



Nonlinear geophysics and climate closure:

Game over for climate skeptics

McGill, Homer's physics
21 November, 2014

S. Lovejoy

What is the climate?

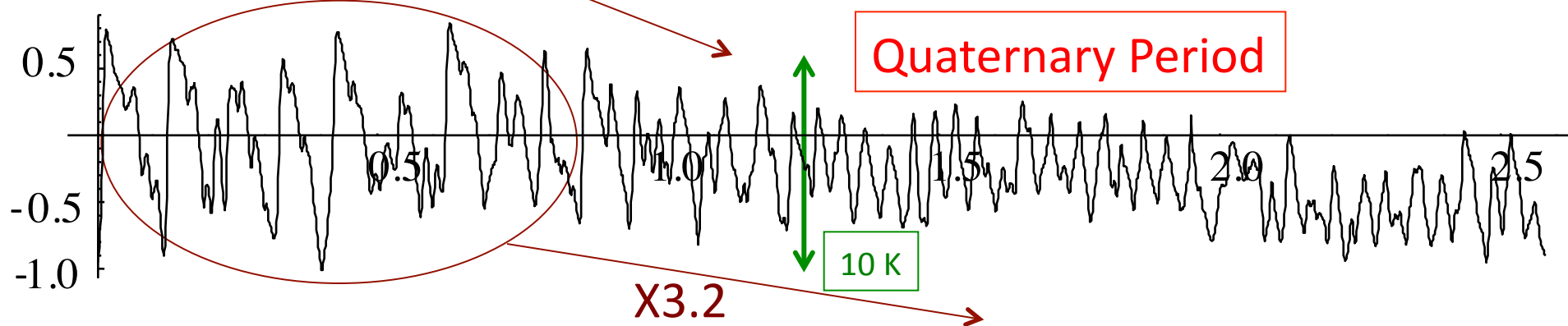
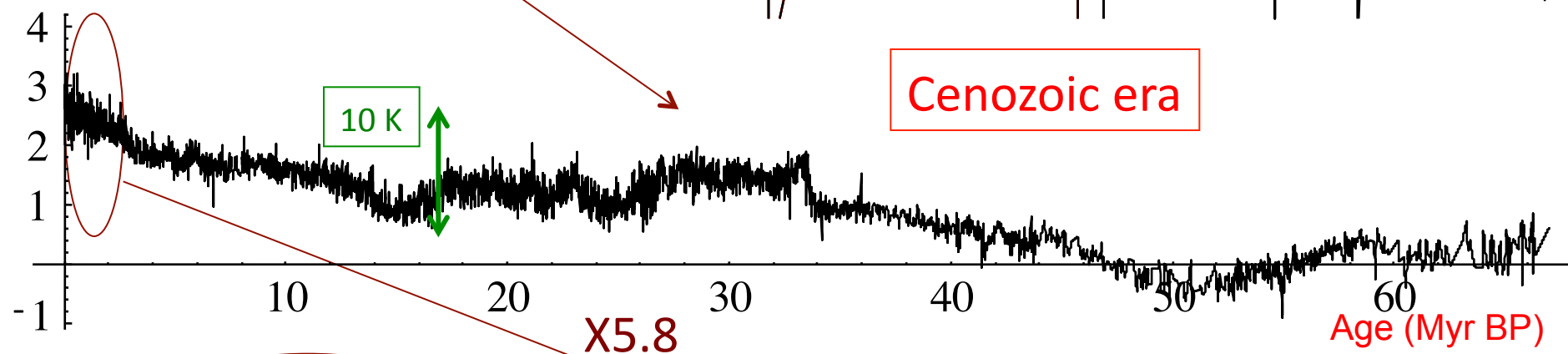
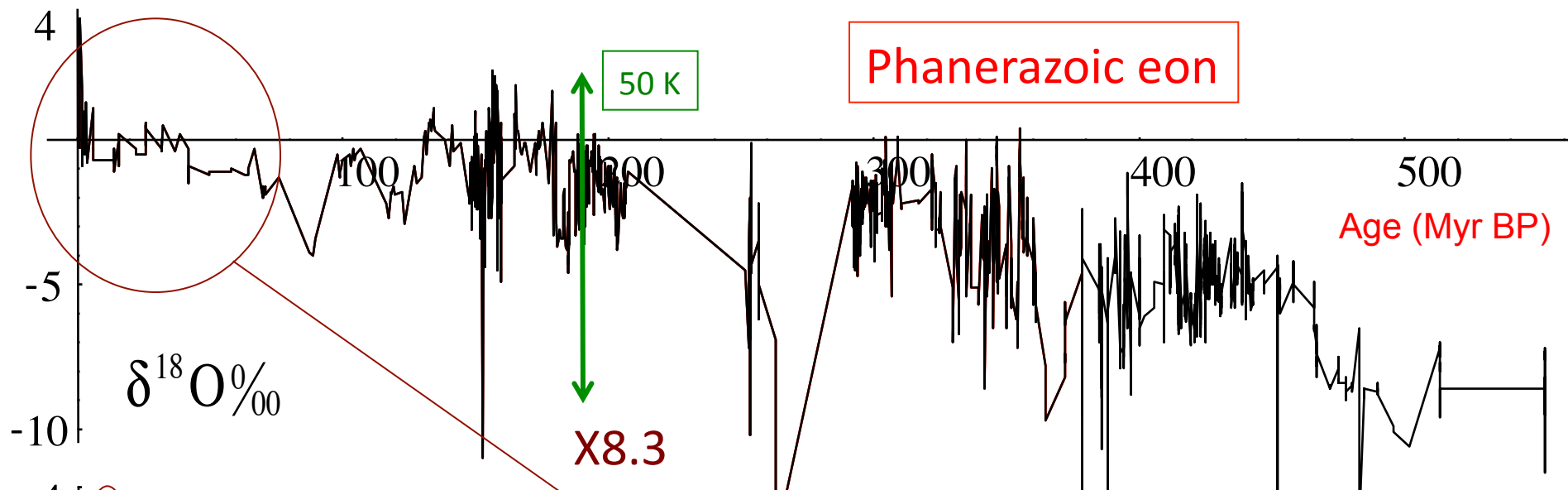
A voyage through scales

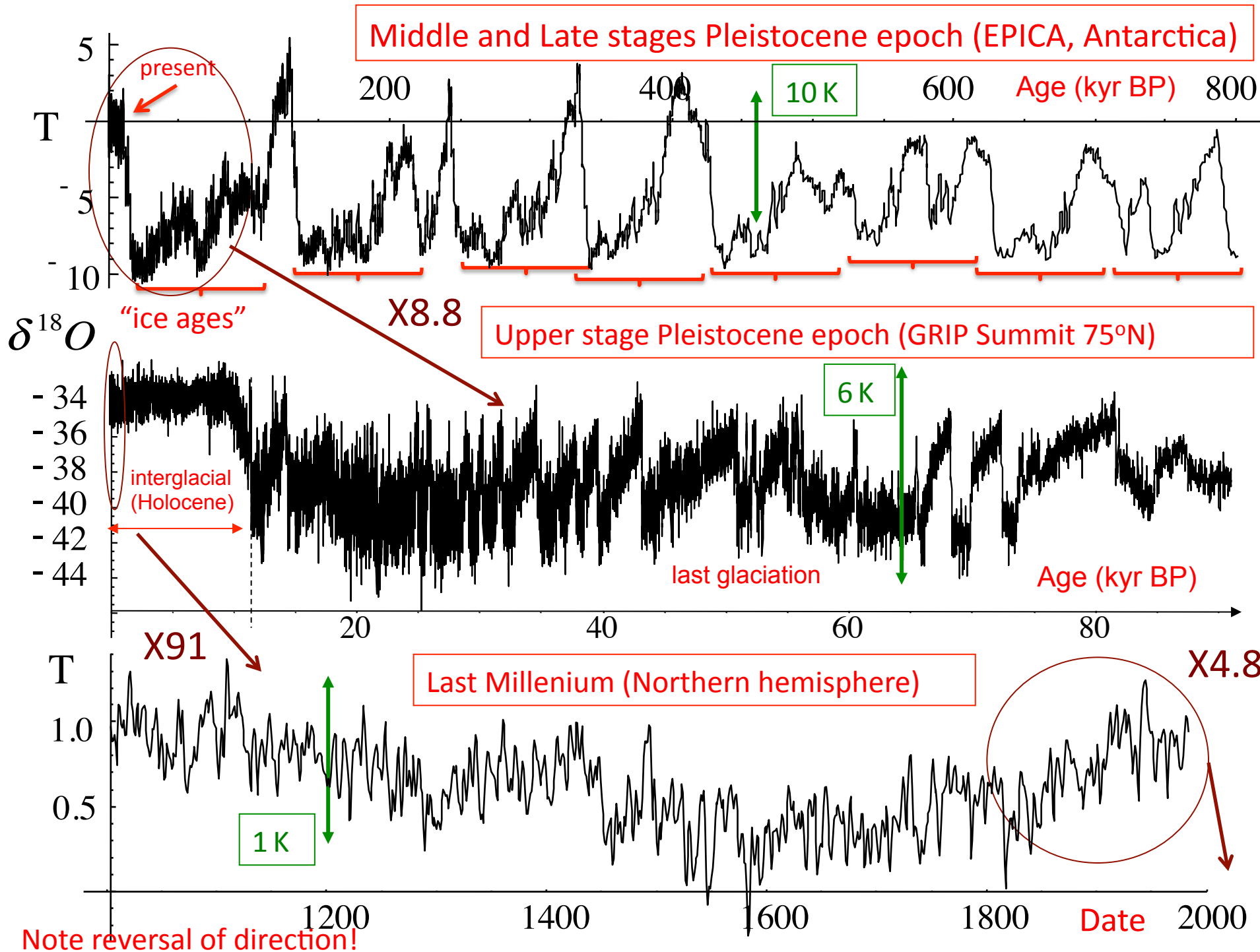
From the age of the earth to the
viscous dissipation scale: 4.5×10^9
years - 1 ms:

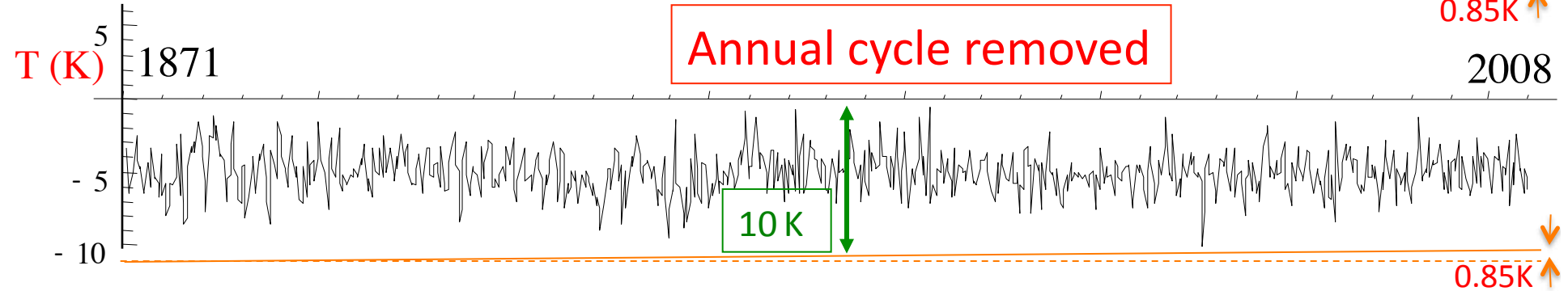
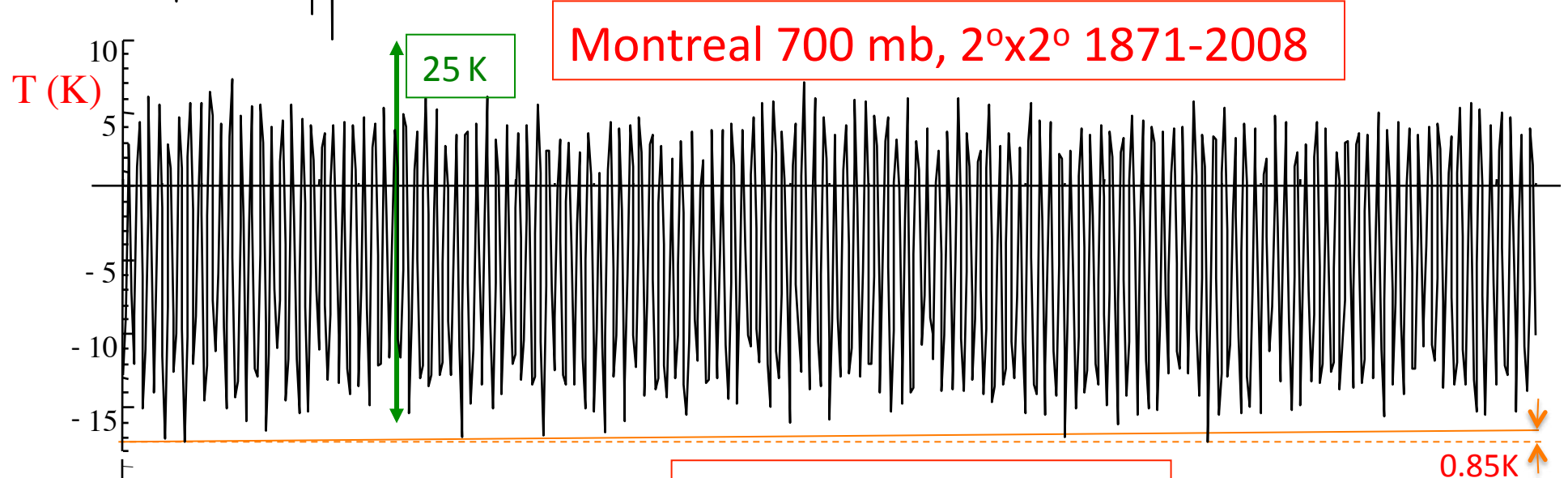
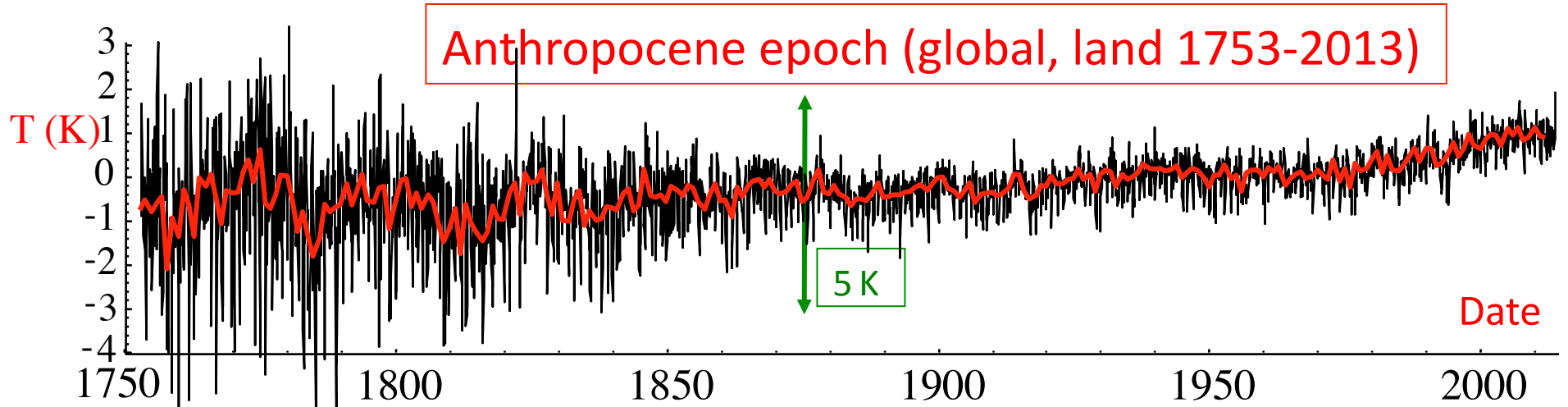
20 orders of magnitude in time

In space: the size of the planet to viscous
dissipation scales:

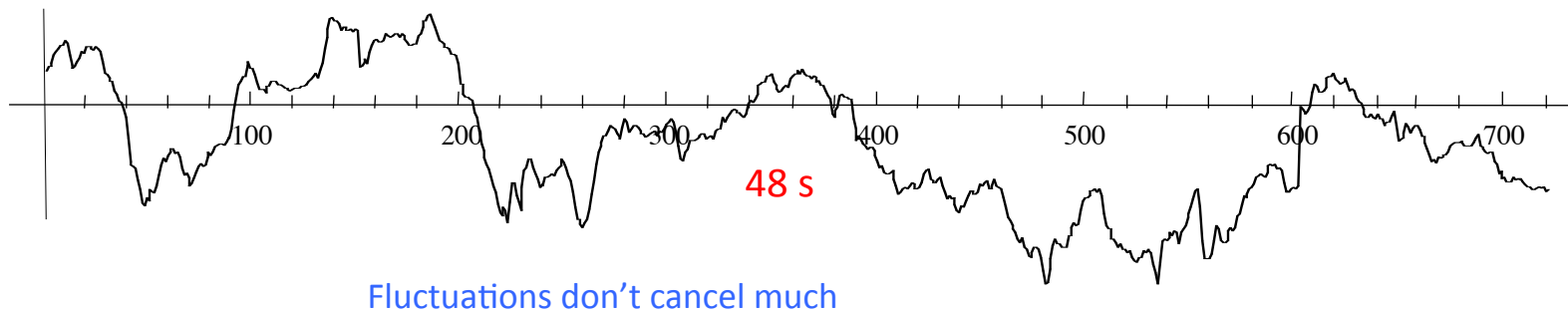
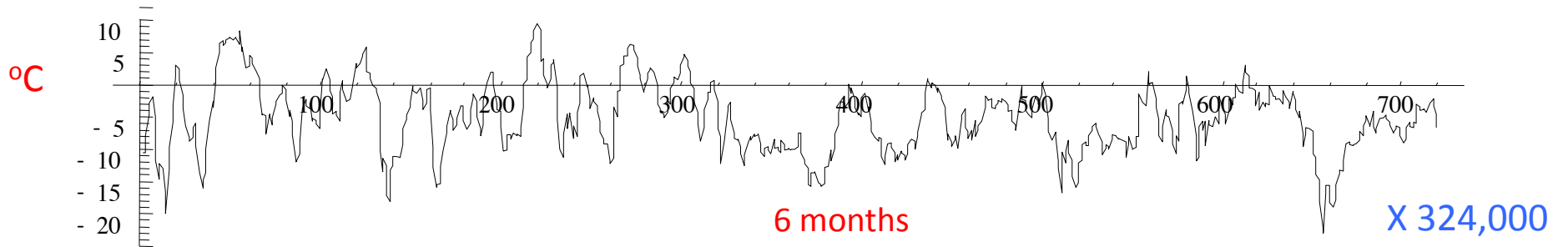
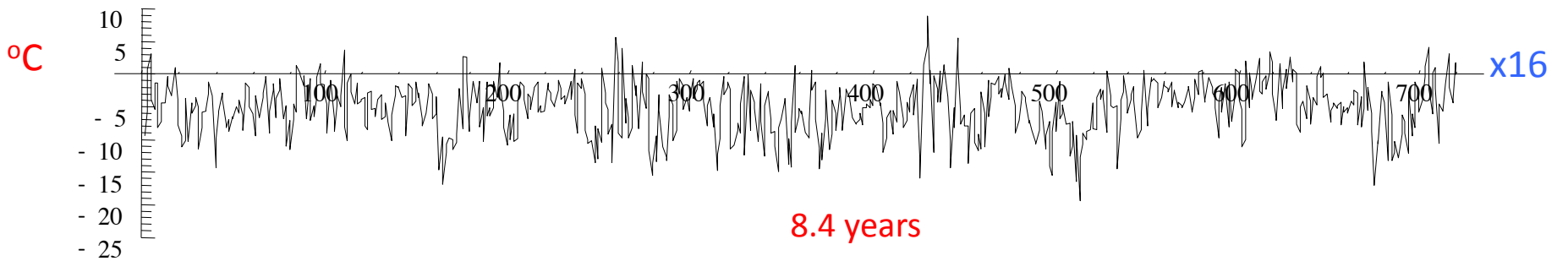
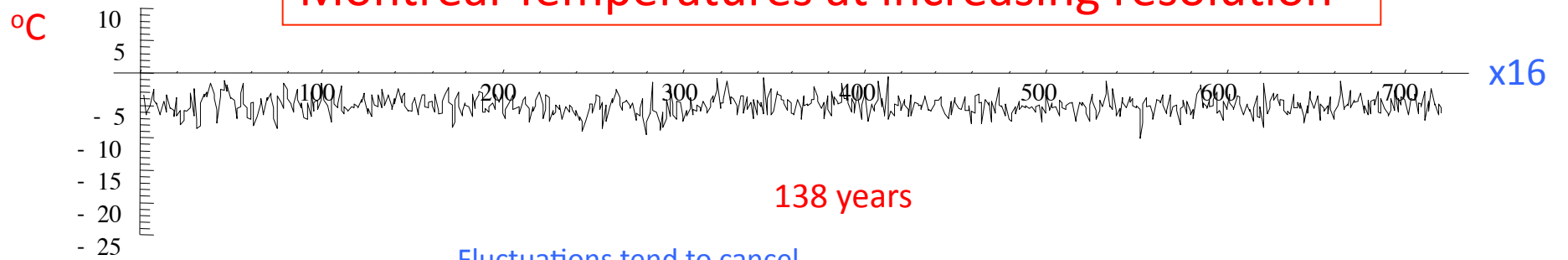
10 orders of magnitude







Montreal Temperatures at increasing resolution



The climate is not what you expect...

"Climate is what you expect, weather is what you get."

-Lazarus Long, character in R. Heinlein 1973

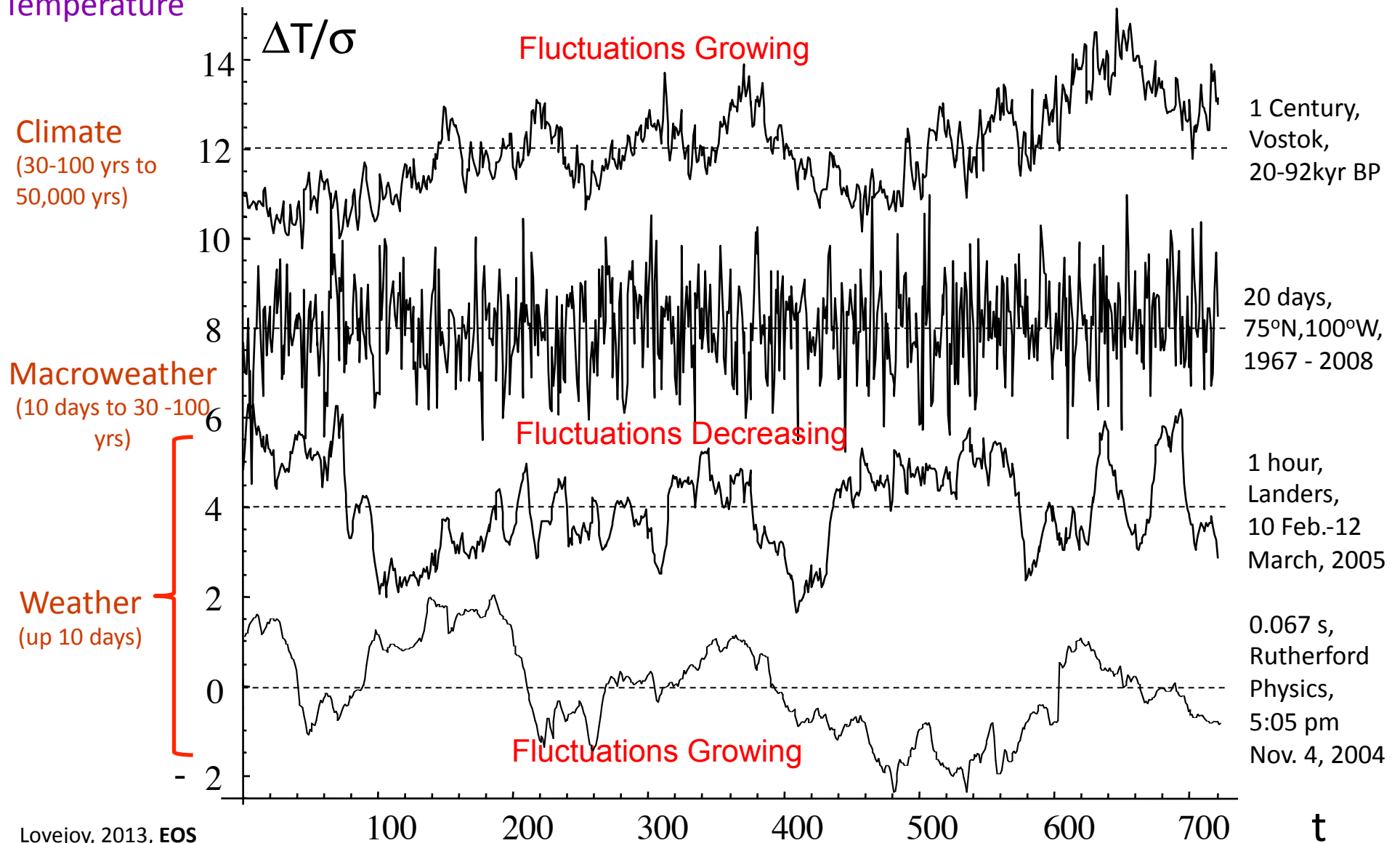
"Climate in a narrow sense is usually defined as the "average weather" ... The classical period is 30 years, as defined by the World Meteorological Organization (WMO)... Climate in a wider sense is the state, including a statistical description, of the climate system."

-Intergovernmental Panel on Climate Change, 2007

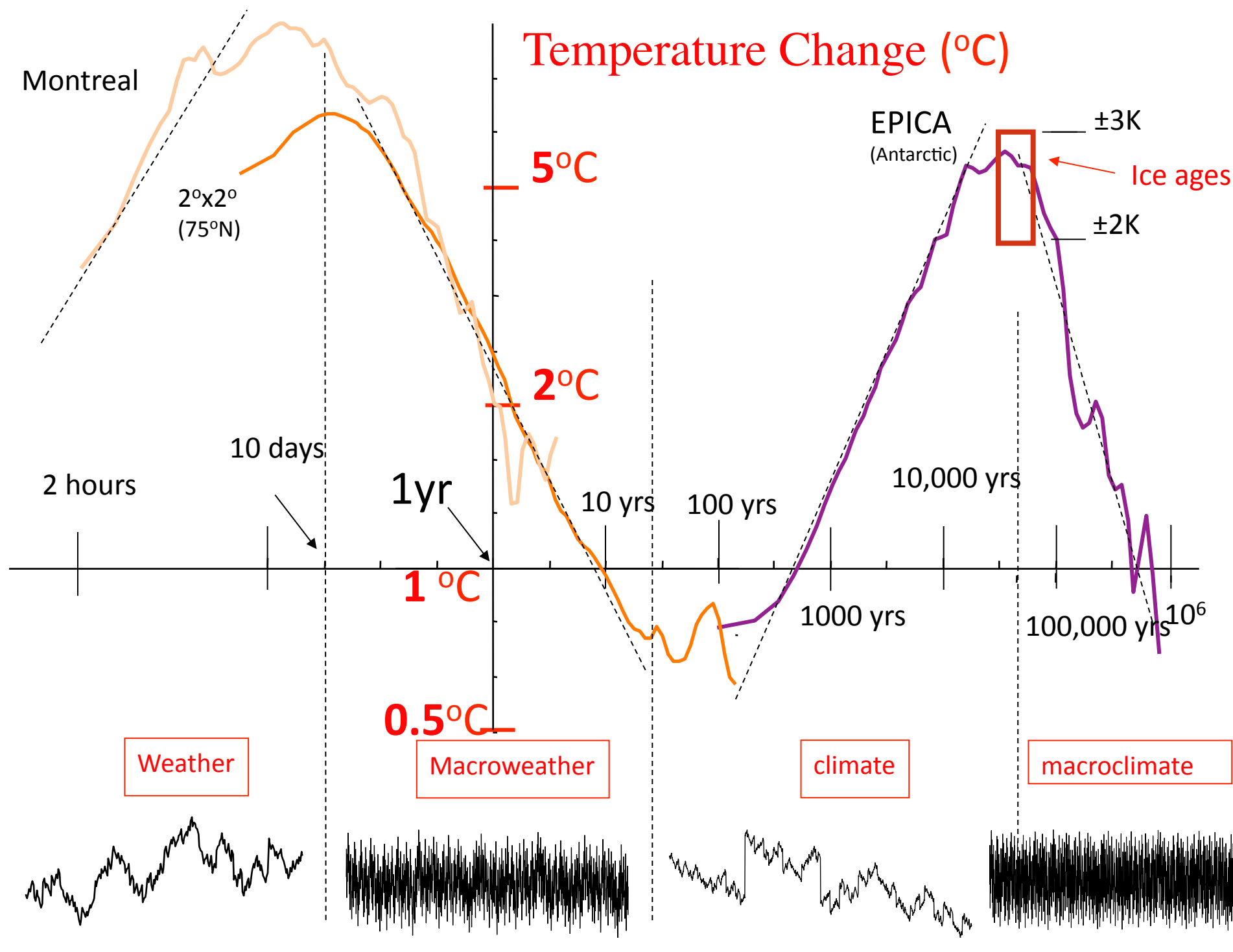
Trichotomy:

Weather – macroweather - climate

Temperature



Temperature Change (°C)



Montreal

2°x2°
(75°N)

EPICA
(Antarctic)

±3K

Ice ages

±2K

2 hours

10 days

1 yr

10 yrs

100 yrs

10,000 yrs

1000 yrs

100,000 yrs

10⁶

1°C

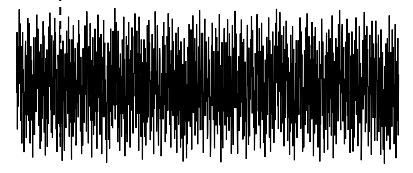
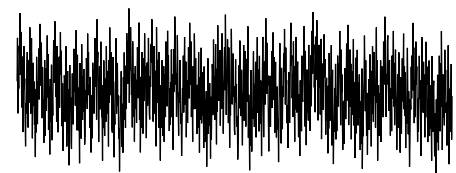
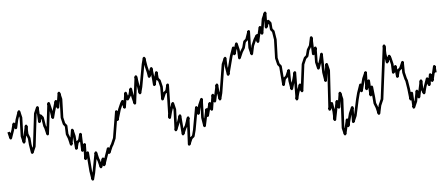
0.5°C

Weather

Macroweather

climate

macroclimate



This week...

 AGU PUBLICATIONS



Geophysical Research Letters

RESEARCH LETTER

10.1002/2014GL061861

Key Points:

- Mars has weather/macroweather transition very similar to Earth's
- We can calculate the transition scale from first principles
- Lander, Mars reanalysis, and terrestrial data agree

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On Mars too expect macroweather

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¹Department of Physics, McGill University, Montreal, Quebec, Canada, ²Mullard Space Science Laboratory, Department of Space and Climate Physics, Dorking, UK

Abstract Terrestrial atmospheric and oceanic spectra show drastic transitions at $\tau_w \approx 10$ days and $\tau_{ow} \approx 1$ year, respectively; this has been theorized as the lifetime of planetary-scale structures. For wind and temperature, the forms of the low- and high-frequency parts of the spectra (macroweather and weather) as well as the τ_w can be theoretically estimated, the latter depending notably on the solar-induced turbulent energy flux. We extend the theory to other planets and test it using Viking lander and reanalysis data from Mars. When the Martian spectra are scaled by the theoretical amount, they agree very well with their terrestrial atmospheric counterparts. We discuss the implications for understanding planetary fluid dynamical systems.

1. Introduction

Atmospheric wind spectra undergo some kind of transition at scales of $\tau_w \approx 2$ –10 days. First ascribed to “migratory pressure systems of synoptic weather map scale” [Panofsky and Van der Hoven, 1955; Van der Hoven, 1957], the corresponding pressure feature was termed the “synoptic maximum” by Kolesnikov and Monin [1965] and Panofsky [1969]. More recently, Vallis [2010] attributed it to baroclinic instabilities and

This morning....

COVER STORY

Five stars that could go **BANG**

The world's best-selling astronomy magazine



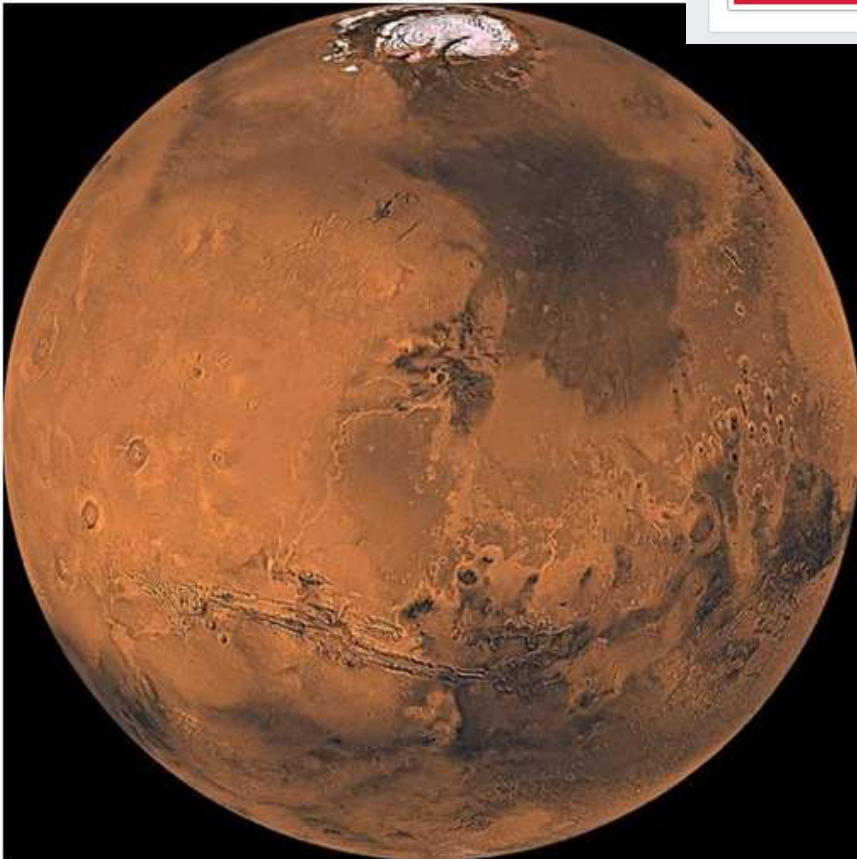
Astro Astronomy Magazine

J'aime S'abonner Partager

Journal À propos Photos Subscribe Plus

Astro Astronomy Magazine
19 novembre

A new study found that Earth's three-part pattern of weather, moisture, and climate applies to atmospheric conditions on Mars. The results show that the Sun plays a major role in determining macroweather. Learn more at <http://goo.gl/2GGBp2>



J'aime · Commenter · Partager

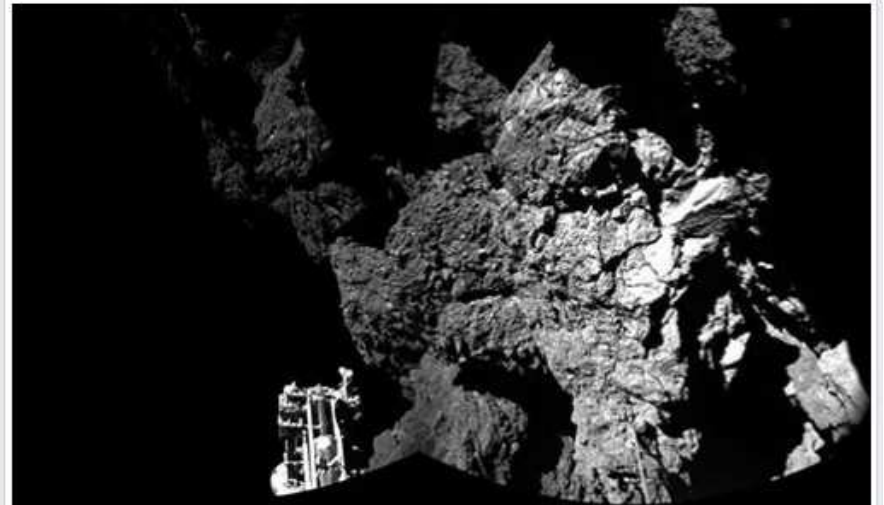
705 partages

3 360 personnes aiment ça.

Meilleurs commentaires

Astro Astronomy Magazine
19 novembre

Philae's instruments found hard ice and organic molecules on the surface of Comet 67P/Churyumov-Gerasimenko before the Rosetta lander went into hibernation. Learn more at <http://goo.gl/0SqiDF>



J'aime · Commenter · Partager

51 partages

324 personnes aiment ça.

Meilleurs commentaires

Conclusion:

“Macroweather is what you
expect

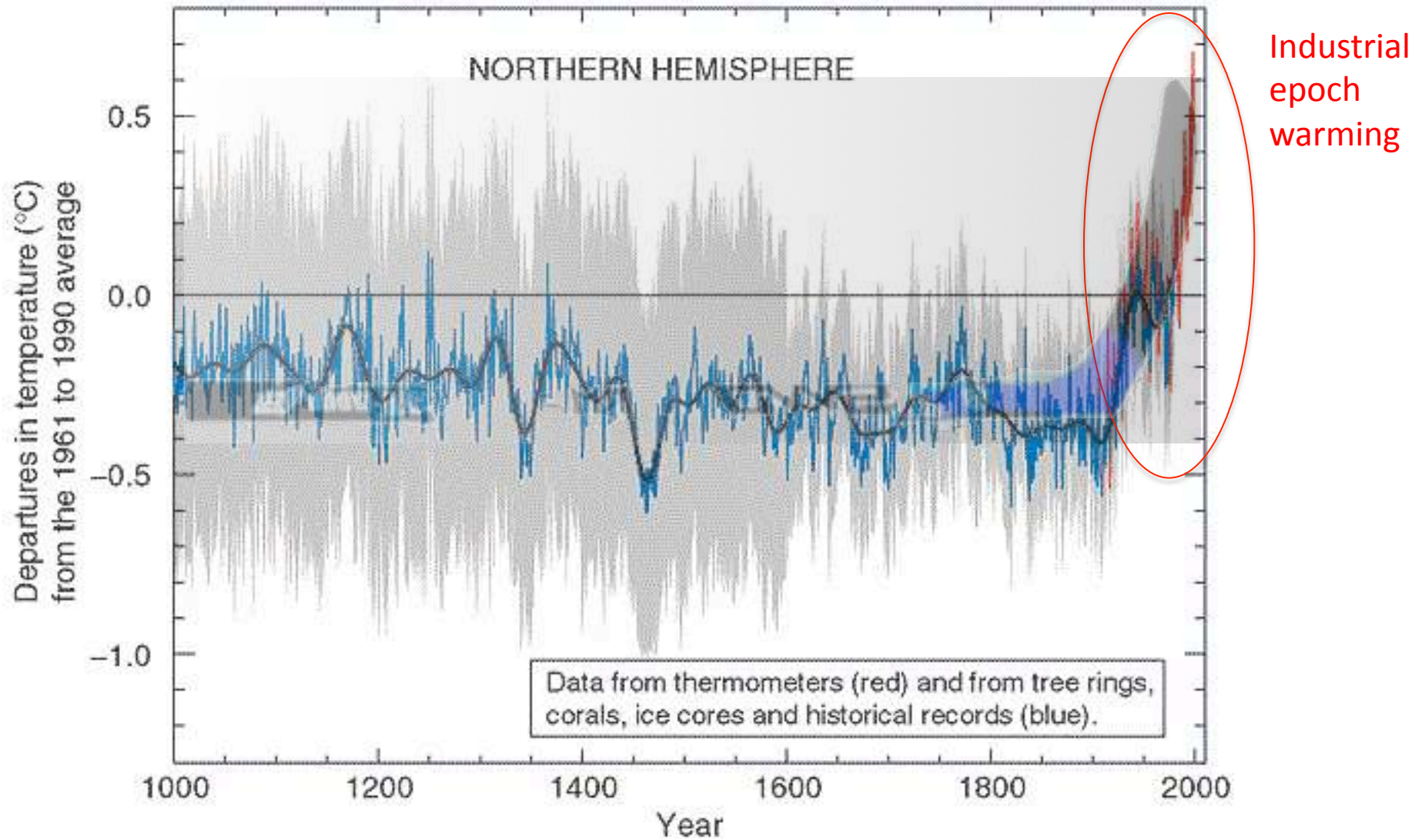
The climate is what you get!”

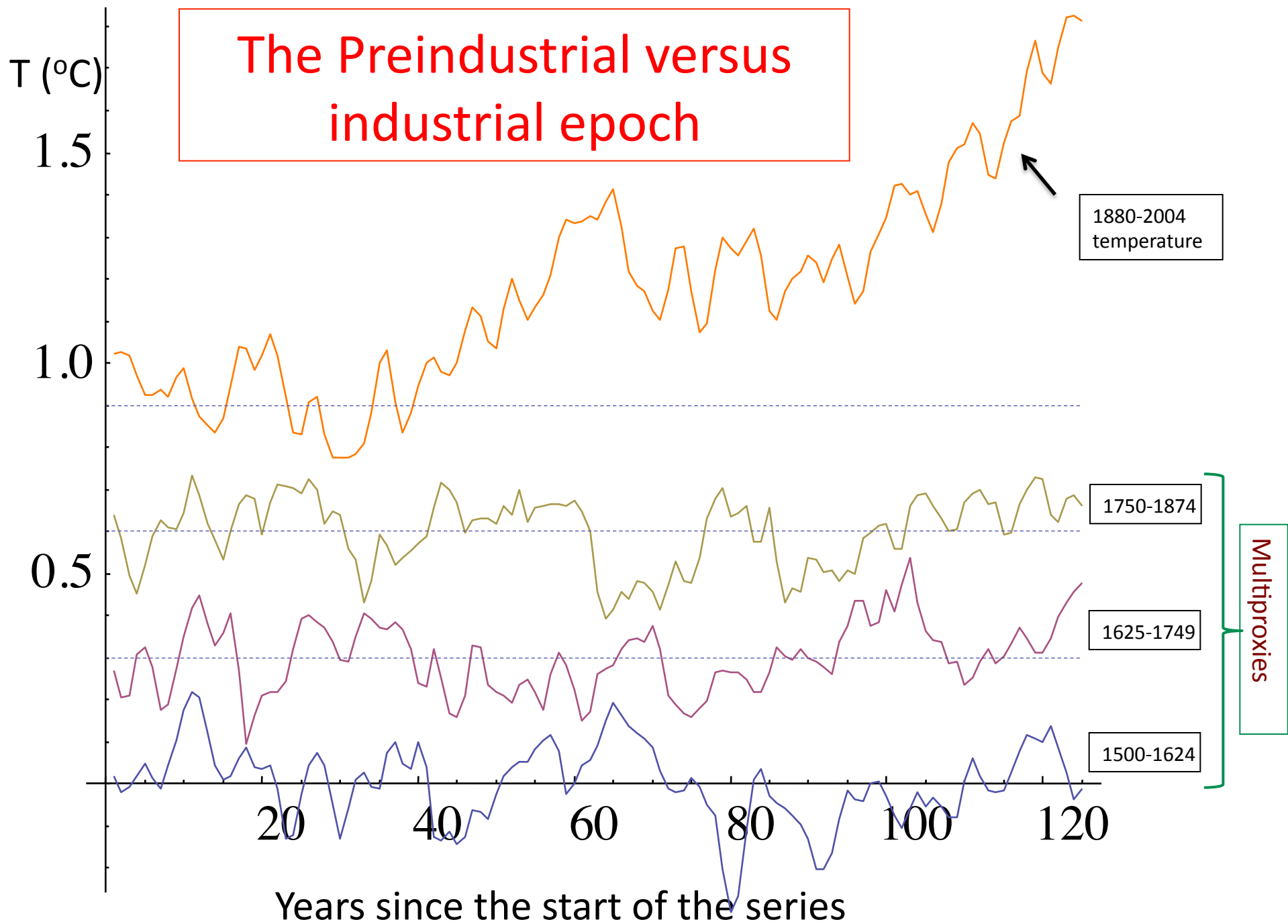
Weather, macroweather and the climate are distinguished by the way they change under a zoom!

Evidence for warming

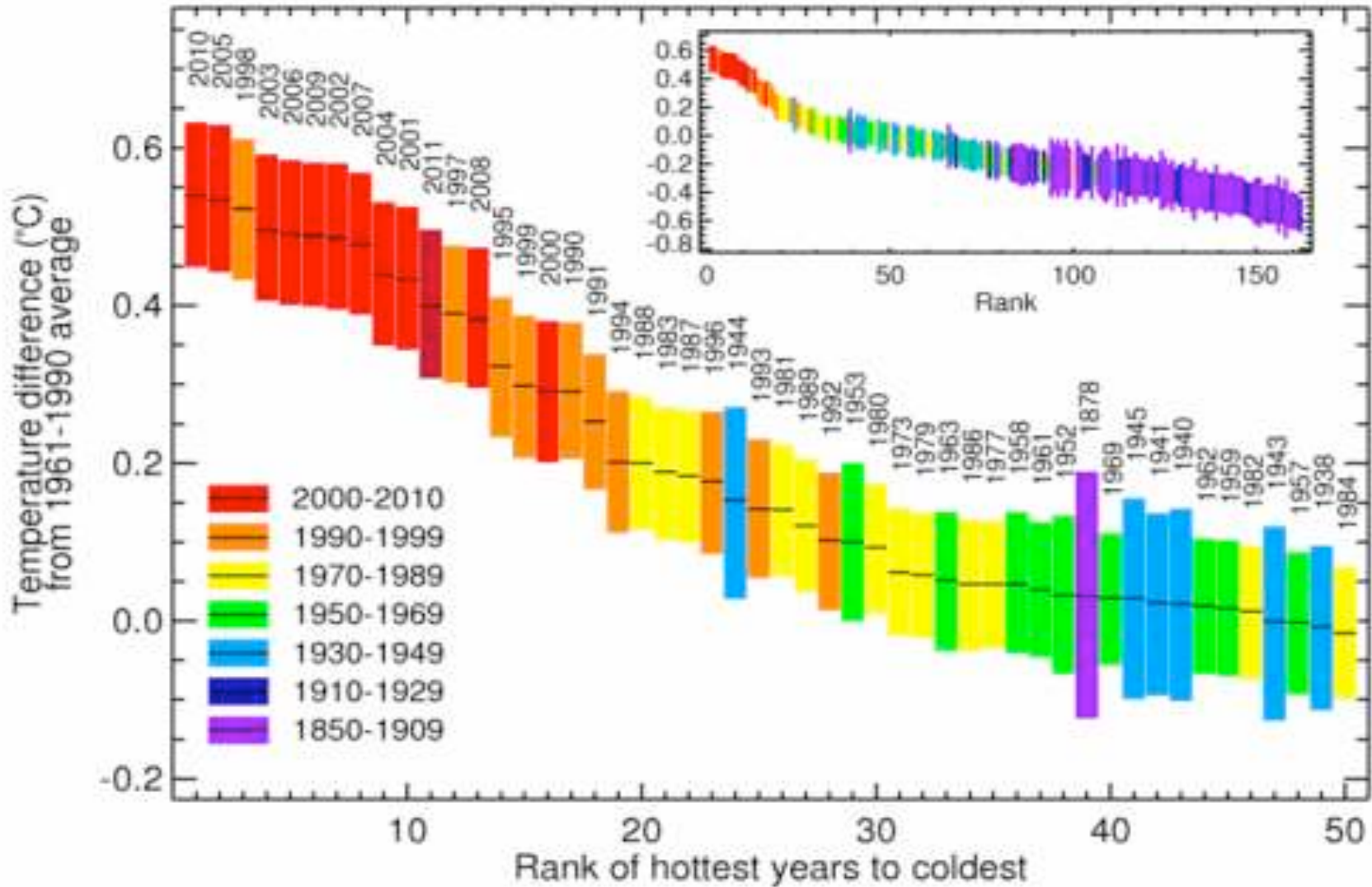
The “hockey stick”

Mann, Bradley, Hughes 1998





Ranking of temperatures from hottest to coldest



The Arctic

(melting of sea ice)



1979 SSMI Composite Data

1979

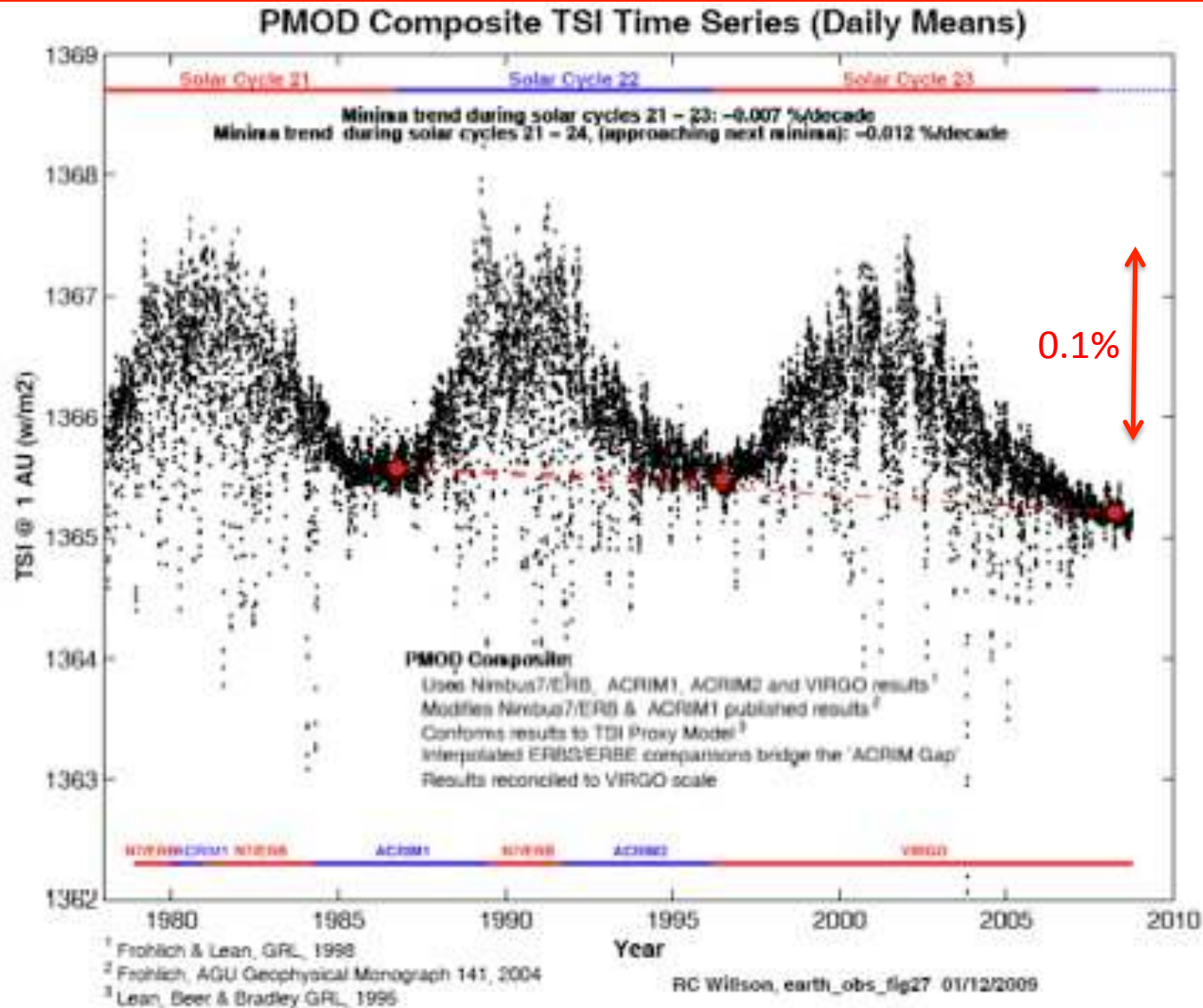


2003 SSMI Composite Data

2005

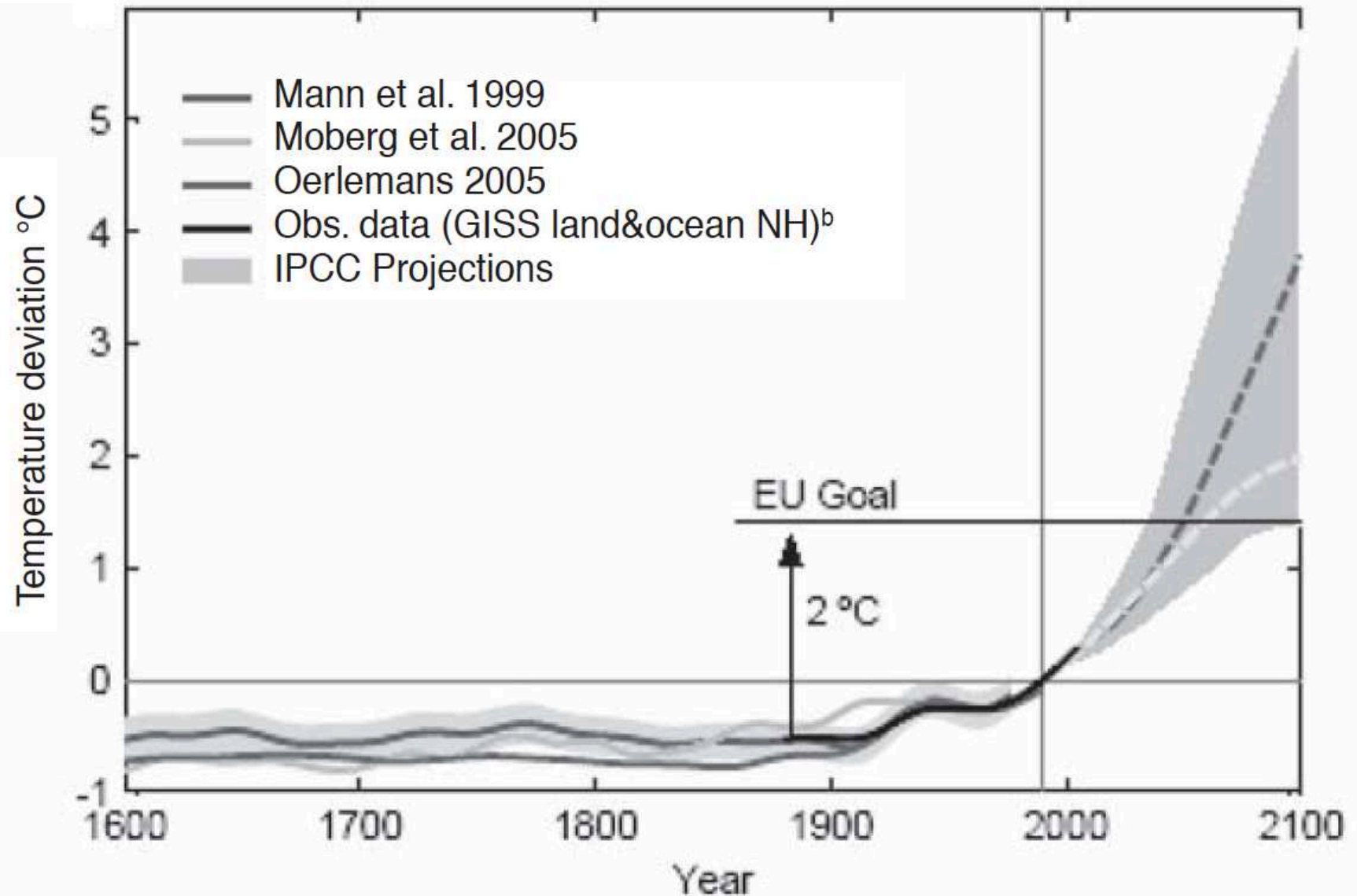
It's not the sun:

Total Solar Insolation (satellite)



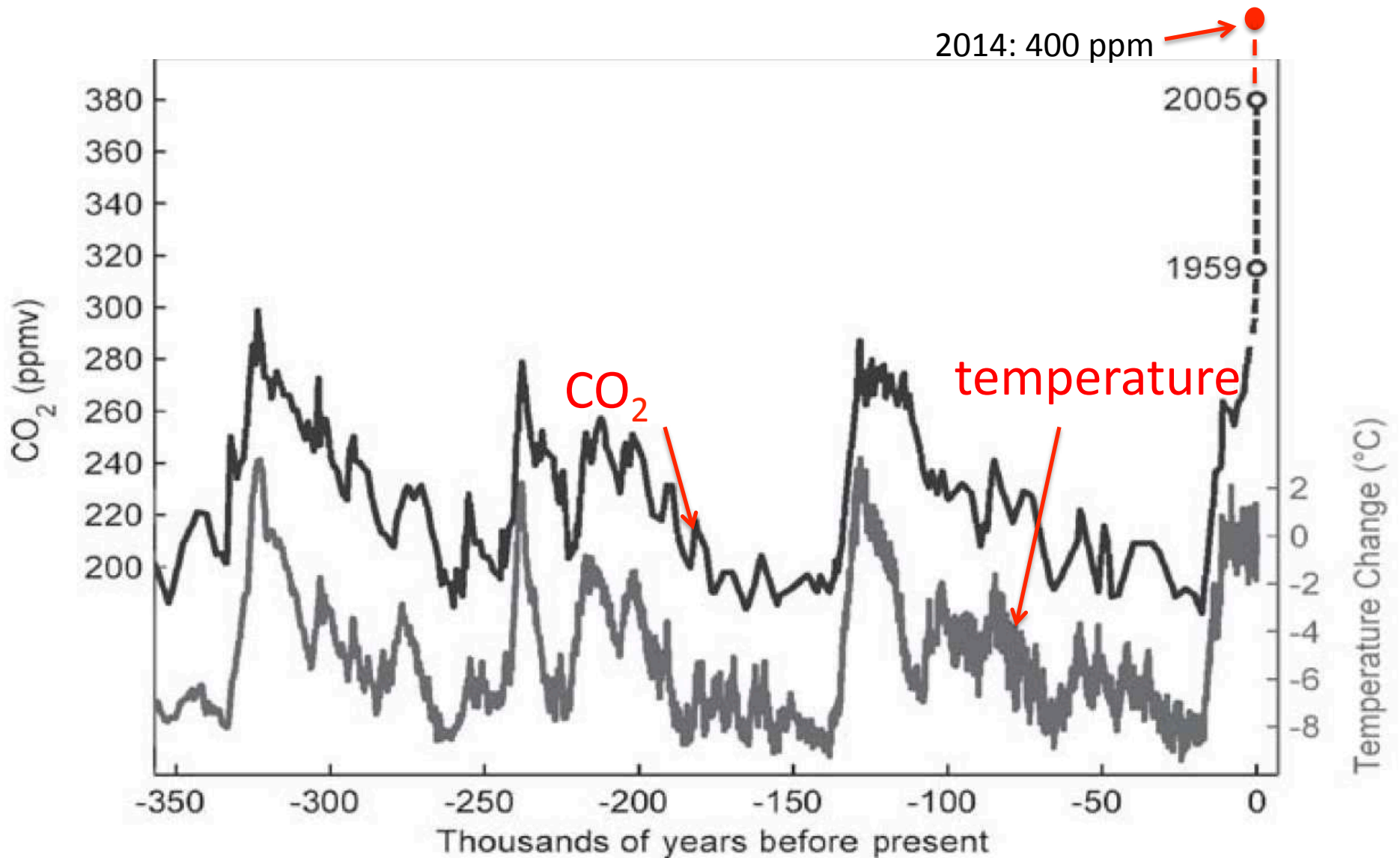
21st century

Global Temperature Projections for the Twenty-First Century^a



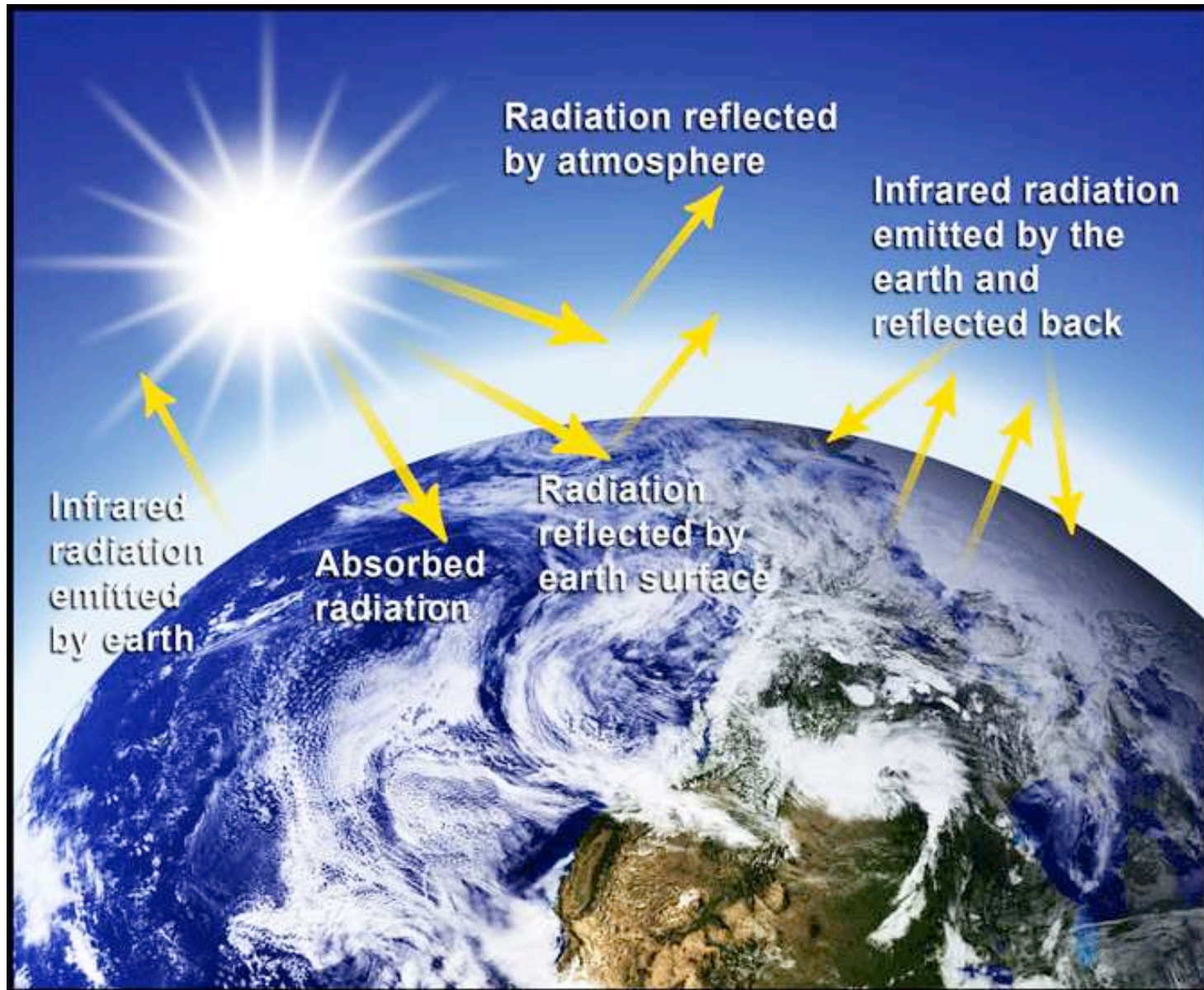
Why is it warming?

CO₂: The last 350,000 yrs



Source: J. R. Petit and others, "Climate and Atmospheric History of the Past 420,000 Years from the Vostok Ice Core, Antarctica," *Nature* 399 (June 1999): 429–36.

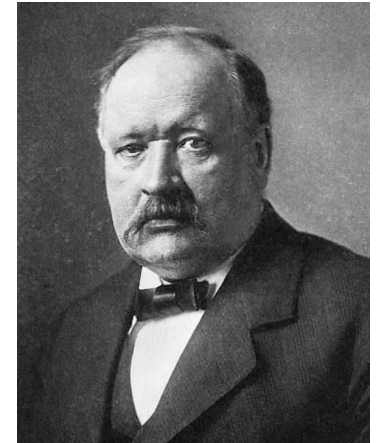
The theory of anthropogenic warming: the “Greenhouse effect”



History of the theory of anthropogenic warming (1)

1896

Nobel prize winner Svante Arrhenius: CO₂ doubling: 5 – 6°C of warming, “climate sensitivity” (c.f. IPCC 2013: 1.5 - 4.5°C).



Svante Arrhenius
(1859 –1927)

1938

Callender estimated the warming as 2° C



Guy Stewart Callendar
1898 - 1964

1957

Keeling started his celebrated CO₂ measurements at Mauna Loa and at the south Pole



Charles David Keeling
1928 –2005

1960

Skepticism:

- a) The idea that a single factor was responsible was “simplistic”.
- b) The idea that human action could have such vast consequences was repugnant.
- c) In error, the meteorological authorities opposed the theory.

History (2): Global Climate Models (GCM)



Richardson:
1881-1953
Father of numerical
models of the
atmosphere: 10^{-2} Flops (?)

GCM's: for CO₂ doubling:

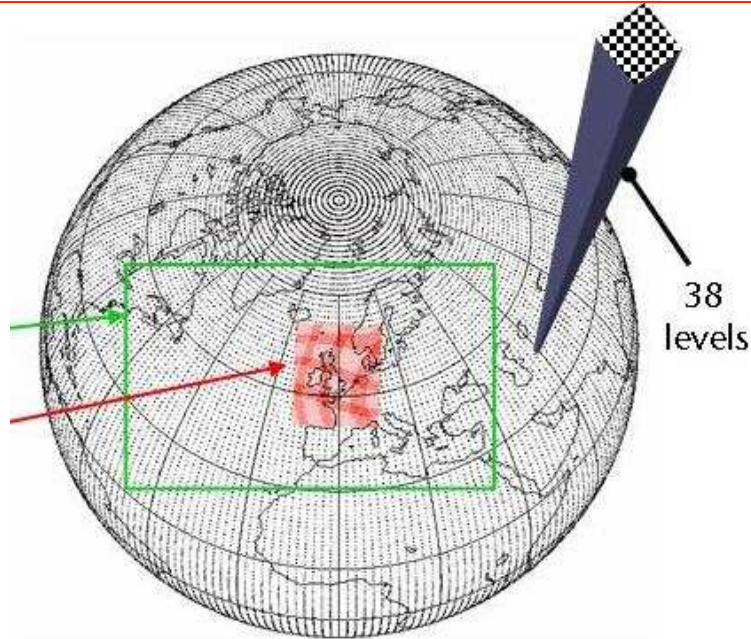
US National Academy of Science (1979):

1.5- 4.5°C

IPPC3 (2002): 1.5- 4.5°C

IPPC4 (2007): 2- 4.5°C

IPPC5 (2013) : 1.5- 4.5°C (*"high confidence"*)



1975:
The first numerical
climate models:
GCM's ("Global
Circulation Model")

MilkyWay-2: World's fastest supercomputer (June 2013)

National University of Defense Technology, Changsha, China



"天河一号" 千万亿次超级计算机

3,120,000 cores: 3×10^{16} Flops

Skeptics and Deniers

Some legitimate Grounds for climate skepticism

- 1. The models are unreliable they have not been tested, they aren't valid.
They have been tested but are only valid to a point: no model is perfect, predictions of warming doesn't depend on the models
- 2. The historical observations of warming are not reliable.
- 3. Other data contradict the warming.
- 4. Even if the Earth is warming it is due to natural causes.
- 5. The "pause": earth has stopped warming since 1998 hence the warming can't be anthropogenic.

(legitimate until at latest 2005)

Disproved in 2014... see the following!

Illegitimate Climate skepticism: The deniers (1)

A few examples:

In 1998, the Marshall Institute for Science and Environmental Policy and ExxonMobil launched a \$20 million campaign to:

- Find reputable scientists to spread doubt about anthropogenic warming.
- Fund an advertising campaign proting the idea that the warming is neither real nor worrying.
- To lobby the US congress.

In 2007, the American Enterprise Institute: \$10,000 plus expenses to scientists willing to denigrate the IPCC 4th Assessment Report.

In 2012, the Heartland Institute:

- Funded denier literature:
 - paid several persons to spread climate denier views on the internet
 - paid scientists to write reports to decision makers or the public promoting skeptical views.
- Funded a campaign to encourage schools to teach climate denier material.

In 2014, in the US:

There are currently 91 different organizations with combined funding of over \$900 million (think tanks, advocacy groups, and trade associations) that collectively comprise a "climate change counter-movement. [[Brulle, 2014](#)],

Illegitimate skepticism: The deniers (2)

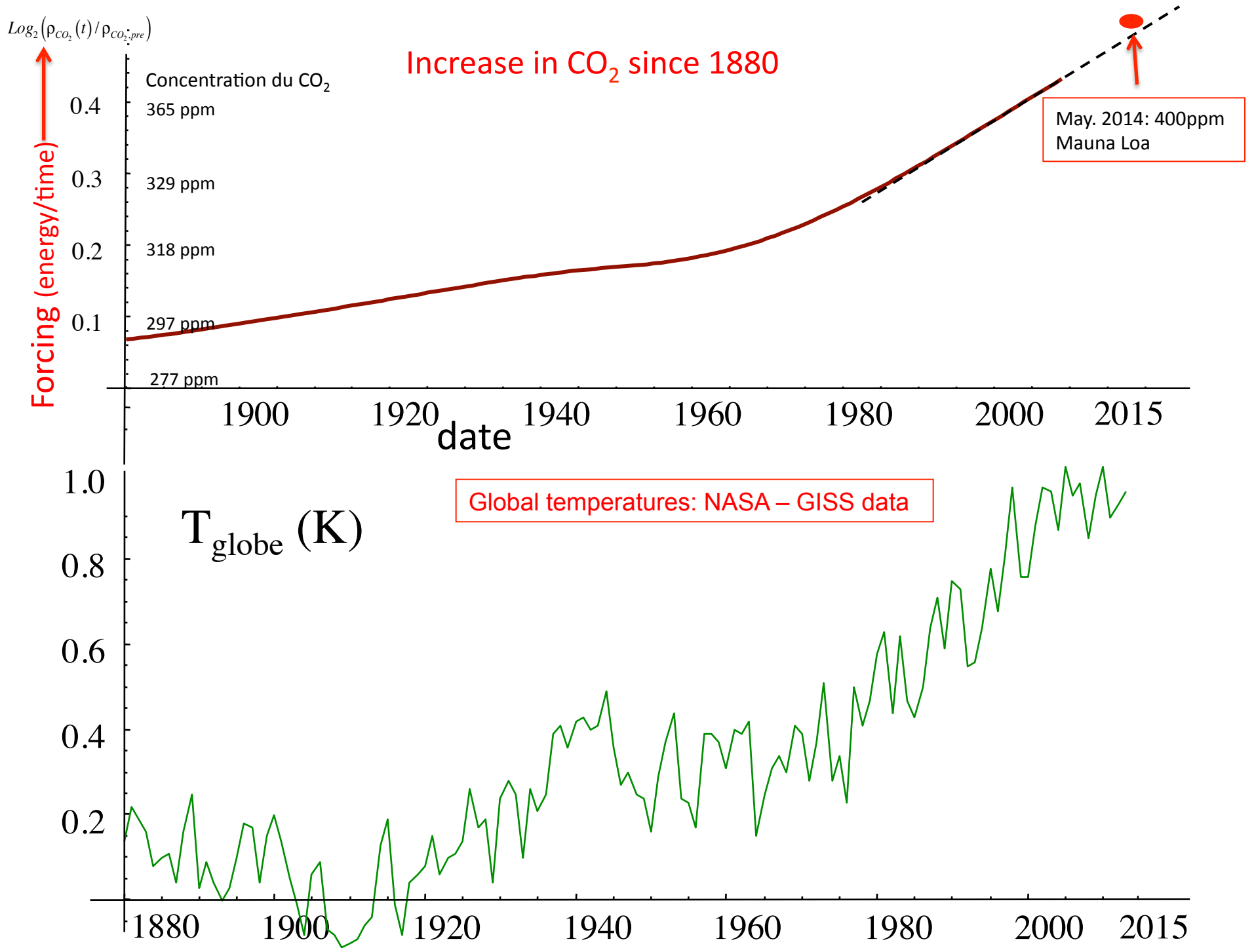
Tactics shared with the industry, creationists and holocaust deniers

- Quotation mining: citing short quotes from reputable scientists out of context.
- Juxtaposing cites from different sources to amplify minor disagreements between scientists in order to ridicule them.
- Drawing attention to minor scientific errors in order to bring into question the entire scientific enterprise.

Other indices of illegitimate criticism:

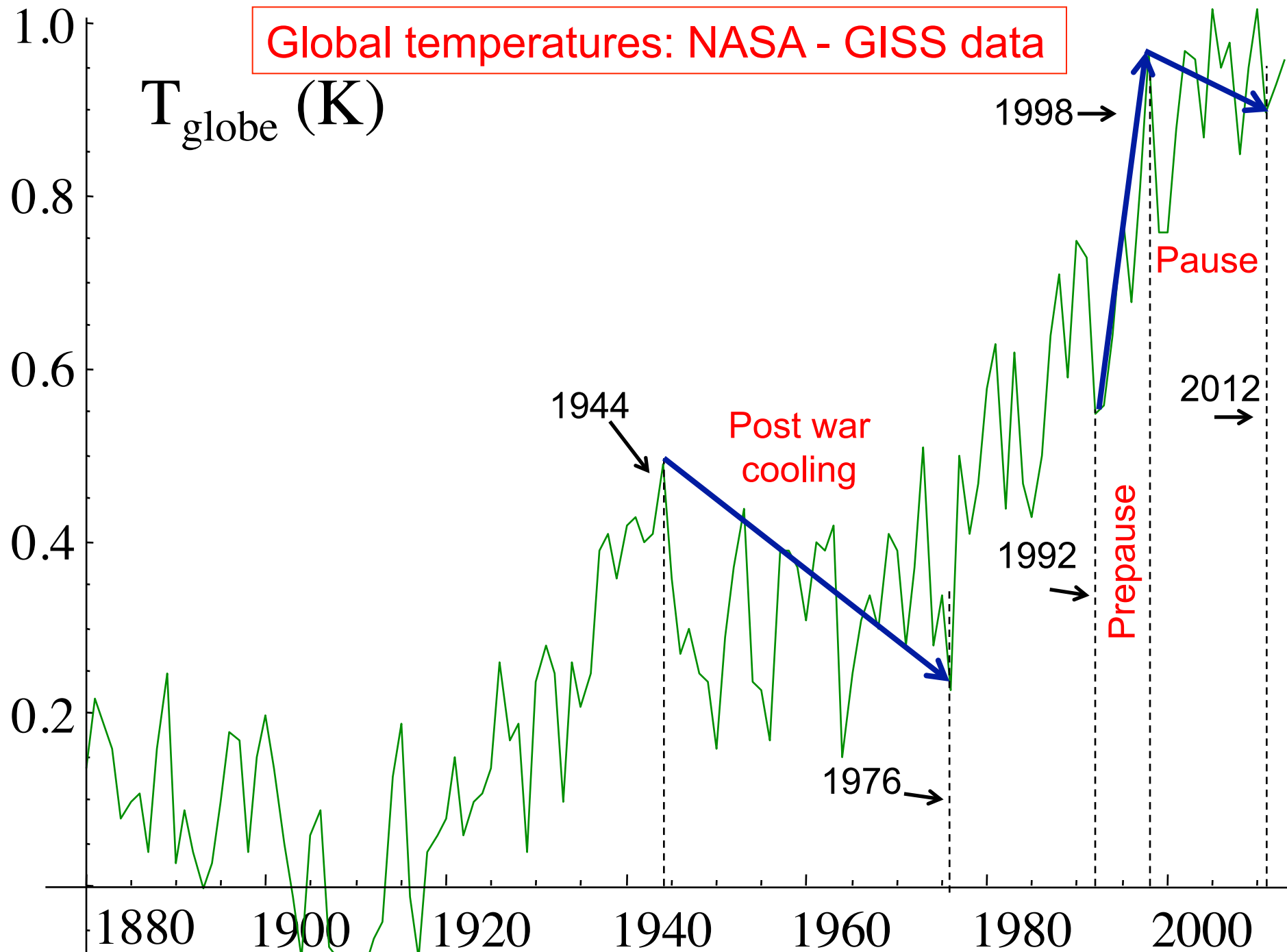
- The members of creationist and climate skeptic groups have a lot of overlap.
- Their antiscientific views are covered in the same media in the US:
Fox News, Glenn Beck, Rush Limbaugh. Creationism and Climate denial are increasingly the same people, organizations, outlets.

Disproving Natural warming
without GCM's

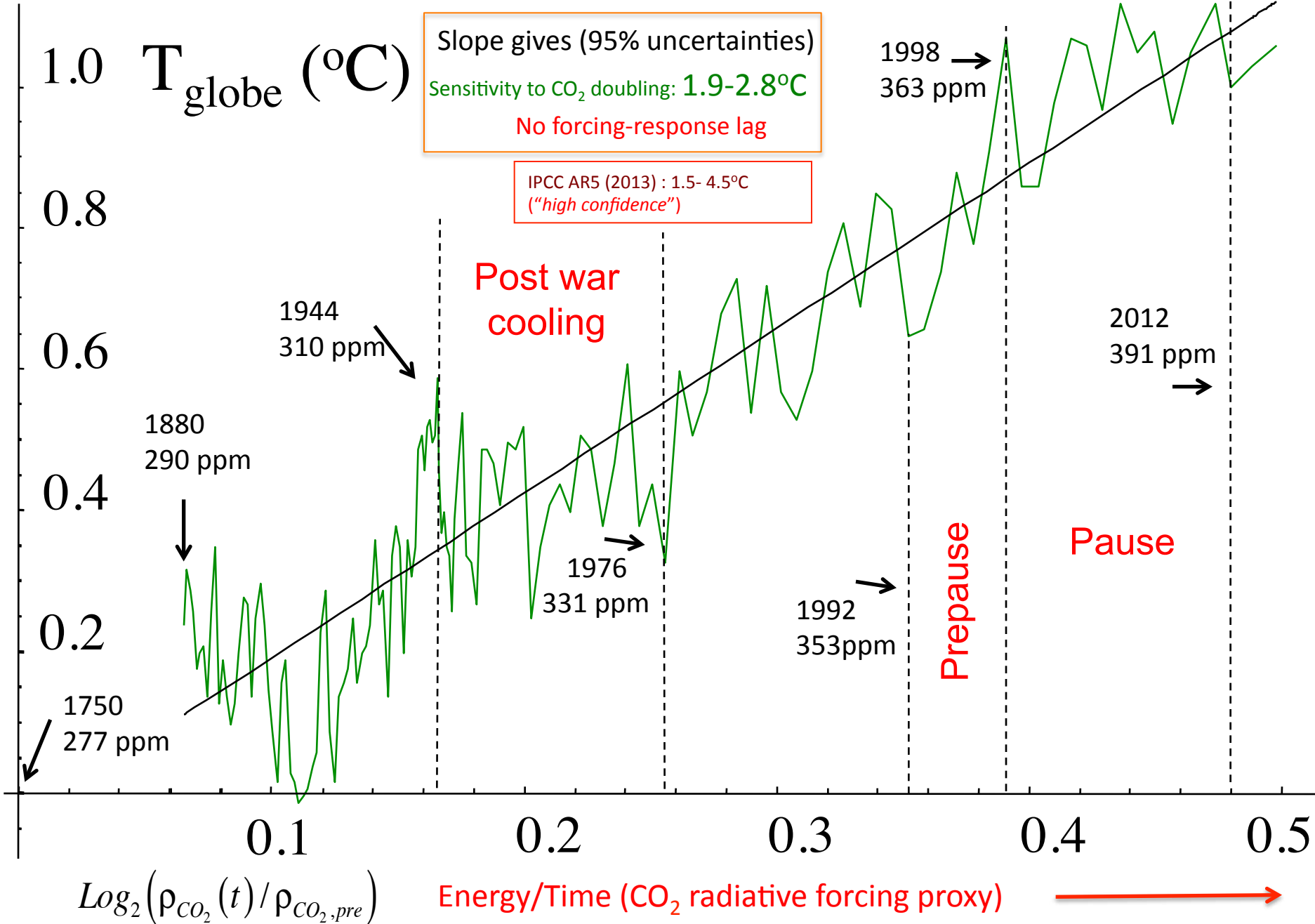


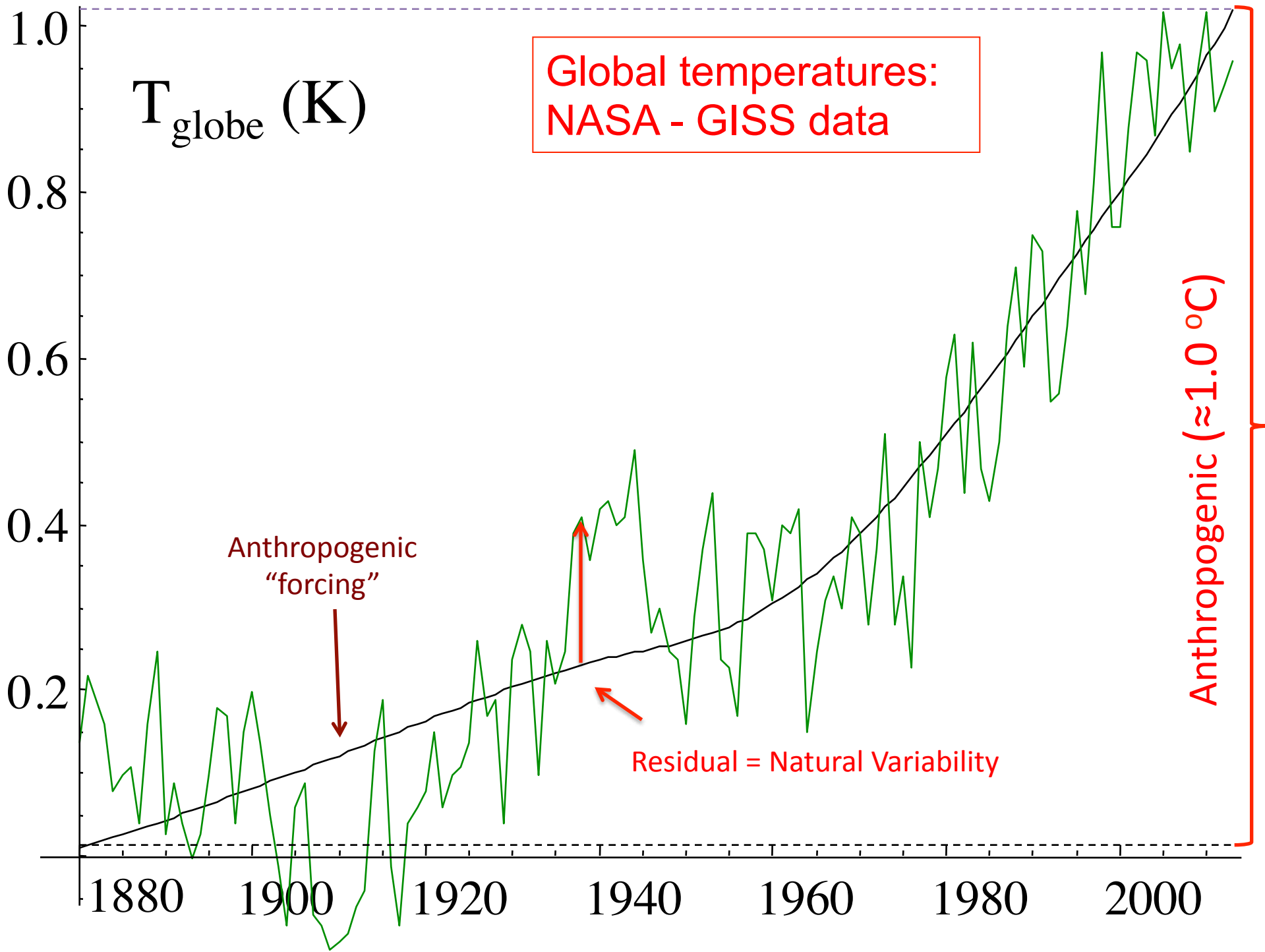
CO₂ forcing as surrogate for all anthropogenic effects

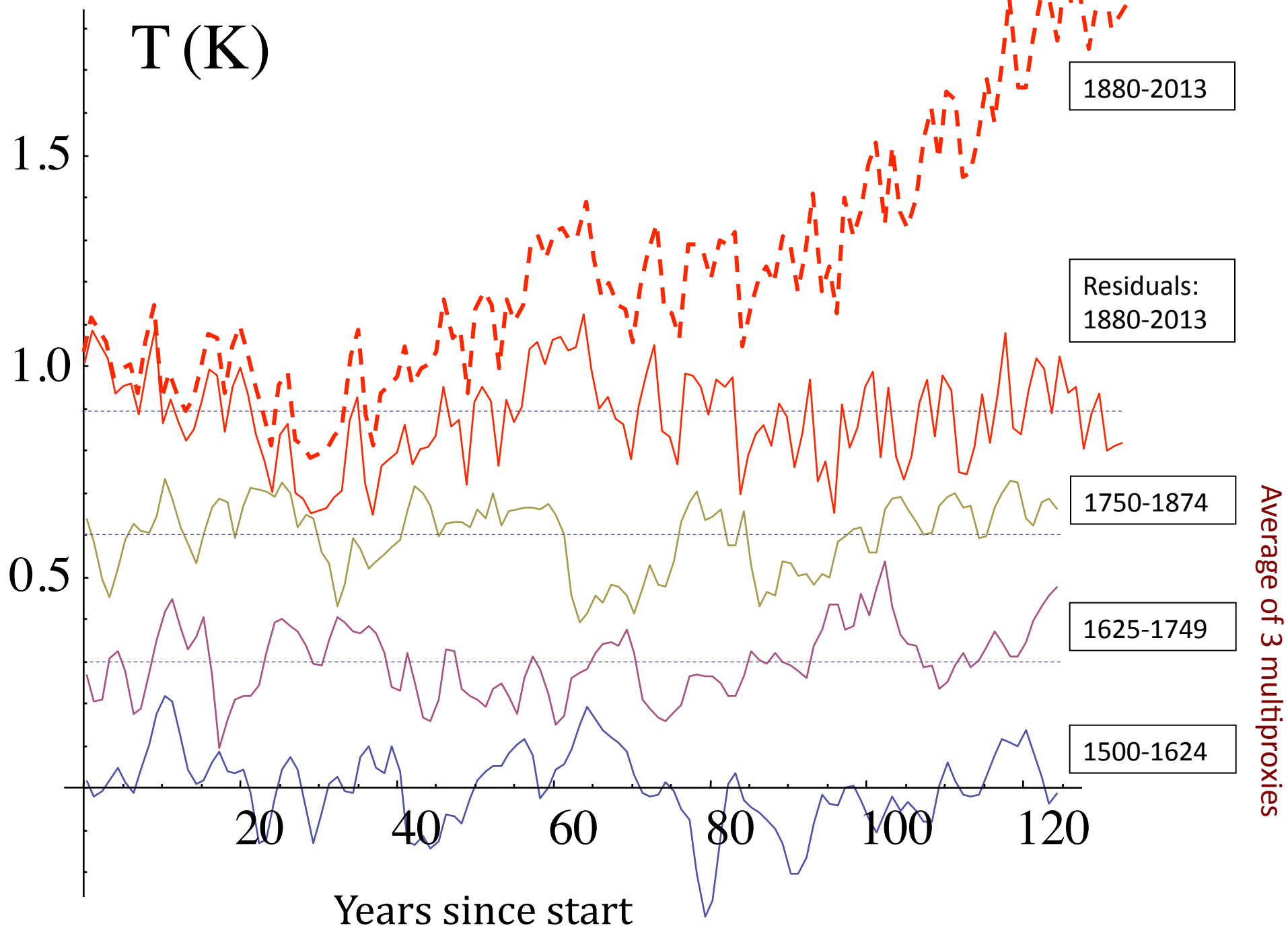
Roughly: you double the global economy, you double the emissions, land use and other changes, you double the effects



Global temperatures: NASA - GISS data

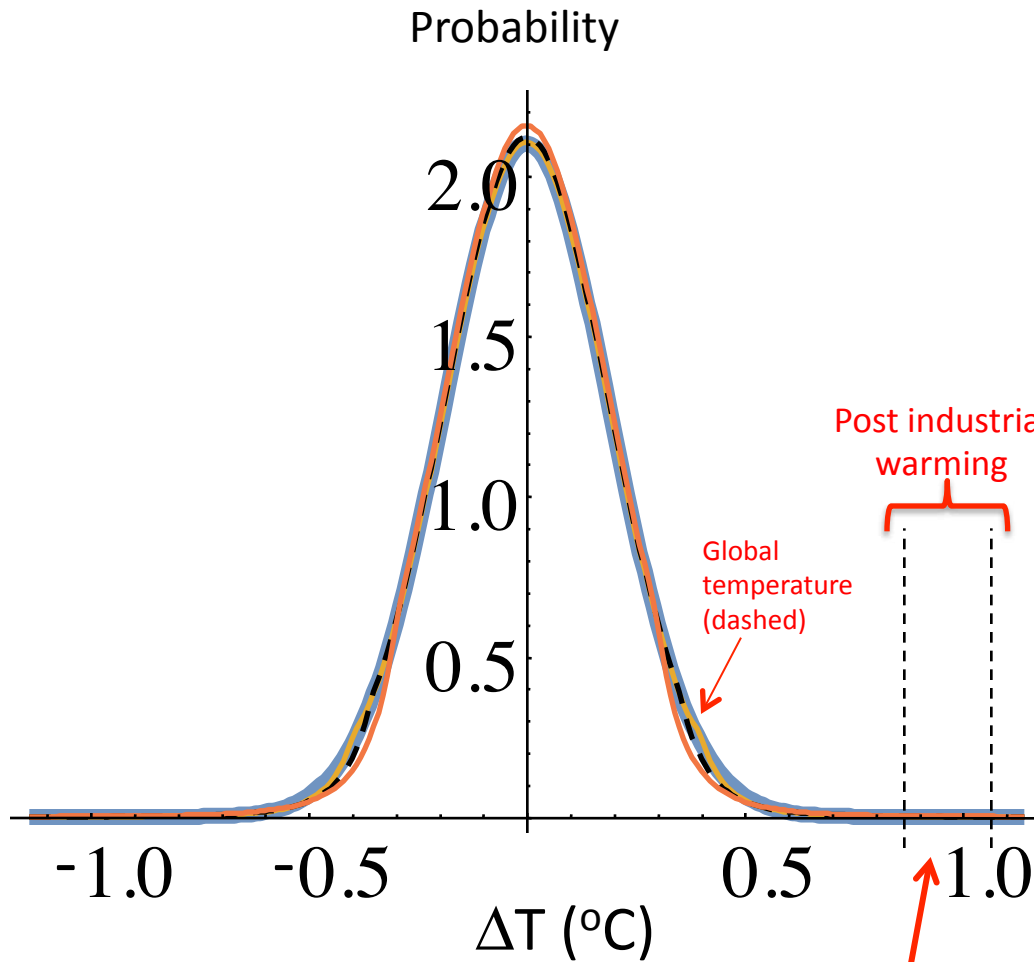






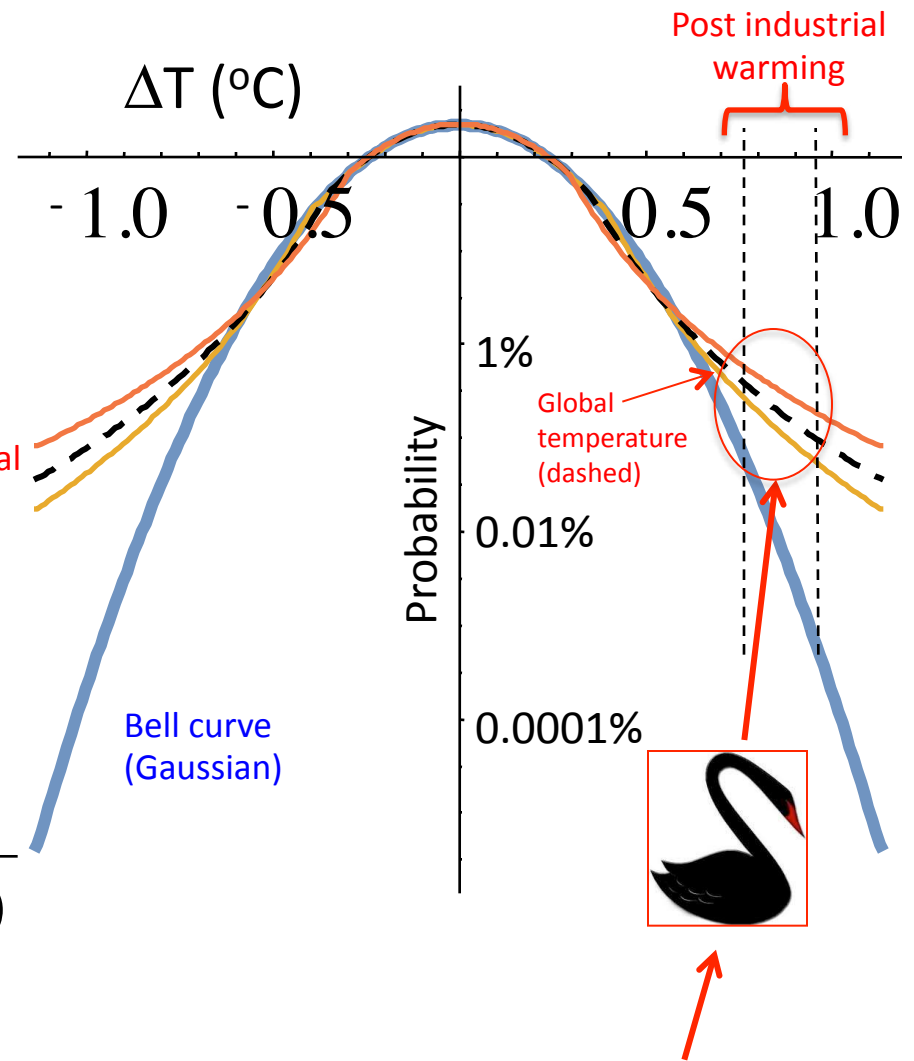
Probabilities of extremes: Bell Curve, Black Swans

Usual representation

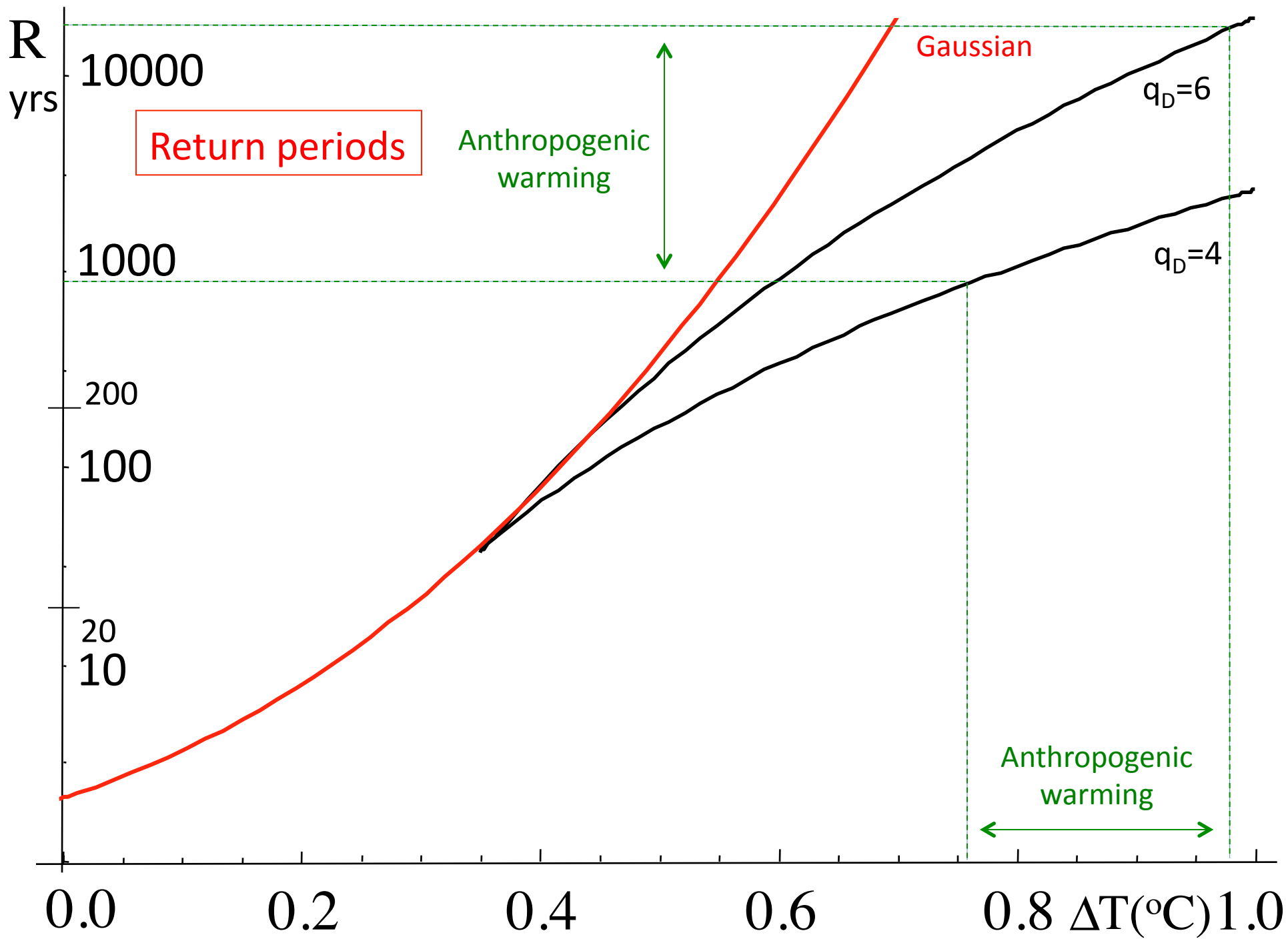


≈ 5 standard deviations: one in a million chance

Representation showing extremes



one in a thousand chance



The Pause



CLIMATE CHANGE

Global warming slowdown just a 'pause'

NATURAL COOLING FLUCTUATION

It can't be used to prove that temperature changes not man-made, McGill prof says

KAREN SEIDMAN
GAZETTE UNIVERSITIES REPORTER

McGill University physics professor Shaun Lovejoy, already a global warming denier's worst enemy, has done it again with his latest statistical analysis showing that a recent slowdown in global warming is merely a "pause" — and not any kind of proof that man-made global warming has waned.

Lovejoy already regularly gets hate mail from global warming skeptics, so he figures this will just give them more ammunition.

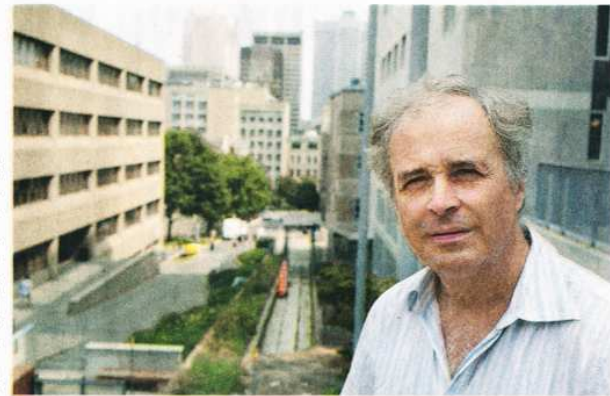
"I don't get death threats, but I do get a lot of nasty emails. There are some people with vested interests who are not going to be convinced by rational arguments," said Lovejoy whose last study, in April, elicited a response from one of the more distinguished skeptics:

Lord Christopher Monckton of Brenchley, who referred to Lovejoy's work as an emanation "of the forces of darkness."

That was Lovejoy's study which proved conclusively, he says, that there is such a tiny probability that what we are experiencing is natural warming — probably less than 0.1 per cent — that it can be dismissed.

He has followed it up with a statistical analysis of average global temperatures between 1998 and 2013, which shows the slowdown in global warming during this period is consistent with natural variations in temperature that occur historically every 20 to 50 years.

In a paper published in Geophysical Research Letters, Lovejoy concludes that a natural cooling fluctuation during this period is largely masking the warming effects



McGill physics professor Shaun Lovejoy says, "There are some people with vested interests who are not going to be convinced by rational arguments" on global warming.

of a continued increase in man-made emissions of carbon dioxide and other greenhouse gases.

So yes, he said, while it may seem contradictory, the statistical methodology he has developed has ruled out the possibility that global warming

is just a natural fluctuation in the Earth's climate, while at the same time showing that a recent deceleration in rising temperatures is actually a natural cooling.

While the focus of his research has largely been on atmospheric variability,

Lovejoy has focused on the issue of global warming recently, saying in an interview that his methodology of disproving natural warming is possibly more indisputable than the traditional approach of trying to prove the hypothesis that warming is

man-made.

His most recent study addresses the argument raised by skeptics that, since greenhouse gases have continued to rise in the last 15 years while there has been a deceleration in rising temperatures, it must disprove the theory that global warming has been caused largely by man-made emissions.

But Lovejoy says his study concludes there has been a natural cooling fluctuation of about 0.28 to 0.37 C since 1998.

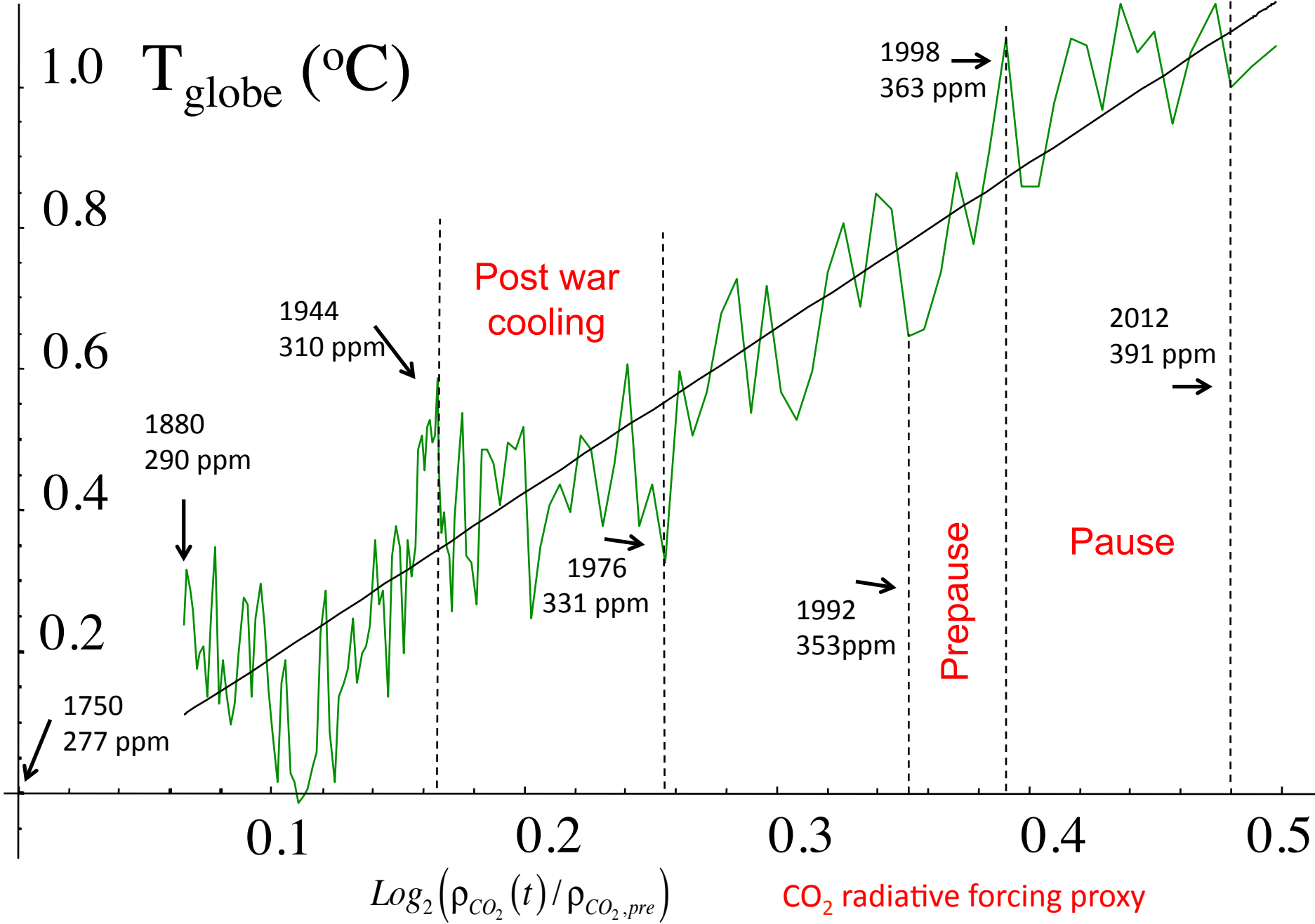
"Being based on climate records, this approach avoids any biases that might affect the sophisticated computer models that are commonly used for understanding global warming," he said.

And while his new finding may sound encouraging because it may mean the Earth isn't heating up as quickly as scientists had forecast, Lovejoy also believes it is likely to be short-lived.

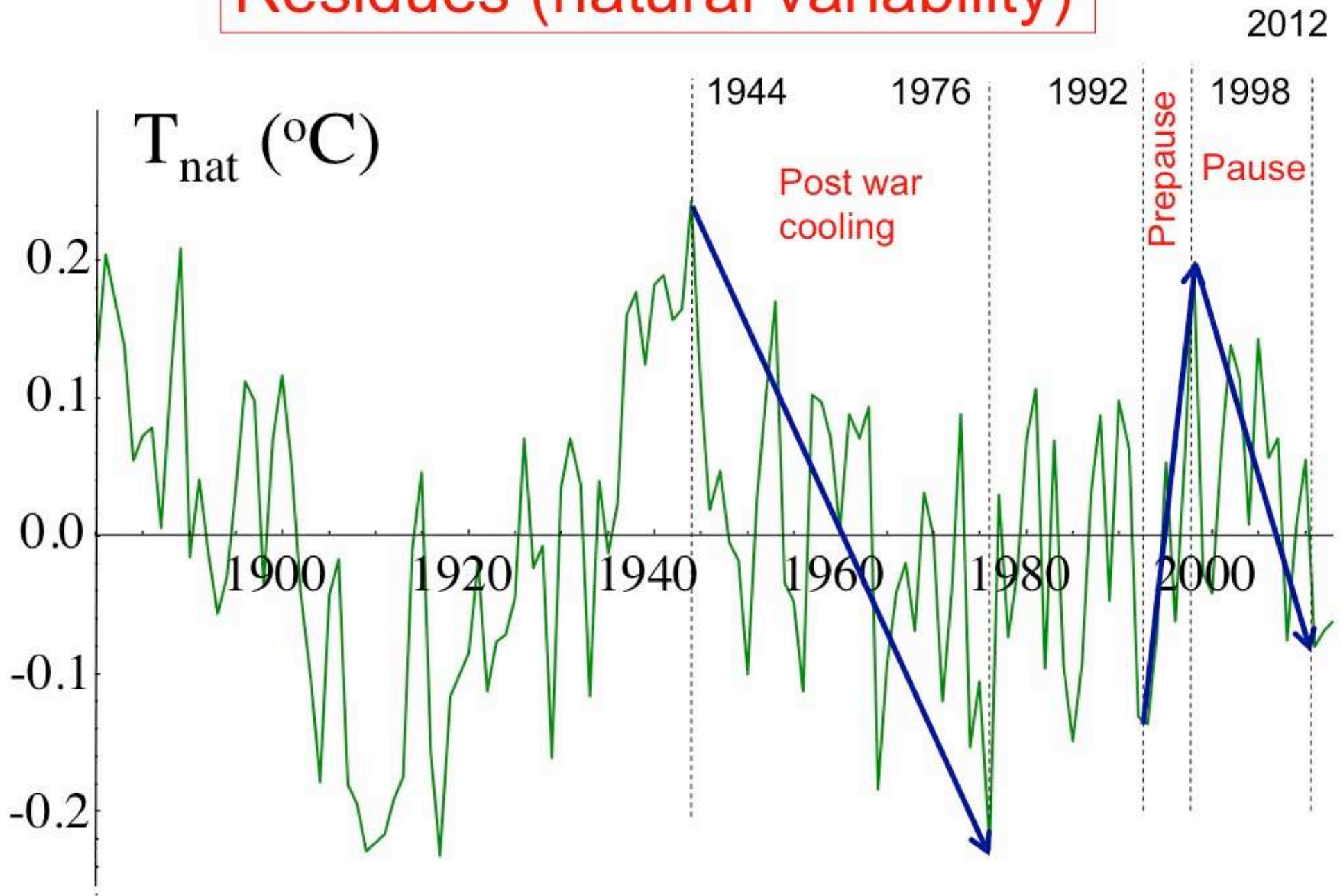
"The chances of it continuing much longer are small," he said.

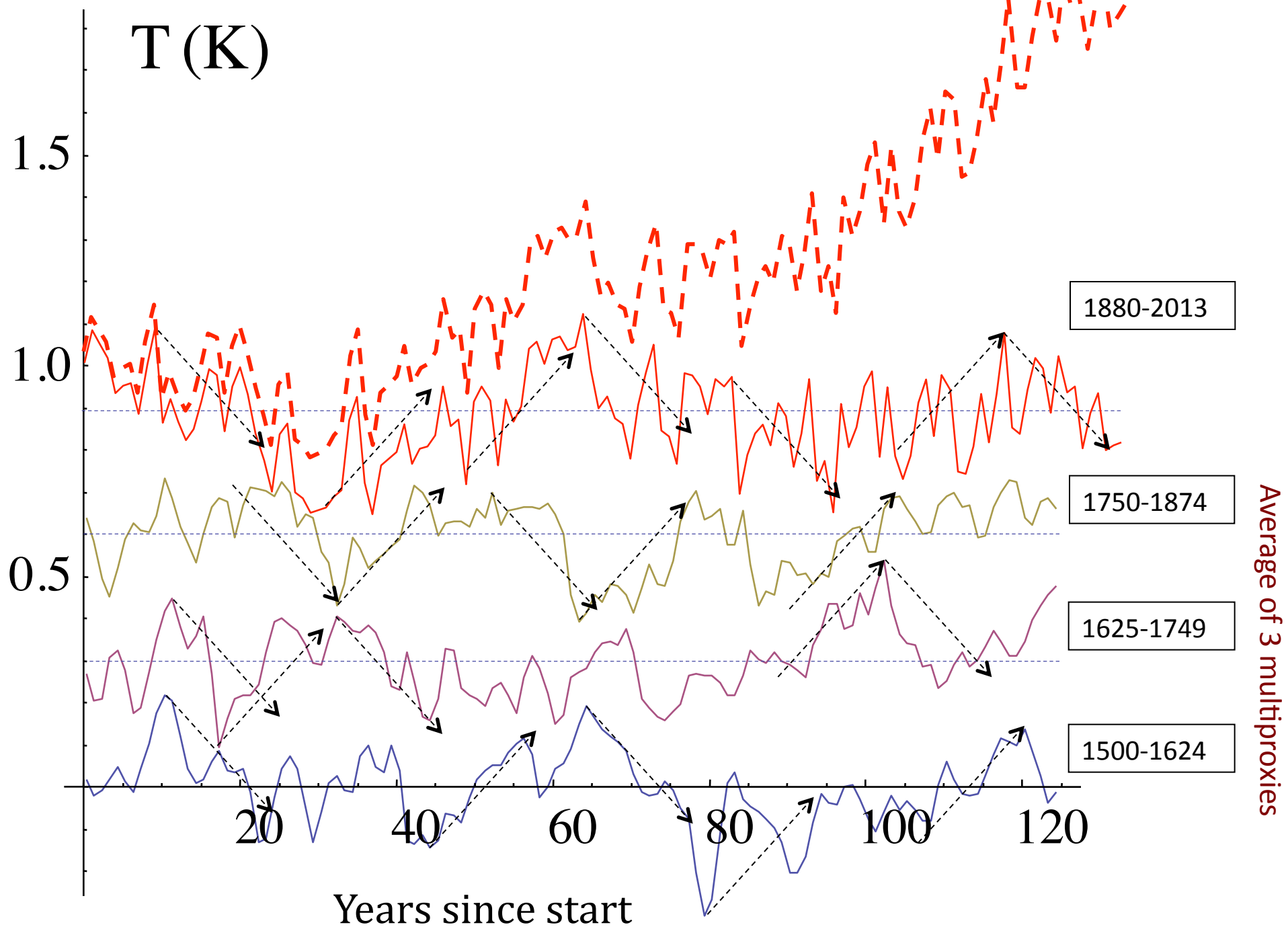
kseidman@montrealgazette.com
Twitter: KSeidman

Global temperatures: NASA - GISS data

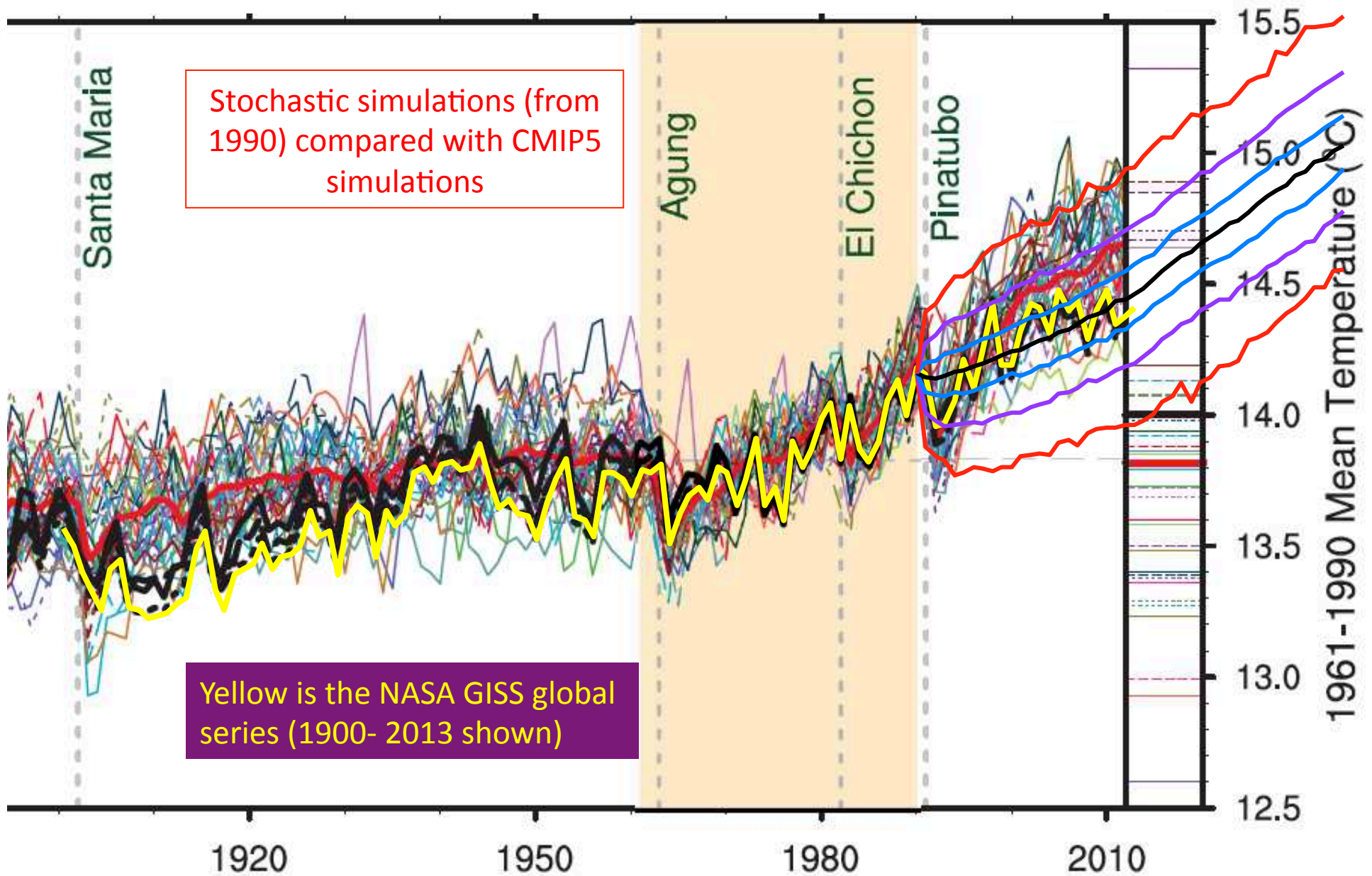


Residues (natural variability)





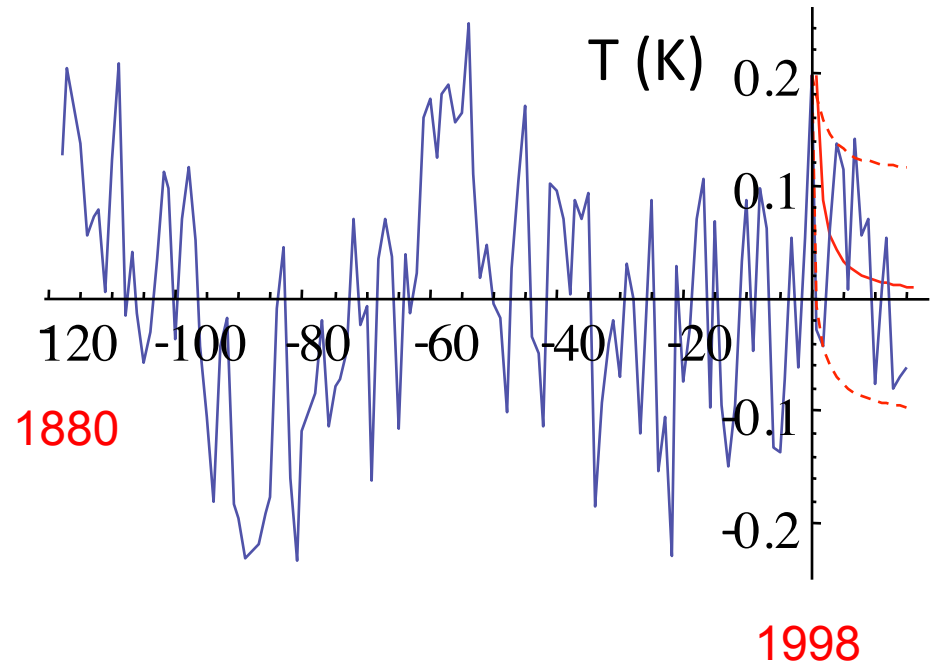
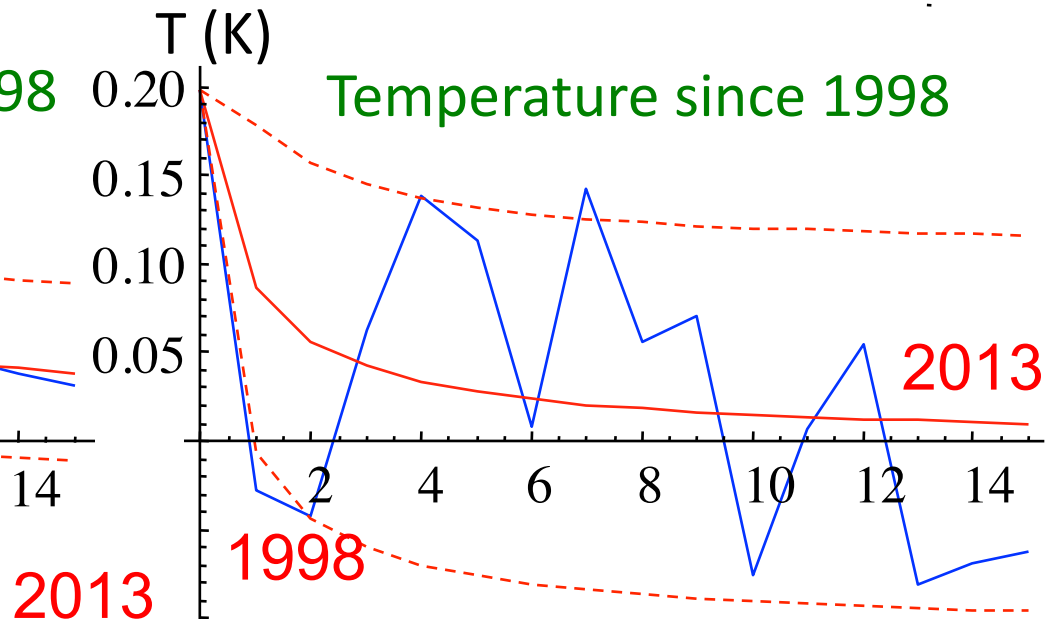
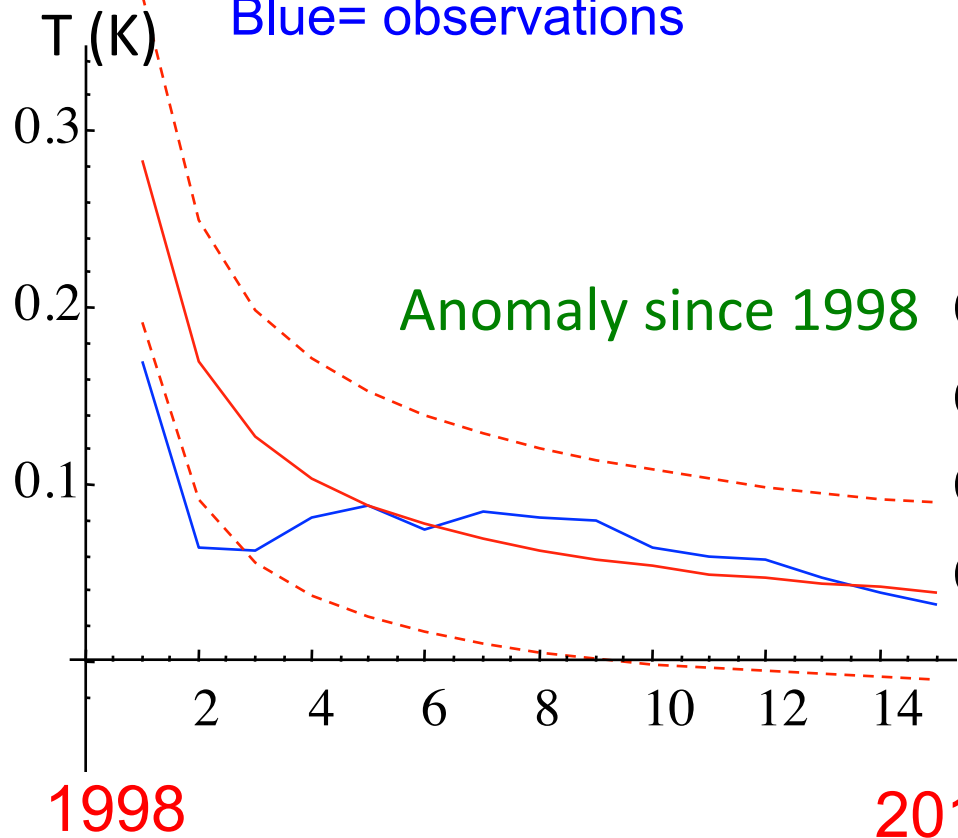
Observed and CMIP5 mean surface temperature



The memory: Hindcasting the Pause

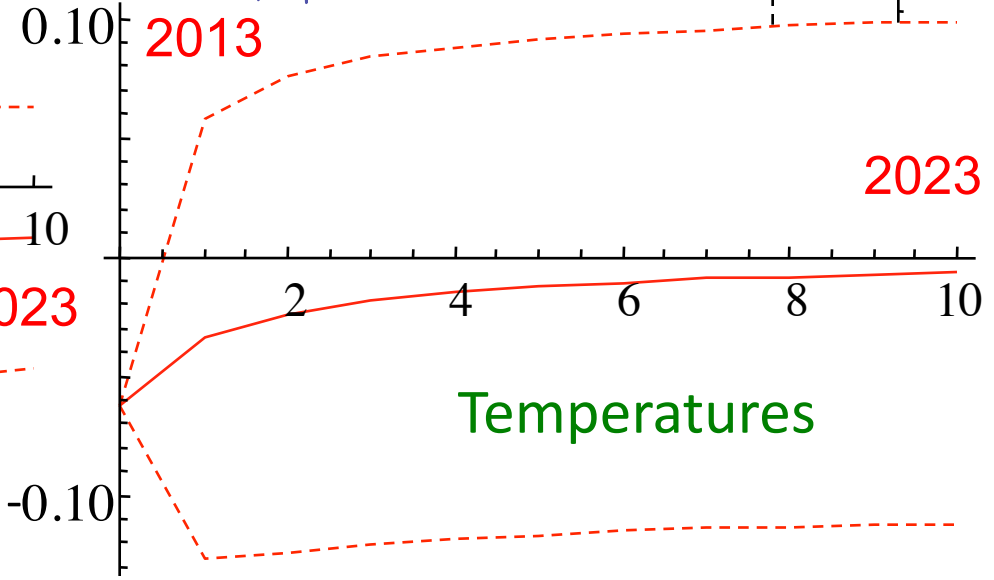
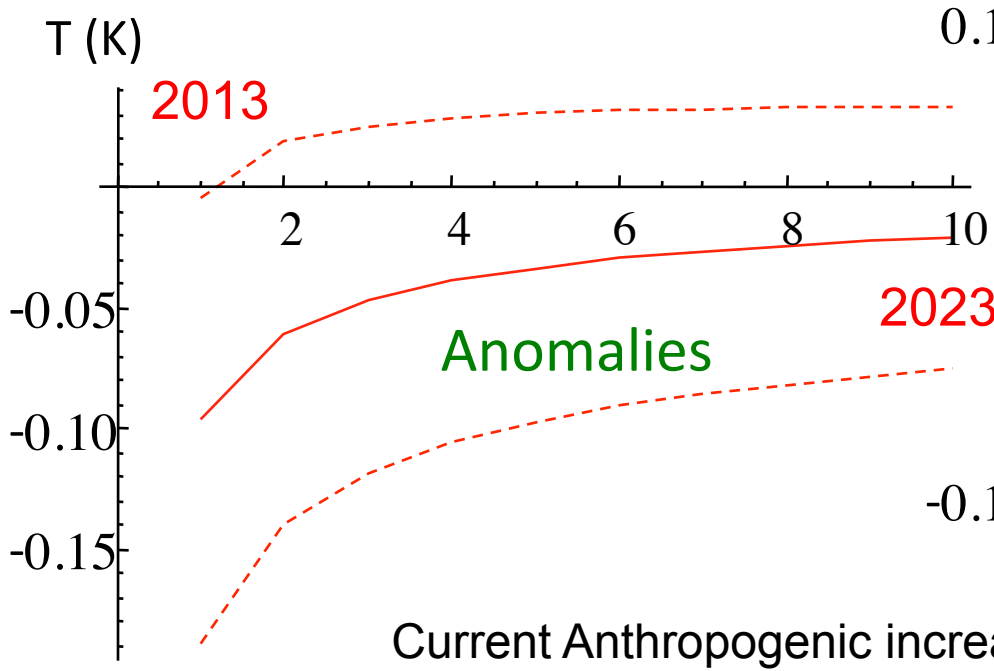
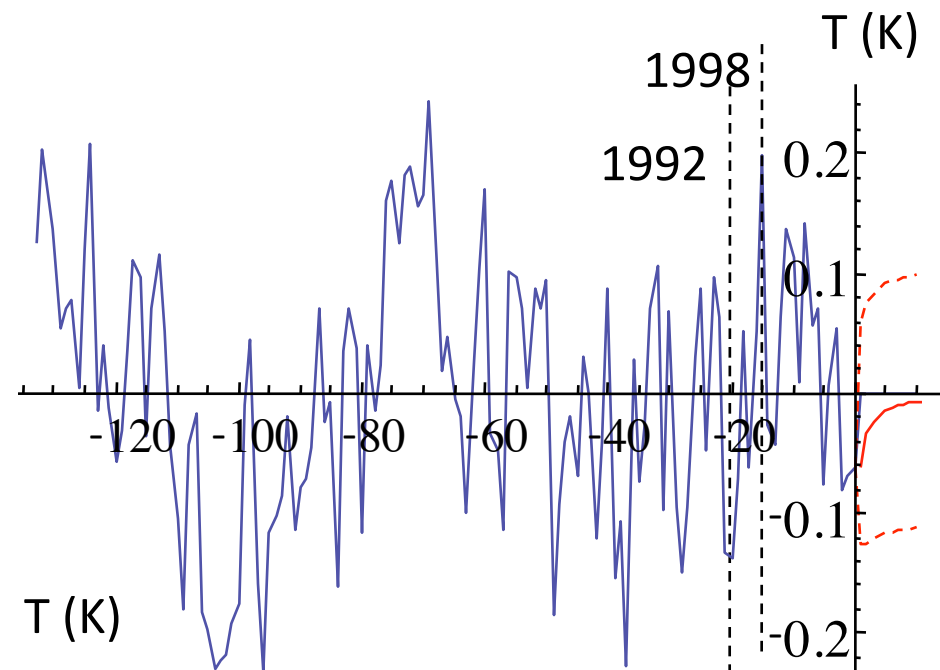
(Global mean annual T since
1998, natural variability only)

Red= forecast
Blue= observations



The Future

The next 10 years: Global: 2014-2023 (natural variability only)



Current Anthropogenic increase: $\frac{d \log_2 CO_2}{dt} \approx 0.010 / yr$ $\frac{dT}{dt} \approx 0.023 / yr$

Forecast for 2023: $+0.05 \pm 0.10 K$ (natural) $+0.23 \pm 0.02 K$ (anthropogenic) = $0.28 \pm 0.11 K$ above 2013

The skeptics reaction (1)



CALGARY, April 17, 2014 /Canadian News Wire/

Friends of Science (Calgary based group)

...Friends of Science are also calling up the Chancellor of McGill University to retract the McGill press release and issue an apology for the use of Lovejoy's quote "This study will be a blow to any remaining climate-change deniers..."

"This is not the language of science or good taste that one expects from a Nobel Laureate university," says Gregory.

Friends of Science Rescuing TransCanada's Energy East pipeline

On the TransCanada Hwy.,
near Anjou (since Nov. 19)

From the Facebook site of:
L'Association des communicateurs scientifiques du Québec
(Nov. 20, 2014)

Panneau qui aurait été vu sur la 40 à Anjou. Friends of Science est un organisme créé par la Canadian Society of Petroleum Geologists. Ou-wa-che. Via @Isabelle Burgun.

Vu aujourd'hui sur le long de la 40 à Anjou.
Et ça tombe la même journée que la révélation du Devoir que «TransCanada dispose d'un plan précis [et de sommes colossales] pour faire aboutir le projet Énergie Est».
Sur leur site, ils disent qu'ils ont un budget très limité... Ah? Et ils peuvent se payer une pub sur panneau lumineux?
Qui connaît ça, Friendsofscience.org?

« Our Goal:
To educate the public about climate science and through them bring pressure to bear on governments to engage in public debates on the scientific merits of the hypothesis of human induced global warming and the various policies that intend to address the issue.
Our Opinion:
It is our opinion that the Sun is the main direct and indirect driver of climate change. »

Après les créationnistes, voici les autruches patentées.



The skeptics reaction (2)

“A mephitic ectoplasmic emanation of the forces of darkness”

-Viscount Lord Christopher Monckton of Brenchley evaluating on this work



An ectoplasm

Common reactions.. and misconceptions:

-Use of historical information

Q: 800 years ago in medieval Europe *global* temperatures might have been warmer than today if so, doesn't this contradict the analysis?

A: Our conclusions are for **125 year periods** - there is nothing to prevent the same changes occurring much more slowly (i.e. over much longer periods).

-Use of unrepresentative paleo or instrumental sources, (the “Friends”):

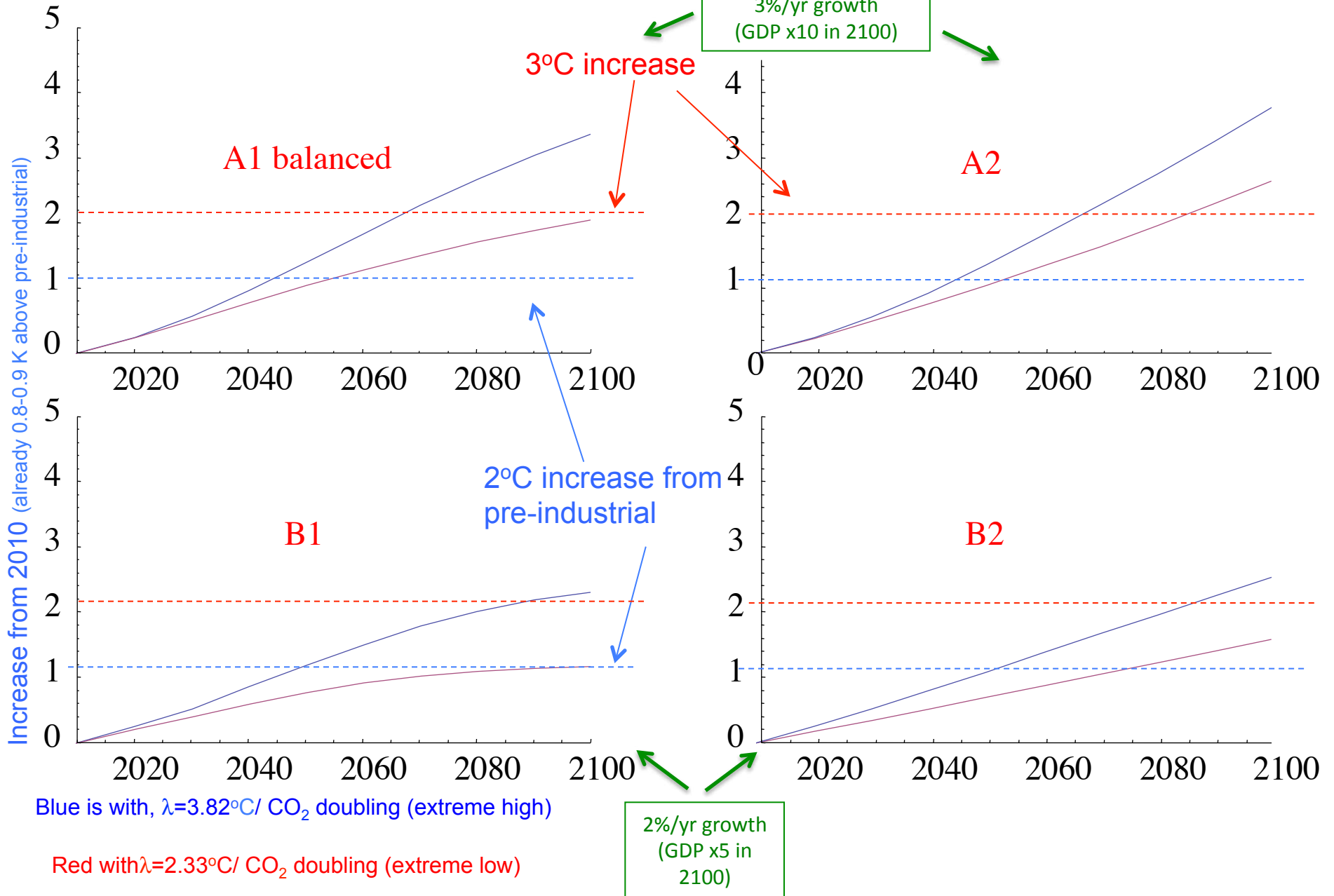
Q: The temperature change in central England from 1663-1762 was 0.90 °C, so such changes are not unusual.

A. England is only 0.04% of the earth's surface. The *global scale* temperature change was only 0.21±0.12 °C.

Impacts

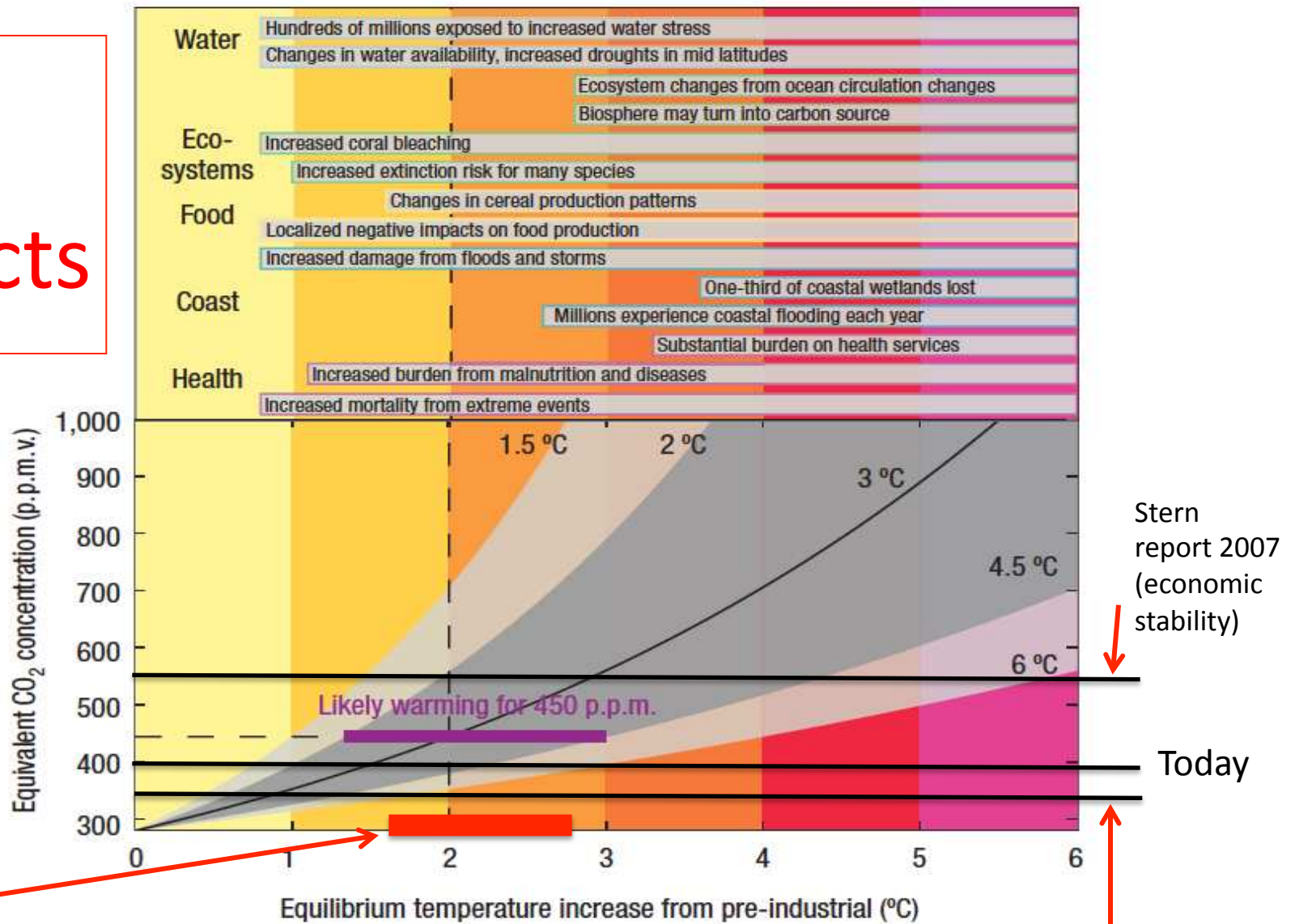
Future Projections

Based on SRES (Special Report on Emissions Scenarios, IPCC, AR2-4)



The impacts

Knutti et al 2008



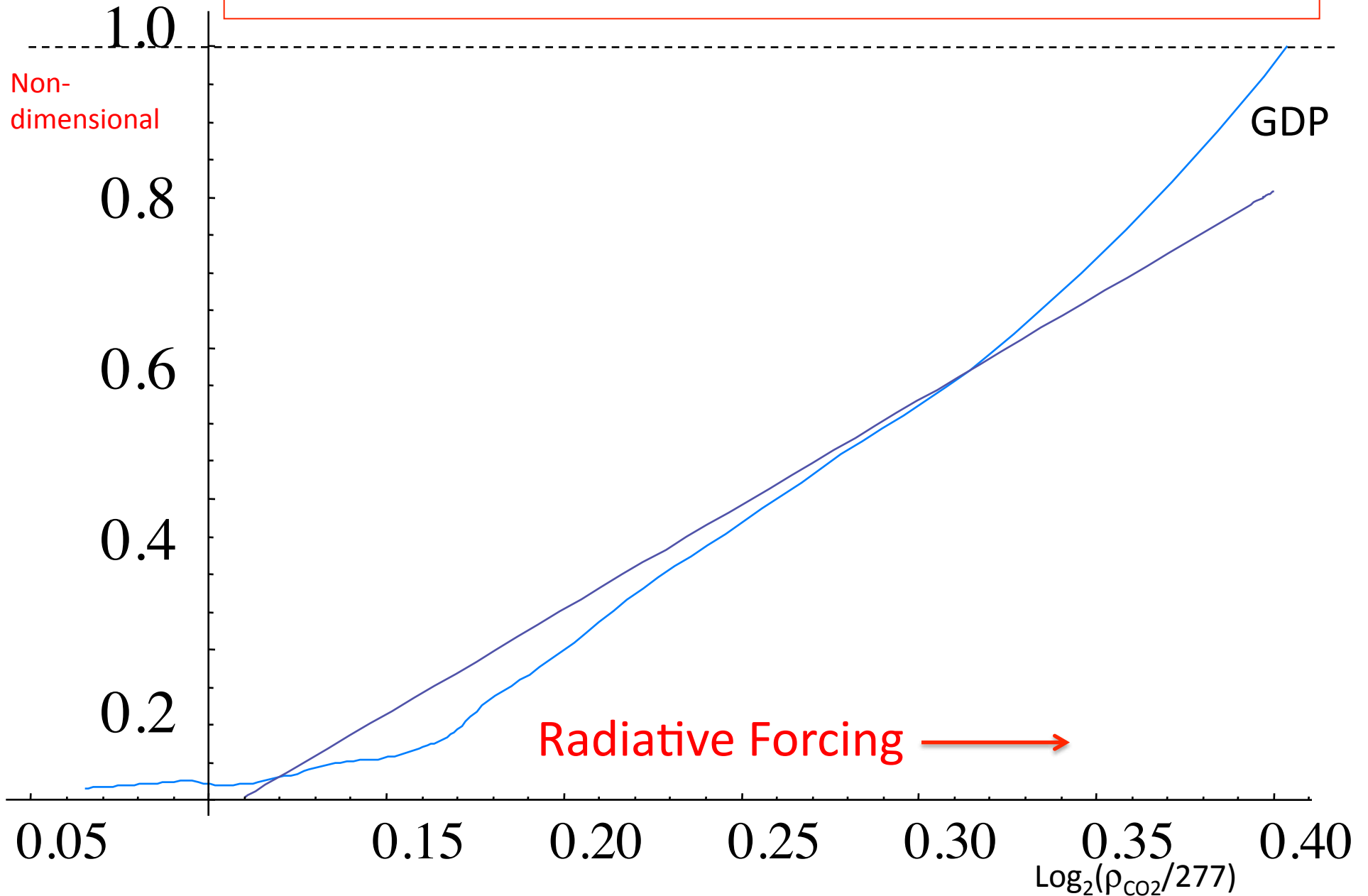
Our simple method:
doubling CO₂:
3.08±0.58 °C

For 450 ppm:
2.2±0.4 °C
(0.6±0.15 °C more than in 2013)

“Levels of CO₂ in excess of only 350 ppm are not compatible with the planet on which civilization developed or to which life on earth is adapted”:
Hansen et al 2008

What is to be done?

Tight link between CO₂ forcing and GDP



The challenge:

Decarbonize the
economy

Can we break the link between economic growth
and CO₂ emissions?

Mainstream economists: Climate change is no big deal

“Agriculture, the part of the economy the most sensitive to climate change, accounts for just 3% of national output. That means that there is no way to get a very large effect on the US economy”.

-Yale Economist William Nordhaus *Science* (1993)

“Even if the net output of US agriculture fell by 50% by the end of the next century, this is only a 1.5% cut in GNP”

-Oxford economist Wilfred Beckerman in *Small is Stupid* (1995)
(echoed by economics Nobel prize winner Thomas Schelling).

One might be forgiven for concluding that if climate change made all agriculture impossible, that the economy would contract by a mere 3%...

Nordhaus now estimates the reduction of global economic output in the year 2100 due to climate change as 3% of GDP.

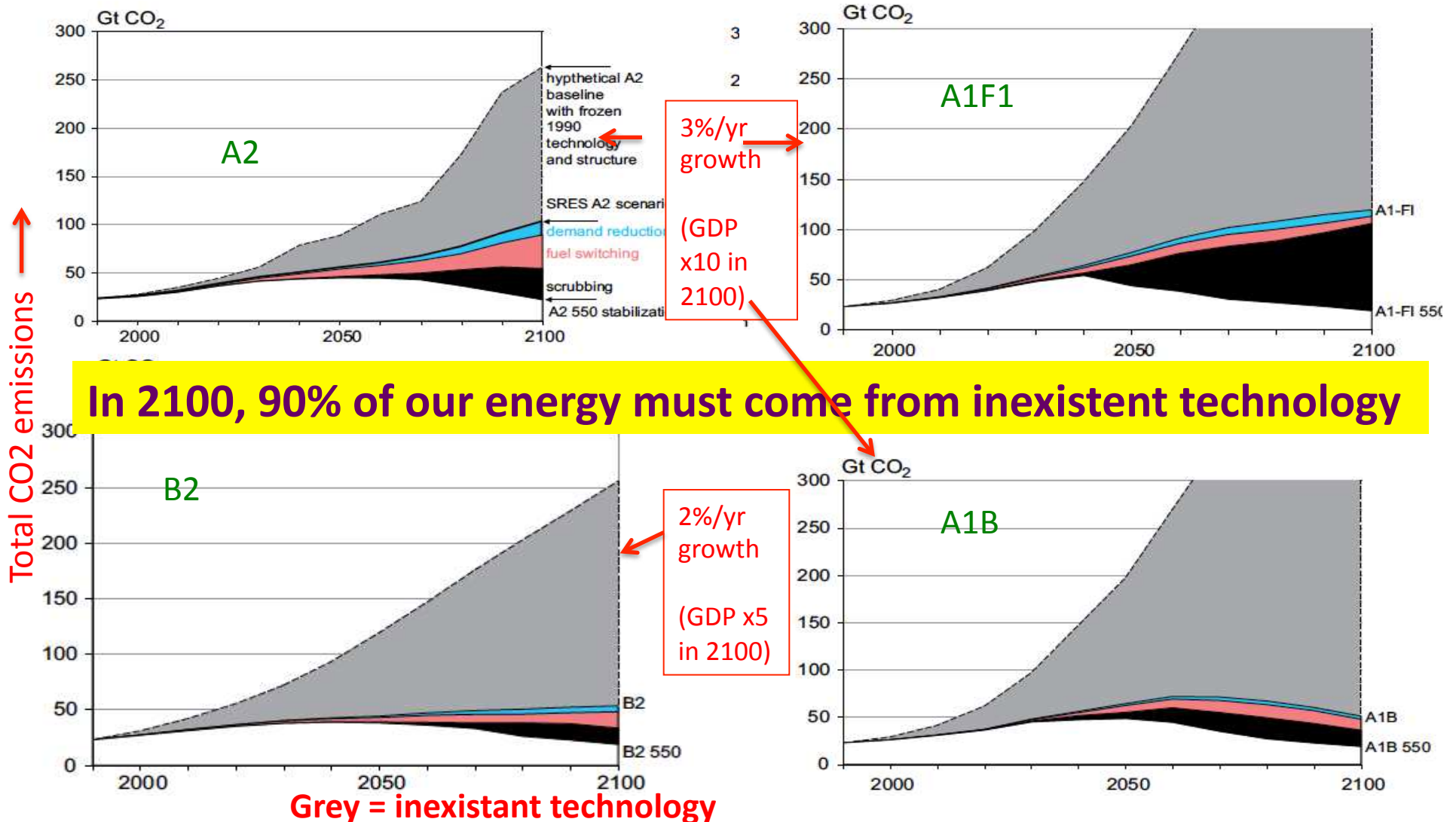
This is in line with the IPCC working group 3 on mitigation and the IPCC Synthesis report that appeared on Sunday, Nov. 2.

Linear thinking

Magical thinking: if the price is right then technology can be conjured up to solve any problem...

The role of existent and new technologies

(IPCC scenarios, 2007; Stabilisation at 550ppm)



IPCC 2014

(working group 3 on mitigation and adaptation)

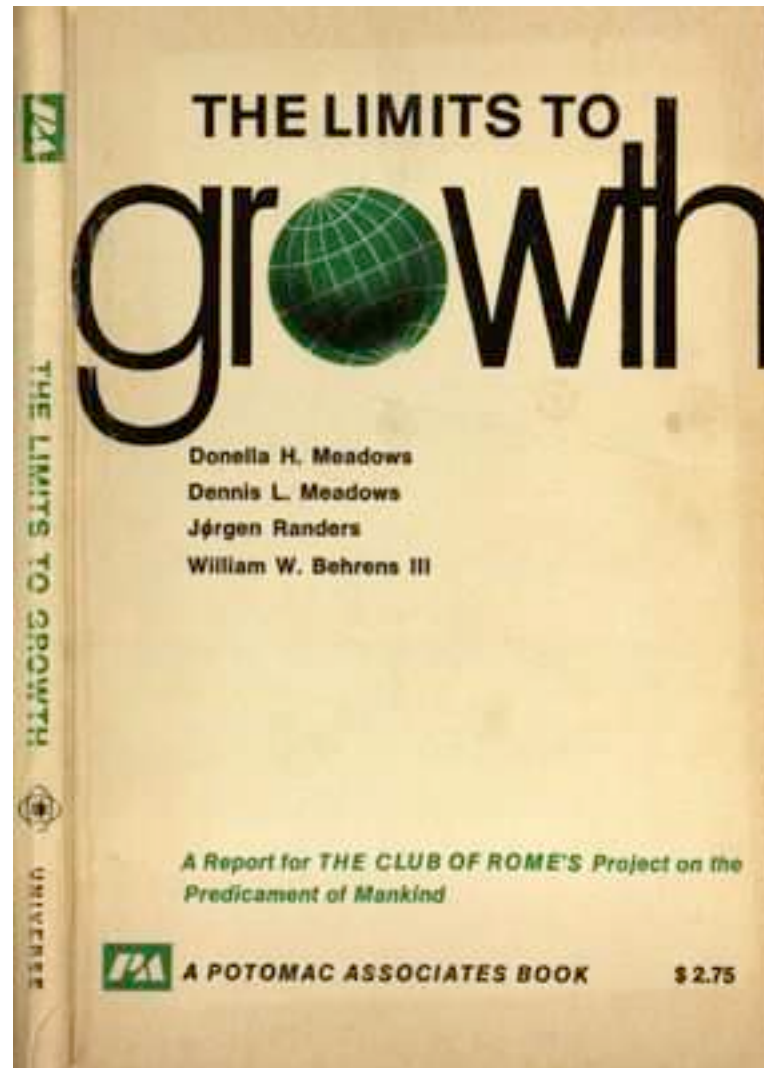
In addition to carbon free energy:

**A major role for Carbon Capture
and Storage technology that
doesn't exist...**

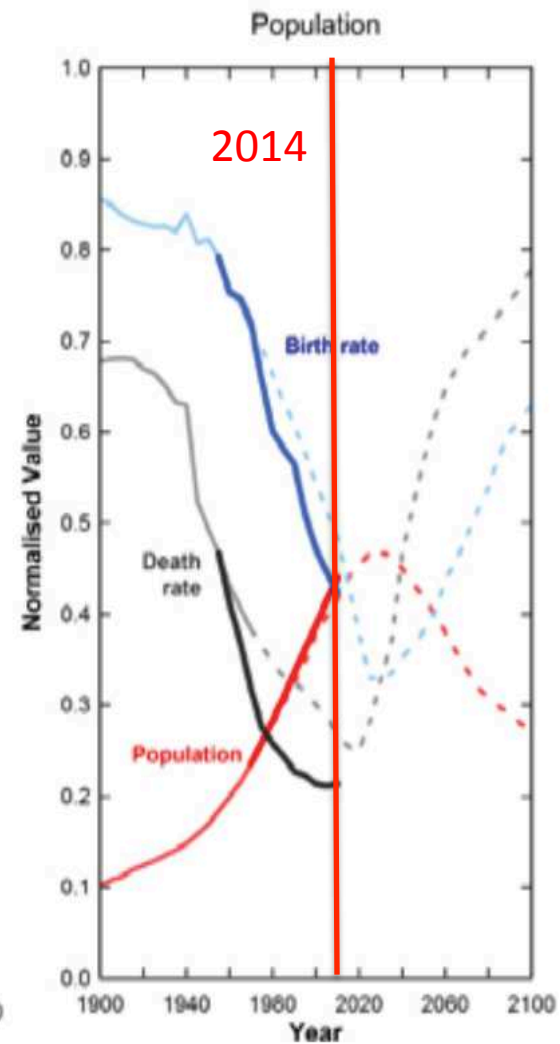
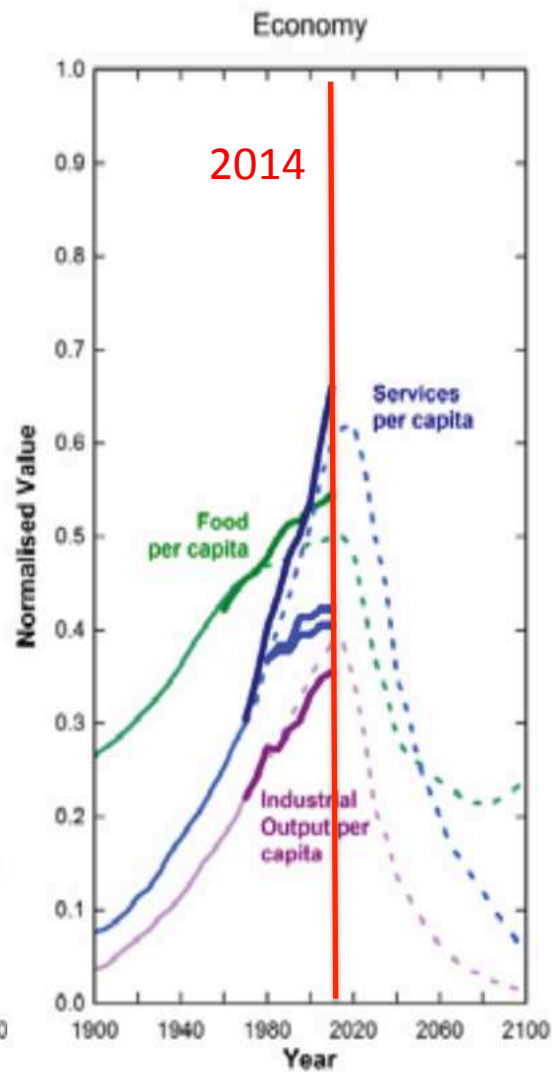
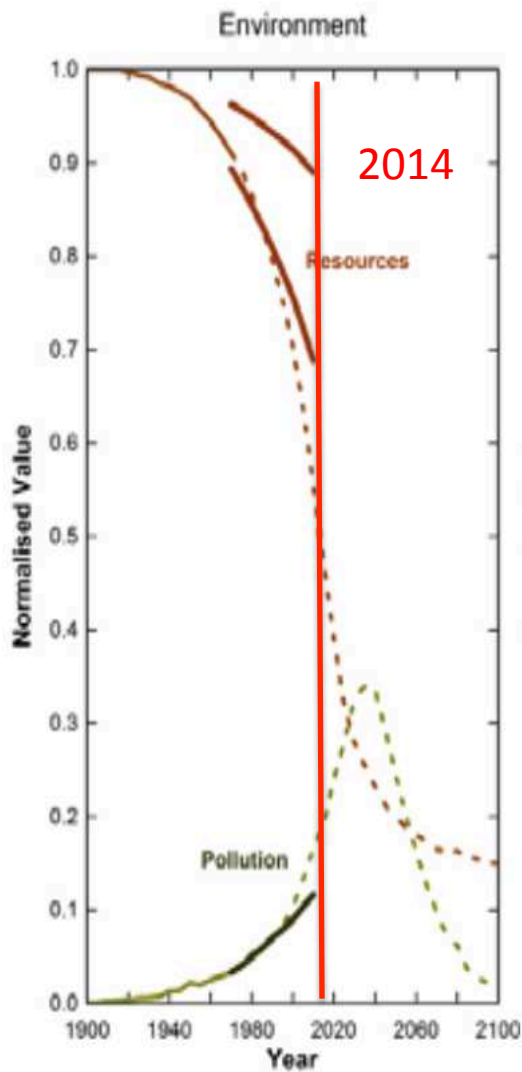
Is continued quantitative economic growth *possible*?

Limits to Growth: Overshoot and collapse

Note: The **nonlinear** model is completely based on physical (not financial inputs and outputs).



1972



G. Turner, Sept. 2014

Limits to Growth numerical model (1972):
 Business as usual scenario (dashed), historical data, (solid).

Reason for collapse: capital increasingly diverted from production to resource extraction

Is continued quantitative growth *desirable?*

-Classical economics:

Formulated in an epoch where climate change and resource depletion were either undreamt of or were so remote as to be of only academic relevance.

Since the 19th century the desirability and need of quantitative economic growth has been taken for granted in order to better the human condition.

-The world's poor countries:

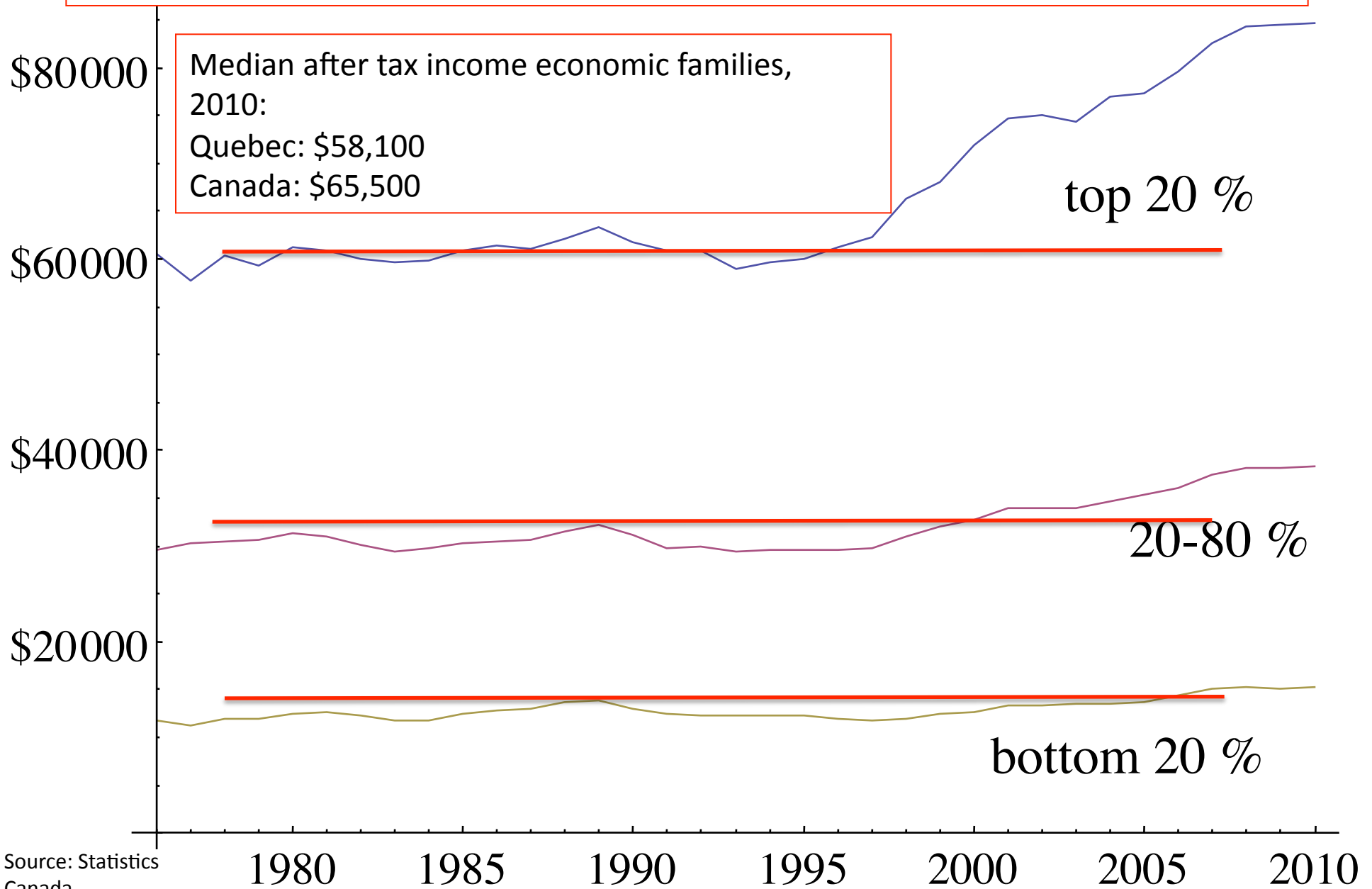
(Justifiably) want to grow in order to bring themselves out of their relative misery.

-The developed world: Canada:

Since the 1980, the per capita Gross Domestic Product (GDP) has roughly doubled, yet median family income has stagnated, virtually all the increase in economic activity has gone into the pockets of the top 20%, mostly to the top 1% (Statistics Canada).

After - tax income, by family unit, Canada, 1976 – 2010

(2010 constant dollars, economic families)

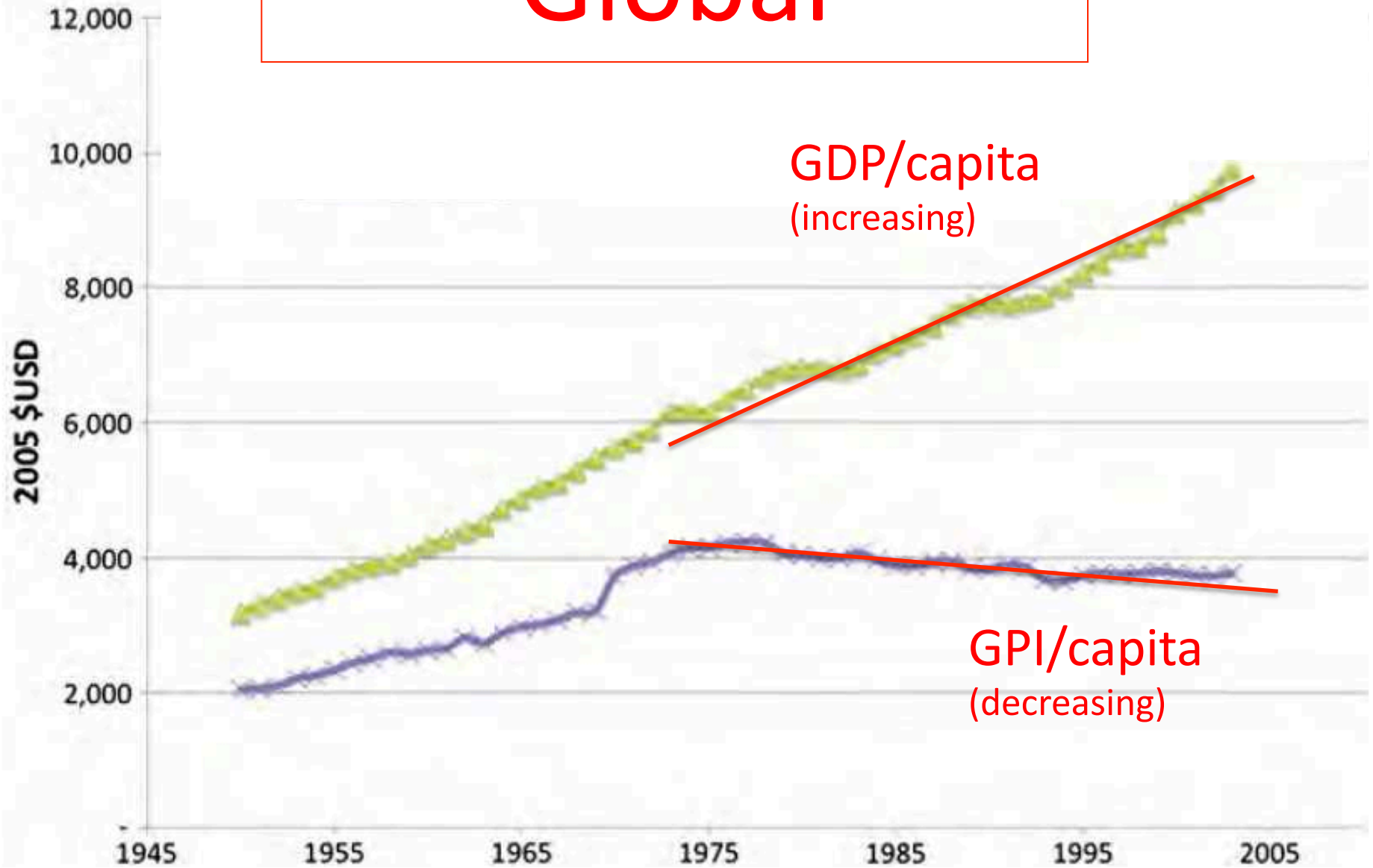


GDP is a very poor indicator of
economic well being

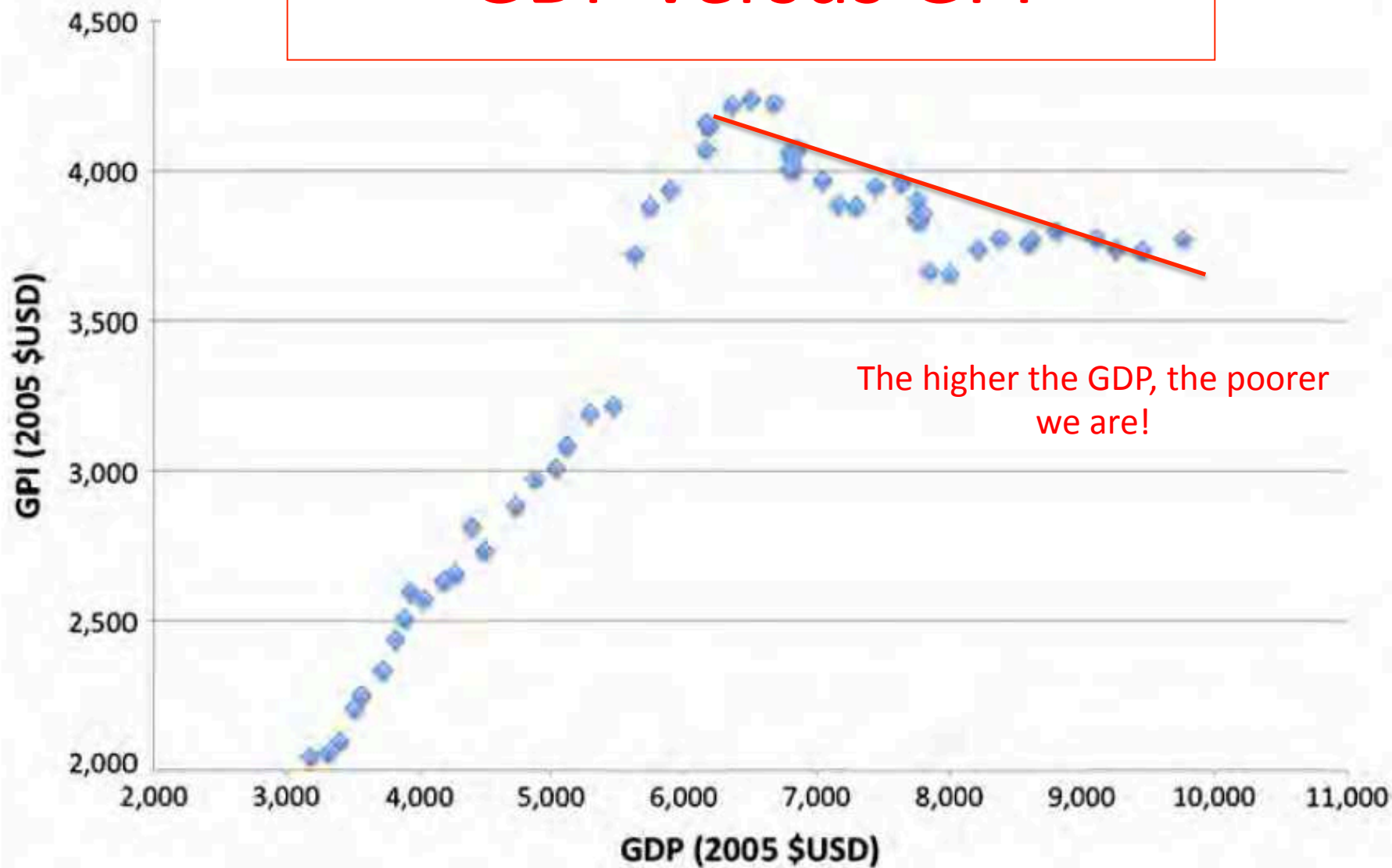
Genuine Progress Indicator (GPI)

- The GPI is the GDP (value of all goods and services produced) minus the environmental and social costs.
- Accordingly, the GPI will be zero if the financial costs of poverty and pollution equal the financial gains in production of goods and services, all other factors being constant.

Global



GDP versus GPI



The higher the GDP, the poorer we are!

Implications of GDP growth

- Radiative forcing, hence warming is a strong function of GDP
- Since at least the mid 1970's GDP in Canada has not increased income for 80% of the population.
- Since 1978, the global Ecological Footprint/capita exceeded global Biocapacity/capita: as of 2014, humans were using 150% of the resources that can be sustainably generated in one year
- Since 1976, globally, the GDP is negatively related to GPI so that we become poorer as the GDP rises.

What is to be done?

<http://divestmcgill.com/petition/>



SIGN THE PETITION AT DIVESTMCGILL.COM



@DivestMcGill



"Divest McGill"



divestmcgill@gmail.com

WHAT'S A "DIVEST MCGILL" ?

Divest McGill is a campaign calling on McGill University to clear its endowment of investments in the fossil fuel industry and to reinvest in sustainable alternatives. We're part of a movement of 500+ fossil fuel divestment campaigns worldwide getting their institutions to address the urgency of climate change and work towards climate justice.

FOSSIL FUELS ARE RISKY BUSINESS

- Fossil fuel companies are valued under the assumption that all of their reserves will be burnt and that they will continue to receive subsidies. But as society catches up to climate realities, this overvaluation means there's a \$6 trillion USD "carbon bubble" that's poised to burst.
- There are profitable alternatives: fossil-free portfolios have performed better in the last ten years than those including fossil fuel companies.¹

WHERE ARE WE AT?

- Divest McGill has the support of all 3 student societies, 1500+ signatures on our petition from students, staff, faculty & alumni, and endorsements from a wide variety of campus and community organizations.
- We are currently challenging a May 2013 decision by McGill's Committee to Advise on Matters of Social Responsibility (CAMSR) in response to our petition not to divest from fossil fuel companies.
- Our day-to-day is filled with creative actions, speaking events, research briefs & editorials, meetings with students, alumni, professors & community organizations.

<http://www.mcgillfacultyfordivestment.com/>

McGill Faculty for Divestment

THE LETTER

ADD YOUR NAME

WHY SIGN? ▼

DIVEST MCGILL

An Open letter from Faculty to McGill's Board of Governors

Search ...

There is undeniable scientific evidence that climate change is urgent, and best estimates call for keeping at least 80% of our existing fossil fuel reserves in the ground in order to stay below the safe limit of a 2 degree Celsius increase in temperature ^[1]. A large-scale transition to renewable energy sources is eminently necessary for the future well-being of our society and our planet ^[2]. As such, **continued investment in the companies that actively work against this transition and profit from continued fossil fuel dependence is not morally tenable for a public institution.** As concerned McGill faculty and emeritus faculty, we join with Divest McGill in calling on the Board of Governors to divest McGill's endowment fund from the top 200 fossil fuel companies by estimated carbon reserves, with an immediate focus on companies heavily involved in the Canadian oil sands.

In the face of climate threats to current and future generations, fossil fuel companies have continued with business as usual, spending more than \$674 billion in 2013 on exploration and development of new

Recent Comments

- [Richard Janda](#) on [Sign the Letter](#)

Archives

Conclusions



1. The climate is not what you expect.
2. Legitimate versus illegitimate climate skepticism. It is much easier to disprove a theory (natural warming) that to prove one (anthropogenic warming).
3. The total anthropogenic warming since 1880 is about 1°C , for CO_2 doubling, $3.08 \pm 0.58^{\circ}\text{C}$.
4. The probability of the warming being natural is less than 0.1%.
5. The pause is a natural cooling event.
6. Impacts rise rapidly after 2°C .
7. Decarbonizing unlikely with continued global economic growth (“magical thinking”).
8. For many of us, continued economic growth is undesirable (lower GPI).