

# Reconsidering the Climate Change Act

Global Warming: How to approach the science.

(Climate Models and the Evidence?)

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I wish to thank the Campaign to Repeal the Climate Change Act for the opportunity to present my views on the issue of climate change – or as it was once referred to: global warming. Stated briefly, I will simply try to clarify what the debate over climate change is really about. It most certainly is not about whether climate is changing: it always is. It is not about whether CO<sub>2</sub> is increasing: it clearly is. It is not about whether the increase in CO<sub>2</sub>, by itself, will lead to some warming: it should. The debate is simply over the matter of how much warming the increase in CO<sub>2</sub> can lead to, and the connection of such warming to the innumerable claimed catastrophes. The evidence is that the increase in CO<sub>2</sub> will lead to very little warming, and that the connection of this minimal warming (or even significant warming) to the purported catastrophes is also minimal. The arguments on which the catastrophic claims are made are extremely weak – and commonly acknowledged as such. They are sometimes overtly dishonest.

Here are two statements that are completely agreed on by the IPCC. It is crucial to be aware of their implications.

1. A doubling of CO<sub>2</sub>, by itself, contributes only about 1C to greenhouse warming. All models project more warming, because, within models, there are positive feedbacks from water vapor and clouds, and these feedbacks are considered by the IPCC to be uncertain.

2. If one assumes all warming over the past century is due to anthropogenic greenhouse forcing, then the derived sensitivity of the climate to a doubling of CO<sub>2</sub> is less than 1C. The higher sensitivity of existing models is made consistent with observed warming by invoking unknown additional negative forcings from aerosols and solar variability as arbitrary adjustments.

Given the above, the notion that ***alarming*** warming is 'settled science' should be offensive to any sentient individual, though to be sure, the above is hardly emphasized by the IPCC.

Carbon Dioxide has been increasing

There is a greenhouse effect

There has been a doubling of equivalent CO<sub>2</sub> over the past 150 years

There has very probably been about 0.8 C warming in the past 150 years

Increasing CO<sub>2</sub> alone should cause some warming (about 1C for each doubling)

Nothing on the left is controversial among serious climate scientists.

Nothing on the left implies alarm. Indeed the actual warming is consistent with less than 1C warming for a doubling.

Unfortunately, denial of the facts on the left, has made the public presentation of the science by those promoting alarm much easier. They merely have to defend the trivially true points on the left; declare that it is only a matter of well-known physics; and relegate the real basis for alarm to a peripheral footnote – even as they slyly acknowledge that this basis is subject to great uncertainty. We will soon see examples of this by the American Physical Society and by Martin Rees and Ralph Cicerone.

The usual rationale for alarm comes from models. The notion that models are our only tool, even, if it were true, depends on models being objective and not arbitrarily adjusted (unfortunately unwarranted assumptions).

However, models are hardly our only tool, though they are sometimes useful. Models can show why they get the results they get. The reasons involve physical processes that can be independently assessed by both observations and basic theory. This has, in fact, been done, and the results suggest that all models are exaggerating warming.

The details of some such studies will be shown later.

Quite apart from the science itself, there are numerous reasons why an intelligent observer should be suspicious of the presentation of alarm.

1. The claim of 'incontrovertibility.' Science is never incontrovertible.
2. Arguing from 'authority' in lieu of scientific reasoning and data or even elementary logic.
3. Use of term 'global warming' without either definition or quantification.
4. Identification of complex phenomena with multiple causes with global warming and even as 'proof' of global warming.
5. Conflation of existence of climate change with anthropogenic climate change.

## Some Salient Points:

1. Virtually by definition, nothing in science is 'incontrovertible' – especially in a primitive and complex field as climate. 'Incontrovertibility' belongs to religion where it is referred to as dogma.

2. As noted, the value of 'authority' in a primitive and politicized field like climate is of dubious value – it is essential to deal with the science itself. This may present less challenge to the layman than is commonly supposed. Consider the following example:

This letter appeared in Spring of 2010 in *Science*. It was signed by 250 members of the National Academy of Science. Most signers had no background whatever in climate sciences. Many were the ‘usual suspects.’ (ie, Paul Ehrlich, the late Steve Schneider, George Woodwell, Don Kennedy, John Schellnhuber, ...) but a few were indeed active contributors.

## LETTERS

edited by Jennifer Sills

### Climate Change and the Integrity of Science

WE ARE DEEPLY DISTURBED BY THE RECENT ESCALATION OF POLITICAL ASSAULTS ON SCIENTISTS in general and on climate scientists in particular. All citizens should understand some basic scientific facts. There is always some uncertainty associated with scientific conclusions; science never absolutely proves anything. When someone says that society should wait until scientists are absolutely certain before taking any action, it is the same as saying society should never take action. For a problem as potentially catastrophic as climate change, taking no action poses a dangerous risk for our planet.

Scientific conclusions derive from an understanding of basic laws supported by laboratory experiments, observations of nature, and mathematical and computer modeling. Like all human beings, scientists make mistakes, but the scientific process is designed to find and correct them. This process is inherently adversarial—scientists build reputations and gain recognition not only for supporting conventional wisdom, but even more so for demonstrating that the scientific consensus is wrong and that there is a better explanation. That’s what Galileo, Pasteur, Darwin, and Einstein did. But when some conclusions have been thoroughly and deeply tested, ques-



tioned, and examined, they gain the status of “well-established theories” and are often spoken of as “facts.”

For instance, there is compelling scientific evidence that our planet is about 4.5 billion years old (the theory of the origin of Earth), that our universe was born from a single event about 14 billion years ago (the Big Bang theory), and that today’s organisms evolved from ones living in the past (the theory of evolution). Even as these

is nothing remotely identified in the recent events that changes the fundamental conclusions about climate change:

(i) The planet is warming due to increased concentrations of heat-trapping gases in our atmosphere. A snowy winter in Washington does not alter this fact.

(ii) Most of the increase in the concentration of these gases over the last century is due to human activities, especially the burning of fossil fuels and deforestation.

(iii) Natural causes always play a role in changing Earth’s climate, but are now being overwhelmed by human-induced changes.

(iv) Warming the planet will cause many other climatic patterns to change at speeds unprecedented in modern times, including increasing rates of sea-level rise and alterations in the hydrologic cycle. Rising concentrations of carbon dioxide are making the oceans more acidic.

(v) The combination of these complex climate changes threatens coastal communities and cities, our food and water supplies, marine and freshwater ecosystems, forests, high mountain environments, and far more.

Much more can be, and has been, said by the world’s scientific societies, national academies, and individuals, but these conclusions should be enough to indicate why scientists are concerned about what future generations will face from business-as-usual practices. We urge our policy-makers and the public to move forward immediately to address the causes of climate change, including the unrestrained burning of fossil fuels.

We also call for an end to McCarthy-like



Here are two of their assertions:

*(iii) Natural causes always play a role in changing Earth's climate, but are now being overwhelmed by human-induced changes.*

*(iv) Warming the planet will cause many other climatic patterns to change at speeds unprecedented in modern times, including increasing rates of sea-level rise and alterations in the hydrologic cycle.*

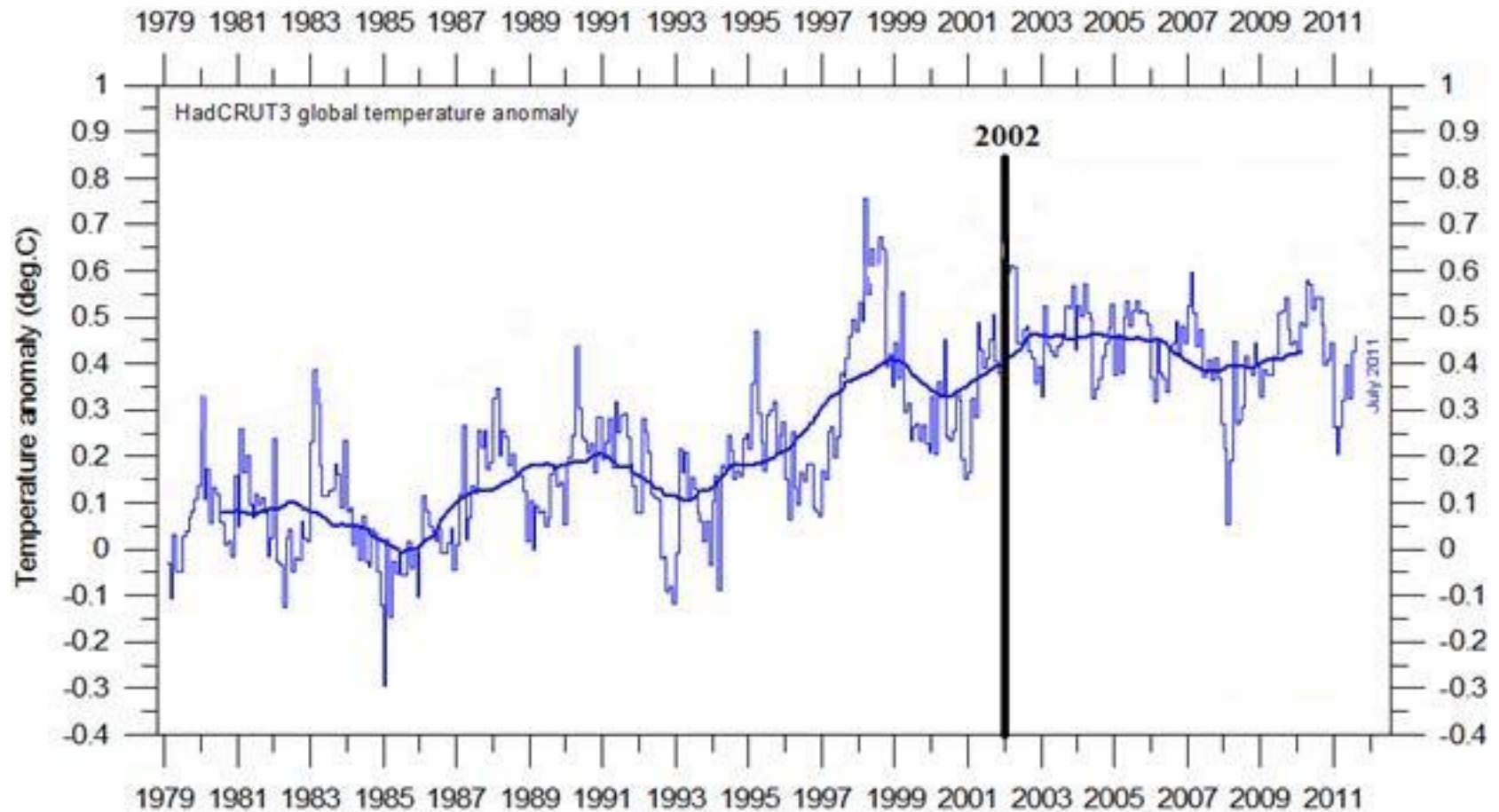
Now, one of the signers was Carl Wunsch. Here is what he says in a recent paper in *Journal of Climate* (Wunsch et al, 2007) (and repeated a couple of weeks ago in a departmental lecture):

*It remains possible that the data base is insufficient to compute mean sea level trends with the accuracy necessary to discuss the impact of global warming—as disappointing as this conclusion may be.*

In brief, when we actually go to the scientific literature we see that the 'authoritative' assertions are no more credible than the pathetic picture of the polar bear that accompanied the letter.

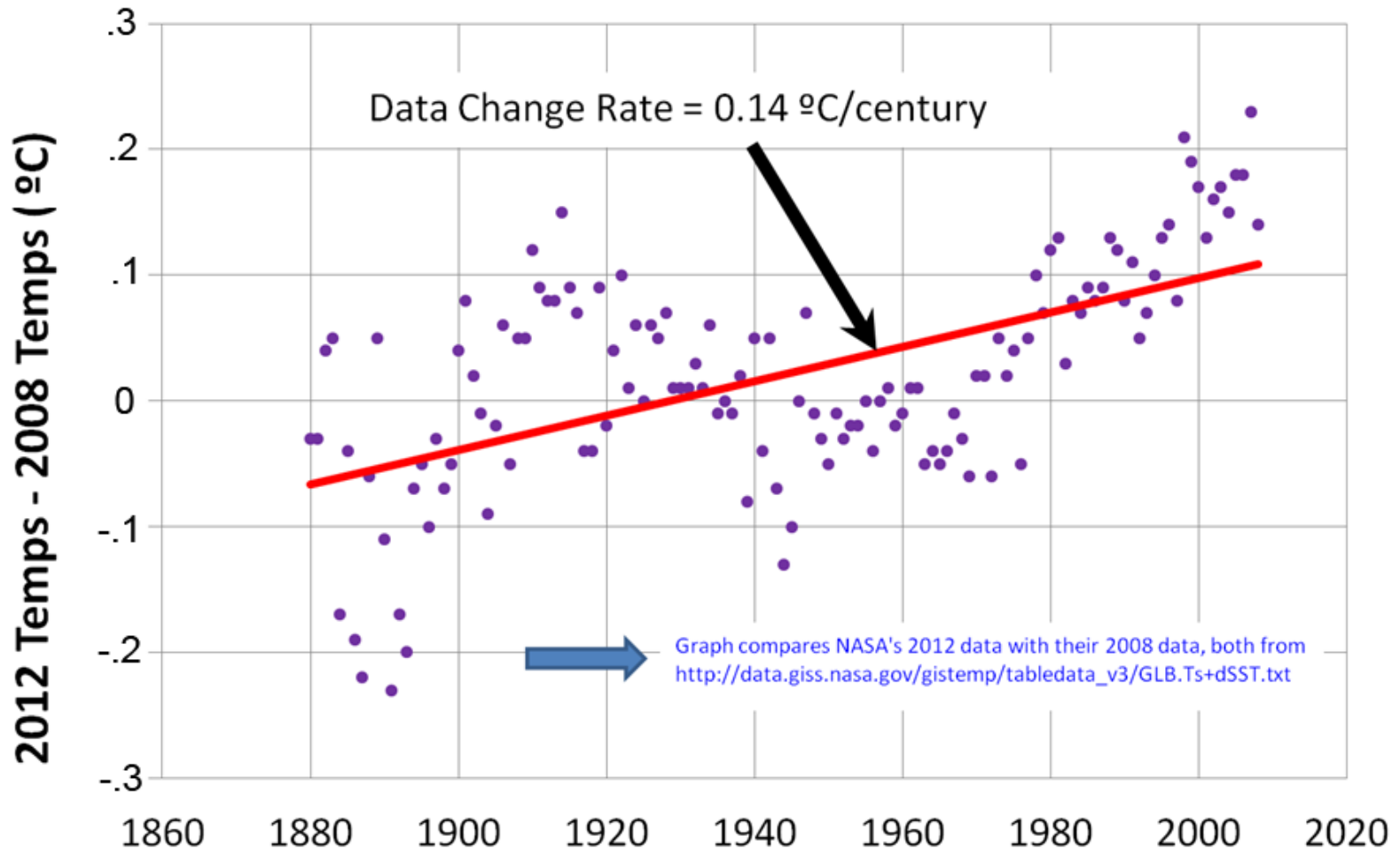
3. 'Global Warming' refers to an obscure statistical quantity, globally averaged temperature anomaly, the small residue of far larger and mostly uncorrelated local anomalies. This quantity is highly uncertain, but may be on the order of 0.7C over the past 150 years. This quantity is always varying at this level and there have been periods of both warming and cooling on virtually all time scales. On the time scale of from 1 year to 100 years, there is no need for any externally specified forcing. The climate system is never in equilibrium because, among other things, the ocean transports heat between the surface and the depths. To be sure, however, there are other sources of internal variability as well.

Because the quantity we are speaking of is so small, and the error bars are so large, the quantity is easy to abuse in a variety of ways.



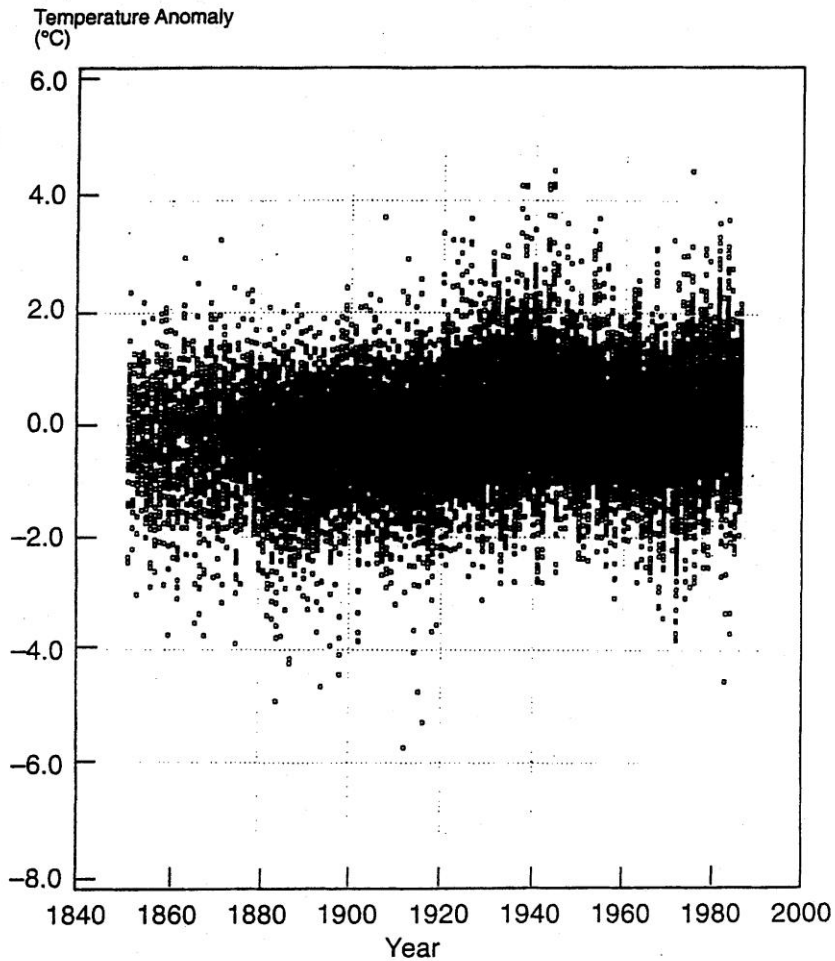
Looking at the above, one can see no warming since 1997. As Phil Jones acknowledged, there has been no statistically significant warming in 15 years. However, there are uncertainties in the above data, and small adjustments can result in negligible warming or cooling over this period. In the polarized public discourse, this leads each side to claim the other side is lying. However, Jones' statement remains correct.

# NASA-GISS Data Manipulation: Change in Historical Record 2008-2012



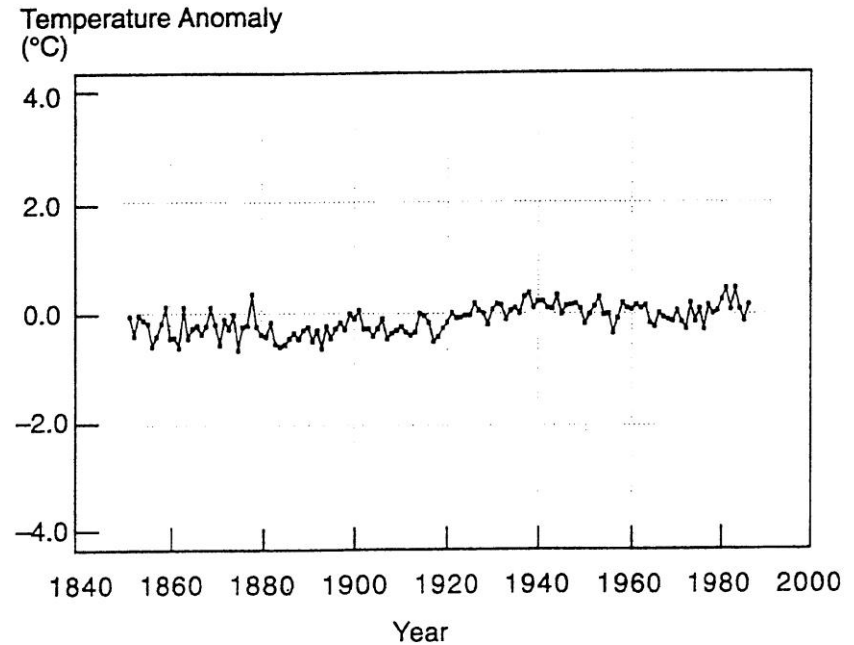
We may not be able to predict the future, but in climate 'science,' we also can't predict the past.

## Deviations of Annual Mean Temperature from Long-term Average



**1. Data points averaged to obtain time record of global mean temperature. Note points range from less than -2C to more than +2C.**

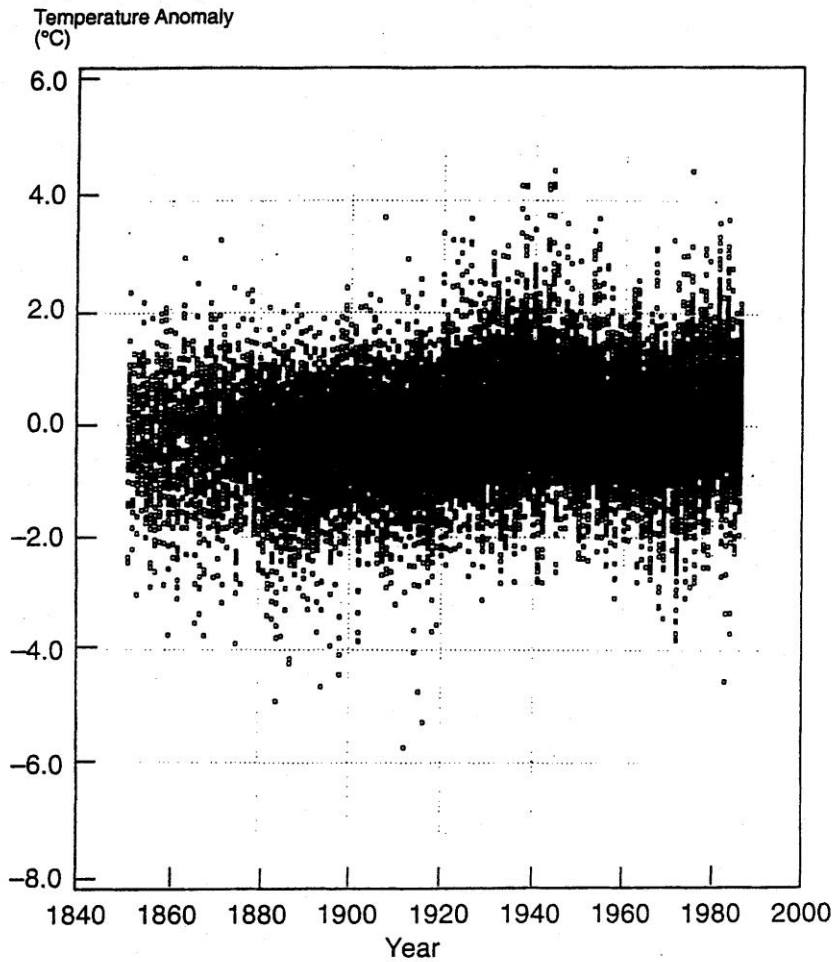
## Globally Averaged Deviations from Average Temperature Plotted on a Scale Relevant to the Individual Station Deviations



**2. Average of points in previous figure.**

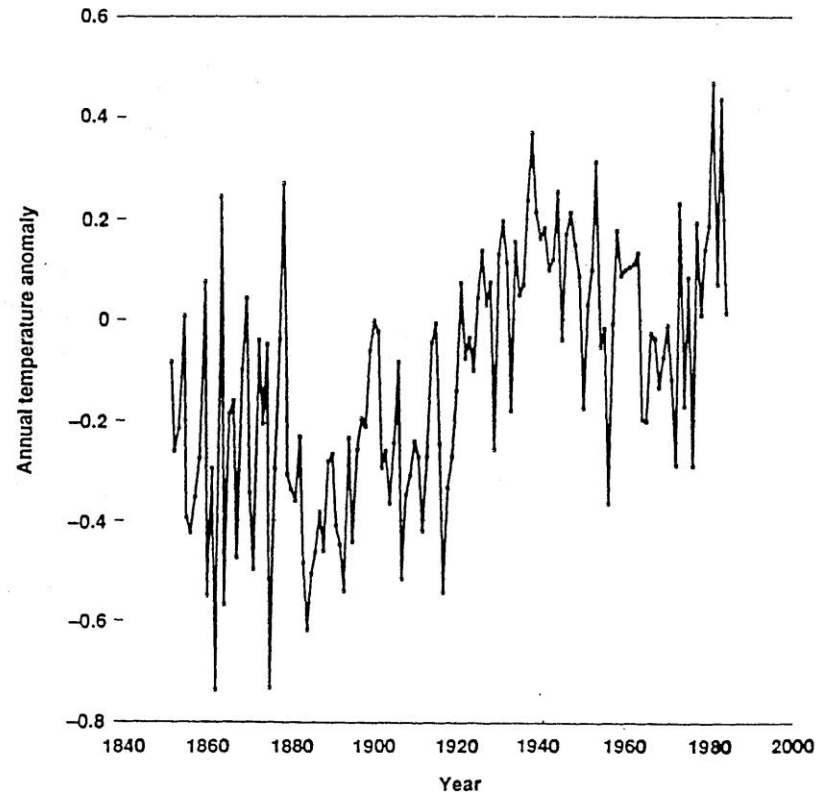
Notice the vertical scale in the above diagrams. Relative to the variability in the data, the changes in the globally averaged temperature anomaly look negligible.

## Deviations of Annual Mean Temperature from Long-term Average



**1. Data points averaged to obtain time record of global mean temperature. Note points range from less than -2C to more than +2C.**

## CRU NH Average Annual Anomalies (1851-1984)

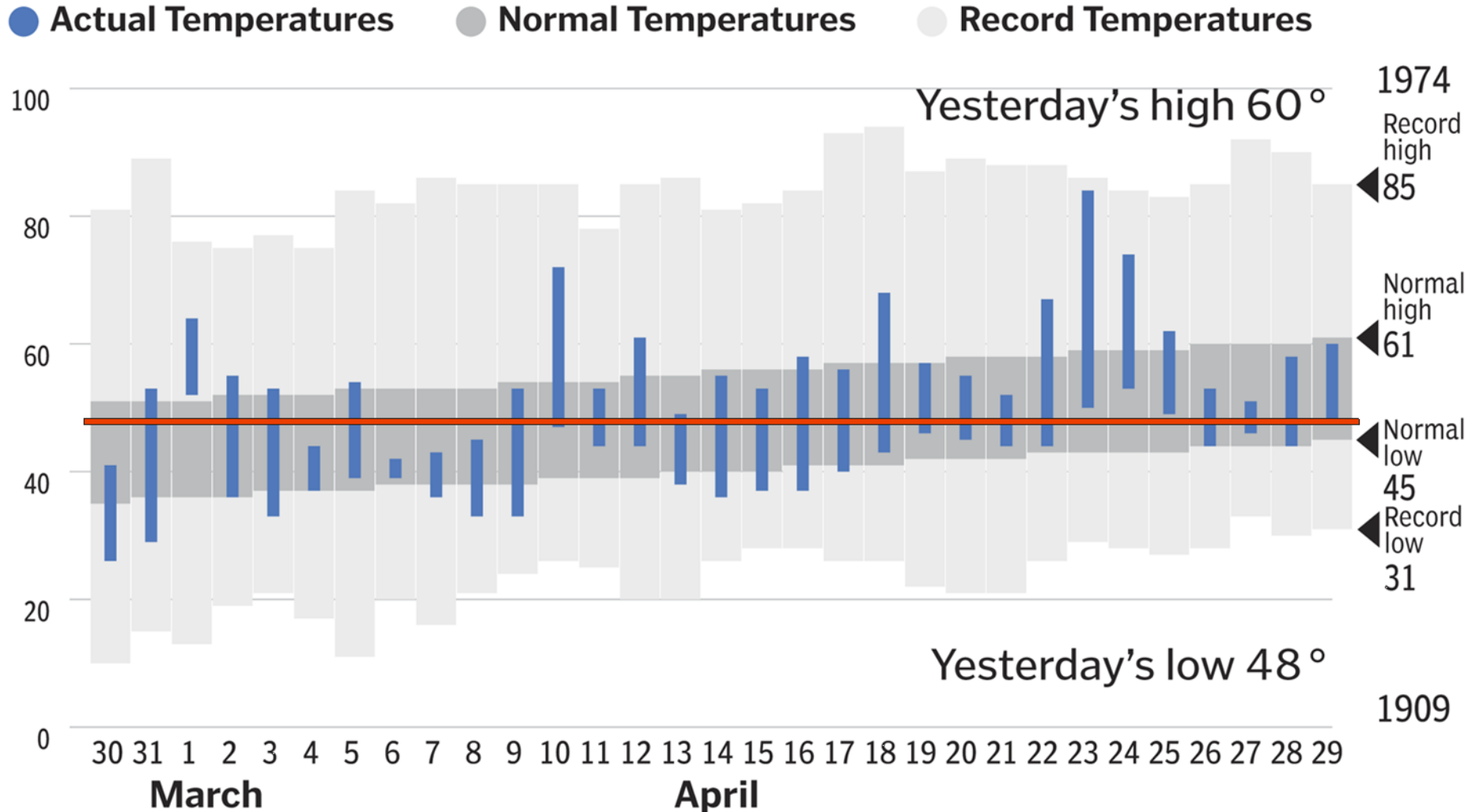


**3. Curve in previous figure stretched to fill graph. Note that range is now from about -0.6C to +0.3C.**

Source: S. L. Grotch, Lawrence Livermore Laboratory, Livermore California

The thickness of the red line represents the range of global mean temperature anomaly over the past century.

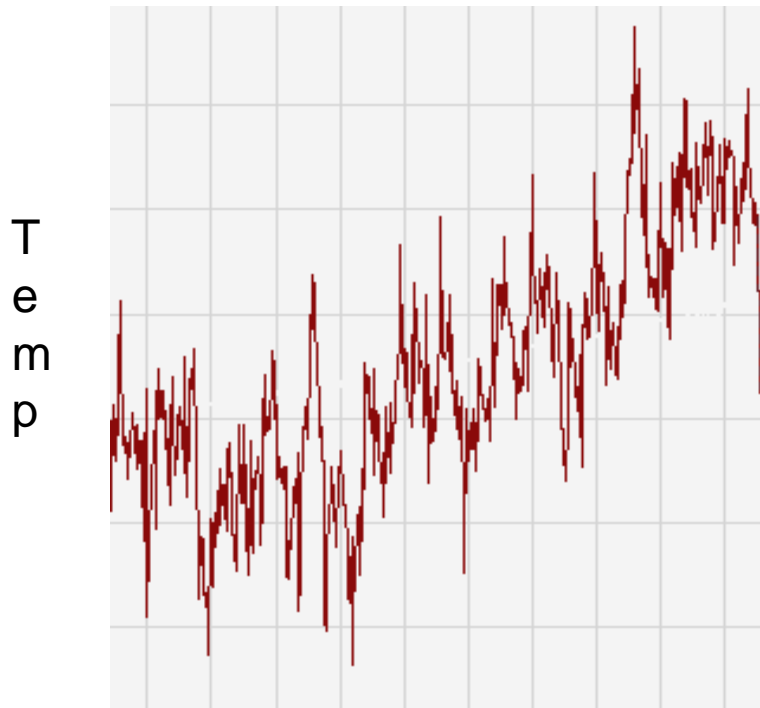
April 30, 2008



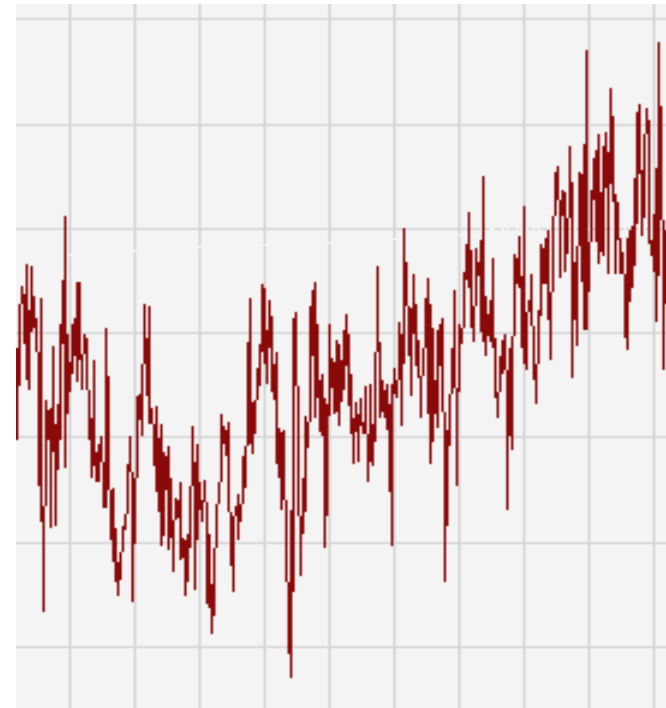
One month's record of high and low temperatures for Boston.

Just for fun: You've been told that earlier warming was natural but recent warming is due to man. Can you tell which is which?

*Global Average Temperature in Two Half Century Periods:  
Which is 1895-1946 (Nature); Which is 1957-2008 (Us?)*



Time →



Time →

*Global average temperature and time scales are identical*

Hadley CRUT3 global average temperature record



Some take away points of the global mean temperature anomaly record:

Changes are small (order of several tenths of a degree)

Changes are not causal but rather the residue of regional changes.

Changes of the order of several tenths of a degree are always present at virtually all time scales.

Obsessing on the details of this record is more akin to a spectator sport (or tea leaf reading) than a serious contributor to scientific efforts – at least so far.

**4. The claims that the earth has been warming, that there is a greenhouse effect, and that man's activities have contributed to warming, are trivially true and essentially meaningless in terms of alarm.**

Nonetheless, they are frequently trotted out as evidence for alarm. For example, here is the response of the American Physical Society to the resignation letter of the late Hal Lewis (a distinguished physicist and a fellow of the Society):

*On the matter of global climate change, APS notes that virtually all reputable scientists agree with the following observations: Carbon dioxide is increasing in the atmosphere due to human activity; Carbon dioxide is an excellent infrared absorber, and therefore, its increasing presence in the atmosphere contributes to global warming; and The dwell time of carbon dioxide in the atmosphere is hundreds of years. On these matters, APS judges the science to be quite clear.*

*The first two items refer to the trivial agreement. The last item, however, does not and is actually quite misleading on its own terms. The APS also denies financial involvement despite the fact that POPA's chair is Bob Socolow who is chair of the Carbon Mitigation Initiative, and on the advisory board of Deutsche Bank.*

Two separate but frequently conflated issues are essential for alarm:

- 1) The magnitude of warming, and
- 2) The relation of warming of any magnitude to the projected catastrophe.

When it comes to unusual climate (which always occurs some place), most claims of evidence for global warming are guilty of the 'prosecutor's fallacy.' For example this confuses the near certainty of the fact that if A shoots B, there will be evidence of gunpowder on A's hand with the assertion that if C has evidence of gunpowder on his hands then C shot B.

However, with global warming the line of argument is even sillier. It generally amounts to something like if A kicked up some dirt, leaving an indentation in the ground into which a rock fell and B tripped on this rock and bumped into C who was carrying a carton of eggs which fell and broke, then if some broken eggs were found it showed that A had kicked up some dirt. These days we go even further, and decide that the best way to prevent broken eggs is to ban dirt kicking.

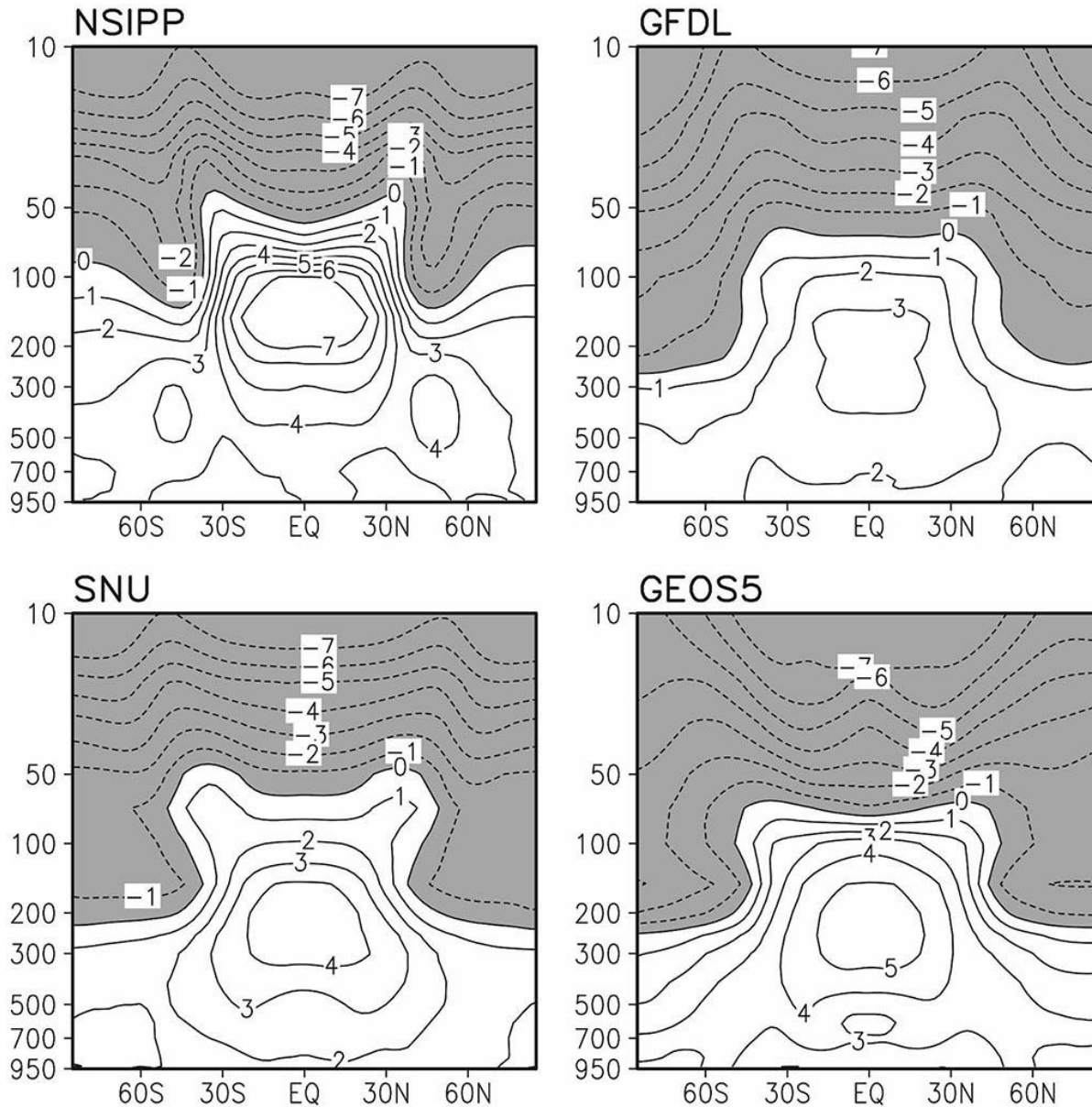
## Some current problems with science

1. **Questionable data.** (Climategate and involvement of all three centers tracking global average temperature anomaly.) This is a complicated ethical issue for several reasons. Small temperature changes are not abnormal and even claimed changes are consistent with low climate sensitivity. However, the public has been misled to believe that whether it is warming or cooling – no matter how little – is of vital importance. Tilting the record slightly is thus of little consequence to the science but of great importance to the public perception.

2. More sophisticated data is being analyzed with the aim of supporting rather than testing models (validation rather than testing). That certainly has been my experience during service with both the IPCC and the National Climate Assessment Program. It is also evident in the recent scandal concerning Himalayan glaciers.

(Note that in both cases, we are not dealing with simple measurements, but rather with huge collections of sometimes dubious measurements that are subject to often subjective analysis – sometimes referred to as ‘massaging.’)

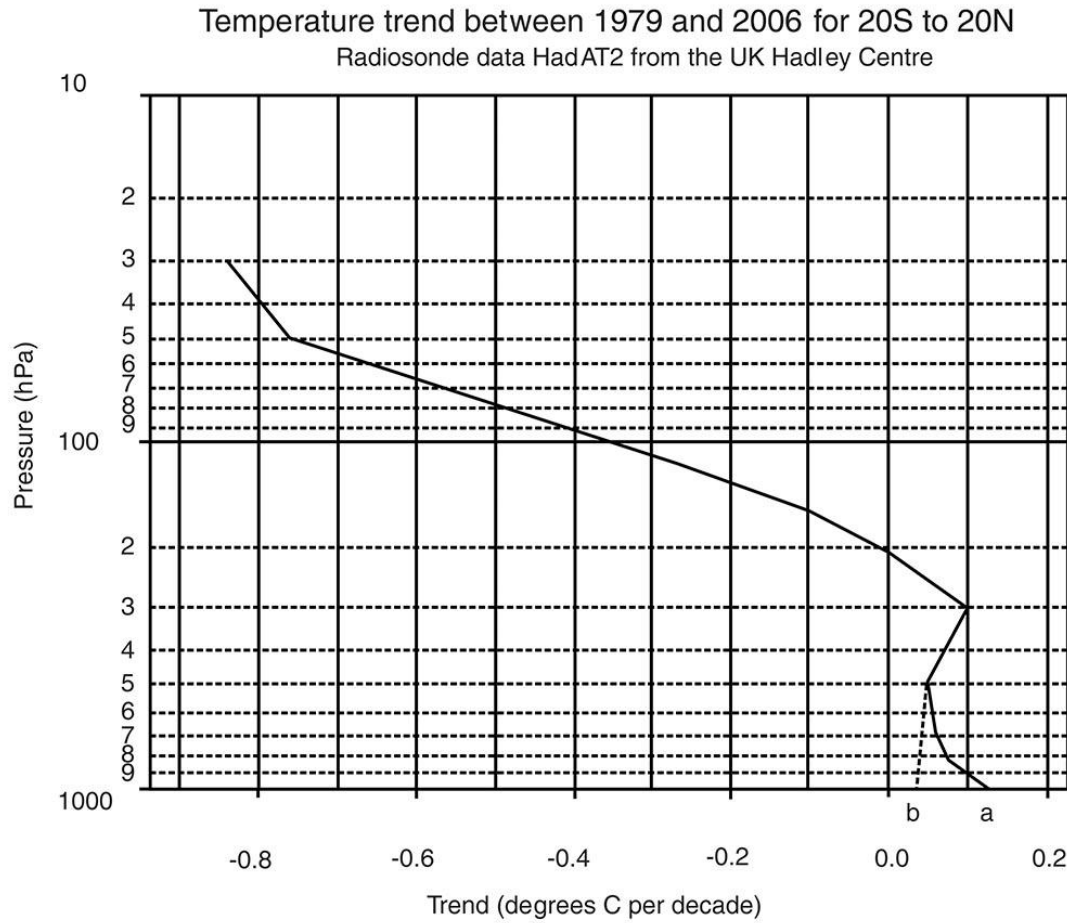
In point of fact, we know that some of the recent temperature data must be wrong!



Here we see the meridional distribution of the temperature response to a doubling of CO<sub>2</sub> from four typical models. The response is characterized by the so-called hot spot (ie, the response in the tropical upper troposphere is from 2-3 times larger than the surface response). We know that the models are correct in this respect since the hot spot is simply a consequence of the fact that tropical temperatures approximately follow what is known as the moist adiabat. This is simply a consequence of the dominant role of moist convection in the tropics.

FIG. 14. Zonal-mean distributions of temperature change ( $2 \times \text{CO}_2 - \text{Control}$ ). Units are kelvin.

However, the temperature trends obtained from observations fail to show the hot spot.



The resolution of the discrepancy demands that either the upper troposphere measurements are wrong, the surface measurements are wrong or both. If it is the surface measurements, then the surface trend must be reduced from 'a' to 'b'.

Given how small the trends are, and how large the uncertainties in the analysis, such errors are hardly out of the question.

Figure 5: Temperature trend as a function of pressure level for period 1979–2006 in the tropics (20S-20N) based on balloon data analyzed by the Hadley Centre.

3. Sensitivity is a crucial issue. This refers to how much warming one expects from a given change in CO<sub>2</sub> (usually a doubling). It cannot be determined by assuming that one knows the cause of change. If the cause is not what one assumes, it yields infinite sensitivity. This problem infects most attempts to infer climate sensitivity from paleoclimate data.

4. Models cannot be tested by comparing models with models. Attribution cannot be based on the ability or lack thereof of faulty models to simulate a small portion of the record. Models are simply not basic physics.

All the above and more are, nonetheless, central to the IPCC reports that supposedly are 'authoritative' and have been endorsed by National Academies and numerous professional societies.



## What's happening to the climate is unprecedented

Print

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*From Prof Martin Rees and Dr Ralph J. Cicerone.*

Sir, We were stimulated by your editorial "[Cooler on warming](#)" (April 5). There has undoubtedly been a shift in public and media perceptions of climate change – a consequence of, at least in part, leaked e-mails from some climate scientists and the publication of errors in the fourth Intergovernmental Panel on Climate Change report.

However, as your editorial acknowledges, neither recent controversies, nor the recent cold weather, negate the consensus among scientists: something unprecedented is now happening. The concentration of carbon dioxide in the atmosphere is rising and climate change is occurring, both due to human actions. If we continue to depend heavily on fossil fuels, by mid-century CO<sub>2</sub> concentrations will reach double pre-industrial levels. Straightforward physics tells us that this rise is warming the planet. Calculations demonstrate that this effect is very likely responsible for the gradual warming observed over the past 30 years and that global temperatures will continue to rise – superimposing a warming on all the other effects that make climate fluctuate. Uncertainties in the future rate of this rise, stemming largely from the "feedback" effects on water vapour and clouds, are topics of current research.

It is the responsibility of scientific organisations like ours to present the public and politicians with a balanced assessment of the evidence – and, importantly, to indicate the level of confidence and the range of uncertainties attached to them.

Our two science academies have long contributed critical, objective and open reports on climate change. We intend to draw upon the efforts of leading scientists everywhere to make our future reports more accessible and valuable and, by fostering scientific research, we hope to do a better job of reducing inherent uncertainties. We must also promote best scientific practice, especially with regard to the sharing of data. But policymakers and the public must realise that, even if scientific uncertainties could be reduced to zero, formulating effective political responses would still be controversial and challenging. Our academies will provide the scientific backdrop for the political and business leaders who must create effective policies to steer the world toward a low-carbon economy.

**Martin Rees,**  
President of the Royal Society

**Ralph J Cicerone,**  
President of the US National Academy of Sciences

Here is a recent letter signed by the presidents of both the Royal Society and the National Academy of Science.

It tells us a great deal about the current state of science, and the exploitation of authority.

Let us focus on three sentences in this letter.

*1. However, as your editorial acknowledges, neither recent controversies, nor the recent cold weather, negate the consensus among scientists: something unprecedented is now happening. The concentration of carbon dioxide in the atmosphere is rising and climate change is occurring, both due to human actions.*

Note that this statement seems to go well beyond the IPCC statement that claimed that only more than half the temperature change over the preceding 50 years could be attributed to man's emissions – with aerosols included in order to cancel much of the excess warming the models produce.

Moreover, the assumptions underlying this claim have been shown to be false (namely that all other possible causes had been adequately accounted for).

Of course, one could carefully parse the sentence. Perhaps they meant that there was increasing CO<sub>2</sub> due to man, and that there was warming due to this though it might only be a small part of the already small observed warming. If this is what they meant, then the statement is trivial and suggests no basis for alarm. However, there is no doubt that this is not what they intended the reader to infer.

*2. Uncertainties in the future rate of this rise, stemming largely from the “feedback” effects on water vapour and clouds, are topics of current research.*

Who would guess from this throw away comment, that feedbacks are the critical issue? Without strong positive feedbacks there would be no cause for alarm, and no need for action. What Rees and Cicerone are actually saying is that we don't know if there is a problem.

*3. Our academies will provide the scientific backdrop for the political and business leaders who must create effective policies to steer the world toward a low-carbon economy.*

Rees and Cicerone are saying that regardless of the evidence the answer is predetermined. If the government wants carbon control, that is the answer that the Academies will provide. Nothing could better epitomize the notion of science in the service of politics – something that, unfortunately, has characterized so-called climate science.

Where do we go from here?

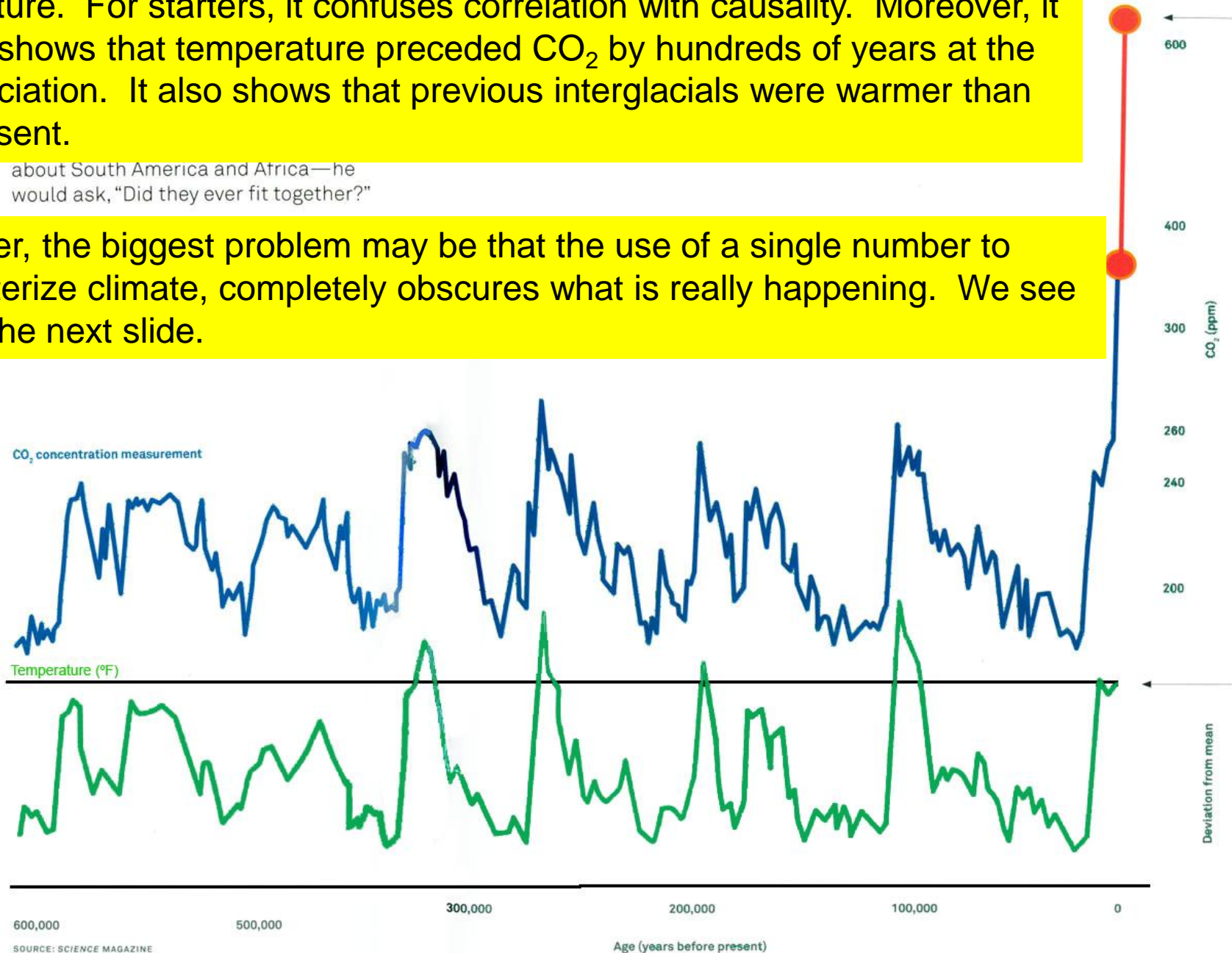
Given that this has become a quasi-religious issue, it is hard to tell. However, my personal hope is that we will return to normative science, and try to understand how the climate actually behaves. Our present approach of dealing with climate as completely specified by a single number, globally averaged surface temperature anomaly, that is forced by another single number, atmospheric CO<sub>2</sub> levels, for example, clearly limits real understanding; so does the replacement of theory by model simulation. In point of fact, there has been progress along these lines and none of it demonstrates a prominent role for CO<sub>2</sub>. It has been possible to account for the cycle of ice ages simply with orbital variations (as was thought to be the case before global warming mania); tests of sensitivity independent of the assumption that warming is due to CO<sub>2</sub> (a circular assumption) show sensitivities lower than models show; the resolution of the early faint sun paradox which could not be resolved by greenhouse gases, is readily resolved by clouds acting as negative feedbacks.

So far we have approached the science in a somewhat peripheral way. In the remainder of this talk, we will deal with the science more directly.

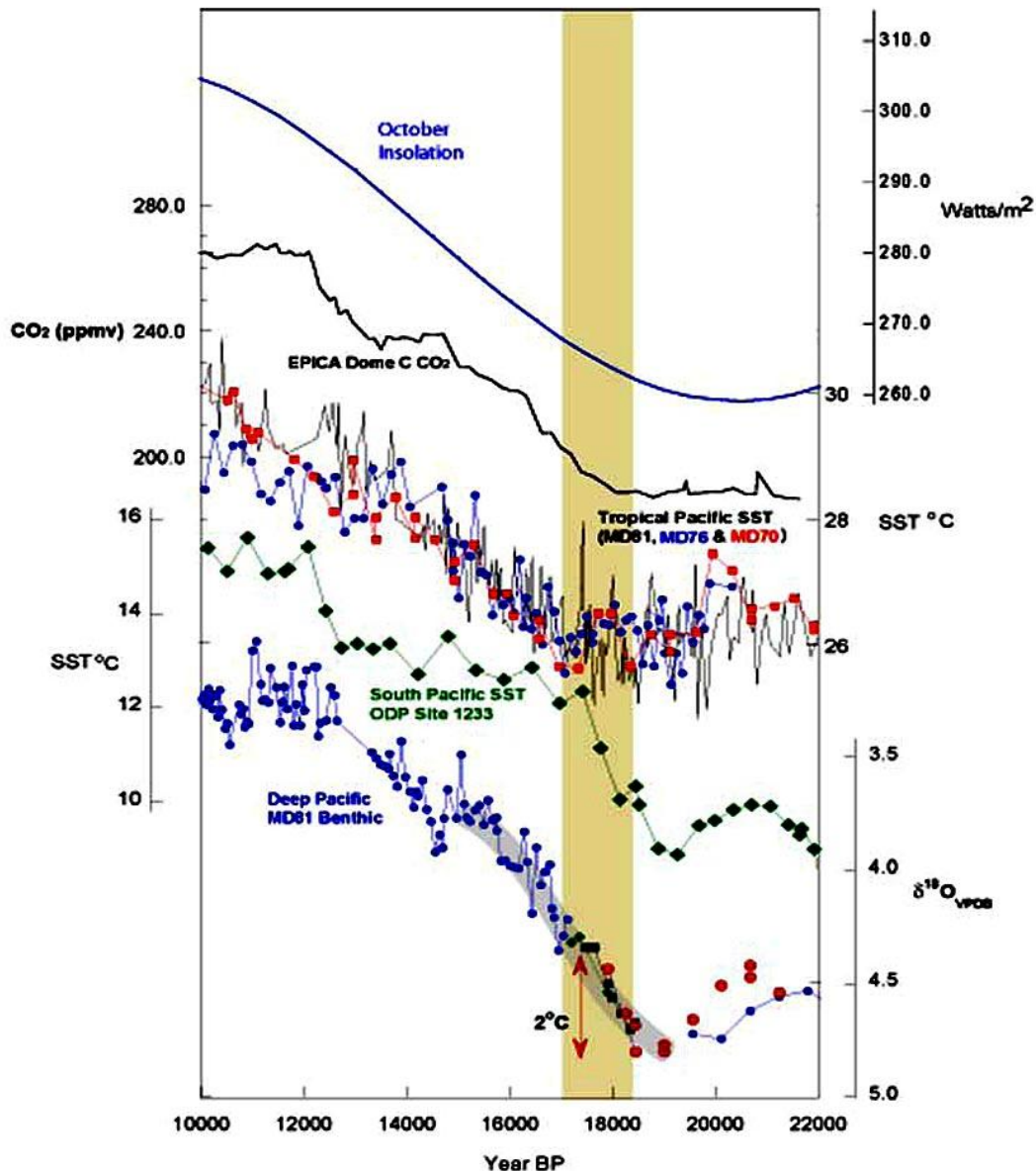
Here is a graphic made famous by Al Gore. There are lots of problems with this picture. For starters, it confuses correlation with causality. Moreover, it clearly shows that temperature preceded CO<sub>2</sub> by hundreds of years at the last glaciation. It also shows that previous interglacials were warmer than the present.

about South America and Africa—he would ask, “Did they ever fit together?”

However, the biggest problem may be that the use of a single number to characterize climate, completely obscures what is really happening. We see this in the next slide.



Here is we see why it is often useless to consider merely global mean temperature anomaly and CO<sub>2</sub>.



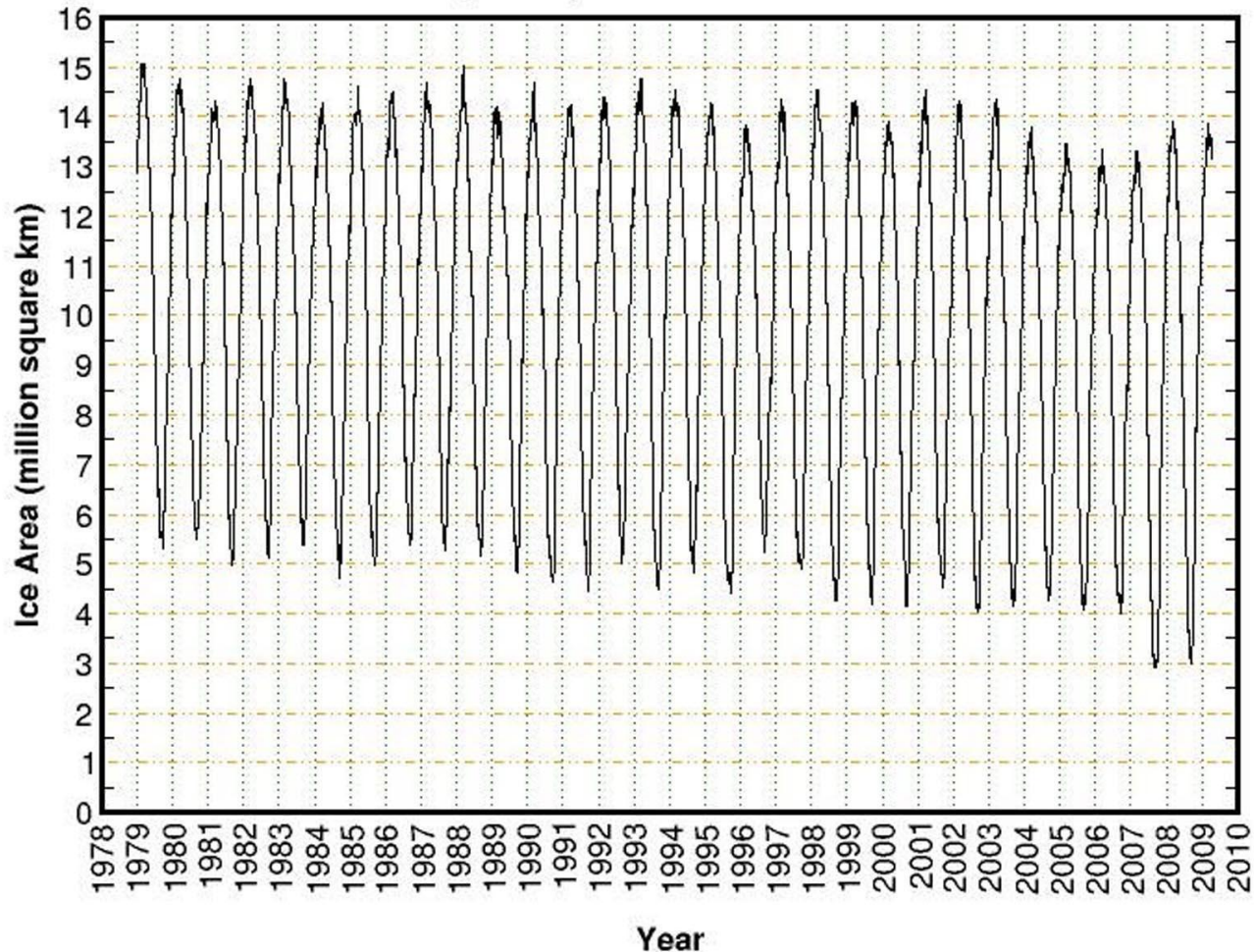
According to Stott et al, warming first occurred in the South Pacific in the region of formation of Upper Circumpolar Deep Water between 19,000BP and 17,000 BP. It was not until about 17,000 BP that the tropical surface water began to warm and the CO<sub>2</sub> concentration also began to rise at this time. It was not until 15,000BP that the Greenland region began to warm. With such a sequence it is apparent that the interglacial warming was initiated in the waters of the Southern Ocean and took nearly 4,000 years to be reflected in Greenland changes; also, the CO<sub>2</sub> variations would seem to be tied to tropical ocean temperature changes.

**Here is a simple example of how current approaches inhibit progress.**

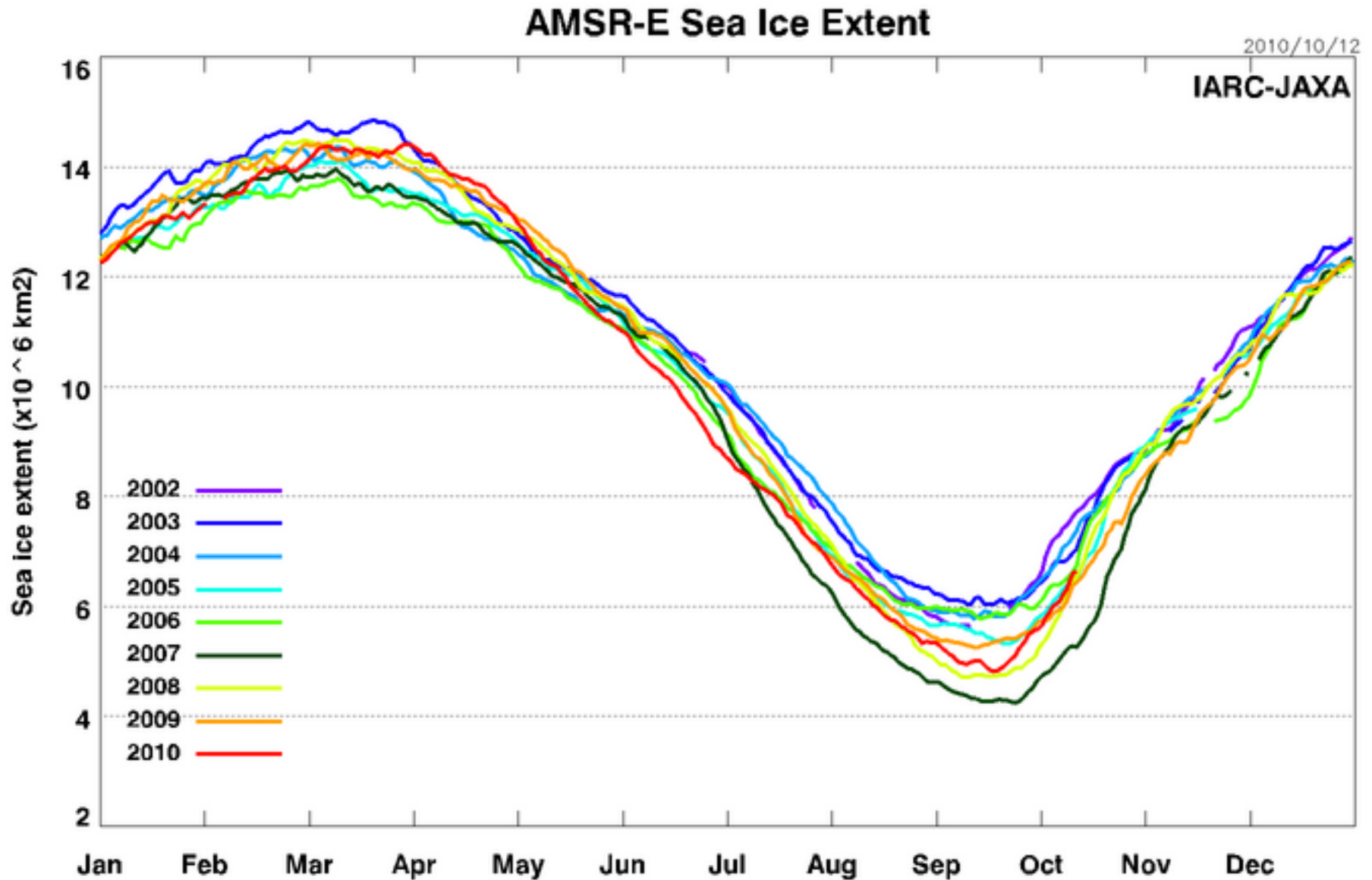
You have all heard about the arctic sea ice disappearing. Here is what is being spoken of.

## Northern Hemisphere Sea Ice Area

*Data provided by NSIDC: NASA SMMR and SSMI*



The latest value : 6,599,688 km<sup>2</sup> (October 11, 2010)

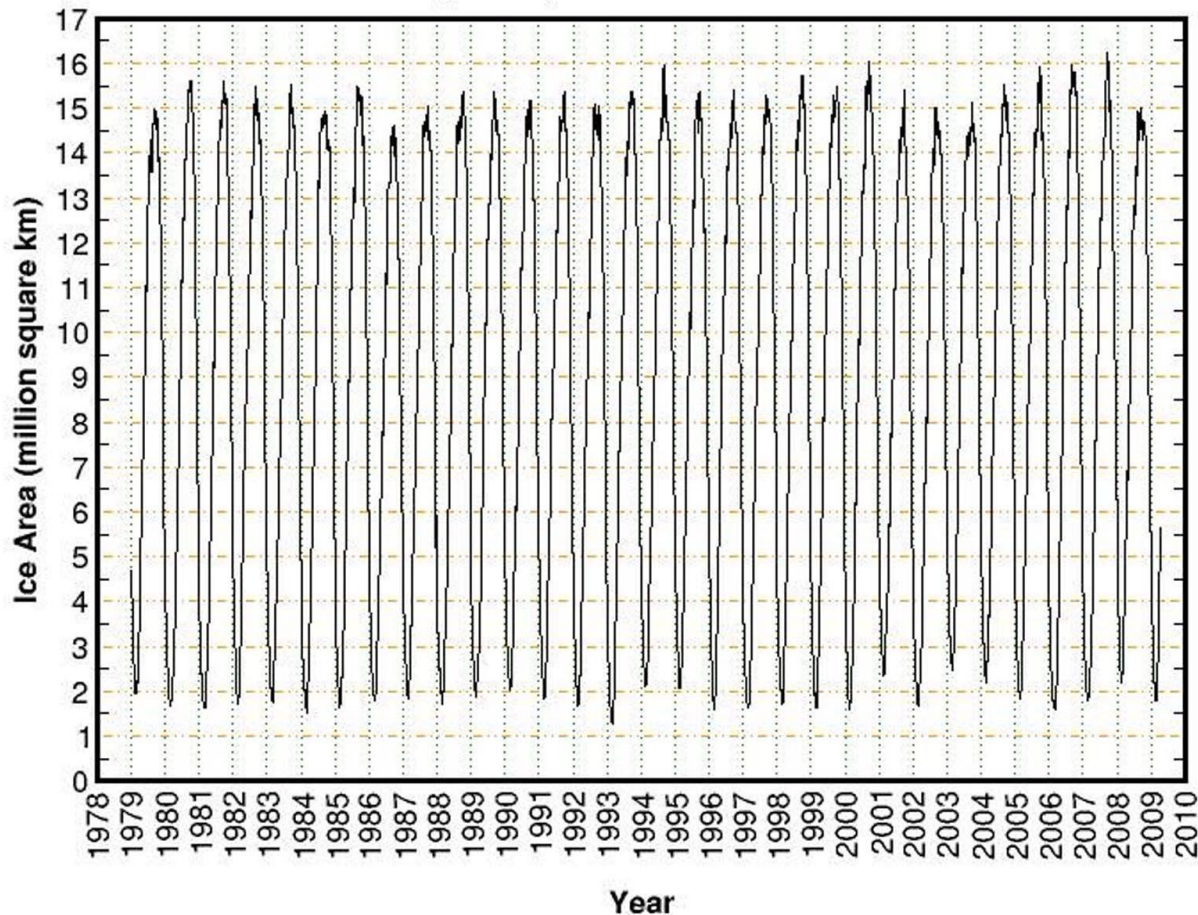




As you may have heard, nothing of the sort has been happening to Antarctic sea ice, although claims of record extent of Antarctic sea ice are also overly dramatic.

## Southern Hemisphere Sea Ice Area

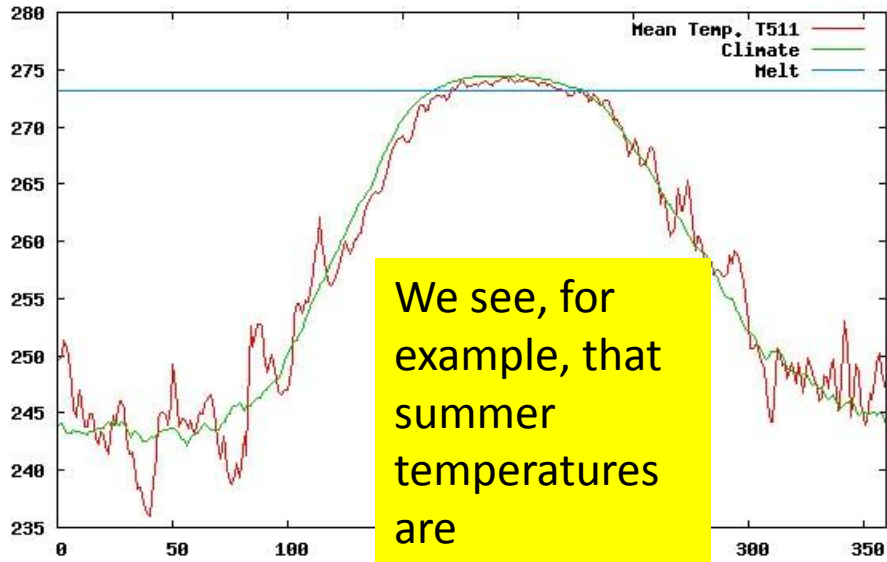
*Data provided by NSIDC: NASA SMMR and SSM/I*



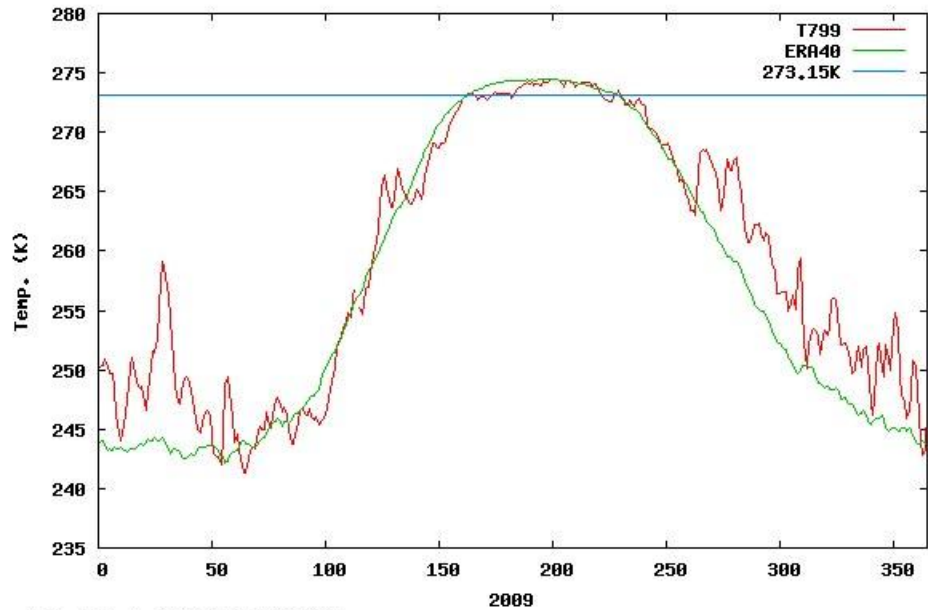
Let us now look at the temperature of polar regions in some detail. The following figures show daily arctic temperatures for each day available from reanalyses since 1958. They also show the average temperatures for each day.

If one focuses on variations in annually averaged temperatures, one misses some crucial information, and that information tells us quite a lot.

Daily Mean Temperature for plus 80N - with ERA40 climate

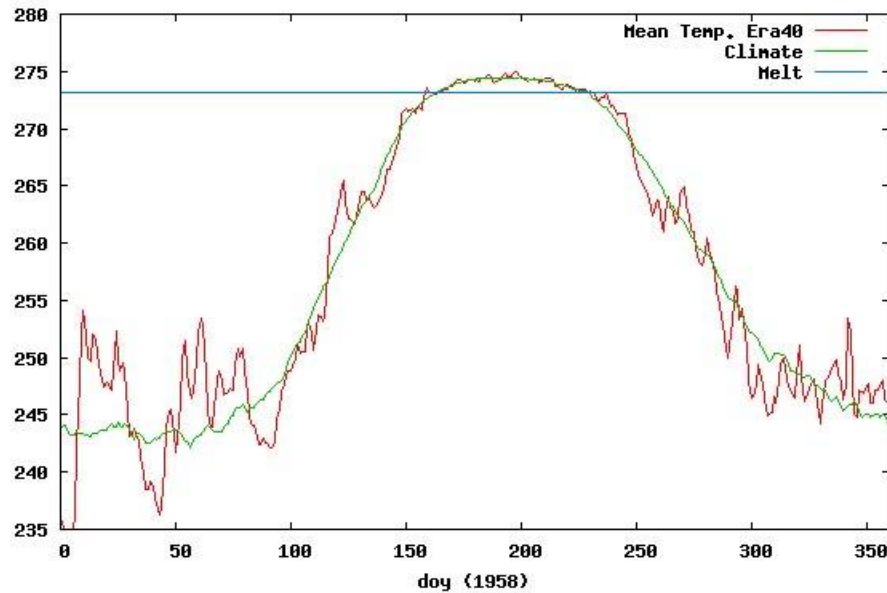


We see, for example, that summer temperatures are unchanging.

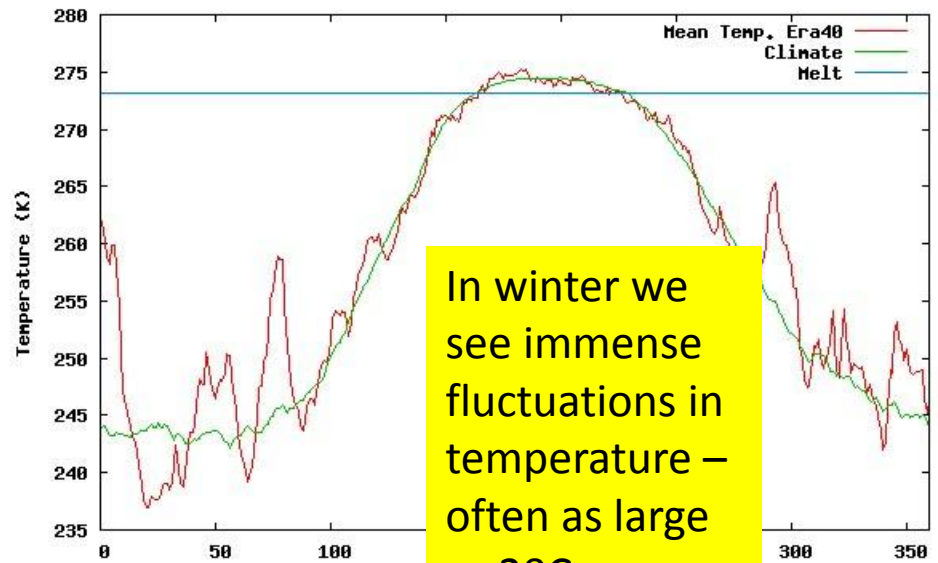


Sun Jan 3 19:00:05 GMT 2010

Daily Mean Temperature for plus 80N - with ERA40 climate

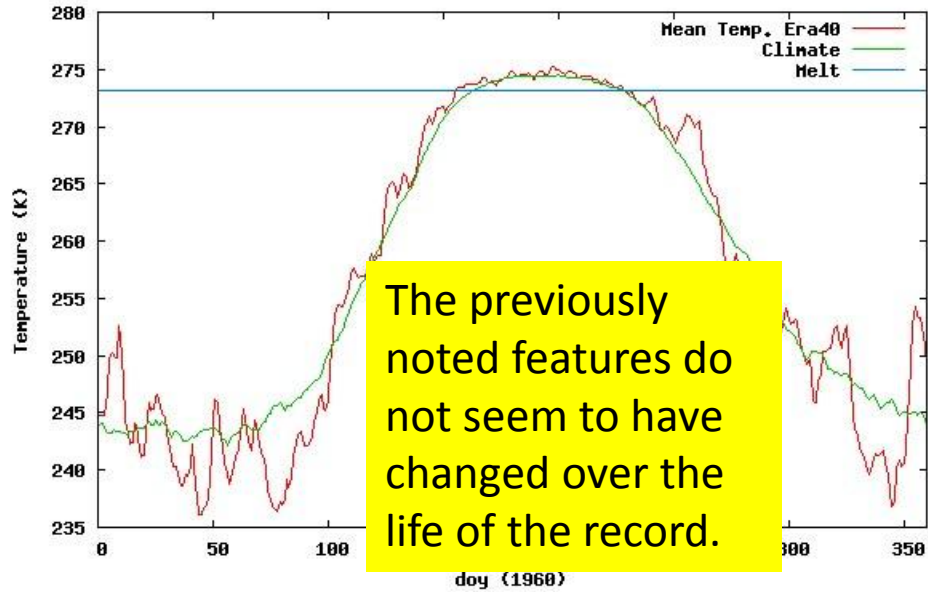


Daily Mean Temperature for plus 80N - with ERA40 climate

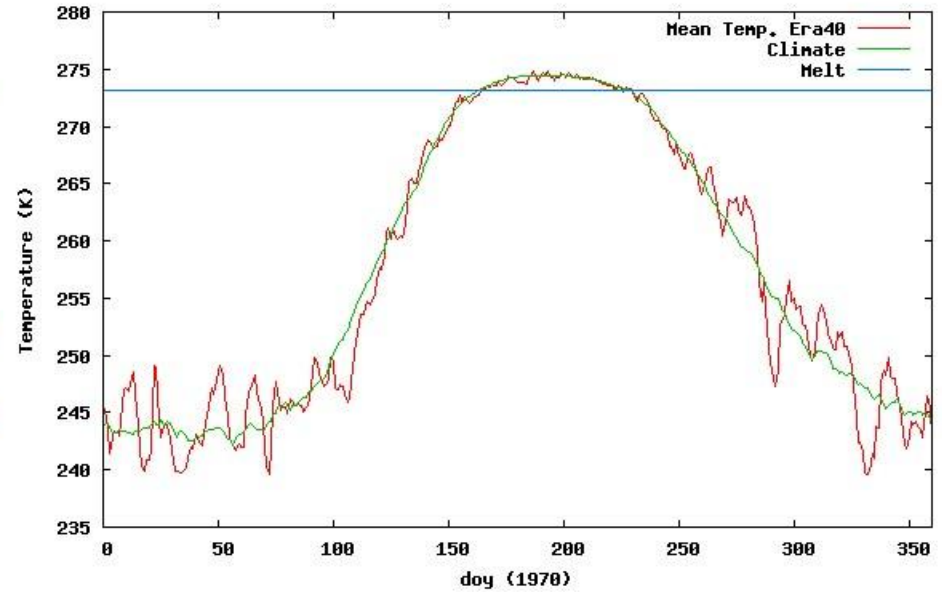


In winter we see immense fluctuations in temperature – often as large as 20C.

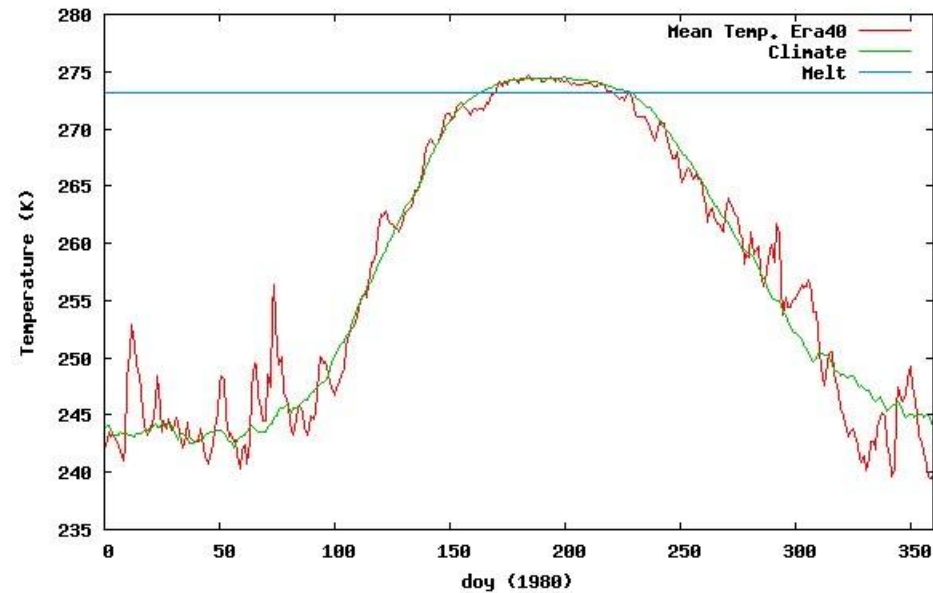
Daily Mean Temperature for plus 80N - with ERA40 climate



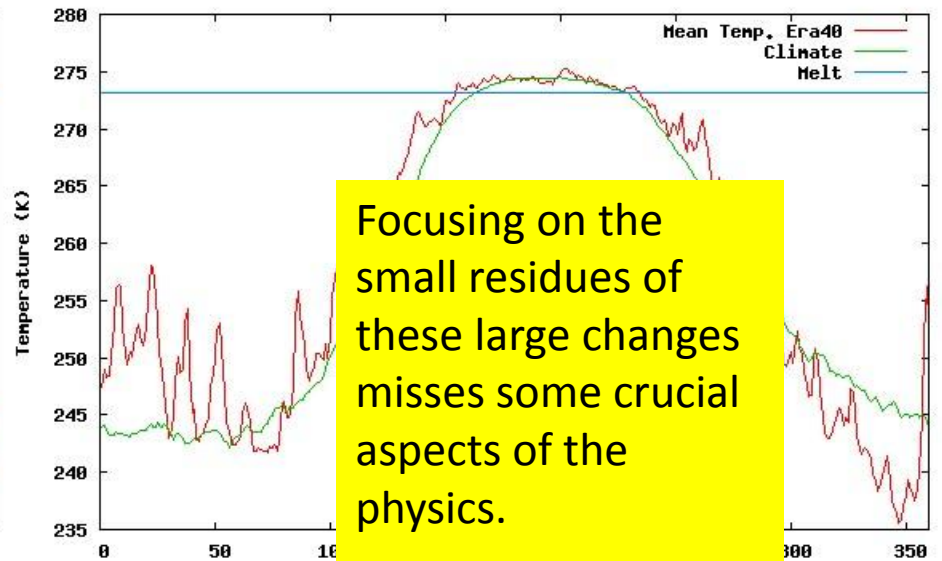
Daily Mean Temperature for plus 80N - with ERA40 climate



Daily Mean Temperature for plus 80N - with ERA40 climate



Daily Mean Temperature for plus 80N - with ERA40 climate



What the previous slides illustrate is that during summers, when there is sunlight, temperatures are largely determined by local radiative balance and this does not seem to be changing. However, during the winter night, temperatures would be even colder than they are but for the transport of heat from lower latitudes. This transport is by the turbulent eddies or storms. Understanding arctic temperatures must involve understanding why these storms erratically penetrate to the arctic. Judging from the behavior of summer temperatures, CO<sub>2</sub> is not obviously a major player.

Just for the record, summer ice depends mostly on how much is blown out of the arctic basin – something that used to be textbook information.

While there really doesn't appear to be that much going on, anecdotal information can be more dramatic.

**“The Arctic ocean is warming up, icebergs are growing scarcer and in some places the seals are finding the water too hot. Reports all point to a radical change in climate conditions and hitherto unheard-of temperatures in the Arctic zone. expeditions report that scarcely any ice has been met with as far north as 81 degrees 29 minutes. Great masses of ice have been replaced by moraines of earth and stones, while at many points well known glaciers have entirely disappeared.”**

**—US Weather Bureau, 1922**

In fact, the arctic is notoriously variable; similar statements are available for 1957, and the Skate surfaced at the N. Pole in 1959. So much for 'unprecedented.'

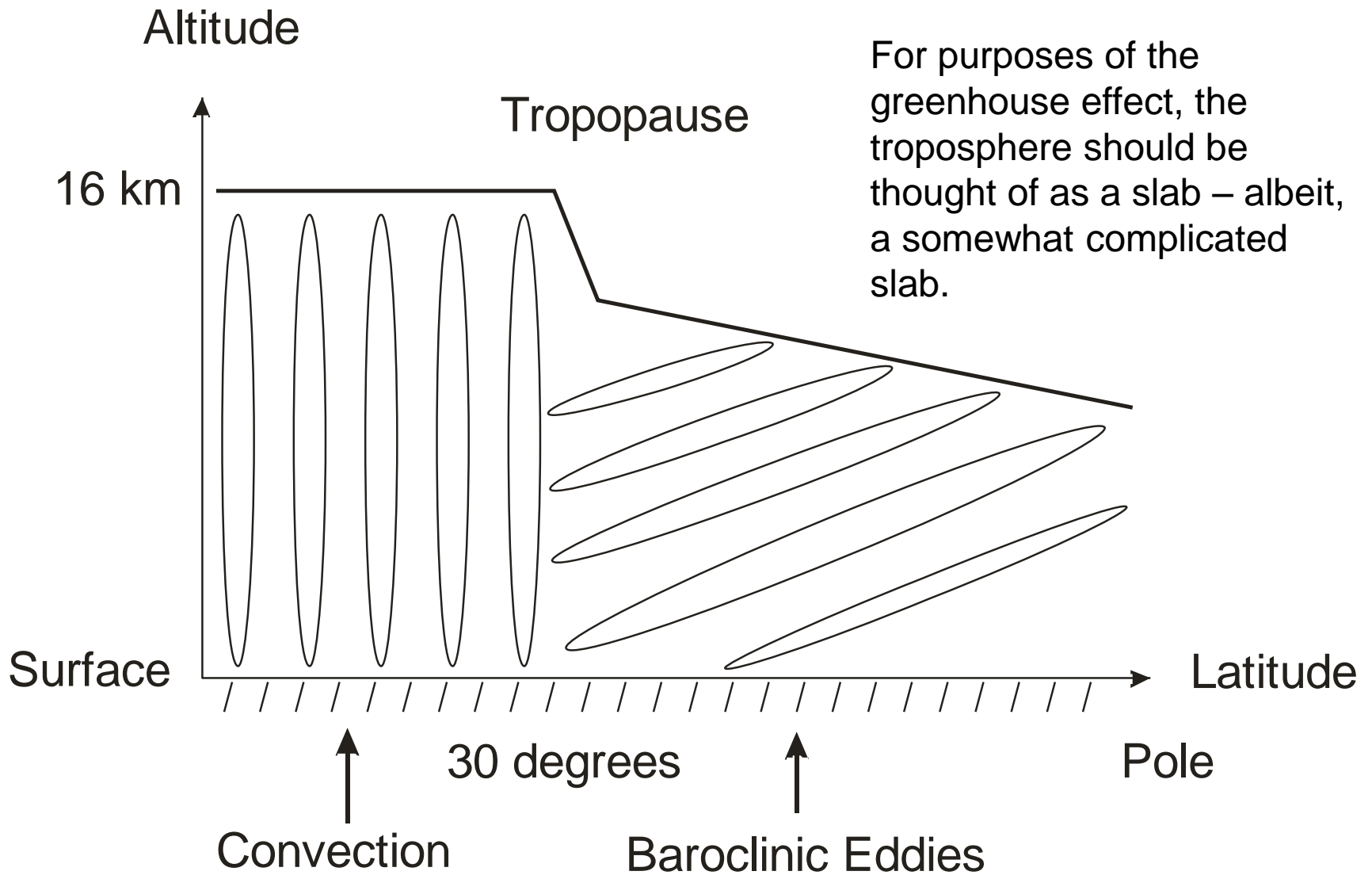
As already mentioned, it is essential to know climate sensitivity. Model predictions depend on positive feedbacks and not just the modest effect of CO<sub>2</sub>. However, it is first necessary to understand the climate version of the greenhouse effect.

## *Real nature of greenhouse effect*

All attempts to estimate how the climate responds to increasing CO<sub>2</sub> depend on how the climate greenhouse actually works. Despite the concerns with the greenhouse effect that have dominated environmental thinking for almost a quarter of a century, the understanding of the effect is far from widespread. Part of the reason is that the popular depiction of the effect as resulting from an infrared 'blanket' can be seriously misleading, and, as a result, much of the opposition that focuses purely on the radiation is similarly incorrect. The following description is, itself, somewhat oversimplified; however, it is probably adequate for understanding the underlying physics.



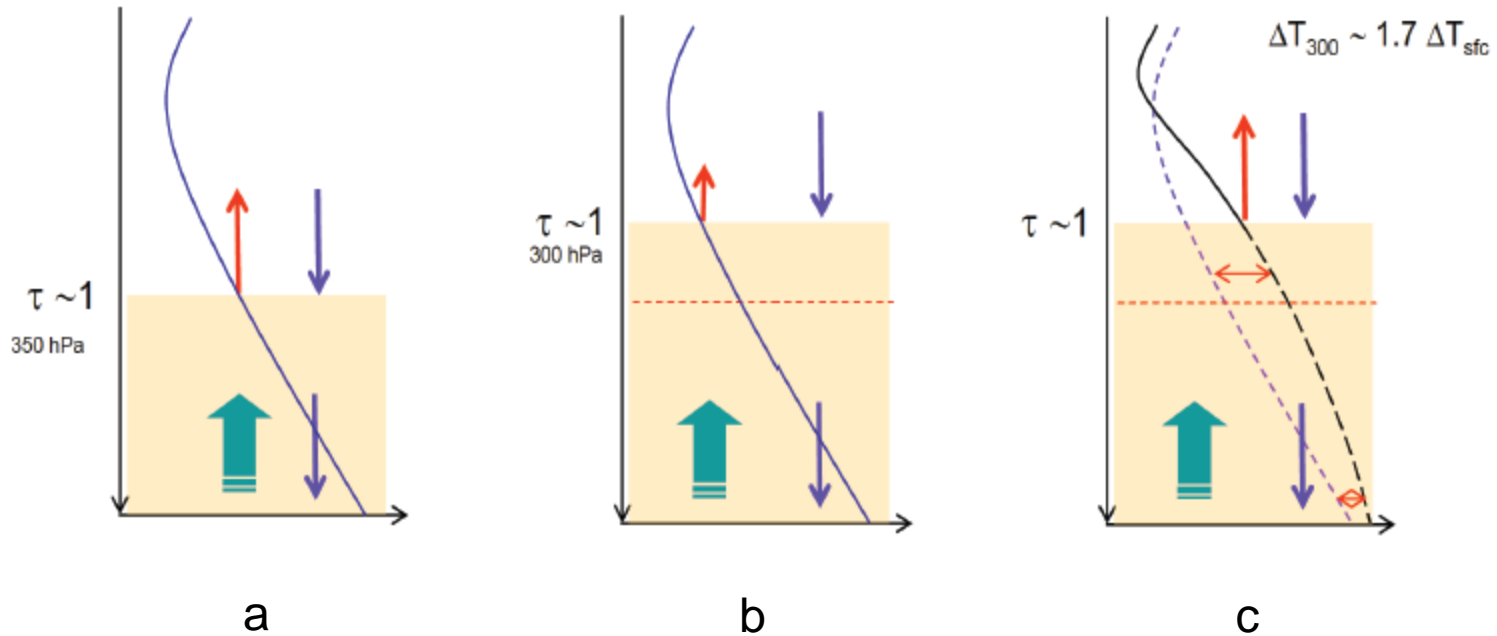
**First**, one must recognize that the troposphere, the layer of the atmosphere in contact with the surface, is a dynamically mixed layer. For a gaseous atmosphere, mixing requires that the resulting atmosphere is characterized by temperature decreasing with altitude. The rate of decrease is approximately 6.5K/km which is sometimes taken as an approximation to the moist adiabatic lapse rate, but the real situation is more complicated. To be sure, in the tropics, the mixing is effected by moist convection, but outside the tropics, the mixing is accomplished mostly by baroclinic eddies. Moreover, the moist adiabat in the tropics does not have a uniform lapse rate with altitude (viz the 'hot spot'). For our immediate purposes, the important facts are that the lapse rate is positive (not zero or negative), and relatively uniform over most of the globe.



Schematic of the troposphere as a dynamically mixed layer.

**Second**, one must recognize that gases within the atmosphere that have significant absorption and emission in the infrared (ie greenhouse gases) radiate to space with a flux characteristic of the temperature of the atmosphere at about one optical depth (measured from space downward). To be sure, this level varies with wavelength, but the average emission level is about 5-6 km above the surface and well within the troposphere.

**Third**, adding greenhouse gases to the atmosphere must elevate the average emission level, and because of the first point, the new emission level is colder than the original emission level. This reduces the outgoing infrared radiative flux, which no longer balances the net incoming solar radiation. ***Thus, the troposphere, which is a dynamically mixed layer, must warm as a whole (including the surface) while preserving its lapse rate.***

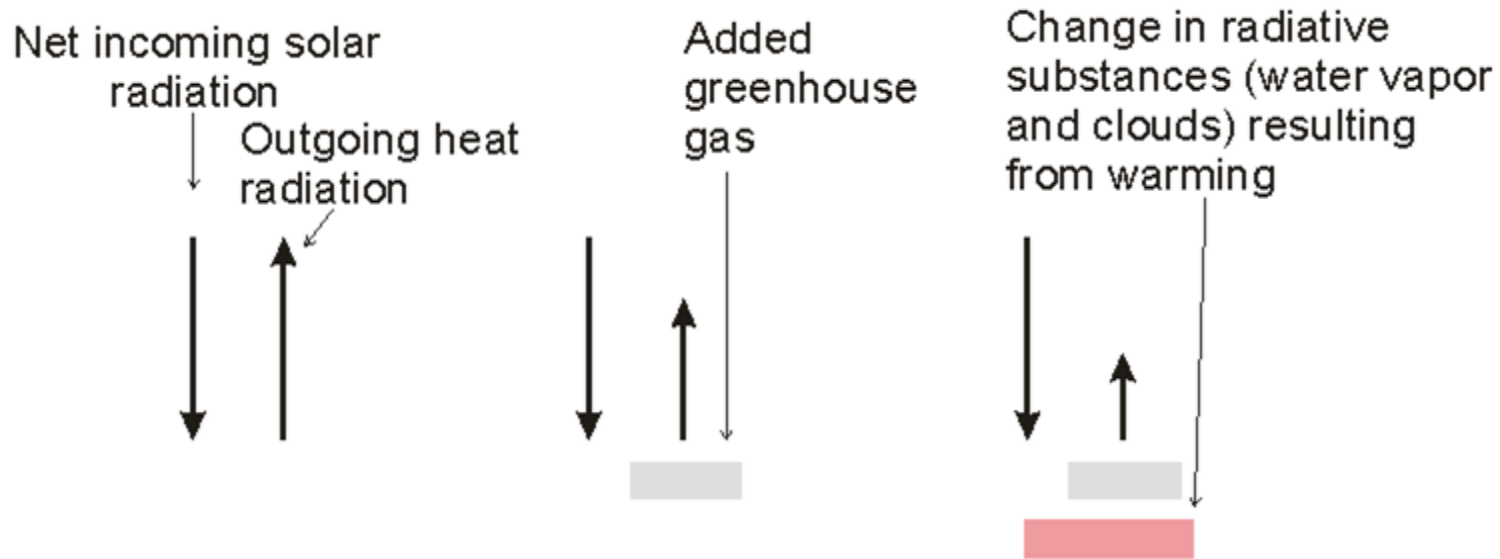


a) Situation with atmosphere in equilibrium with space. b) The situation when added greenhouse gas elevates the characteristic emission level to a cooler level, leaving a radiative imbalance that constitutes the radiative forcing. c) Re-equilibration with moist adiabat.

Note that this mechanism leads to the simple result that doubling  $\text{CO}_2$  gives rise to warming of about 1C. This would not suggest significant concern. Larger warming calls for positive feedbacks.

There follows a schematic of what we mean by feedbacks.

## Feedback Schematic



Initially, net incoming solar radiation and outgoing heat radiation are in balance.

Added greenhouse gas initially reduces outgoing radiation, leading to warming until outgoing radiation again balances incoming radiation.

Warming, in turn, causes changes in radiative substances or feedback. In models, this causes further reduction in outgoing radiation, leading to still more warming.

One is able to use satellite data from ERBE and CERES (that measures net outgoing radiation in both the visible and infrared portions of the spectrum) to test the preceding situation, and to quantitatively evaluate climate feedback factors. These are related to climate sensitivity by the following equation:

$$\Delta T = \frac{\Delta T_0}{1 - f},$$

$\Delta T_0$  is the zero feedback response to a doubling of  $\text{CO}_2$ . It is about 1C.

The basis of the approach is to see if the satellite measured outgoing radiation associated with short term fluctuations in Sea Surface Temperature (SST) is larger or smaller than what one gets for zero feedback. Remember that a positive feedback will lead to less outgoing radiation (increased blanket) while a negative feedback will lead to more.

It turns out that the model intercomparison program has the models used by the IPCC, forced by actual SST, calculate outgoing radiation. So one can use the same approach with models, while being sure that the models are subject to the same surface temperature fluctuations that applied to the observations.

Feedbacks as measured by ERBE and CERES  
(after corrections described by Trenberth et al, 2010)

Mean+/-standard error of the variables.

	Variables	Value	Comments
a	Slope, LW	5.3±1.3	Lag = 1
b	Slope, SW	1.9±2.6	Lag = 3
c	Slope, Total	6.9±1.8	= a+b for the same SST interval
d	$f_{LW}$	-0.3±0.2	Calculated from a
e	$f_{SW}$	-0.3±0.4	Calculated from b
f	$f_{Total}$	-0.5±0.3	Calculated from c



Note that feedbacks are negative.

Lags are used to distinguish fluctuations caused by SST (ie feedbacks) from radiation changes that are not feedbacks (due to volcanic eruptions for example).



For all models, the feedbacks are positive.

	N	LW				SW				LW+SW			
		Slope	R	SE	$f_{LW}$	Slope	R	SE	$f_{sw}$	Slope	R	SE	$f$
CCSM3	17	1.2	0.4	2	0.3	-3.7	-0.9	1	0.6	-2.5	-0.5	2.2	<b>0.9</b>
ECHAM5/MPI-OM	16	1.1	0.4	1.6	0.3	-0.1	0	1.9	0	1	0.3	2.1	<b>0.3</b>
FGOALS-g1.0	16	0.4	0.2	1.2	0.4	-2.8	-0.8	1	0.4	-2.4	-0.6	1.4	<b>0.9</b>
GFDL-CM2.1	16	2.1	0.8	0.9	0.2	-2.1	-0.4	2.4	0.3	0	0	2	<b>0.5</b>
GISS-ER	21	3.2	0.8	1.1	0	-3.7	-0.6	1.8	0.6	-0.5	-0.1	1.3	<b>0.6</b>
INM-CM3.0	23	2.7	0.6	1.4	0.1	-3.4	-0.7	1.3	0.5	-0.7	-0.1	1.8	<b>0.6</b>
IPSL-CM4	21	-0.4	-0.1	1.1	0.6	-2.3	-0.5	1.6	0.3	-2.7	-0.5	1.7	<b>0.9</b>
MRI-CGCM2.3.2	21	-0.8	-0.3	1.3	0.6	-3.8	-0.6	2.5	0.6	-4.7	-0.7	2.5	<b>1.2</b>
MIROC3.2(hires)	21	2.4	0.6	1.4	0.1	-2.4	-0.7	1.4	0.4	0	0	1.3	<b>0.5</b>
MIROC3.2(medres)	21	3.4	0.8	1	0	-3.6	-0.7	2	0.5	-0.3	-0.1	1.6	<b>0.5</b>
UKMO-HadGEM1	17	4.4	0.8	2.2	-0.2	-3.6	-0.7	1.5	0.5	0.8	0.2	2.1	<b>0.4</b>

Note that much of the 'error' in the regressions arises because radiatively important factors like clouds and aerosols vary due to many factors apart from SST. For observations there is also instrumental error, though relative errors over short time scales are likely to small.



We see that all the models are characterized by positive feedback factors (associated with amplifying the effect of changes in CO<sub>2</sub>), while the satellite data implies that the feedback should be negative. Similar results are being obtained by Roy Spencer.

This is not simply a technical matter. Without positive feedbacks, doubling CO<sub>2</sub> only produces 1C warming. Only with positive feedbacks from water vapor and clouds does one get the large warmings that are associated with alarm. What the satellite data seems to show is that these positive feedbacks are model artifacts.

This becomes clearer when we relate feedbacks to climate sensitivity (ie the warming associated with a doubling of CO<sub>2</sub>).

## Models

Models	IPCC AR4	Estimate in this study				
		Sensitivity	Sensitivity	Confidence interval of sensitivity		
				90%	95%	99%
CCSM3	2.7	8.1	1.6 – Infinity	1.4 – Infinity	1.1 – Infinity	
ECHAM5/MPI-OM	3.4	1.7	0.9 – 8.0	0.9 – 28.2	0.8 – Infinity	
FGOALS-g1.0	2.3	7.9	2.2 – Infinity	2.0 – Infinity	1.6 – Infinity	
GFDL-CM2.1	3.4	2.2	1.1 – 351.4	1.0 – Infinity	0.8 – Infinity	
GISS-ER	2.7	2.5	1.5 – 8.7	1.4 – 16.4	1.2 – Infinity	
INM-CM3.0	2.1	2.7	1.3 – Infinity	1.2 – Infinity	1.0 – Infinity	
IPSL-CM4	4.4	10.4	2.1 – Infinity	1.8 – Infinity	1.4 – Infinity	
MRI-CGCM2.3.2	3.2	Infinity	2.5 – Infinity	2.0 – Infinity	1.4 – Infinity	
MIROC3.2(hires)	4.3	2.2	1.3 – 6.4	1.2 – 10.0	1.1 – Infinity	
MIROC3.2(medres)	4	2.4	1.3 – 14.7	1.2 – Infinity	1.0 – Infinity	
UKMO-HadGEM1	4.4	1.7	1.0 – 8.8	0.9 – 38.9	0.8 – Infinity	

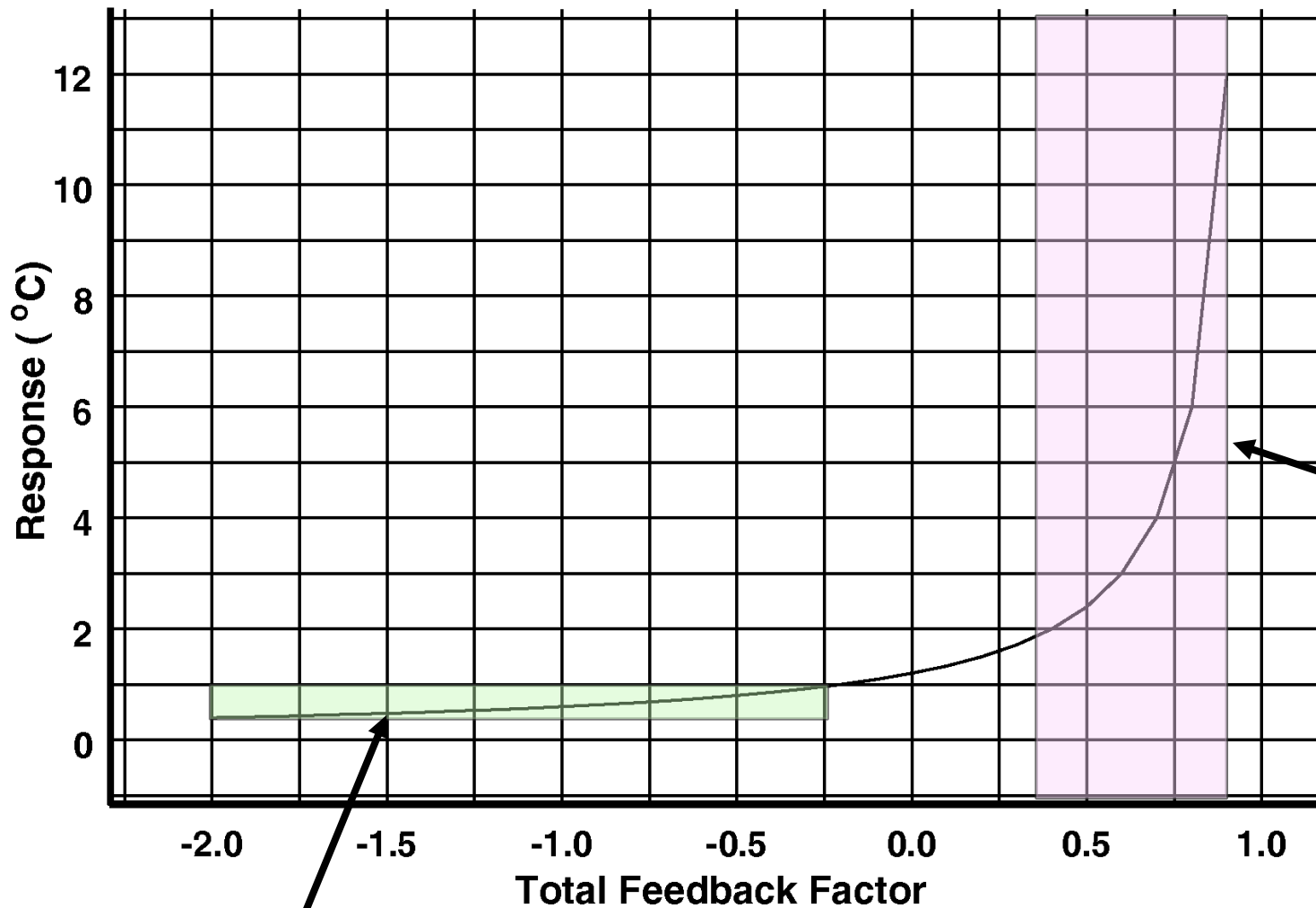
## Observations

Sensitivity, mean	0.7
Sensitivity, 90%	0.6–1.0
Sensitivity, 95%	0.5–1.1
Sensitivity, 99%	0.5–1.3

$$\Delta T = \frac{\Delta T_0}{1 - f},$$

Note that when  $f$ , the feedback factor, approaches +1, the response blows up. Presumably, this is what is meant by a tipping point. For larger values of  $f$ , the system is unstable.

# Response as a function of Total Feedback Factor



For negative feedbacks, large variations in the feedback lead to only small changes in response.

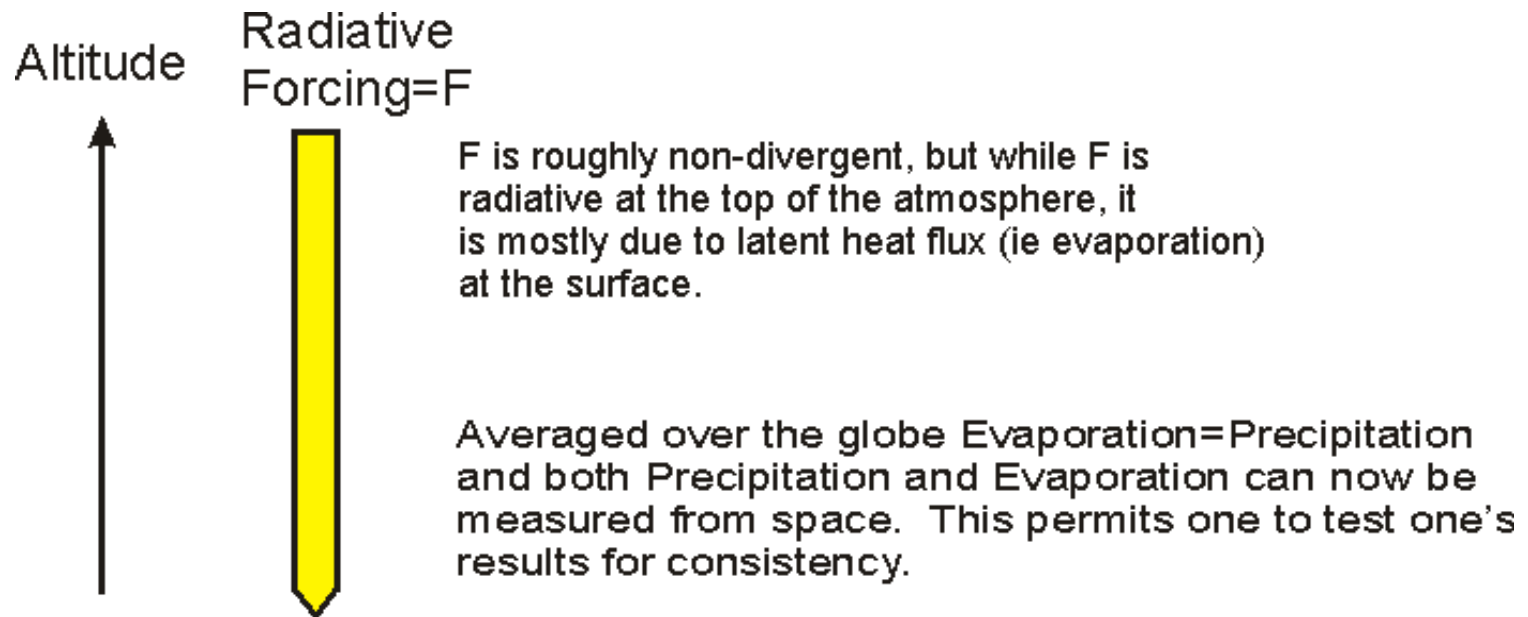
For positive feedbacks, relatively small variations in feedback lead to large changes in response.

It is the positive feedbacks in the models that leads to the uncertainty.

The delicate dependence of the amplification on the precise value of the feedback factor – when the feedback factor is greater than about 0.5 – is important in its own right.

The feedback factor is almost certainly not a true constant since cloud radiative properties depend on aerosols and cosmic rays among other things. If climate sensitivity is currently large, it is unlikely that over the 4.5 billion years of the Earth's history that it would not have exceeded one, and then we would not be here discussing this.

A possible alternative approach to measuring sensitivity:



From the above, we see that an alternative to observing outgoing radiation from space is to measure evaporation from the surface. This has, in fact, been done. Wentz, F.J. et al (How much more rain will global warming bring. *ScienceExpress*, 31 May 2007) used the above and space based observations to measure how evaporation changed with temperature and compared their results with GCM results.

In GCMs, E (evaporation) increased from 1-3% for each degree increase in temperature. Observationally, E increased 5.7%. Now a 1% change in E corresponds to about 0.8 watts  $m^{-2}$ . Climate sensitivity is essentially  $\Delta T/\Delta F$ .

$EC = \Delta \text{Evaporation} / \Delta T$  (in units of percent change per degree)

$CF = \text{Radiative Forcing due to doubling of CO}_2 = 3.6 \text{ Watts m}^{-2}$

$FL = \text{Heat Flux associated with EC} = 0.8 \text{ Watts m}^{-2} \times EC$

$\text{Climate sensitivity} = CF / FL$

Source	EC (percent change in E per degree)	Climate Sensitivity (degrees Centigrade)
Model Range	1	4.5
	3	1.5
Observed	5.7	0.8

We may reasonably consider the observed sensitivity to be an overestimate since Wentz et al explicitly rejected observations that were 'too' far from models. The results are, however, very similar to those based on measurements of outgoing radiation.



Discussion of other progress in science can also be discussed if there is any interest. Our recent work on the early faint sun may prove particularly important. 2.5 billion years ago, when the sun was 20% less bright (compared to the 2% change in the radiative budget associated with doubling  $\text{CO}_2$ ), evidence suggests that the oceans were unfrozen and the temperature was not very different from today's. No greenhouse gas solution has worked, but a negative cloud feedback does.

You now have some idea of why I think that there won't be much warming due to  $\text{CO}_2$ , and without significant global warming, it is impossible to tie catastrophes to such warming. Even with significant warming it would have been extremely difficult to make this connection.

Perhaps we should stop accepting the term, 'skeptic.' Skepticism implies doubts about a plausible proposition. Current global warming alarm hardly represents a plausible proposition. Twenty years of repetition and escalation of claims does not make it more plausible. Quite the contrary, the failure to improve the case over 20 years makes the case even less plausible as does the evidence from climategate and other instances of overt cheating.

In the meantime, while I avoid making forecasts for tenths of a degree change in globally averaged temperature anomaly, I am quite willing to state that ***unprecedented*** climate catastrophes are not on the horizon though in several thousand years we may return to an ice age.