6°C warming case to a fall in the rate of economic growth over the next century of less than 0.1% per year.” (Keen 2019)*

POLICY ECONOMISTS FROM EVEN FARTHER TO-THE-POLITICAL-RIGHT THAN THE NEOCLASSICALS, ARE ATTACKING NORDHAUS FOR ACKNOWLEDGING THE REALITY OF CLIMATE CHANGE AT ALL, AND FOR CALLING OUT CLIMATE DENIERS.

Examples:

- R. Murphy 2012
- B. Zycher from the American Enterprise Institute, here
- And David Henderson at the Hoover Institute, here

- These op/eds appear to be without quality content, so I'll not say more.

ECONOMISTS LESS ALIGNED WITH THE DOMINANT NEOCLASSICAL PARADIGM, ARE ALSO PREDOMINANTLY AND STRONGLY CRITICAL…

- *“’Nordhaus' model -- known as DICE, or Dynamic Integrated Model of Climate and the Economy – ‘is so badly flawed that it shouldn't be taken seriously,’ Columbia University professor **Joseph Stiglitz**, who won an economics Nobel of his own in 2001 (for insights in handling incomplete information), told AFP. ‘In fact, it's dangerous because we don't have another planet we can go to if we mess this up. The message he's been conveying is foolhardy.’“ (quoted here).*

NORDHAUS' DICE MODEL IS AN EXAMPLE OF THE DSGE MACROECONOMIC MODELS – WHICH HAVE BEEN SHARPLY CRITICIZED FOR THEIR FAILURES

- *Joseph Stiglitz finds "staggering" shortcomings in the "fantasy world" the models create and argues that "the failures [of macroeconomics] were the wrong micro-foundations, which failed to incorporate key aspects of economic behavior". He suggested the models have failed to incorporate "insights from information economics and behavioral economics" and are "ill-suited for predicting or responding to a financial crisis."[30] Oxford University's John Muellbauer put it this way: "It is as if the information economics revolution, for which George Akerlof, Michael Spence and Joe Stiglitz shared the Nobel Prize in 2001, had not occurred. The combination of assumptions, when coupled with the trivialization of risk and uncertainty...render money, credit and asset prices largely irrelevant... [The models] typically ignore inconvenient truths."[31] Nobel laureate Paul Krugman asked, "Were there any interesting predictions from DSGE models that were validated by events? If there were, I'm not aware of it."[32] (from the Wiki article on DSGE economic models)*

I COMPLETELY AGREE WITH STIGLITZ, AND OTHER WORKERS WHO, UNLIKE THE NEOCLASSICISTS, BETTER INCORPORATE ASYMMETRIC INCOMPLETE KNOWLEDGE INTO ECONOMICS,

- And I completely disagree with any who feel (as an apologist for Neoclassic economists said to me) Nordhaus' modelling is *"all we've got and the best we can do".*
- Further, I contend that the awarding of a media mis-labelled "Nobel" Prize (created by the Swedish Central Bank, not Alfred Nobel, and Swedish tax-payer funded) for such modelling is the greatest setback to effective climate action of any in the stymied history of climate inaction. I cannot emphasize too strongly… the work of Nordhaus is an absolute disaster for its effects on current policy for our future.
- Let's look why…

2. FLAWED ECONOMIC MODELLING

DICE'S ADDITIONS TO THE STANDARD NEOCLASSICAL ECONOMIC MODEL ARE:

- *"A "damage function" that relates the increase in average global temperature to a decline in GDP.*
- *An 'abatement function' that calculates the cost of reducing global temperature rise over what would happen if nothing were done to tackle Climate Change.*
- *Equations to relate GDP growth to the increase in CO2 levels in the atmosphere, along with the impact of that increased CO2 on the average global temperature."*
- *The goal is a cost/benefit assessment of climate action*

THE MOST FATAL OF ALL FLAWS, AND UNRECOGNIZED IN THE LITERATURE SO FAR AS I CAN FIND: NORDHAUS ASSUMES FUTURE GENERATIONS' VALUATION OF THEIR OWN WELFARE DESERVES NO CONSIDERATION IN DETERMINING CIVILIZATION UTILITY

- Instead, it is only our valuations of their future that matter in his and other Neoclassic modelling, and even that value is discounted away at their preferred steep rates of 3-5% annually. These correspond to our valuing, in 2017, the value of our grandchildren's year 2100 at only 8.6%, 3.8%, and 1.7% of today's value.
- **I suggest these economists confront this reality by having a heart-to-heart with their grandchildren, tonight, and confess to them how little they value their grandchildren's future.**
- **How can this possibly be justified, ethically? It cannot.**

SO FAR AS I KNOW, HERE IN MAY 2022, NO ONE ELSE HAS POINTED OUT THIS INEXCUSABLE FLAW. HOW IS THAT POSSIBLE?

- This flaw alone is enough to justify a complete rejection of these models on moral grounds.
- Including future life's own valuation of their own lives, forces all such models' true damage functions to explode, and unveils how ethically reprehensible such ideologically based, pseudo-scientifically dressed, and mathematically naïve their modelling really is.

SEPARATELY, IS THE QUESTION OF DISCOUNTING THE VALUE OF THE FUTURE AT ALL – REGARDLESS OF WHETHER AS FELT BY US, OR BY OUR DESCENDANTS

- Advocates for climate justice argue that the welfare discount applied in any damage functions should be zero.
- I might even suggest; negative. A negative discount rate would value the future higher than the present. Justice indicates, since it is current and recent generations who have enjoyed the benefits of high energy fossil fuel burning, while shifting the external burden of climate change and high debt on to future generations who do not have a voice, and whose interests are valued at zero worth.
- This cost should be shifted back to the perpetrators, and a negative discount rate would be powerful motivation to stop procrastinating. Yet if, as is traditional, it's given as an exponential, it's mathematically unbounded. Looking at history, one yet wonders if that is what it would take to finally get attention and action.

THE IDEA OF WELFARE DISCOUNTING IN NEOCLASSICAL ECONOMICS ORIGINATES FROM HOTELLING'S RULE (HOTELLING 1931) (Emphasis mine: RN)

- *"**Hotelling's rule** defines the net price path as a function of time while maximizing economic rent in the time of fully extracting a non-renewable natural resource. The maximum rent is also known as **Hotelling rent** or **scarcity rent** and is the maximum rent that could be obtained while emptying the stock resource. (*RN: "Emptying the stock resource" – meaning, there is a "death date" assumed*).*
- *In an efficient exploitation of a non-renewable and non-augmentable resource, the percentage change in net-price per unit of time should equal the discount rate in order to maximize the present value of the resource capital over the extraction period."*
- **Is this how we should think of Earth? As a death-dated "resource" from which to squeeze maximum profit by discounting the dropping future value of Earth as we exhaust it to death? What ethical ideology does this reveal?**

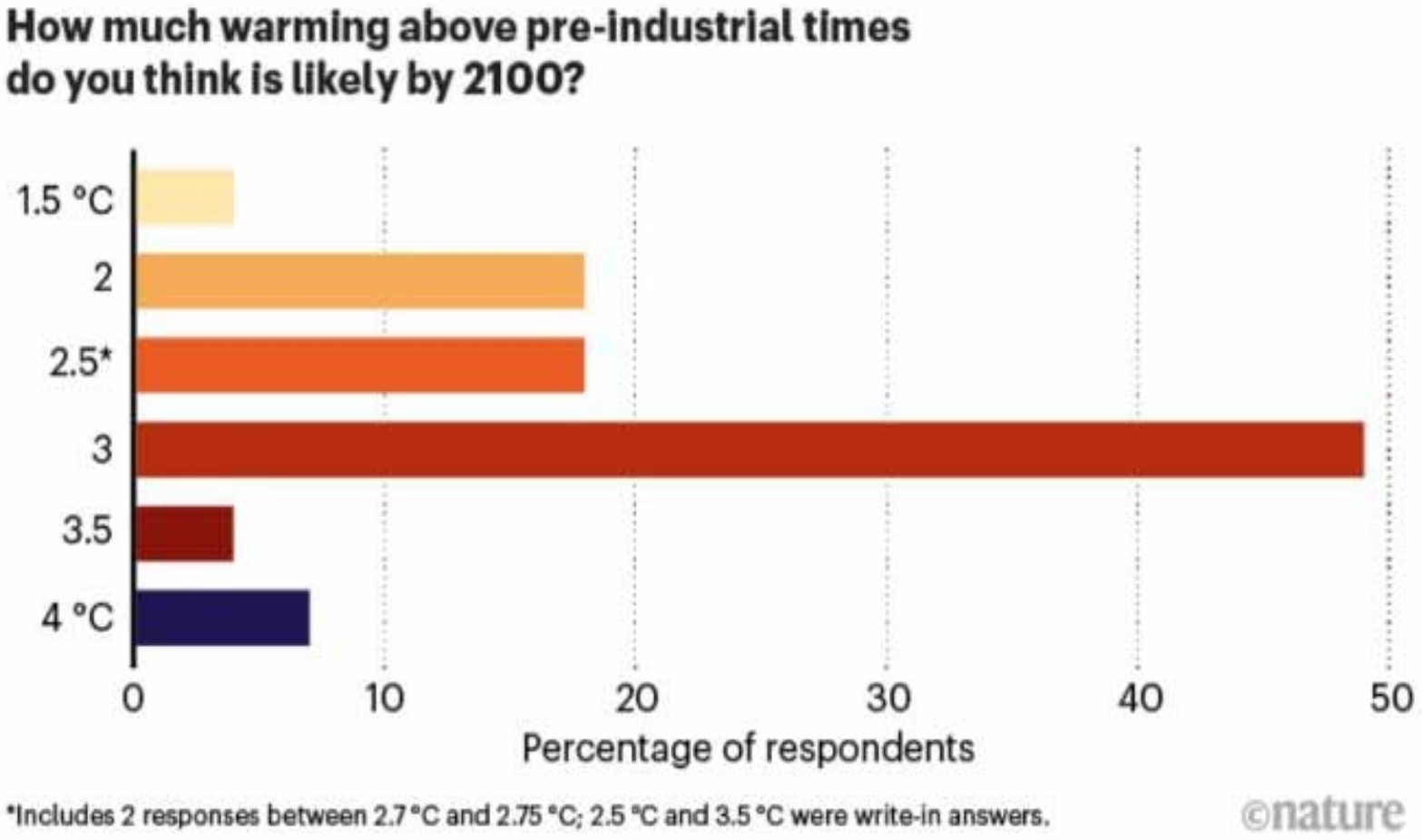
WELFARE DISCOUNTING ONLY MAKES SENSE FOR FINITE-LIFETIME ASSETS. THIS DOES NOT DESCRIBE EARTH. NOR DOES IT DESCRIBE CIVILIZATION (UNLESS THEIR INTENT IS TO KILL US ALL)

- There is some logic to applying a discount rate to a capital asset which has a finite amount and lifetime, if the goal is to maximize the profit potential of its limited lifetime of use to a single individual or finite-life entity, and in a small-scale context.
- But civilization itself, on the long term living Earth, does not have a death date.
- It is an on-going enterprise which morality requires we safeguard for all future generations, and which evolutionary biology instills such motivation within most of us (except the Neoclassical economists and their patrons, it seems).

IN THE CONTEXT OF CLIMATE CHANGE ECONOMICS, THE APPLICATION OF WELFARE DISCOUNTING THEREFORE MAKES NO MORAL SENSE, AND HAS NO MORAL JUSTIFICATION

- Realize the fundamental moral point here – Nordhaus' DICE model isn't just saying that individual people on average value rewards in the near term more than in the future. It's one thing to make this statement, which has truth to it.
- No; the moral point is that his **Civilization** Utility function insists on this discounting, and he, and all Neoclassical economists so defined, **advocate** that policy **should maximize** this absurd quantification of a Utility function.
- It is the moral equivalent of blurring the distinction between noting that some enraged sociopaths feel the desire to get an AR-15 rifle and go shoot up the local school (tragically true), *vs.* the Neoclassical Economists' advocacy that we therefore enforce this in our Utility function and make policy to encourage this behavior to the maximum (which is reprehensible in the extreme).

Six in ten of the respondents said that they expect the world to warm by at least 3 °C by the end of the century, compared with what conditions were like before the Industrial Revolution. That is far beyond the Paris agreement's goal to limit warming to 1.5–2 °C.



Source: *Nature* analysis

MOST CLIMATE SCIENTISTS ESTIMATE THAT THE SCIENCE, CONVOLVED WITH LIKELY HUMAN RESPONSE, WILL RESULT IN +3C TO +4C AND BEYOND BY 2100.

THIS, I'LL SHOW, WILL BE CATASTROPHIC ON INTO THE FAR DISTANT FUTURE.

FLAW: NORDHAUS USES THE COBB-DOUGLAS EQUATION TO LINK PRODUCTION, LABOR, AND CAPITAL, WITHOUT ENERGY INCLUDED

- This equation has poor fundamental justification by economists, is dimensionally inconsistent, and gives no recognition to energy in capital, labor, and production. Energy is only included as an independent(!) factor: the energy industrial group, which is only ~5% of the S&P 500 Index.
- In fact, the discovery of millions of years worth of fossilized solar energy can be shown to be the chief source of the remarkable production and wealth trends since the 1700's, not free-market capitalism. Labor and capital without energy will provide nothing.
- Without explicit inclusion of energy discovery, efficiency, and use, the Cobb-Douglas equation makes little sense in the real world. Economist Steve Keen has made a good attempt to include energy into Cobb-Douglas as an illustration of how radically it changes the outcomes.

ENERGY IS EVERYTHING; IN ECONOMICS AND ELSEWHERE

- ***"Labor without energy is a corpse. Capital without energy is a statue" – Economist Steve Keen***
- Unlike the Neoclassical school's belief that ~everything is substitutable, in fact NOTHING can substitute for energy. It is essential to all wealth. One can attempt to substitute within energy options, but in historical reality we're instead only adding energy options to our portfolio, not substituting.
- The fraction of global primary energy that comes from fossil fuels has remained at 81-87% ever since the 1970's, right up to today.

CLOUD PHYSICIST TIM GARRETT CONTRASTS THIS KIND OF QUESTIONABLE MACROECONOMICS WITH THE RIGORS OF FALSIFIABLE TESTING IN THE SCIENCES (GARRETT (2014) *"IS MACROECONOMICS A SCIENCE?")*

- My answer to Tim's rhetorical title question is: **No.**
- Neoclassical Economics is instead closer to being a Religion.
- …an ideology built on the faith that, no matter what problem we cause, innovation, price changes, and substitutability will always produce continual growth in civilization wealth, and, in practice, GDP is the marker to optimize.
- I will show in my future seminar "Civilization as a Thermodynamic System", that lauded innovations only make the final payment on a finite planet much worse.

ECONOMIST WILLIAM BARNETT – ON SELF EVALUATION, ALSO FINDS THAT "IS MACROECONOMICS A SCIENCE"? IS A VALID QUESTION, IN A (2006) PAPER OF THE SAME TITLE AS GARRETT'S…

- *"I started out as a rocket scientist (yes, a real one)*, after receiving my engineering degree from MIT in 1963. I worked on the development of the F-1 booster rocket… Although I changed professional directions, when I went back for my Ph.D., I have never forgotten what real science is. The more that I think about what Paul Samuelson has written in his Foreword to Barnett and Samuelson (2006) and my experience as an economist for over 30 years, the more I recognize the depth of the insights provided by Paul in his short Foreword."*
- And *"In short, as has been pointed out by Paul Samuelson (2006), we macroeconomists work within an environment of pressure and influence from our governments and societies. While few are willing to recognize or admit the existence of those pressures or the influence of those pressures on our own work, a clear understanding of trends in macroeconomic research is not possible without recognition of the influence of the intellectual, societal, and political environment within which the research is conducted".*

- *(Right; And reminds me [RN] of my days as a space systems thermodynamics designer/analyst at General Dynamics).

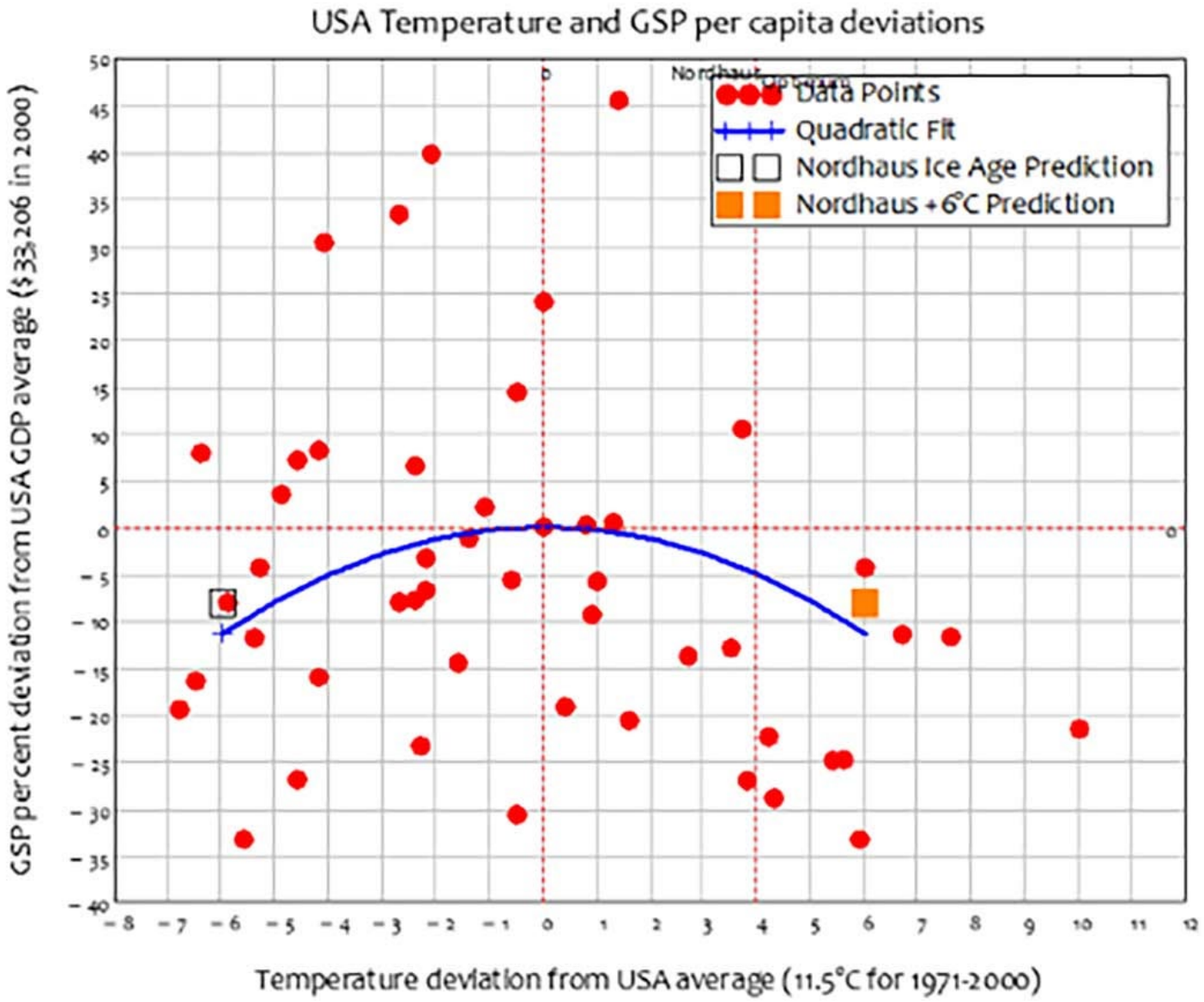
MORE BLUNTLY, BY INET (INSTITUTE FOR NEW ECONOMIC THINKING) GRANTEE ERIC WEINSTEIN (MATHEMATICAL PHYSICIST BY EMPLOYMENT AND TRAINING, AND PHYSICS OF ECONOMICS INVESTIGATOR)

- *"If you imagine a time when astronomy and astrology are housed in the same department, or chemistry and alchemy sit side by side at a university, such is the situation currently with economic theory. There is a portion of the field that seeks to return dependable conclusions to those who are its patrons. And there's another portion of the field that is fundamentally focused on getting things right, and understanding how the world works, but it is not the dominant part of the field that we see."*

ECONOMIST STEVE KEEN HAS BEEN ESPECIALLY CRITICAL OF NORDHAUS' WORK, AND ESSENTIALLY ALL OF NEOCLASSICAL ECONOMIC IDEOLOGY AND MODELLING

- His thoughts on explicitly including energy into the production function, together with others' work, shows that climate damages are much harsher than Nordhaus' claims. (Keen *et al.* 2019 also show a more accurate "Cobbs Douglas" function which includes energy.)
- I find myself in strong agreement with Keen's analyses.
- (Relevant slides will have to wait till my 3rd seminar).

Figure 3: Correlation of temperature and USA Gross State Product per capita



THIS DATA CHOICE, AND NORDHAUS' ARBITRARY PARABOLIC FIT, BEAR NO RATIONAL RELATIONSHIP TO THE DAMAGES FROM CLIMATE CHANGE.

IT IS NEVER JUSTIFIED AND, IN FACT, IS TRANSPARENTLY ABSURD. YET IT'S A CORE BASIS FOR HIS DAMAGE FUNCTION.

REGARDLESS OF THE QUESTIONABLE PARABOLIC FIT, IT ERRONEOUSLY ASSUMES LOCAL CLIMATE DAMAGE IS ONLY LINKED TO LOCAL TEMPERATURE

- This is rather amazingly naive to hear from an economist, who should know better than most the importance of trade, of imports of goods from far locations, and the fragility of networks affected by climate changes beyond the local. We are all linked globally to goods and services produced globally.
- And too - it is climate CHANGE and the well-known non-linearities of climate feedbacks that are so damaging to critical systems which can themselves try to adapt only slowly.
- Rapid change causes not just inconveniences, but extinctions.

PRECIPITATION PATTERNS, RIVER HEALTH, SOIL CARBON LOSS, EROSION RATES, ALBEDO CHANGES, PEST CHANGES, WEED AND PLANT CHANGES, ECOSYSTEM COLLAPSES, ARE ALL DEPENDENT ON THE VARIABLES OF NOT JUST TEMPERATURE, BUT CO2 LEVELS, CLOUD COVER, RAINFALL, AND THE COMPLEXITIES OF ECOSYSTEMS LOCALLY, REGIONALLY, AND GLOBALLY, ALL TIED TO CLIMATE CHANGE FROM GHG CHANGES.

IT IS STUNNINGLY NAÏVE TO ASSERT THAT WORKERS' TEMPERATURE COMFORT SOMEHOW IS THE DETERMINER OF ECONOMIC PRODUCTIVITY, AND INDEED, UTILITY GENERALLY. IT FLIES IN THE FACE OF ANY REPUTABLE ENVIRONMENTAL SCIENCE, AND TOO, HOW CENTRAL IS TRADE OF VITAL GOODS ACROSS WIDELY DIFFERENT CLIMATE ZONES.

FROM NORDHAUS 2017 *"REVISITING THE SOCIAL COST OF CARBON"*

- *"The damage function was revised in the 2016 version to reflect new findings. The 2013 version relied on estimates of monetized damages from ref. 6. It turns out that that survey contained several numerical errors (7). The current version continues to rely on existing damage studies, but these were collected by Andrew Moffat and the author and independently verified (see Supporting Information for details). Including all factors, the final estimate is that the damages are 2.1% of global income at a 3 °C warming, and 8.5% of income at a 6 °C warming."*
- **Damage of only 8.5% of accumulated year 2100 income in a +6C world? That's a trivial reduction to annual GDP of only 0.10% (!).**

NORDHAUS JUSTIFIES THIS SMOOTH MODELLING WITH A FRAUDULENT CLAIM THAT IT IS CONSISTENT WITH CLIMATE SCIENTIST TIM LENTON'S SURVEY, WHICH NORDHAUS CLAIMS SAYS THERE'S "NO TIPPING POINTS". LENTON IS A GOOD SCIENTIST; AND HE SAID, IN FACT, THE OPPOSITE.

Mainstream Economics Climate Change "data"

- Nordhaus justifies use of simple quadratic for damages from climate change:
  - "The current version assumes that damages are a quadratic function of temperature change and ***does not include*** sharp thresholds or ***tipping points***, but this is ***consistent with the survey by Lenton*** et al. (2008)." (Nordhaus & Sztorc 2013, p. 11)
- Lenton et al.'s actual conclusion:
  - ***"Society may be lulled into a false sense of security by smooth projections of global change.***
  - Our synthesis of present knowledge suggests that ***a variety of tipping elements could reach their critical point within this century*** under anthropogenic climate change." (Lenton 2008, p. 1792)

NORDHAUS' BLATANT MISREPRESENTATIONS OF THE CONCLUSIONS OF LENTON'S WORK

Lenton (Lenton, Held et al. 2008)	Nordhaus
Conclusion: Society may be lulled into a false sense of security by smooth projections of global change.	The current version [of the damage function in Nordhaus's DICE model] assumes that damages are a quadratic function of temperature change and does not include sharp thresholds or tipping points, but this is consistent with the survey by Lenton et al. (2008) (Nordhaus and Sztorc 2013, p. 11)
Our synthesis of present knowledge suggests that a variety of tipping elements could reach their critical point within this century under anthropogenic climate change.	Their review finds no critical tipping elements with a time horizon less than 300 years until global temperatures have increased by at least 3°C. (Nordhaus 2013, p. 60)
The greatest threats are tipping the Arctic sea-ice and the Greenland ice sheet, and at least five other elements could surprise us by exhibiting a nearby tipping point. (Lenton, Held et al. 2008, p. 1792)	The most important tipping points, in their view, have a threshold temperature tipping value of 3°C or higher (such as the destruction of the Amazon rain forest) or have a time scale of at least 300 years (the Greenland Ice Sheet and the West Antarctic Ice Sheet). (Nordhaus 2013, p. 60)

EVEN MORE AMAZING: NORDHAUS ASSUMES 87% OF THE ECONOMY WILL BE UNAFFECTED BY CLIMATE CHANGE BECAUSE IT IS CONDUCTED INDOORS, WHERE AIR CONDITIONING WILL FIX THINGS. THIS IS AN INCREDIBLY NAIVE CLAIM. (NORDHAUS' CLAIMS BELOW)

Mainstream Economics Climate Change "data"

- "Data" used by economists concocted to fit pre-existing biases
  - "First, it must be recognised that ***human societies thrive in a wide variety of climatic zones***. For the bulk of economic activity, ***non-climate variables*** like labour skills, access to markets, or technology ***swamp climatic considerations in determining economic efficiency***." (Nordhaus 1991, p. 930)
    - Mistaking climate:GDP data today for impact of climate change as energy levels of biosphere increase dramatically
  - "3% of ***United States national output*** is produced in highly sensitive sectors, another 10% in moderately sensitive sectors, and about ***87% in sectors that are negligibly affected by climate change***… (p. 930)
  - for the bulk of the economy - ***manufacturing, mining, utilities, finance, trade, and most service industries*** - it is difficult to find major direct impacts of the projected climate changes over the next 50 to 75 years…

IN FACT, WELL BEFORE A +6C WORLD, MOST OF THE PEOPLE STAYING IN THE TROPICS COULD BE DEAD OR DYING FROM HEAT STROKE

- The wet bulb temperature T_{WB} reaches fatal levels (for mid-latitude acclimated test subjects) regularly during the year when the average annual temperature exceeds 30C = 85F.
- No place on Earth experiences that today, although places in India and the Red Sea are very close.
- As we climb past +2.5C average global temperature, such dangerous areas rapidly begin to occupy the tropics.
- At +3C, 3 billion currently situated people will be in areas above this limit (Xu *et al.* 2021).
- Already, T_{WB} extremes are arriving much sooner than climate models had predicted (~2080) (source)
- See also Raymond *et al.* 2020, and Sandra Faber's excellent talk to lead off this series.

THE PRIOR SLIDES' BLUE SHADED IMAGES ARE FROM A TALK BY ECONOMIST STEVE KEEN IN 2020

- **Nordhaus' DICE model claims that climate damages are so low that it's uneconomical to do anything about climate change until +4C is reached.**
- In this polite company here at EFI, I will not use the appropriate words to describe my reaction to such a claim – which is not made by an uneducated freshman econ undergrad, but from a Yale economist of high profile and influence. It's utterly disgraceful.
- In fact, I don't believe such a claim could happen in a context of sincere academic diligence and proper consultation with climate scientists. This modelling simply cannot be justified in any responsible, ethical way. It is reprehensible.
- In fact, Nordhaus admits his advisors were almost exclusively economists.

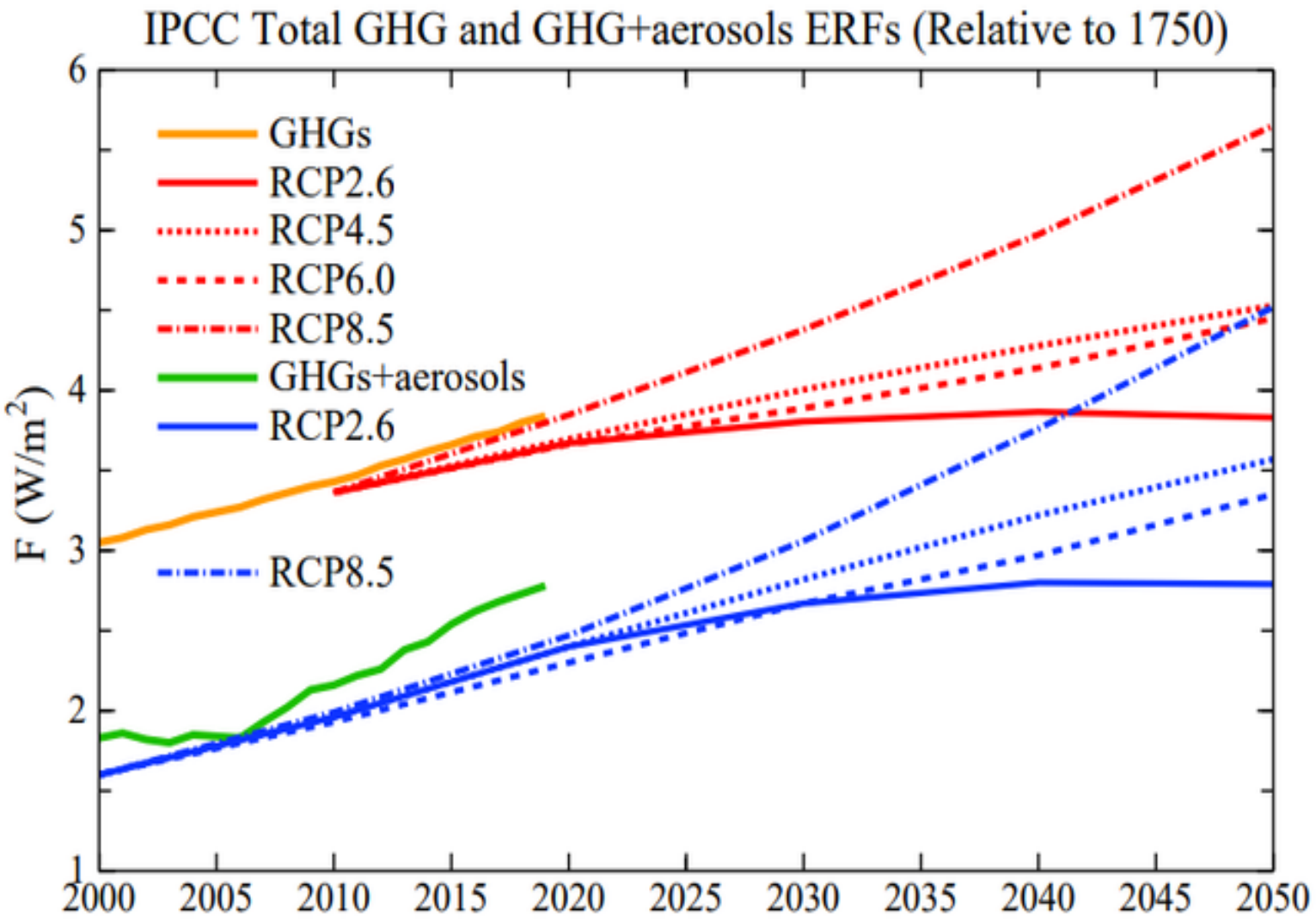
AND TO DATE, NO APOLOGY, NO RETRACTION, DESPITE THE OUTRAGE FROM CLIMATE SCIENTISTS

- Only rather weak tweeks to his model…. Consider his “Nobel” award lecture:
- *“The latest full version of the DICE model (DICE2016-R2) has much the same structure as the first version, but it has revised each of the major sectors in small or large ways. The evolution of the DICE model 1992–2016 is reviewed in Nordhaus (2018a)”* (Nordhaus 2018). And here, adding a bit more to damage for “unknowns”.
- And even more appalling: *“there is at this point no serious evidence of the presence of fat tails for the damage distribution”. (Nordhaus 2018 p. 11)*
- The true damages and risks from climate change are, in fact, the main subject of my 3-part series of talks, begun here.

FROM A PHYSICS NOBEL LAUREATE AND FORMER ENERGY SECRETARY STEVEN CHU…

- *"As we warm to +4, +5, +6C, many scientists are feeling this (runaway permafrost feedback thaw) will really kick in. WE CANNOT GO THERE"* (source) This was said in 2010. Now…

- Our improving permafrost feedback understanding with higher near-term methane emissions from thermokarst, from neglected winter emissions, from higher Global Warming Potential numbers, has only shown deeply worsening dangers with each new study since then.

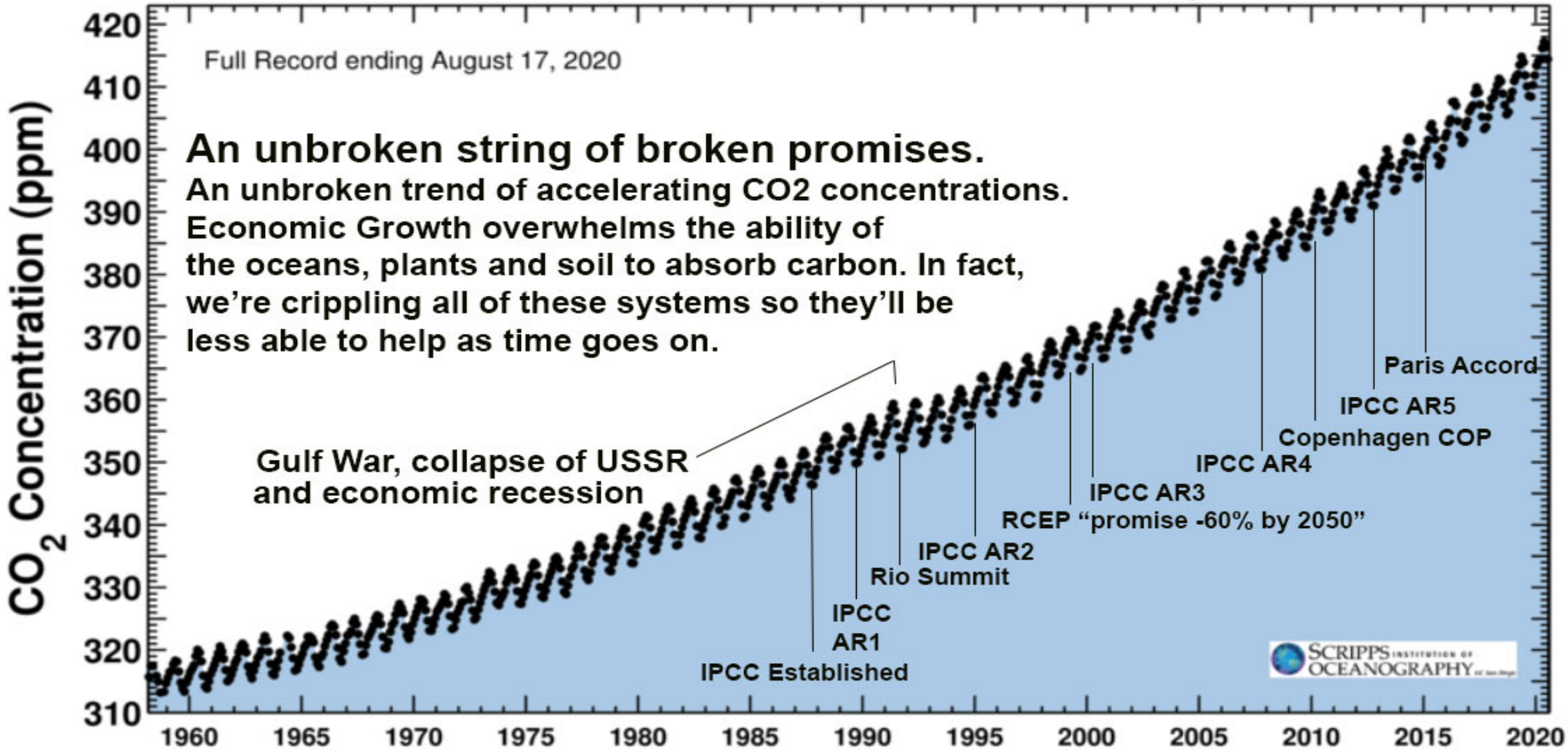


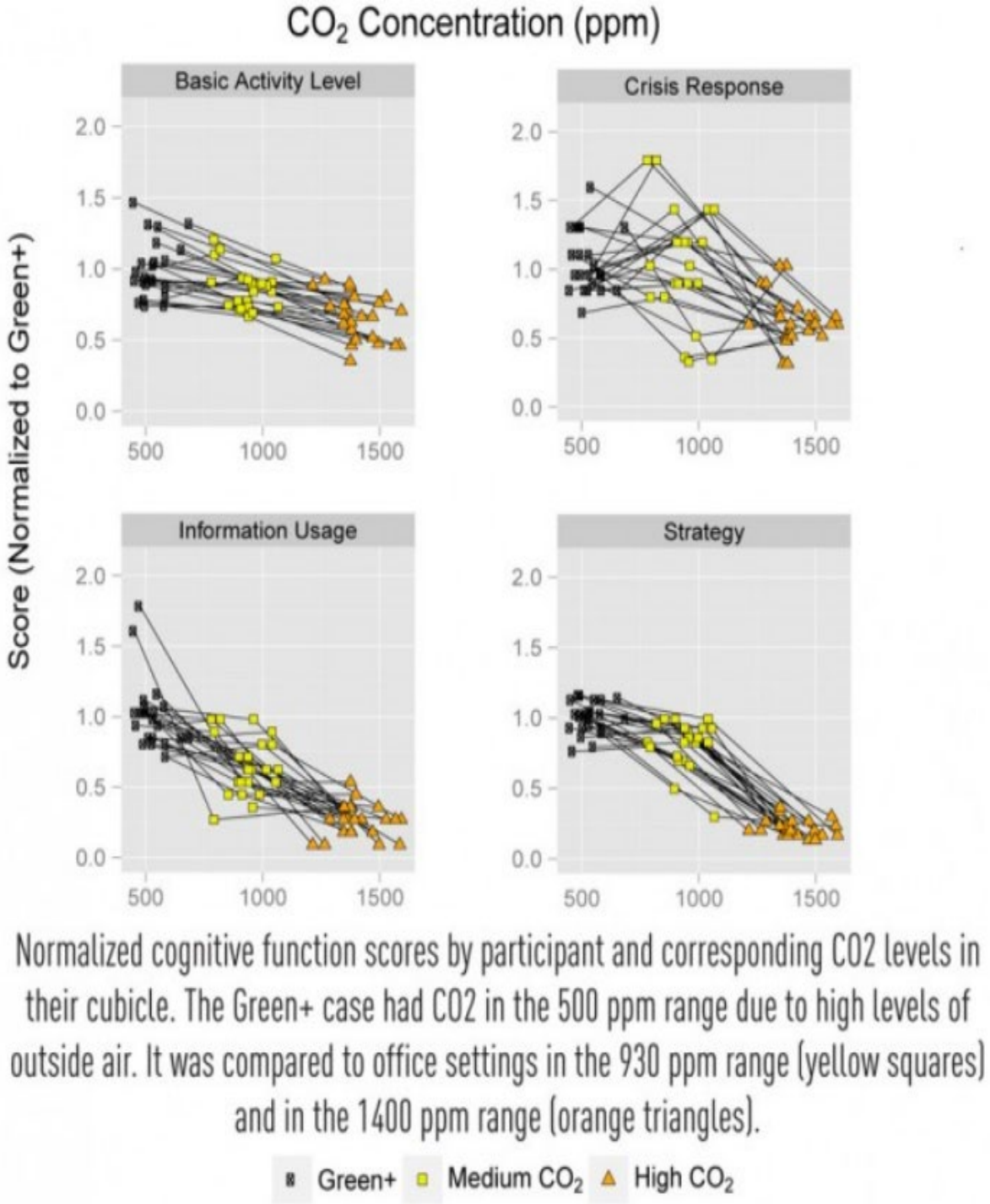
Histotical Data are from IPCC(2021) Table AIII.3
RCPs GHGs data are the sum of IPCC(2013) Table AII.6.1−6.7b
RCPs GHGs data are from IPCC(2013) Table AII.6.8

MEANWHILE, GHG EMISSIONS HAVE STAYED STUBBORNLY ABOVE THE STRONGEST GLOBAL WARMING TREND CONSIDERED BY THE IPCC: THE RCP=8.5 EMISSIONS TREND... THE GREEN GHG + AEROSOLS CURVE IS LOWER BECAUSE AEROSOLS (*e.g.* COAL SMOG) REFLECT SUNLIGHT AND ACT AS CLIMATE COOLANTS. IF WE DO EVENTUALLY DECIDE TO REDUCE COAL, THIS COOLING EFFECT WILL ALSO BE REDUCED.

August 17, 2020

Carbon dioxide concentration at Mauna Loa Observatory





Normalized cognitive function scores by participant and corresponding CO2 levels in their cubicle. The Green+ case had CO2 in the 500 ppm range due to high levels of outside air. It was compared to office settings in the 930 ppm range (yellow squares) and in the 1400 ppm range (orange triangles).

HIGH CO2 IS TOXIC TO MENTAL FUNCTIONS, (AND TO PHYSICAL FUNCTIONING), QUITE ASIDE FROM EFFECTS ON TEMPERATURE AND OTHER CLIMATE DAMAGE.

WAS THIS FACTORED INTO ANY NEOCLASSICAL CLIMATE ECONOMICS MODELLING? **NO**.

IT IS INEXCUSABLE FROM SUPPOSEDLY PHD LEVEL ACADEMICS TO SO WIDELY DISREGARD CLIMATE SCIENCE - IS ECONOMISTS' OWN MENTAL DECLINE ALREADY IN PLAY HERE?

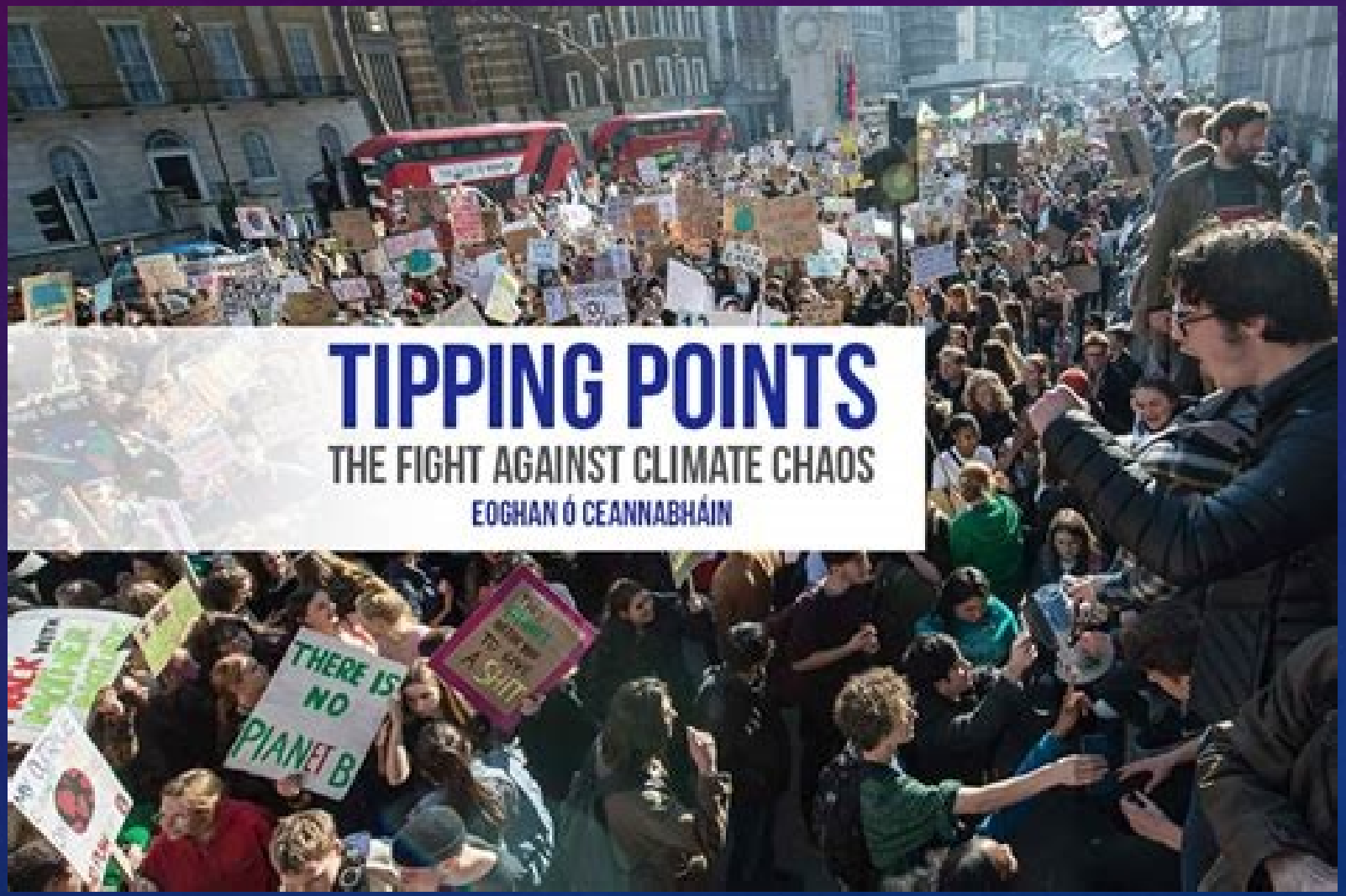
FLAW: ASSUMPTION THAT OUR CLEVERNESS WILL ALWAYS INSURE ECONOMIC GROWTH (HUSSEN 2004)

- Nordhaus and Neoclassicals believe: Malthus and Paul Ehrlich-type doomists have been wrong (true), therefore they will always be wrong…
- False. We're today using up 1.7+ Earth's worth of sustainability on our 1.0 Earth's, expanding exponentially. Innovation has so far outrun paying the consequences, but this will not continue forever, as we'll show.
- Our dangers are being masked by the fact we're eating through our environmental seed corn (which is not quite exhausted, yet) and off of our children's inheritance.
- This future is a qualitative change from futures that earlier generations could look forward to.
- Yet, Nordhaus continues to advise (in a recent interview), ***"why don't we just keep getting wealthier now, so we'll have more resources to deal with the problem later"***
- **Innovation, in the context of actual human motivations, will not save us. See "Civilization as a Thermodynamic System", a later slide set and Presentation in this series.**

HISTORY SHOWS POLICY MAKERS PREFER TO "KICK THE CAN" DOWN THE ROAD

- Nordhaus' work is being used as permission by policy people to leave future generations a problem that will have tipped beyond their control.
- I wonder: How will this affect future generations' motivations, their emotional abilities to cope, their willingness to get up each morning and be well-behaved units of production?

FLAW: IGNORING STEEPLY NON-LINEAR SOCIAL EMERGENT BEHAVIOR COSTS: RIOTS, WARS, SHUT-DOWNS, BORDER CONFLICTS…



THE COLLAPSE OF EMPIRES HAPPENS FROM WITHIN; A SYSTEM SUCH AS WE'VE CREATED, AND ABETTED BY NEOCLASSICAL ECONOMISTS, HAS CONSEQUENCES. A TALK FROM BILLIONAIRE NICK HANAUER… "THE PITCHFORKS ARE COMING"

CONSIDER: THE DROUGHT A FEW YEARS AGO IN SYRIA RESULTED IN ONE MILLION REFUGEES, MOSTLY INTO TURKEY AND EUROPE, CAUSING WORSENING POLITICAL CHANGE IN BOTH.

- The previous historically welcoming attitude of Europe toward immigrants has reversed, installing right-wing anti-globalist leaders in many countries.
- Yet even the UN is predicting **100 million, on up to 2 billion refugees** from climate damaged tropical countries. (added later: We'll see in Part 3 it could be significantly higher still).
- More and more countries are tilting towards Fascism, and erecting border walls…

…IN THE UNITED STATES…

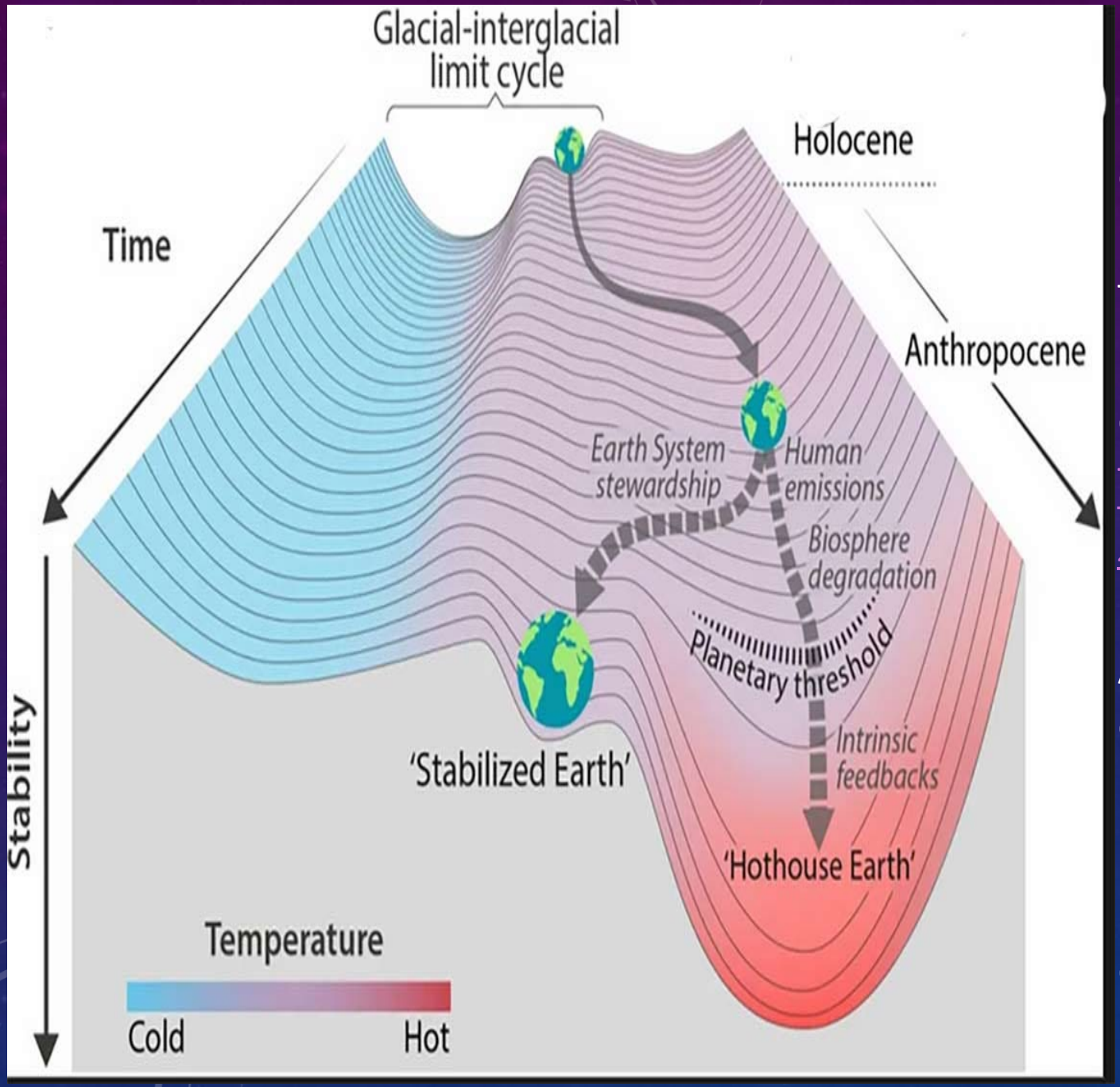
IN BRAZIL, HOME TO THE AMAZON RAIN FOREST: “THE LUNGS OF THE EARTH” – WHICH IS IN STEEP DECLINE, AIDED BY JAIR BOLSONARO

AND OTHER COUNTRIES, TRENDING TOWARDS RIGHT WING AUTHORITARIANISM AND DE-GLOBALIZATION

- Russia
- Italy
- Turkey
- almost France, this month (May ‘22)
- Afghanistan
- China’s re-born Mao-ist leadership
- And others…

3: BADLY UNDERPLAYED CLIMATE DANGERS

- and ignorance of modern climate science



BY FAR THE WORST SCIENTIFIC OFFENSE OF ALL OF THESE NEOCLASSICAL ECONOMISTS' MODELS, IS THEIR REFUSAL TO RECOGNIZE TIPPING POINTS. EVEN DURING THE MUCH MORE MILDLY PACED CLIMATE SHIFTS IN THE PALEO DATA, TIPPING POINTS WERE REAL (SETTY *et al.* 2023)

A +6C WORLD WILL BE VIRTUALLY CERTAIN TO HAVE TIPPED US INTO A NEW "HOT HOUSE EARTH" REGIME (STEFFEN *et al.* 2018) . INDEED, TIPPING POINTS ARE BEING CROSSED TODAY AT ONLY +1.2C

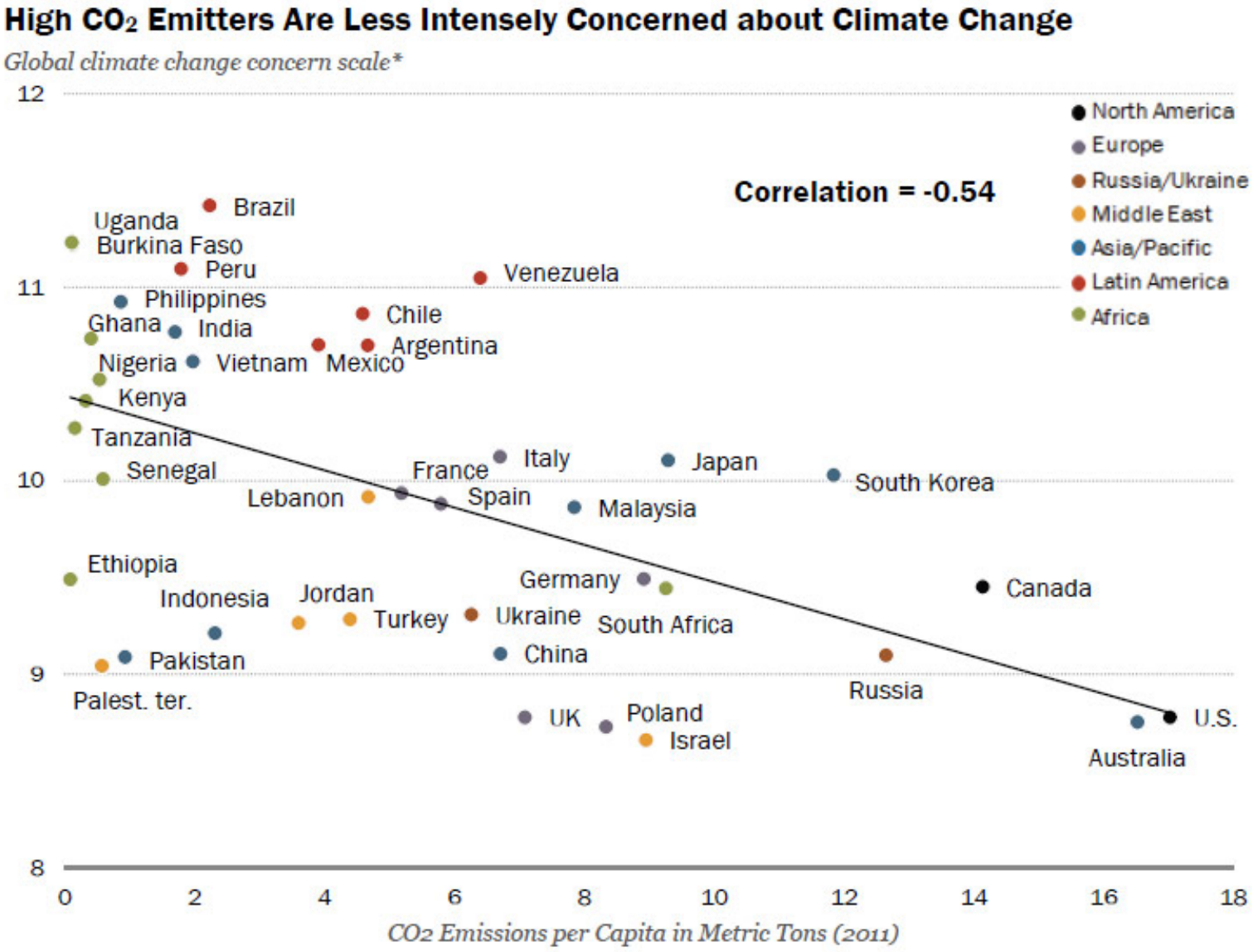
WELL BEFORE +6C, DEADLY TEMPERATURES AND HUMIDITIES WILL HAPPEN REGULARLY OVER AREAS CURRENTLY OCCUPIED BY HUNDREDS OF MILLIONS, TO BILLIONS OF PEOPLE.

- *e.g.* Raymond *et al.* 2020
- See Sandra Faber's earlier EFI Econ talk last month.

BACKGROUND FOR INTERPRETING CLIMATE SCIENCE SOURCES: GO TO THE PEER-REVIEWED JOURNALS.

DO NOT RELY ON POLITICALLY DOCTORED OFFICIAL U.N. IPCC STATEMENTS…

- In fact, my first recommendation to effective climate action: I urge the IPCC scientists to divorce themselves from the UN and the IPCC.
- I urge the scientists to issue their summary reviews and their policy evaluations, but WITHOUT interference and intimidation from the politicians' and economists' censorship. And require only ~95% consensus from scientists, not 100%. Don't let good science be stone-walled by a few industry/economic corrupt members.



* 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.

PEW RESEARCH CENTER

THE WORLD'S HIGHEST CO2 EMITTERS ARE ALSO THE LEAST CONCERNED ABOUT CLIMATE DANGERS.

THEY ARE ALSO THE MOST POWERFUL COUNTRIES IN THE U.N..

THE U.S. IS THE WORST.

THE POLITICAL MANIPULATION OF THE IPCC SCIENTISTS

- Scientists are complaining that the latest AR report, as well as earlier ones, have a “vast blind spot” on the role of the fossil fuel and right-wing sponsored mis-information campaigns.
- *“This is an important barrier to climate action, but it is never addressed,” said Professor Robert Brulle of Drexel University, who has published research on the funding* ***and influence of climate science denial efforts.***
- *“A large existing literature on this was ignored by the IPCC,” he added.*

ON COMING CLIMATE CHANGE…

"…Scientists were not telling the whole truth. Because they were discouraged from telling the whole story, even explicitly told not to do so."

- Page 4 of James Hansen, 2019

THE UN'S IPCC: PROMISED TO SCIENTISTS AS A MEANS FOR SCIENCE TO INFLUENCE POLICY…

- …but in operation, by choosing scientists and policy people with a "range of views" and then encapsulating the scientists within the UN mandated rules for 100% "consensus" reached with political policy overlords, the IPCC acts as a mechanism to instead **neuter** the science (see following slides).
- Far worse, it places the public imprimatur of science on these compromised and under-stated documents.
- **Each new IPCC Assessment Report reveals how they have underestimated future damages in previous AR's.**

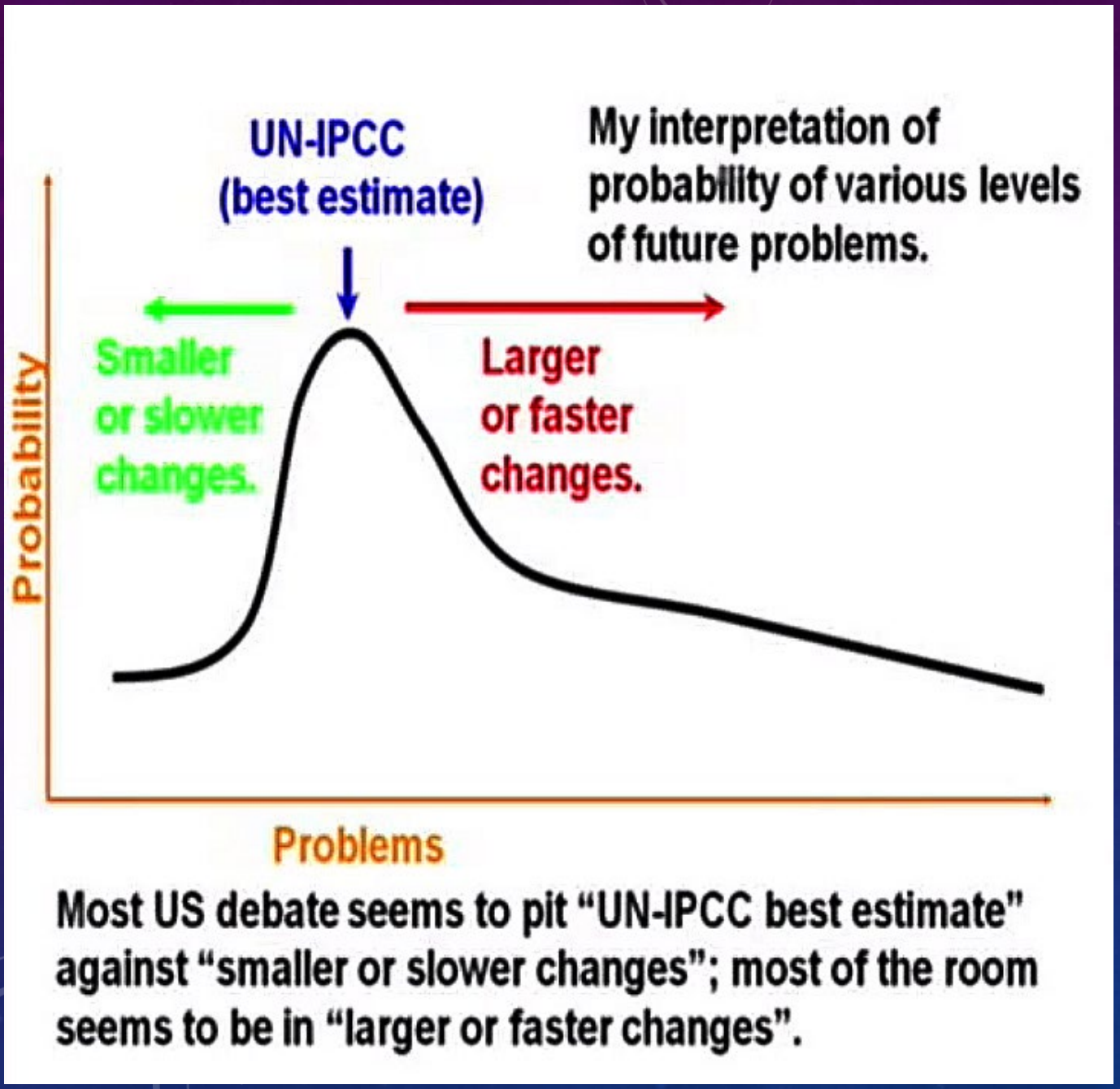
IPCC MEMBERS ARE CHOSEN DELIBERATELY WITH A *"RANGE OF VIEWS"*, 100% OF WHOM MUST AGREE TO A "CONSENSUS" TO ALL PUBLICATIONS…

- The UN thus insures veto-power for the small minority of industry-sponsored members, and the IPCC economists and policy representatives, therefore biasing towards bland pronouncements that don't question the existing political/economic paradigm.
- The rules can be seductive wording to scientists, who are used to truth-seeking debates with fellow scientists, and appeals to their valuing of inclusiveness as well. But the political / economics people are a different sort.

EVEN FOR GOOD ACADEMIC CLIMATE SCIENTISTS - FUNDING SUPPORT IS LARGELY BY GOVERNMENTS STRONGLY FAVORING PRO-GROWTH

"The modelling community is actually self-censoring its research to conform to the dominant political and economic paradigm..."

-- Tyndall Climate Centre Deputy Director, Dr. Kevin Anderson



THE IPCC'S SCIENTISTS *vs.* POLICY PEOPLE - HAGGLING OVER CONSENSUS THUS ENDS UP BEING BETWEEN THE IPCC "BEST" (ACTUALLY, TOO MILD) AND THE EVEN MILDER CLIMATE CHANGE SIDE; NOT WITH THE BETTER SCIENCE-SUPPORTED WORSENINGS. IPCC IS "BIASED TOWARDS LEAST DRAMA"…

YET FAT-TAIL SEVERE AND IRREVERSIBLE CONSEQUENCES CONTINUE TO GET FATTER WITH NEWER RESEARCH.

THE FOREGOING WAS A WARNING

- … for the reader to realize the official IPCC statements, especially those taken from the brief and far more widely influential "Summary for Policy Makers", are not down the middle of the best published science, but instead biased to the mild side, as enforced by the veto power of the economists / policy members of the IPCC.
- Let's now look at the best current climate science *vs.* Nordhaus' assumptions…

GREENHOUSE FORCING RISE RATES ARE NOT ONLY RISING, THE RISE **RATE** IS ITSELF ACCELERATING (HANSEN *et al.* 2017). THIS FORCES RAPIDLY ACCELERATING TEMPERATURE RISES. **MANIFESTLY NOT THE EQUILIBRIUM BEHAVIOR INHERENT IN NEOCLASSICAL ECONOMIC ASSUMPTIONS.**

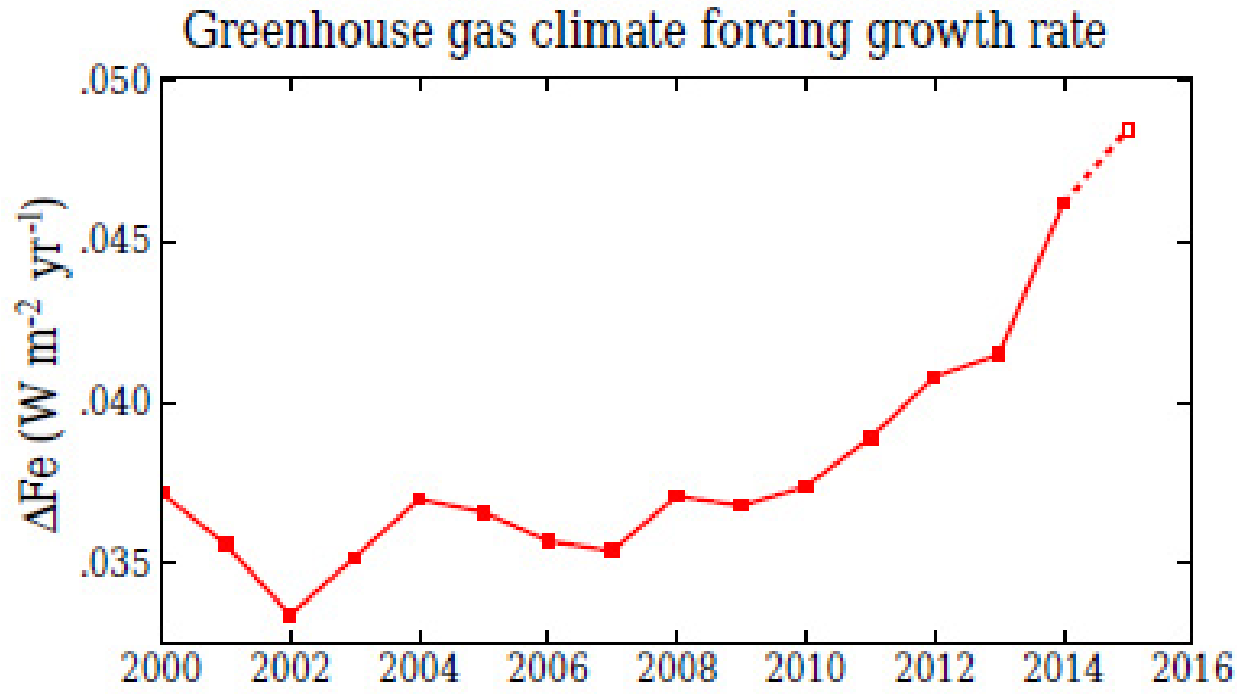
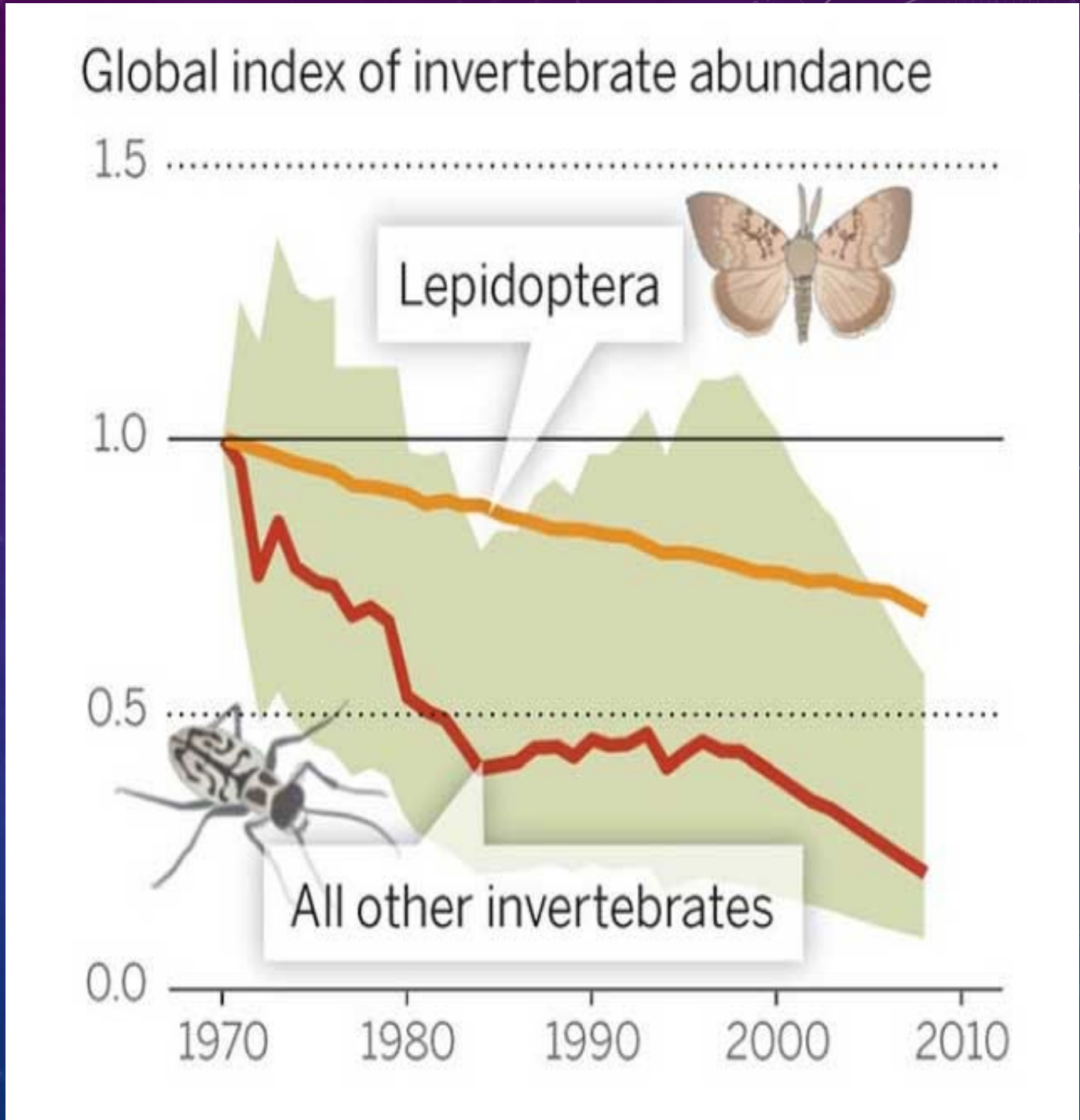
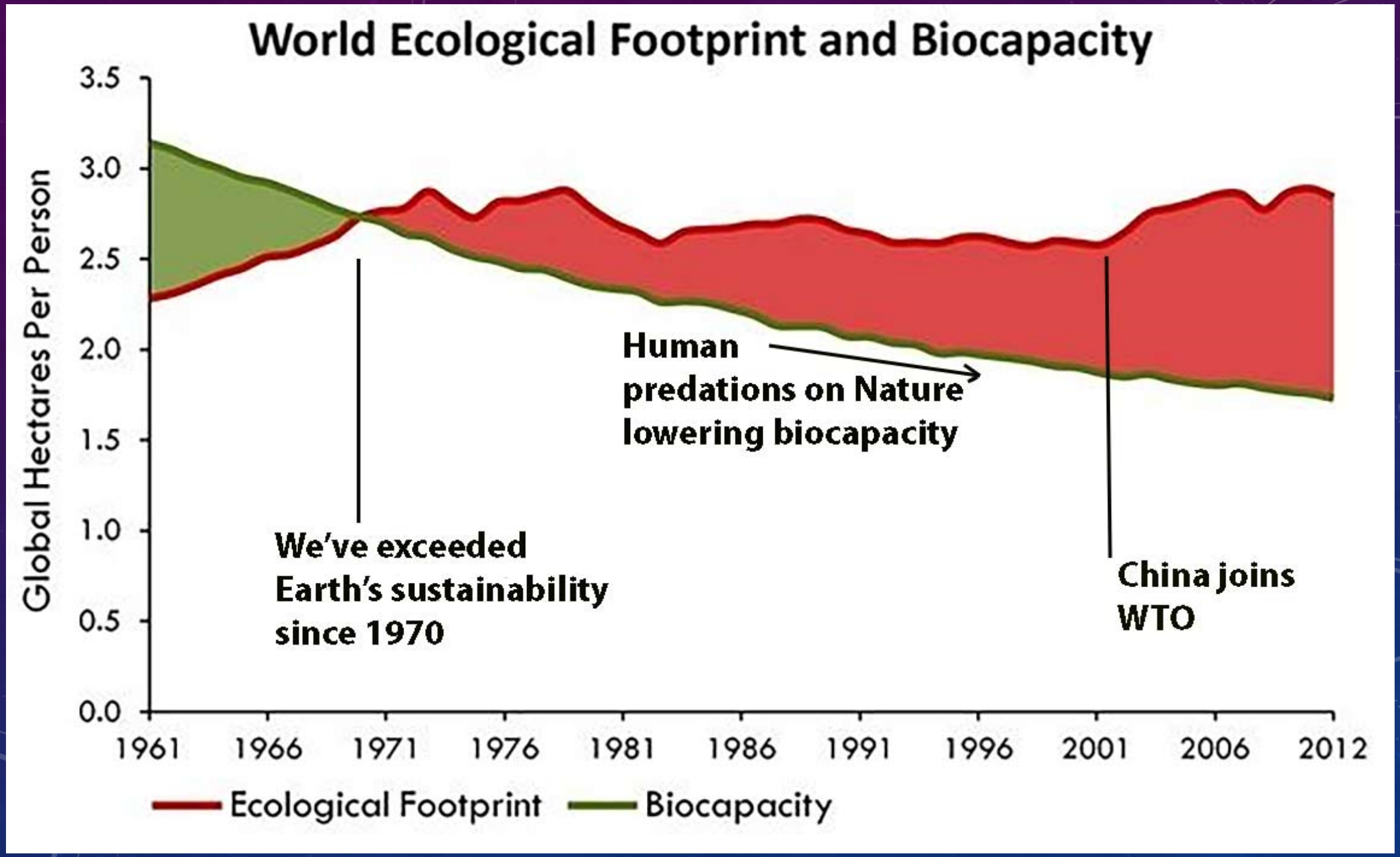


Figure 14. Recent growth rate of total GHG effective climate forcing; points are 5-year running means, except for 2015, which is a 3-year mean. See Fig. 8 for individual gases.

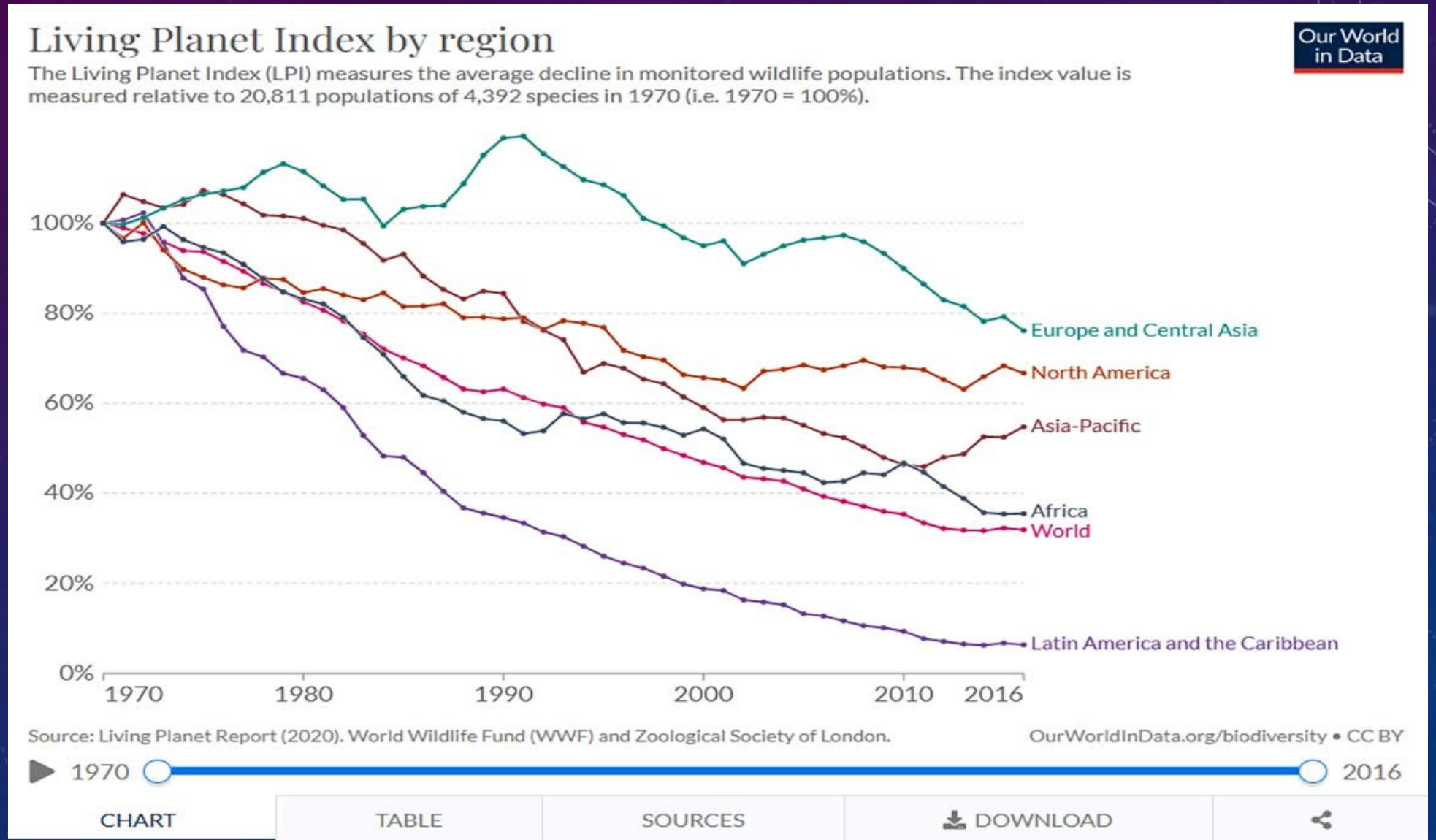
INSECT POPULATIONS, ESSENTIAL FOR PLANT ECOLOGIES AND A KEY BASE OF THE GLOBAL FOOD CHAIN – ARE PLUMMETING GLOBALLY AT 2.5% PER YEAR.

- That’s a halving time of only 29 years.




World Ecological Footprint and Biocapacity
Global Hectares Per Person
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1961
1966
1971
1976
1981
1986
1991
1996
2001
2006
2012
Human predations on Nature lowering biocapacity
We've exceeded Earth's sustainability since 1970
China joins WTO
Ecological Footprint
Biocapacity

AS OF 2017, LPI SPECIES POPULATIONS AS MEASURED BY THE LIVING PLANET INDEX LPI, HAS DECLINED TO ONLY 30% OF ITS 1970 VALUE; THE TIPPING POINT WHEN OUR RESOURCE CONSUMPTION FIRST SURPASSED EARTH'S SUSTAINABILITY.

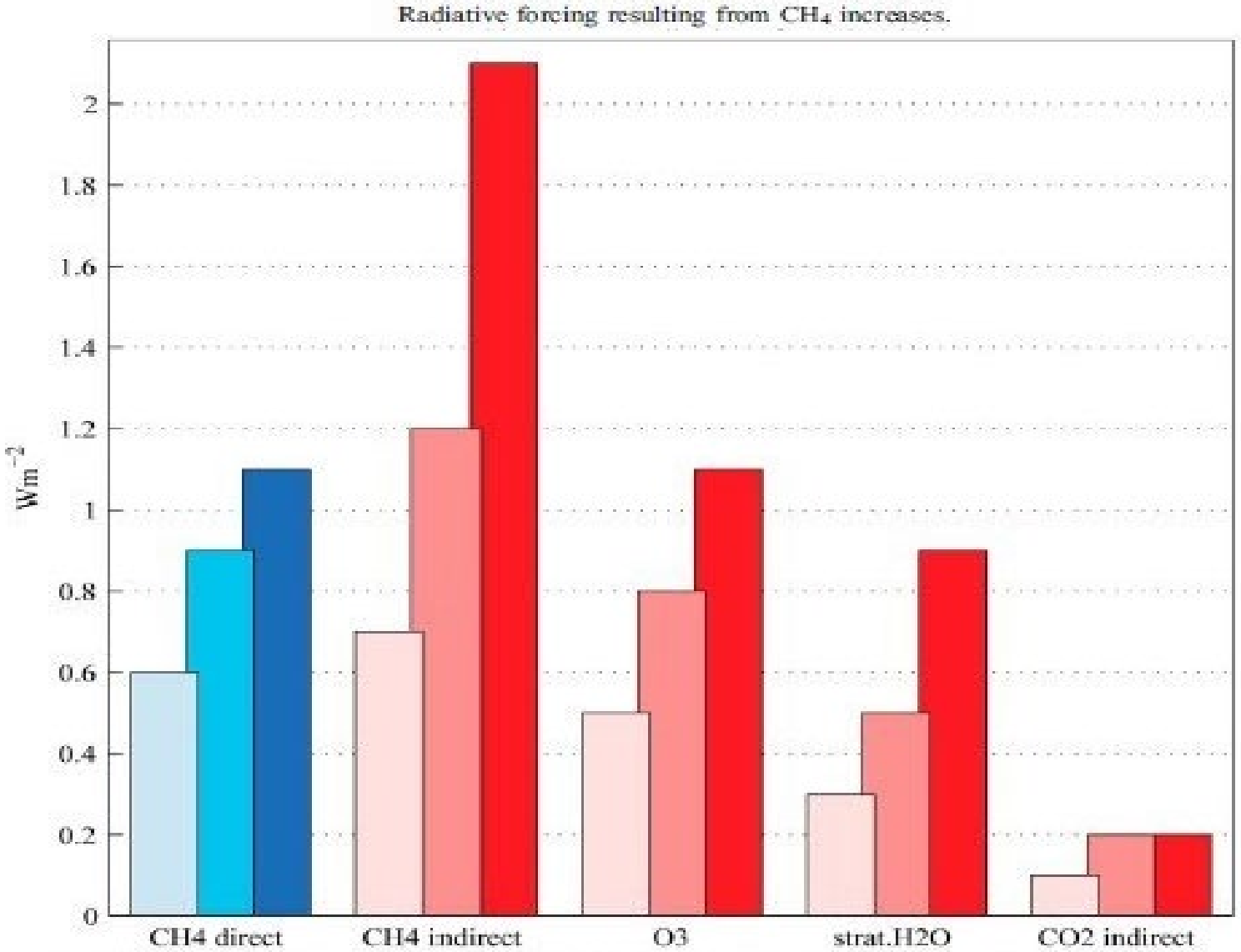


REALTY INFORMATION COMPANY ZILLOW CALCULATED THAT U.S. HOME VALUE LOSSES FOR MERELY A 6 FT SEA LEVEL RISE, (AT THE MILD END OF REALISTIC PROJECTIONS FOR 2100, AND RISING MORE STEEPLY THEREAFTER IN ANY CASE), AND FOUND…

- It would total **$1 Trillion in the U.S. alone.** For the world, obviously far higher.
- That only includes home values, not the larger losses of infrastructure, ports, *etc.*, nor loss of life (these floodings will happen during storms at first, before settling into permanence).
- So, assumed required continuous rebuilding may happen faster than Nordhaus believes

CLIMATE DAMAGE EFFECTS IGNORED…

- Ignored: Societal emergent phenomena when damages become manifest (wars, food riots, chaotic border violence, rise of fascism…)
- Ignored: The fact that it is not temperature *per se*, it is rapid CHANGE that is so dangerous. And, interlocking feedback loops that cause systemic change which Neoclassical's simple treatments ignore.
- In general, the "Enumerative" damages approach of Neoclassical Economics here, ignores the non-linear interactions between climate aspects and damages.
- Neoclassical economists are fond of the "Gales of creative destruction"; they may be consciously or unconsciously welcoming ANY change as being a great opportunity for more spending, with at least some of us getting rich. But damage that must be repaired is not true increases in welfare, it is inflation at its purest, and some will financially benefit, while others, especially future generations, bear the cost.
- **Is this creating wealth, or is it theft from future generations and from other life?**



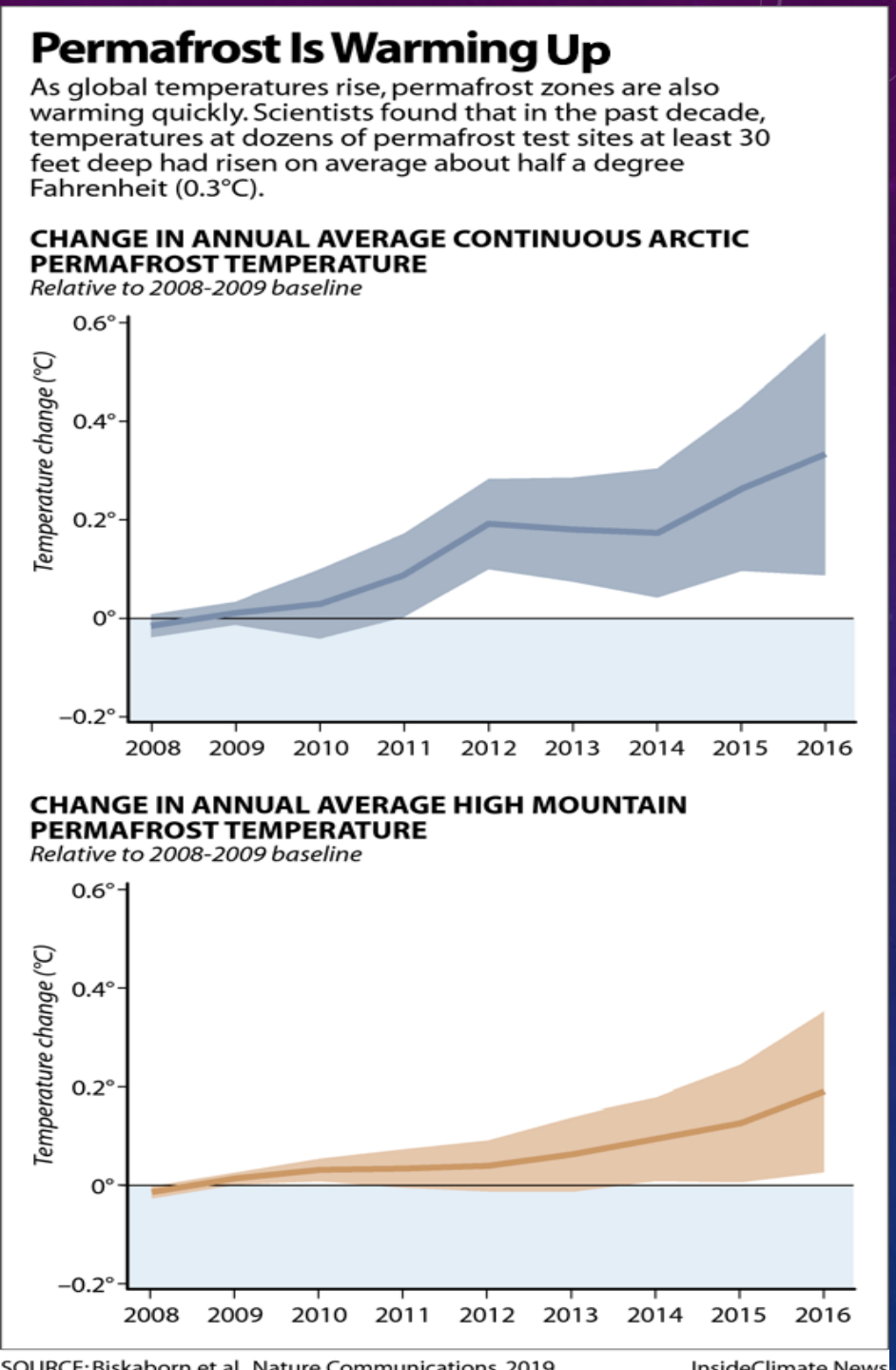
Credit: Isaksen et al. doi:10.1029/2010GB003845, 2011 Blue bars denote contributions from direct emissions, and red bars are contributions from CH_4 initiated changes in atmospheric composition. "CH_4 indirect" represents the CH_4 enhancement that is due to the increase in its lifetime. "CO_2 indirect" relates to the CO_2 enhancement due to oxidation of the additional CH_4. The lightest colors refer to the 4 × CH_4, medium light colors to the 7 × CH_4 and dark colors to the 13 × CH_4 case. The radiative forcing is not related to a particular year but to the time when the CH_4 increase is reached. The 13 × CH_4 case refers to a shorter time horizon (30 years) while the other cases are based on a 50 year time horizon.

INDIRECT HUMAN-CAUSED METHANE EMISSIONS NOW LARGER THAN DIRECT EMISSIONS; CHARACTERISTIC OF UNRECOVERABLE TIPPING POINT BEHAVIOR.

"CONSIDERING THE LARGE, NONLINEAR ATMOSPHERIC CHEMISTRY FEEDBACKS DISCUSSED HERE, FUTURE CH_4 EMISSIONS FROM PERMAFROST DEPOSITS COULD BE A LARGER CONCERN FOR CLIMATE WARMING THAN PREVIOUSLY THOUGHT." – (ISAKSEN *et al.* 2011)

THE PERMAFROST THAW TIPPING POINT IS CLOSE

- Vaks *et al.* 2013 found that Arctic permafrost will thaw as far north at +60 latitude once global surface equilibrium temperature of +1.5C is reached and maintained.
- While his later data questions whether the +1.5 C limit corresponds to a GLOBAL average temperature, because the North Atlantic ocean temperature also affects speliothem growth, the worry remains that observed thaw suggests we're already very close to that now.
- We are at +1.21C at the close of 2019 using the old 1880-1910 convention as "pre-industrial" baseline temperature (adopted only because pre-1880 data is poorer).
- **But we are at +1.42C** using the better motivated Schurer, Mann, *et al.* (2017) pre-industrial temperature baseline. And yet the permafrost is already thawing.



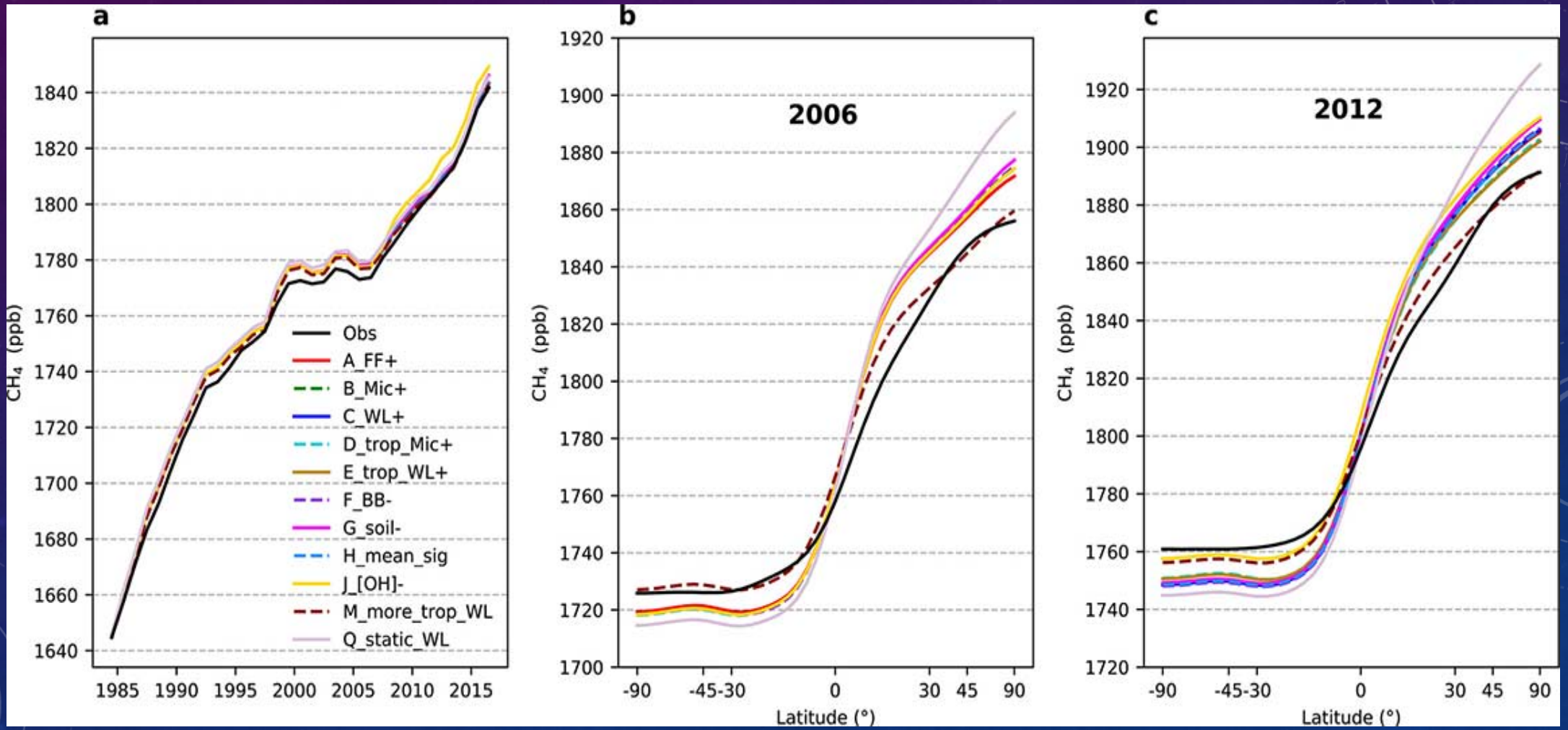
IN 2020, A NEW STUDY (MARTENS *et al.* 2020) SUGGESTS THAT PERMAFROST IS INDEED CLOSE TO THE TIPPING POINT, AT TODAY'S +1.45C ABOVE SCHURER, MANN, *et al.'s* BETTER MOTIVATED NEW PRE-INDUSTRIAL BASELINE.

OTHER NEW STUDIES ARE CONSISTENT.

HOW MUCH OF RISING METHANE IS FROM SUCH INDIRECT HUMAN-CAUSED SOURCES, *vs.* DIRECT HUMAN-CAUSED?

- This is a critical question – we can only directly control methane emissions from direct human causation, such as fossil fuel mining and *e.g.* pipeline leakage.
- We cannot control the permafrost except very indirectly and with a major time lag and risk of loss of all control via tipping point crossing and hysteresis (see later slide).
- Global CO2 is up only 50% since pre-industrial. But global methane is up over 300% since pre-industrial, despite its short ~10 year atmospheric chemical half-life.

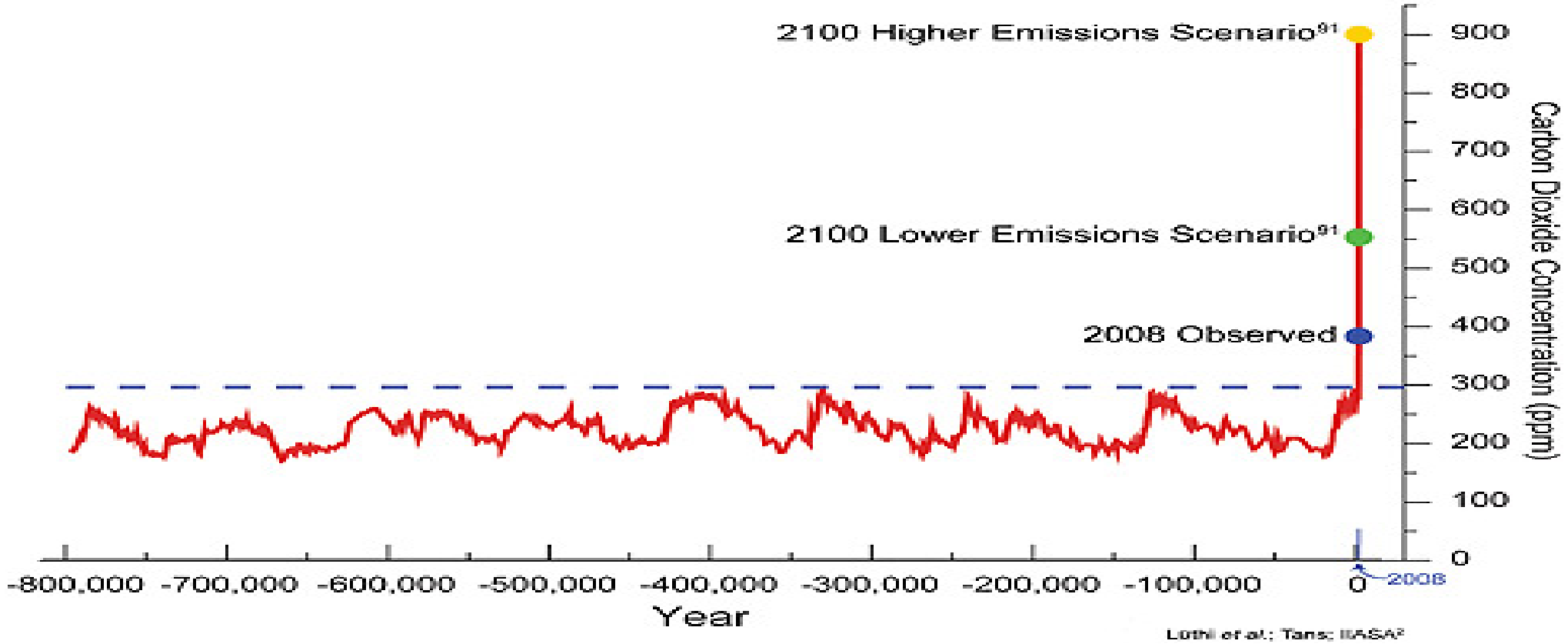
ATMOSPHERIC METHANE CONCENTRATIONS ARE HIGHEST IN THE ARCTIC, AND ACCELERATING (LAN *et al.* 2021). WETLANDS METHANE FROM THAWING THERMOKARST LAKES IS A PRIME SUSPECT, GIVEN WALTER-ANTHONY'S WORK.



LAN *et al. (2021)* CONCLUDE DIRECT HUMAN EMISSIONS BY FOSSIL FUELS IS NOT THE MAIN CAUSE OF ACCELERATING CH4 EMISSIONS. IT MUST BE INDIRECT EMISSIONS

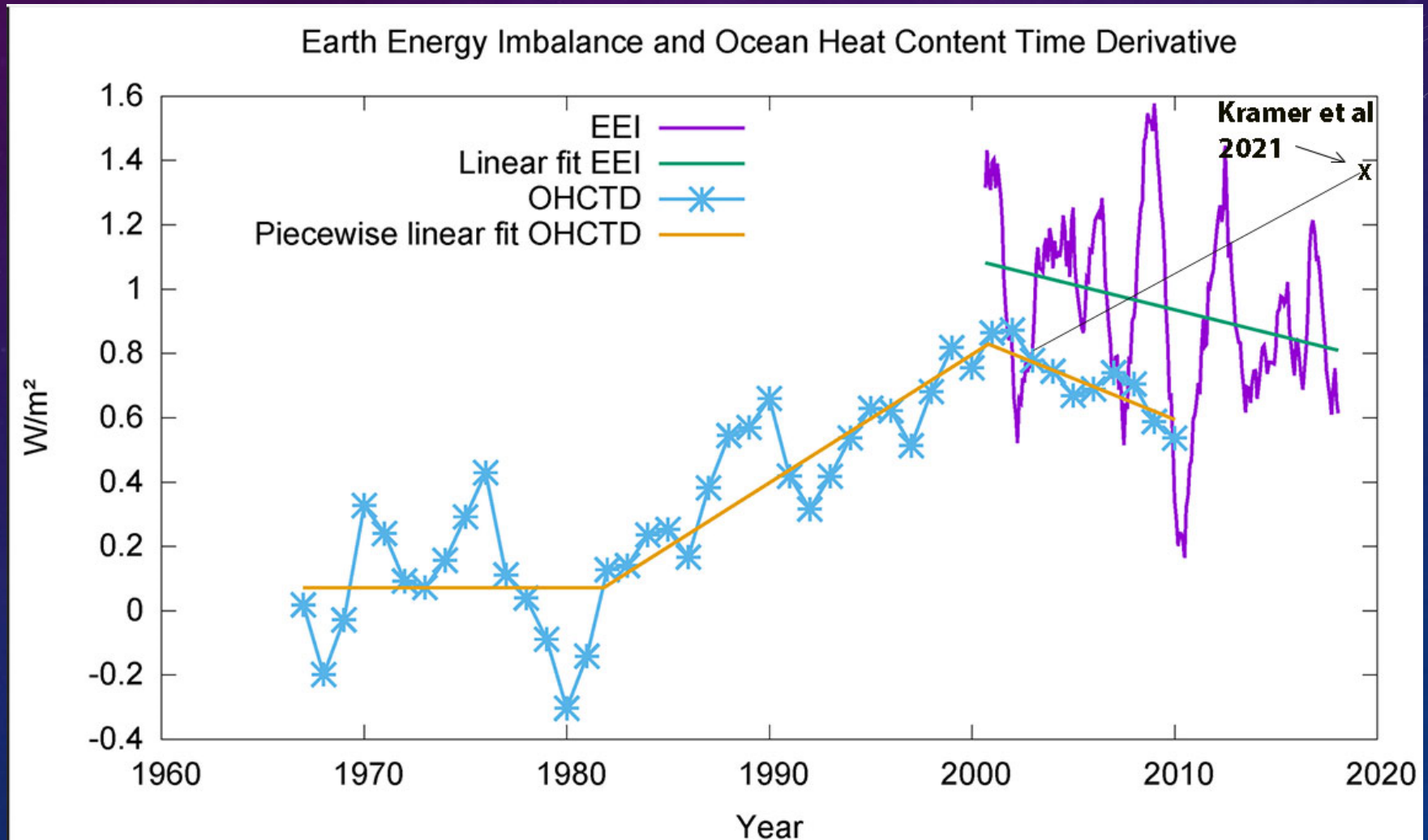
- *"The (isotope) data pointed to microbial sources, such as natural wetlands, shallow lakes and rivers, and human-managed sources like livestock, landfills, rice paddies, and wastewater treatment.*
- *"Our analysis indicates that methane emissions from fossil fuels are unlikely to be the dominant driver of the post-2006 increase," said Lan. "The long-term change can't be explained by a reduction in the rate at which the atmosphere degrades methane either." (source)*

HUMANS ARE SENDING EARTH INTO A NEW STATE…

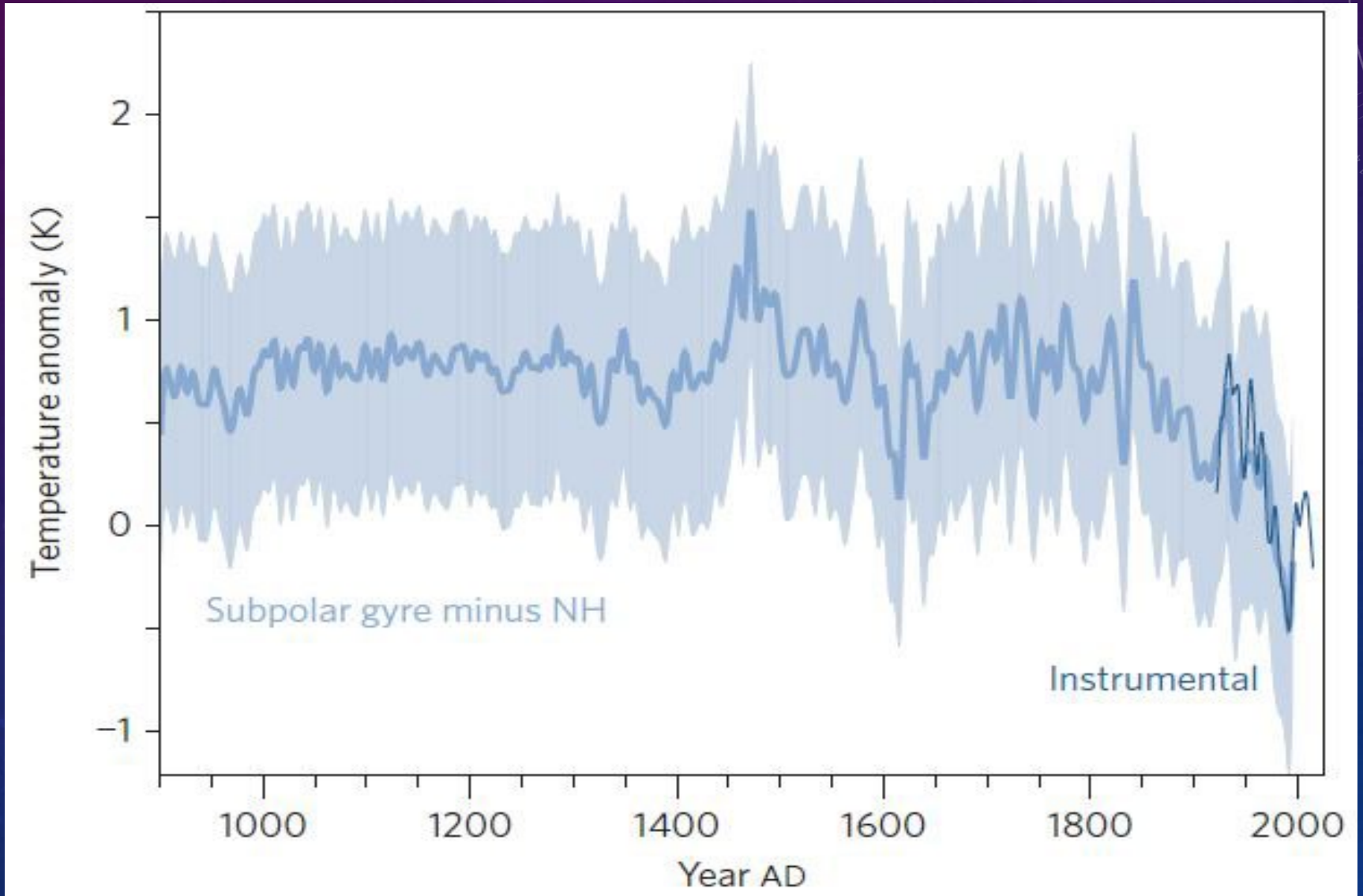


Analysis of air bubbles trapped in an Antarctic ice core extending back 800,000 years documents the Earth's changing carbon dioxide concentration. Over this long period, natural factors have caused the atmospheric carbon dioxide concentration to vary within a range of about 170 to 300 parts per million (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.

THE LATEST: FROM DEWITTE *et al.* 2019 COMBINED WITH KRAMER *et al.* 2021. THE EARTH'S ENERGY IMBALANCE HAS INCREASED BY A STRONG 0.53 WATTS/M^2 IN JUST THE 2003 – 2018 INTERVAL, DUE TO RISING GHG'S AND FALLING REFLECTIVE AEROSOL POLLUTION, MAINLY.



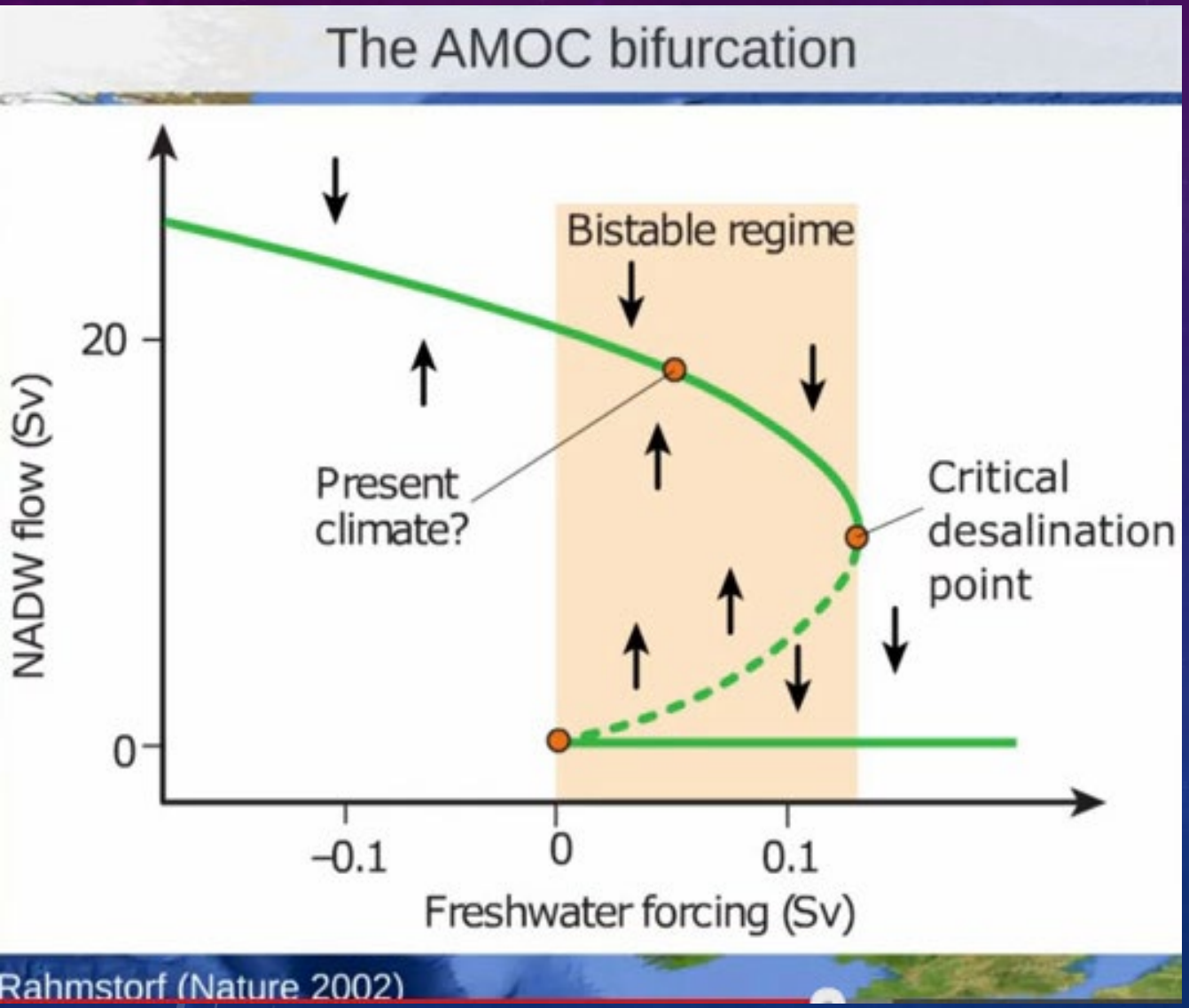
TIME SERIES OF THE TEMPERATURE DIFFERENCE BETWEEN THE SUBPOLAR NORTH ATLANTIC AND THE ENTIRE NORTHERN HEMISPHERE, WHICH CAN BE INTERPRETED AS AN INDICATOR OF THE STRENGTH OF THE AMOC (ATLANTIC FLOW). FROM RAHMSTORF *et al.* 2014, SEE HERE



COULD THE GLOBAL OCEAN CIRCULATION REALLY SHUT DOWN?

- **Yes.** James Hansen thinks it's likely, in fact. The IPCC AR4 thought the AMOC would weaken but not halt in this century, but the new data (below) is indicating a more rapid decline than their models expected. **Again, IPCC under-estimation is evident.**
- Current greenhouse forcing is far stronger than any prior climate forcing, including the Eemian interglacial yet the Eemian Period did see global ocean circulation shut down, and via temperatures we already have. Now. Today. And at CO2 forcing coming from only 280ppm, not today's 420ppm. It therefore looks unlikely we'll avoid AMOC shutdown.
- **The Atlantic Meridional Overturning Circulation (AMOC), which is the only portion of the global currents on which we now have good data as of 2015, has already weakened…**

THE SYSTEM STABILITY TRAJECTORY RAHMSTORF *et al.* (2002)

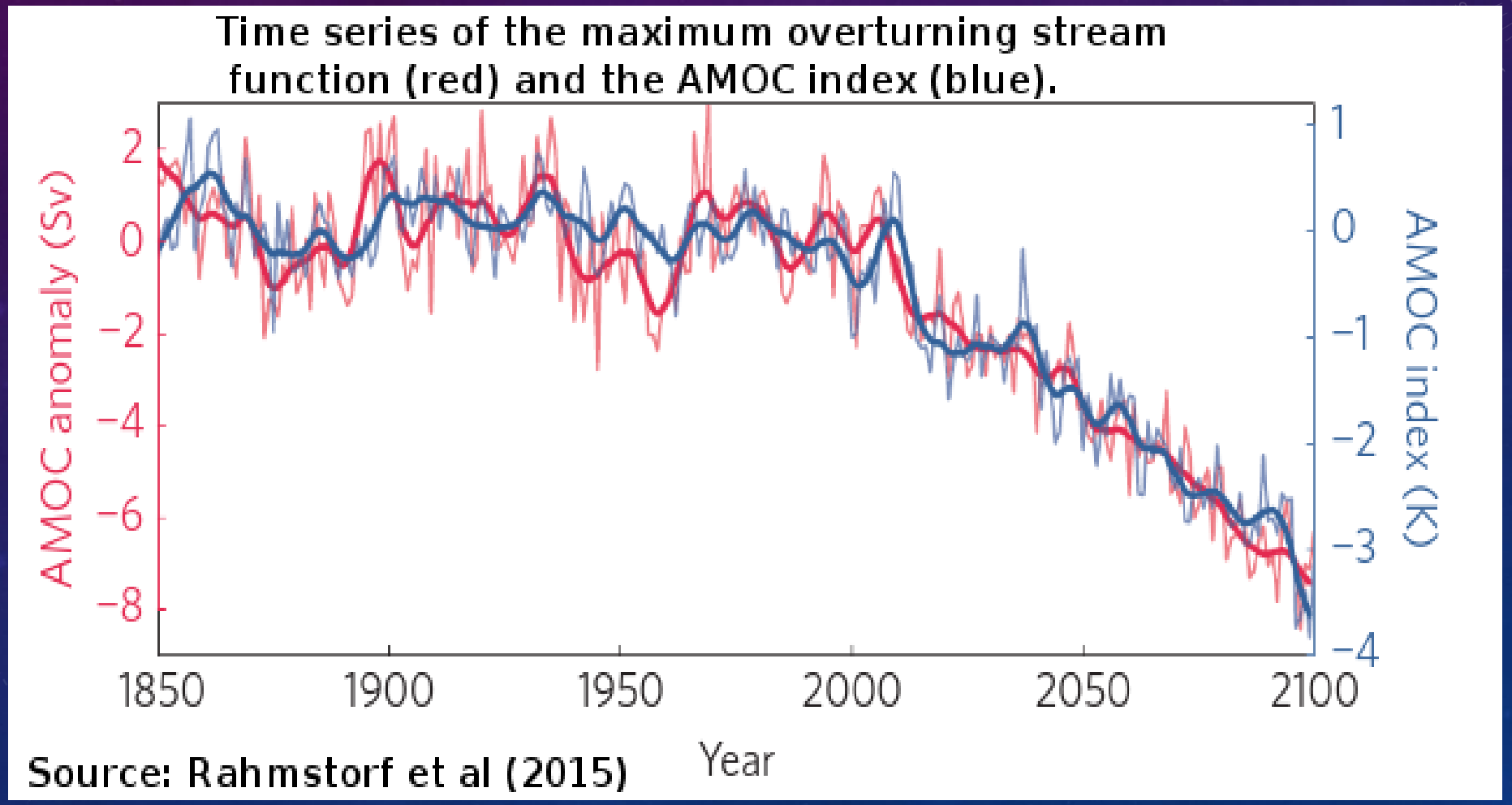


We're already in a salinity regime where there are two stable solutions, one being total shutdown.

If melt increases and salinity declines further, a critical desalinization point is reached and the current shuts down.

Then, only drastic re-salinization (re-freezing Greenland) can push it all the way back to a point where the current can resume, **and that would take many centuries even with sufficient global cooling immediately, according to James Hansen. Hysteresis is strong.**

THE STRENGTH OF THE AMOC IS PREDICTED TO CONTINUE DECLINING (RAHMSTORF *et al.* 2015). WHEN WILL SUPER-STORMS ARRIVE (HANSEN, SATO *et al.* 2015)? SINCE THE COLD MELT SURFACE HAS CLEARLY BEGUN, IT'LL PROBABLY BE A GRADUAL ONGOING INCREASE IN STORM INTENSITIES. PERHAPS THE HURRICANES OF '17 AND '18 ARE A SMALL TASTE. (PBS NOVA ON AMOC TIPPING POINT)



LIU et al. 2016 SHOW HOW UNSTABLE THE AMOC IS…

- Prior studies had assumed that freshwater from rains flowed from the Southern Ocean around Antarctica and into the South Atlantic, but actual observations are showing the opposite direction of freshwater flow.
- This has the effect of making the surface North Atlantic less salty and hence less dense; makes even weaker the AMOC's ability to densify around Greenland and sink through the Thermocline.
- **Liu *et al.*** did not consider Greenland meltwater as **Hansen *et al.* *2016*** did, and so these two different effects actually should be **added** together.

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 BE INITIATING 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).

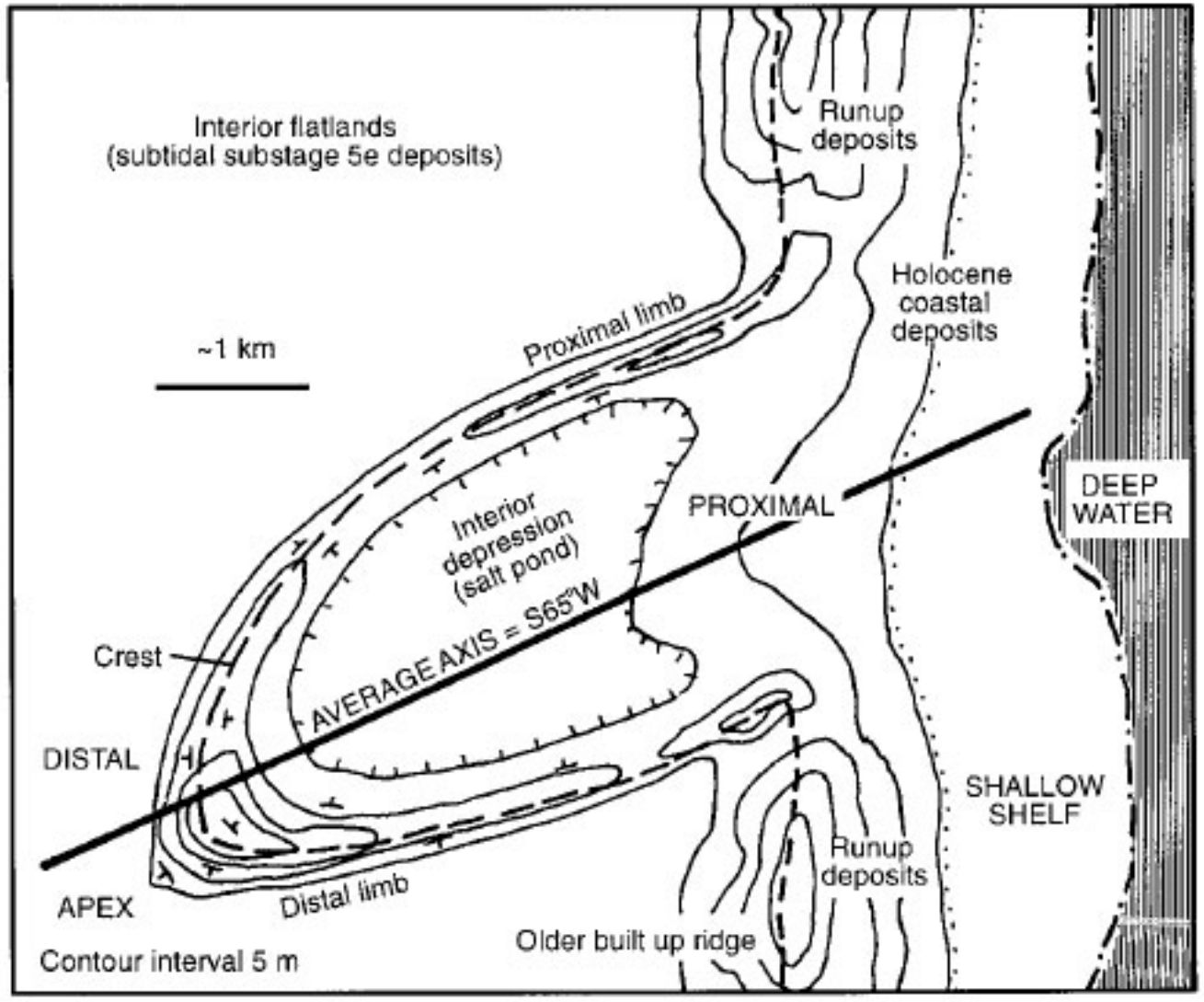
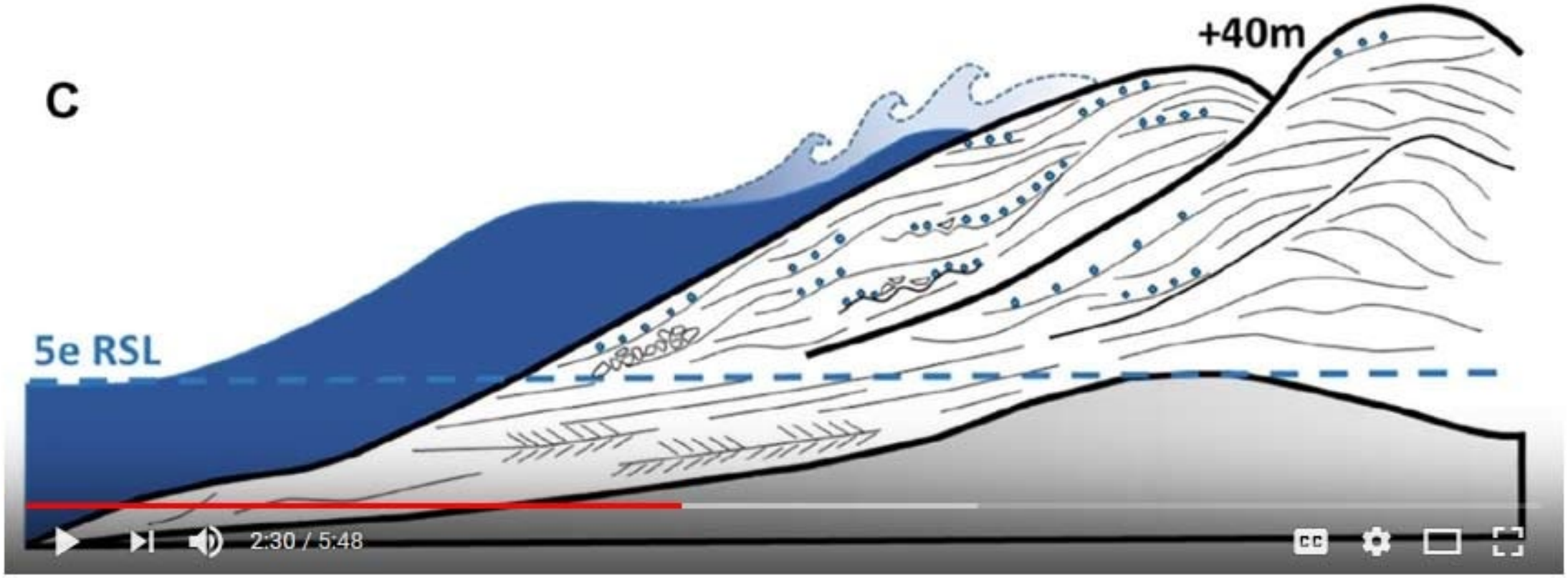


FIG. 1. Schematic map of chevron beach ridge.

HANSEN: 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



Climate, Sea Level, and Superstorms

REMEMBER THE WAVES IN THE FILM *"INTERSTELLAR"*? THAT'S ABOUT THE CORRECT HEIGHT

CONSEQUENCES OF GLOBAL OCEAN CURRENT SHUTDOWN, IS MORE THAN JUST TEMPERATURE CHANGES…

- Paleo data shows shutdown is sometimes accompanied in the major mass extinction events. Oxygenation of the ocean bottom ceases, changing microbe ecosystem towards hydrogen sulfide producers, raising H_2S content to saturation right up to the ocean surface and the photic zone.
- H_2S is fatal in concentrations of only 300 ppm or less, to all mammals and many other species. **Imagine our vast oceans, now stagnant and smelling like an outhouse.**
- The Kump (2005) Hypothesis is that at least part of the killing mechanism in the Devonian, Permian, Ordovician mass extinctions is H_2S poisoning.
- Recent climate modelling of this situation is indicating concentrations perhaps unlikely to reach killing levels. No mass extinction with Eemian shutdown. But we're forcing the system far harder than ever in Earth's history. More work needed.

NEOCLASSICAL ECONOMIST RICHARD TOL HAD THIS RESPONSE TO THE PROSPECT OF SHUTDOWN OF THE GLOBAL OCEAN CIRCULATION…

- "Good!", he said on Twitter.
- He's not worried about social conflict arising from climate change…. "*He concludes that 'poor and exhausted people are unlikely to take up arms, and if they do, they are probably not very effective'*".[26]
- Tol's comments speak for themselves, and for his colleague economists' attitudes towards climate change and the most affected peoples. Amazing.
- Tol was selected as a lead coordinating author for the IPCC AR5, and also listed by Senate Republicans as a "scientist disputing man-made global warming claims" (here, under "climate change").

AS TEMPERATURES RISE… CAN WE "GMO" TOUGHER CROPS?

- We've had some success engineering 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).
- And elevated CO2, far from being "good for plants", is robbing food crops of vital nutrients (**Myers *et al*. 2014)**

MORE RAIN IN THE FUTURE: BUT IT FALLS OVER THE ARCTIC, TRIGGERING HIGHER METHANE EMISSIONS, AND OVER THE OCEANS. BUT WHERE CROPS AND PEOPLE LIVE? **DROUGHT.**

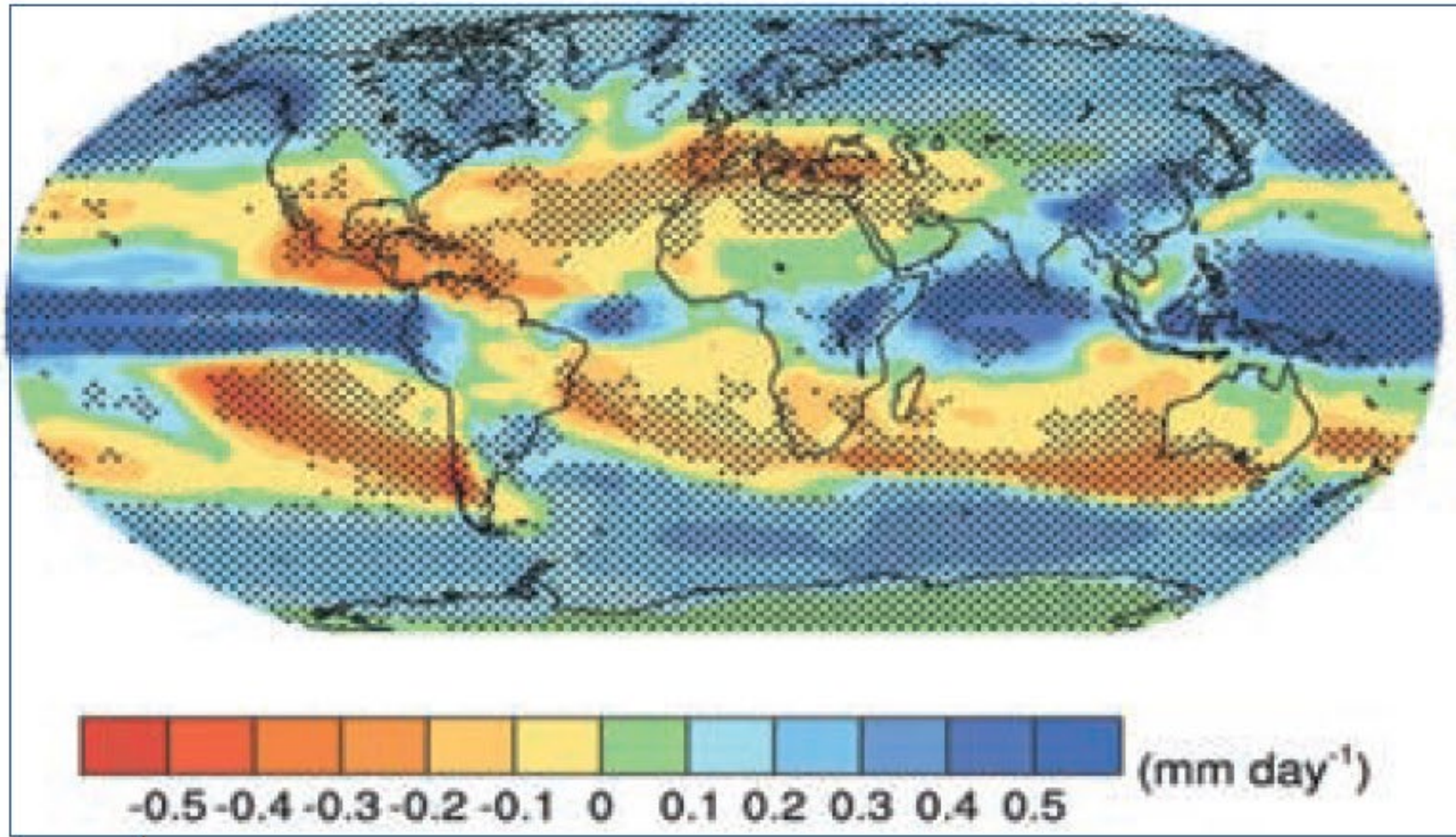
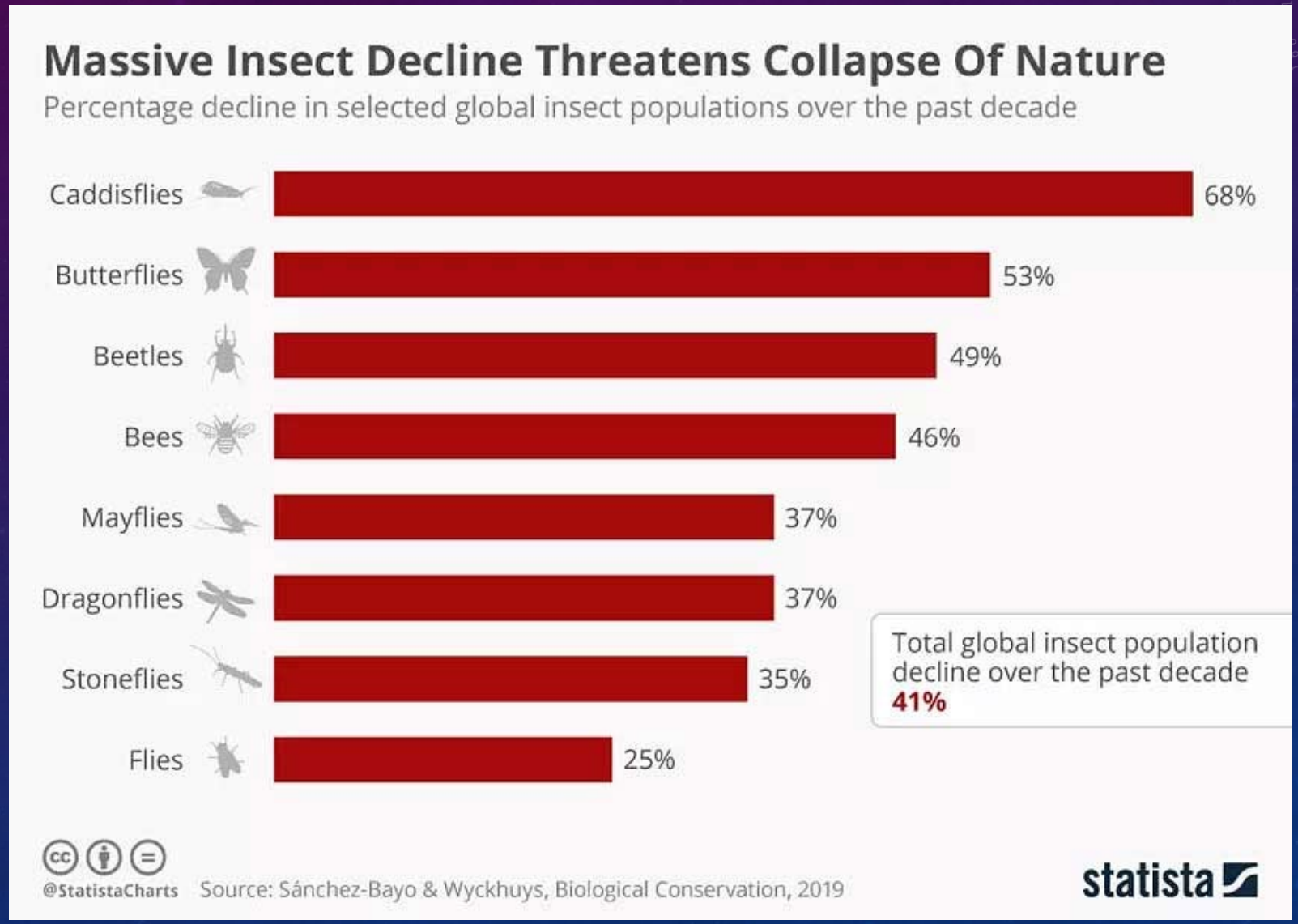


Figure 11: By 2099, precipitation is expected to increase in the Arctic and decrease in temperate zones based on this multi-model mean from the IPCC Fourth Assessment Report. The units are millimeters per day and the changes are annual means for the A1B scenario for the period 2080 to 2099 relative to 1980 to 1999. Stippled areas indicate where at least eight out of ten models agree *(IPCC 2007, Figure 10.12)*.

FROM SANCHEZ-BAYO AND WYCKHUYS 2019. THAT'S A 41% DECLINE IN 1 DECADE. NATE HAGENS QUOTES 40% BIOMASS LOSS IN 25 YEARS, AND 2.5% DECLINE PER YEAR.



STABLE SEA LEVELS ALLOWED TRANSITION FROM THE STONE AGE, TO CIVILIZATION.

- *“The stable sea level not only provided early humans with a high-protein marine food supply, but it also made possible grain production in estuary and floodplain ecosystems. With these conditions, food for the human population could be produced by a fraction of the people, thus allowing a transition from the Neolithic way of life to urban social life and the development of complex state-governed societies.*
- *The period of stable sea level is almost surely over…”*

-- James Hansen

IT WAS THE DEPENDABLE STABILITY OF TEMPERATURES, CLIMATE, RAINFALL PATTERNS, RIVERS, AND SEA LEVEL THAT PERMITTED HUMANS TO SETTLE DOWN FROM ROAMING BANDS 10,000 YEARS AGO, AND CREATE AGRICULTURE-BASED CIVILIZATION

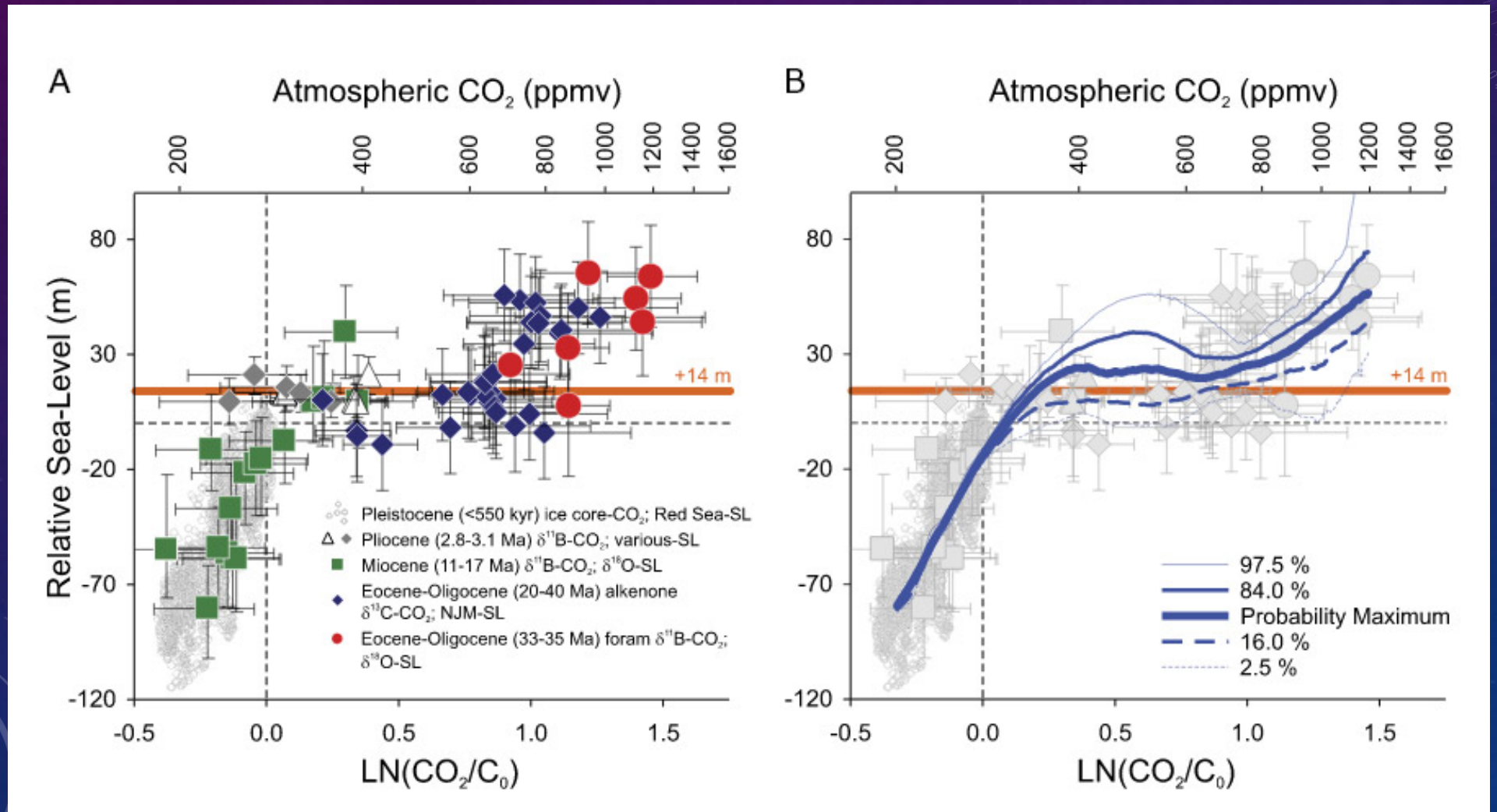
- Ruddiman (2015) finds that early civilization's agriculture and tree cutting raised CO2 at a rate which happened to compensate for the Milankovitch cooling which had been growing for 10,000 years. Just good luck, as it turned out.
- But now we're overwhelming Milankovitch effects, exiting that climate stability state, thanks to fossil fuels.

SEA LEVEL RISE RATES: HIGH RISK THEY ARE FAR HIGHER THAN OLD, SLOW ESTIMATES

"If we get warming of two or three degrees Celsius, then I would expect that both West Antarctica and parts of Greenland would end up in the ocean, and ***the last time we had an ice sheet disintegrate, sea level went up at a rate of 5 metres in a century, or one metre every 20 years. That is a real disaster, and that's what we have to avoid."***

- James Hansen, interviewed in 2012 (source)

EVEN AT TODAY'S CO2 LEVEL, PALEO DATA SHOWS EQUILIBRIUM SEA LEVELS ARE ABOUT **24M (80 FEET) HIGHER THAN TODAY** (FOSTER AND ROHLING 2013): SEA LEVEL RISE WILL CONTINUE.

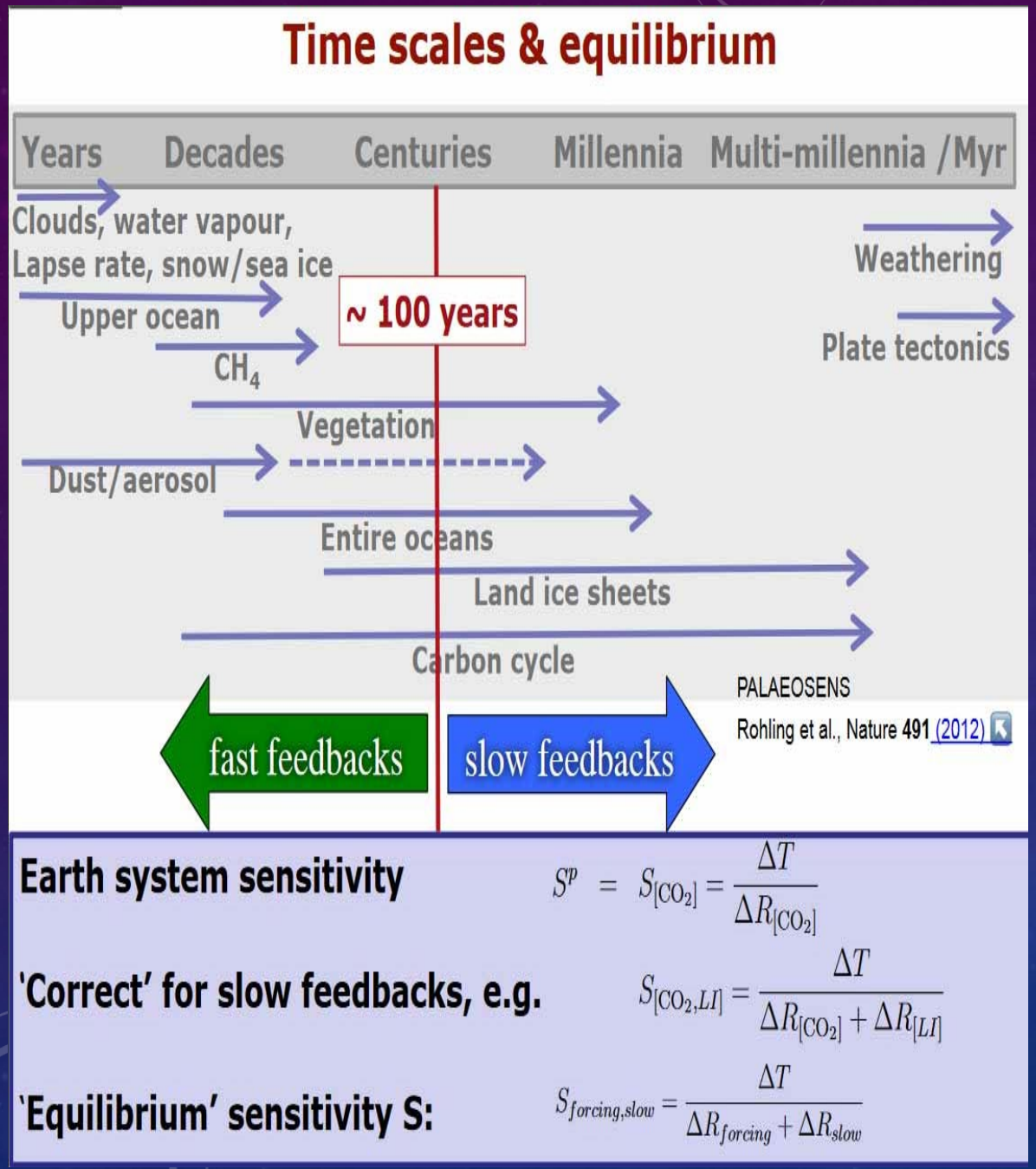


EQUILIBRIUM CLIMATE SENSITIVITY

- It is higher than Nordhaus assumed, and many older estimates.
- Let’s see why.

ECS: WHAT IT MEANS…

- **Equilibrium Climate Sensitivity** – Imagine doubling pre-industrial CO2 concentrations of 280 ppm to 560 ppm.
- Now wait for temperature to rise until the “fast climate feedbacks” are levelling off and the “slow climate feedbacks” are mostly what’s left.
- That will take ~200 years. But “Equilibrium” is widely acknowledged as a misnomer… temperatures continue rising, but at a slower rate.
- The slow feedbacks will take several to many millennia to play out , and roughly double the temperature rise. We find **longer term temperature change is about 2 x ECS**.



ECS – FORMALLY IT IS THE "EQUILIBRIUM" REACHED AFTER ONLY THE FAST FEEDBACKS ARE CONSIDERED. IN PRACTICE, IT'S A BLURRED BOUNDARY. TREATING ECS AS AN EQUILIBRIUM STABLE TARGET IS WRONG. TEMPERATURES CONTINUE RISING BUT MORE SLOWLY, FOR MANY THOUSANDS OF YEARS.

ECS: BIASED LOW IN MOST PAST WORK

- *"A 2017 paper by Dr Cristian Proistosescu and Prof Peter Huybers at Harvard University found that amplifying feedbacks that play a large role in ECS in climate models have not fully kicked in for current climate conditions. A similar paper by Prof Kyle Armour of the University of Washington suggests feedbacks will increase ECS by about 25%, from today's warming as the Earth moves towards equilibrium.*
- *This means that sensitivity estimates based on instrumental warming to date would be on the low side, as they would not capture the larger role of feedbacks in future warming. The authors suggest that "accounting for these…brings historical records into agreement with model-derived ECS estimates".*
- *A recent paper by NASA's Dr Kate Marvel et al. explore the discrepancy between instrumental and model-based sensitivity estimates. They find natural climate variability over the past few decades has lined up, by pure coincidence, in a way that results in low instrumental ECS estimates." (astronomers' "Cosmic Variance", at work in climate too, we see)*

ECONOMISTS PREFER TO USE SIMPLE "INTEGRATED ASSESSMENT MODELS" (IAMs) TO EXPERIMENT WITH DIFFERENT ASSUMPTIONS. IAMs TAKE "EQUILIBRIUM CLIMATE SENSITIVITY" (ECS) AS AN INPUT, SO IT IS CRITICAL TO KNOW WHAT ECS REALLY IS.

- Nordhaus assumes **ECS = 2.9C**. In fact, the old standard median is 3.2C. But past decade's climate science finds it to be much closer to **ECS=4-5C in past interglacials, and higher** for our future, and higher in hotter climate states (see later).
- His reference on Greenland thaw's economic implications (Nordhaus 2019) uses outdated (Alley 2010), overly mild references on Greenland's sensitivity to temperature, even though Nordhaus had access to more recent and better studies showing the tipping point for Greenland is nowhere near +7C but instead at only +1.5 to 2C (*e.g.* Pattyn *et. al* 2018)

HANSEN AND SATO 2012 FIND THAT AN AVERAGE ECS=3.0C (BLACK) FITS EARTH CLIMATE (RED) GOING INTO AND OUT OF ICE AGES FOR THE PAST ~MILLION YEARS, *i.e.* FOR CO2 RANGES FROM 170-280PPM. BUT, THEY POINT OUT THIS ECS SHOULDN'T BE USED FOR PROJECTIONS IN *OUR* FUTURE SINCE WE ARE QUITE ABOVE THIS LOW CO2 RANGE: 422 PPM AS I WRITE THIS IN 2022, AND OVER 500 PPM CO2e INCLUDING OTHER GHG's.

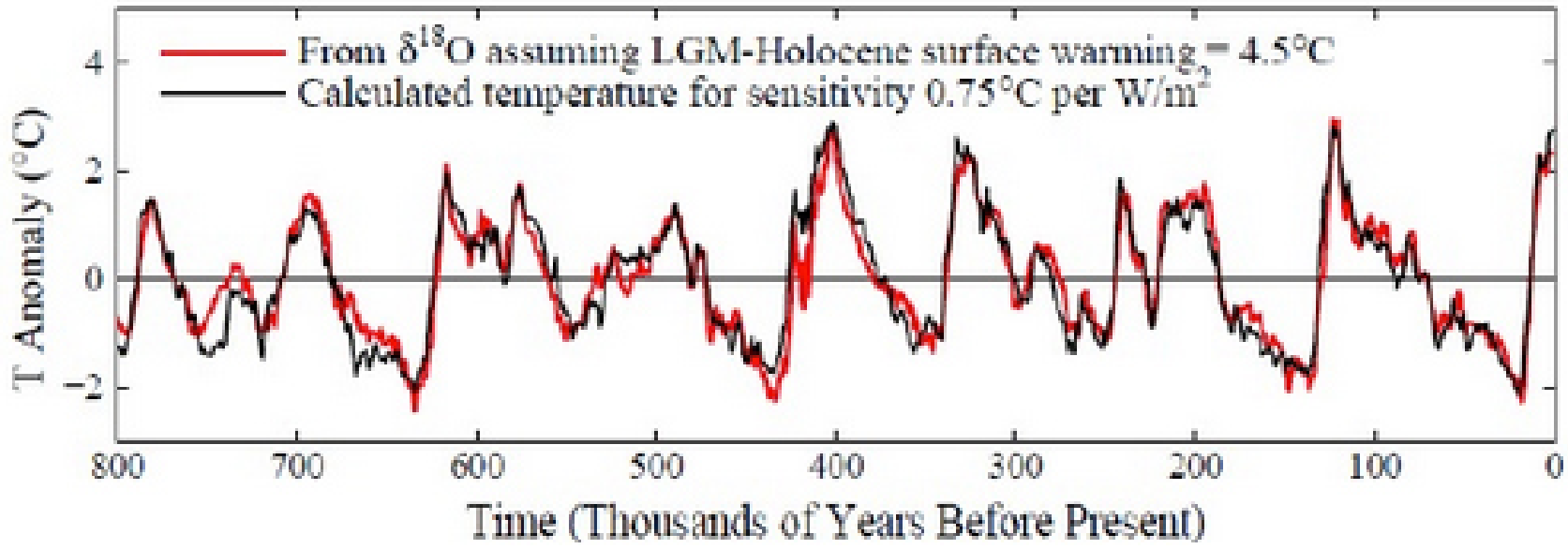
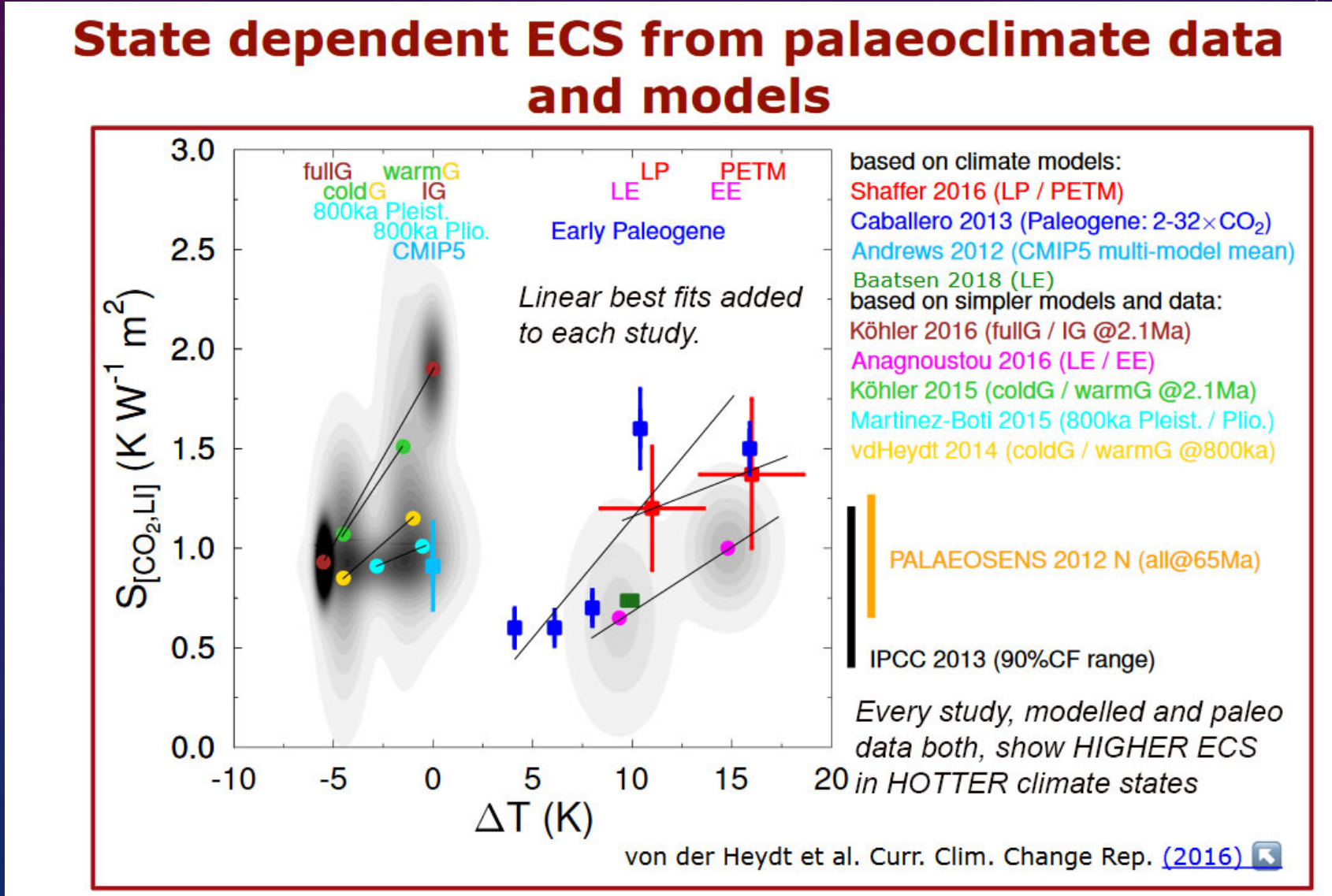


Figure 3: Black curve: calculated surface air temperature change for climate forcings HS12 and climate sensitivity 0.75°C per W/m2. Red curve: estimated global surface temperature change based on deep ocean temperatures and assumption th LGM-Holocene surface temperature change is 4.5°C. Zero point is the 800 ky mean Figure 6 from HS12.

STATE DEPENDENCE OF ECS: ALL STUDIES SHOW HIGHER ECS IN HOTTER CLIMATE STATES, EVEN STARTING ON AN ICE-FREE EARTH

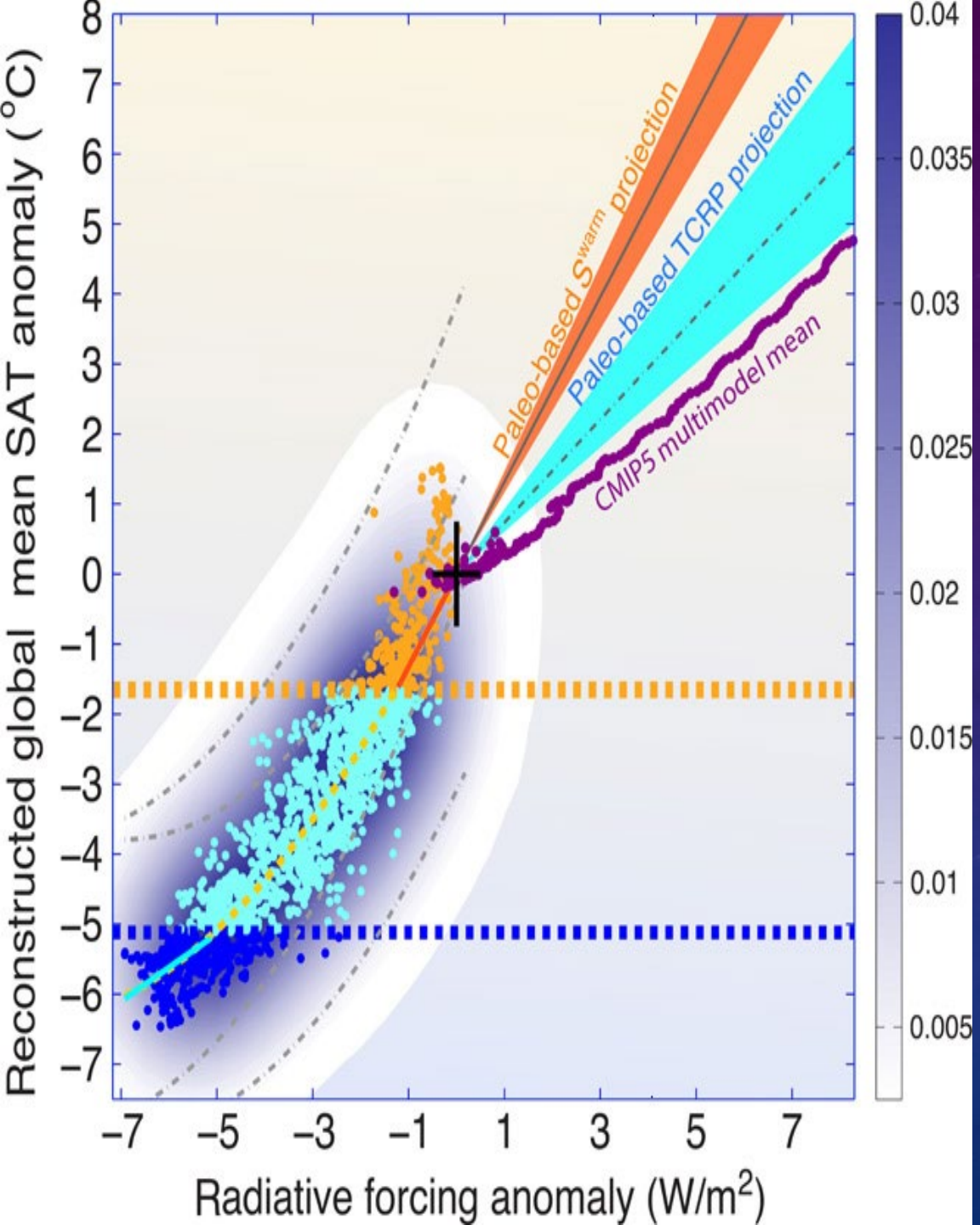


NCAR'S LATEST MODELS: AEROSOL COOLING IN CLOUDS IS NOW SEEN TO HAVE BEEN UNDERESTIMATED BY A FACTOR OF 2 (!)

- With improved aerosol modelling but using a conventional ECS, they found that the revised aerosol cooling effect **nearly cancelled out all 20th century global warming**(!)
- Yet, the **20th century most certainly DID warm.** So, how to explain that? …
- It requires **higher** ECS than they assumed, to make consistent with **actual** 20th century warming.

"THE PLANET IS ALREADY WARMING FASTER THAN HUMANS CAN COPE WITH" – NCAR'S ANDREW GETTLEMAN

- ***"The scary part is, these models might be right; because that would be pretty devastating."***
- I can suggest three places to look for causes of underestimated ECS: (1) We've found the ocean is absorbing more heat than we thought, and (2) pollution aerosols are making clouds significantly more reflective of sunlight than we'd thought, as we linked earlier (**Rosenfeld *et al.* 2019**) and **erratum** and now similar findings from **Hasekamp *et al.* 2019**, who find the IPCC estimates of radiative cooling forcing by aerosols **was a factor of 2 too low**. And (3), the loss of climate-coolant low stratocumulus clouds over the mid latitude oceans. More later on this.



FRIEDRICH *et al.* 2016 **FIG 3.** DOTS ARE PALEO DATA: A STRAIGHT TREND CORRESPONDS TO ECS=CONSTANT. BUT THE STRONG UPWARD CURVATURE SAYS HIGHER ECS APPLIES AT HIGHER TEMPERATURES. THE ORANGE STRAIGHT TRENDING BAND ASSUMES **ECS=4.88C** HOLDS TODAY AND FOR THE FUTURE. HOWEVER, THE ORANGE FUTURE SLOPE LOOKS SHALLOWER (LOWER ECS) THAN THE ORANGE PALEO DATA INDICATE.

MEANING, WE MAY BE ENTERING A NEW REGIME OF EVEN HIGHER ECS.

WHY? CO2 NEVER ROSE ABOVE 280 PPM DURING PRIOR INTERGLACIALS, BUT IT IS 422 PPM TODAY, PLUS STEEPLY RISING METHANE AND MAN-MADE NOx AND CFC'S, HFC'S *etc* WHICH DID NOT EXIST IN PALEO TIMES.

IS FRIEDRICH *et al's* WORK FAR OUTSIDE MAINSTREAM CLIMATE SCIENCE THINKING? NO.

- Lead IPCC author Michael Mann has studied the paper, and concludes the study is, in his words: ***"Sound, and quite defensible".***
- **New CMIP6 climate models, for the IPCC AR6, also find similar ECS; ECS may well be +4-5C, although the ECS literature's authors frequently muddle the difference between ECS (Charney's formal definition) and the more relevant Earth System Sensitivity (ESS). See Hansen *et al.* 2022.**
- Friedrich's work finds that on our current trajectory, we're on our way to **+6C by 2100**.
- This would almost certainly cause the severe fraying of civilization's support networks, and worse. Widespread loss of life, economic collapse, resource wars, would mean human direct emissions drop significantly before reaching that point.
- Indirect human-triggered emissions would be slower to drop within a civilization in steep decline, as they have significant hysteresis (see later).

STEINTHORSDOTTIR *et al.* 2020 STUDYING PALEO EARTH DATA FIND ECS MUST BE MUCH HIGHER THAN PRIOR STANDARD CLIMATE MODELS' CANONICAL 20TH CENTURY ECS OF 3C…

- … in order to explain the high temperatures of the Miocene epoch; +7C hotter than today yet at pCO2 of only ~500 ppm, which is the same as today's CO2e.
- *"A problem remains that climate models cannot reproduce MCO [mid Miocene] temperatures with less than ~800 ppm pCO_2, while most previously published proxies record [that] pCO_2 < 450 ppm (back then)".*
- Today, 450 ppm will be reached on trend in about a decade. But in the MCO, the sun was 1.6 W/m^2 less luminous than today. 1.6 W/m^2, for comparison, is almost equal to today's entire Earth energy imbalance driving today's accelerating temperatures.

LET'S DO A SIMPLE BACK-OF-ENVELOPE ESTIMATE OF ECS TO JUSTIFY THESE HIGHER NEW ESTIMATES…

- As of 2020, we are at +1.48C above the best (**Schurer, Mann *et al.* 2017**) new estimate of the Pre-Industrial temperature baseline (not the conventional ~1880-1910 baseline, when CO2 annual emission rates were already almost 10% of today's).
- CO2 concentrations in 2020 were at seasonally adjusted 415 ppm, or 48% of the way to a formal doubling of the 280 ppm pre-industrial baseline.
- Therefore…

A REASONABLENESS TEST: DO A SIMPLE LINEAR EXTRAPOLATION TO FIND TCR = TRANSIENT CLIMATE RESPONSE = TEMPERATURE AT THE MOMENT CO2 HITS 2X(PRE-INDUSTRIAL 280PPM)=560PPM…

- Assume, conservatively, that delta(temperature) rises linearly with delta(CO2), at least until TCR is reached and temperature rise then starts to shallow out.
- TCR is then, by linear extrapolation…

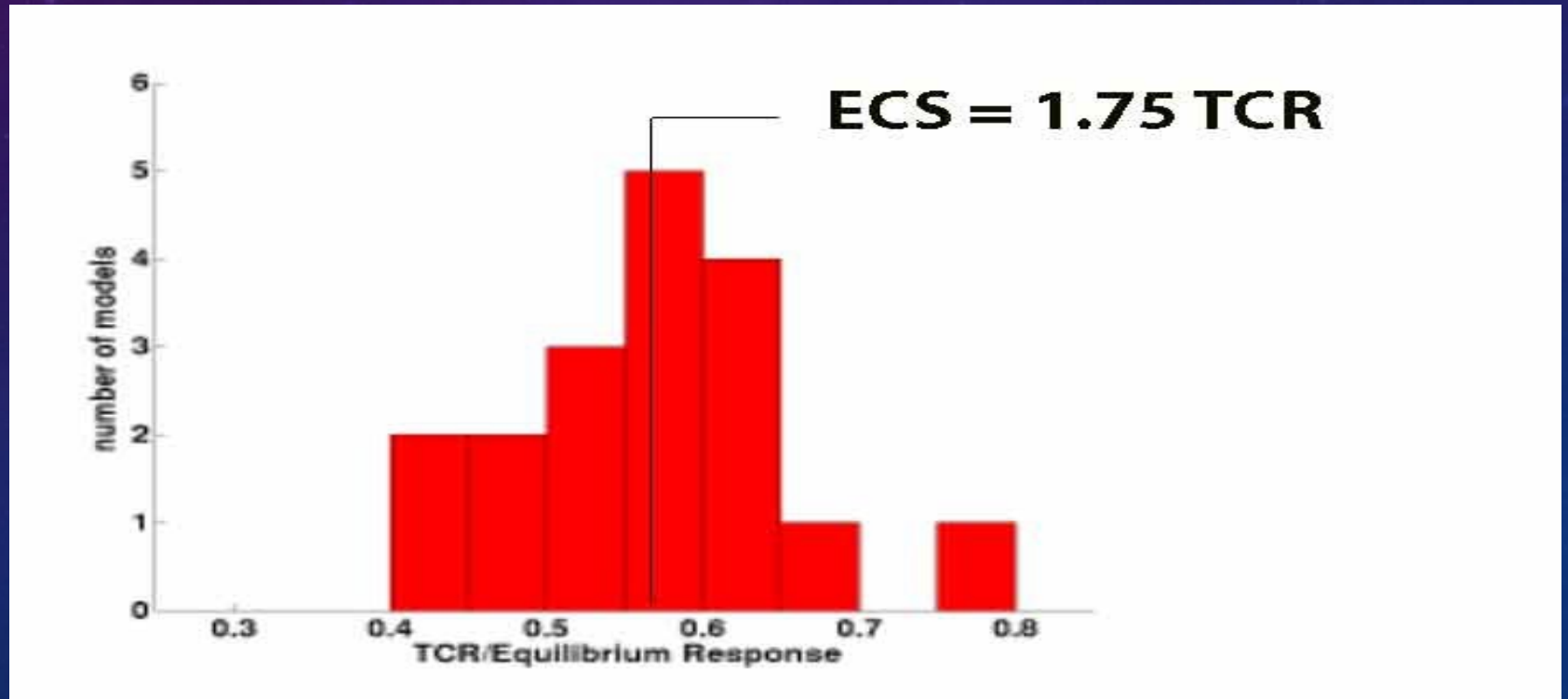
- **TCR= +1.48C/0.48 = 3.1C**

THIS GIVES TRANSIENT CLIMATE RESPONSE or TCR = 3.1C

- But that's not yet equilibrium, so ECS will sail higher until shallowing slope, many decades further into the future, at fixed 560ppm of CO2.
- **But this is certainly an underestimate of even just TCR: Why?**
- **1.** It is only in the past 20 years that the Arctic Ocean ice cover has gone from unchanged, to now being melted through, strongly increasing the ice albedo feedback.
- **2.** Methane is rising much more steeply than CO2 and is roughly 1/3 of climate forcing. Methane is 300% of pre-industrial values, while CO2 is only 148% of pre-industrial values and only in the past 12 years accelerating rapidly
- **3.** Cloud feedbacks increasingly look to add further to this, especially low cloud losses.

BUT EVEN TAKING THE LOW-BALL +3.1C AS TCR…

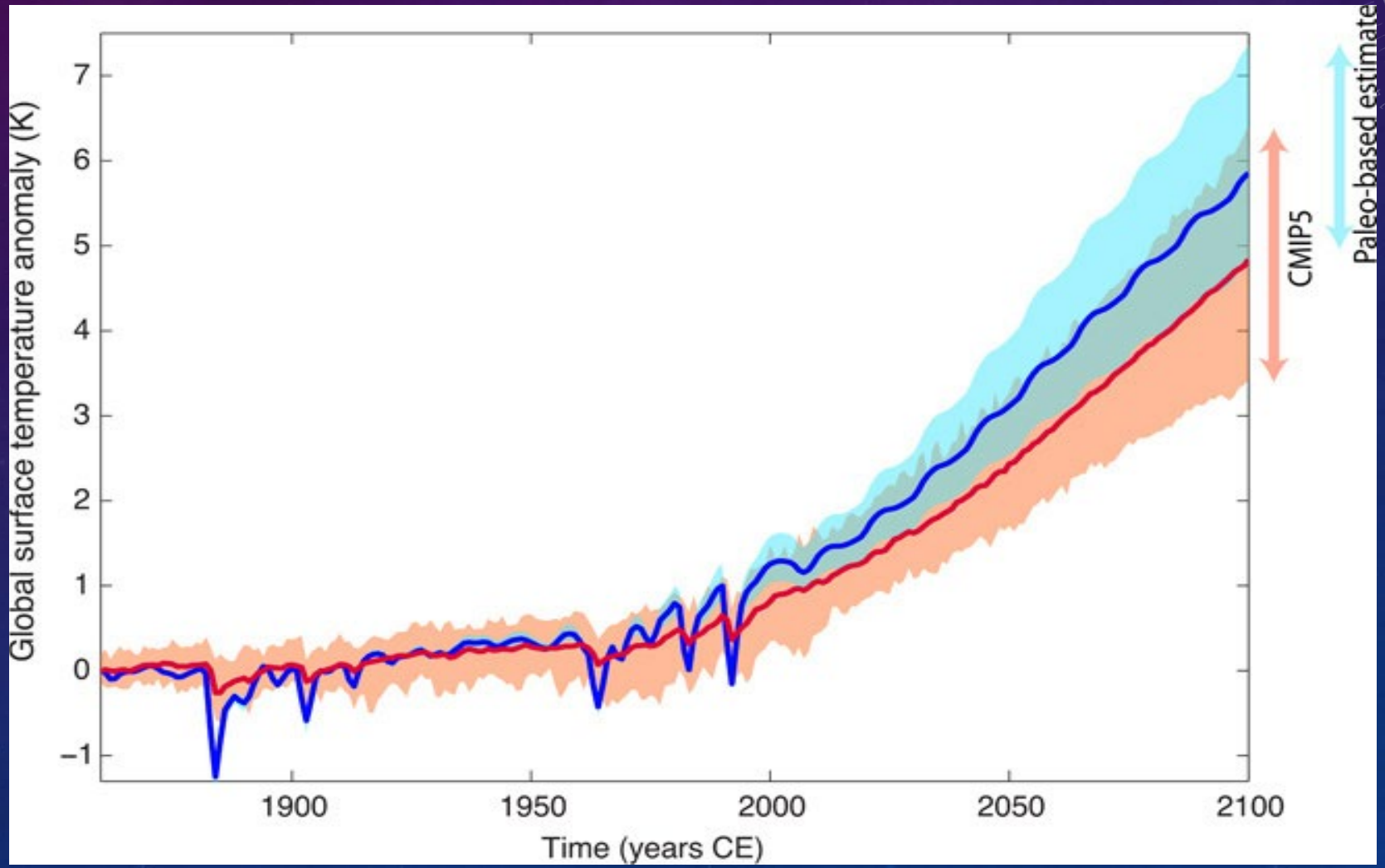
- TCR/ECS is ~1.75 (here) or 2.1 (Schwartz 2011)
- Even using the lower 1.75 value gives 1.75 x 3.1C = **ECS = ~+5.4C**
- …which aligns well with the "Wolf pack" CMIP6 values of ~+5C, and the Friedrich *et al.* 2016 past interglacial's value of ECS=+4.9C (yet even that, was at prior CO2 of only 280 ppm *vs.* today's 420 ppm).
- If we use conventional pre-industrial T and so current T=+1.2C, and average in the Schwartz TCR/ECS, we then get ECS=4.84C, in good agreement with Friedrich *et al.* 2016 and closer to the middle of CMIP6 models



LET'S TRY ANOTHER BACK OF ENVELOPE…

- If sensitivity S[CO2 LI] in the von der Heydt review paper Figure 1 (slide 89 here), is proportional to ECS, and using the Anagnoustou (2016) slope as the best representative, then we get a state-dependent ECS of 0.26 per background state temperature rise of 1C. (might be conservative, since methane and other non-CO2 GHG's are not considered, and methane is rising faster; 3x higher than pre-industrial, while CO2 is only 50% higher, today)
- So, if we're concerned with estimating the best ECS for the 21st century, and if T rise to 2100 is about +3C, which is in the middle of the estimates by a poll of climate scientists, then we get an additional
- 3 x 0.26 = 0.78, added on to the canonical ECS=3.2C from the late 20th century, gives…
- **ECS = +4C**
- **Average this into the ECS's from the previous discussion here, and an ECS in the low/mid 4's seems a good compromise. Say…. <u>ECS=4.3C</u>**

UNDER “BUSINESS AS USUAL”, THE FRIEDRICH *et al.* (2016 FIGURE 4) PALEO STUDY (BLUE) GIVES TEMPERATURES +6C ABOVE CONVENTIONAL (1880-1910 AVG) PRE-INDUSTRIAL, AND RISING. THIS WOULD BE DISASTROUS, EXCEEDING THE TEMPERATURE DIFFERENCE BETWEEN THE DEPTHS OF THE LAST ICE AGE, AND PRE-INDUSTRIAL MODERN TIMES… AND LIKELY SUCH ENERGY CONSUMPTION RATES COULD NOT CONTINUE IN THE RESULTING STEEPLY CRIPPLED CIVILIZATION.



FROM PORT *et al.* 2012. CO2 DROPS (TOP) WHEN ALL HUMAN DIRECT AND INDIRECT-CAUSED EMISSIONS CEASE, BUT TEMPERATURES DO NOT DROP (BOTTOM LEFT)

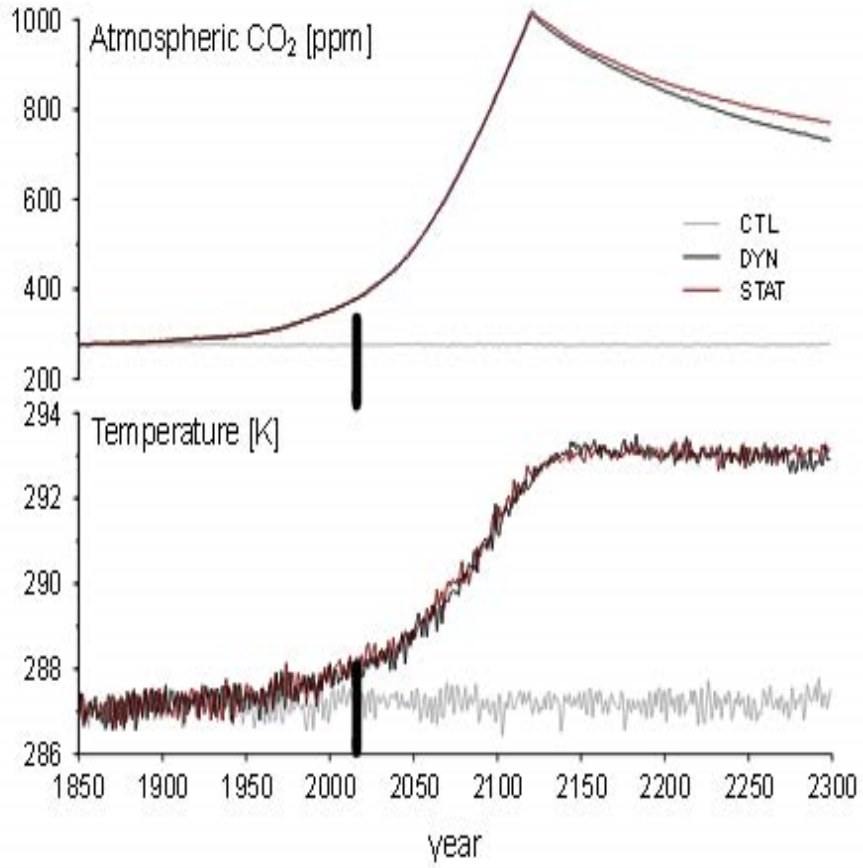


Fig. 2. Time series of annual mean atmospheric CO_2 concentration and global annual mean temperature in the CTL (grey line), the DYN (black line), and the STAT (red line) simulation.

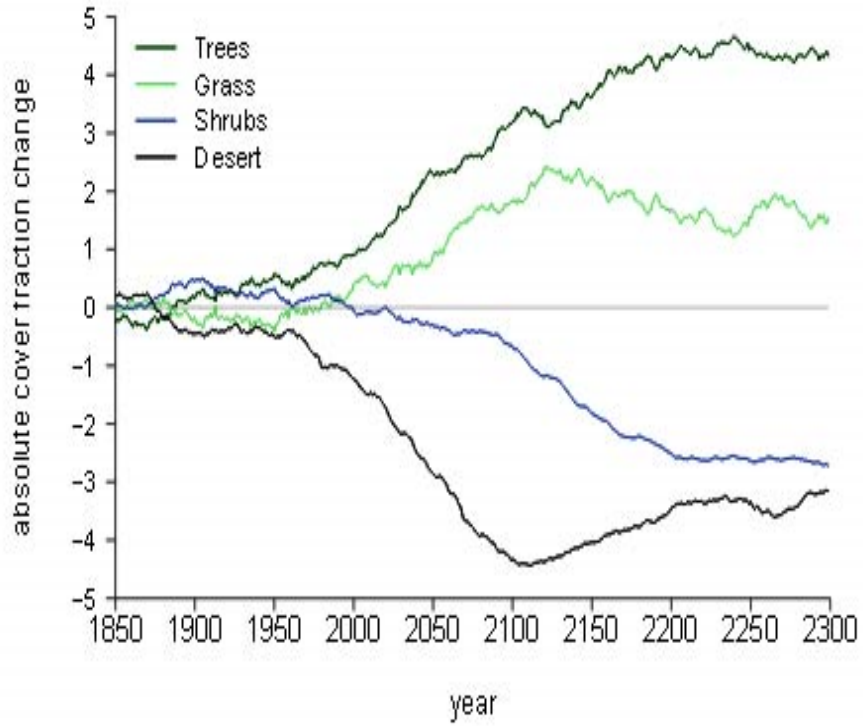


Fig. 3. Time series of changes in absolute global mean vegetation cover (DYN – CTL) in [%]. Forest includes tropical evergreen and deciduous trees as well as extra-tropical evergreen and deciduous trees. Shrubs contain cold and rain green shrubs and grass includes C_3 and C_4 grass.

IRREVERSIBLE ICE SHEET LOSS

- The Antarctic Ice Sheet is also at risk of irreversible loss.
- Garbe *et al. (*2020 in Nature) show at +2C West Antarctica begins collapse (except, it has already), and at +6-9C even East Antarctica collapses
- **Hysteresis: simply returning to pre-industrial temperatures will not bring the ice back. Why?...**
- …The albedo and altitude feedbacks require an Earth much colder than pre-industrial for re-icing to even begin.

Article | Published: 23 September 2020

The hysteresis of the Antarctic Ice Sheet

Julius Garbe, Torsten Albrecht, Anders Levermann, Jonathan F. Donges & Ricarda Winkelmann

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Abstract

More than half of Earth's freshwater resources are held by the Antarctic Ice Sheet, which thus represents by far the largest potential source for global sea-level rise under future warming conditions[1]. Its long-term stability determines the fate of our coastal cities and cultural heritage. Feedbacks between ice, atmosphere, ocean, and the solid Earth give rise to potential nonlinearities in its response to temperature changes. So far, we are lacking a comprehensive stability analysis of the Antarctic Ice Sheet for different amounts of global warming. Here we show that the Antarctic Ice Sheet exhibits a multitude of temperature thresholds beyond which ice loss is irreversible. Consistent with palaeodata[2] we find, using the Parallel Ice Sheet Model[3,4,5], that at global warming levels around 2 degrees Celsius above pre-industrial levels, West Antarctica is committed to long-term partial collapse owing to the marine ice-sheet instability. Between 6 and 9 degrees of warming above pre-industrial levels, the loss of more than 70 per cent of the present-day ice volume is triggered, mainly caused by the surface elevation feedback. At more than 10 degrees of warming above pre-industrial levels, Antarctica is committed to become virtually ice-free. The ice sheet's temperature sensitivity is 1.3 metres of sea-level equivalent per degree of warming up to 2 degrees above pre-industrial levels, almost doubling to 2.4 metres per degree of warming between 2 and 6 degrees and increasing to about 10 metres per degree of warming between 6 and 9 degrees. Each of these thresholds gives rise to hysteresis behaviour: that is, the currently observed ice-sheet configuration is not regained even if temperatures are reversed to present-day levels. In particular, the West Antarctic Ice Sheet does not regrow to its modern extent until temperatures are at least one degree Celsius lower than pre-industrial levels. Our results show that if the Paris Agreement is not met, Antarctica's long-term sea-level contribution will dramatically increase and exceed that of all other sources.

PART 2 OF THIS PRESENTATION WILL BE OUR NEXT SEMINAR

- Additional climate science arguing against the Neoclassical, and especially the Nordhaus, frameworks.
- If time permits: Ethical considerations, more realistic damage modelling thoughts, and arguments for rejection of the Neoclassical framework entirely, and approach instead from strict enforcement of a stable livable future as determined by physics. Only then should we consider how to pay for it.
- Might need a 3rd talk to give adequate time.