

This is the studio version of a presentation I made to an audience in Phoenix, Arizona on November 10, 2009.

I am Warren Meyer and I run a climate site called climate-skeptic.com. And just to answer questions early on, I have an equivalent climate degree to Al Gore's, which means I don't have one. But I did actually get A's in college and I did actually study a technical degree. My degree is in mechanical and aerospace engineering, and my specialization was in control theory and the stability of dynamic systems, topics that tend to be at the very crux of the arguments for and against catastrophic man-made warming.

This presentation was written for the skeptic's side of a number of debates I have participated in. Unfortunately, I guess a lot of strong global warming advocates have taken Al Gore's lead and don't debate anymore. So, I'm going to have to do their part, too. I will begin by quickly presenting the case for catastrophic global warming. And then, I will talk about the science behind the skeptics' position of why manmade warming almost certainly will not be catastrophic.

The word catastrophic is important - it is why I have labeled this presentation "Catastrophe Denied." That's because we are not talking about just global warming theory -- that name is incomplete - we are talking about catastrophic man-made global warming theory. All three of those pieces matter.

A lot of skeptics have been positioned as "deniers" mainly because that evokes the term holocaust deniers. Using this term helps position skeptics as somehow beyond the pale of civilized society, espousing views that aren't really fit to be listened to or, as some have suggested, do not even qualify for first amendment speech protections. It is a way of avoiding actually addressing skeptic's arguments, and pigeon-holing skeptics as folks whose views don't need to be examined.

But really, to the extent that I am a denier, I don't deny the world has warmed over the last 150 years. I don't even deny that man may be helping to contribute to that warming. What I deny is the catastrophe. And so, in this presentation you will see that, yes, there has been some warming over the past century or so; and yes, manmade greenhouse gasses may have contributed somewhat to this warming. But manmade greenhouse gas warming is likely to remain at trivial levels, less than one degree Celsius over the next century.

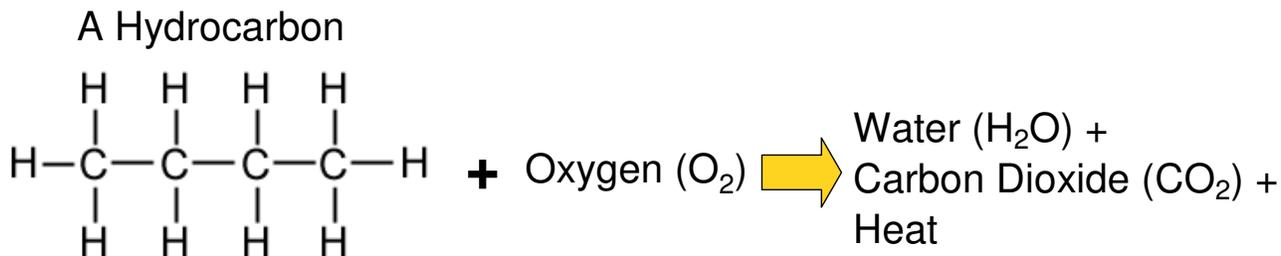
By the way, I know that global warming has been re-branded as climate change, but marketing is not science and the warming matters. We're going to talk about it later, but recognize that no human being that I know of has ever suggested a method whereby CO2 causes climate change except via warming. If we don't see warming from greenhouse gases, then they aren't causing climate change.

The Case For Global Warming

- How do greenhouse gasses work?
- How do models arrive at catastrophic temperature forecasts?
- Links between warming and other climate changes

So, let's talk about the case for global warming. For those of you that don't know the basics, we're going to talk about CO₂ and how it can cause warming. We're going to talk about how scientists reach catastrophic temperature forecasts. And then, we're going to talk about other climate changes that may or may not result from such warming.

How Does Man Create CO₂?



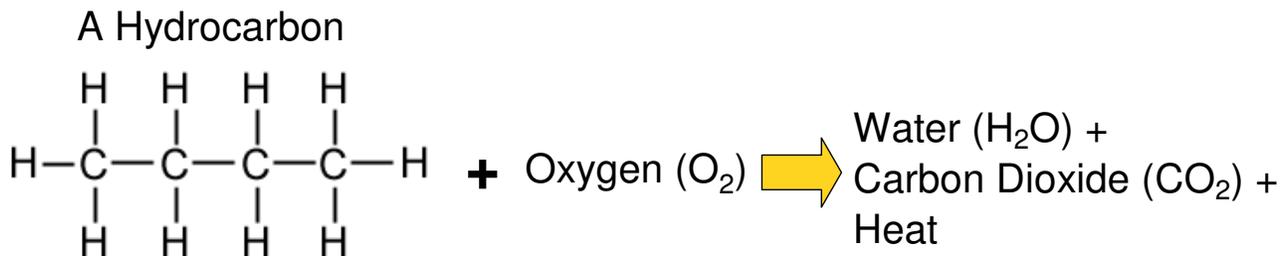
It is the same basic process whether in a power plant furnace or in the human body

That little thing in the upper left with the C's and H's connected is a representation of a hydrocarbon molecule. Almost everything we combust for fuel is a hydrocarbon. The natural gas that we use out of the pipeline is one carbon with four hydrogen's. Coal is a whole bunch of carbons in a chain with hydrogen's attached. And gasoline and liquids are somewhere in the middle of that.

Combustion is the process of breaking up these molecules into their component hydrogen and carbon atoms that then combine with oxygen. Hydrogen combines with oxygen to make H₂O, or water, and carbon combines with oxygen to make CO₂, or carbon dioxide. And of course, this combustion produces heat because that's the whole point of it -- we want to get useful work out of the combustion.

By the way, there's really no difference between this and what goes on in your body when we metabolize food. It's the same basic process. That's why your body breathes in oxygen, expels CO₂, and produces heat, because basically it's doing a kind of combustion in your body from the hydrocarbons in your food.

How Does Man Create CO₂?



Traditional pollutants were much easier to eliminate

- Pollutants like sulfates (SO_x) reduced by reducing impurities in the fuel and by scrubbing exhaust gasses
- Pollutants like ozone, carbon monoxide, NO_x reduced by better combustion
- Pollutants like carbon and ash reduced by filtration

The only way to prevent carbon dioxide in emissions is not to burn fossil fuels - it is fundamental to combustion

In the last few days, the EPA has officially named CO₂ a pollutant under the Clean Air Act. CO₂ is different from most things that we call pollutants because these other pollutants are not necessarily inherent to fossil fuel combustion. The clean air act was aimed at sulfur dioxide and nitrous oxide and ash from smokestack emissions. These were pollutants that resulted from impurities in the fuel or from inefficiencies in the combustion process itself.

CO₂ is different from all these other pollutants because of all those other compounds are ancillary or accidental -- they're not fundamental to this basic combustion process. But CO₂ is fundamental to hydrocarbon combustion. Unlike other substances we could filter or design around, the only way to not produce CO₂ is to not have combustion. And that's why reduction of CO₂ is orders of magnitude more difficult than was elimination of previous pollutants we have tackled.

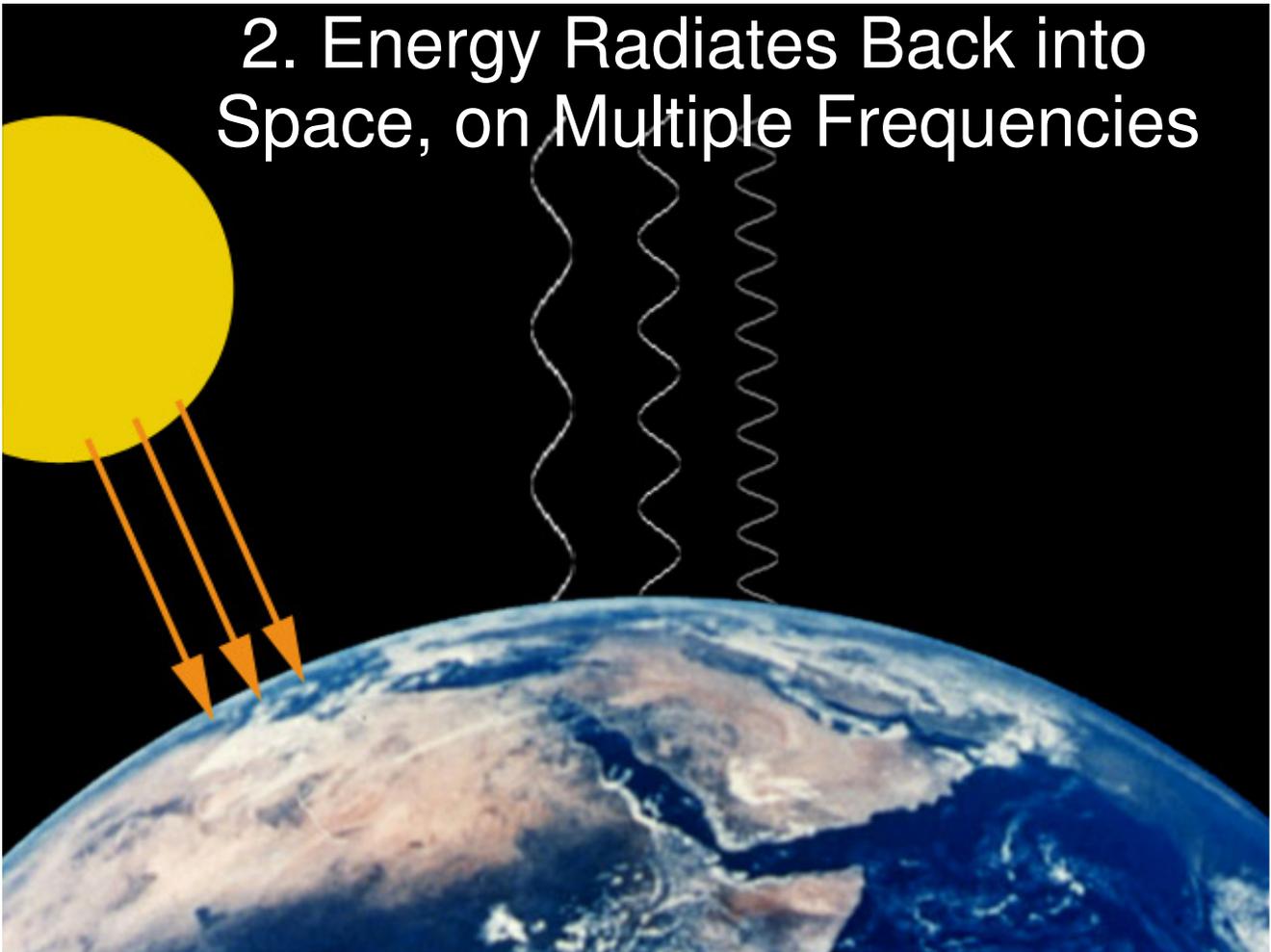
1. Sun Warms the Earth



So, what is the greenhouse effect? I will try explain quickly, and for those who really understand this, I already know I'm oversimplifying -- just bear with me.

To begin, the Earth is warmed by incoming radiation from the sun.

2. Energy Radiates Back into Space, on Multiple Frequencies

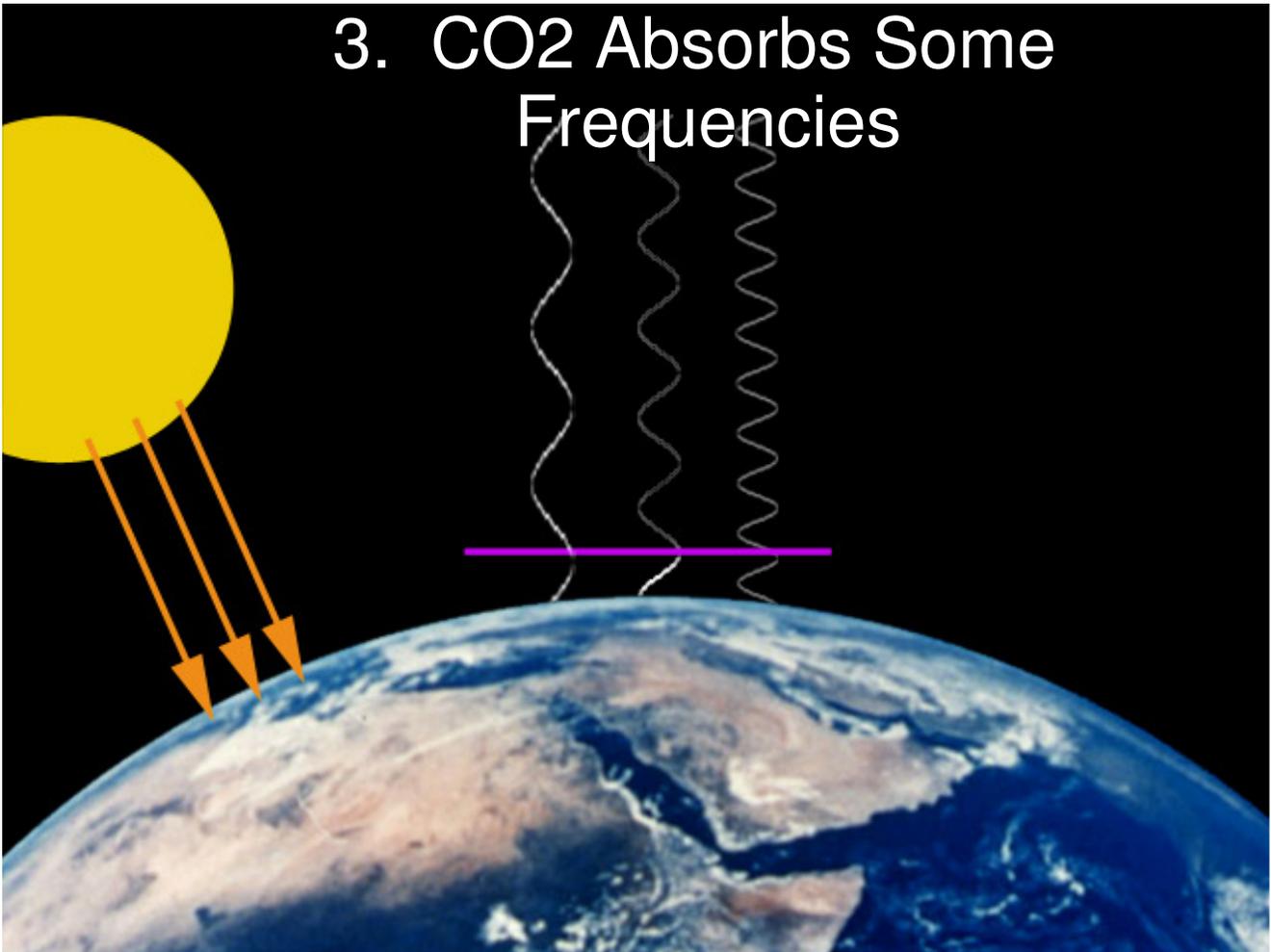


The Earth then reradiates this energy back into space, as shown here, on many different wavelengths.

These two sets of radiation, one into and the other out of the earth, must roughly balance** because if they don't balance, the temperature of the Earth is going to evolve over time to make them balance. So, think of temperature as always changing to try to force these two energy flows into balance. If, for example, more radiative energy suddenly starts coming in than is going out, the temperature is going to go up until the outgoing energy increases and brings the system back into balance.

*[**note: I use the word roughly because heat fluxes from the core of the Earth as well as radioactive decay provide a terrestrial heat flux to the Earth's surface]*

3. CO2 Absorbs Some Frequencies



Now we add a layer of CO₂ to the atmosphere, which I have drawn in pink. CO₂, like other greenhouse gasses, absorbs some of that radiation that's going back into space. Not all of it -- it only absorbs, as you can see in this picture, some of the frequencies.

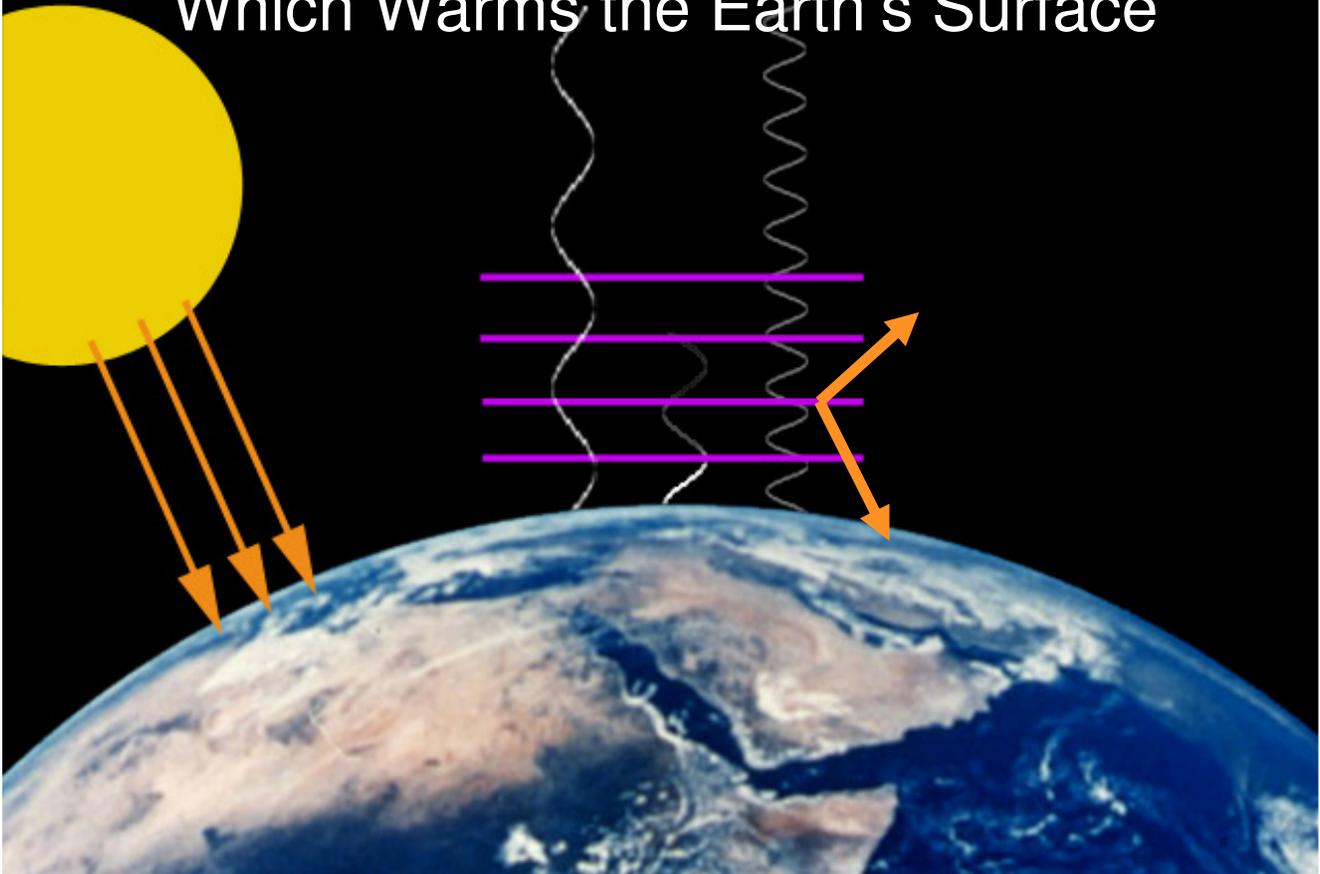
4. More CO2 Absorbs More Radiation, But There is A Diminishing Return



As you add more CO₂, more of the radiation returning to space is absorbed. Eventually, though, the CO₂ has a diminishing effect as its ability to absorb radiation become saturated in certain frequency bands. The analogy that is often used is painting a window. You put one coat of paint on it, and a lot of light is blocked, but it's still translucent. You put another coat of paint on it, and there's still a little light that gets through. You put yet another coat of paint on it and nothing gets through. Further coats of paint have no effect on light transmission, because all the light is already blocked.

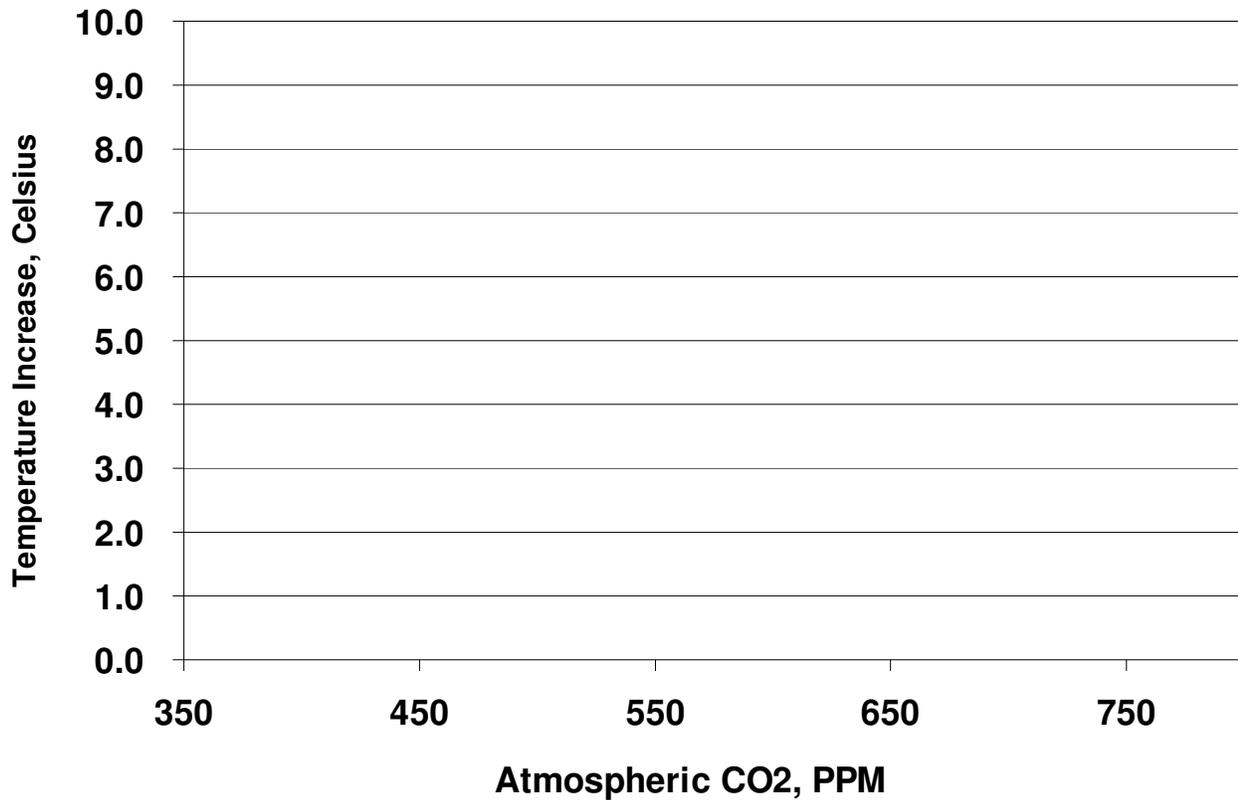
CO₂ is a little like that, working as a diminishing return. Later on, when we look at a curve of CO₂ and its effect on temperature, you're going to see that the CO₂ that's already in the air has a bigger warming effect than the CO₂ we'll add in the future. Each additional molecule added has less effect than the last.

5. CO2 Re-Radiates the Heat, Some of Which Warms the Earth's Surface



Finally, CO₂ re-radiates that energy it has absorbed. Some of it goes into space, where not much happens because that is where it was headed anyway in the first place. But some of this captured energy gets radiated back down to Earth. And so, the effect of warming comes because radiation that is leaving the Earth gets absorbed by the CO₂ and some of it gets sent back down to the surface rather than continuing on into space. This becomes an additional energy flux or forcing on the surface temperatures. And that's how CO₂ or any other greenhouse gas works.

Temperature Projections From CO2

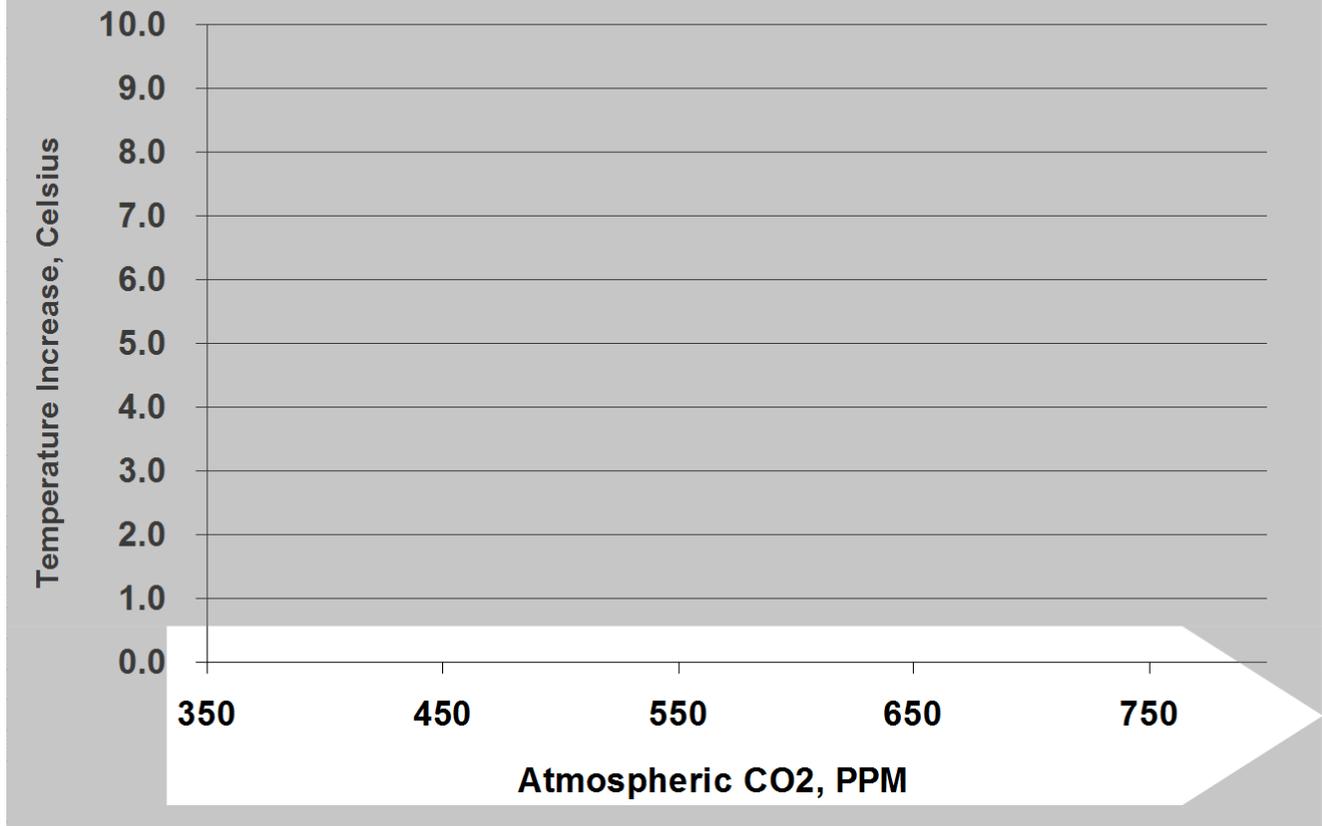


This is a chart we're going to use a lot. It is simple, but just to make sure we all know how it's laid out I am going to walk you through it in detail.

The key question in climate is not whether CO₂ causes warming. If you want to talk about "settled science" (and people really overuse that term), the portion of anthropogenic global warming theory that really is fairly well settled, even to most skeptics, is that CO₂ does cause some incremental warming. This can be demonstrated with careful experiments in the laboratory. Further, we know this to be true in a macro sense, as the Earth would be far cooler without greenhouse gasses to make our climate more congenial.

So, CO₂ certainly causes warming. The question is: how much? Or more specifically, how much warming is caused by small changes in atmospheric concentrations of CO₂?

Temperature Projections From CO2



The CO₂ concentration of our atmosphere right now is around 385 parts per million. On our graph, we will put the concentration of CO₂ in the atmosphere on the bottom axis, running up to values of 650 to 800 ppm, which are estimates of possible atmospheric CO₂ concentrations by the year 2100 presuming we do nothing legislatively to limit fossil fuel combustion.

Getting a Feel For Parts per Million

- Current CO₂ concentration in the atmosphere is about 385 ppm
- Riddle: When flying from Los Angeles to New York, if you have traveled the equivalent of 385 ppm of the entire trip, where would your airplane be?

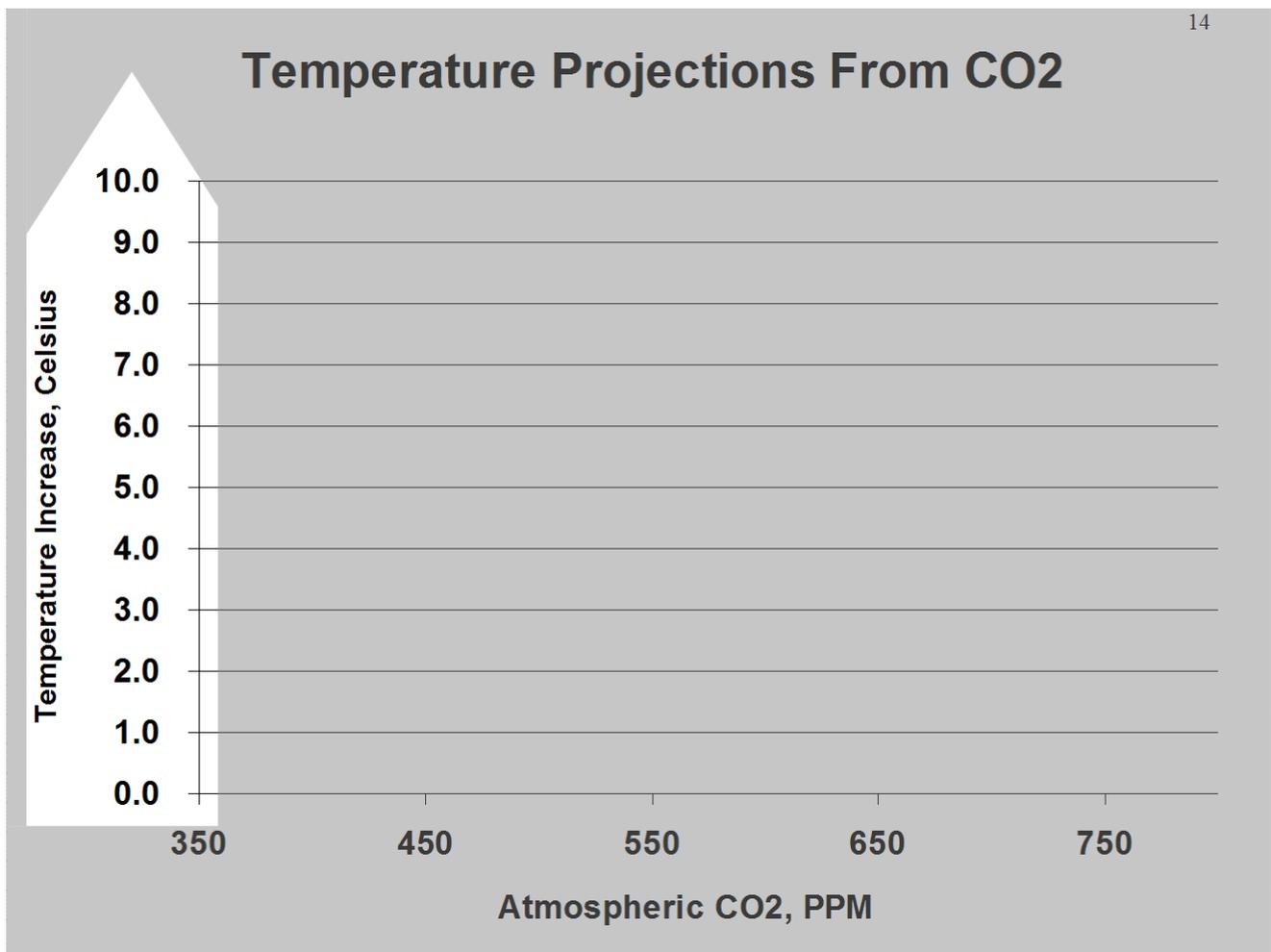
I think a lot of people struggle to visualize just how small 385 parts per million really is, so I will demonstrate it with an example. 385 parts per million is the equivalent of .0385%. If you were to fly from Los Angeles to New York, what would be the equivalent of 385 parts per million of that journey? What would you be flying over once you were .0385% of the way to New York?

Getting a Feel For Parts per Million

- Current CO₂ concentration in the atmosphere is about 385 ppm
- Riddle: When flying from Los Angeles to New York, if you have traveled the equivalent of 385 ppm of the entire trip, where would your airplane be?
- Answer: Less than halfway down the runway at LAX.
- Man is thought to have increased CO₂ from about 270 to 385 ppm. That is a 0.011% change in the mix of atmospheric gasses

The answer is that you would still be only halfway down the runway at LAX. Hopefully that gives you an idea how small 385 parts per million is.

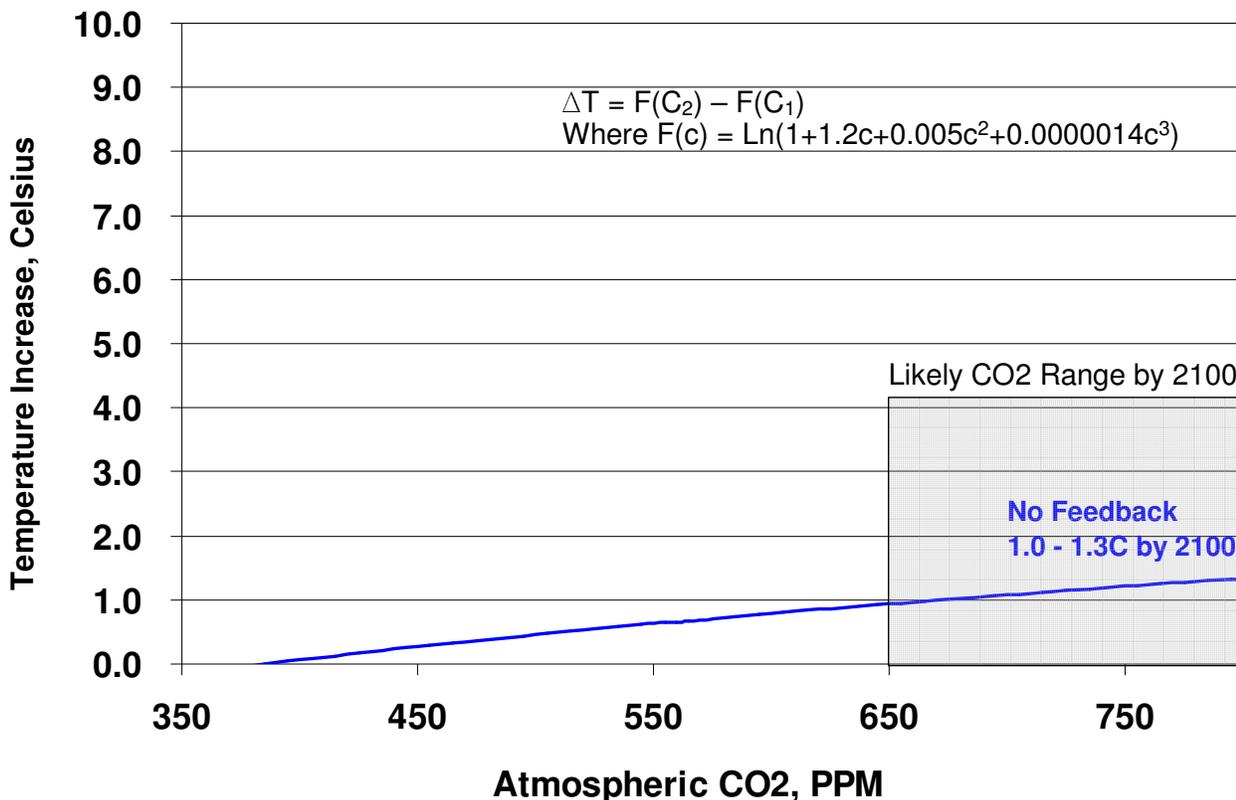
I should note that there are skeptics who do not think that man is actually increasing the CO₂ in the atmosphere -- that the increase is actually occurring as a result of temperature increases, rather than vice versa. Since I am not an expert on the CO₂ cycle, which is horrendously complex, I don't find this a very productive way to argue global warming. I will assume that most of the increases in CO₂ are in fact anthropogenic, or due to man. There are lower hanging fruit than this in taking on catastrophic manmade global warming theory.



So, back to our chart. We looked at CO₂ concentration on the bottom axis. And on the left axis we will put the global temperature increase expected for a given level of CO₂. Often we will use something called temperature anomaly rather than absolute temperature. Don't worry, the exact numbers don't matter as much as the changes over time. Besides, scientists actually have an easier time saying how much the world temperature has changed over the last 10 years than they have in saying exactly what the Earth's average temperature is, or whether a global temperature even has any meaning. One way to think about it -- scientists may not know what road they are on, but they can keep track of how far they have driven.

Temperature Projections From CO2

IPCC A2 (no Abatement) Case



This formula is from several of the past IPCC reports, and I believe is originally attributable to a work published by Michael Mann in 1998. Since this is the first time I have mentioned the IPCC, let me give a quick background on it. The IPCC is a branch of the United Nations -- It's a quasi-science, quasi-political organization that every five years puts out a report on climate change. These reports are monstrous -- hundreds of pages long -- but only the "summary for policy makers" is really reported on very much. I won't delve too much in this presentation into the shortcomings of the IPCC process, but one interesting thing to remember is that in the last IPCC report (number 4) the "Summary for Policy Makers" was written first, mainly by political types rather than scientists, and then circulated with a note to scientists telling them to conform their sections to the summary.

Anyway, back to temperature projections. In the last several IPCC assessments, they said that if you look just at CO2 without any other effects, without any complex interactions with the rest of the atmosphere, this is the formula that is their best estimate of how global temperature would vary with CO2 concentration.

It's hard to have any real intuition about a formula this complex, so I have graphed it. The IPCC says that as CO2 concentration increases, assuming no feedback effects which we will come to in a moment, global temperatures should follow this blue line. As CO2 concentrations increase to 650 ppm or more by the end of the century (from today's 385ppm), global temperatures would rise about 1 degree Celsius.

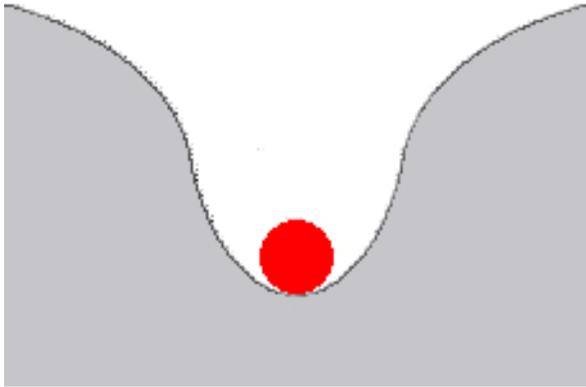
One Degree? We Must Be Missing Something.

- The Answer is Feedback

I know you're going to say: "Warren, now you're BS-ing us because I know I've never seen a forecast as low as 1 degree for global warming in anything on the news. It's all 3 degrees, 5 degrees, 10 degrees. You got to be missing something." And it's true; there's a second piece to this and that piece is feedback.

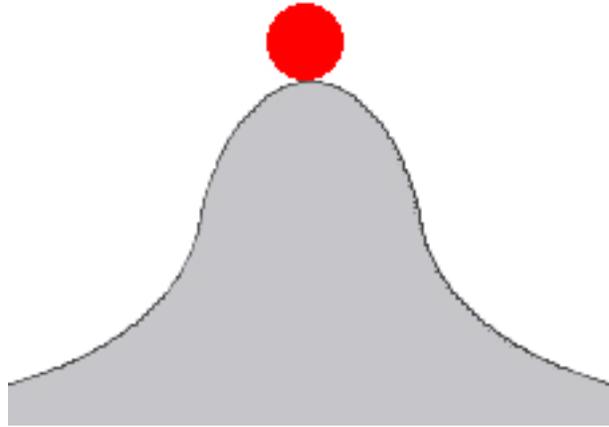
Feedback Multiplies or Reduces An Initial Disturbance

Negative Feedback



- Disturbances are damped
- System remains near its starting point, though it can oscillate

Positive Feedback



- Disturbances are amplified
- System may end up far from its starting point

[live lecture / video include an actual demonstration with a large bowl and a golf ball]

This is the one place I'm going to have to teach you a little more science because feedback is absolutely the heart of where the climate models and catastrophic forecasts go wrong. And so, we're going to talk about feedback and instead of using these charts, I am going to be using props. You can tell from these expensive props that I am obviously funded by the oil-coal-utility cabal.

I'm going to put this ball on the bottom of this bowl and start the ball at rest. Now I am going to give it a good tap. The ball rolls around and around. It's eventually going to come to a stop really close to where it started because the sides of the bowl and gravity tend to neutralize whatever input I give it. Even if I give the ball a good shove this way or that way or that way, everything conspires to bring it back to where it started, to counteract the input I put into the system.

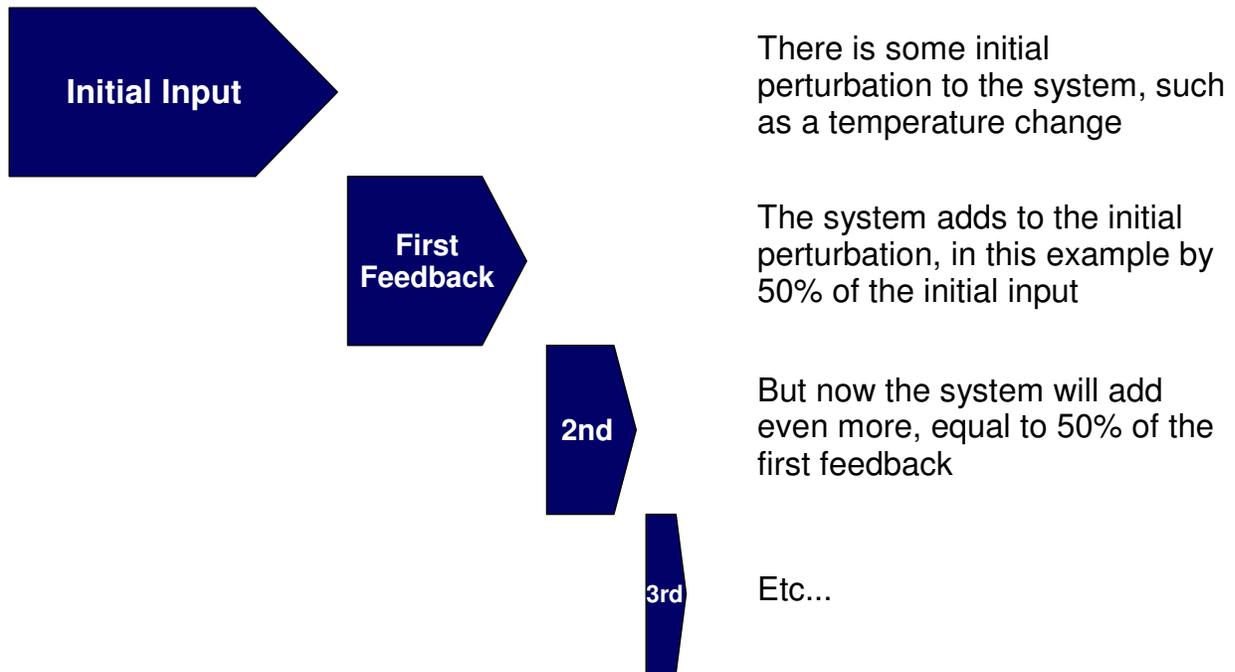
That's an analogy for negative feedback. Negative feedback is where a process acts to partially counteract any disturbance to its equilibrium. It's like pushing a car uphill with the breaks on. When I shove a system dominated by negative feedback, the system shoves back. As a result, I might not have as much effect on the process as I thought I would before I started.

The opposite of this is positive feedback. Positive feedback is more dramatic. I'm going to turn the bowl upside down and balance a ball on its top. In the previous case, even when I gave the ball a very solid tap, it ended up about where it started. Now, I will give this ball the tiniest little nudge. I barely touched it and the ball is now 15 feet away. This is a good analogy for positive feedback. The system amplified my tiny input and caused that ball to roll away a long way. Small inputs can lead to very large changes in a system dominated by positive feedback.

A basic introduction to feedback can be found at <http://en.wikipedia.org/wiki/Feedback>

Positive Feedback Example

50% Positive Feedback Fraction



Final Value is $1/(1-f)$ times Initial Input, so Final Value is double the Initial Input when $f=50\%$

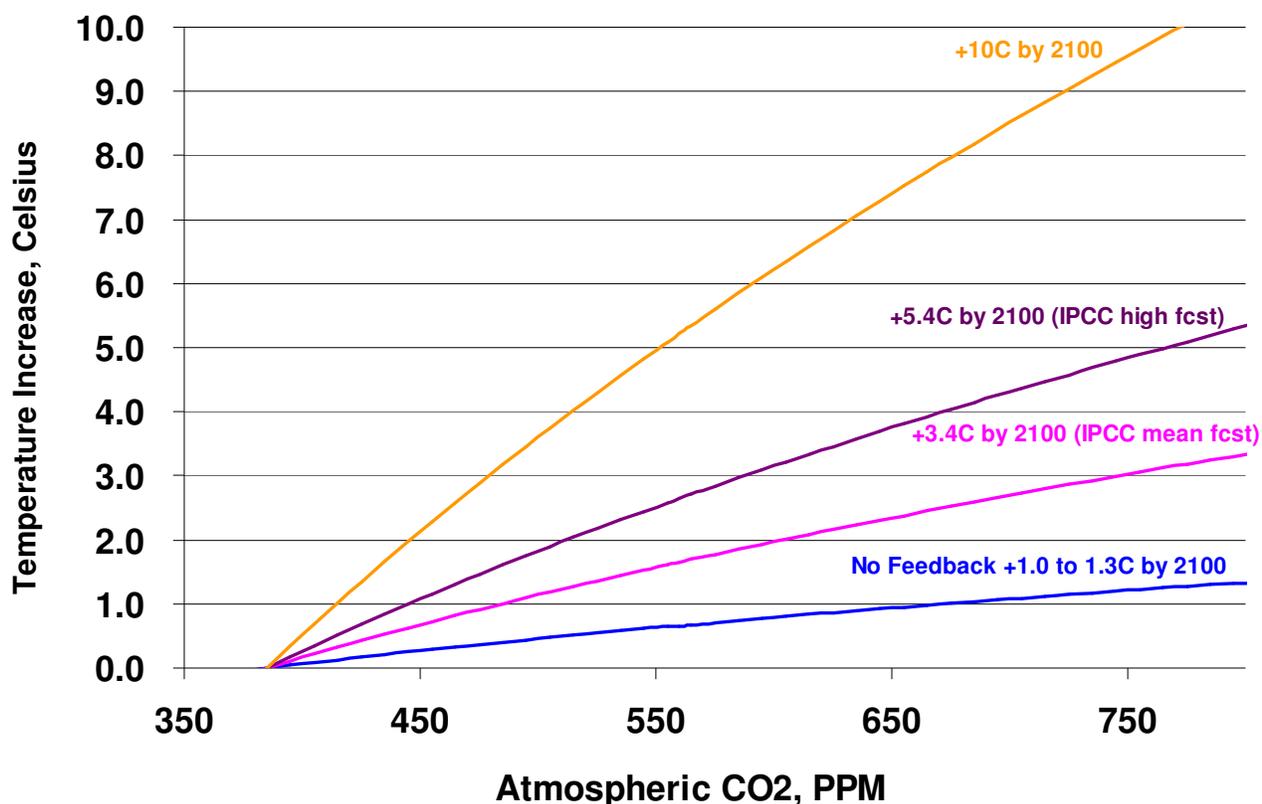
This is how the multiplier effect works. Lets presume an initial input or disturbance to the system – this could be some initial CO₂ driven warming or the tap on the golf ball. We are going to assume that the first order feedback from such a disturbance is a positive 50% of the initial input. This means that the first order feedback adds an additional 50% to the initial input. But there is feedback operating on the first order feedback. So we also get a 2nd order feedback equal to 50% of the first feedback. And a third order feedback equal to 50% of the 2nd feedback, etc. into infinity.

Fortunately, we do not have to count into infinity to solve for the final value – this whole infinite series reduces to the equation above, such that with our 50% feedback, the final output of the system is twice the input [e.g. $1/(1-.5) = 1/.5 = 2$] Any feedback factors of positive 100% or greater result in runaway processes or tipping points.

Note that this formula also works for negative feedbacks. For example, a 50% negative feedback would result in a final value 67% of the initial input [e.g. $1/(1-(-.5)) = 1/1.5 = 0.67$].

Temperature Projections From CO2

IPCC A2 (no Abatement) Case



Coming back to our topic of global warming, warming from greenhouse gasses alone, as we saw on the chart above with the blue “no feedback” line, is really quite small. Even a lot of added CO₂ is only able to give a small nudge to the climate system (even by the estimates of the alarmists). What really makes for the catastrophe are the assumptions in various climate models of enormous net positive feedbacks. Nearly every climate model you ever heard of assumes that climate is that ball on top of the bowl, not the ball in the bowl. When Al Gore is talking about tipping points, think of the ball running away from the bowl - he is talking about positive feedbacks so high that the equations literally go to infinity.

A good way to think about it is to picture the Earth's climate as your stalled car. Skeptics picture the climate as your car stalled in the parking lot, needing a lot of pushing and shoving to move it just a little ways. Climate modelers, however, assume that the Earth is a car perched precariously on the top of the hill. You give the slightest nudge and it's going to start running downhill and accelerating just from that small nudge. And it's going to crash into smithereens at the bottom. And note that in this case the key factor was not the nudge itself, but the fact that the car was sitting precariously on top of the hill so the slightest force starts it running away.

And that's positive feedback. And that's the assumption that these climate models are built from. So, if you remember that one degree blue line above, that's not their final forecast. That's the nudge. That's from greenhouse gas theory alone. Here we see their actual forecasts, the final forecasts taking feedbacks into account. These forecasts from 3-1/2 degrees C by the end of the century (the IPCC base case) to 5.4C (the IPCC high case) and even as high as 10C (by folks such as Joe Romm). The 3.4C forecast would correspond to a feedback fraction of about 60%, the 5.4C to a fraction of 75%, and the 10C forecast to staggeringly high positive feedback factor of 87%.

Source: IPCC Fourth Assessment & author's analysis. The chart is based on the end point forecasts (CO₂ concentration and temperature increase) in the Fourth Assessment. Intermediate points are extrapolated proportional to the IPCC no feedback formula in chart 15.

One Degree? We Must Be Missing Something.

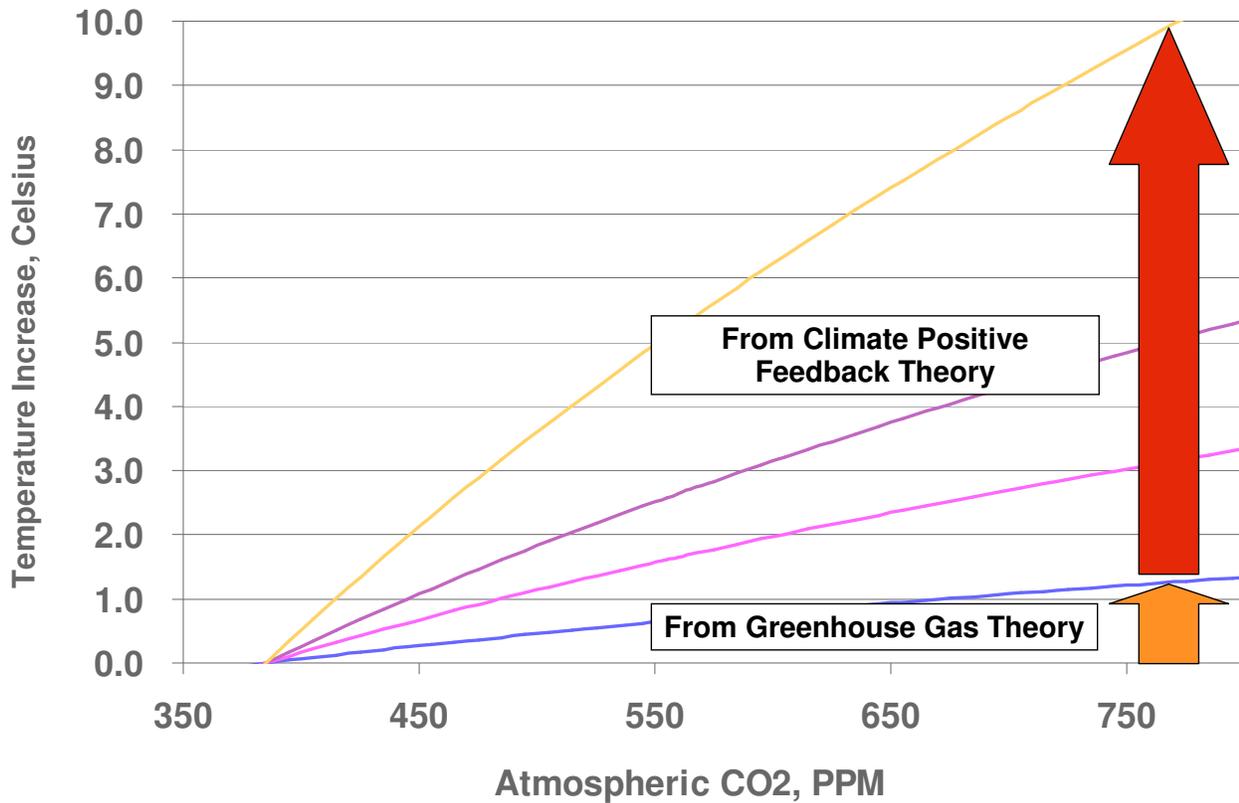
- The Answer is Feedback
- Catastrophic forecasts assume that positive feedbacks multiply the warming by 3-8x
- Example positive feedback assumptions of high-warming models
 - Increase in atmospheric water content (relative humidity constant with rising temps = more H₂O)
 - Increase in methane releases from northern tundra
 - Increase high cirrus clouds
 - Decrease in albedo from melting ice
 - Release of CO₂ from warmer oceans
- High enough feedback leads to tipping points and runaway processes

And so, the answer to our question before about what we were missing with our original forecast of 1C from greenhouse warming is that feedback multiplies the forecast by three to eight times.

So what are these feedbacks? I won't talk about all of them, but I'll give you an example. One thing that may surprise you, if you only learn about climate from the major media: CO₂ is a very weak greenhouse gas. A stronger greenhouse gas is water vapor and much stronger greenhouse gas is methane.

And so, what all these climate models do is they assume that the small nudge of warming from CO₂ then puts more water vapor in the air, which is a very big greenhouse gas, and more methane in the air, which is a big greenhouse gas. The extra water vapor results from higher evaporation rates as the world warms. And methane is theoretically released as certain arctic tundra and frozen peat bogs thaw. The water and methane in turn cause a lot more warming. And then, you get the whole cycle that repeats itself in a recursive manner.

Catastrophic Global Warming Theory Based on Two Chained Theories



And even in this complexity, we are grossly oversimplifying certain assumptions, ignoring time delays, etc. But what you need to know for now is that catastrophic man-made global warming theory is a two-part theory -- greenhouse gasses provide the nudge, and positive feedback creates most of the warming by multiplying the nudge many fold.

By the way, don't think that this is some weird skeptics version of the theory. I don't believe I have strayed off the orthodoxy in describing this two-part theory. But it is not well communicated, and there is perhaps a reason for this. Scientists and alarmists love to fixate on greenhouse gas theory, and they love to argue about greenhouse gas theory being settled science. And its true that many, including a lot of skeptics, will grant that CO2 without feedbacks probably causes about a degree of warming for every doubling in CO2 concentration. This is the best understood part of the science, so it's the place they most want to defend.

But one degree is not a catastrophe. We have seen now that the catastrophe results from the multiplier effect of CO2. It's this theory of positive feedback, the theory that the climate is a car perched on the top of the mountain ready to run away, that leads to the catastrophe. The catastrophe does not come from greenhouse gas theory. The catastrophe comes from a second independent theory that the earth's climate and temperature system is dominated by very large net positive feedbacks. Ironically, alarmist writers almost never touch on this second theory that drives so much of the warming – 90% of the ink is spilled discussing just 10% of what's driving the warming forecast.

Rising Temperatures Lead to Other Negative Climate Changes

- Changing precipitation patterns (more drought in some areas, more rain in others)
- Melting ice and rising sea levels
- Species extinctions
- Increase hurricanes, tornadoes, and severe storms
- Migration of tropic diseases to new areas

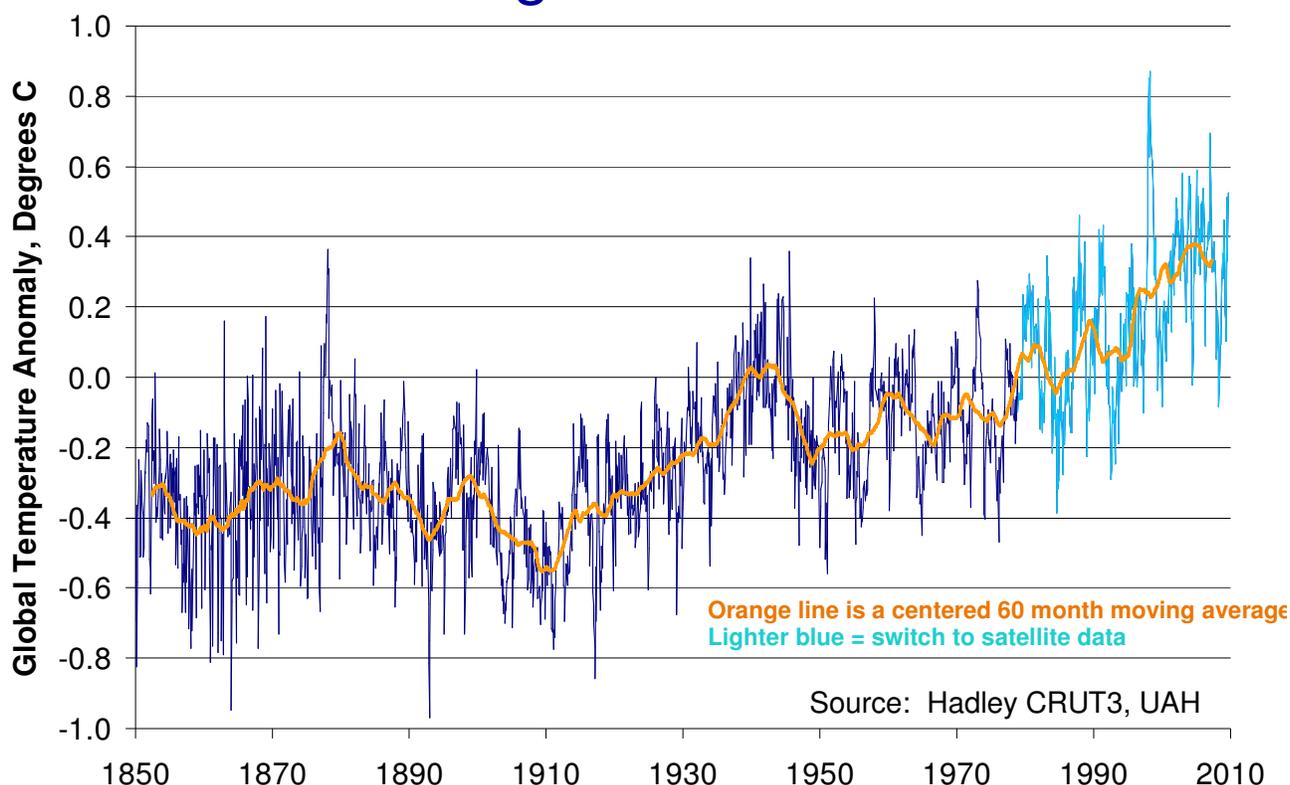
Just to finish off the alarmists' case, the rise in temperatures are feared to cause all these knock-on effects: changing precipitation, droughts, melting ice, rising sea level, species extinction, the polar bears drown, more hurricanes, more tornadoes, severe storms, bird migration, topical diseases, more acne, more suicides, more prostitution, everything. Basically, anybody who writes a PhD nowadays has to include global warming. If your writing your thesis on the ruby-throated hummingbird, you're going to write about the effects of global warming on the ruby-throated hummingbird because that's how you get your funding.

Five Key Climate Questions

- Is the world warming?
- Is that warming due to man's CO₂?
- Will future man-made warming be substantial?
- Will we see catastrophic effects from warming?
- Do CO₂ abatement laws like cap-and-trade make sense?

OK, I've done enough for the alarmist's case. If they want it presented better, they can debate me in public. Now, I'm going to talk about science of the skeptic case because I don't think this gets communicated very well, and it is way too nuanced to survive a television sound byte. I'm going to ask five questions about global warming. First, I am going to ask if there has been warming over the last century and a half. Then, I'm going to ask if the warming is due to manmade CO₂. And then, I'm going to ask how much warming will there be in the future from CO₂. And I'm going to ask what catastrophic effects we can expect to see, or perhaps are already seeing, from manmade global warming. Finally, we'll talk about a little bit about CO₂ abatement programs like the cap and trade bill currently in Congress and the Copenhagen Treaty.

Historic Temperature Record Shows Warming of About 0.6C



OK, first, is the world warming?

Yes, I'm not going to argue about it; there's no point. The early 19th century was the end of the little ice age, perhaps the coldest period in the last 1000 years and maybe longer. A warming trend in recovery from this frigid period is entirely to be expected. Again, I think a lot of skeptics waste their time arguing stuff there's no point arguing about.

This graph shows the temperature history going back into the 19th century. The source is from the East Anglia Climate Research Unit and the Hadley Center, a totally normal source of data (though recently under fire as the result of numerous improprieties in the CRU's scientific process, but since this presentation pre-dated the now famous email release, I will largely ignore the topic in the rest of this lecture). The data source switches over on the right to more modern satellite technology. The orange line is the moving average. From it we see a trend of 0.6-0.8C, or about 1 degree Fahrenheit over the period.

But while I acknowledge the likelihood of some past warming, there are a couple of twists to our tale that are not well-publicized.

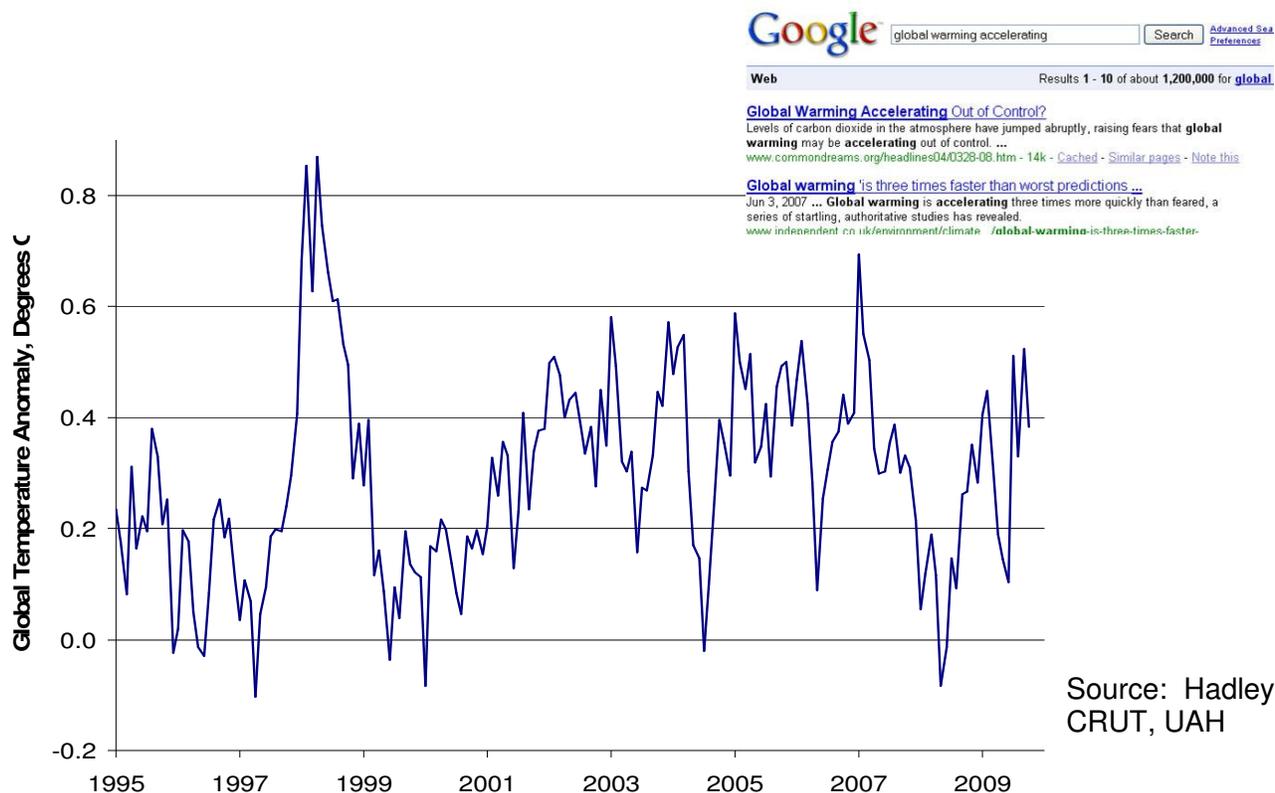
[source note: The dark blue surface temperature history is from the Hadley CRUT3 data base, and is currently under review for a variety of methodology problems, including how they make manual adjustments to the station data, how stations are selected for inclusion, whether the data set adjusts adequately for urban biases, and for the statistical methodologies in homogenizing multiple stations. After 1979, temperatures are from the UAH satellite data set. These two data sets have different base periods for their anomaly. To reconcile them, the avg UAH anomaly for its first 60 months of data was normalized against the Hadley CRUT3 data for the same period, resulting in an addition of 0.1C to all UAH anomalies. UAH data is here:

<http://vortex.nsstc.uah.edu/data/msu/t2lt/uahncdc.lt>. Hadley CRUT3 data is here:

http://www.junkscience.com/MSU_Temps/CRUglobal.csv

Where's The Acceleration?

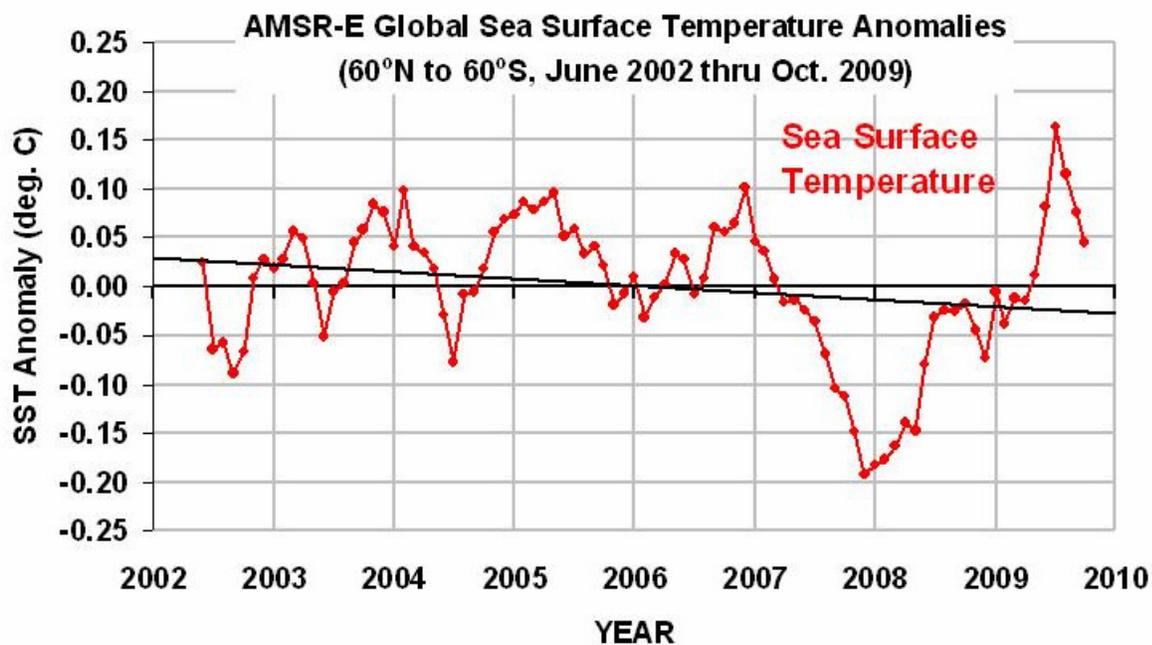
Temperatures Have Been Flat for a Decade



Before I get into these, I encourage you to try an interesting exercise. Go on Google and search for "global warming accelerating," and you will get over a million articles that all say global warming is accelerating. As recently as December of 2009 UN Secretary General Ban Ki-moon said "climate change is happening much, much faster than we realized and we human beings are the primary cause." So let's look at the tale of the tape.

Here is a zoom-in of the last 10-15 years of the previous temperature chart. I have not put a trend line on it because currently we're in the midst of trend line wars, where various people are taking this chart and cherry-picking end dates to show the trend they desire. But I think visually you can tell that: one, I don't see any acceleration here; and two, it sure looks awfully flat for the last eight or nine or even 12 years. And that is not something, no matter what climate scientists say, that their models predicted. One scientist famously said in the CRU emails, "where the heck is global warming?... The fact is that we can't account for the lack of warming at the moment and it is a travesty that we can't."

Sea Surface Temperatures Flat

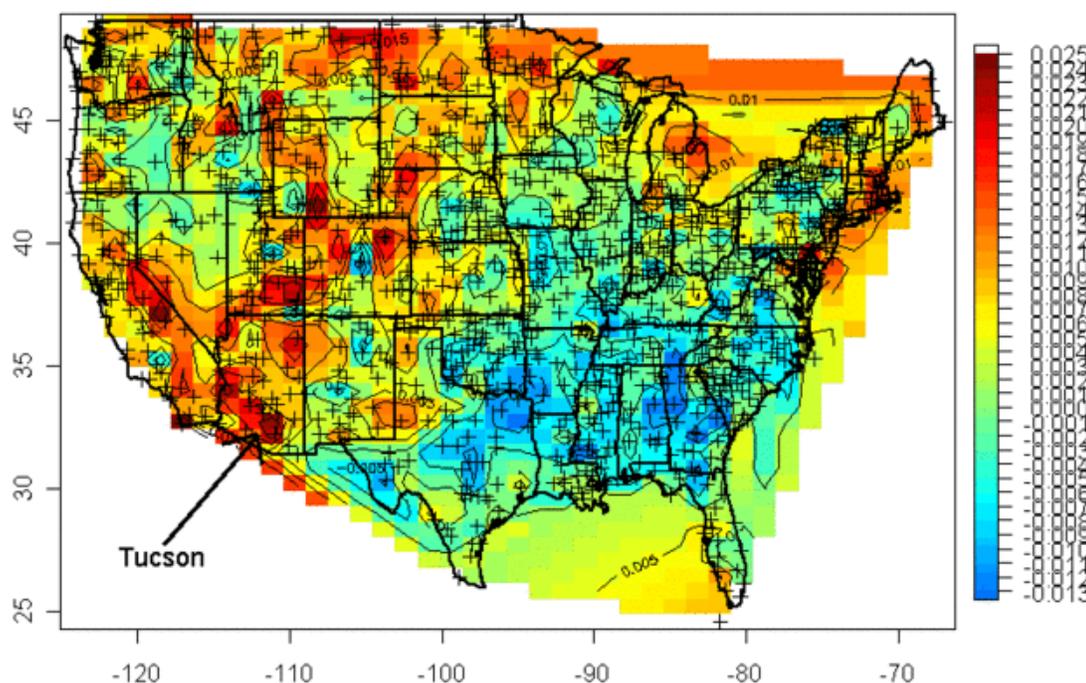


The oceans are a particularly good place to look for global warming. Land does not hold onto heat very well, so most of the heat the earth's surface retains is buried in the oceans. They are the heat reservoirs for the Earth's surface. And so, measuring ocean temperature is critical. Over the last 10 years we have launched new satellites to perform these measurements better. We also have these really cool ARGO floating buoys that drift around the world measuring ocean conditions and from time to time sending a probe as deep as 800 meters to sample ocean temperatures at various depths.

This chart shows what these new technologies tell us about ocean temperatures over 8 years or so that they have been in operation. Again, we can play endpoint games, but it is difficult to find a warming trend in this data.

Source: http://www.ssmi.com/amsr/amsre_sst_validation_statistics.html

Tucson Had Most Warming Since 1900 (According the USHCN Weather Station Data)



I'm going to take a little bit of an aside here on temperature measurement because I promised some folks that I would talk about two things. One is the role of amateurs in climate because I'm an amateur. And the other is the role that kids can play, since I'm presenting at my kid's school.

Forget about the colors for a second. This is the map of the US Historical Climate Network, and each cross is an official temperature station in the USHCN. It's basically the thousand plus US stations that roll up into the global temperature number I showed you before.

And a lot of these are actually still operated by amateurs. I've been to some of them. They're actually in their backyards. For decades, most of our climate data came from amateurs who would go out and they would read the thermometer and read the anemometer and read the rain gauge and write down the measurements and turn them into the Weather Service. And that's how we would monitor a lot of climate. Today, most of these have been automated, but quite a few are still sited in people's backyards.

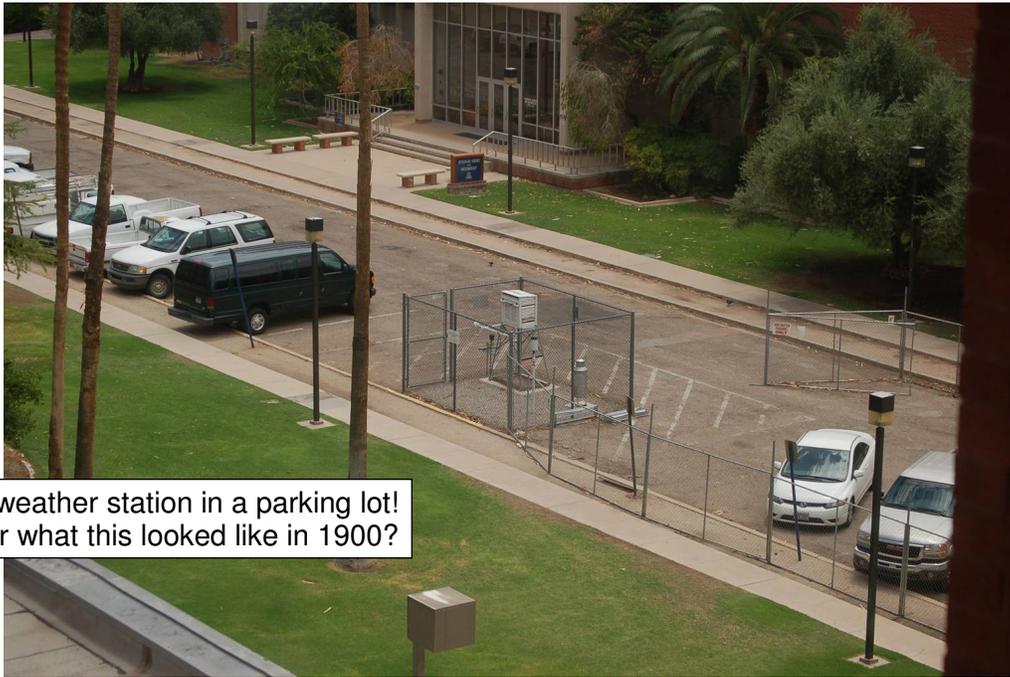
So, there has always been a strong role for amateurs. And over the last year or two there has been an amateur effort to document the condition of these weather stations led by a guy named Anthony Watts up in California. He is a meteorologist who went out to visit a few climate stations and concluded that the installations were terrible. They were not at all what the standards book says the temperature installation should look like. One has to be careful how one sets up the temperature stations to avoid biases -- for example one would prefer to have the measurement point in an open field than, say, on a patch of black asphalt or near a metal building that might reflect or radiate heat onto the thermometer.

Let's go back to this chart. The colors represent how much a certain area of the country has warmed or cooled over the last 100 years according to the USHCN data base. And for some reason, Tucson had the most measured warming of any place in the country. I had already talked to Anthony Watts about his project to document station conditions so I volunteered to start by driving a couple hours down to Tucson to check the site out. Was this a quality site, or were there biases that might explain the large reported warming?

Source: Map by Steve McIntyre in 2007 of USHCN data adjusted for Time of Observation. <http://www.climateaudit.org/?p=1687>

USHCN Weather Station Survey

Tucson, AZ



Survey archived at www.WeatherStations.org

This is probably the most famous photograph I will ever take because it's all over the Internet. It has been in many presentations all around the world. I still see it all the time in the oddest places. It is the USHCN official temperature station in Tucson, located on the campus of the University of Arizona.

I think even those inexperienced with this topic get it immediately when looking at this picture - this is a terrible location for a temperature station. Weather monitoring stations are supposed to be in natural ground, not near buildings, not near anything that could raise the temperature of the device, or bias the temperature from what would be a natural temperature. You can see it sitting in an asphalt parking lot and surrounded by buildings. The asphalt of the parking lot absorbs heat during the day and releases it at night, warming the surroundings higher than the ambient temperature. In addition, the buildings block the wind that might help mix the air.

The ability of manmade structures and paving and machinery to raise temperatures in cities is called the urban heat island effect. Most of you who live in cities probably see the effects of the urban heat island every night on the news. The weather forecaster will often give the evening forecasts as "low of 59 in the city, 52 in the outlying areas." Unless you live in certain parts of Hawaii, a few miles drive does not generally take you to a different climate zone - the difference in these forecast temperatures is the urban heat island effect at work.

Photos by W. Meyer archived at www.climatestations.org. Anthony Watts presentation to CIRES/UCAR in 2007 describing the survey process and results can be found at <http://gallery.surfacestations.org/UCAR-slides/index.html>

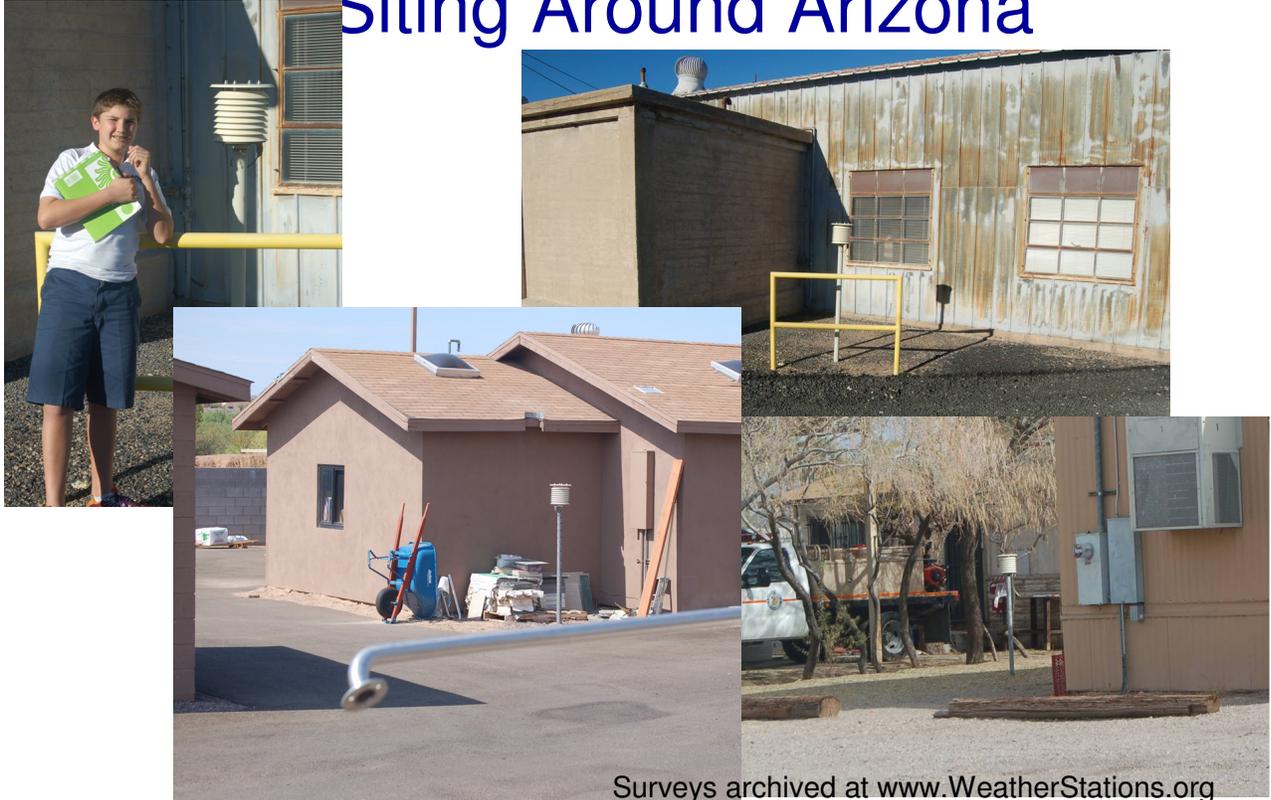
Tucson AZ Site circa 1900



We can time travel back to 1900 and see what this site looked like at the turn of the century - remember that Arizona at the time was still a territory, it wouldn't become a state for 12 years - and we see the area was entirely rural. This is Old Main, the original building on the University of Arizona campus, not far from the location of the current temperature station. No cars, no asphalt, no buildings. And so it has gone from this to this *[flip this and previous slide back and forth]*. So, are we measuring global warming or are we measuring the growth of Tucson?

Image: Old Main, University of Arizona, c. 1900

We Found Consistently Bad Siting Around Arizona



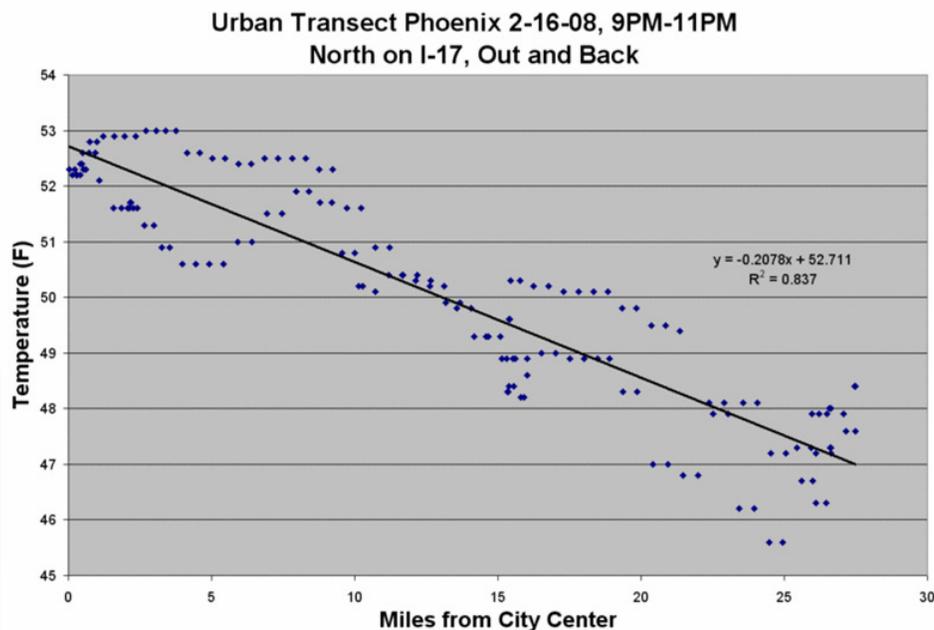
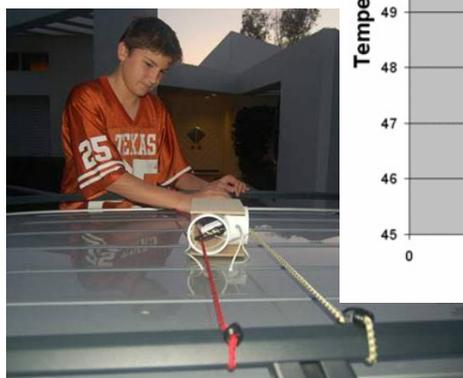
Surveys archived at www.WeatherStations.org

After surveying the Tucson location, my son and I did a series of surveys of other Arizona locations for his 7th grade science fair project (by the way, this is a great school project, and the online instructions at Watts' site are easy to follow). You can see the types of installations we found - in short, they were all poorly sited stations. We found a metal building that reflected heat on one temperature station (the little white beehive-like cylinder on the pole) We found one next to an air conditioning exhaust between two closely spaced buildings and one in an asphalt parking lot right up against a maintenance building of a hospital.

These are terrible locations that are full of biases. The NCDC handbook indicates that stations with these siting problems likely have errors and biases as large as five degrees C. Which raises the obvious question - how can we reliably measure a warming signal we think might be on the order of magnitude of a half degree Celsius with an instrument that has a 5 degree error? The signal to noise ratio is terrible.

Photos by W. Meyer archived at www.climatestations.org. Anthony Watts presentation to CIRES/UCAR in 2007 describing the survey process and results can be found at <http://gallery.surfacestations.org/UCAR-slides/index.html>

Measuring the Phoenix Urban Heat Island 5 to 10 Degrees F



Meyer, 2008

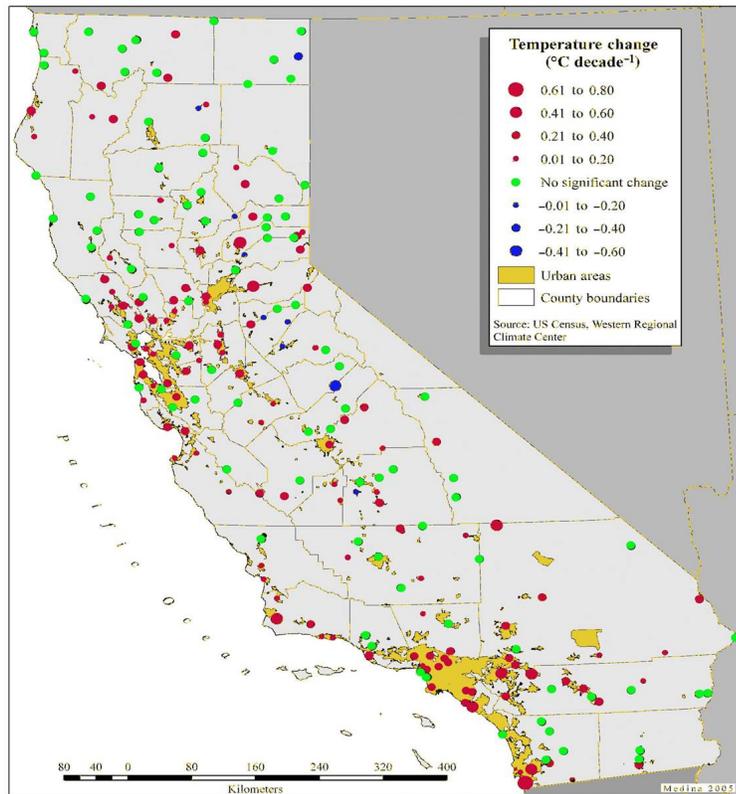
In eighth grade my son did a second science fair project related to these issues of temperature measurement. We had heard from climate alarmists that the urban heat island either didn't exist or was irrelevant to temperature measurement. So we attempted to measure the Phoenix urban heat island. We strapped a PVC tube to the top of the family truckster and put a small, inexpensive temperature measurement device in the tube. This device is accurate to within about a tenth of a degree Fahrenheit and can be connected to a computer to dump its data. We also carried in the car a GPS receiver that could log the data for later download to our computer.

After synchronizing the clocks in the two devices (we used the time stamps to match temperatures to locations) we began driving around Phoenix at night. First, we started at the center of town and we drove north. Then we returned to the center and drove south. This is the data from our northbound trip. The temperature began at 52-1/2 degrees in the center of town. By the time we got to the outlying areas about 25 minutes later, the temperature had dropped 7 degrees in that short drive. We wanted to make sure that this drop couldn't be attributable to general cooling at night, so we drove the route backwards to average the results and thus eliminate any background cooling trend. What we found was a 7 degree difference due to the urban heat island effect (we found an even large difference driving south the next night).

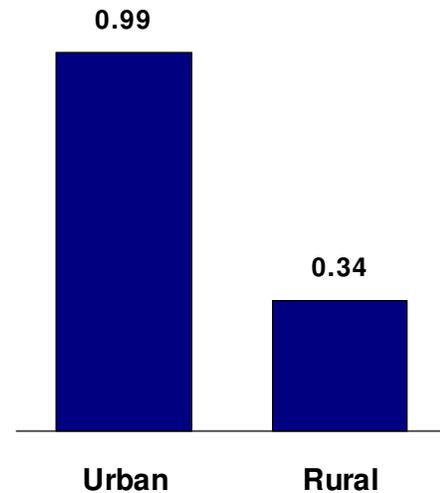
Source: Meyer & Meyer, 2008. <http://www.climate-skeptic.com/2008/02/measuring-the.html>

Urban Growth Biases Temperatures Upwards

Half or More of Measured Temperature Increases May Be Due to Urban Biases



1950-2000 California Temperature Change, Celsius



Source: LaDochy, 2007

To wrap it back up, the professionals have done these same types of experiments, too. This particular chart is from a study in California, but similar work has been done a number of times. In California, they found that over the last 50 years, the urban thermometers showed a degree of warming. The rural thermometers in contrast showed about a third of a degree of warming. So, does that mean that CO₂ is somehow preferentially picking on cities, or does that mean that maybe the big city thermometers are biased by the city growing around it, and that some of what we call global warming is in fact local urban heat island growth around measurement points?

Source: LaDochy, S., R. Medina, and W. Patzert. 2007. Recent California climate variability: spatial and temporal patterns in temperature trends. *Climate Research*, 33, 159-169.

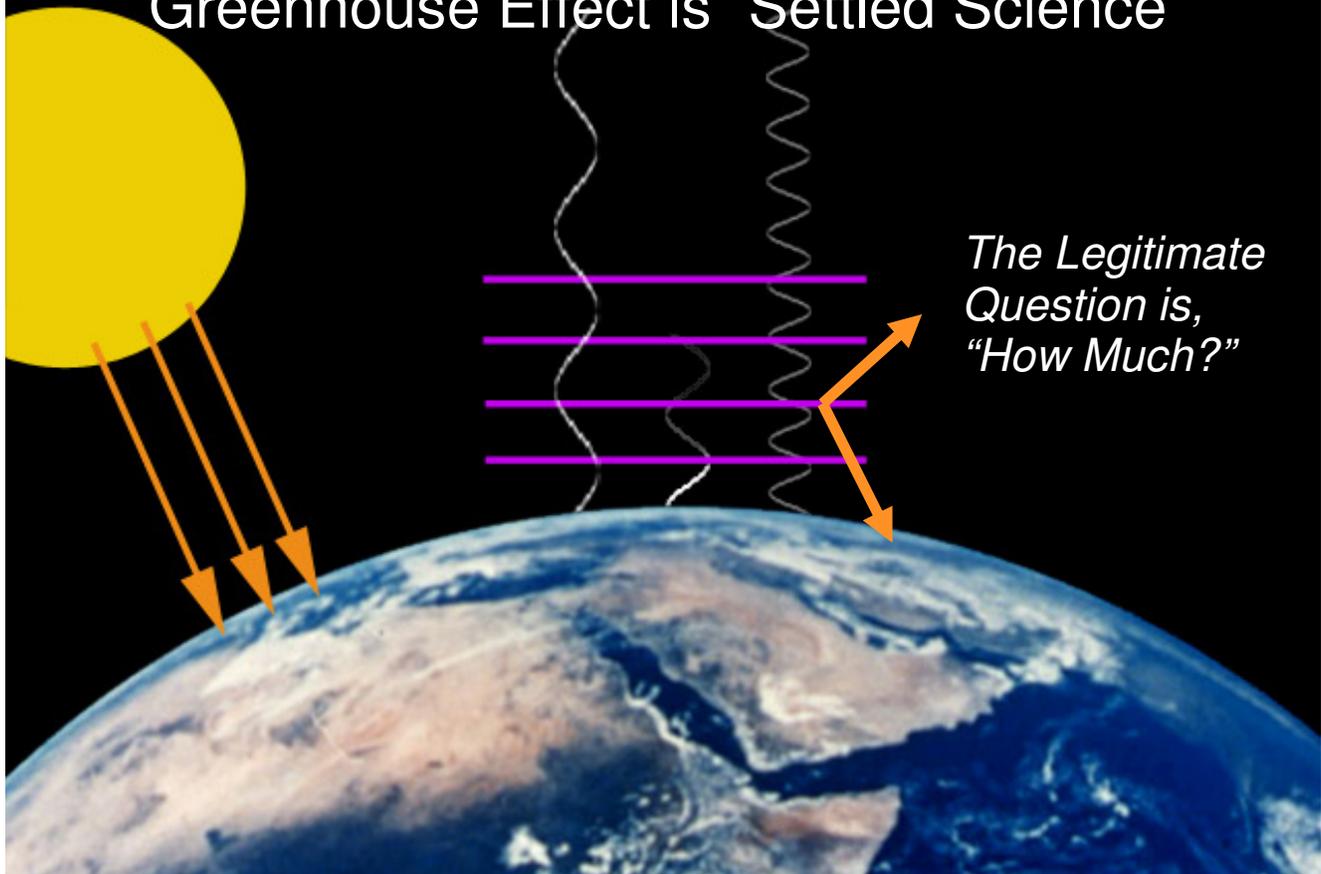
Five Key Climate Questions

- Is the world warming?
 - *Yes, but historic record likely overstated, and there has been no warming in last 10-15 years*
- Is that warming due to man's CO₂?
- Will future man-made warming be substantial?
- Will we see catastrophic effects from warming?
- Do CO₂ abatement laws like cap-and-trade make sense?

And so, the conclusion is that there almost certainly has been warming, though temperatures have been flat for the last 10-15 years. And past warming likely has been overstated due to biases in the surface temperature record, with several studies estimating that as much as half the warming in the surface temperature record may be due to uncorrected urban biases.

So, the world has warmed since the little ice age ended in the early 19th century. Now I'm going to ask how much of that warming is from CO₂.

The Existence of Warming from the Greenhouse Effect is "Settled Science"



Here is an analogy I use a lot. Take your cell phone. If you have been using it, the battery case is probably warm. In fact, one can say it is "settled science" that the electronics in your phone produce heat. But does that mean cell phones are the primary driver of the temperature in your room? Probably not. The air conditioning system, the weather when the door is open, our body heat -- all have a lot more to do with temperature changes than does your cell phone.

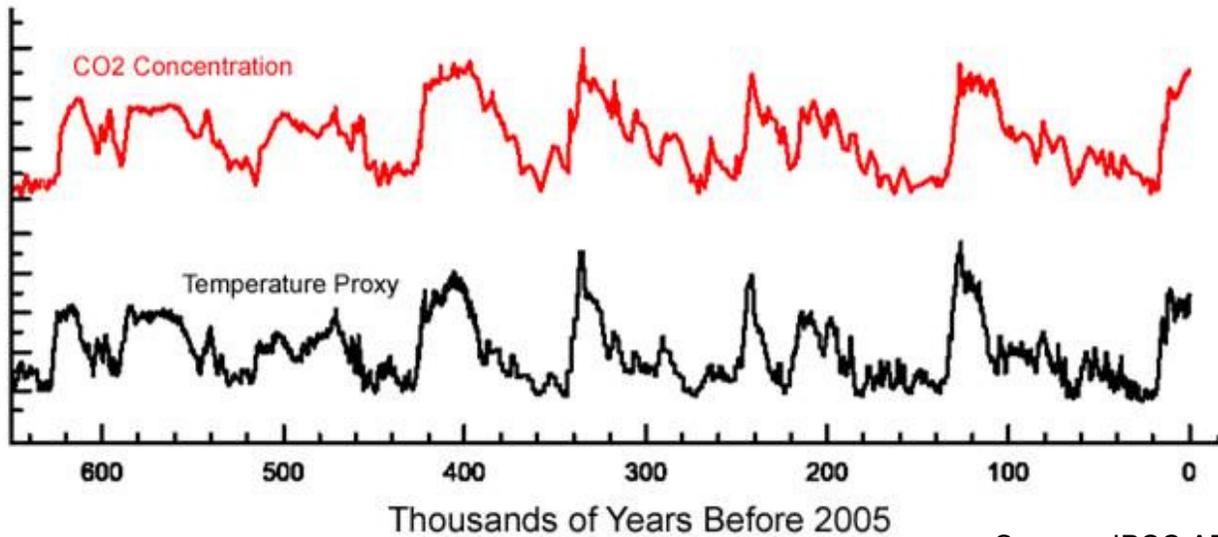
I am always amazed when strong manmade greenhouse warming advocates declare that their "proof" is complete once you admit that CO₂ and other greenhouse gasses can cause some warming. But the fact of some warming is not as important as its magnitude. We are looking at investing literally trillions of dollars on CO₂ abatement because of a promised catastrophe, not some minor warming. So it matters whether, outside the lab and in the complex climate system of the Earth, CO₂ causes a trivial amount of warming or a lot.

So the question with CO₂ boils down to: Is it the cell phone, warming the room but by a trivial and nearly undetectable amount? Or is CO₂ more like the room's thermostat, acting as the primary driver of temperatures? To put the question more in the parlance of climate science, is the climate system's temperature sensitivity to CO₂ large or small?

I am going to discuss three important arguments alarmists have made to try to try to prove that CO₂ is a substantial rather than a trivial driver of global temperature changes.

Early Ice Core Studies Seemed to Have Found the Smoking Gun

CO₂ appeared to be a strong driver of global temperatures...



Source: IPCC AR4

The first of these three "proofs" of a high climate sensitivity to CO₂ was used by Al Gore in his movie. Gore is obviously much cooler than I am because if you saw the movie *An Inconvenient Truth*, he presented this chart spanning across six giant screens – that must be a pretty fun way to present. And this for a long time was the smoking gun of CO₂ alarmism. Before I talk about what the chart means, I want to discuss how it was created.

We want to look at climate, thousands, even hundreds of thousands of years ago. But obviously, the Geico caveman did not have a thermometer. He wasn't writing temperature numbers down on his cave wall. And so, we have to find a different way of taking temperatures without actually using thermometers. And the way we do it is we look for natural processes that layer themselves.

An obvious example is a tree. Trees have layers - they are called rings -- one ring per year. You can match each tree ring to a particular year. And so, if tree rings somehow had some information in them about climate, we could match this information to a particular year. For example, scientists posit that tree rings are wider in warmer years and narrower in cooler years (actually its more complicated than this, looking at something called late season growth, but the concept is the same). This tree ring data is called a "proxy" for temperature.

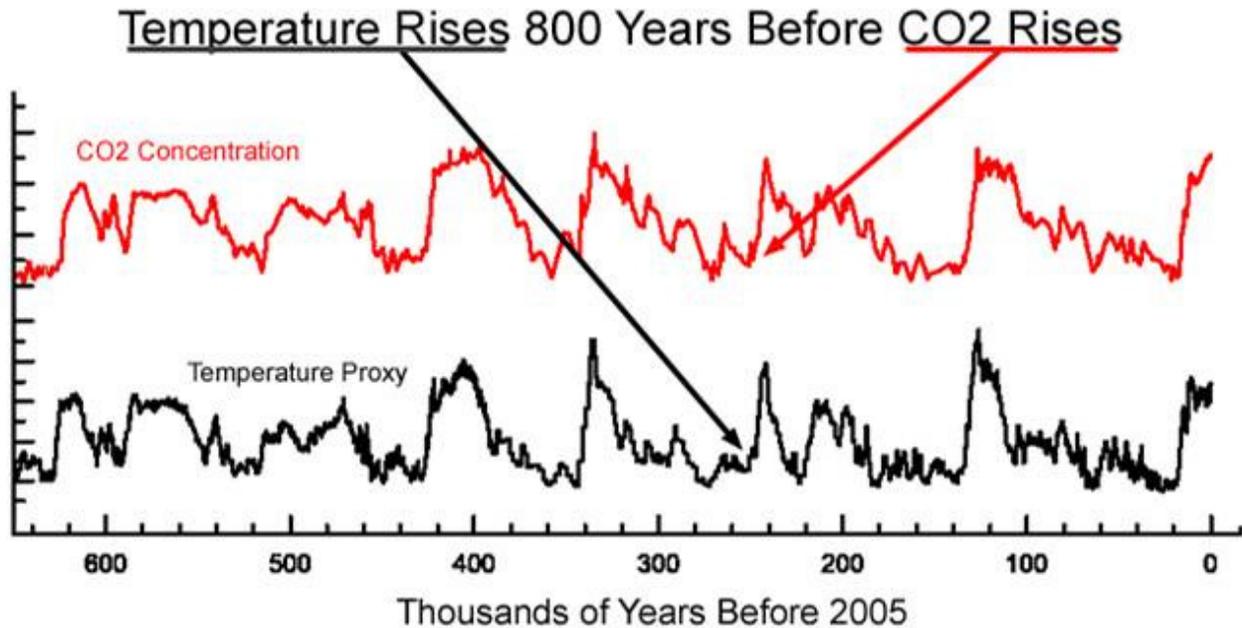
Another such potential proxy is sediments at the bottom of the lake. Every year, runoff and rivers wash new sediments into the lake. One might look at those sediments and their contents, again matching layers to years, to derive information about plant growth or pollen types and perhaps form a hypothesis about what the climate was like in these years.

Stalactites and stalagmites are another example of layering that sometimes contains climate data. Ditto peat bogs. But the resource that was first used was ice -- Ice in Greenland and Antarctica, places where once ice is laid down it seldom melts. One can actually drill cores through the ice, just like oil companies do in potential oil-bearing strata. Like with the tree rings, one can match different layers of the ice to different time periods. And from samples taken from these layers researchers can infer the regional temperature when the ice was laid down. They do this by measuring the ratio of certain oxygen isotopes in the ice; they can also measure the composition of microscopic traces of trapped air in the ice to figure out how much CO₂ was in the atmosphere when the ice formed. This is what was done in the chart above.

Just looking at this chart, one has to say, "wow!" As Al says, these two lines fit together. It's just unbelievable. You almost never see independent variables correlate this closely. This looks like CO₂ is the main thermostat of the climate system, not just the irrelevant cell phone. This was a smoking gun.

Source: figure TS.1 and figure 6.3 of the Fourth IPCC Climate Assessment

More Careful Measurements Have Reversed the Findings



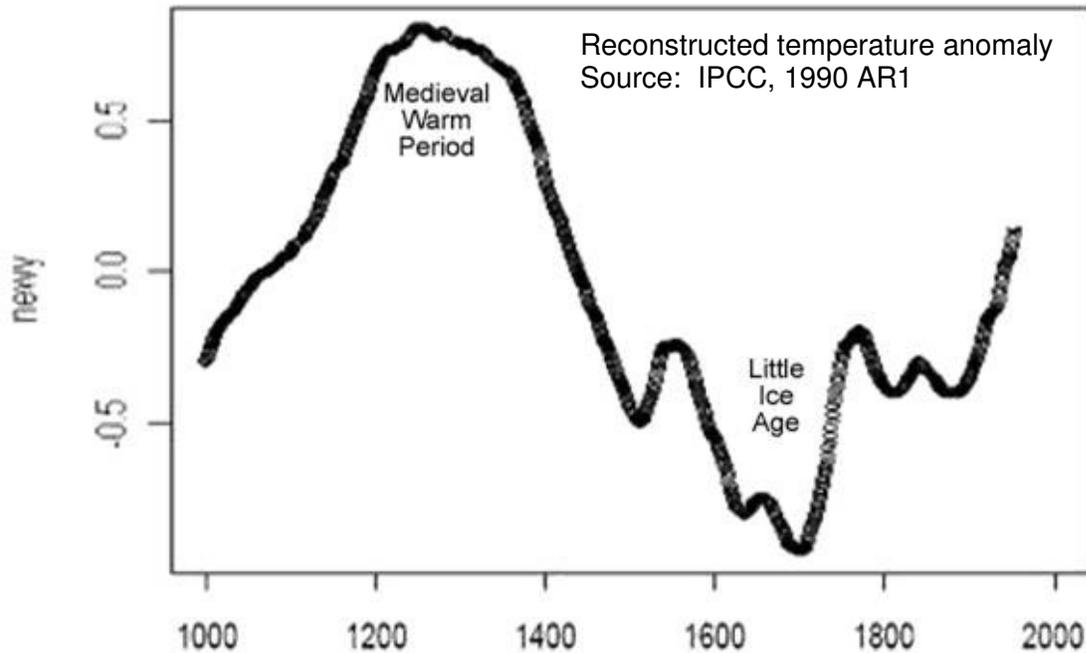
But scientists have gotten better at doing this analysis. While we really would like to be able to sample annual layers from the ice, we just aren't that good (and besides, who wants to take 600,000 samples?) But over time scientists have been able to take finer and finer slices. One of the things researchers found as they took finer and finer slices is that these two curves weren't exactly matched, that in fact the temperature was rising on average 800 years *before* the CO2 was rising. That obviously posed a causality problem. It's like having a body hit the floor and then two minutes later, the suspect fires his gun. It's hard to call the suspect a murderer when his gunshot occurred after the victim died.

As you can imagine, we don't really treat this analysis as proof any more of a high climate sensitivity to CO2. And I suspect that Gore knew it too, even at the time of his move, because he doesn't just say "case closed, QED." You have to watch his words, but he says something like, "Well, the relationship is complicated but these lines move together." Well, that's a really wimpy way to state your case, particularly given how devastating the correlation seemed to be in his chart.

What most scientists currently think happened is that rising temperatures actually caused the rising CO2 levels, rather than the other way around. The oceans actually hold far more CO2 than the air does. The oceans contain substantial dissolved CO2, but their ability to keep CO2 dissolved reduces as the water gets warmer. And so, when the oceans heat up, they release CO2 into the air. And that is what is probably happening in this chart. Temperatures rise and oceans heat up, releasing CO2 into the atmosphere which causes the concentrations to rise.

Source note: This result has been confirmed by many studies, resulting in lag values of 800-2000 years, and the basic finding is not in dispute. One example was Lowell Stott, Axel Timmermann, Robert Thunell: "Southern Hemisphere and Deep-Sea Warming Led Deglacial Atmospheric CO₂ Rise and Tropical Warming" Science, 2007

Early IPCC Reports Found Current Temperatures to be Unexceptionable



OK, so much for ice cores. Let's look at "proof" number two that CO₂ is the primary driver of the warming we're seeing. This analysis is best known as the hockey stick, originally from Michael Mann. To understand this analysis, it is first useful to review some history.

Back in our naive days, before we knew that CO₂ was the cause everything, the IPCC itself produced this analysis of temperatures over the last 1000 years. You can see what we call the Medieval Warm period, though we think now the dates here are a bit late. And you can see a cold period called the little ice age in the 17th and 18th centuries. And you can see temperatures today higher than they were a century ago but not outside of the range of the last 1000 years, and likely still cooler than in the Middle Ages.

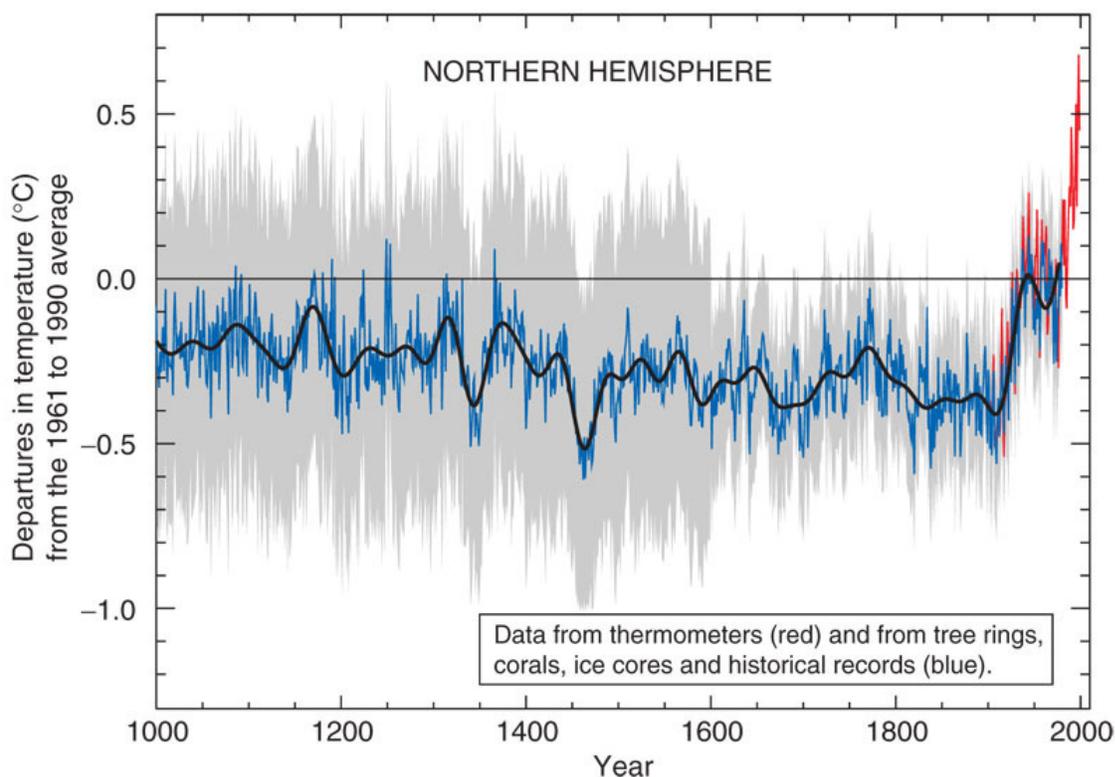
In fact, it was the end of the Medieval Warm Period that caused a whole series of cold weather and crop failures which led to famines which many historians say may have weakened the population making it more susceptible to the black death of the mid 14th century. It was also during this period of time that the Vikings colonized Greenland, which they did not call glacier-cold-uninhabitable land; they called it Greenland. Similarly, we have other historical records pointing to a time period potentially warmer than it is today, including records of vineyards in the UK growing grapes where it is too cold to grow them today.

Similarly, we have a lot of historical evidence for the little ice age as well. It actually corresponds with the solar phenomenon called the Modern Minimum, a time where sunspot activity was very low indicating a relatively dormant period in the sun's output. We have narratives of skating on the Dutch canals and ice fairs on the Thames. Towards the end of this period, we have Washington's terrible winter at Valley Forge and Napoleon's losing battle with the Russian winter of 1812.

But its hard to create a panic about warming when temperatures are below historic levels where humanity demonstrably prospered. Which is why a small cadre of climate researchers set out to eliminate the Medieval Warm Period from the historical record.

Source: IPCC first climate assessment, 1990

Mann's Hockey Stick Purported to Show Recent Warming as Unprecedented



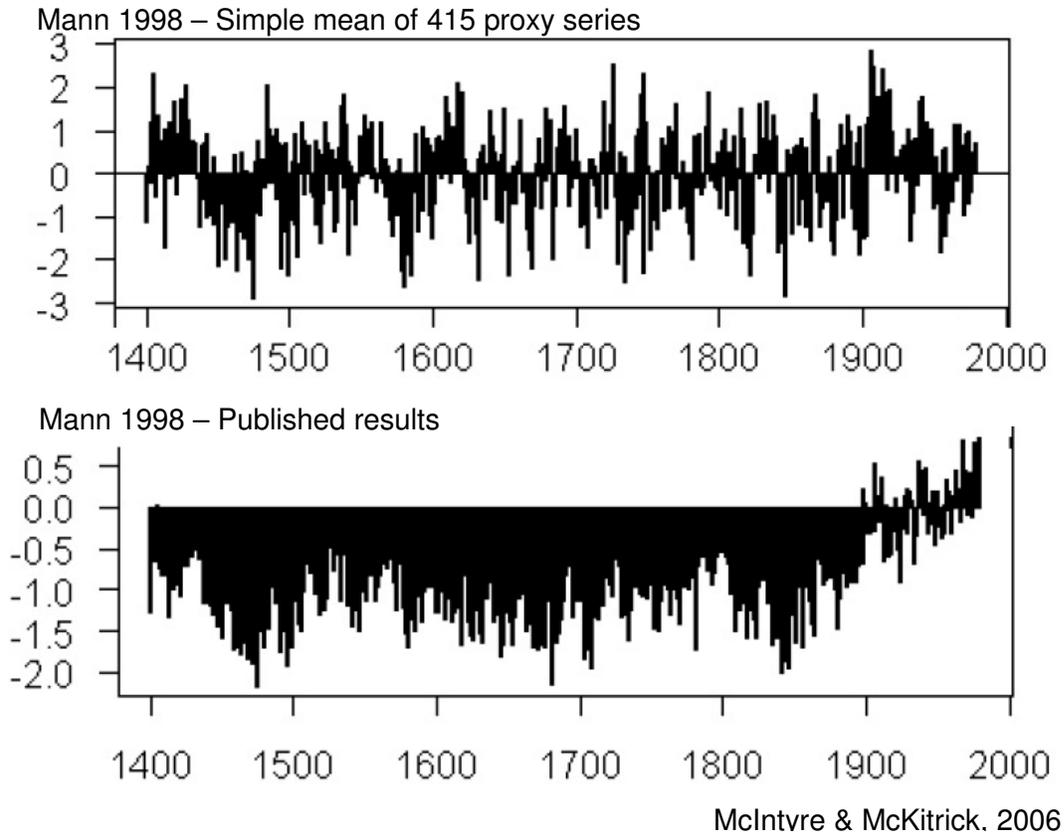
This is the data series from Michael Mann that Al Gore showed in his movie, though he incorrectly attributed it as "Dr. Thompson's thermometer" (apparently he or his staff pulled the wrong chart out of a published journal for the movie). This same analysis was the centerpiece of the IPCC third assessment. To create this chart, Michael Mann and his team used tree ring data to reconstruct temperatures over the last 1000 years. He used about 400 or so different tree ring samples or proxy series. From this analysis he concluded, "There's no Medieval Warm Period. There's no Little Ice Age. And temperatures have been astoundingly constant for a thousand years until we started burning fossil fuels and then temperatures took off in an unprecedented manner."

If this were the true picture, one would say, "Gee, maybe we are doing something unusual to the climate. Maybe these climate alarmists have a point, because it surely looked like Earth's temperatures were awfully stable until we started burning stuff."

The whole issue of the hockey stick has resurfaced again of late with the release of internal emails from the CRU at East Anglia University. These emails seemed to point to a range of either sloppiness or outright malfeasance in temperature reconstructions like the hockey stick, so much so that a number of prominent alarmists have declared that the hockey stick doesn't matter and never really was critical evidence, an odd claim since it was clearly the featured, centerpiece analysis of the third IPCC assessment and was given significant coverage in the fourth assessment as well as in Al Gore's movie. So, if for no other reason than to open a window on the scientific process, I will give this and subsequent reconstructions a bit of attention.

Source: Mann, 1998 via the IPCC Third Assessment

“Novel” Statistical Methods



The first issue that comes up over and over in evaluating many tree ring studies like that by Mann is one of statistical method. I have had the opportunity to visually inspect over a thousand proxy series, and it is hard to escape the conclusion that there are very few hockey stick shaped curves in the individual proxy data – perhaps 5 in every hundred. So it is no real surprise to be that if you take Mann’s original 450 tree ring proxies and you just take a simple mean, it looks like the top graph. The average output from the proxy series just looks like random noise, certainly with no discernable hockey stick-shaped trend.

Source: McIntyre and McKittrick, 2006

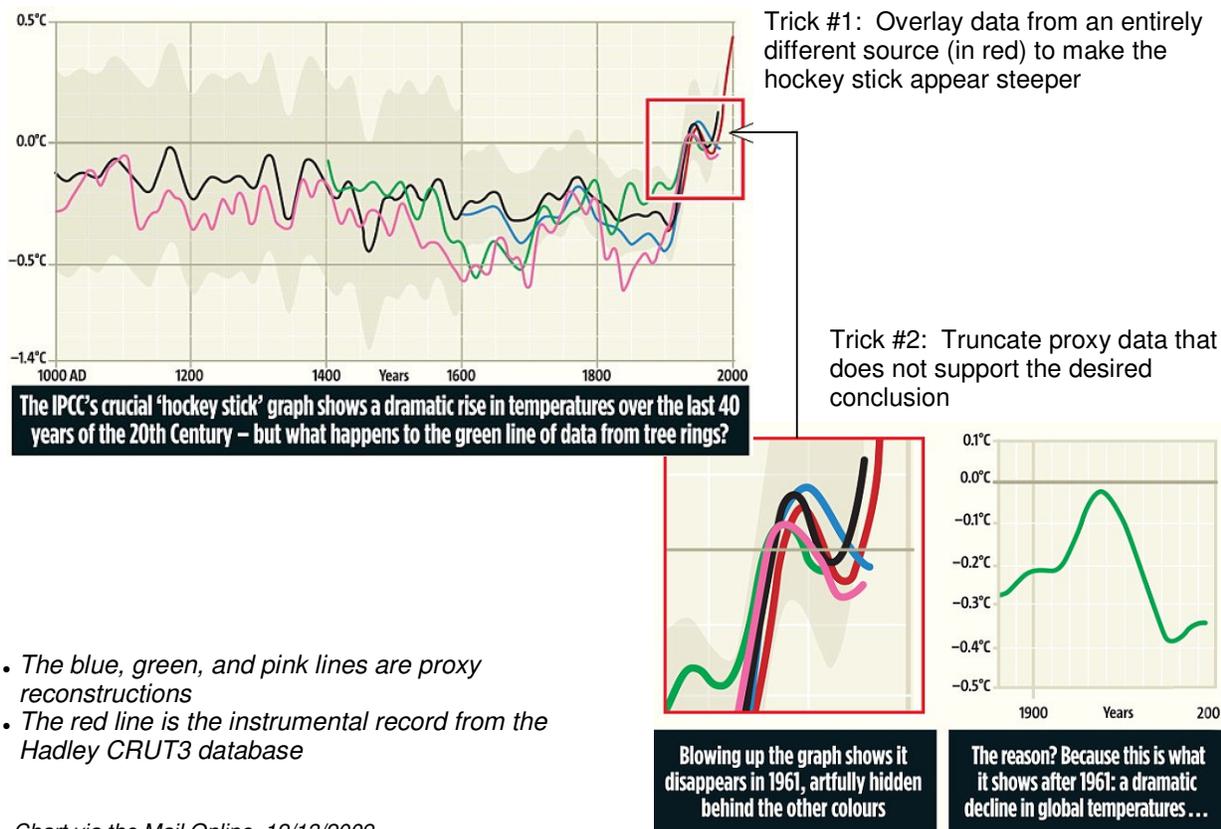
A Few Proxy Series (<5% of the total) Drive the Result

- Multiple studies, but they are not independent
 - Same researchers, same reviewers
 - Different proxies at the margin, but all use a core of 2-3 proxies known to drive hockey stick results
- McIntyre & McKittrick (2005) showed the Mann methodology used and re-used by these studies
 - Creates hockey sticks from random noise
 - Seeks out and overweights HS shaped proxy series
- High-Altitude southwest US bristlecone pines were for years the “secret sauce” to make hockey sticks
 - Questionable proxy – are we measuring rainfall, temperature, or CO2 fertilization?
 - Many modern anthropogenic factors
 - Proxies used by Mann and others have not been replicated by more recent work (Ababneh 2007)

An experienced statistician but climate amateur named Steve McIntyre started looking into the hockey stick years ago. Because he couldn't understand what statistical methods Mann was using to get hockey stick averages from raw data that didn't seem to contain hockey stick shaped data series. And what McIntyre eventually demonstrated was that Mann had created an algorithm that essentially mathematically cherry picked hockey stick curves in the data set and emphasized them with large weights in the final rollup. So much so that McIntyre was able to feed Mann's algorithm randomly generated proxy series, essentially noise, and obtain hockey stick shaped results.

At the end of the day, trees make really bad thermometers. Sure, they may grow more or less rapidly depending on the temperature, but they can also change growth rates based on precipitation, changing soil chemistry, and even changing CO2 in the atmosphere. Further, the relationship between growth and temperature may not be linear, and may even change over time. It turns out that a lot of the trees Mann used are actually fertilized by CO2. That means they grow faster when there's a lot of CO2. So have his trees grown faster over the last 100 years because they are measuring temperature, or CO2?

“Hide the Decline”



Many of you may have heard of a reference to “hiding the decline” from the CRU email scandal. I will use a nice graphic from the Mail Online to illustrate an example of one such obfuscation. The chart in question actually takes advantage of two graphical “tricks” to exaggerate the hockey stick shape of the curve and hide data that does not support the author’s conclusions.

The top chart shows three proxy series, including ones by Michael Mann and Keith Briffa, as they were reported on the cover of a key climate report. The three proxy series are in pink, green and blue and the instrumental temperature record is overlaid in red.

The first trick is that the big uptick in the hockey stick does not come from the proxy data, but from the overlaid instrumental data. Sure, these two data sources seem to match really closely between about 1900 and 1950, but that is because they are forced to match by their authors – this is the calibration period where the proxy series coefficients are set. However, once the calibration period is over, one can see that the instrumental records and the proxy series values immediately diverge.

The best analogy I can offer is that the proxies are a dog on a leash until about 1950, so it is no surprise they stay close to their master. But the real test is what happens when the leash is taken off, and in the case of these proxies, they quickly wander far away. The proxies don’t show a steep slope during the 1950-2000 supposedly “anthropogenic” period.

This does not mean, of course, that temperatures have not risen over the last 50 years just because the tree rings say they have not. The point, however, is that if the proxies are not following the current uptick in temperature, then they may well have not followed upticks in the past, casting doubt on the conclusion that these proxies somehow prove temperatures have been flat and stable for a thousand years. Again, further evidence that trees make bad thermometers.

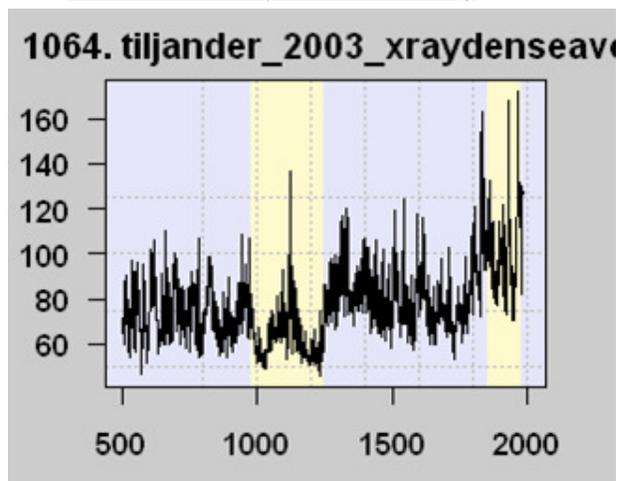
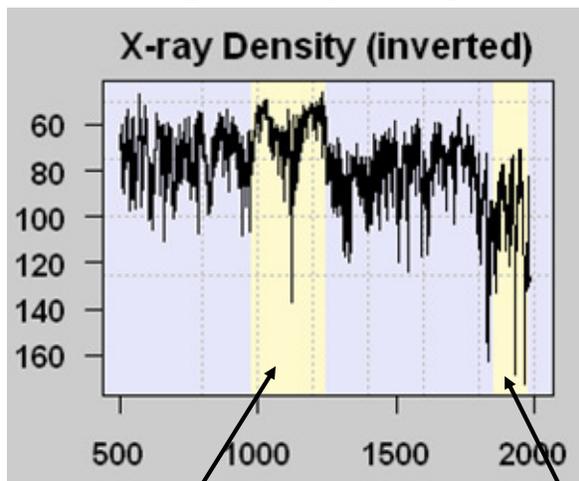
The second trick is perhaps more blatant and less ethical, and is illustrated on the lower right. For a reason never explained in any document in which this chart was included, the green line (Keith Briffa’s series) was cut off around 1960. The reconstructed Briffa data above shows that this was pretty clearly done to hide a sharp decline in the proxy data. Again, the proxy data should closely follow actual temperatures up to about 1950 as this is the period that they are “on the leash.” But once let off the leash, they quickly go in the exact opposite direction as the instrumental record. While this may in part be because the instrumental record is exaggerated in some of the ways we discussed previously, the main reason for this again is that these tree rings and other such data series do not appear to be very reliable proxies for temperature. If they fail so miserably in measuring temperatures that we have a pretty good handle on, how can we trust them to be correct for temperatures in 1400? And this is the problem the scientists were trying to hide.

Flipping Proxies Upside Down Tiljander Sediments Example

Warmer Year → More Organic Matter in Sediment → Lower X-ray Density

Original Proxy Findings

Mann 2008 (and others) Used the Proxy Upside-Down to Show Hockey Stick Warming



Medieval Warm Period

Sediments Disturbed by Agriculture
(e.g. proxy meaningless in this period)

I probably have already taken more time than I should on these reconstructions, but I can't resist one more example, again from Mann, this time from a more recent study. Here is a proxy series based on layers of lake sediments in Finland. This is how the proxy works: In warmer years, more things grow, and more organic matter can be found in a particular layer of sediment. This organic matter reduces the density of the sediment, so the lower the density of a year's layer, the higher the organic matter and therefore higher the implied temperature. In this series, you can see a Medieval Warm period (in yellow), with some really crazy cold data for that last 100 years. We might expect from an initial inspection of the data that unless there is something climatically anomalous about Finland, this might not be a very good proxy. And, in fact, the researchers who originally gathered this data determined that the last 100 years of data were probably corrupted by manmade agriculture, deforestation, and disturbance of the sediments over the last century.

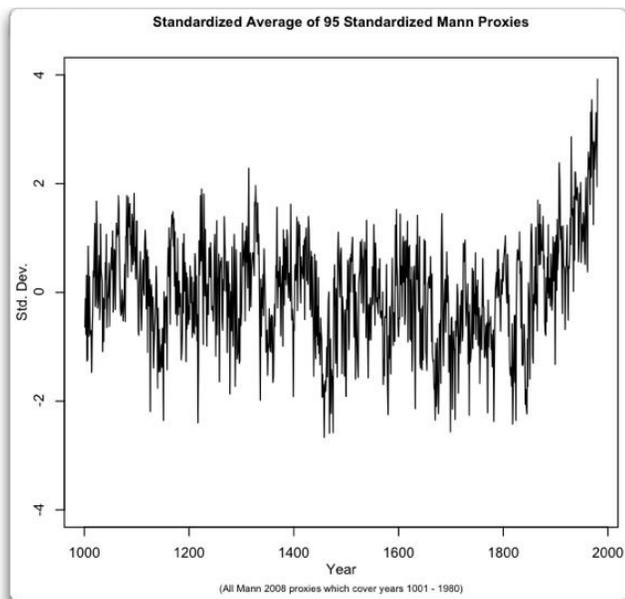
So enter again Michael Mann. Climatologists putting together these studies claim that they do not cherry pick the proxy series that give the answer they want, but the fact is that despite there being well over a thousand proxy series from various studies, the same twenty or thirty get used over and over again, and what these have in common is that they reliably produce hockey stick results.

When Mann approached these Tiljander sediment series, he did two things. First, he kept the data known to be corrupted from the last century. And then, his algorithm flipped the chart upside down and used the proxy in reverse. So now he has a series with a Medieval cool period and incredible hockey stick warming in the last century.. He basically used this upside down Tiljander sediments four times to create his newest hockey stick.

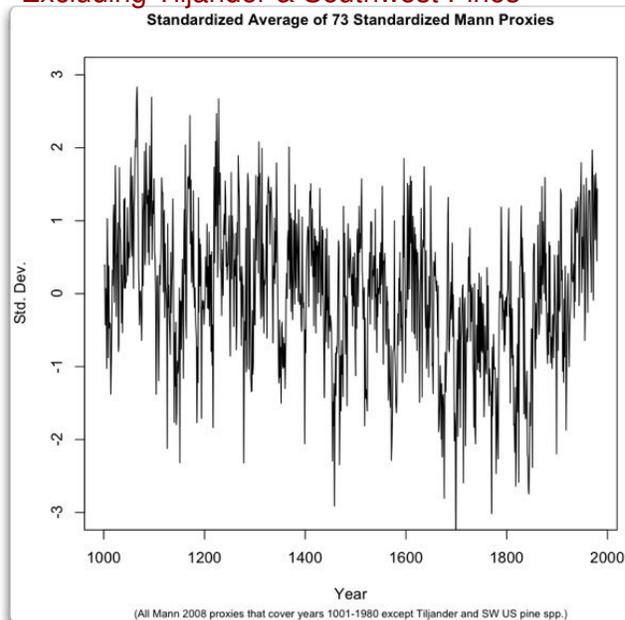
Source: McIntyre, 2009. <http://www.climateaudit.org/?p=7599>, among others

Excluding Tiljander Sediments and SW Pines Changes the Entire Answer

Mann 2008 Long-Term Proxy Average



Mann 2008 Long-Term Proxy Average
Excluding Tiljander & Southwest Pines



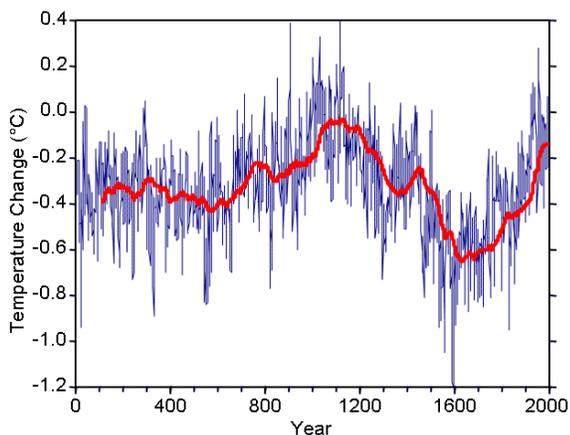
Eschenbach, 2008

If you leave these four series out of his numbers, and if you remove the some strip bark bristlecone pine tree ring series from Southern California that are hotly contested as a reliable proxy, the hockey stick goes away. In fact, you get a chart very similar to the one we started with, showing a medieval warm period and little ice age.

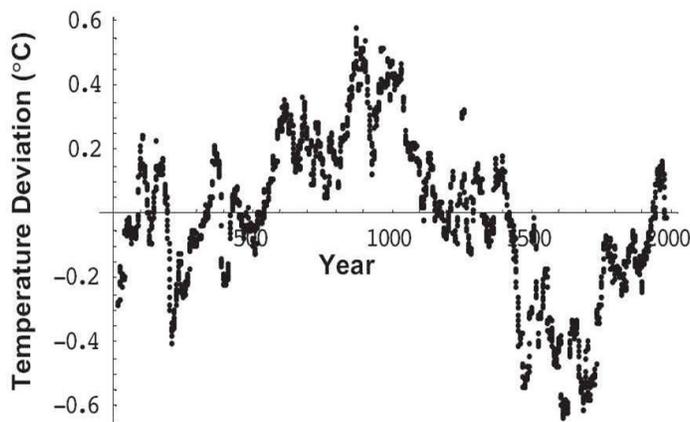
Source: <http://www.climateaudit.org/?p=4428>

Proxy Studies Without These Questionable Series Take Us Back to the Traditional View

Moberg, 2005



Loehle, 2007

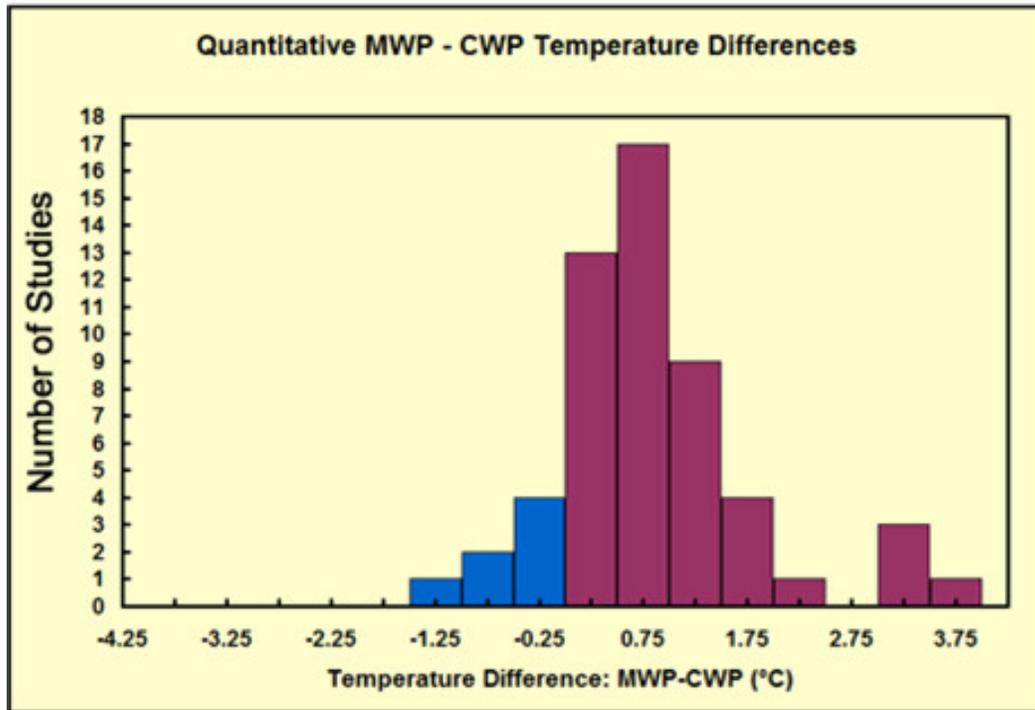


Medieval Warm Period, Little Ice Age, and Temperatures Today That Are Not Unprecedented

So a combination of cherry-picking, questionable statistical practices, and outright data abuse produce hockey sticks. Several folks have tried to step back from the Mann hockey team approach and to use a fair selection of less controversial proxies. Two such researchers are Moberg, who is generally considered a strong global warming supporter, and Loehle who is more of a skeptic. And lo and behold, it comes right back to where we started. We get the Medieval Warm Period around 1000. We get a Little Ice Age. And the temperature today is similar or even lower than those in the Middle Ages.

So, we're right back to where we were 20 years ago, after a little ten year diversion via the hockey stick.

Comparing the Medieval Warm Period to Today ⁴⁵



Center for the Study of Carbon Dioxide and Global Change

One last note – here in the Phoenix area is the Center For The Study Of Carbon Dioxide And Global Change. They have a project where they catalog all the published proxy series, asking a simple question: Does the proxy show temperatures in the Middle Ages higher or lower than today, and by how much. We can see that the vast majority of these published proxies show that the Medieval Warm period was warmer than it is today, by about a degree Fahrenheit.

Current Lead Argument: Warming Caused By Man Because We Can't Think of Anything Else It Could Be

Per Dr. Richard Lindzen of MIT:

What was done, was to take a large number of models that could not reasonably simulate known patterns of natural behavior (such as ENSO, the Pacific Decadal Oscillation, the Atlantic Multidecadal Oscillation), claim that such models nonetheless accurately depicted natural internal climate variability, and use the fact that these models could not replicate the warming episode from the mid seventies through the mid nineties, to argue that forcing was necessary and that the forcing must have been due to man. (Lindzen)

So much for proxy studies as proof of a strong relationship between CO₂ and warming. That's two down. Which brings us to the third argument for a high climate sensitivity to CO₂. Remember again that we are not talking about proof of CO₂'s ability to act as a greenhouse gas -- we know that it acts as a greenhouse gas in the laboratory and we know that in a meta sense that greenhouse gasses warm the earth. What we don't know is the amount of warming that results from incremental increases in CO₂ concentrations -- is it large or small?

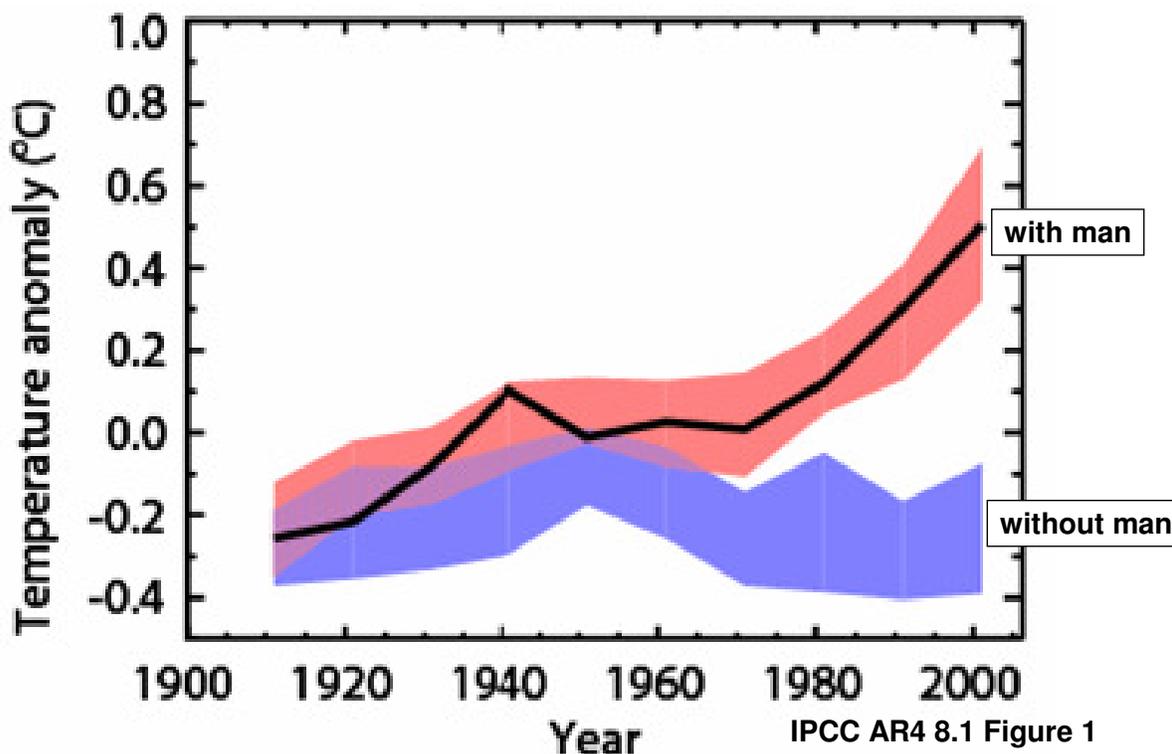
The third argument that the warming can be large from even small changes in concentrations of CO₂ comes from the IPCC fourth report and is really the dominant current argument for high sensitivities. As you may know, scientists have built computer models to try to emulate the behavior of the Earth's climate. None of these models even come close to modeling the complexities of the actual climate system. For example, most are unable to explain multi-decadal ocean cycles much less longer term climate cycles such as the decent into and out of the little ice age. Nevertheless, climate scientists used their models to try to duplicate the actual temperature history of the last 50 years, and unsurprisingly, they failed to do so.

Now, I might have said this leads to the conclusion that we don't have a full understanding of the climate and that our models are simplistic and flawed. However, climate scientists concluded something entirely different. They said "Because the models can't duplicate the increases in global temperatures over the last 50 years of history, then these increases must be due to non-natural factors, i.e. due to CO₂. The temperature increases since 1950 couldn't have been natural because our climate models that are supposedly based on nature couldn't reproduce them.

In effect, the entire theory that most of the late 20th century warming is caused by manmade CO₂ is based on the deep scientific finding that "well, we can't think of anything else it could be." Dr. Richard Lindzen of MIT has a great quote I will share

"What was done, was to take a large number of models that could not reasonably simulate known patterns of natural behavior (such as ENSO, the Pacific Decadal Oscillation, the Atlantic Multidecadal Oscillation), claim that such models nonetheless accurately depicted natural internal climate variability, and use the fact that these models could not replicate the warming episode from the mid seventies through the mid nineties, to argue that forcing was necessary and that the forcing must have been due to man"

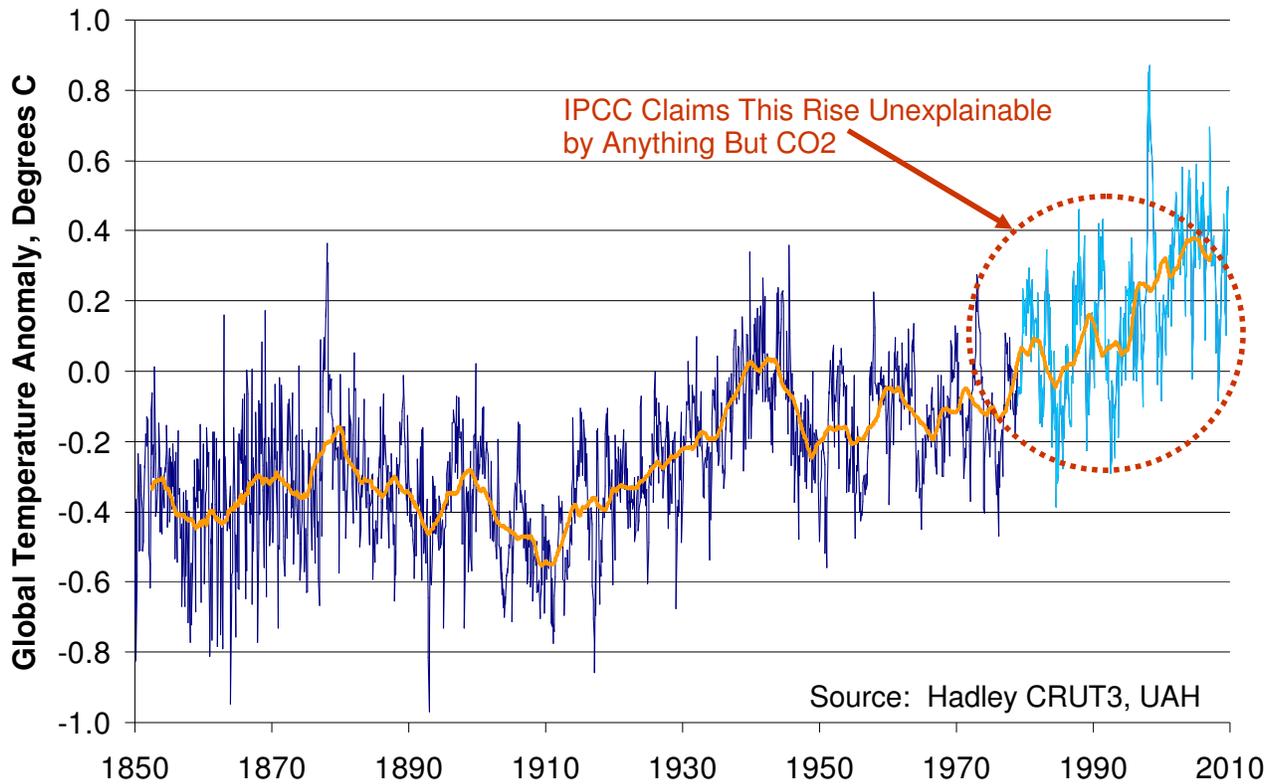
IPCC Models Say Nature Would Have Cooled Without Man



Here is an illustration in graphical form of this logic, from the fourth IPCC assessment. The black line is a highly smoothed temperature history for the last 100 years (though exaggerated because they chose the peak year of 1998 as an endpoint). The blue band is what their models tell them would have happened without anthropogenic or manmade effects – as you can see, the models apparently project that the Earth would have cooled over the last 50 years without increased CO₂ from man. The pink band is the output from their models after assumptions for CO₂ increases are added. The conclusion they draw is that because the models are unable to match history considering only natural effects but can emulate history when they include CO₂, then CO₂ must be causing the warming.

I don't know how many people out there are familiar with computer modeling, perhaps in the financial world, but this is incredible hubris. Give me a few hours and I can force any model to match history. To actually bet real money that such model results are correct in the future just because we have tweaked the model to match history is madness, a sure way to bankruptcy – which come to think of we have seen a fair amount of on Wall Street recently

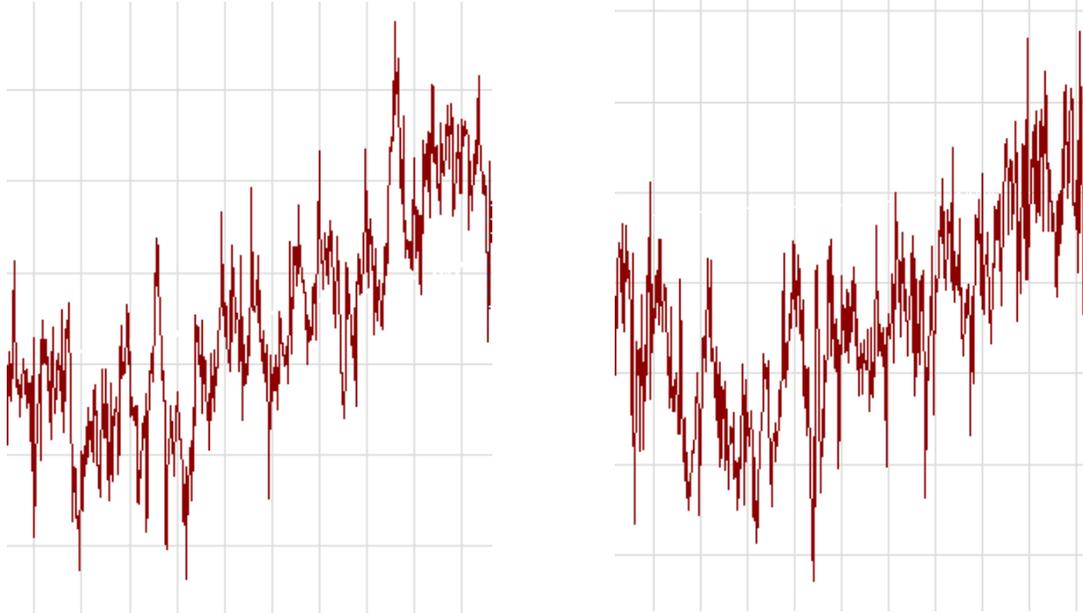
Climate Alarmists Claim 1970-2000 Temperature Rise Must Be Due to Man



Just to be specific, here is our temperature history we have been using. We have been talking about the IPCC's claim that it is impossible to explain temperature increases since 1950 by natural factors alone, but since temperatures were flat for the early part of this period, what we really mean is that climate scientists believe it to be impossible to explain the temperature increase from about 1975 to 1998 by natural factors alone – this is the area I have circled on the chart.

Two 51-Year Periods: Which Is Man, And Which is Mother Nature?

One Period is 1895-1946 (“nature”) and the other Period
is 1957-2008 (supposedly “Anthropogenic”)

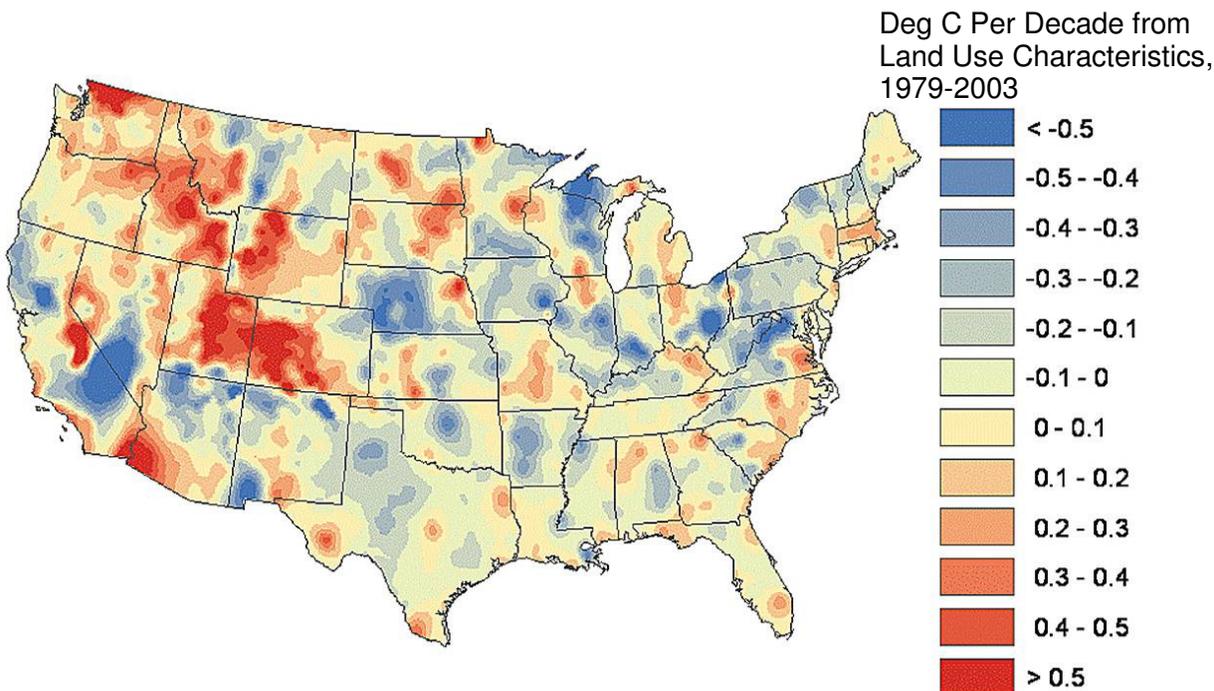


Both time and temperature scales are the same between graphs

I'm going to show you four alternate explanations for the late 20th century warming other than manmade CO₂, but before I do that I wanted to pose a fun little exercise that I think illustrates my point. Here are two graphs of global temperature over a period of 50 years. Each graph has the same temperature and time scale – in fact both were just cut and pasted from the same larger graph. One of these charts is of the period 1957-2008, a period in which the IPCC says that global temperature increases can't be natural but must be manmade. The other is from 1895 to 1946, a period with little manmade CO₂ where temperature increases almost have to be natural. These two periods sure look the same to me. How can one of these historical temperature increases be natural but the other supposedly so steep and fast it can't be natural, when the two look nearly identical?

Source: Hadley CRUT3 global surface temperature record. Both graphs are scaled exactly the same (in fact are crops from the same image). The graph on the left is 1957-2008. The graph on the right is 1895-1946

Omitted: Land Use Changes Affect Temperatures



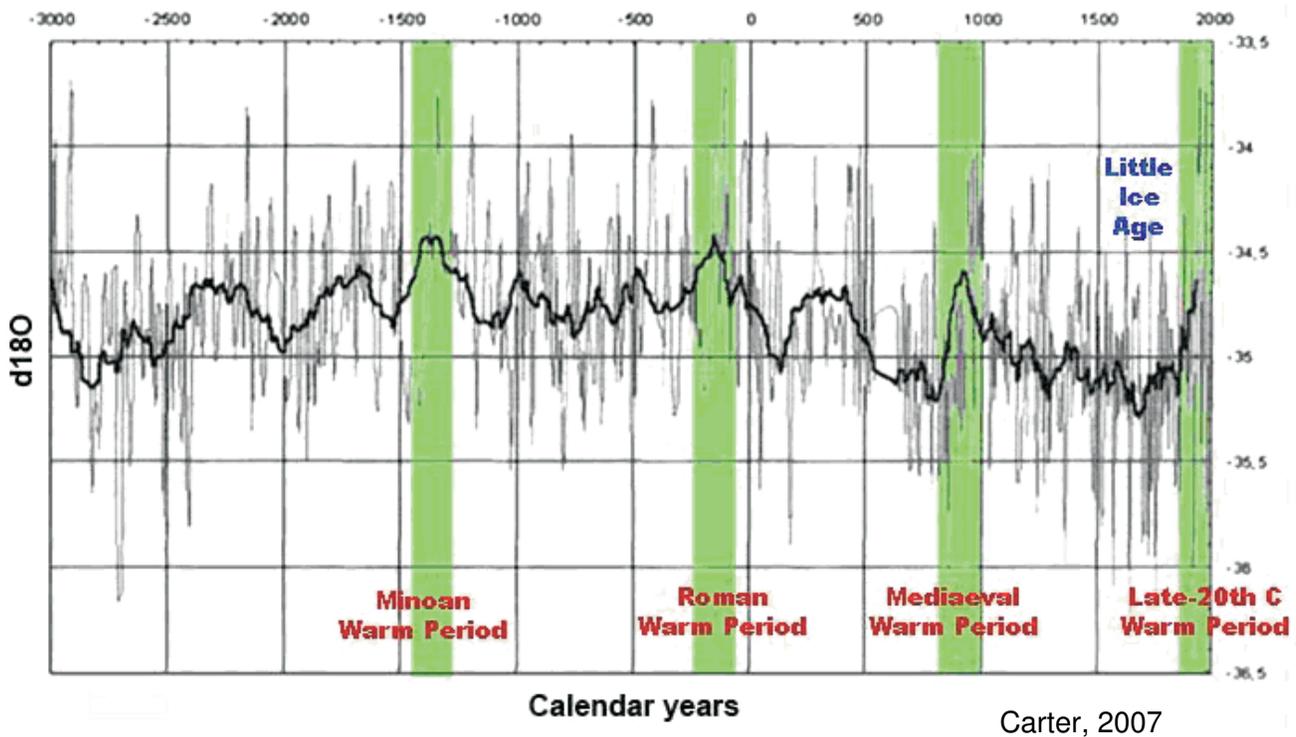
Fall, S., D. Niyogi, A. Gluhovsky, R. A. Pielke Sr., E. Kalnay, and G. Rochon, 2009

Now, as promised, I am going to show you four potential alternate explanations for the measured warming in surface temperature since 1950, all of which are at least as plausible as manmade CO₂. I am not saying that any of these is the one and only cause – likely it is all of these plus manmade CO₂ plus other effects we do not yet even understand, interacting in an incredibly complex way. But I think they will show you how absurd it is to rely on imperfect climate models to tell us that CO₂ is the only possible forcing that could have caused late 20th century warming.

The first of the four alternatives I will offer is land use. We have already talked about man's land use changes – remember my son and I measuring the Phoenix urban heat island effect as 6-10 degrees Fahrenheit of warming. Recent studies have shown that nearly all of man's land use changes tend to cause warming, from building cities to tearing down forests for agriculture. This particular chart is from a recent study that claimed that most of the warming we have seen in the United States over the last 50 years can be explained by land use changes alone. So changing land use is one possible explanation of recent warming.

Source: Fall, S., D. Niyogi, A. Gluhovsky, R. A. Pielke Sr., E. Kalnay, and G. Rochon, 2009

Omitted: Recovery from the Little Ice Age

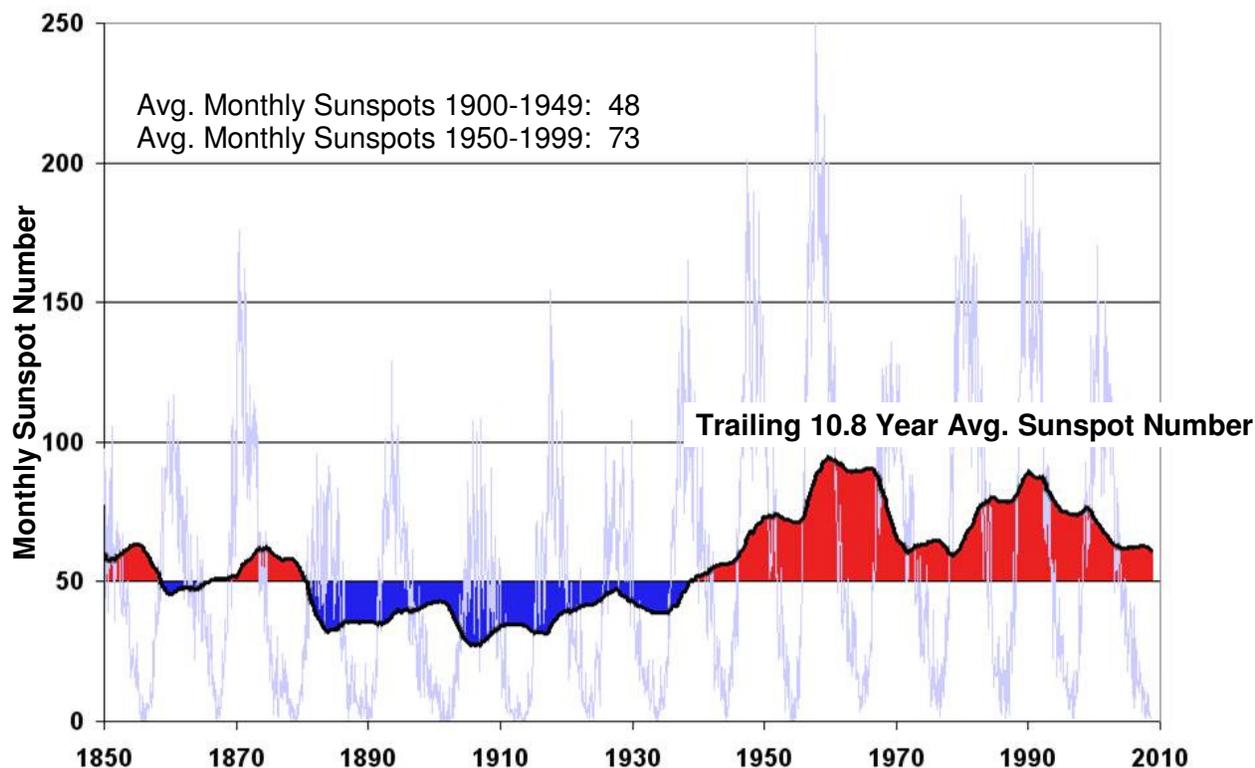


Here's number two: Recovery from Little Ice Age. We talked about the Little Ice Age a bit already, the several hundred year very cool period in the seventeenth and eighteenth centuries. Remember the ice core analysis that Al Gore showed over 600,000 years? In this chart we're zooming in on just the last 5,000 years of that data. So, here we are today. Here's the Mediaeval Warm Period. Here's the Little Ice Age.

The first thing you can see here is a monotonic 1000 year cycle of warm and cold in the context of which recent warming seems entirely consistent with history. The second thing you can see is that not only was the little ice age cold, it was one of the two or three coldest periods in the last 5000 years, or since the development of human civilization. In fact, the seventeenth and eighteenth centuries may have been the coldest sustained period civilized man has ever experienced. And, coincidentally, it was right in the middle of this period that man invented the thermometer. I have always wondered how much our perceptions of whether recent warming is unusual are colored by the fact that we began measuring temperatures at perhaps the coldest point in 5000 years.

So our second possible explanation is that we are just experiencing natural warming as part of a recovery from the little ice age. We are going to see more data to support this proposition later, as glacier retreat and sea level data since 1800 are much more easily explainable as a continuous recovery from the little ice age rather than as a peculiarly recent phenomenon.

Omitted: Sun Has Been Unusually Active in Last 50 Years



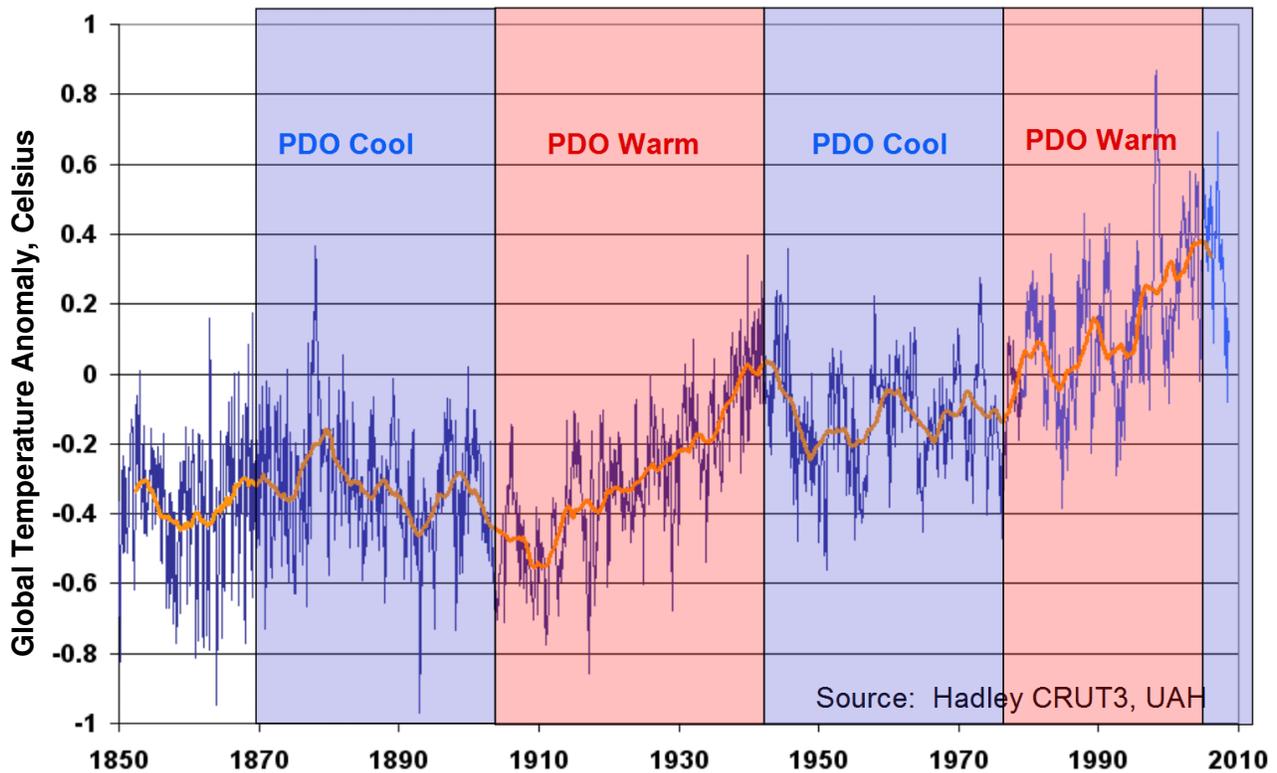
The third potential explanation for some of the recent warming is the sun. It is frankly hilarious watching climate alarmists try to deny the sun has anything to do with climate variability. It's a fascinating spectacle. Over the second half of the century, when warming supposedly can't be explained by natural factors, the sun was far stronger than in the first half of the century.

One way to measure the activity level of the sun is to look at sunspots – when the sun is more active, we typically see more spots. This chart shows the sunspot count by month for the last century or so. Since sunspots follow an 11 year cycle, I have applied an 11-year moving average. I think it is pretty obvious that the sun has been substantially more active in the second half than the first half of the century.

Now, there are a lot of reasons why this may not be enough activity to explain all the warming. Another measure of the sun's output, solar irradiance, only changes by a small percentage from the early to the late half of the century, though there are some theories being tested right now explaining how solar output might be magnified by their effect on cosmic rays and cloud formation. Never-the-less the sun is yet another likely contributor to recent warming.

[Chart note: The light blue lines that spike up every 11 years or so is the monthly sunspot number. The black line is a 10.8-year moving average, chosen to smooth the sunspot number across an entire cycle. The number 50 was chosen as an arbitrary reference point to visually demonstrate that the 2nd half of the century has higher activity than the first half. International sunspot number by month, ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_NUMBERS/MONTHLY]

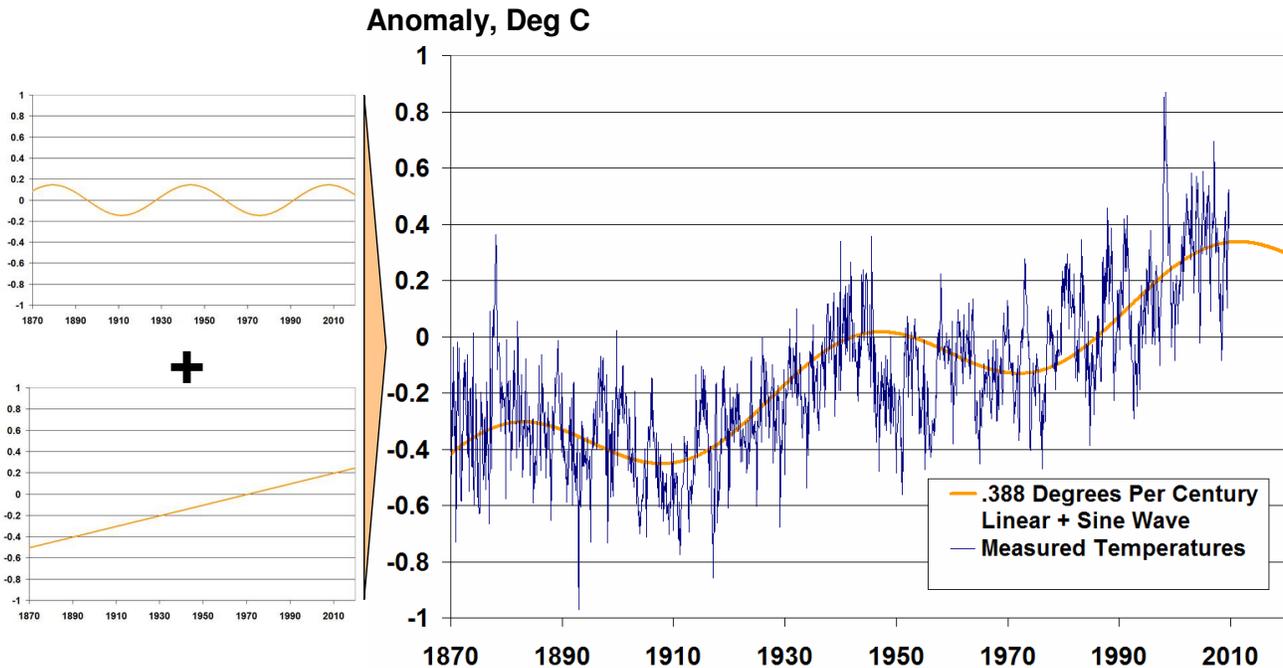
Omitted: The Pacific Decadal Oscillation Has An Enormous Effect on Temperatures



The fourth warming suspect is multi-decadal ocean cycles.. This is an important flaw in most climate models as nearly all admit that they don't include these ocean cycles in their algorithms. I am going to over-simplify, but the oceans have circulation patterns that change every 20 or 30 years. In some of these cycles, the oceans act to bury surface heat in the deep oceans, and in other cycles the oceans bring this buried heat back to the surface.

I think it is fairly clear from looking at this chart, which has the same surface temperature record we have been using in this presentation overlaid with the warm and cold cycles in the Pacific Decadal Oscillation or PDO. We can see a pretty strong correlation between the slope of the temperature curve and the phase of this one ocean cycle -- temperatures are falling to flat in the cool cycles, and they rise in the warm cycles, as in the key period from 1978-1998. The scientists say that the warming in this period has to be man made, because their models cannot replicate the actual temperature trends -- but their models leave out the PDO and other ocean cycles.

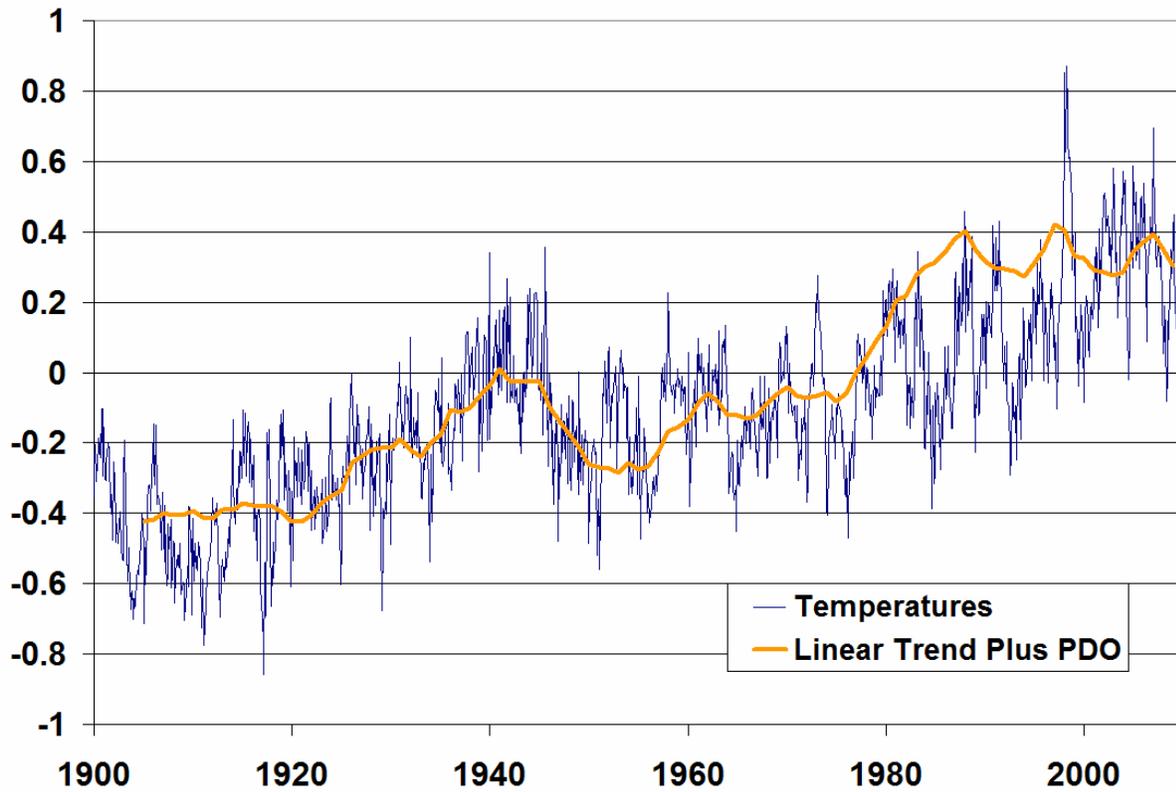
Historic Temperatures Can Be Modeled with a Constant Linear Trend + A 60-Year Cycle



I decided to try an experiment. I wanted to see if temperatures over the last 100 years could be explained by two natural factors -- a linear rise in temperatures, as a recovery from the little ice age, and a sine wave representing a rhythmic ocean cycle. Note that neither of these shapes is what you would see if anthropogenic CO₂ were the main driver -- you would see a rising curve of increasing slope that matches the rapid growth in CO₂ output in the latter half of the century. So I took a 20-30 year cycle and combined it with a .04 degree per decade linear trend, as shown on the left.

When I combined the two (in orange) and overlaid them on the temperature trend, you can see a pretty good fit. Now, this doesn't necessarily have any physical meaning. Correlation can be accidental (a fact alarmists tend to have a selective memory of). But it does give the lie to the proposition that there are not any possible explanations of late 20th century warming other than CO₂. Alarmists argue that the late 20th century represents a discontinuity from previous times where temperatures were driven by natural factors rather than CO₂, but we can see from this chart it is perfectly possible to explain the recent temperature rise as being consistent with the same mechanics that dominated the early part of the century.

Modeling Historic Temperatures with PDO + Linear Trend



Just to take it one step further and make it more real and less theoretical, here is the same analysis with the hypothetical sine wave replaced by the actual values of the Pacific Decadal Oscillation, showing that 20th century temperatures, both early and late, are explainable by a linear trend plus cyclic variation.

Five Key Climate Questions

- Is the world warming?
 - *Yes, but historic record likely overstated, and there has been no warming in last 10 years*
- Is that warming due to man's CO₂?
 - *Likely "some," but probably not "most"*
- Will future man-made warming be substantial?
- Will we see catastrophic effects from warming?
- Do CO₂ abatement laws like cap-and-trade make sense?

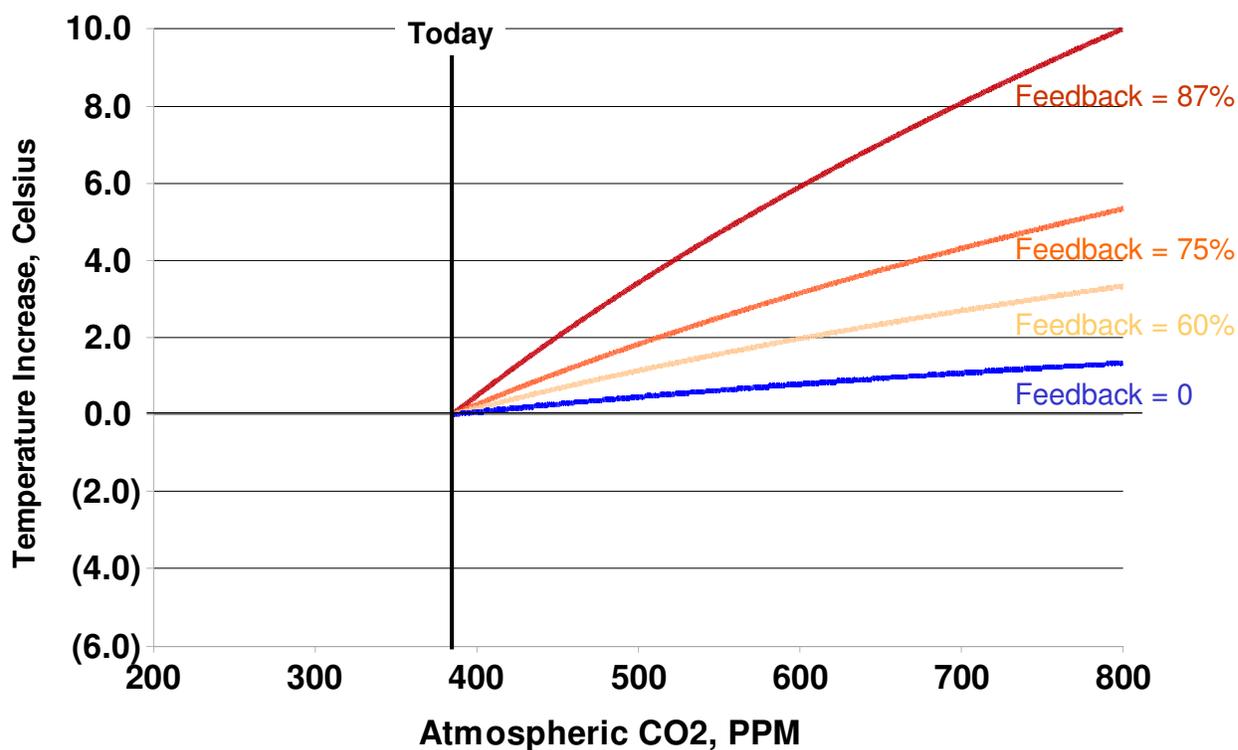
Alarmists always say that skeptics don't offer any alternate explanations for recent warming. Well, we don't really have to, any more than we have to find an alternative story to how your socks went missing if you were to argue that invisible aliens were hiding in your closet and stealing them. But nevertheless, I have offered four alternatives, four potential natural effects that are all likely to have been partial contributors to the warming in the critical period from 1978-1998. Add in CO₂ and we get five contributors. And there probably are several more drivers in our complex climate systems we don't even understand yet.

The net result? CO₂ from man has probably caused some of the historic warming, but more likely in the range of a couple of tenths of a degree than the majority.

Though the world has warmed, there's not really a smoking gun that CO₂ is the primary driver of that warming. It may have driven a small part of the warming, in fact likely has created some warming -- we don't know how much -- but we do know there are many other natural factors that have also helped contribute to the rising temperatures of the last 100 years.

So, now we can get to the really controversial part -- the climate models

Feedback Assumptions for IPCC Forecasts are VERY High

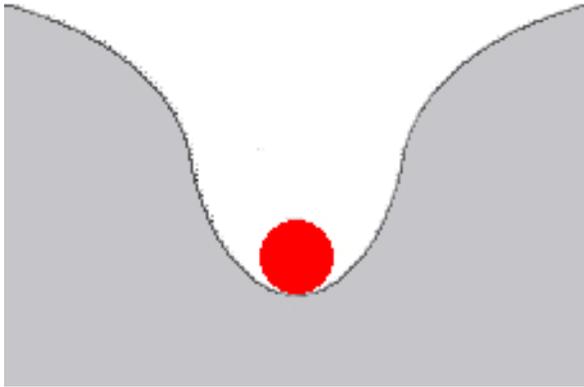


Remember this chart? These are various forecasts of warming vs. CO2 concentration that I showed earlier -- the only thing I've changed is I have shifted the axes a bit to give myself some extra room to extend these lines. As a reminder -- this is the CO2 concentration range we expect to be at toward the end of the century. This is where we are now. And this is approximately where we started in the mid 19th century. [in video, pointer moves respectively from about 700ppm to 385ppm to 270ppm]

Source: The non-feedback formula is from the IPCC fourth assessment. Feedback calculations by author, and are based on the formula: $G=1/(1-f)$ where G is the total gain or multiplier and f is the percentage feedback. Feedbacks $f>1$ result in infinite gains. Feedback $1>f>0$ are positive feedbacks that accelerate or intensify a process. Feedback $f<0$ is negative feedback that damps or slows a process. See notes for slide 19

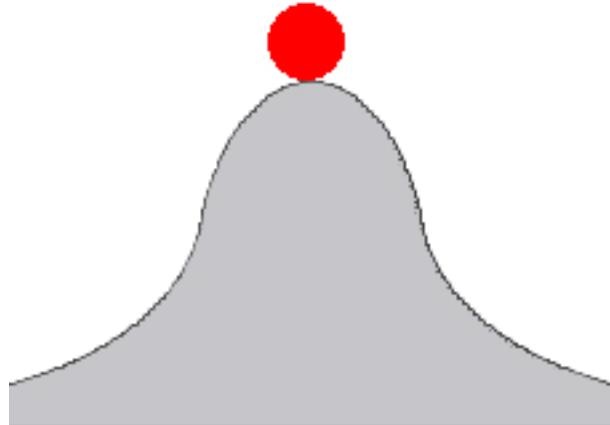
Positive Feedback is Unusual for Long-Term Stable Natural Processes

Negative Feedback



- Disturbances are damped
- System remains near its starting point, though it can oscillate

Positive Feedback



- Disturbances are amplified
- System may end up far from its starting point

How can Mann (very narrow temperature variation over 1000 years) and assumptions of very high positive feedback both be right

There's one thing I didn't tell you about feedback the first time around. Here's an analogy for you: if I'm found on my kitchen floor with a knife in my back and my wife is standing there, the police are probably going to think of her first as a suspect. When a spouse is murdered, the police know that in a high percentage of cases, the other spouse did it. Experience has taught them some rules of thumb of what is and isn't probable.

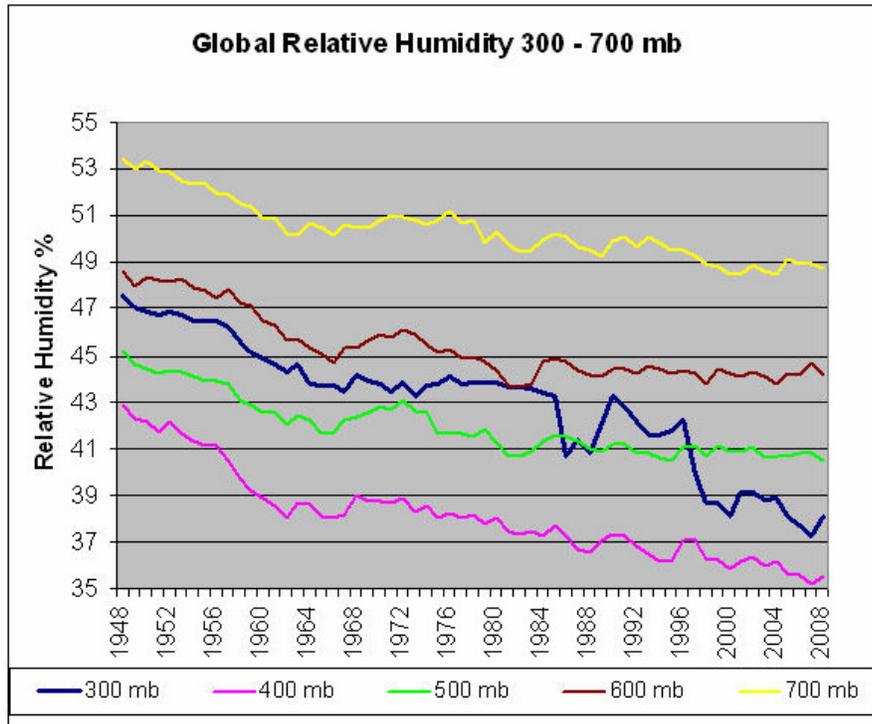
When a natural scientist looks at a natural process that is new to her, she is going to assume that process is driven by negative feedback, especially if that process has been stable for hundreds of millions, even billions of years. Take climate - it has been fairly stable within certain bounds for millions of years. Just look at Michael Mann's hockey stick, where he says that temperatures have been dead flat for a thousand plus years.

But this hypothesis of incredible stability is hard to square with the positive feedback hypothesis we discussed before, that the climate is a car perched on the top of the hill, needing only a small nudge for it to roll out of control. This strong positive feedback case, and in particular the tipping point phenomenon that alarmists are always talking about in the news, make no sense -- they defy any intuition a natural scientist might bring to a complex process. Long-term stable processes are not balanced on the top of a mountain where they could be tipped over the edge, or else they would've already been tipped over the edge long ago. Something would have sent that car down the mountain millions of years ago if it was really so precarious. The same is true with climate.

So, the natural scientist tends to assume negative feedback dominates most stable natural processes. Of course, we cannot just rest on this assumption. There are natural processes dominated by positive feedback (though typically not as strong as the feedback assumed by climate models) and there are a few spectacular processes that have tipping points and runaway feedback - nuclear fission is one example.

I will deal directly with a couple of the larger positive feedbacks, and then try to offer a more elegant approach to get a handle on the net of all possible feedbacks.

Atmospheric Moisture Content Not Growing as Fast as Modeled



Models assume flat relative humidity as temperatures rise, but in fact it has been falling.

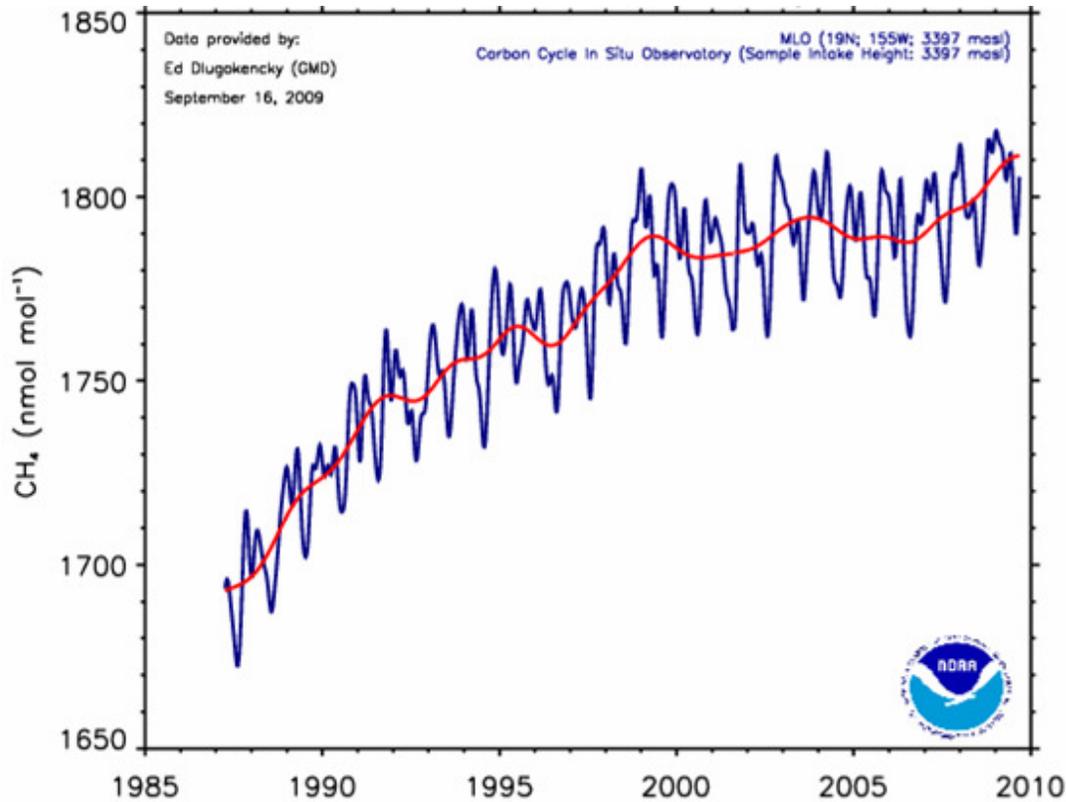
The most important feedback factor, positive or negative, is moisture in the air and its effects are both critical and poorly understood. Everyone agrees that warmer weather puts more moisture in the air, but does it show up as an increase in humidity, in high clouds, or in low clouds? Some of these may have positive feedback effects, some negative.

Most all of the climate models assume that as the world warms, the relative humidity stays constant. Relative humidity is a measure of how much water vapor is in the air compared to how much water the air could contain at a given temperature and pressure. And that carrying capacity increases as the air gets warmer, meaning that warming with a constant relative humidity results in an increase in total water vapor in the atmosphere.

It turns out, though, that as we have warmed over the last 50 to 60 years, relative humidity at most levels of the atmosphere has actually fallen off. So, the models are actually wrong here. They're overestimating the increase in water vapor from rising temperatures, and thus overestimating feedbacks and total warming.

Source: Data via KNMI climate explorer, compiled by Ken Gregory (http://www.friendsofscience.org/assets/documents/The_Saturated_Greenhouse_Effect.htm). Further discussion here <http://www.climateaudit.org/?p=5416> including Partridge, 2009

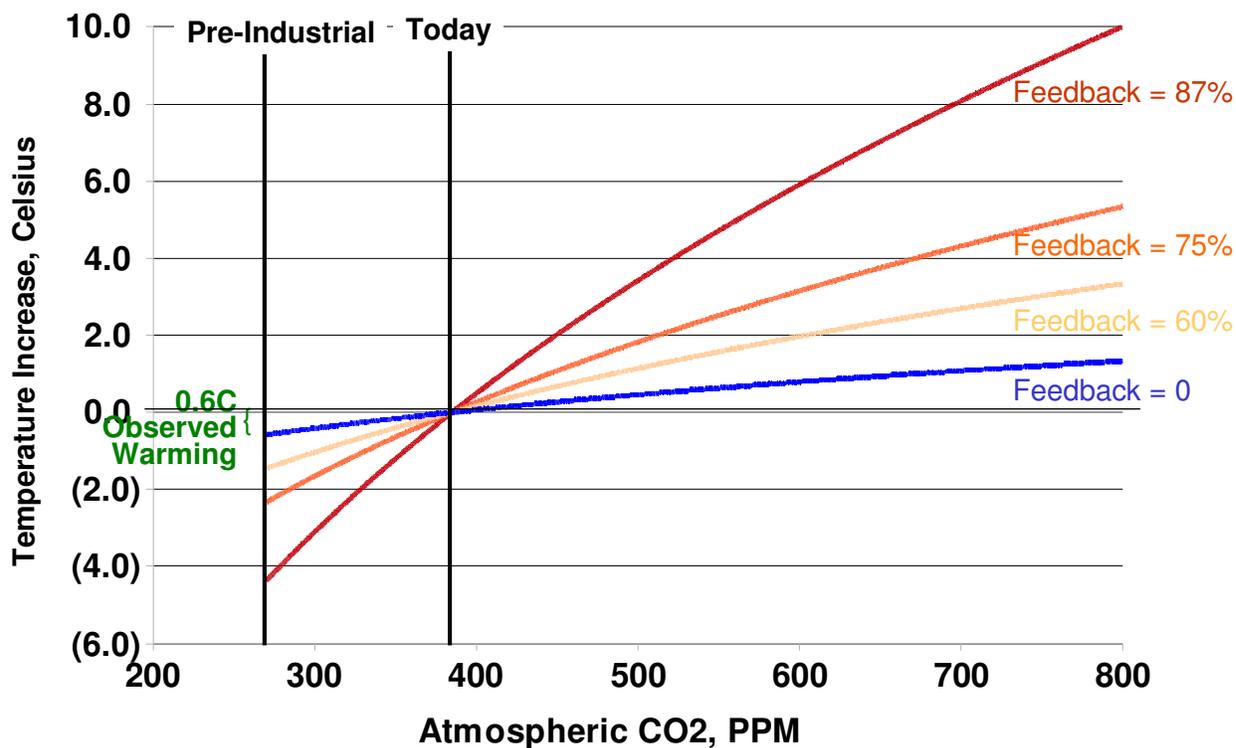
Methane Growth Slowing, Not Accelerating



The other positive feedback effect I want to discuss briefly is methane. Methane is the hot talking point in the catastrophist camp right now. Just do a Google search, you will see all kinds of articles about manmade warming causing methane to be released from melting Arctic tundra, which in turn has a warming effect as methane is a much stronger greenhouse gas than CO₂. The alarmists are all saying that methane release is accelerating and increasing faster than ever due to man.

But this is simply not true. Methane has been increasing, true, over the last decades, but in fact the rate of change is actually decreasing, not accelerating. It is doing exactly the opposite of what we might expect were the methane positive feedback theory correct.

High Feedbacks Greatly Over-Predict Past Warming



But I said I had a better and more elegant way of getting at feedbacks and the climate's sensitivity to CO₂. The key is that if a certain sensitivity and feedback level exists going forward in models, it has to exist going backwards in history. Physics that apply in 2050 have got to apply in 1850 as well. If we have strong positive feedback in the future, it had to exist in the past as well. Since we have been measuring CO₂ and temperature, however imperfectly, for a century and a half or so, we can extend these forecasts backwards into the past to see how well they explain past warming.

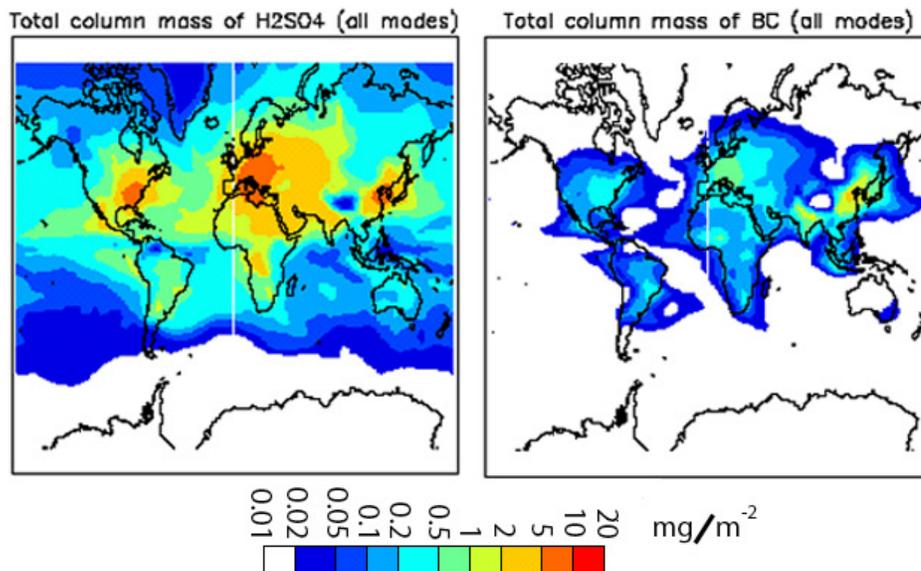
So we can ask, to believe this 10-degree forecast, what do we have to believe about past warming? As you can see, we would have to believe that we've already had 4 C of warming.

Of course there is probably a time delay, maybe 10-15 years, but this changes the answer only a small amount, by a few tenths. We still find ourselves in the position, to support high positive feedback forecasts, of having to believe that there have been levels of warming way beyond what we have actually observed -- remember I showed that we had seen perhaps 0.6C of warming over the last century, and even that may have been exaggerated by measurement biases. And that 0.6C is for all warming effects combined, so that warming from CO₂ is only a portion of that number,

So, we might say that warming from CO₂ historically, with all these other effects, was maybe a couple of tenths of a degree. That means the actual sensitivity curve should go through a point about here [between the blue line and the 0 degree line], which would put us in the negative feedback zone. Which is exactly where a natural scientist would assume the process operated, and would imply a total warming from man-made CO₂ over the next 100 years of less than one degree C.

Sulfates & Black Carbon too Localized to Mask Substantially

Atmospheric Sulfates & Black Carbon



If they cover 40% of the land area (10% of the world's surface), it takes 10C of local masking to lower world temps 1C

So, the amount of warming we've seen historically is consistent with negative, not positive, feedback. But climate scientists say all the time that their models accurately describe past warming. To some extent, this means that they have managed to tweak and tune their models to spit out something like the 20th century temperature profile. I was a financial and economic modeler for years, and the typical technique is to use what I call a "plug" variable, or an arbitrary variable whose value in each period is set to exactly match what one needs to make the model spit out the desired output. For climate modelers, one such plug variable is aerosols. Aerosols are solid and liquid particles in the atmosphere that can reflect solar radiation back into space and thus have a cooling effect on the Earth. They can be of natural and manmade origin -- manmade aerosols typically are byproducts of combustion and industrial activities, and include things like sulfur dioxide and soot or black carbon.

I am actually not going to talk much about black carbon, as the evidence is increasingly equivocal as to whether its net effect is cooling or warming. I personally believe that black carbon soot from Asia is in part responsible for recent summer melting events in the arctic. So let's focus on the sulfate aerosol concentrations on the left. Sulfate aerosols, unlike CO₂, are short lived, so that they tend to be concentrated downstream of the industrial areas that produce them. These aerosols are concentrated near parts of North America, Asia, and Europe, and cover perhaps 10% of the globe.

The appeal of man-made aerosols as a plug figure is that, unlike CO₂, we have a pretty good understanding of how to run an industrial economy while limiting the output of these aerosols. Countries like the US are already well on the way to reducing their emissions of these aerosols, and most countries will follow suit over the coming decades. So if these aerosols are assumed to have a large cooling effect today, they can help plug the gap between reality and the hyper-sensitive climate models, while still allowing catastrophic forecasts as the aerosols and their theoretical cooling effect go away in the future.

The IPCC is the first to tell us that scientists really don't have a good handle on the magnitude of aerosol cooling. In a sense, this is a benefit to climate modelers, as it allows them to assume any cooling number they need to make their models back-cast accurately. The most telling sign of this is that most modelers nowadays can produce results that look like history, but they all have very different cooling rates for aerosols. By some coincidence, every single modeler has assumed an aerosol cooling rate that is the exact value needed to make his or her model fit history. This is what I mean by a "plug" variable.

But simple logic tells us that these assumptions almost have to be outlandish. Remember, high sensitivity assumptions were overstating past warming by 1-3C, meaning that if aerosols cover about 10% of the globe, we would have to see local cooling effects in these areas of 10-30C! And we can detect no real cooling whatsoever or substantial change in warming trend between aerosol effected areas and those without aerosols.

Is the Heat Hiding? Ocean Heat Content Hasn't Risen

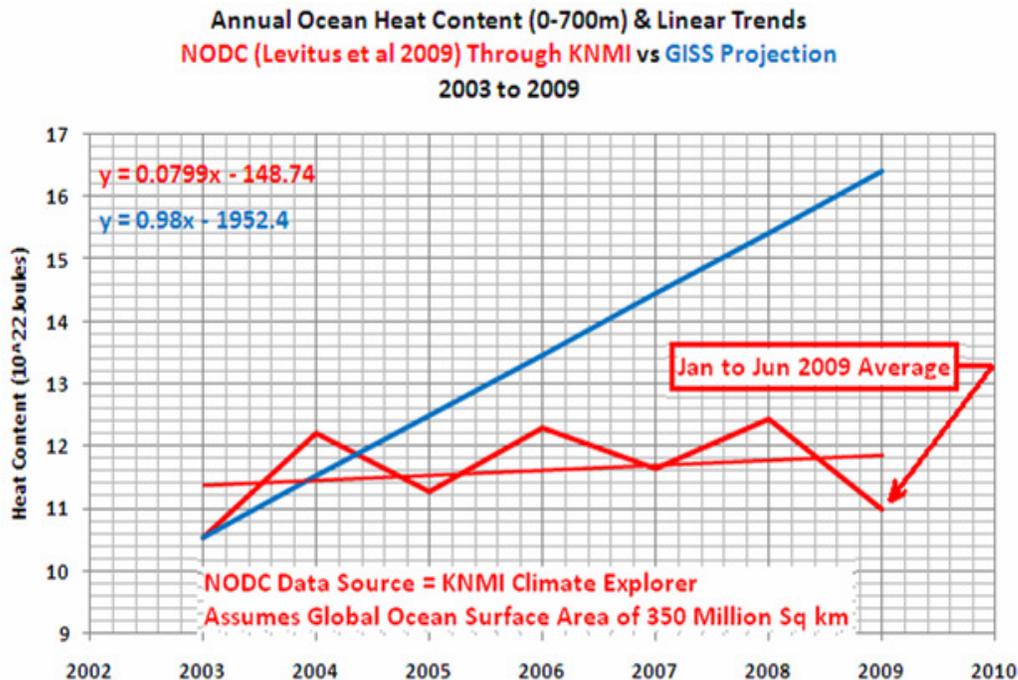


Chart Via Bob Tisdale

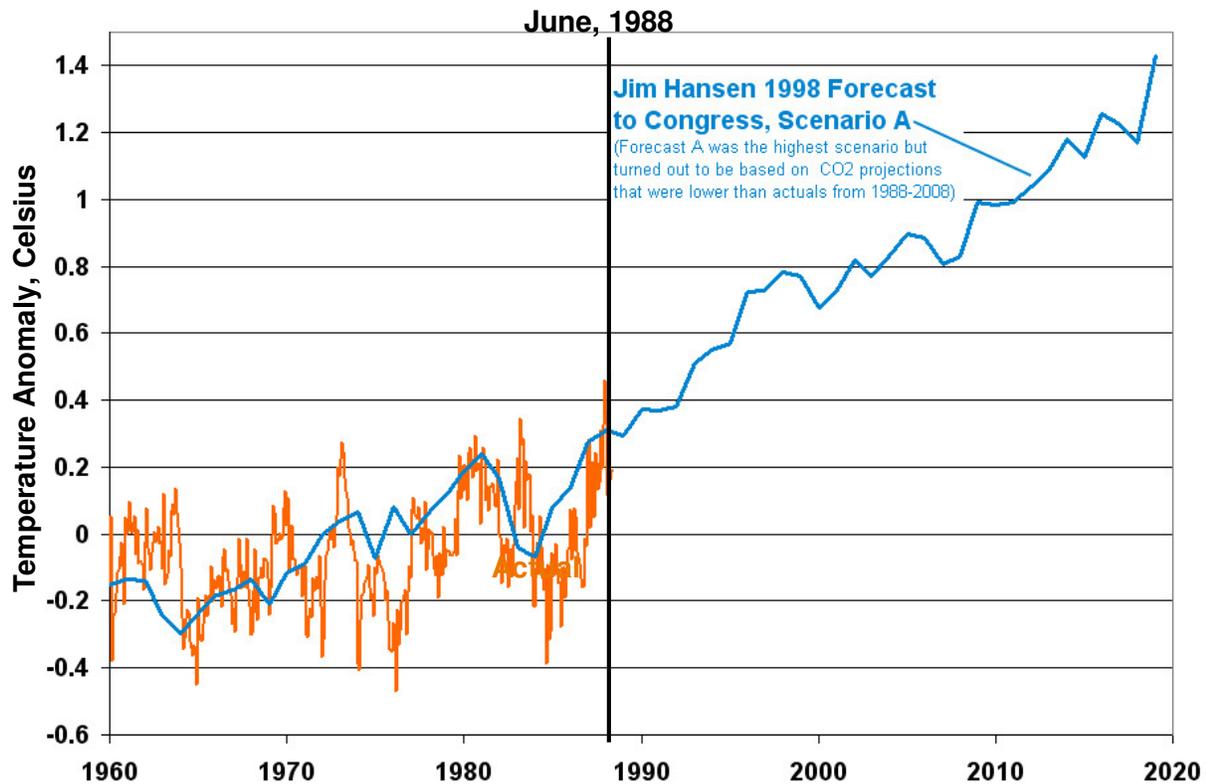
The other explanation for differences between forecasted and past warming is time delays and having heat "hide" in ways that don't show up in the surface temperature record. These are basically the same argument -- the same oceans that may provide a dampening or slowing effect on warming after a change in radiative flux are the only real locations where heat may be stored without it appearing in the surface temperature record.

I mentioned earlier that scientists added new satellite and floating tools to better measure the heat content of the oceans down to 800 meters. Since these tools were put in place in 2003, we have not seen any meaningful increase in ocean heat content (in red), as compared to the blue upwardly sloping line which is the change in ocean heat content we might expect from the models' high-feedback, high sensitivity assumptions were correct.

If we really are seeing increased forcings from CO₂ concentrations, the heat has to be going somewhere -- it can't just go on holiday for a year or two or ten. But if we are not seeing it in the surface temperature record and we are not seeing it in the ocean heat content, it's hard to imagine where it might be hiding.

Source: Ocean heat content via KNMI climate explorer. Compiled by Bob Tisdale, 2009

In 1988, James Hansen's Speech to Congress Showed Good Fit Between His Climate Models and History



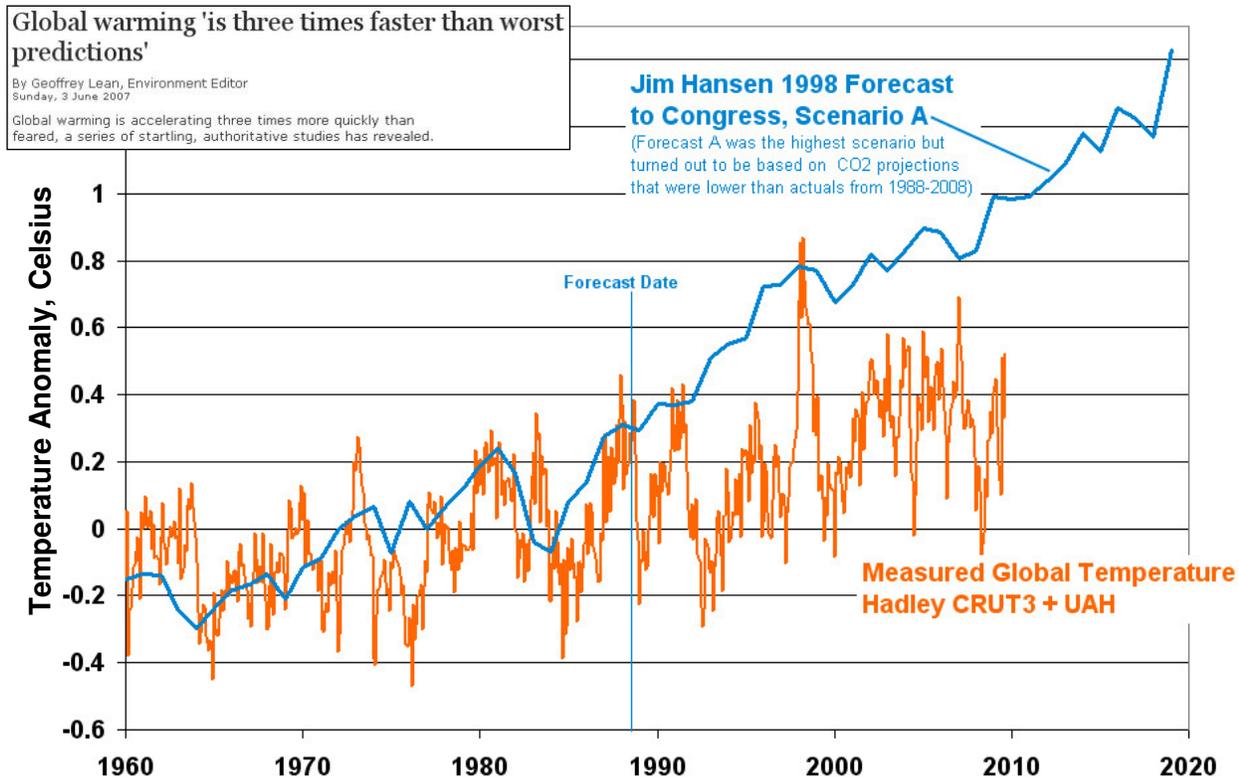
The final test I will discuss for these high-sensitivity climate models is to actually compare their forecasts with actual temperatures after the forecast was made. This seems like an obvious test, but the IPCC has been pretty clever. They bring out a new 100 year forecasts every five years and throw out the old one, such that we never really get to test more than the first couple years of a century-long projection.

James Hansen, who is the head of NASA GISS and a friend of Al Gore and a consultant to his movie, stood before Congress with this chart in 1988. First, he pointed out how well his model matched historic temperatures and used that as proof of the accuracy of his modeling techniques. Of course, a lot of folks in the financial industry have led their investors over a cliff with a similar claim.

Second, Dr. Hansen presented three forecasts based on a variety of CO₂ emissions scenarios (from low to high emissions). As it turns out, actual emissions have exceeded even his high emissions case (scenario A), so I have used that one for comparison.

Source: Actuals same source as slide 24. Forecast from appendices to "Statement of Doctor James Hansen, Director, NASA Goddard Institute for Space Studies" before Congress June 23, 1988. <http://image.guardian.co.uk/sys-files/Environment/documents/2008/06/23/ClimateChangeHearing1988.pdf>. Hansen's Scenario A was chosen for comparison because it's CO₂ production assumptions most closely match actuals (it assumes 1.5% emissions growth, whereas actuals have been about 1.6% growth)

James Hansen's 1988 Forecast to Congress Was Grossly Exaggerated



So we take his forecast and.... we find that it completely falls apart practically from the first day after his presentation. Current temperatures are not even close to those he predicted. He is off by a factor of 5 or more on the temperature increase since his presentation to Congress.

Again, the reason is simple. Yes, CO2 concentrations have an effect on world temperatures, but scientists like Hansen are grossly over-estimating that effect, in particular because of crazy-high assumptions about positive feedback. I and many skeptics don't deny that increased CO2 will have a warming effect in the future, but we expect that effect to be at most a half to one degree C over a century. Hansen told Congress we would see that much in a decade.

Source: Actuals same source as slide 24. Forecast from appendices to "Statement of Doctor James Hansen, Director, NASA Goddard Institute for Space Studies" before Congress June 23, 1988. <http://image.guardian.co.uk/sys-files/Environment/documents/2008/06/23/ClimateChangeHearing1988.pdf>. Hansen's Scenario A was chosen for comparison because it's CO2 production assumptions most closely match actuals (it assumes 1.5% emissions growth, whereas actuals have been about 1.6% growth)

Five Key Climate Questions

- Is the world warming?
 - *Yes, but historic record likely overstated, and there has been no warming in last 10 years*
- Is that warming due to man's CO₂?
 - *Likely "some," but probably not "most"*
- Will future man-made warming be substantial?
 - *Perhaps a degree, at most, over the next century*
- Will we see catastrophic effects from warming?
- Do CO₂ abatement laws like cap-and-trade make sense?

OK, we now move to the effects of warming. When I first wrote this presentation, I wrote the "future effects of warming." But since everyone at the Copenhagen conference in 2009 claimed that catastrophic man-made climate change was *already* devastating parts of the world, particularly in poorer countries, we are going to spend a bit of time trying to find this mythical beast called "man-made climate change."

Marketing is Not Science

- Global warming is being re-marketed as climate change.
- CO2 cannot change the climate by any mechanism we understand or has even been proposed EXCEPT via higher temperatures. CO2 cannot be causing climate change if it is not causing warming.

As many of you have observed, "global warming" has been cleverly re-branded into "climate change." One reason for this is that since we haven't seen any warming for 10 or more years, alarmists need a different term that allows them to duck this inconvenient fact when raising the alarm.

I think most of you know this, but it is important to repeat -- there is no way that CO2 can cause climate change without the intervening step of warming. I'm not just saying that there is no way that Warren Meyer thinks this can happen, I mean that there is not anybody, even in the alarmist community, that has suggested any mechanism by which CO2 could cause climate change without the intermediate step of warming. In other words, if we don't see man-made warming, we can't be seeing man-made climate change from CO2 (we have already seen a number of ways man affects the climate, such as by land use, but in this case we are focusing on CO2).

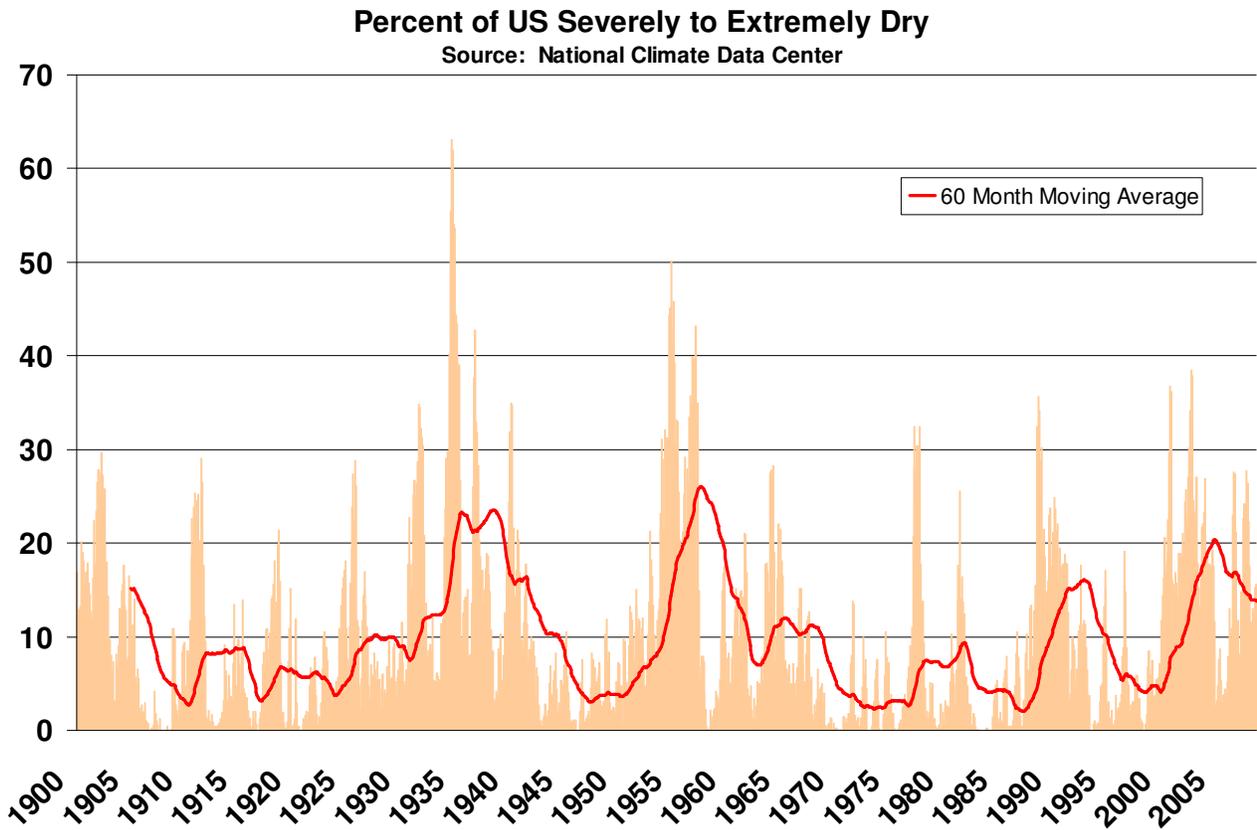
But somehow this simple fact is getting lost, and alarmists are crediting extreme events to CO2 despite lack of warming for a decade, and even assigning the blame for events such as strong tornado years during periods when temperatures have actually been relatively cool. The trick they are undertaking is to seek out events at the tail ends of the normal distribution, highlight these extreme events, and then use their existence to claim that somehow the mean climate pattern is being moved. But in fact, there is little we can learn about changes in the mean from publicizing isolated events in the tails of the distribution, and we will see that in many cases, the phenomena that make the news (extreme weather of all sorts) are actually not occurring with increased frequency (though they may be *reported* with increasing frequency).

Warmer Weather Has Historically Been Beneficial

Take any history course – and warm weather has always been associated with prosperity

One of my hobbies is to audit college level history courses, and I just finished one on the high middle ages, between 1000 and 1300AD. Unlike many people's perceptions of the Middle Ages as a time of stagnation and poverty, the high middle ages were a time of prosperity and innovation and population growth sandwiched between demographic collapses of the early middle ages and of the 14th century famines and plagues. It was funny watching the professor try to deprogram students, telling them that contrary to what they hear on the news, historically warmth has been the harbinger of prosperity and growth, not disaster. In fact, probably the only time between 600 AD and perhaps 1500AD that the European population increased for any sustained period was during the Medieval Warm Period, which was likely at least as warm or warmer than the Earth is today.

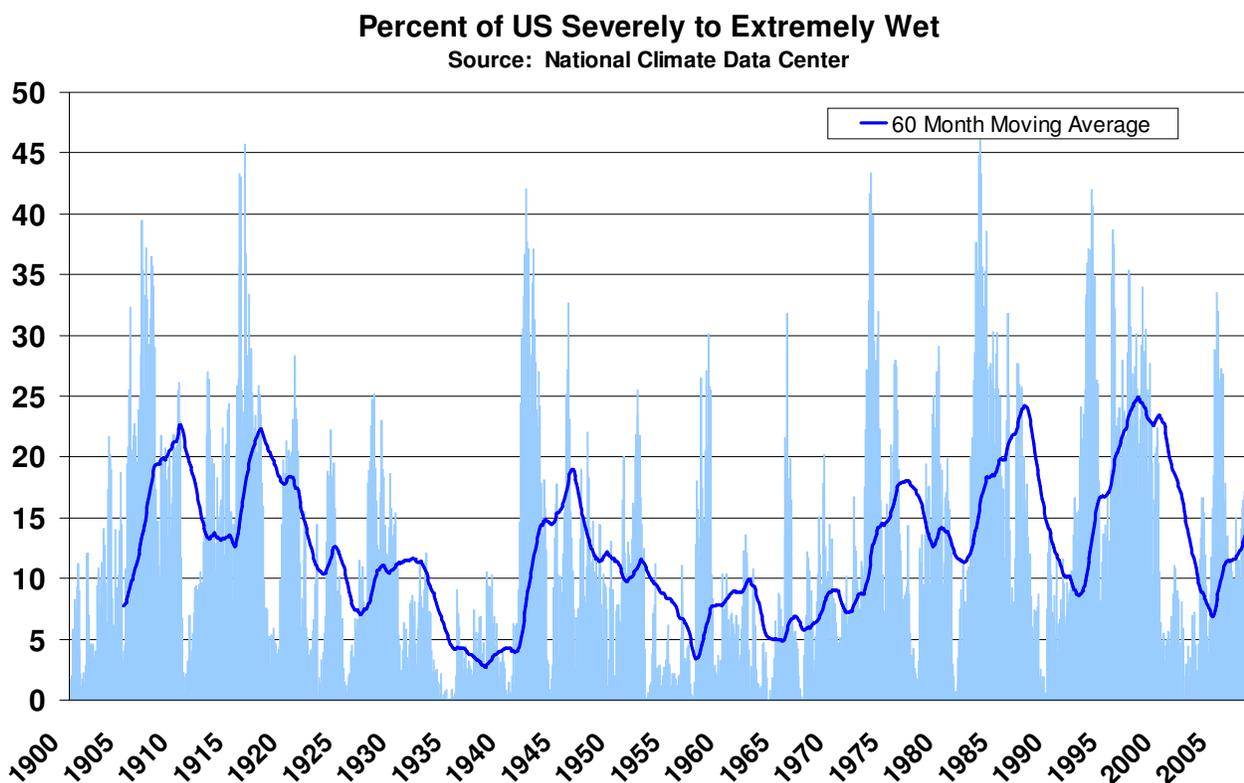
No Upward Trend In Droughts...



Let's zip through several quickly. A lot of this data will of necessity focus on the US, because this is one of the few areas of the world which has had comprehensive weather monitoring for a long period of time. First, drought. As you can see, there is no trend. Droughts may get more TV coverage, lending the sense to the public that they are more frequent, but there is no trend in the numbers.

Source: Slide 69&70: National Climate Data Center. <http://www.ncdc.noaa.gov/oa/climate/research/2008/jul/uspctarea-wetdry-svr.txt>

And No Significant Trend In Wet Weather



Ditto with wet weather. I remember a couple of years ago we had spring flooding up in the Dakotas and the Upper Midwest, and supposedly that was proof of man-made climate change. An odd conclusion to be sure, as the flooding resulted from the melting of higher than average winter snowfall. It makes no sense in the context of global warming, but if you are an alarmist you can still run with it now that the problem has been rebranded "climate change" instead of global warming.

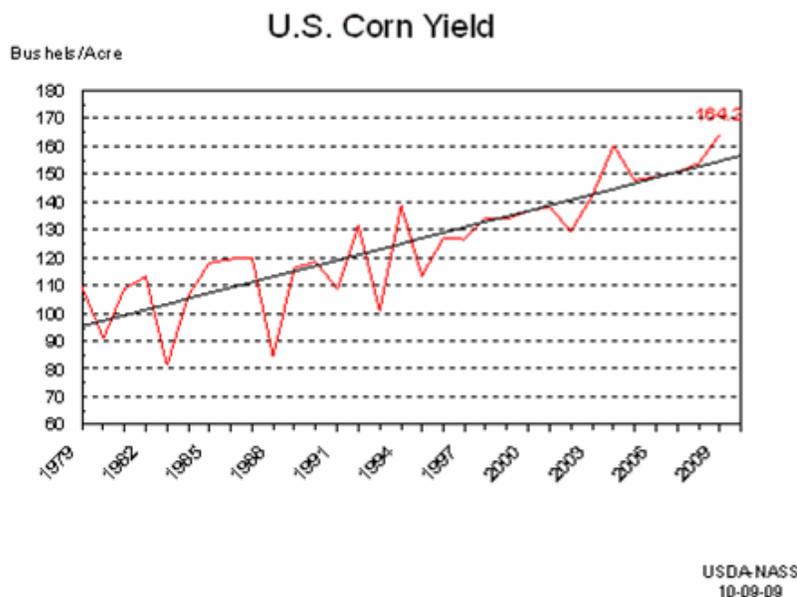
Source: Slide 69&70: National Climate Data Center. <http://www.ncdc.noaa.gov/oa/climate/research/2008/jul/uspctarea-wetdry-svr.txt>

Crops Like Long, Warm Growing Seasons

(Historical Famines Associated with Cold, Not Warm, Weather)

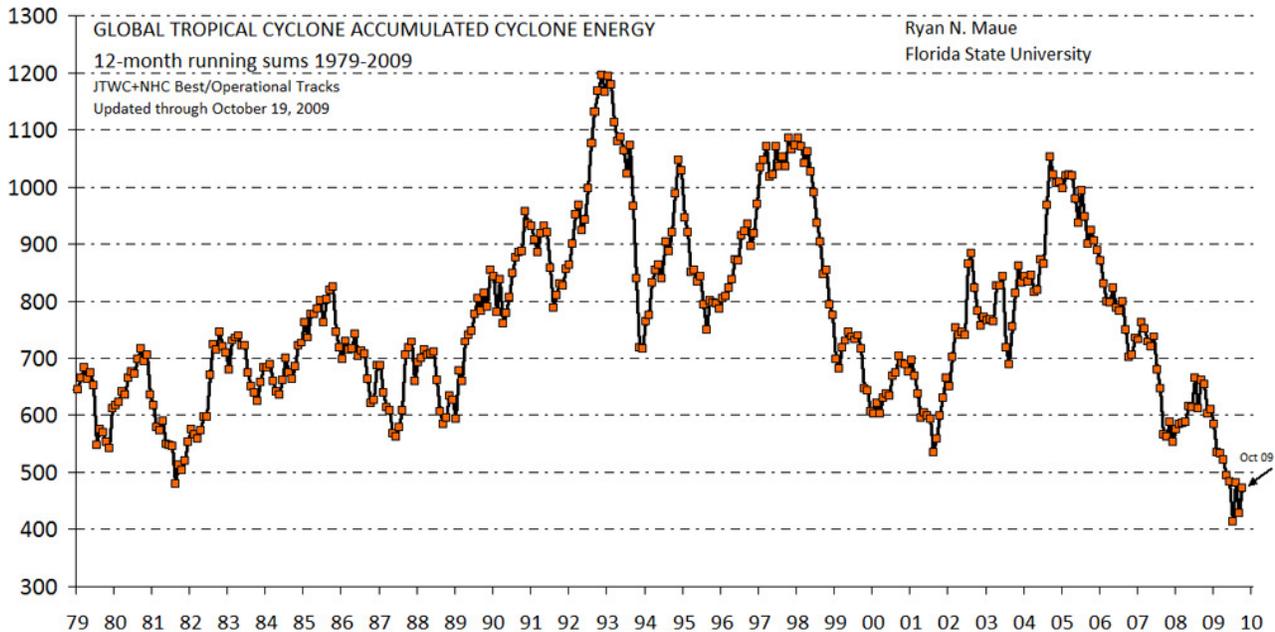
“Corn likes it cool, but global warming is raising temperatures across the nation,” said Environment America Global Warming Advocate Timothy Telleen-Lawton. “Hotter fields will mean lower yields for corn, and eventually, the rest of agriculture.”

-- April, 2009



Just the other day, I saw this quote from an activist that said corn likes it cool, and therefore yields will fall as the world warms. To some extent, this harkens back to the old Paul Ehrlich starvation-disaster PR machine of the 1970s. Never have so few who were so wrong so consistently gotten so much positive press. These guys, who include current Obama science advisor John Holdren, have accurately predicted 20 of the last zero crises. In fact, Holdren gets special bonus credit for being a global cooling alarmist before he was a global warming alarmist. Anyway, many of these Ehrlich disciples have found their way into prominent positions in the global warming movement, so it should be no surprise that they are yet again predicting starvation, and that they are yet again wrong. Throughout recorded history, increased temperatures have corresponded to bumper harvests, while cooler weather has led to demographic disasters.

No Upward Trend in Hurricane or Cyclonic Activity



Next up, hurricanes. As you may have heard, Katrina was supposedly caused by manmade global warming. In fact, a lawsuit is going forward where some power and oil companies are getting sued for creating Katrina. The media links between Katrina and CO₂ probably represent a low point in science journalism in the United States. I challenge anyone to devise an analysis that can separate a "natural" Gulf Coast hurricane (which have existed as long as man has occupied North America) and a manmade one.

The problem with hurricane measurement is that we typically remember the ones that made landfall and did a lot of property damage. But these are just accidents, random luck as to the course of a particular hurricane. And our increasing investment in expensive houses and buildings on the coast nearly guarantees that current hurricanes do more damage than past hurricanes.

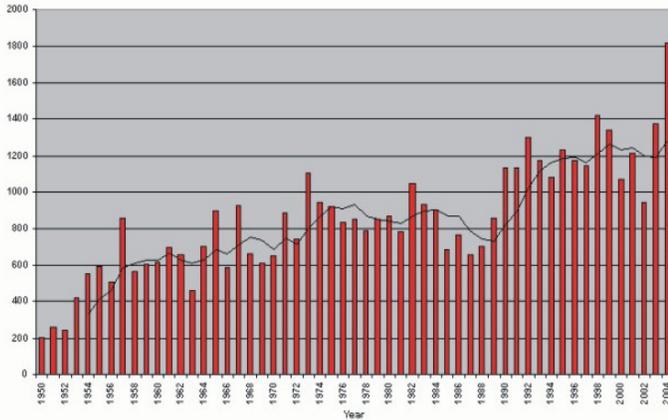
But there is an unbiased way to measure the total strength of hurricanes, cyclones, and tropical storms. You can't just count their numbers, what you really want to do is look at an integral that combines their number with their strength with their duration (really duration at each strength level). That approach yields a number for total energy in the hurricanes from their birth to their death, a number called accumulated cyclonic energy.

I would love to show you data for a hundred years, but it really doesn't exist. The best we can do to get a total picture is to start around 1979 when we have the right satellite coverage. And, interestingly, in 2009 this metric hit not the highest but the lowest point in the last 30 years that we have been measuring it. Recent hurricane and cyclonic activity is very, very low. You all saw that featured on the news, right? No, you didn't.

Source: Florida State University hurricane center, <http://www.coaps.fsu.edu/~maue/tropical/>

Al Gore Said Global Warming Is Increasing Tornadoes

Total US Tornadoes By Year



It looks, at first, like he might be right.

But in fact the increase of measured tornadoes is mainly due to better measurement (e.g. Doppler radar, storm chasers)

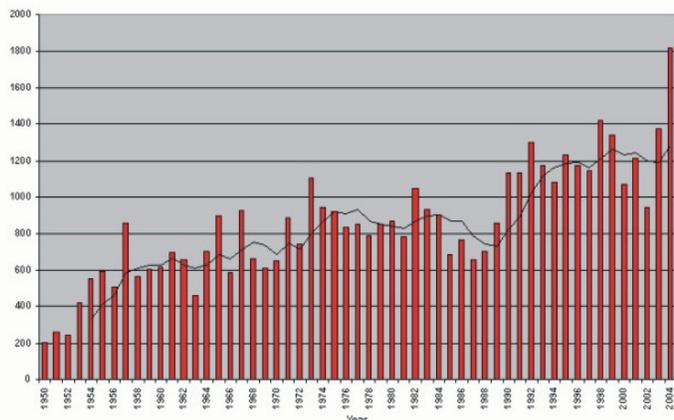
Tornadoes are a similar story. I put this chart in because Al Gore talked about these numbers in his movie. If you look at tornado counts from 1950 to today on this chart, your reaction is likely to be, "Oh my God, there's a horrible upwards trend." If only Gore and his chart makers had looked at the government data site more carefully. If you go to this page, you will see a warning that reads, effectively, "Be careful with this data. The trend is a result of measurement changes."

Today we have Doppler radar. We have storm chasers. We have TV news. We have more population. In 1950, we had none of that stuff. The source where Al Gore took his data specifically warns that the trend in this chart on the left is not due to a change in the underlying number of tornadoes, but a change in our ability to detect, track, and count tornadoes.

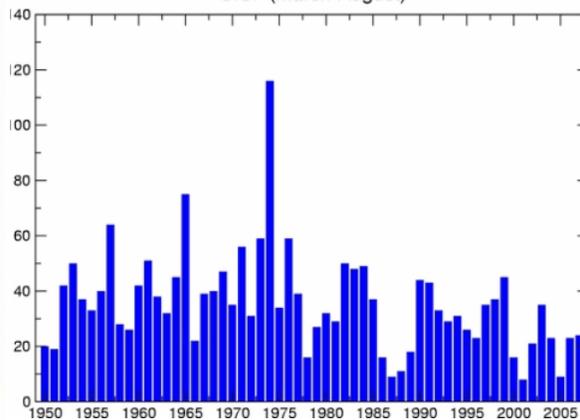
Source: NOAA National Weather Service and Storm Prediction Center

But, in Fact, Large Tornadoes With Consistent Measurement are Flat to Down

Total US Tornadoes By Year



Number of Strong to Violent (F3-F5) Tornadoes U.S. (March-August)



In fact, high tornado spring of 2008 was the coldest spring in 15 years, well below last 30 years average

The site suggests that if one wants to look at trends, one should focus on the larger tornadoes, F3 and above, which were less likely to be missed or overlooked back in 1950. And you can see the trend with this improved metric. There is no trend, or if anything, it is down. So much for increasing tornadoes, and, oh by the way, so much for the related claim that average tornado intensity is somehow increasing.

Interestingly, since this chart was made, we have had two anomalous years. The early part of 2008 was a strong tornado year, with far more tornadoes than average. 2009 has been one of the weakest tornado years in the last 30. 2008's high level of tornadoes made every news outlet, with giant headlines proclaiming the large number of tornadoes was directly attributable to global warming (despite the fact that early 2008 was one of the cooler periods of the last decade). How many of you have seen the stories this year on 2009 being a very weak tornado year? None of you, right.

Source: NOAA National Weather Service and Storm Prediction Center

What is Normal?

“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,

Via Lindzen, 2009

OK, ice in the Arctic. We have all seen the scary pictures of melting ice and forlorn polar bears. And this is report certainly scary ...

“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.”

And this is right from the US Weather Bureau in ...

What is Normal?

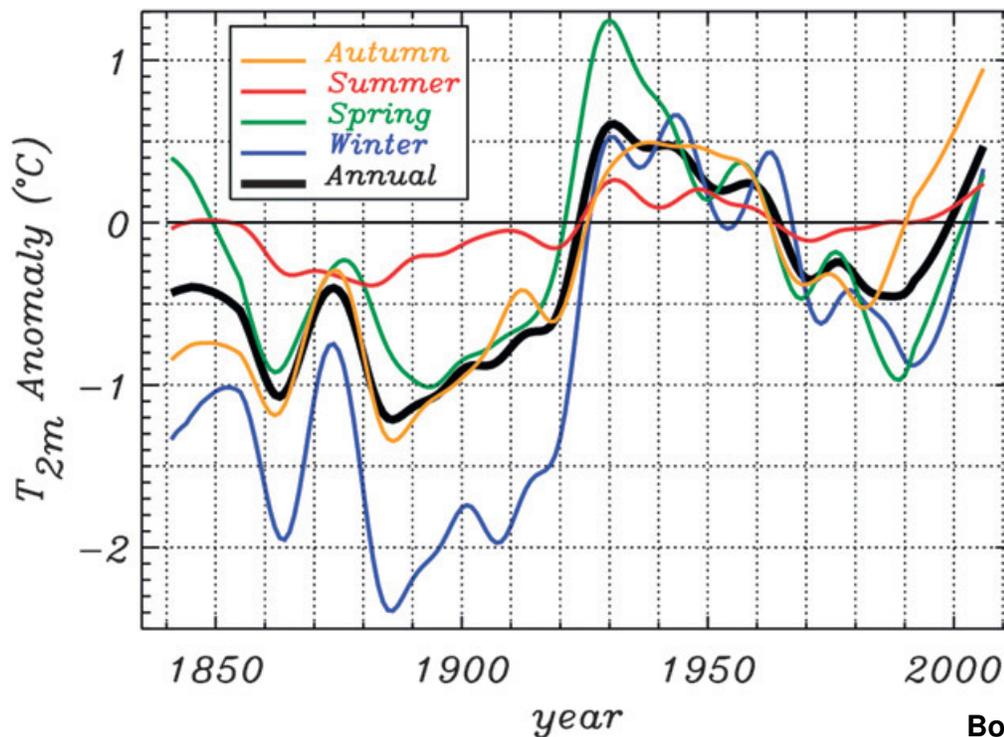
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—US WEATHER BUREAU, **1922**

Via Lindzen, 2009

1922.

Greenland Ice Sheet Temperatures By No Means Unprecedented

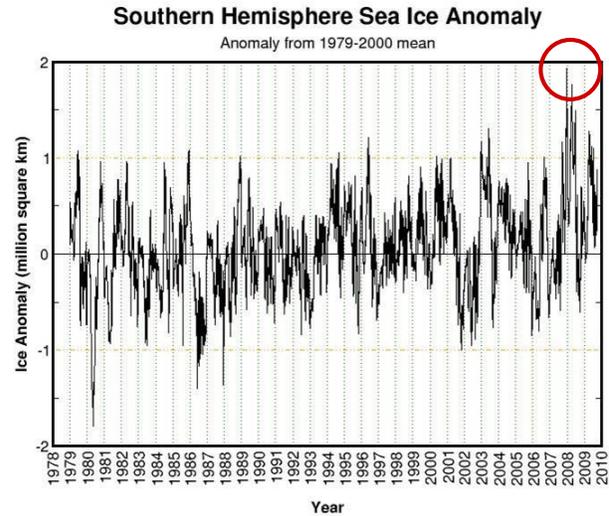
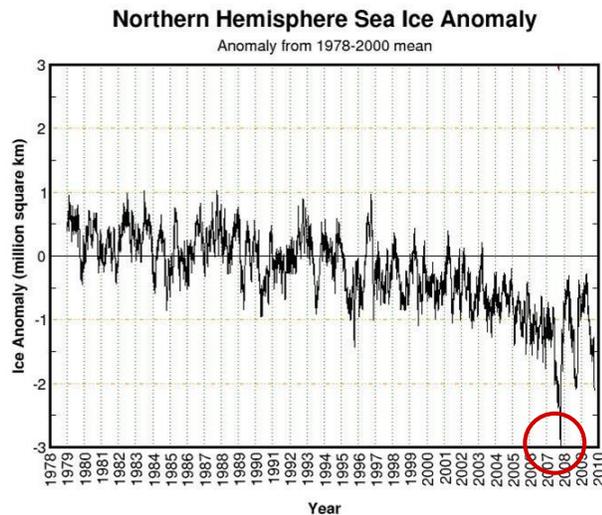


Not to mention the Viking experience – Called Greenland not Glacierland

Again with sea ice, we are stuck with satellite imagery and therefore are limited to the last 30 years. Anecdotal evidence from ships seems to point to the fact that the Arctic was at least as warm in the 1930's, but we don't have good observational evidence to prove it, though this ice core data from Greenland seems to indicate temperatures at least as warm as today back at mid-century.

Source: J. E. Box et al (2009) Greenland Ice Sheet Surface Air Temperature Variability: 1840–2007 *J. Climate* 22, 4029-4049

North Pole Ice “All-Time Low” on Same Day as South Pole All-Time High



Source: University of Illinois Urbana-Champaign Polar Research Institute

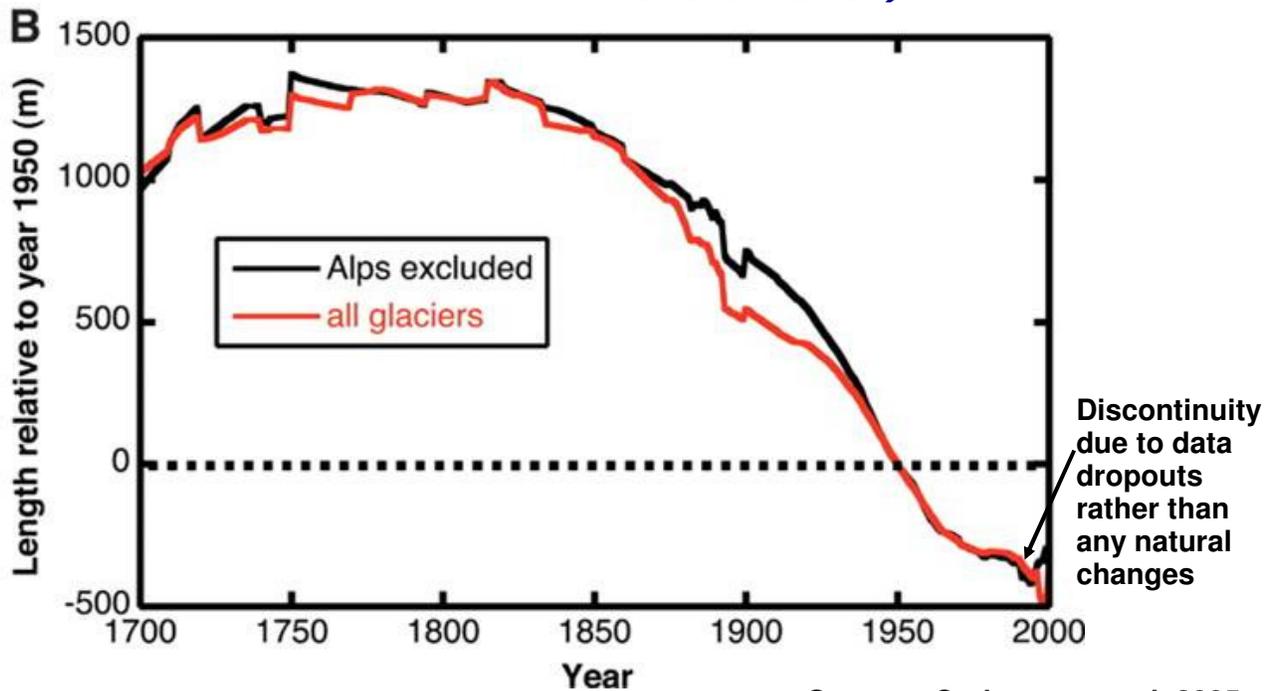
In 2007, in October, our local newspaper the Arizona Republic proclaimed in a headline that Arctic Sea Ice was at an "all-time low," all-time in the Republic's eyes apparently being 30 years. Interestingly, on the exact same day on the other side of the world the Antarctic sea ice hit a 30-year high. You saw that reported too, right? Yeah, neither did I.

By the way, if you are worried about sea levels, the sea ice we are talking about in the Arctic and Antarctic is irrelevant. Just like melting ice in your glass of water, melting sea ice has no effect on sea levels. It is melting land ice that affects sea levels, and 90% of that ice is in Antarctica, about 8% in Greenland, and the rest in various glaciers.

Source: University of Illinois Champaign-Urbana Polar Research Group, <http://arctic.atmos.uiuc.edu/cryosphere/>

Glaciers Have Been Retreating far Longer than We Have Emitted CO₂

79



I told you back when we were discussing the little ice age that we would come back to glaciers. The increasing or decreasing size of glaciers is something more easily tracked by older technologies than sea ice extent, so we have a longer data history on glacier lengths. We have geographers' measurements and maps of glaciers going back hundreds of years in some cases.

What we see from this data is that glaciers were growing through the 1700s, corresponding to the little ice age. After the Little Ice Age ended in the early nineteenth century, glaciers began to retreat. And they have retreated steadily all the way from the early 1800s today, though as this chart shows the glacial retreat has perhaps slowed down over the last fifty years.

So, yes, when the alarmists go to the glaciers and say the glaciers are retreating, they are correct. The glaciers have been retreating in the last 20 years. And they were retreating in 1950 and they were retreating in 1920 and they were retreating in 1900 and they were retreating in 1850. It's a trend that has gone on for nearly 200 years.

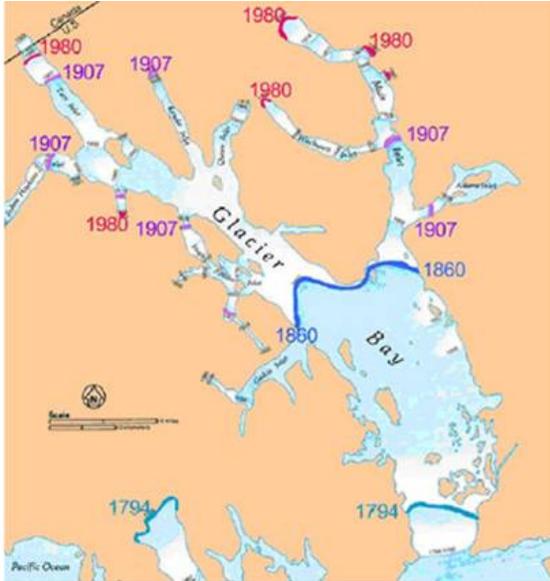
To believe that the current retreat of glaciers is due mainly to man-made global warming, you have to believe that somewhere right here, say around 1950, some natural process that had been causing the glaciers to melt for over 100 years just halted. The natural process halted and at exactly the same time, man-made CO₂ took over and kept glaciers retreating at the exact same pace. Or you could just apply Occam's razor and say that the entire 150 year trend has nothing to do with man and is a natural result of the recovery from the little ice age.

J. Oerlemans, "Extracting a Climate Signal from 169 Glacier Records" Science Vol. 308, No. 5722, pp. 675-677, 29 April 2005.

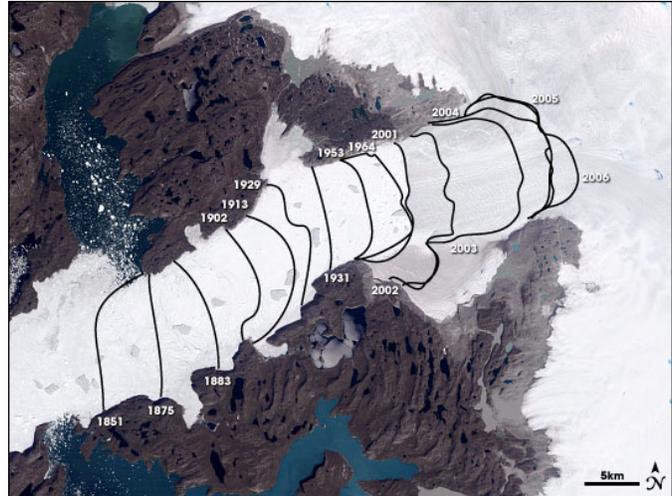
Example Glaciers

Most of the Retreat Long Before Man's CO₂

Glacier Bay, Alaska



Jakobshavn, Greenland



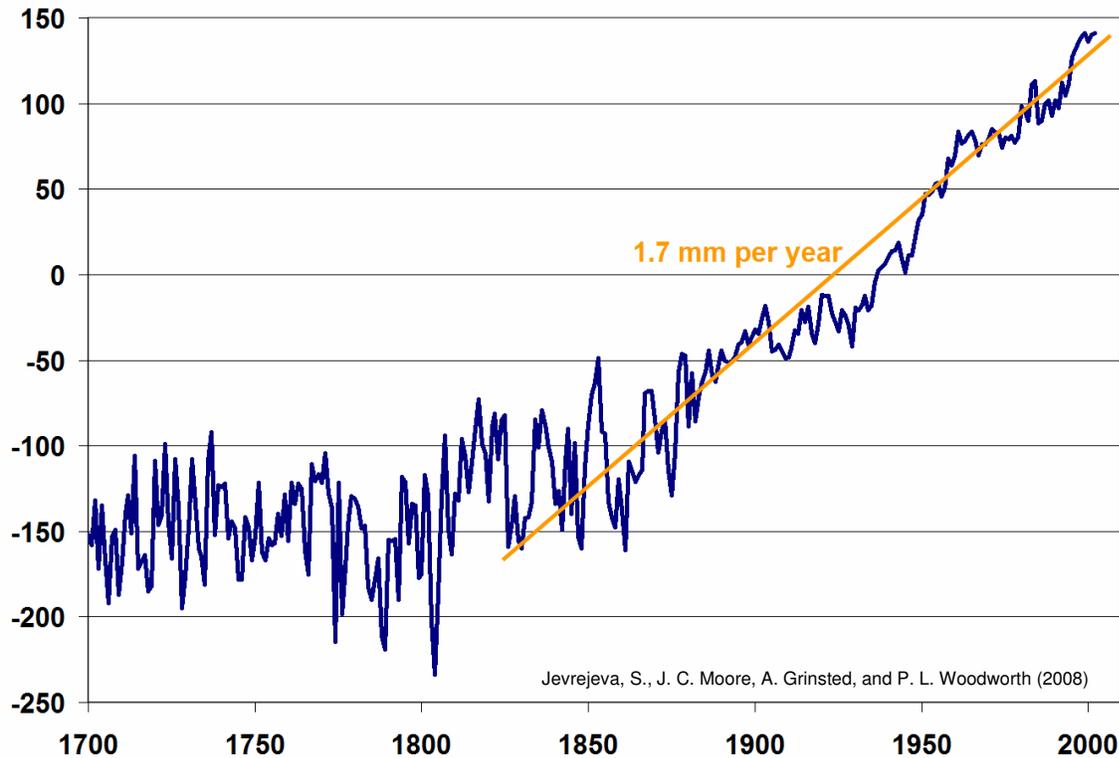
Here are two specific examples among the hundreds that underlie the trend I just showed you. On the left is a map of the glaciers at Glacier Bay, Alaska. I have been up there and its beautiful. This is where the front of the glacier was at 1794. This is where it was in 1860. Somewhere around here we started burning a little bit of coal in London. Here it is in 1907, where we've added a little bit of CO₂ in the atmosphere. So, all this preceding retreat happened by 1907, which was before most of our CO₂ was put into the air. This is what happened between 1907 and today.

A second example is shown on the right. Here's a famous glacier in Greenland that's often used as a case study because it's it has receded a fair amount over the last couple of years. But it started receding way back in 1851, a time well before any substantial fossil fuel combustion.

Again, glacier retreats are not a new phenomenon unique to the last 50-years (ie the "manmade CO₂ era"). Glaciers have been retreating steadily for 150-200 years, for reasons totally unrelated to man's burning of fossil fuels.

Images: Left image Alaska Geographic, 1993. Right image via NASA Earth observatory

Sea Levels Have Risen At A Fairly Constant Rate Since the Little Ice Age

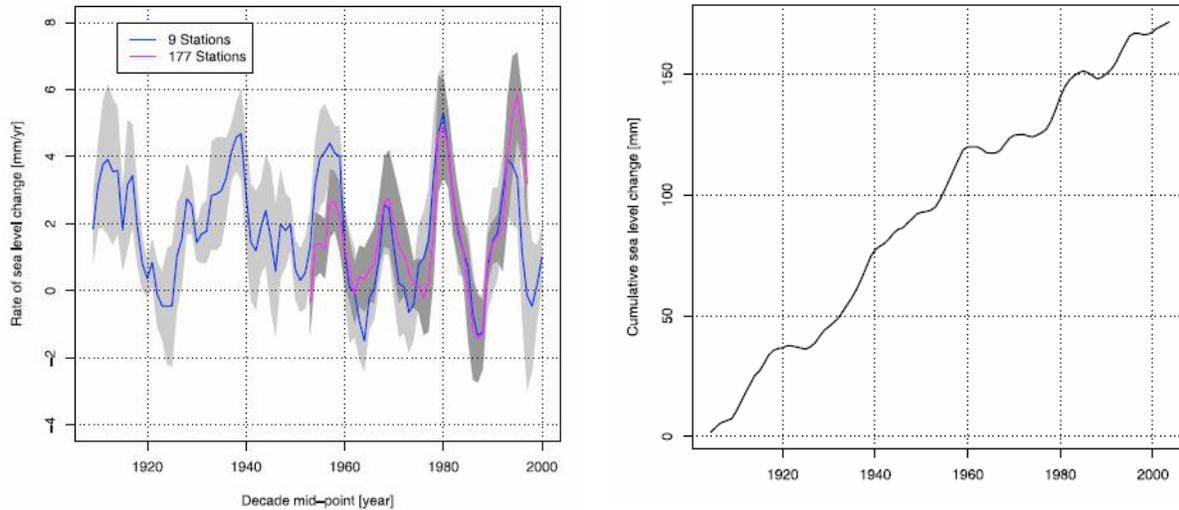


So, the retreat of glaciers correlates much better with the end of the little ice age than it does with the beginning of serious fossil fuel consumption. And you see the same thing with sea level. Sea level goes up for two reasons. One is melting ice, though that is not likely the most important driver. Probably more important to rising sea levels is the thermal expansion of water. When mercury gets warmer, it goes up in the thermometer. When water gets warmer, sea levels rise. By the way, according to the IPCC, all the fuss about Greenland melting is largely irrelevant - ice melting in Greenland is projected to be largely offset by increased ice in Antarctica. It is the thermal expansion of oceans, not melting glaciers, that drives the IPCC sea level forecasts.

Some of the data we have is suspect, because it is from tide gauges where the land may be rising or falling and thus disturbing the sea level measurement. But the data we have says that since the Little Ice Age, we have had a nearly constant rate of sea level rise for 150 years.

Source: Jevrejeva, S., J. C. Moore, A. Grinsted, and P. L. Woodworth (2008)

Sea Levels Have Risen Steadily for Decades, even Centuries

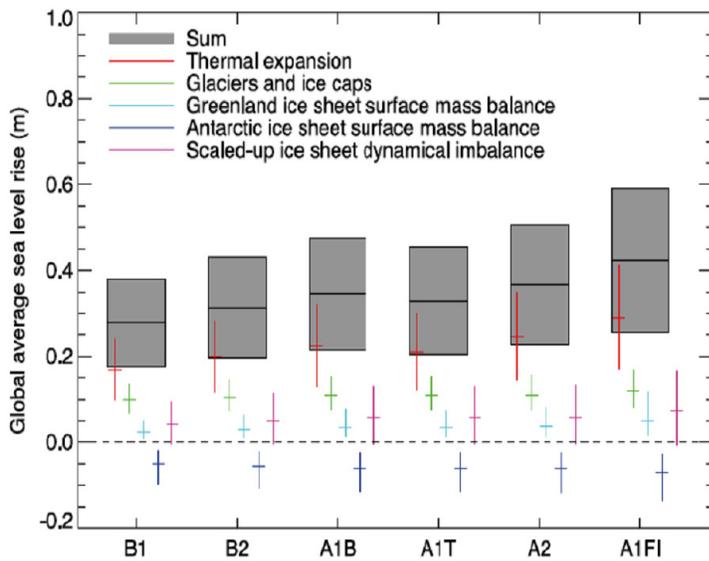


Holgate, 2007

So the answer to a large extent as to why seas levels are rising 2-3mm a year is not manmade CO₂, but because sea levels have been rising at this pace for 150 years. We can see the rate of rise plotted on the left. Again we see cyclical variations, (interestingly on about the same 11-year cycle as sunspots) but no real rising trend.

Source: Holgate, S. J. (2007), *On the decadal rates of sea level change during the twentieth century*, *Geophys. Res. Lett.*, 34, L01602, doi:10.1029/2006GL028492.

Mean Forecast Even from IPCC⁸³ is for 12 inch rise by 2100



This is not readily distinguishable from the change that has been occurring since the end of the last ice age.

- Richard Lindzen, MIT

Figure 10.33. Projections and uncertainties (5 to 95% ranges) of global average sea level rise and its components in 2090 to 2099 (relative to 1980 to 1999) for the six SRES marker scenarios. The projected sea level rise assumes that the part of the present-day ice sheet mass imbalance that is due to recent ice flow acceleration will persist unchanged. It does not include the contribution shown from scaled-up ice sheet discharge, which is an alternative possibility. It is also possible that the present imbalance might be transient, in which case the projected sea level rise is reduced by 0.02 m. It must be emphasized that we cannot assess the likelihood of any of these three alternatives, which are presented as illustrative. The state of understanding prevents a best estimate from being made.

If you saw Al Gore's movie, he said sea levels would rise 20 feet, and implied that this could well occur in the next 100 years. The IPCC is a bit more grounded, arguing that sea level rise will likely be closer to 12-18 inches over the next century, or about 3mm a year, hardly different from the pace we have measured for the last century.

Source: IPCC Fourth Assessment

Five Key Climate Questions

- Is the world warming?
 - *Yes, but historic record likely overstated, and there has been no warming in last 10 years*
- Is that warming due to man's CO₂?
 - *Likely "some," but probably not "most"*
- Will future man-made warming be substantial?
 - *Perhaps a degree, at most, over the next century*
- Will we see catastrophic effects from warming?
 - *Likely not – we have not seen them so far*
- Do CO₂ abatement laws like cap-and-trade make sense?

OK, we could go on with this all day. We could talk about how the snow disappearance on Kilimanjaro is a phenomenon unrelated to global warming, how figures are cited for warming-related species extinction that have absolutely no evidence behind them, and how threats of tropical disease spread tend to be refuted by experts in immunology. But we could spend all day puncturing the myriad of silly non-evidence-based scare stories surrounding global warming. I want to move now to conclude with a brief discussion of policy alternatives.

Problems with the Precautionary Principle

- Insurance makes no sense when the premiums are higher than the value of what you are insuring
- Costs are going to be enormous to really make any kind of impact at all
 - Europeans have \$8-\$9 gas and they are not anywhere near the kinds of reductions activists say are necessary

There is no free lunch on CO₂ abatement

When backed into a corner on their science, most alarmists will fall back on “the precautionary principle.” The precautionary principle says that when there is even a very low probability of something catastrophic happening, we should spend near infinite amounts of money to prevent even this small chance. They claim that this principle is somehow established, but in fact we never follow it in any public policy discussion. If we did, we would be building space lasers to deflect meteors or invading aliens or we would be actively addressing a future Medicare bankruptcy rather than making it worse. And, contrary to what our parents always told us, procrastination isn't always a bad strategy -- we are gaining wealth and new technological capabilities at such a rapid clip that problems which seem overwhelming today can be much easier to fix in a decade or so.

The question I frequently get is, “Warren, you buy insurance don't you? All we are asking is that the governments of the world buy an insurance policy against catastrophic manmade climate change.” And sure, I buy insurance. But if I had a \$4,000 car, I wouldn't pay \$6,000 a year for insurance. That's what you're buying with many of the current CO₂ abatement proposals. You are paying \$6000 a year to insure against a \$4000 accident. We can argue, as I have for the past hour plus, whether manmade global warming will really have a substantial impact -- I obviously believe that it will not. But I think it is beyond argument that trying to roll back CO₂ production and fossil fuel consumption to 19th century levels is going to be expensive, in terms of its outright costs, the reductions in economic growth, and the impingements on individual liberty. I find it terribly frustrating when folks like President Obama talk about such changes being inexpensive, or even a net plus for the economy by creating “green jobs.” The mistakes he is making with that proposition are beyond the scope of this presentation, but if you are interested, Google “the broken windows fallacy.” In short, obsoleting trillions of dollars of existing capital investment in energy infrastructure and then replacing it with more expensive and less reliable energy sources is not a benefit to the economy.

A Plea for Sanity: A Carbon Tax Far Better than Cap and Trade

86

- Carbon tax much simpler to administer. Emissions accounting is a nightmare (California CARB as an example)
- Cap and trade is a lobbyist's dream
 - Nearly infinite space for influence peddling, special deals, exemptions, etc.
- European cap and trade systems are fraught with faulty accounting
- Politicians like cap and trade because it allows them to tax without appearing to tax.
- Tremendously regressive tax
- Doesn't work unless it is painful

Take the cap and trade bill currently in front of Congress. Its supporters have said that it won't be expensive. But this is not just naive, it is disingenuous. They have to know that the bill must be expensive or it won't work. The theory of cap-and-trade is that by limiting carbon emissions, we will cause shortages and raise gas and electricity prices which in turn will cause people to use less. To work, people have to change their behavior and people are not going to change their energy use behavior unless the prices go up. A lot. In Europe, they have \$8-\$9 a gallon gas, and they have not come close to the targets these folks are talking about. We are talking about adding \$10 or more to US gas prices, when historically 30 cent increases have sent folks into a tizzy.

Further, the cap and trade bill in Congress is, unsurprisingly for those who observe Congress much, a playground for special interests. Already, numerous groups have special set asides, exemptions, subsidies, benefits, etc. This group can only grow over time.

Cap and trade is also a terribly regressive tax, hitting the poor the most. It hasn't worked in Europe. It's an accounting nightmare. This is a terrible insurance policy. It has expensive premiums and really doesn't prevent any risks.

Jeff Flake's Proposal – A Real Insurance Policy Instead of a Power-Grab

- Institute a carbon tax of whatever value
- Cut payroll taxes to match, ie to make it revenue neutral
- Would have the benefit of being neutral (no net increase in taxes) – simply shifts from sales tax on labor to sales tax on carbon-based energy
- Decreases one regressive tax to match increase in another regressive tax
- Would provide incentives for employment

If we have to have some sort of legislation, our Arizona Congressman Jeff Flake has proposed an alternative. He proposes a carbon tax on fuel, a tax which may have to be quite high to reach the CO₂ objectives that are being discussed. A carbon tax would tax fuels based on their carbon content, such that natural gas would have a low tax and coal would have the highest tax. To offset the financial damage this would cause to the economy, Flake proposed that whatever revenue accrues from the carbon tax be returned to the public in the form of a cut in payroll taxes (the taxes that currently tax both you and your employer to the tune of about 8% of your paycheck). As a libertarian, I am not much on new taxes, but I am comfortable with substituting one regressive sales tax for another, in this case replacing a regressive sales tax on labor with a regressive sales tax on fuel. Not only would this provide us some sort of an insurance policy against man-made climate change by reducing fossil fuel use, but it would also reduce the cost of labor, thus providing an incentive to increase employment.

Global Warming is Sucking The Oxygen Out of the Environmental Movement

- Other emissions that are more harmful that still need to be addressed (images from Beijing Olympics)
- Driving environmentally stupid behavior
 - Subsidizing corn ethanol, which does not reduce CO2 but has terrible effects on land use
- Many other areas where more impact possible for less money

I want to conclude with one final point. I think 20 years from now, beyond the costs that we're going to pay with this cap-and-trade bill, environmentalists themselves or at least conservationists are going to look back and say the global warming obsession was a disaster for the environmental movement because it sucked the oxygen out of any number of legitimate efforts to improve our world. Environmentalists have gone all-in on global warming, but with all their chips on one bet, their attention has lagged virtually everywhere else.

I'll give you two examples. One is the Beijing Olympics. Did you see their air pollution - it was terrible. People are wearing masks in the street. I'll tell you right now, we have no idea how to have combustion economically without producing CO2. But we do have a very good idea of how to economically have combustion and have a growing society without our air becoming unbreathable. But the full force of our attention with China is on CO2, not on the air quality for their citizens.

The other example is ethanol. Ethanol has gotten huge subsidies from Congress in the name of reducing global warming. This has been Congress's solution of choice. And study after study shows that ethanol actually increases energy use, does nothing to reduce CO2, worsens land use, and raises food prices. In the Amazon, the number one reason for destruction of the rain forest over the last decade or so has been clearing land for ethanol crops, part of Brazil's alternative fuel program that has garnered a lot of praise. Somehow, what used to be real environmental concerns, like preserving the Amazon and having breathable air, have been sacrificed on the alter of altering trace concentrations of carbon dioxide by miniscule amounts. Its simply insane.

Five Key Climate Questions

- Is the world warming?
 - *Yes, but historic record likely overstated, and there has been no warming in last 10 years*
- Is that warming due to man's CO₂?
 - *Likely "some," but probably not "most"*
- Will future man-made warming be substantial?
 - *Perhaps a degree, at most, over the next century*
- Will we see catastrophic effects from warming?
 - *Likely not – we have not seen them so far*
- Do CO₂ abatement laws like cap-and-trade make sense?
 - *Costs far more than it helps. Many more important priorities. Carbon tax preferred over cap-and-trade.*

I hope you have enjoyed "Catastrophe Denied," and I appreciate your time. I do this out of passion and for fun, not for profit (my hobby is totally self-funded.) I am always up for giving this presentation to groups from 30 to 300. I charge no speaking fees, but I do need to figure out an efficient way to get wherever you are. For more information, please visit my web site climate-skeptic.com, which also has a link where you can email me.



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