



Why the warming can't be natural: harnessing butterflies for climate closure

McGill, 20 September 2015

S. Lovejoy, McGill, Montreal

November
2014

“Friends of Science” Versus Science

Montreal



Friends of Science

Montreal

Ce que la science dit VRAIMENT:
Le climat change. À cause de nous.

ACS Association des
communicateurs scientifiques
du Québec acs.qc.ca

Association des Communicateurs Scientifiques

Toronto



Ottawa



What is the climate?

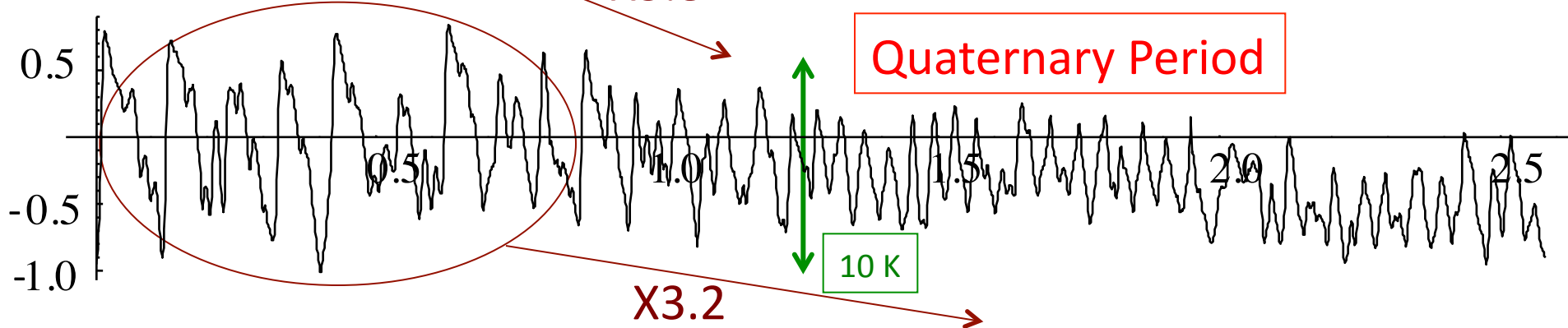
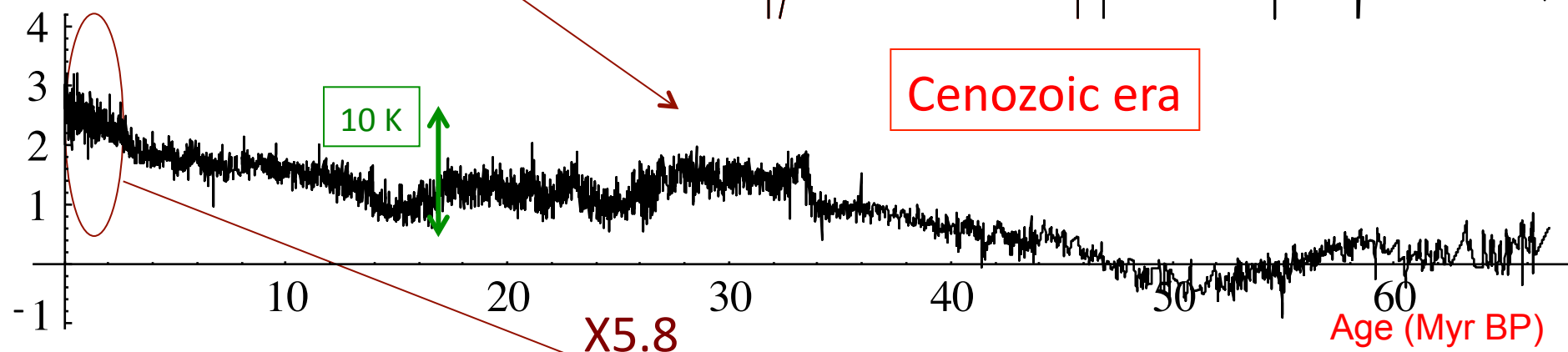
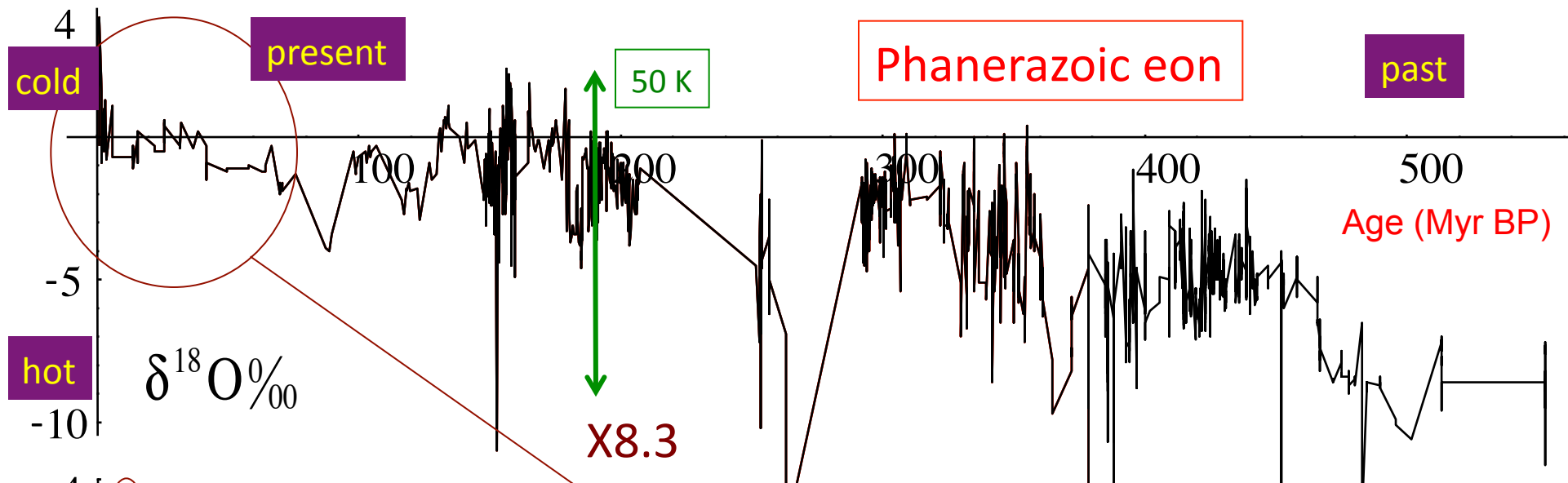
A voyage through scales

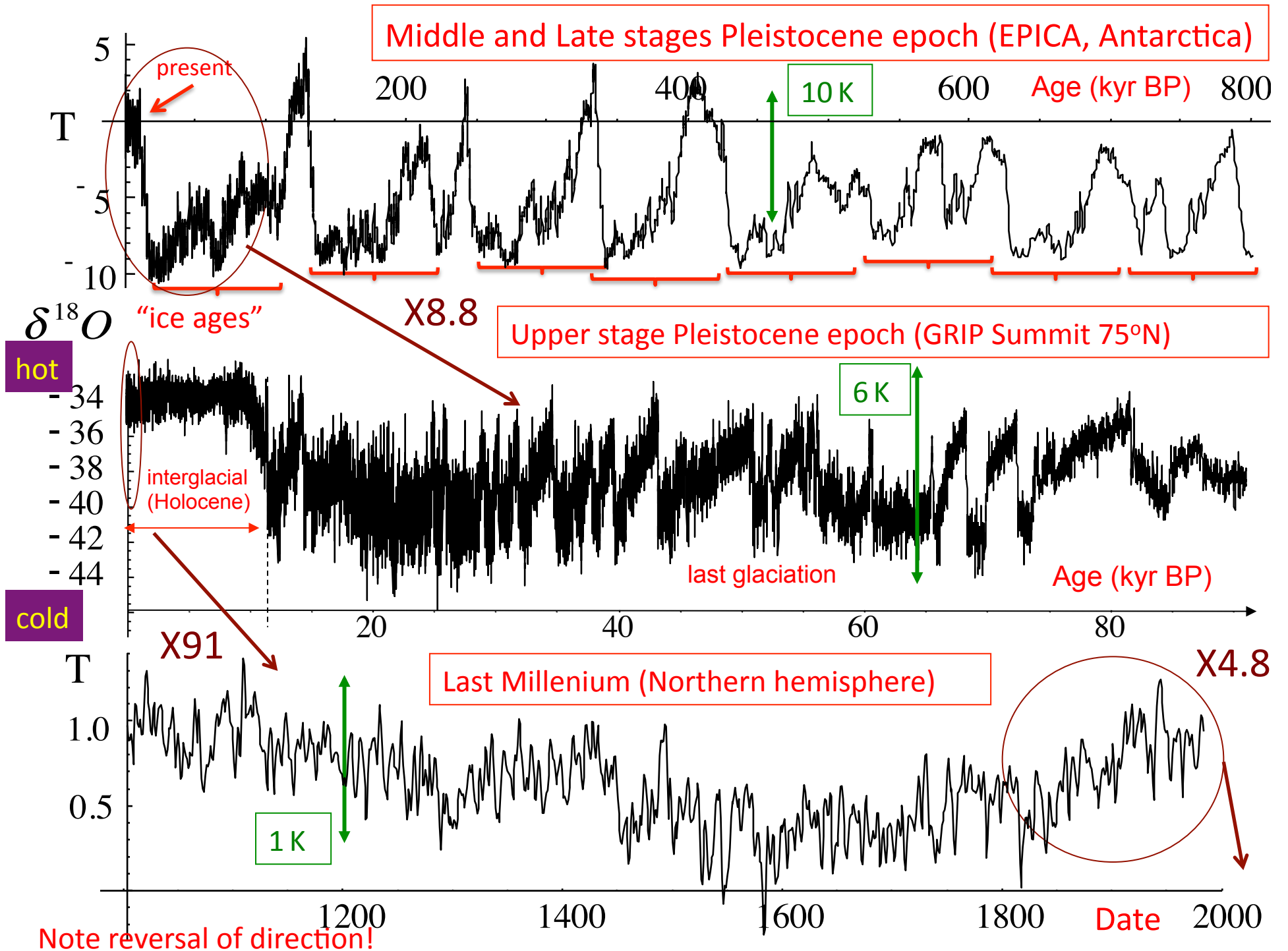
From the age of the earth to
0.001 seconds:

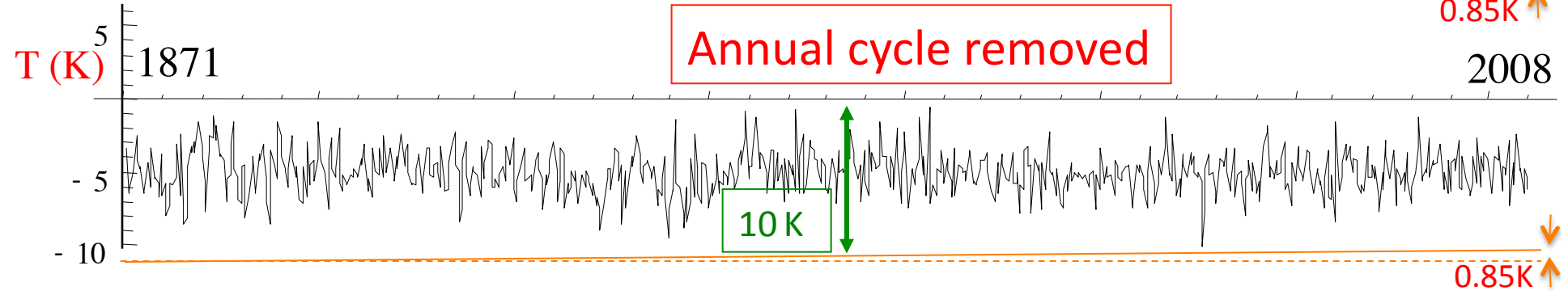
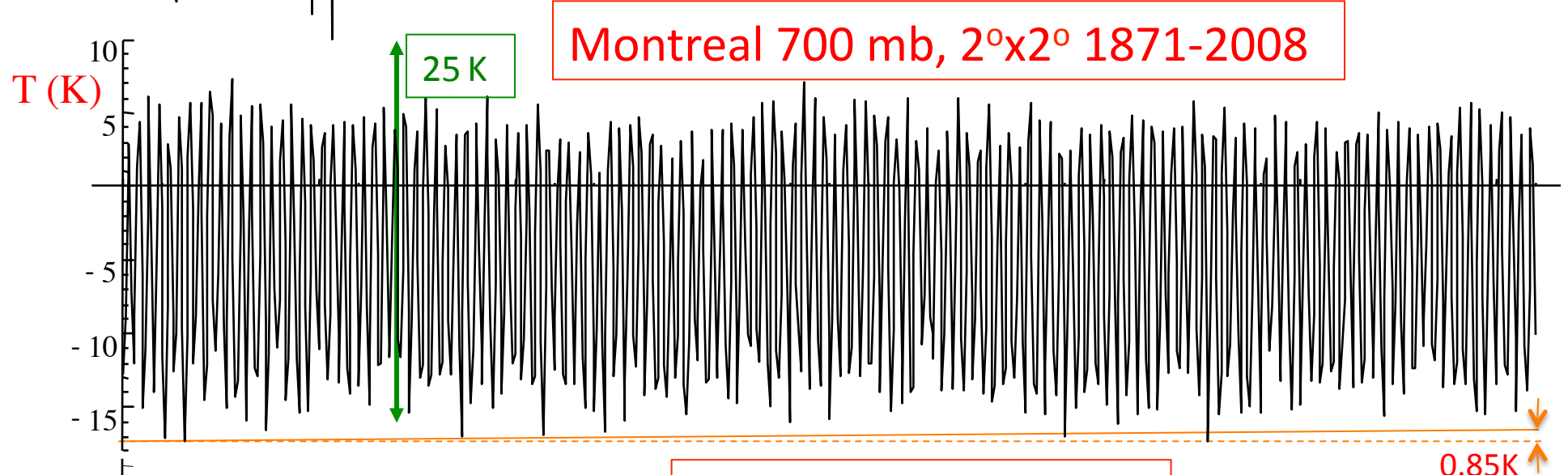
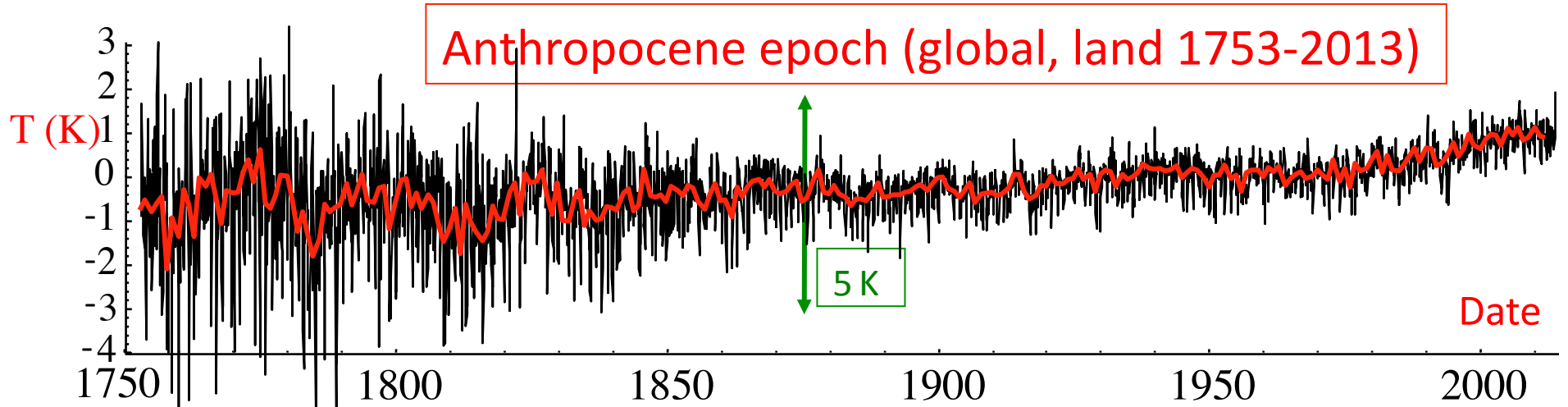
20 orders of magnitude in time

In space: the size of the planet to
millimetres:

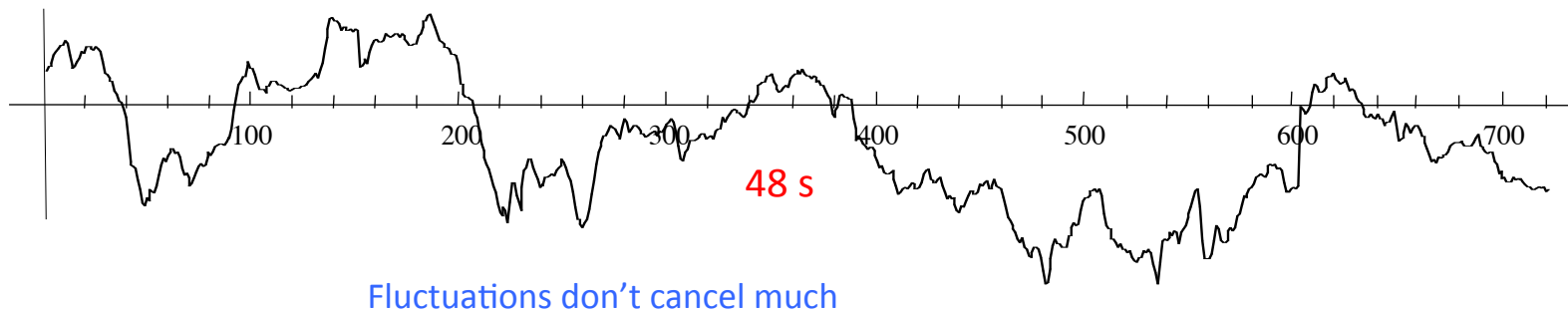
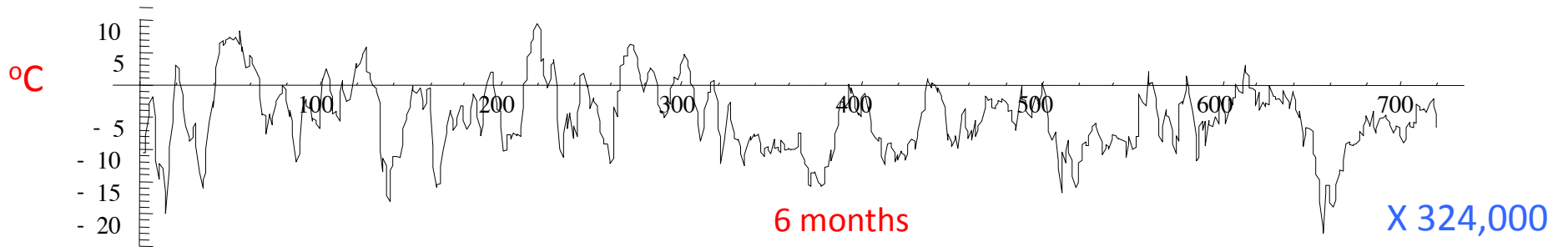
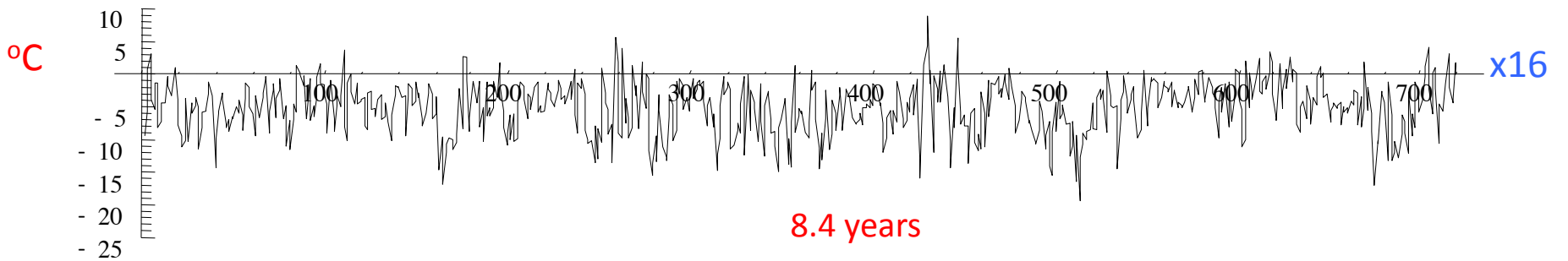
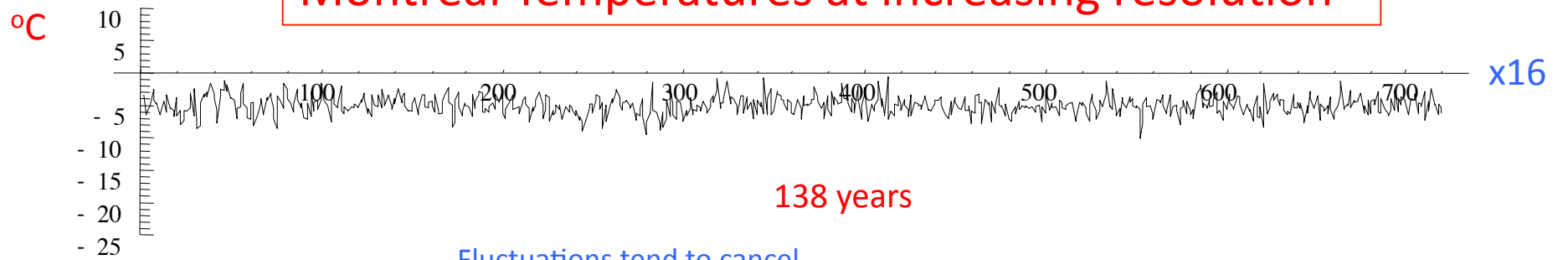
10 orders of magnitude







Montreal Temperatures at increasing resolution



The climate is not what you expect...

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

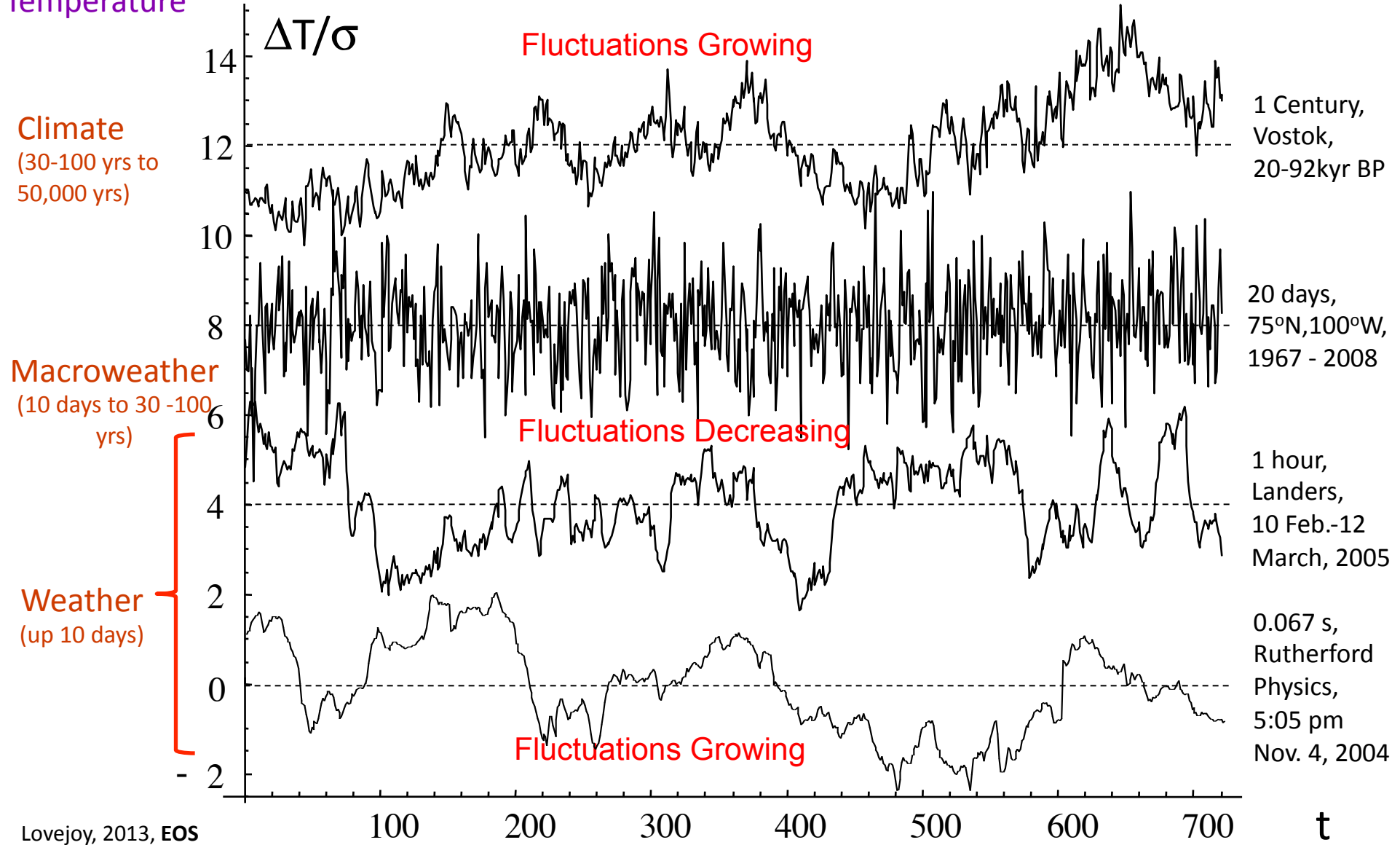
-Lazarus Long, character in R. Heinlein 1973

"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

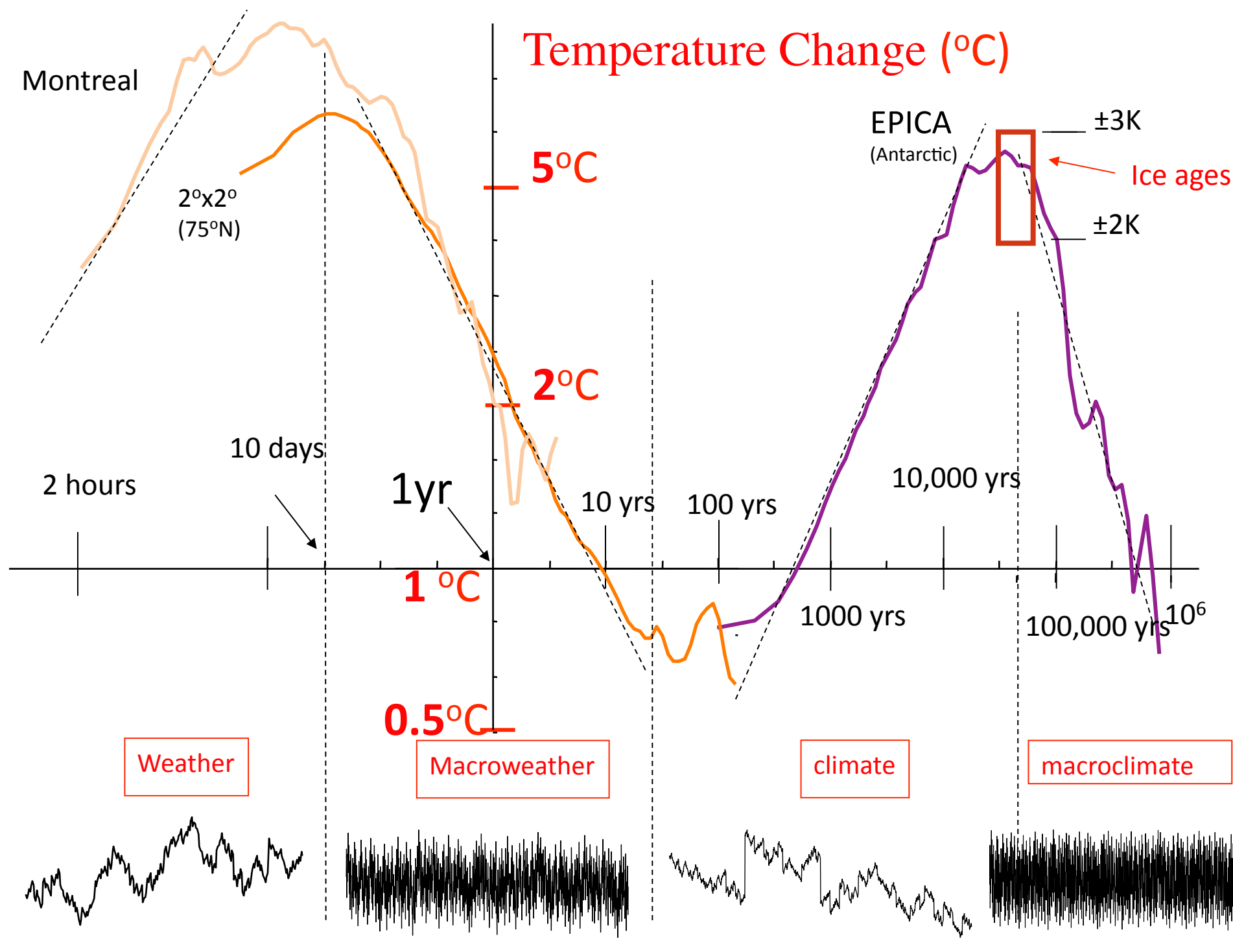
Trichotomy: Weather – macroweather - climate

Temperature



Lovejoy, 2013, EOS

Temperature Change (°C)



Conclusion:

“Macroweather is what you
expect

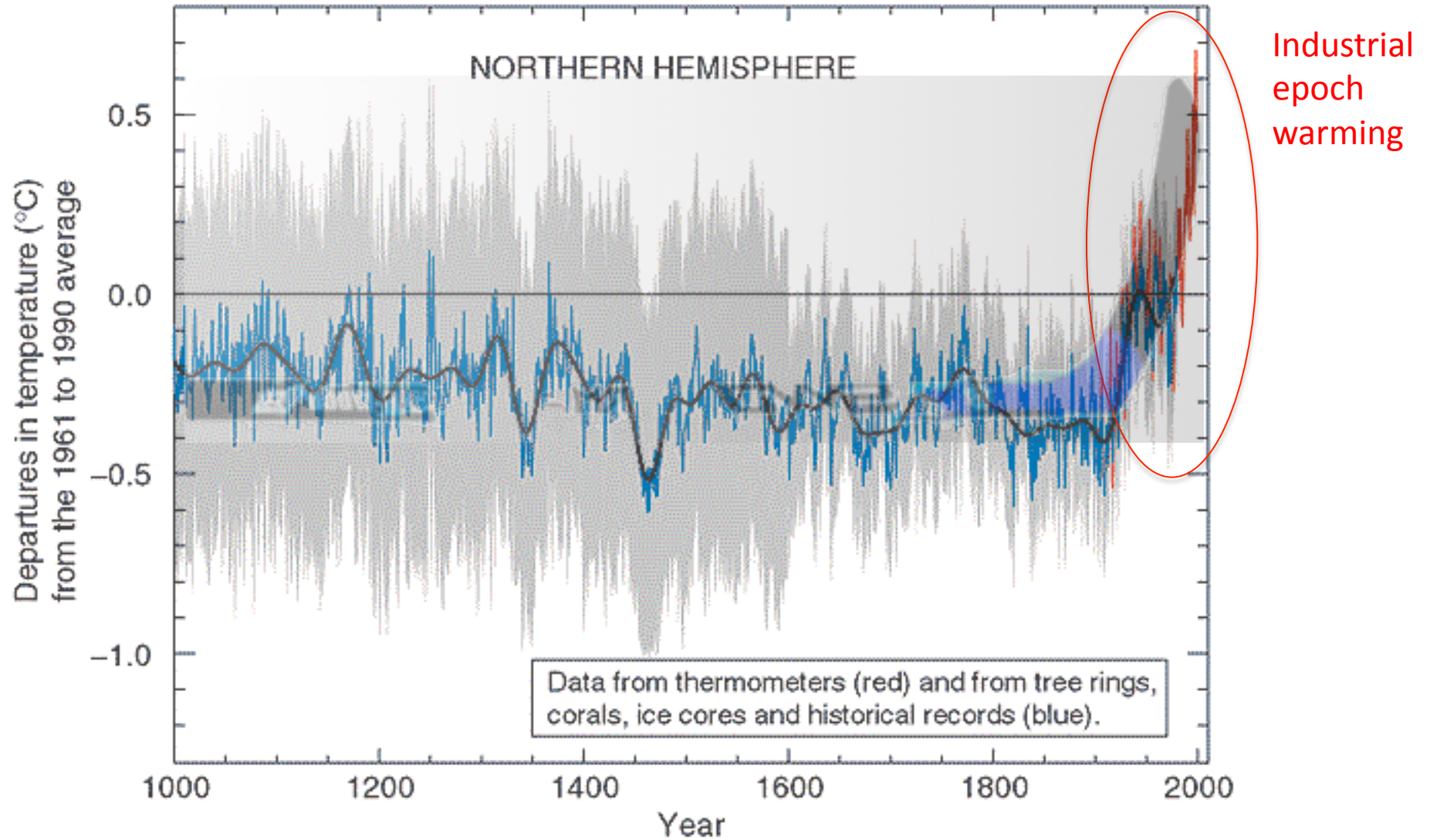
The climate is what you get!”

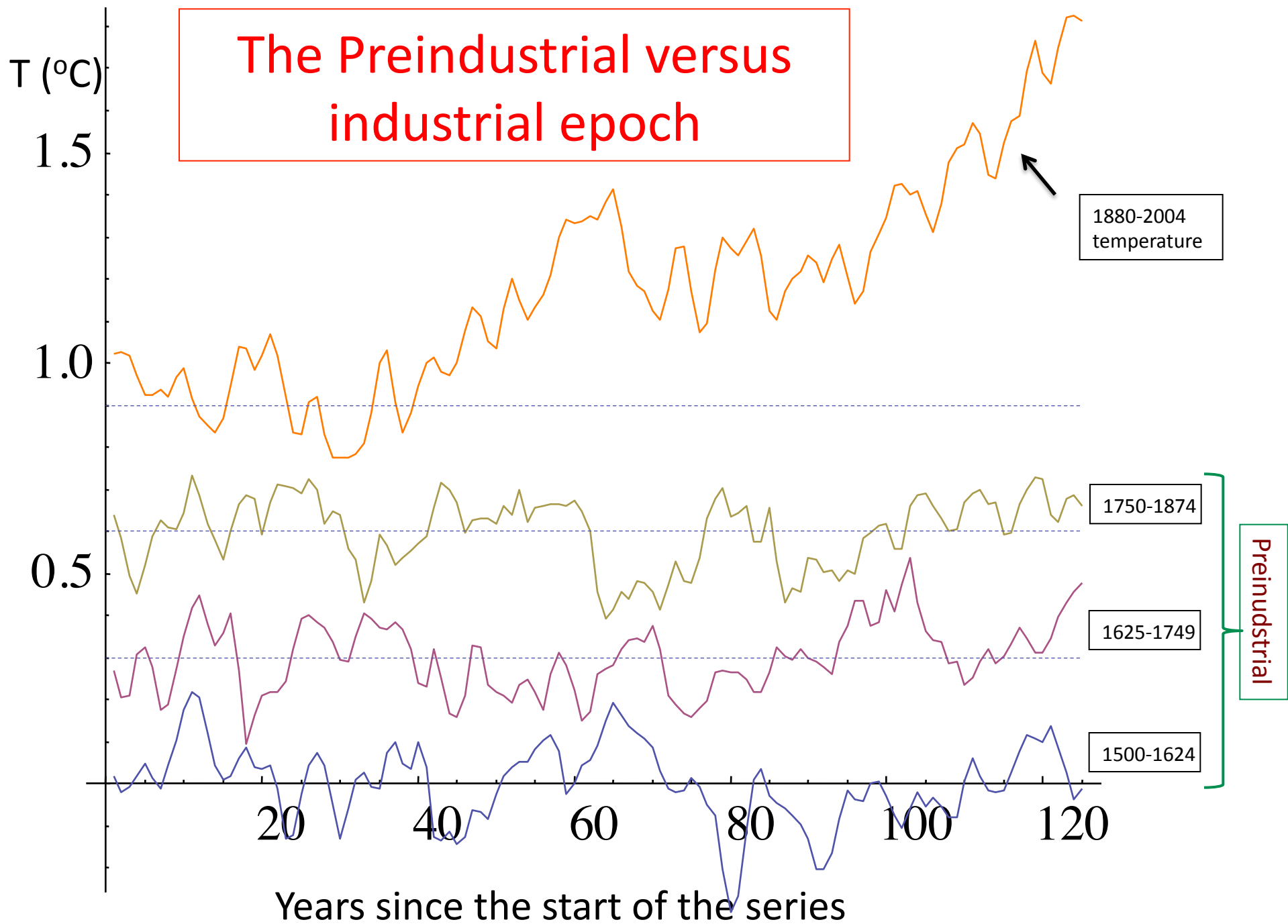
Weather, macroweather and the climate are distinguished by the way they change under a zoom!

Evidence for warming

The “hockey stick”

Mann, Bradley, Hughes 1998

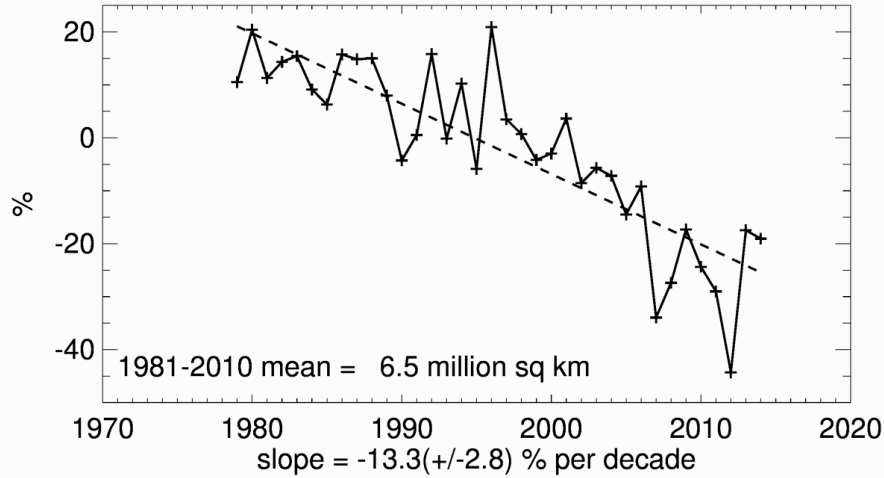




The Arctic

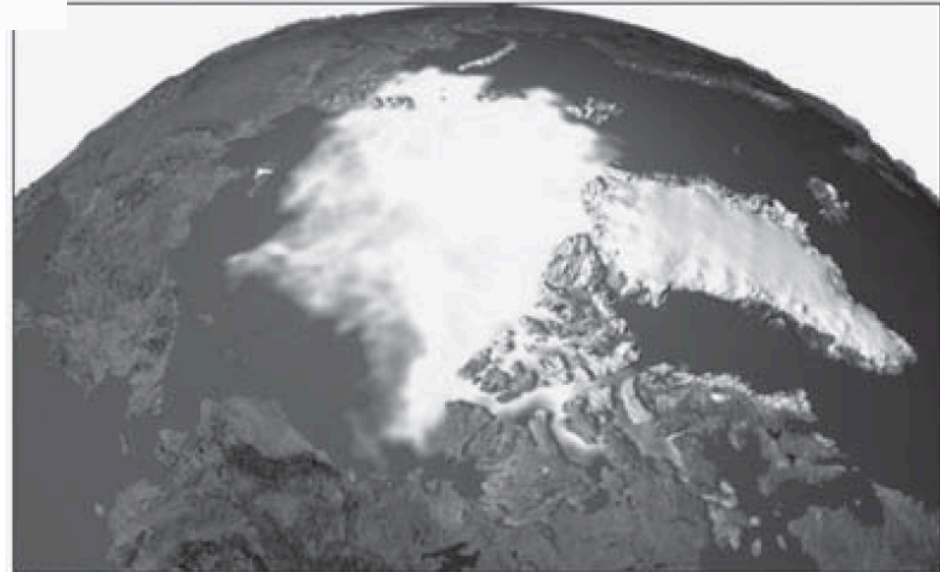
(melting of sea ice)

Northern Hemisphere Extent Anomalies Sep 2014



1979

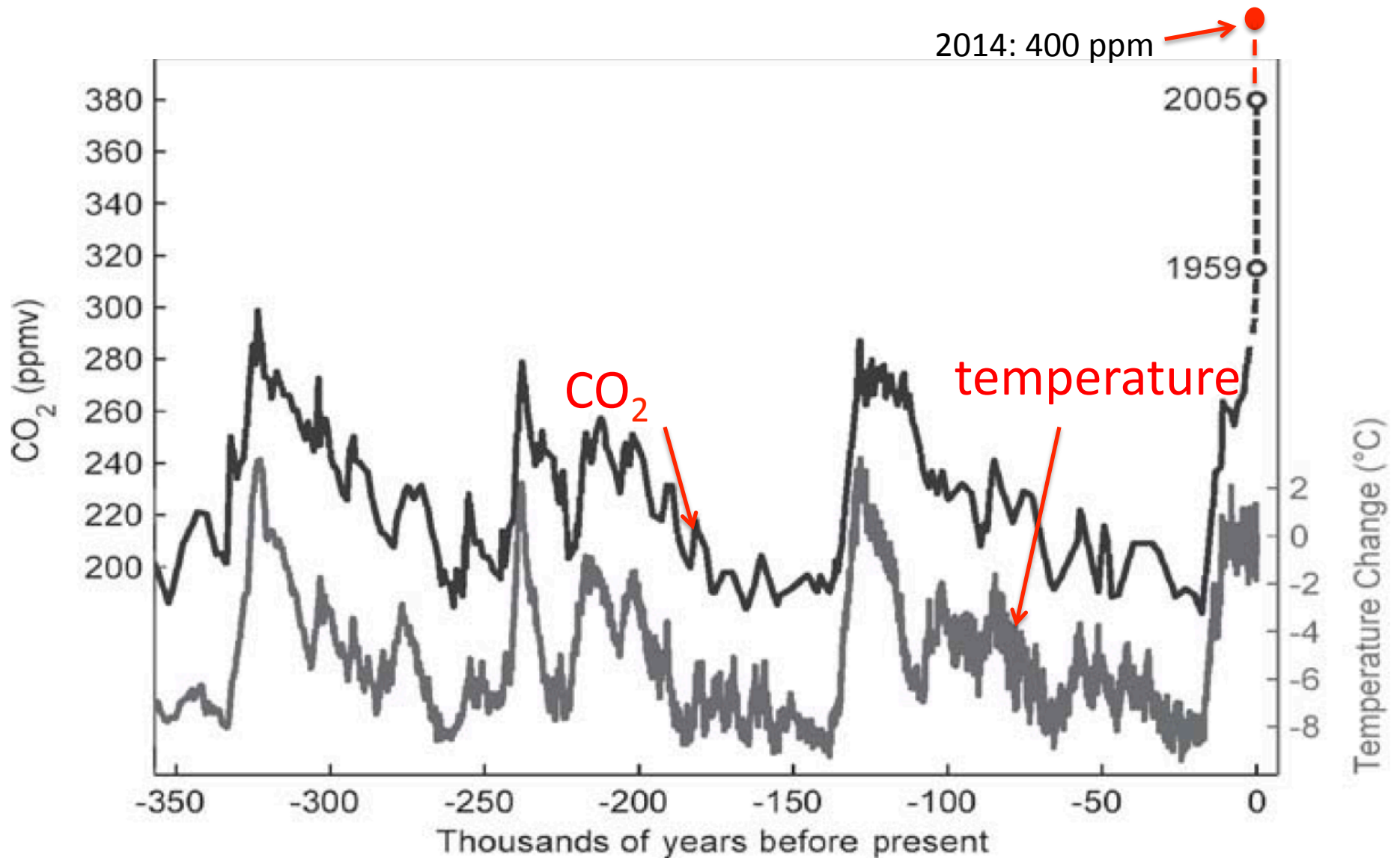
Over 2 million square km of sea ice lost over 35 years



2005

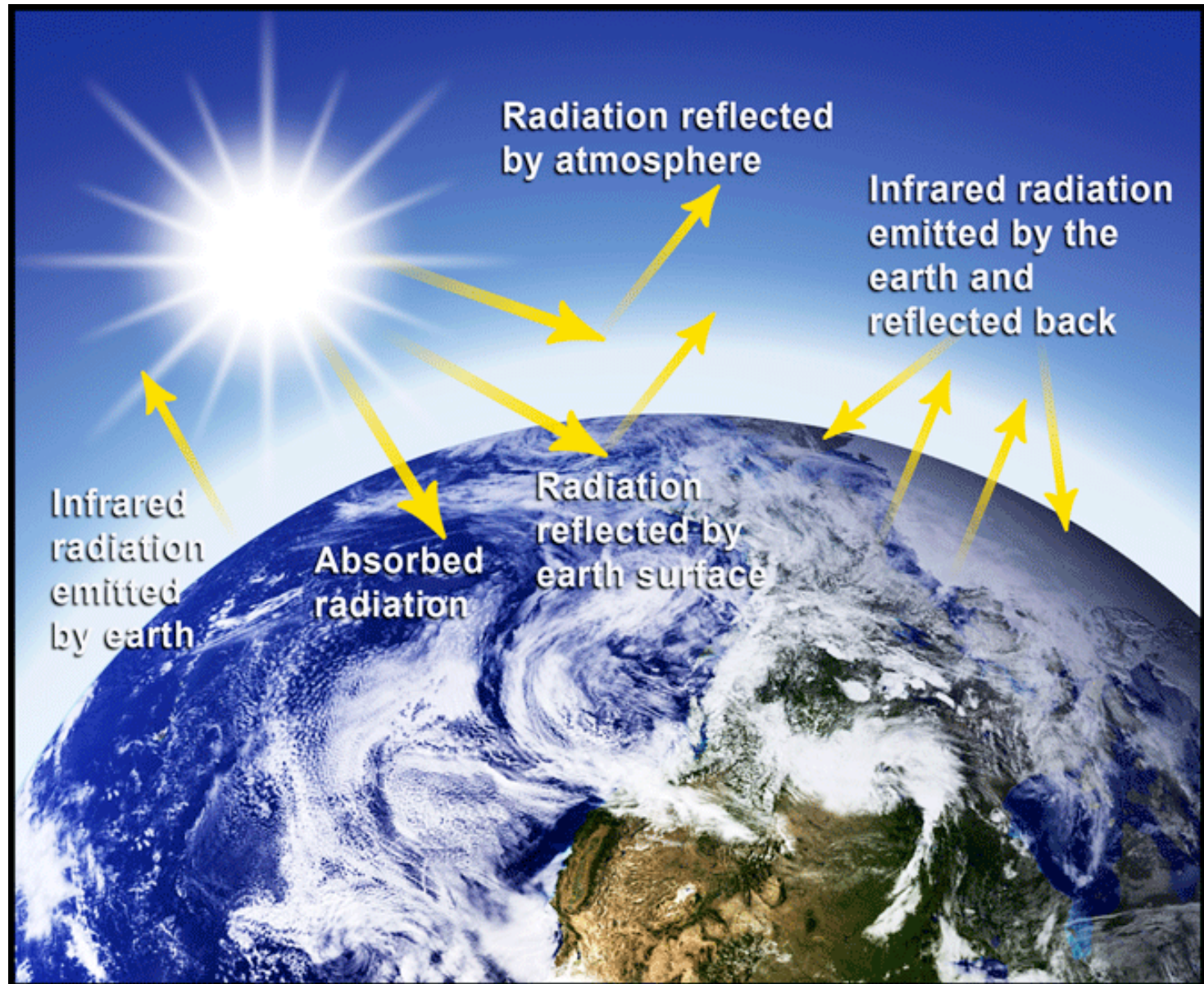
Anthropogenic Theory

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”



Anthropogenic warming: Pre-GCM era

GCM = Global Circulation Model

1896

Nobel prize winner Svante Arrhenius: CO₂ doubling: 5 – 6°C of warming, “climate sensitivity”



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

GCM era (post 1975)

GCM's: for CO₂ doubling:

US National Academy of Science (1979): 1.5- 4.5°C

1998 climate models somewhat over-forecast the warming in the 2000's (the "pause")

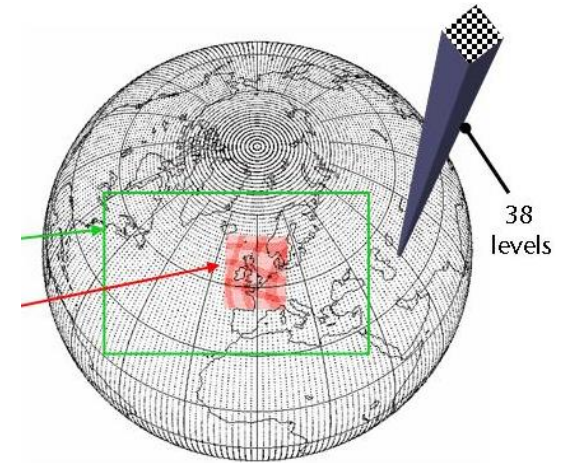
Proving AW: Diminishing Returns

GCM's: for CO₂ doubling:

IPCC3	(2002):	1.5- 4.5°C
IPCC4	(2007):	2- 4.5°C
IPCC5	(2013):	1.5- 4.5°C

IPCC 5 (2013) extremely

IPCC 4 (2007) "it is likely that human influence has been the dominant cause of the observed warming since the mid-20th century"



MilkyWay-2: World's fastest supercomputer



3,120,000 cores: 3x10¹⁶ Flops (Nov. 2014)

Natural variability Theory: A Giant Natural Fluctuation



Friends of Science Billboard, Nov. 2014

Doubting the warming (pre 2006)

- 1. The models are unreliable they have not been tested, they aren't valid.
 - predictions of warming don't depend on the models
- 2. **Pre 2004:** "Heat Island effect": warm biases due to urbanization?
 - The effect is very small and there is a countervailing "cool park" effect
- 3. **1995- 2005:** Satellites don't agree with surface measurements ...
 - 4 errors discovered (now there is agreement).

2006: "Because of the complexity of the problem, environmental skepticism was once tenable. No longer. It is time to flip from skepticism to activism."

-Michael Shermer, editor of the *Skeptical Inquirer*

Skeptics and Deniers (post 2006)

Accepting the warming:
**Alternative theory - Natural
variability** (including solar)

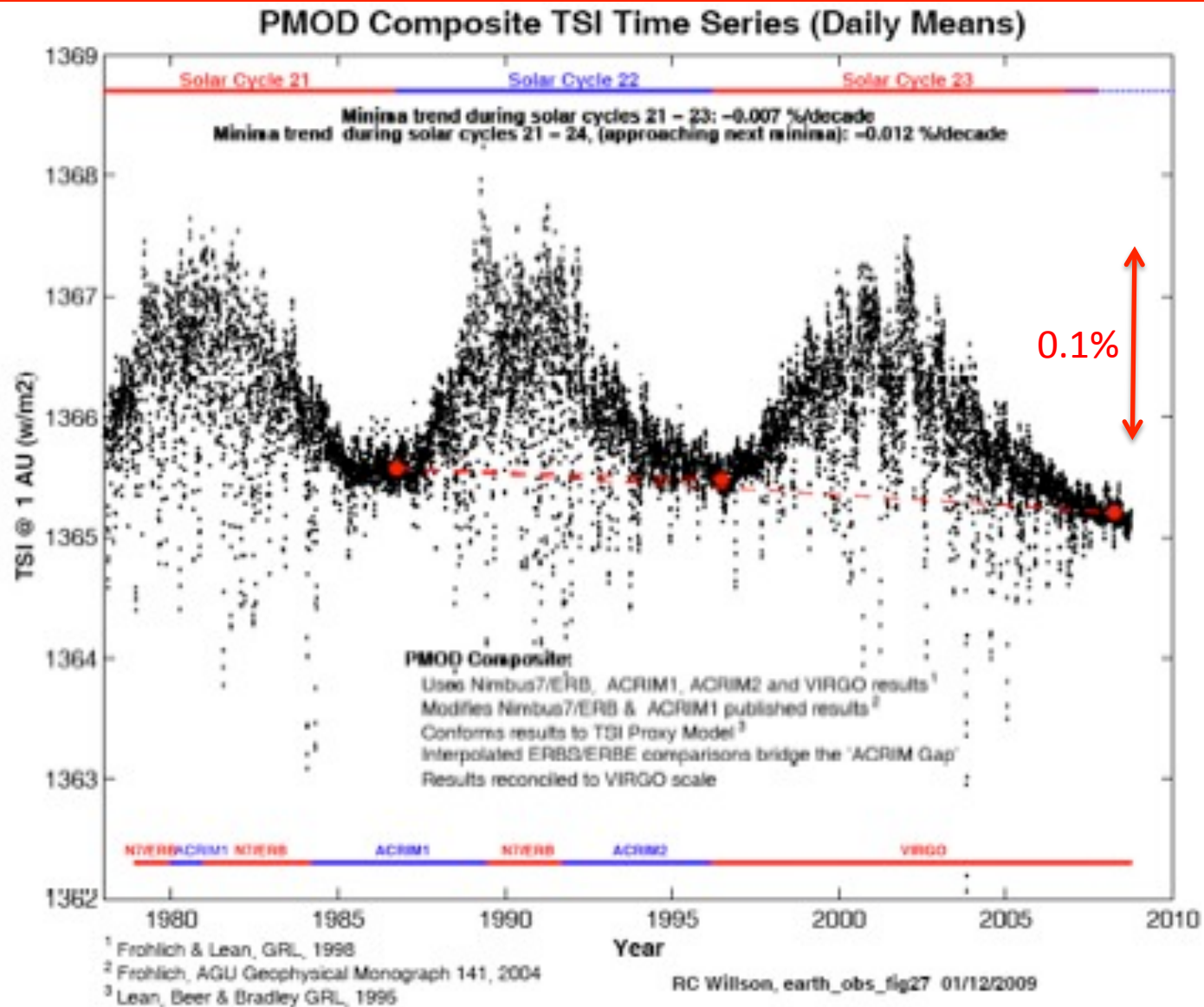
1. The warming is due to natural variability.
2. The “pause”: the earth has stopped warming since 1998.

Implausible but not disproved until 2014...

The sun ? (1):

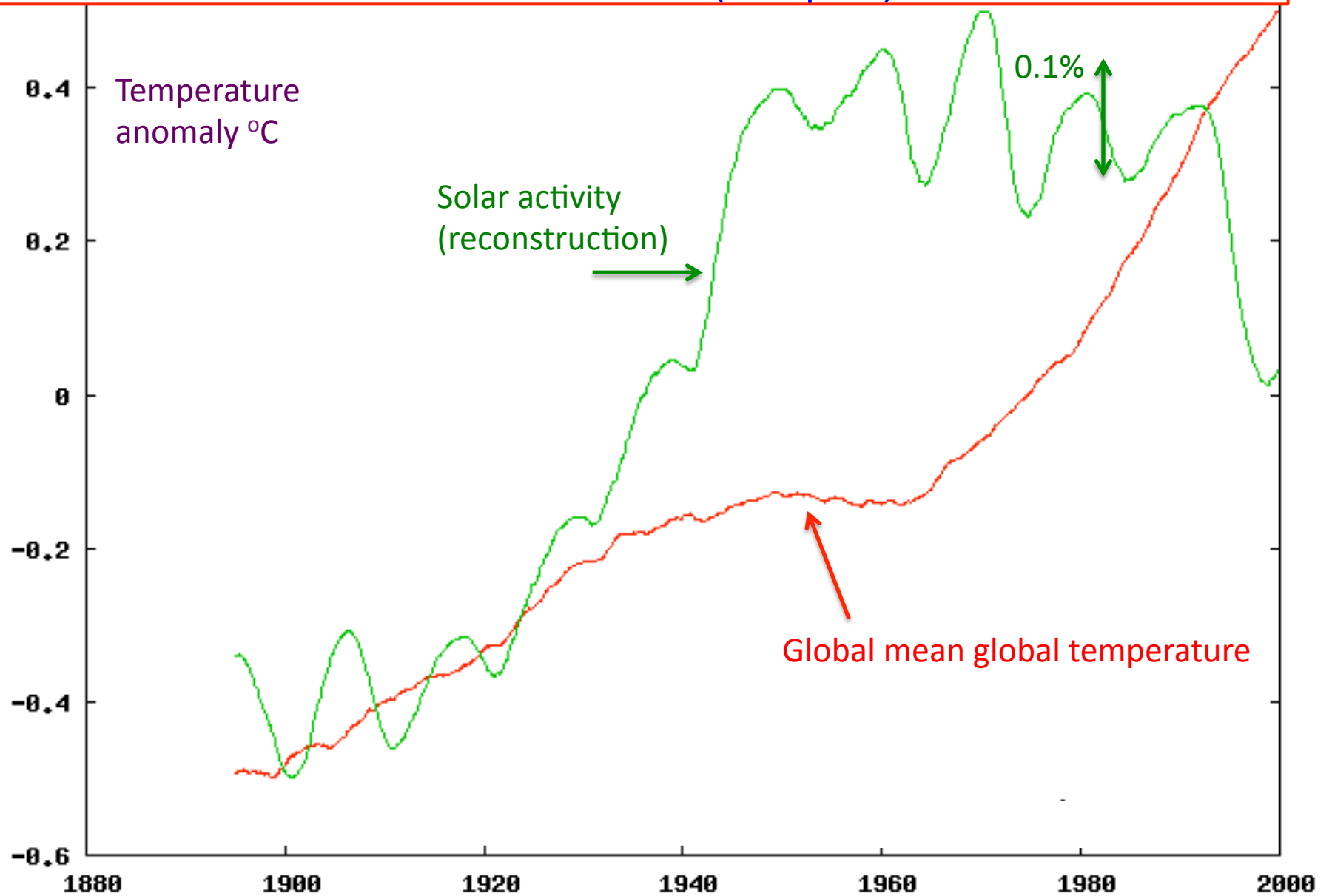
Total Solar Insolation

(satellite)



The sun ? (2):

Solar reconstruction (sunspots)



“Climate Closure” (1)

Disproving Natural warming

Clim Dyn (2014) 42:2339–2351
DOI 10.1007/s00382-014-2128-2

Scaling fluctuation analysis and statistical hypothesis testing of anthropogenic warming

S. Lovejoy

Received: 9 January 2014 / Accepted: 26 March 2014 / Published online: 6 April 2014
© Springer-Verlag Berlin Heidelberg 2014

Abstract Although current global warming may have a large anthropogenic component, its quantification relies primarily on complex General Circulation Models (GCM's) assumptions and codes; it is desirable to complement this with empirically based methodologies. Previous attempts to use the recent climate record have concentrated on “fingerprinting” or otherwise comparing

1 Introduction

Well before the advent of General Circulation Models (GCM's), (Arrhenius 1896), proposed that greenhouse gases could cause global warming and he even made a surprisingly modern quantitative prediction. Today, GCM's are so much the dominant tool for investigating the

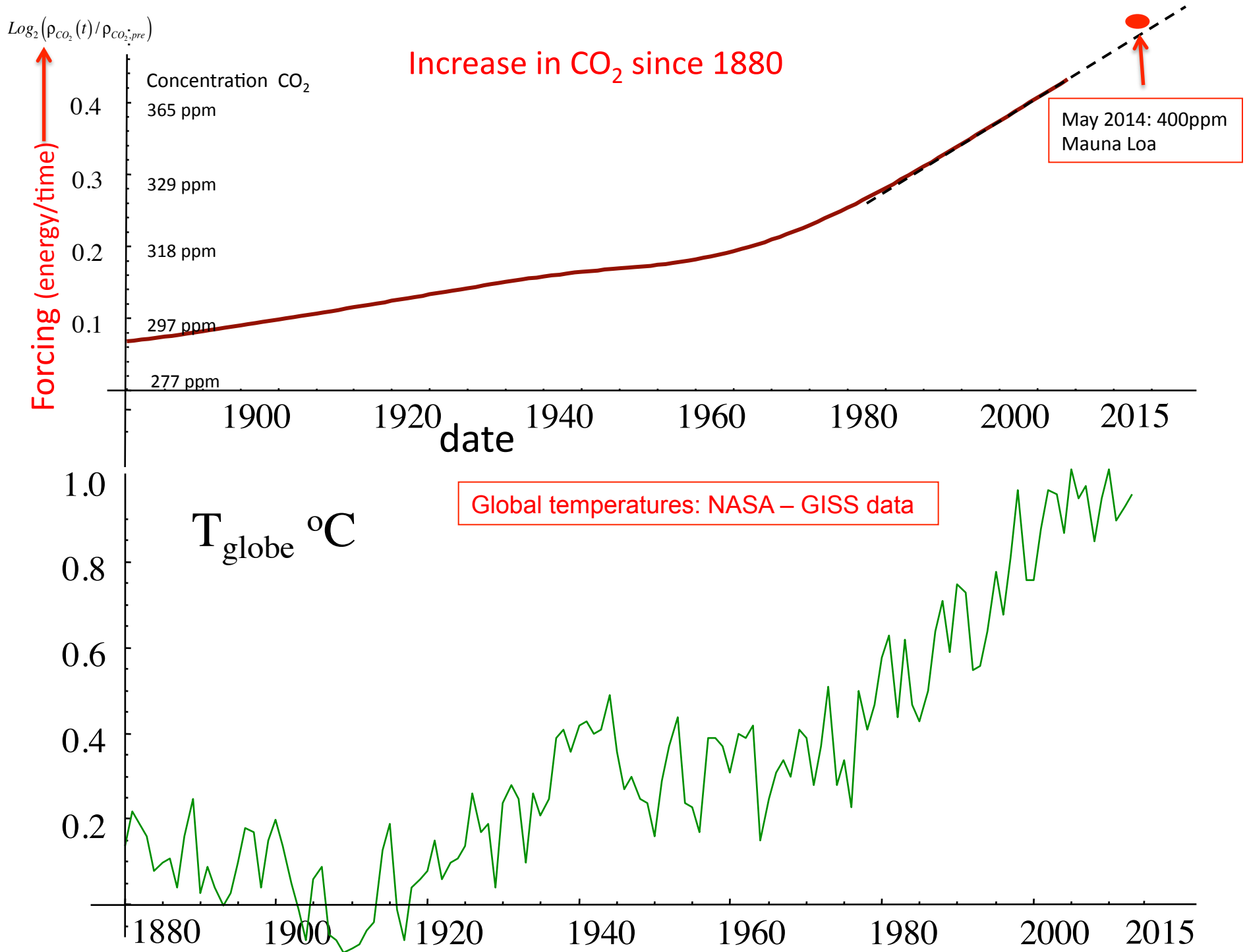
Dec. 12, 2014

The screenshot shows the Altmetric interface for the article. At the top left is a circular score of 181. Below it, a text box states: "Is one of the highest ever scores in this journal (ranked #1 of 759)". To the right, there are navigation tabs for News, Blogs, Twitter, Facebook, Score, Demographics, and Help. Below these, it says "So far Altmetric has seen 18 stories from 18 outlets." Three news stories are listed:

- HAARETZ**: Global warming is man-made with 99.9% certainty, study says. McGill physicist Shaun Lovejoy can't show it's man's hand behind the mayhem, but if it isn't Mother Nature, who's left? .. (2014-04-13T13:20:00+)
- Machineslikeus**: Odds that global warming is due to natural factors: Slim to none. An analysis of temperature data since 1500 all but rules out the possibility that global warming the industrial era is just a .. (2014-04-11T16:43:10+)
- TG DAILY**: Odds that global warming is due to natural factors? Slim to none. An analysis of temperature data since 1500 all but rules out the possibility that global warming the industrial era is just a .. (2014-04-14T07:00:00+)

At the bottom, there is a "Track this article" section with a checkbox for "Get email updates when this article is shared".

Natural variability hypothesis was neglected by the scientific community



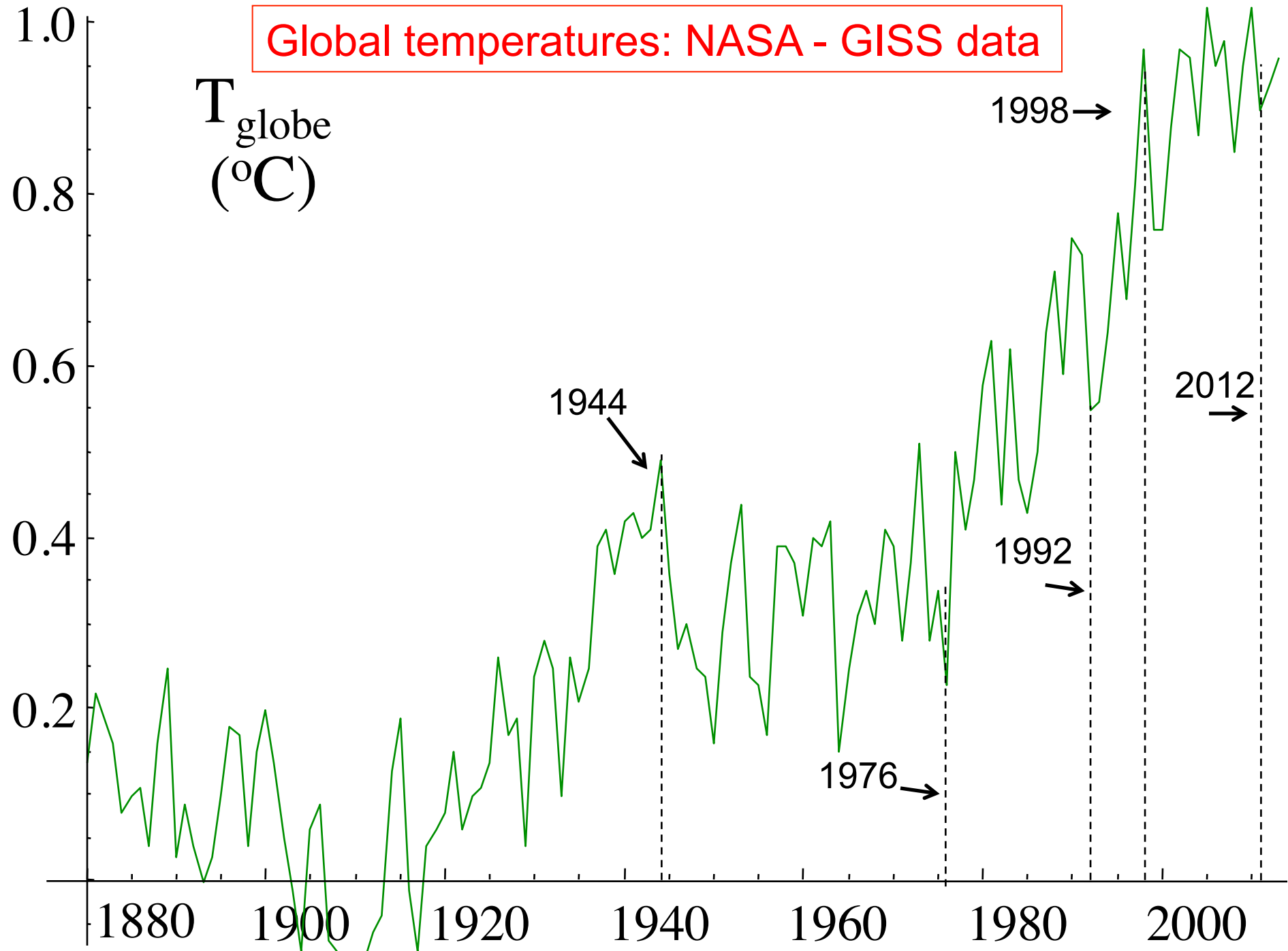
CO₂ forcing as surrogate for all anthropogenic effects

Roughly:

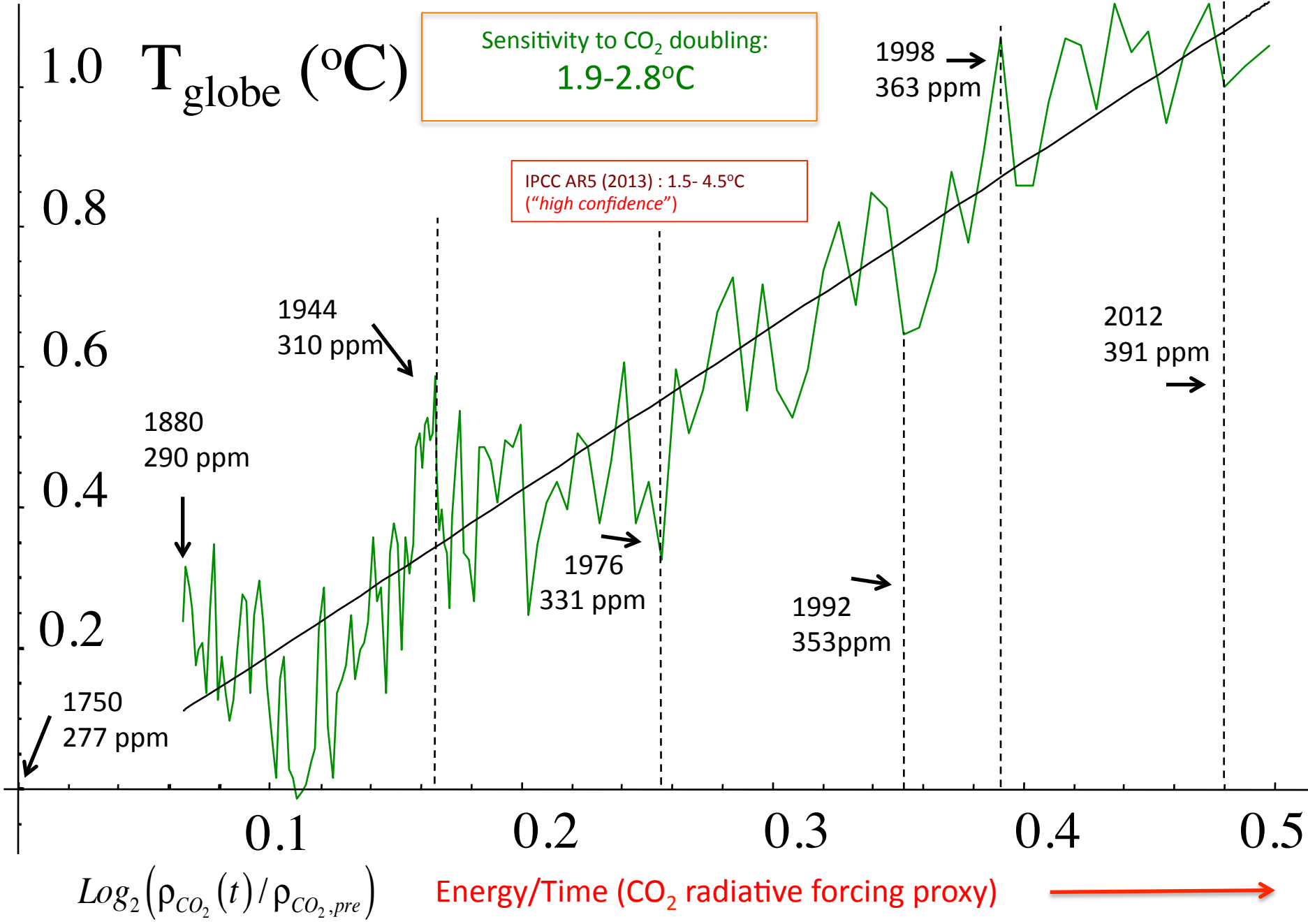
double the global economy, double the emissions, land use and other changes:

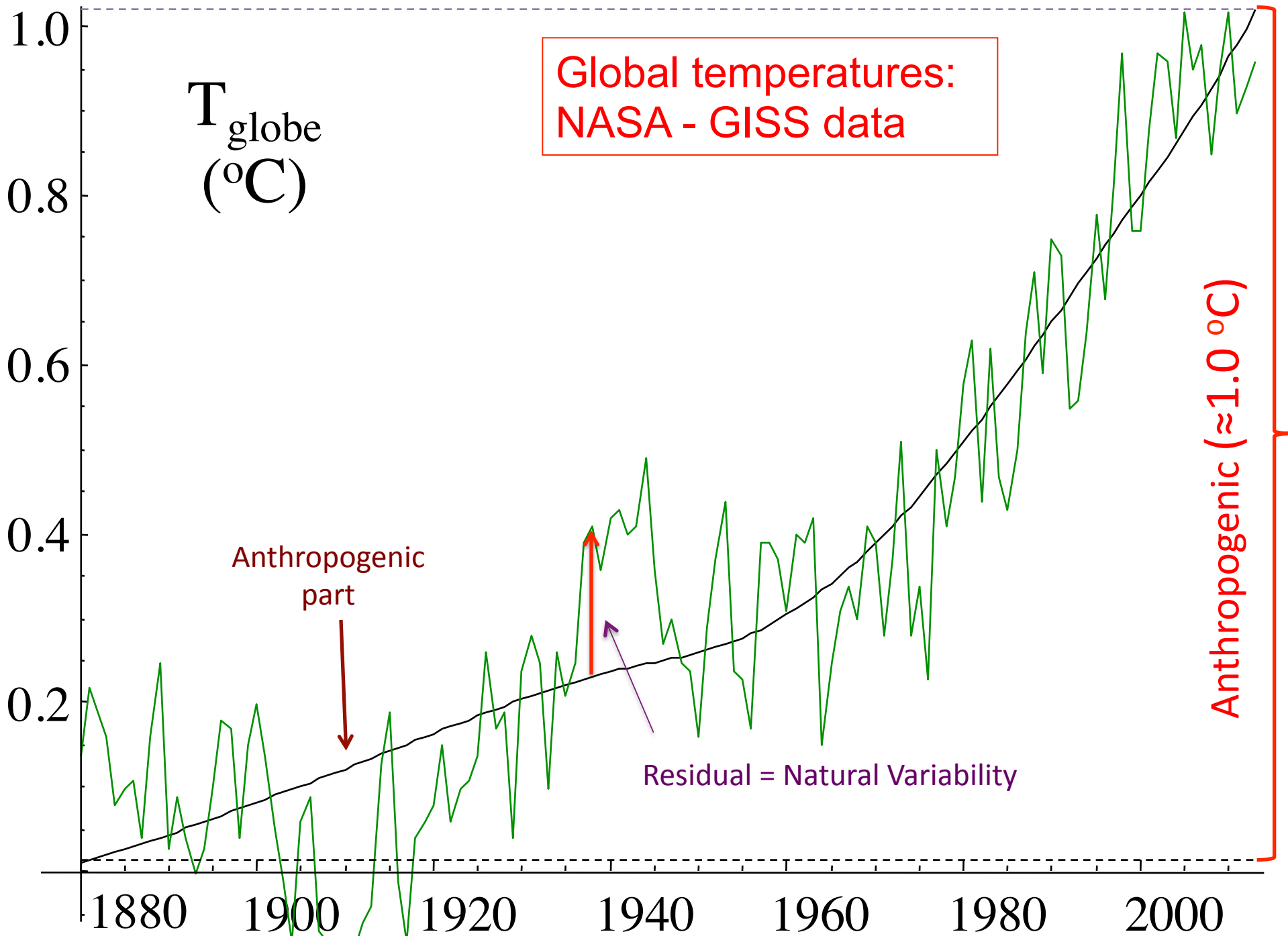
double the effects

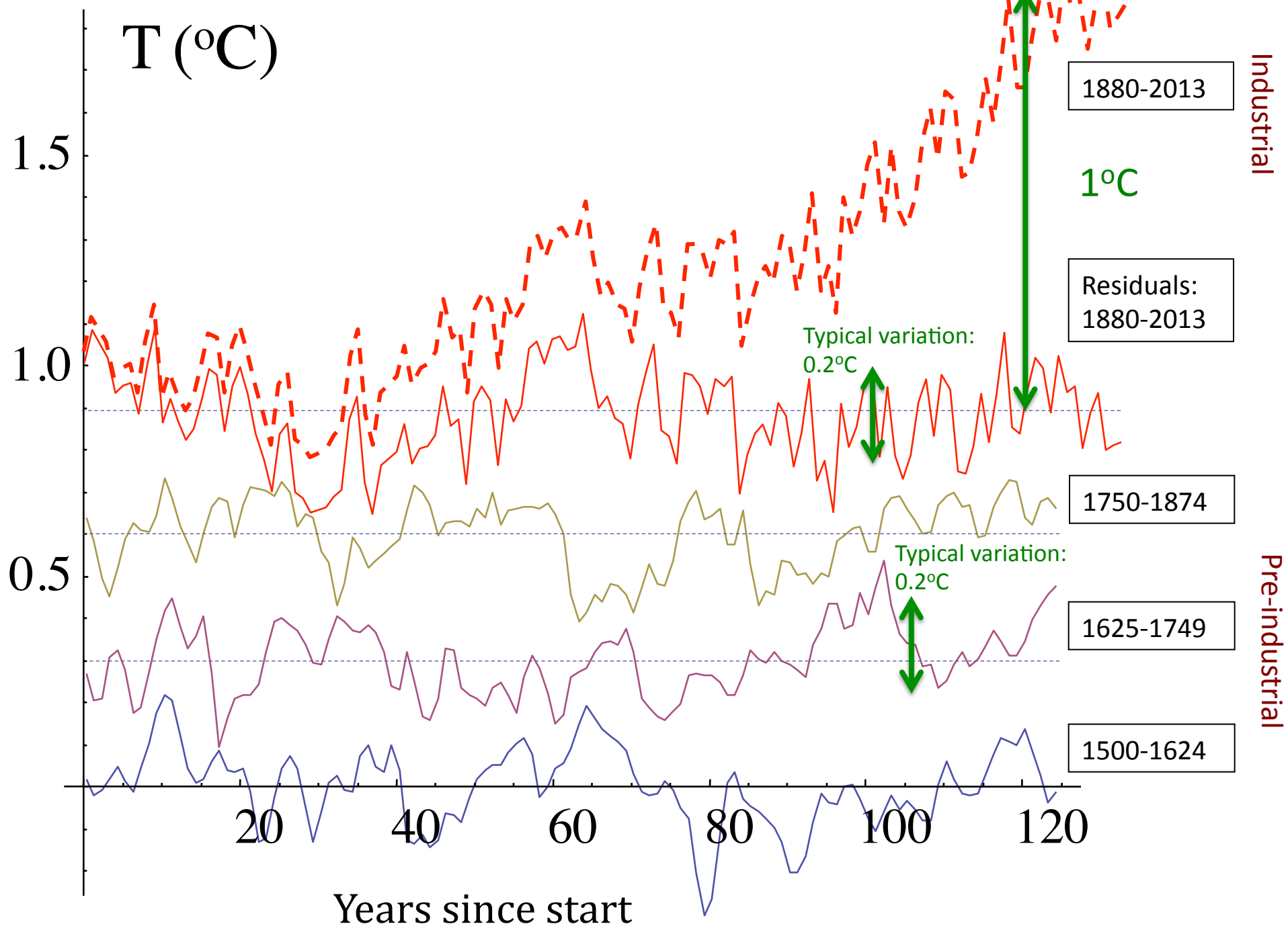
Global temperatures: NASA - GISS data



Global temperatures: NASA - GISS data

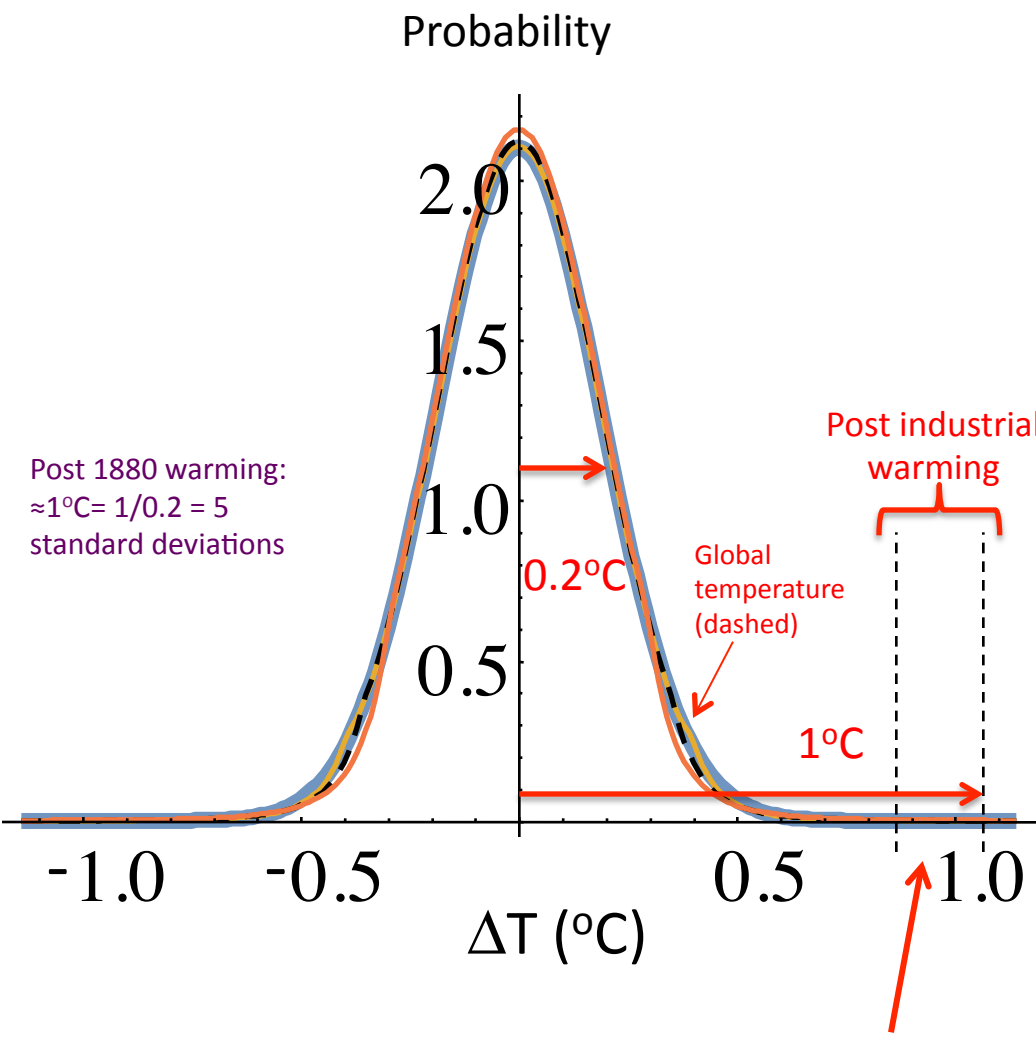




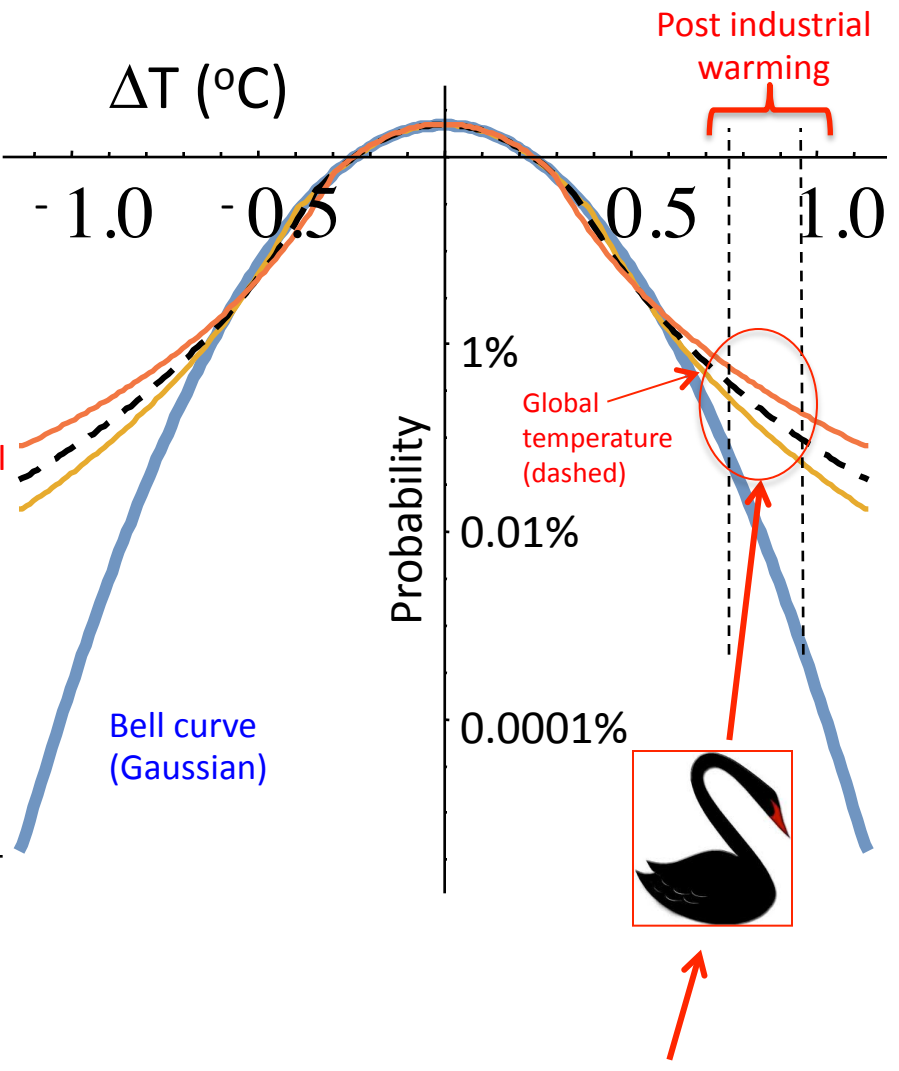


Probabilities of extremes: Bell Curve, Black Swans (1)

Usual representation



Representation showing extremes



Extremes and Black Swans (2)



Bell curve ('normal distribution') probabilities

Probability of exceeding

1 s.d: 16% \approx 1/6

2 s.d: 2.3% \approx 1/50

3 s.d: 0.13% \approx 1/1,000

4 s.d: 0.0032% \approx 1/32,000

5 s.d: 0.000029% \approx 1/3,000,000

Bell curve probability of a
1°C warming since 1880

Black Swan probabilities

Extreme probabilities fall off slowly:

$$\text{Probability} \approx \Delta t^{-5}$$

With black swans: probability of a 5 s.d. event:

$$16\% / (5^5) = 0.03\% = 1/3000$$

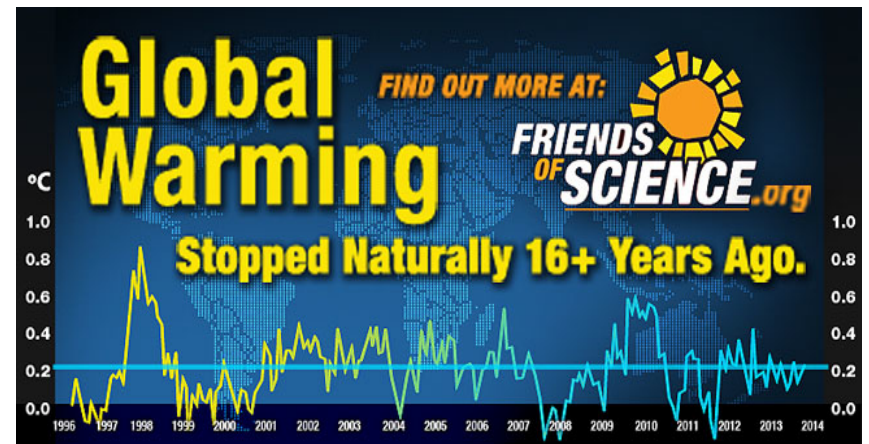
The probability of a 1°C warming since 1880 is 1000 times larger than expected!
But we can still reject it with 99.97% confidence!

“Climate Closure” (2)

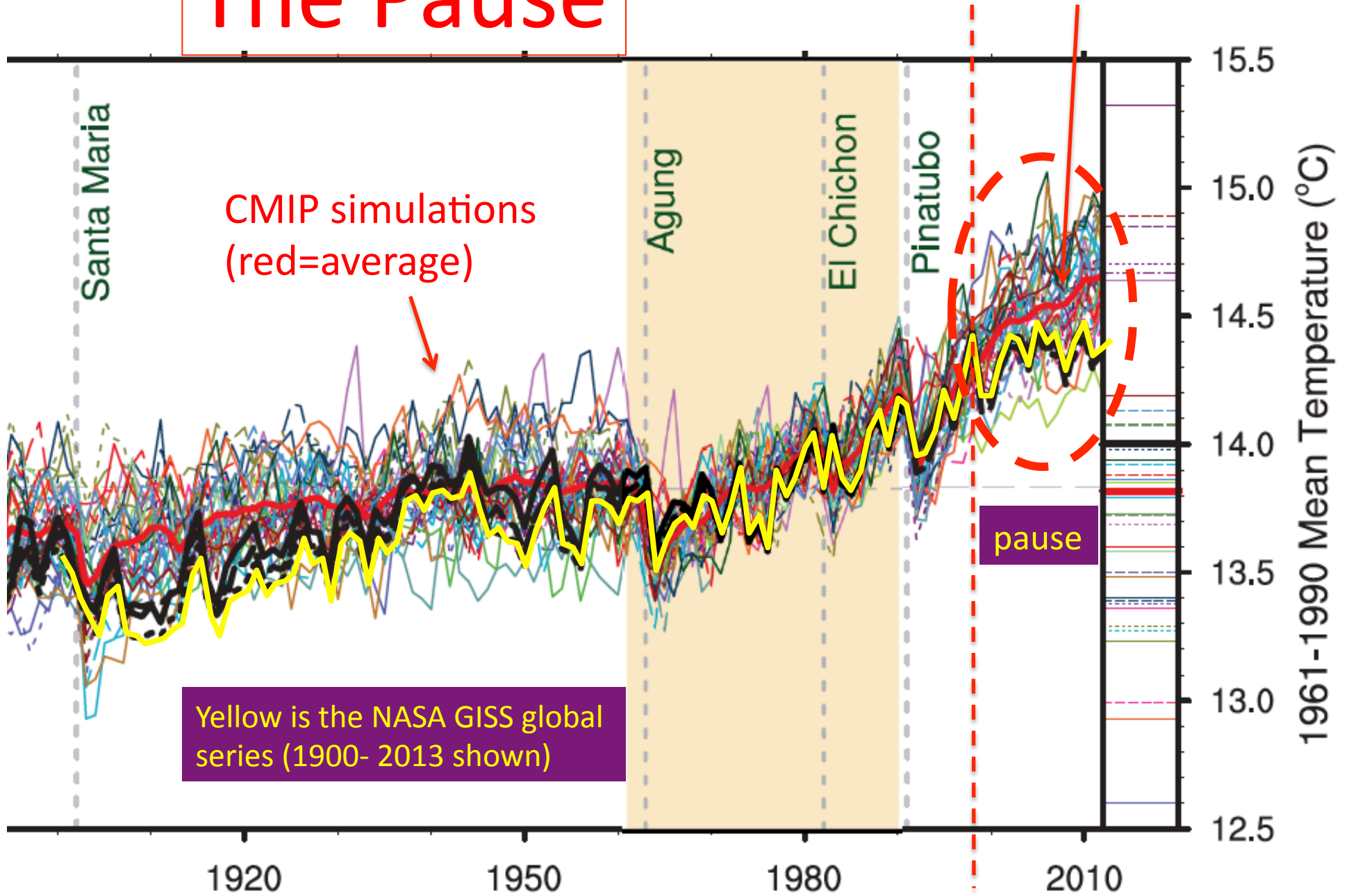
Explaining the “pause”

“Global warming stopped naturally 16 + years ago....”

(Friends of Science Billboard, Nov. 2014)



The Pause



The Pause

Geophysical Research Letters

RESEARCH LETTER

10.1002/2014GL060478

Key Points:

- The “pause” has a return period of 20–50 years (not unusual)
- Pre-pause (92–98) warming cancels the pause cooling
- The largest expected cooling event = 0.47 K; almost exactly the postwar cooling

Correspondence to:

S. Lovejoy,
lovejoy@physics.mcgill.ca

Citation:

Lovejoy, S. (2014), Return periods of global climate fluctuations and the pause, *Geophys. Res. Lett.*, 41, doi:10.1002/2014GL060478.

Return periods of global climate fluctuations and the pause

S. Lovejoy¹

¹Physics, McGill, Montreal, Canada

Abstract An approach complementary to General Circulation Models (GCMs), using the anthropogenic CO₂ radiative forcing as a linear surrogate for all anthropogenic forcings [Lovejoy, 2014], was recently developed for quantifying human impacts. Using preindustrial multiproxy series and scaling arguments, the probabilities of natural fluctuations at time lags up to 125 years were determined. The hypothesis that the industrial epoch warming was a giant natural fluctuation was rejected with 99.9% confidence. In this paper, this method is extended to the determination of event return times. Over the period 1880–2013, the largest 32 year event is expected to be 0.47 K, effectively explaining the postwar cooling (amplitude 0.42–0.47 K). Similarly, the “pause” since 1998 (0.28–0.37 K) has a return period of 20–50 years (not so unusual). It is nearly cancelled by the pre-pause warming event (1992–1998, return period 30–40 years); the pause is no more than natural variability.

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

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 be-



ALLEN MANNING/THE GAZETTE

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 dispute 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

The conventional Global
Circulation Model (GCM)
approach to climate forecasting
(Brute force)

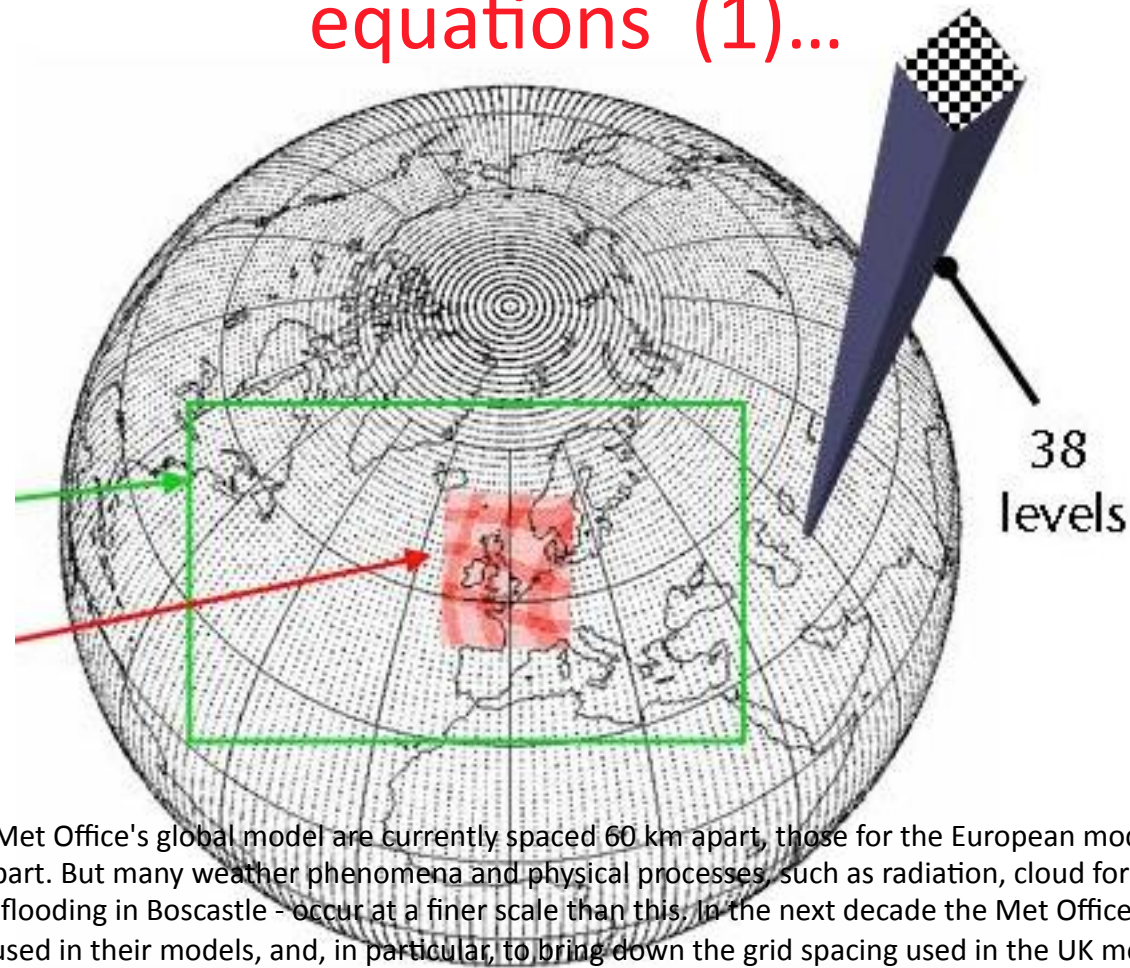
Atmosphere: Laws of continuum mechanics

The image shows four governing equations of atmospheric continuum mechanics, with red arrows pointing to specific terms and their physical meanings:

- Equation 1:** $\frac{\partial \mathbf{u}}{\partial t} = -(\mathbf{u} \cdot \text{grad})\mathbf{u} - 2\boldsymbol{\Omega} \times \mathbf{u} - \alpha \text{grad } p - \text{grad } \Phi + \mathbf{F}$
 - $\frac{\partial \mathbf{u}}{\partial t}$: wind
 - $2\boldsymbol{\Omega} \times \mathbf{u}$: Earth angular velocity
 - α : Specific volume = $1/\rho$
 - $\text{grad } p$: pressure
 - $\text{grad } \Phi$: Gravitational potential
 - \mathbf{F} : Friction
- Equation 2:** $c_v \frac{\partial T}{\partial t} = -c_v (\mathbf{u} \cdot \text{grad})T - \frac{p}{\rho} \text{div } \mathbf{u} + Q$
 - c_v : Specific heat
 - T : temperature
 - $\frac{p}{\rho}$: pressure
 - Q : Heating rate
- Equation 3:** $\frac{\partial \rho}{\partial t} = -(\mathbf{u} \cdot \text{grad})\rho - \rho \text{div } \mathbf{u}$
 - ρ : density
- Equation 4:** $p = \rho R T$
 - ρ : density
 - R : Gas constant

Governing atmospheric laws

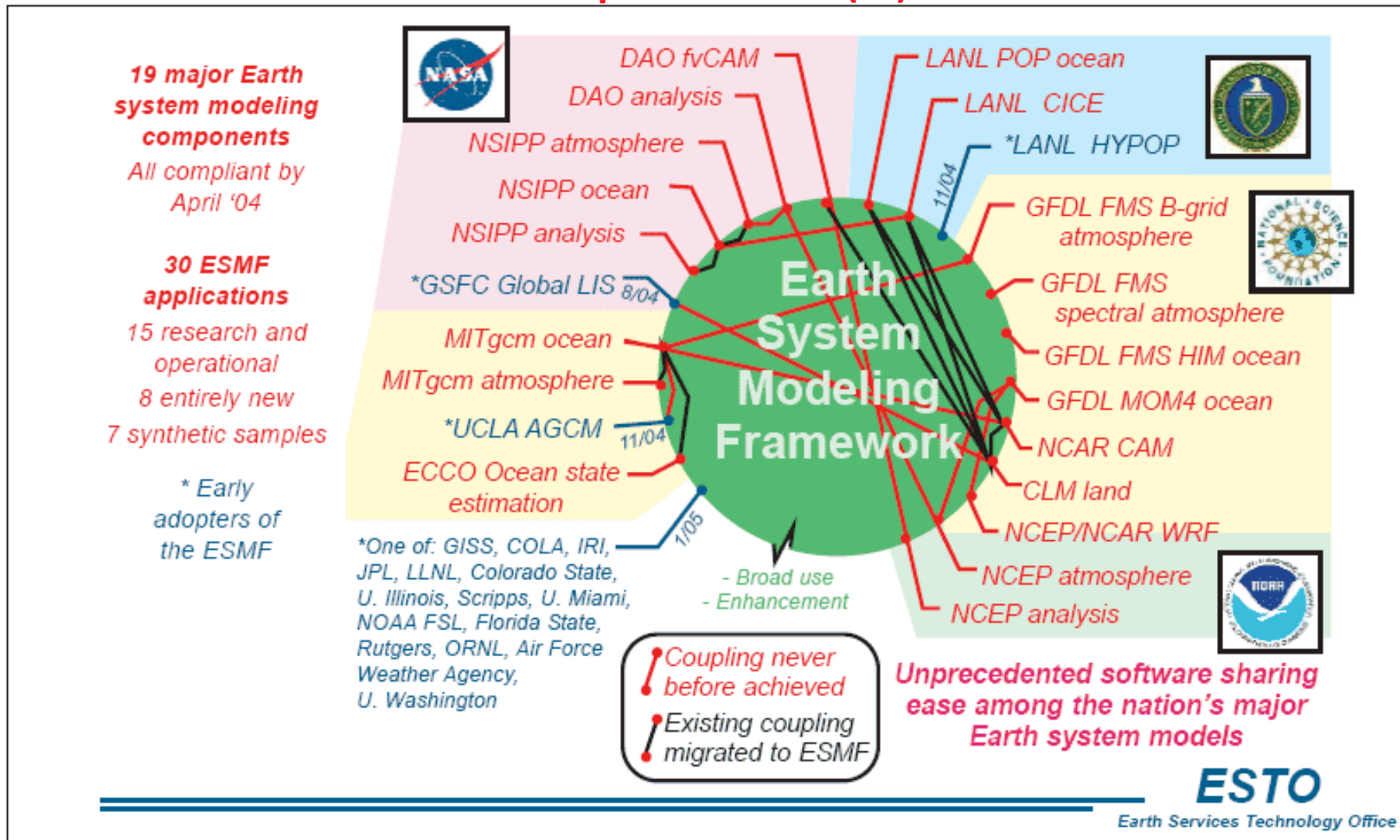
Brute force numerical solution of the equations (1)...



The grid points for the Met Office's global model are currently spaced 60 km apart, those for the European model, 20km apart and those for the UK model, 12 km apart. But many weather phenomena and physical processes, such as radiation, cloud formation and rainfall - and the storms that caused the flooding in Boscastle - occur at a finer scale than this. In the next decade the Met Office hope to improve the resolution of the grids used in their models, and, in particular, to bring down the grid spacing used in the UK model to 4 km in 2005, and to just 1 km by the end of the decade. Preliminary research tests with these 4km and 1km models have had promising results in capturing localised flooding events such as Boscastle.

Discretization of the equations

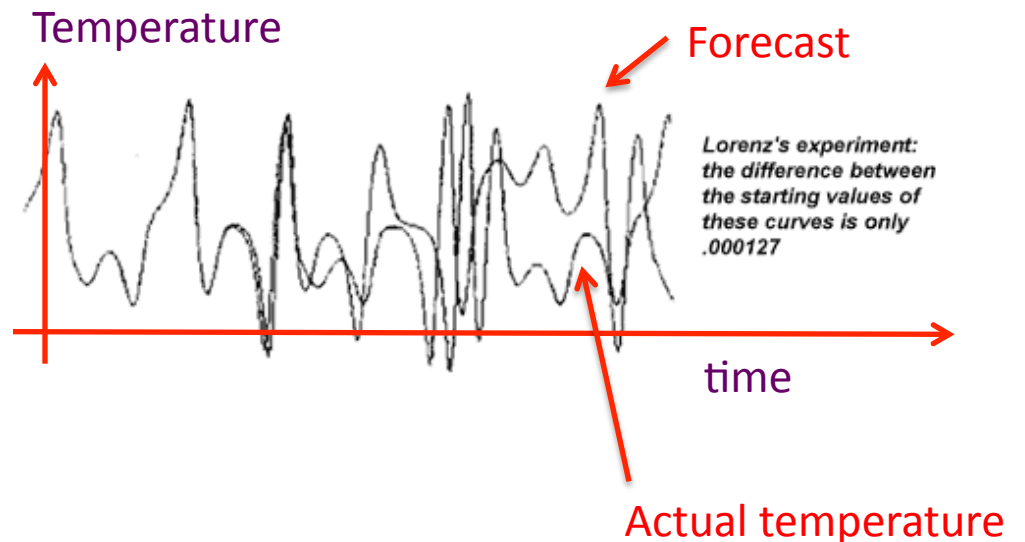
Brute force numerical solution of the equations (2)...



Earth system modelling

Limitations of Global Climate Models and stochastic alternatives

Loss of *deterministic* predictability after 10 days
= “butterfly effect”

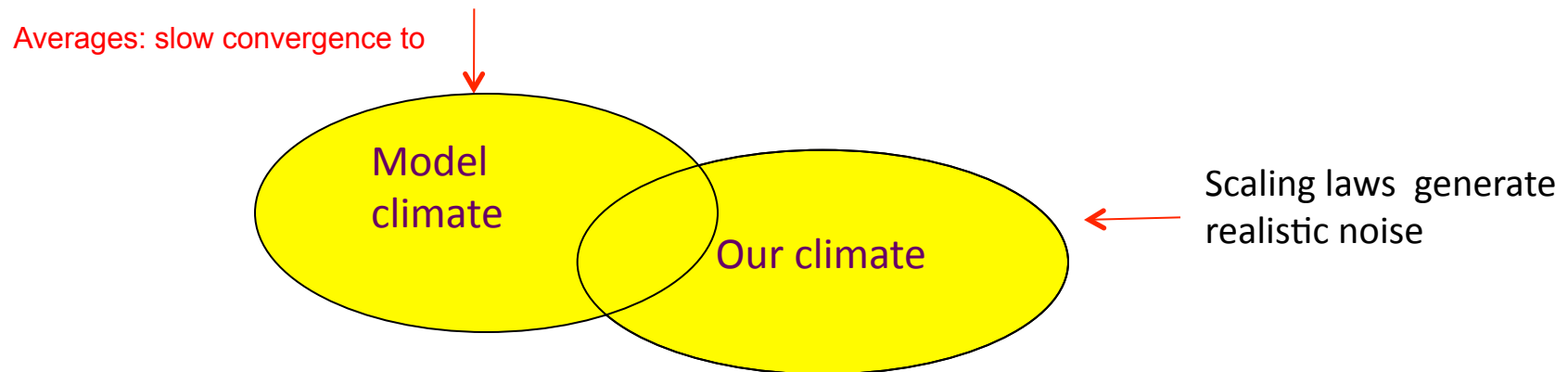


But by harnessing the butterfly effect we obtain
some stochastic predictability....

GCMs for forecasts longer than ≈ 10 days

“Brute force”

Weather systems generated by GCMs = random weather noise... but not fully realistic



Potential advantages of stochastic forecasting:

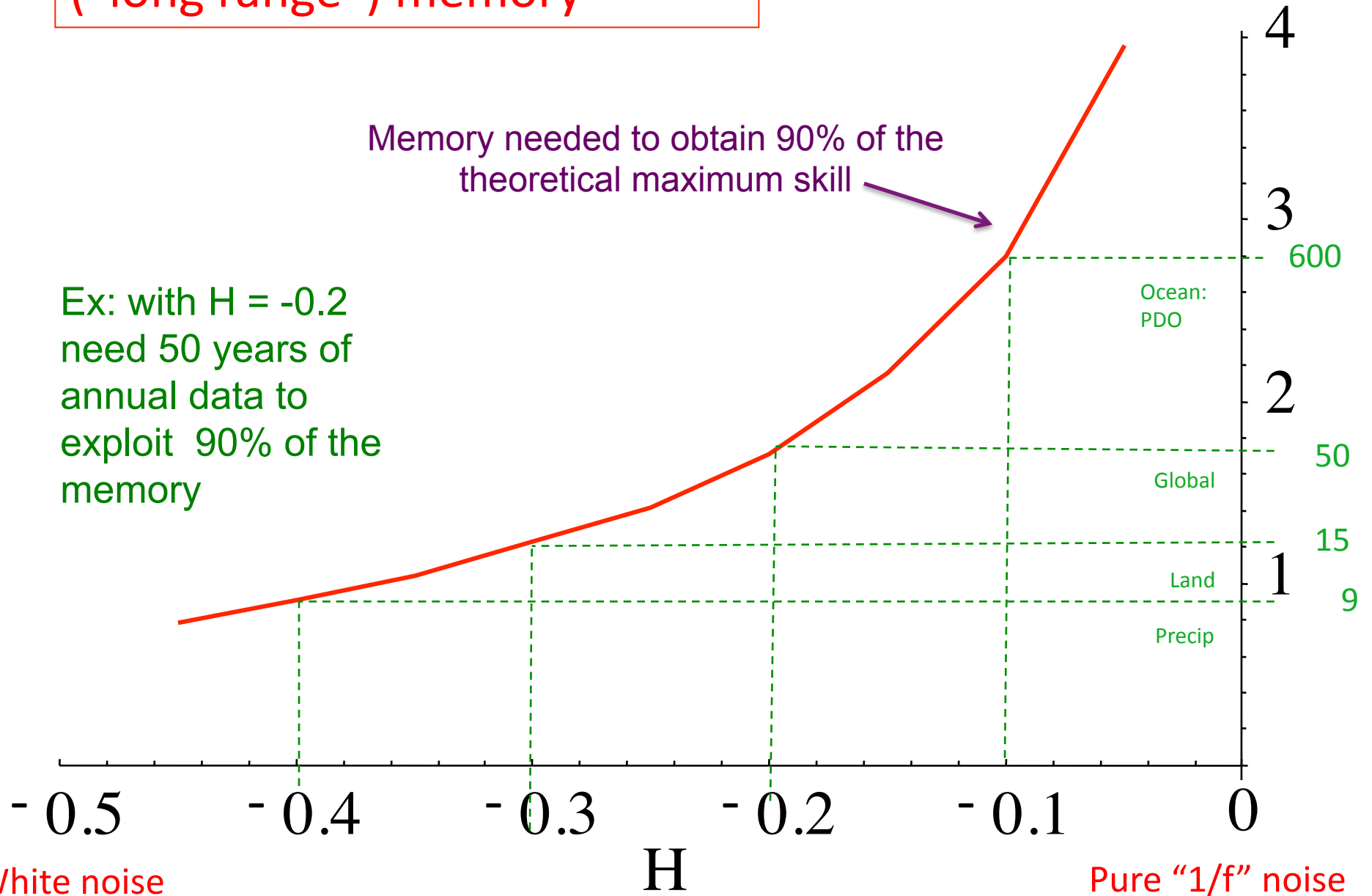
- More realistic weather “noise”
- Ability to use empirical data to force convergence to the real climate

The unsuspected Elephantine (“long range”) memory

$\text{Log}_{10} \lambda_{\text{mem}}$

Memory needed to obtain 90% of the theoretical maximum skill

Ex: with $H = -0.2$
need 50 years of
annual data to
exploit 90% of the
memory

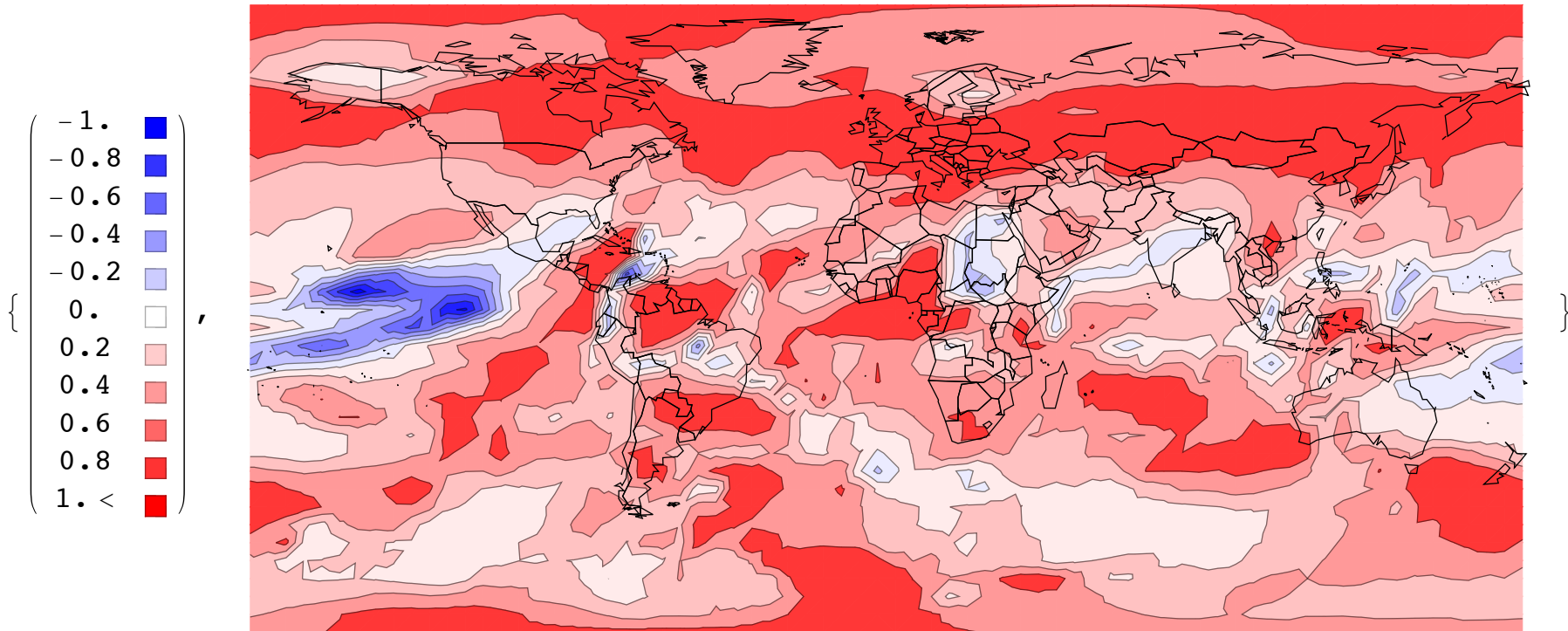


Accuracy of Seasonal (3 month) temperature forecasts

New stochastic model: SLIMM = ScaLIng Macroweather Model

GCM: Canadian Seasonal to Inter-annual Prediction System

SLIMM vs. CanSIPS



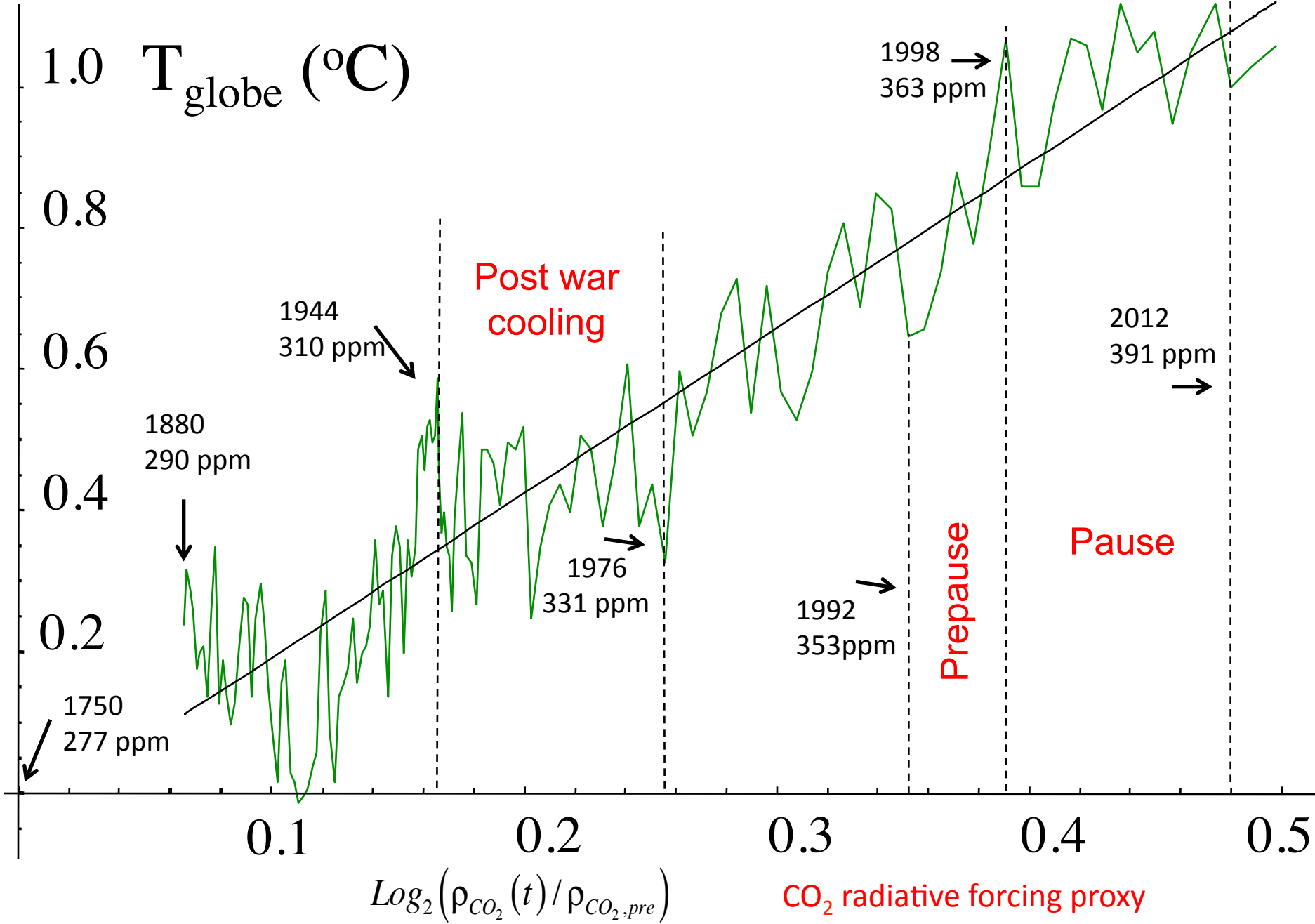
Plot shows: $1 - (\text{Error SLIMM}) / (\text{Error CanSIPS})$

Red: Areas where SLIMM is better than CanSIPS

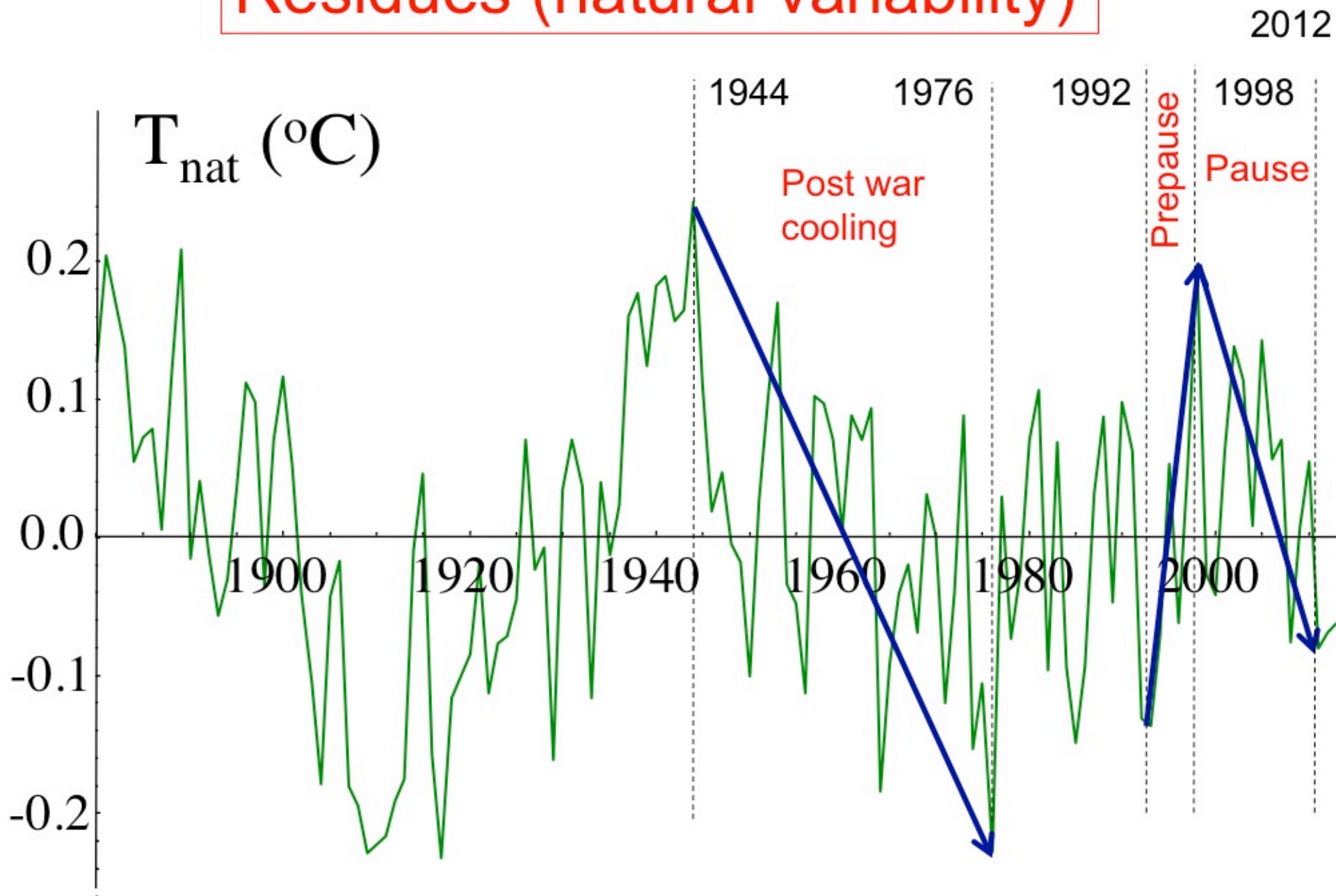
Fractional reduction in error by changing hindcast method from GCM (CanSIPS) to SLIMM (ScaLIng Macroweather Model)

SLIMM and the Pause

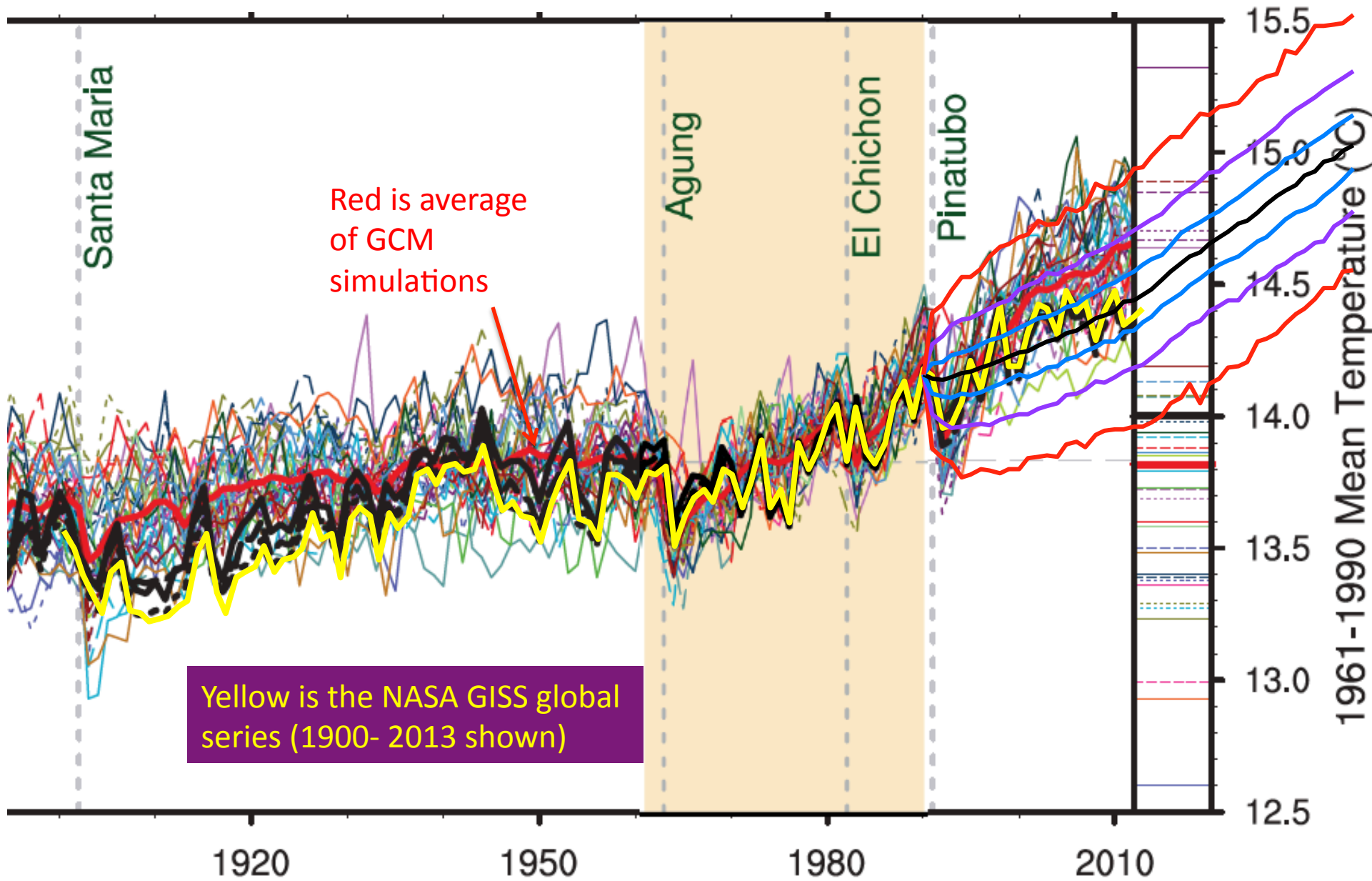
Global temperatures: NASA - GISS data



Residues (natural variability)



The pause with SLIMM forecasts

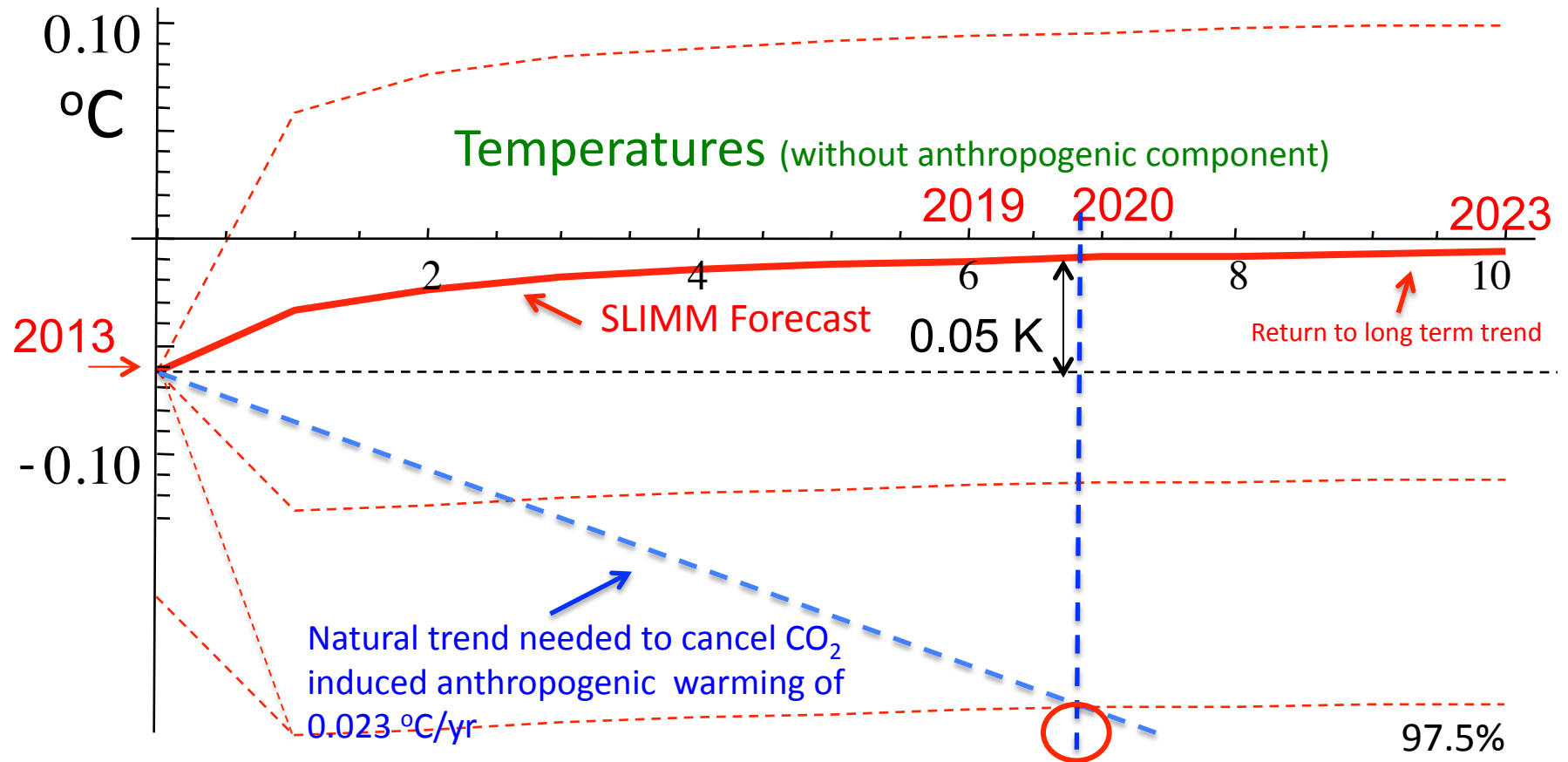


The Future

The next 10 years, Global: 2014-2023

Question: "How long must the pause continue before you admit that the warming is over?" – climate skeptic

Answer: About 6 years...



Current Anthropogenic increase:

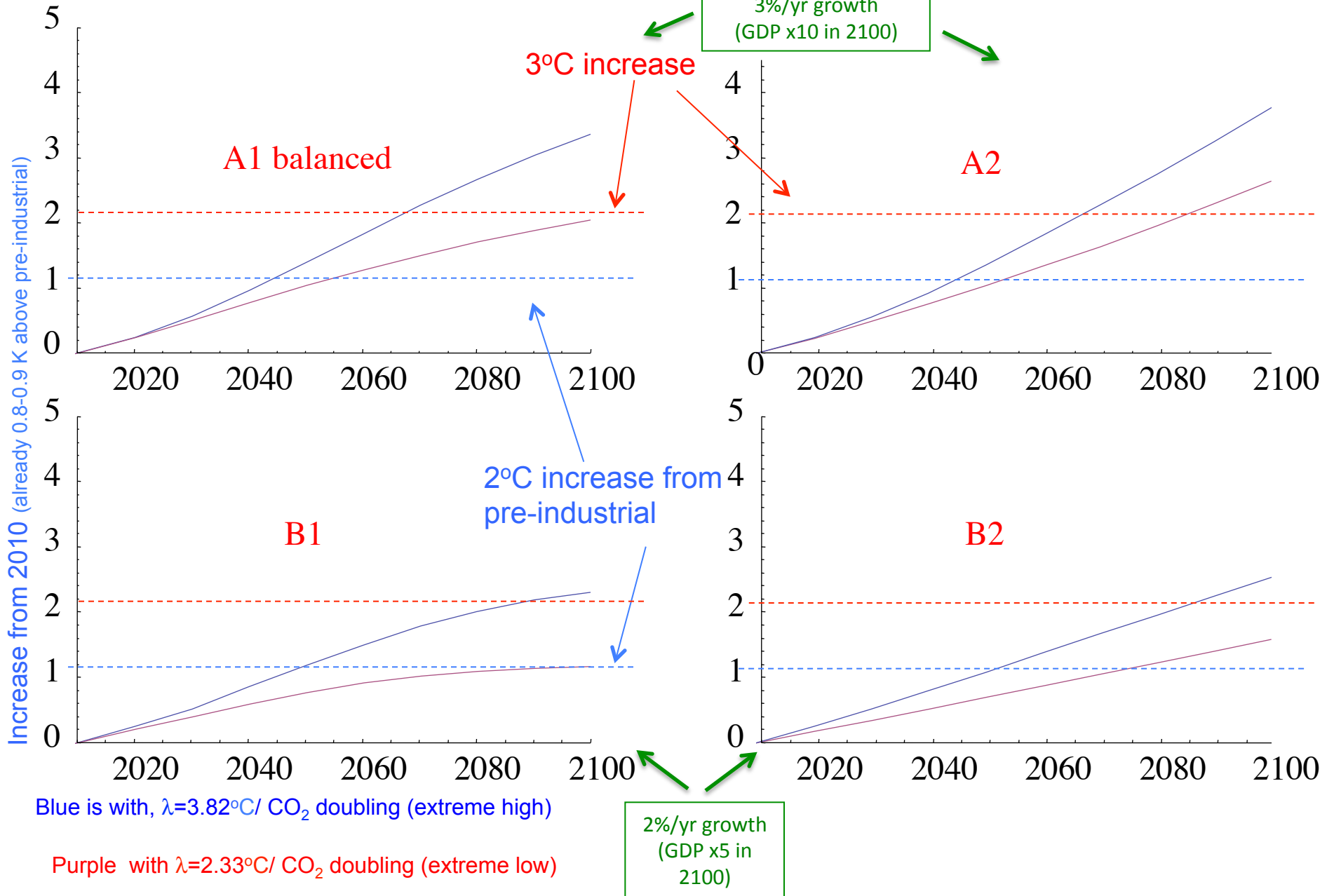
$$\frac{d \log_2 CO_2}{dt} \approx 0.010 / yr$$

$$\frac{dT}{dt} \approx 0.023 / yr$$

Forecast for 2023: $+0.05 \pm 0.10^\circ\text{C}$ (natural) $+0.23 \pm 0.02^\circ\text{C}$ (anthropogenic) $= 0.28 \pm 0.11^\circ\text{C}$ above 2013

Future Projections

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



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.

The skeptics reaction (2)

Hours after the press release went public...

“A mephitic ectoplasmic emanation of the forces of darkness”

-Viscount Lord Christopher Monckton of Brenchley evaluating this work



A mephitic
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.

What is to be done?

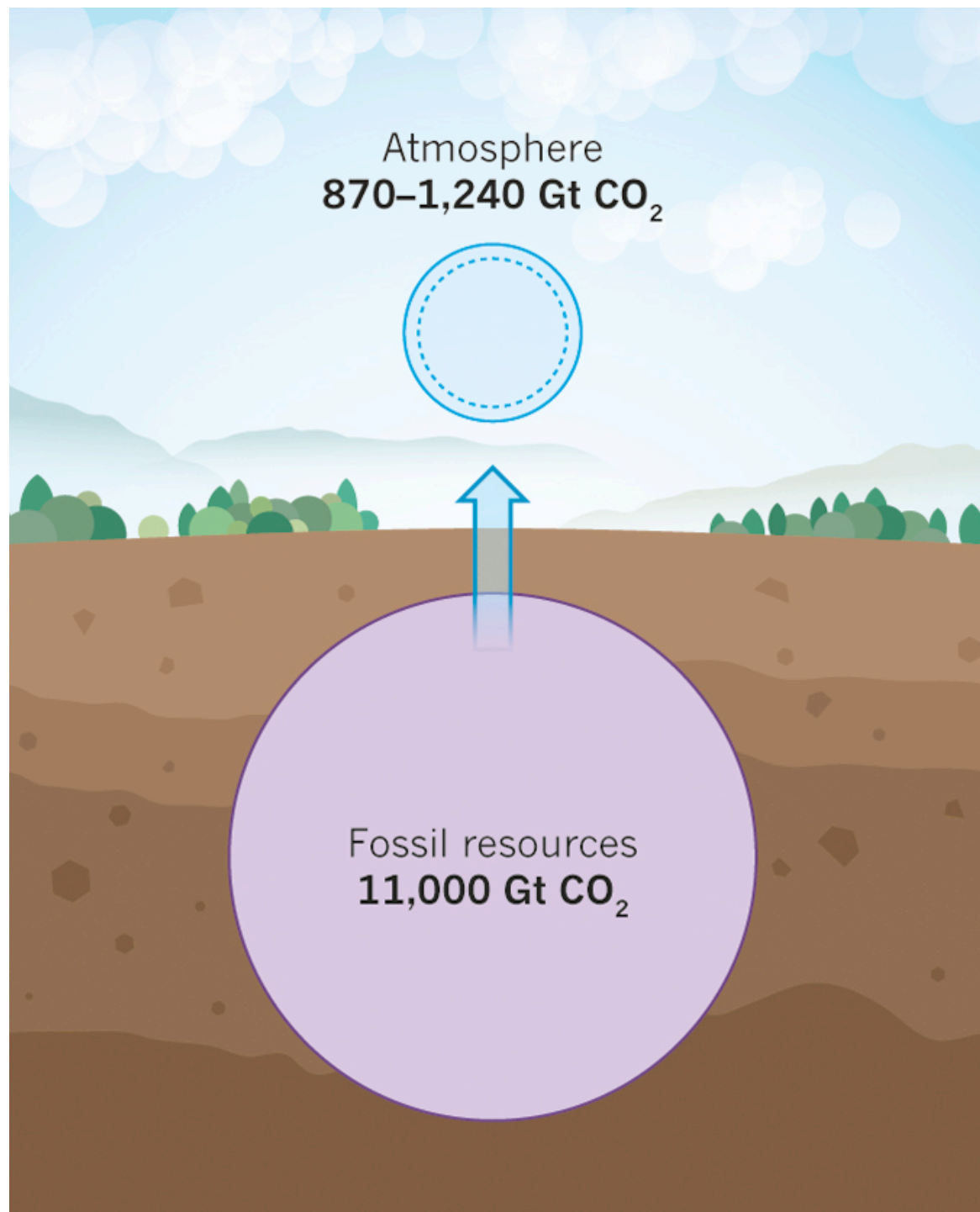
Fossil-free week

How much can we burn without roasting?

The basis of the
campaign to Divest
from fossil fuels

Proven reserves of fossil fuels
are over 3 times the amount
that can be burned while
maintaining the temperature
to within 2° of pre-industrial
levels

Jakob & Hilaire 2015



The challenge: Decarbonize the economy

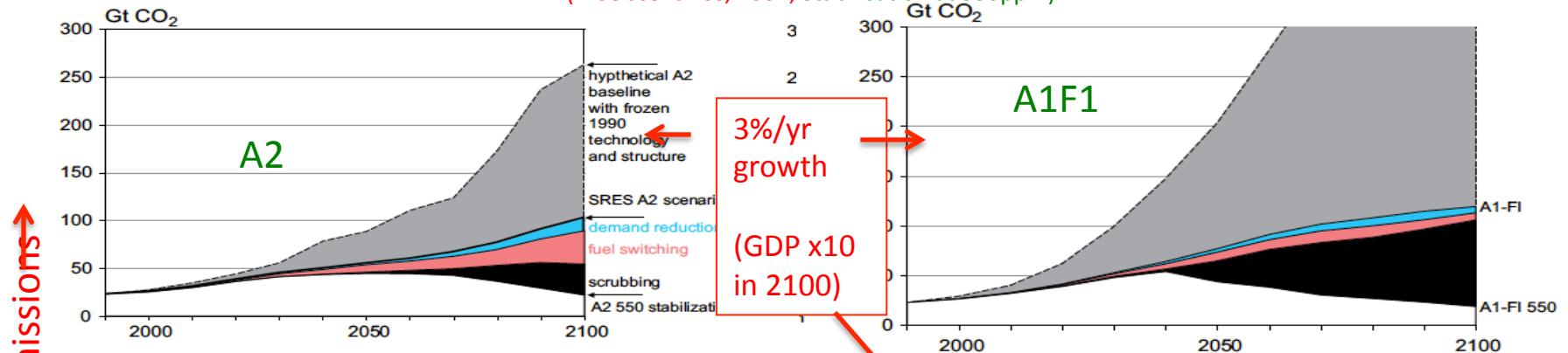
Can we break the link between economic growth
and CO₂ emissions?

Economists' magical thinking

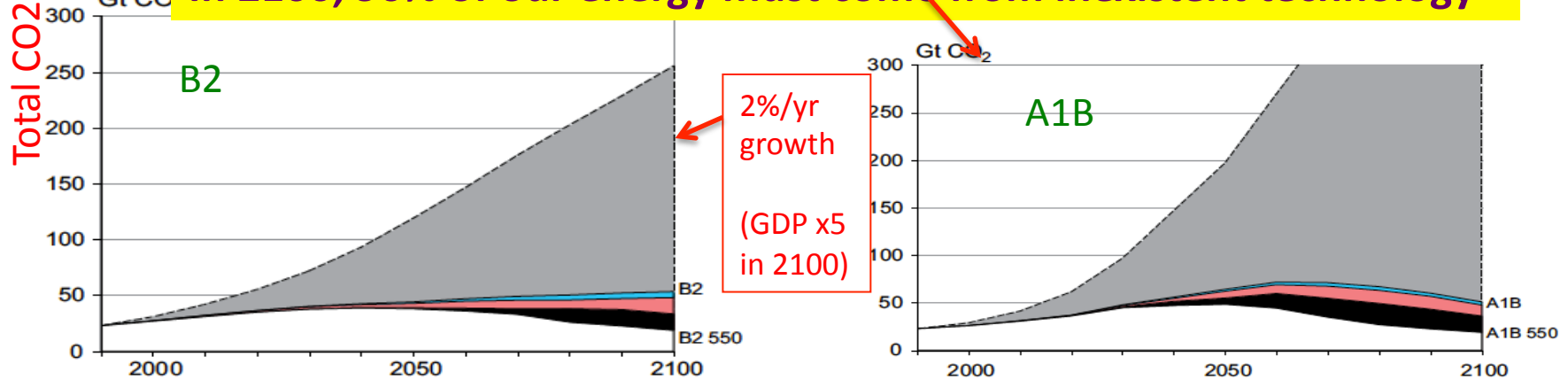
No physical limits: if the price is right then technology can be conjured up to solve any problem...

The role of existent and new technologies

(IPCC scenarios, 2007; Stabilisation at 550ppm)



In 2100, 90% of our energy must come from inexistant technology



Grey = inexistant technology

NEW!

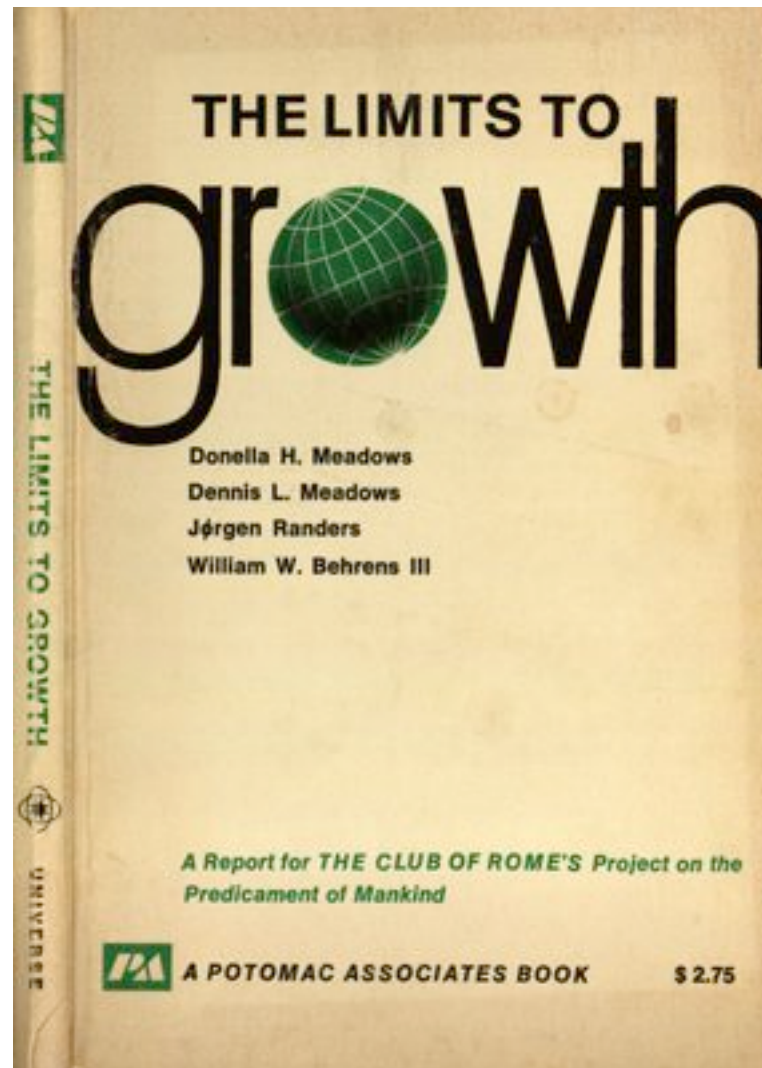
IPCC 2014 (working group 3 on mitigation and adaptation)

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

According to the 1972 “Business as Usual” projection, the last 40 years have tracked well and collapse will start around 2015 (G. Turner, 2014)

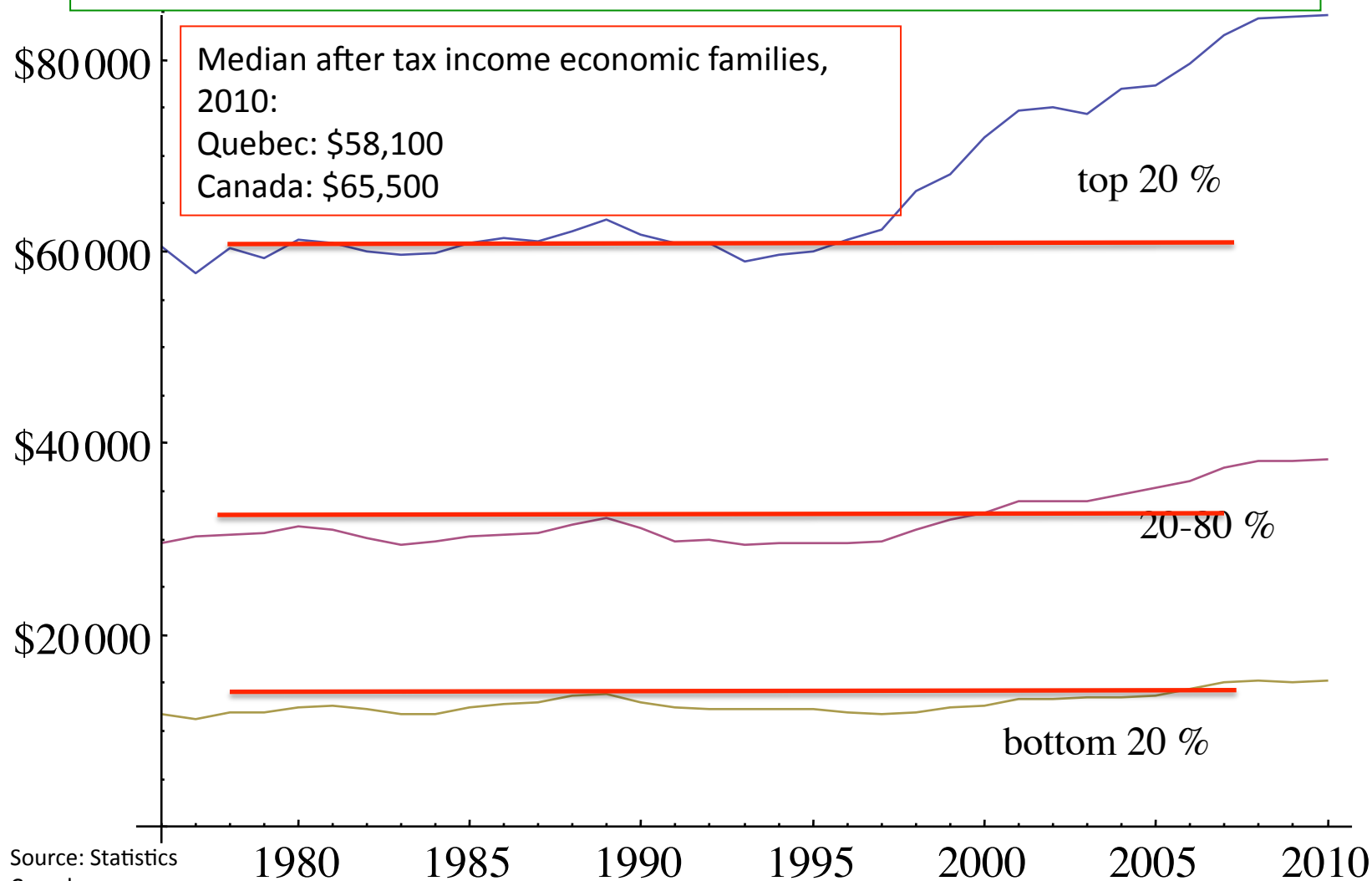


Note: The **nonlinear** model is completely based on physical (not financial inputs and outputs).

1972

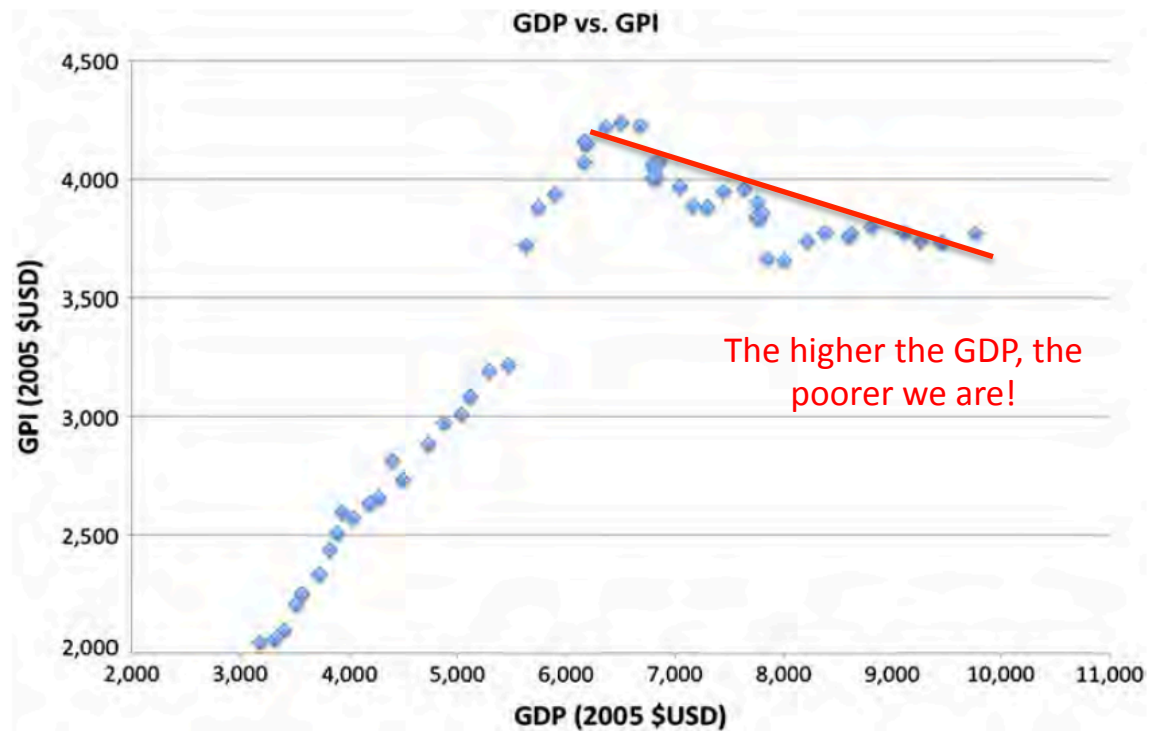
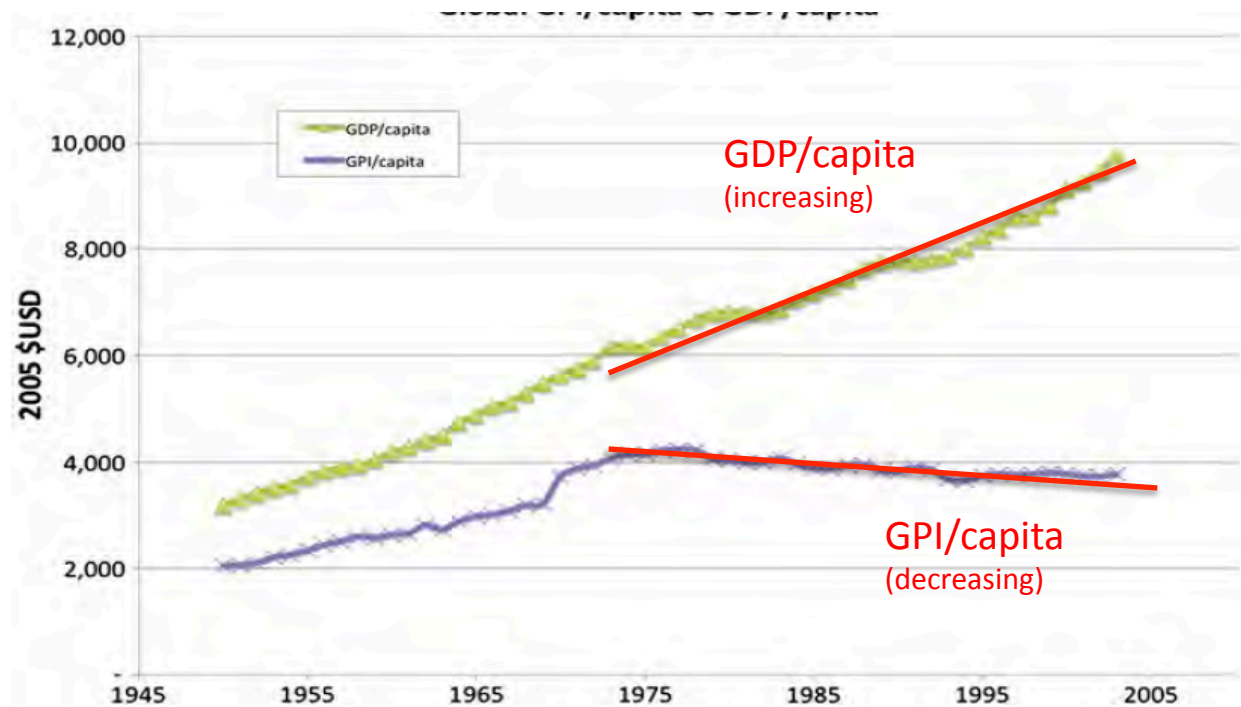
Is continued quantitative growth *desirable*?

After - tax income, by family unit, Canada, 1976 – 2010
(2010 constant dollars, economic families)



GDP versus GPI

GDP=Gross Domestic Product
GPI=Genuine Progress Indicator



What is to be done?

- Global Warming is a global problem requiring global scale cooperation.
- Saving the climate is incompatible with the current triumph of the “free” market.

What is to be done?

**DIVEST
McGILL**



**NAOMI
KLEIN**
THIS CHANGES
EVERYTHING
CAPITALISM vs
THE CLIMATE

McGill: divest
from fossil fuels

Alienar combustiveis fósseis

**COULE
PAS
CHEZ
NOUS**

“L'AVENIR N'EST PAS
DANS LES PIPELINES!”

COULE PAS CHEZ NOUS!
EST UNE CAMPAGNE DE SENSIBILISATION
CITOYENNE QUI DIFFUSE DE L'INFORMATION
AFIN DE MIEUX COMPRENDRE L'ENJEU
PÉTROLIER ET POURQUOI NOUS DEVONS DIRE
NON AU TRANSPORT DE PÉTROLE SUR NOTRE
TERRITOIRE

AGISSONS ENSEMBLE MAINTENANT!!

★★ DÉFILEZ JUSQU'EN BAS POUR NE
RIEN MANQUER! ↓

Quebec: block the tar sands pipelines!

Montreal:
countering the
“Friends of
Science”

Ce que la science dit VRAIMENT:
Le climat change. À cause de nous.

ACS Association des
communicateurs scientifiques
du Québec acs.qc.ca

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) than to prove one (anthropogenic warming).
3. The total anthropogenic warming since 1880 is about 1°C, for CO₂ doubling, 3.08±0.58°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 of warming.
7. Decarbonizing unlikely with continued global economic growth (“magical thinking”).
8. For most of us, continued economic growth is undesirable (lower GPI).