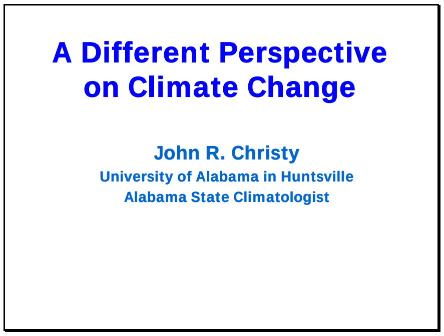
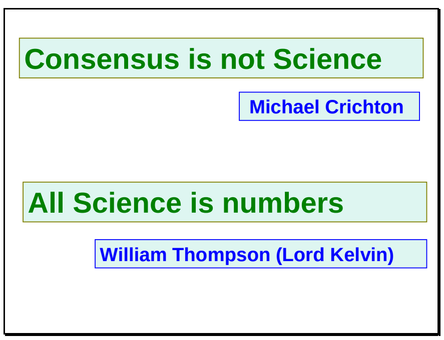
Slide 1



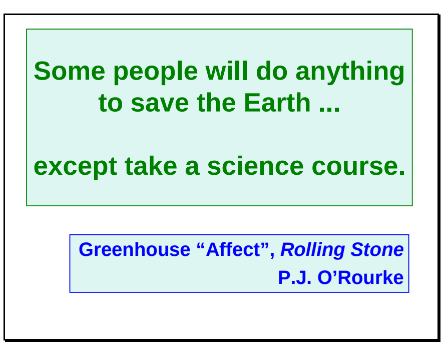
This presentation with notes is not a typical presentation in which information is transmitted, but is one that tries to spur the reader to think in a different way. The reader should be aware that this presentation interprets some aspects of the issue of global warming in ways differently than are commonly done today. While the numbers of science to be shown are defensible, it is the interpretation of the numbers that is designed to expose the reader to a different dimension on how science works in the arena of climate change. It invites the reader to consider whether a preconceived conclusion is driving the interpretation of the numbers of science or the other way around. Again, as indicated above, some of this material is controversial and not shared in general by those, for example, who craft the “consensus” statements of the IPCC AR4.

Slide 2



Michael Crichton is well-known for making the simple assertion that science is not an exercise in consensus. Consensus is a process that involves interpretation of evidence with the hope of convincing a group to come to a common view, and thus allows human bias to impact the conclusions. But what is science? Lord Kelvin said, “**If you can measure that of which you speak, and can express it by a number, you know something of your subject; but if you can not measure it, your knowledge is meager and unsatisfactory.“ Or more simply stated, he said, “all science is numbers.” So when we talk about a scientific issue like global warming, in a scientific way, we need to talk in the language of numbers and be humble about interpretation.**

Slide 3



Humorist P.J. O’Rourke actually backed up this assertion by showing that the number of Americans earning degrees in the “hard” sciences has been dropping.

Slide 4

Energy Technology

1900: World supported
56 billion
human-life years

2005: World supports
429 billion
human-life years

Before discussing human-induced global warming it is important to look at two other numbers. If an index of human-life-experience is defined as the average life expectancy multiplied by the number of living people, then there has been an eight-fold increase in the experience of human life in the past 105 years. In 1900, average life expectancy was 35 years and 1.6 billion people were alive. In 2005 it was 65 years with 6.6 billion living. In all likelihood, the person reading this note is alive today because of the consequences of energy technology. Additionally, the by-product of most of human energy production, CO2, has led to a significant increase in the production of food and fiber due to the fertilization effect of the CO2 (CO2 is plant food). Since the costs and benefits of energy are ultimately where the issue of global warming ends up, it is good to know a little about the numbers which describe the benefits up front.

Slide 5

The Basic Numbers

- **Carbon Dioxide has increased 35%**
- **Global Surface temperature rose 0.7 °C in past 100 years**
- **Surface temperature responses to 2xCO2 increases (alone) is ~ 1 C**
- **The associated feedbacks are where the uncertainties are large (i.e. no confident numbers)**

CO2 has increased from a background of about 280 ppm to 385 ppm in 2007. If all other processes are held constant in a climate model, the impact on global average surface temperature of doubling CO2 (I.e. to 560 ppm) would be about 1°C. When other processes in models are allowed to freely respond to the extra heating caused by CO2, they add to the CO2 temperature increase. In other words, the number of joules of energy in the troposphere and ocean rises due to the way CO2 and other processes operate, and the temperature also rises. Note these are model projections only. Models in general display positive feedbacks, i.e. that as the surface warms up a little due to CO2 forcing, something else begins to operate in a different way to add to the CO2 warming. The simplest example is water vapor, a strong greenhouse gas. In models, as CO2 starts to warm the air, more water is evaporated into the air, and this adds to the greenhouse effect, causing temperatures to rise further than they would with CO2 alone. There are serious uncertainties in such feedback processes however.

Slide 6

The Basic Numbers

- Humans produce about 7 gigatons of CO2 (carbon mass) per year from energy production
- About 3.5 gigatons accumulates in the air each year
- There are about 740 gigatons of CO2 in the atmosphere
- The rate is increasing around 0.5% per year

Human activity, such as (a) energy production from the combustion of fossil fuels and (b) land-use activities, release about 7 gigatons of carbon into the atmosphere per year. (The mass of CO2 is 44/12 times this carbon mass alone, since the molecular mass of CO2 is 44 and of carbon, 12. The 7 gigatons refers only to the mass of the carbon portion of the CO2 emissions.) About half of these emissions remain in the atmosphere while the other half is absorbed in the oceans and in the increasing biomass of the planet. Human-caused CO2 emissions themselves are increasing at around 1.5% per year today, and when added to the current amount already in the atmosphere, the part that stays adds about 0.5% to what is in the atmosphere per year.

Slide 7

The Basics

- Climate is always "changing"
  - Global temperature is rising or falling
  - Sea level is rising or falling
  - Glaciers are retreating or advancing

The climate system is a non-linear, dynamical system which through time exhibits traits of chaotic behavior. The configuration of energy, water and ice at this moment has never before existed exactly as it is now. There have never been two years, two centuries, or two millennia that were identical. Because the climate system is always being forcing by the sun, which creates imbalances and gradients (i.e. hot tropics, cold poles) the system's processes work to remove these imbalances. Thus, the system is never in a completely static state. All parts of the climate system are exchanging energy amongst themselves, and this leads to changing temperature and water state. It is uncharacteristic to speak of "stablizing" the climate since the climate is never exactly "stable."

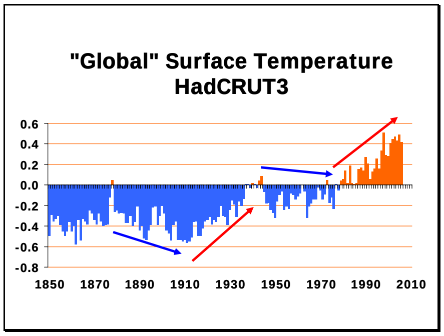
Slide 8

The Basics

- Climate is always "changing"
  - Global temperature is rising or falling
  - Sea level is rising or falling
  - Glaciers are retreating or advancing
- Climate cannot be adjusted in a predictable way
  - Initiatives to control climate have no dependable outcome
  - Initiatives proposed to date have such a tiny impact on the overall emissions, we could not measure any direct effect

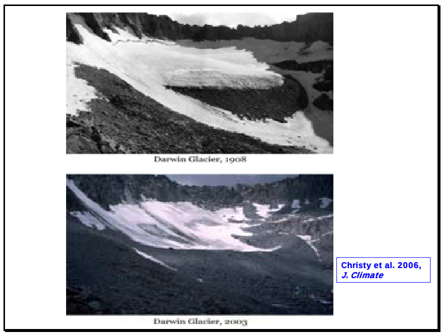
Because the system is essentially infinitely complex and unpredictable, one cannot impose a new climate with reasonably-predictable results. Current proposals which are being seriously considered will have such a tiny impact on total global emissions as to be imperceptible in their emission impact and undetectable in their climate impact. There will be more on this later.

Slide 9



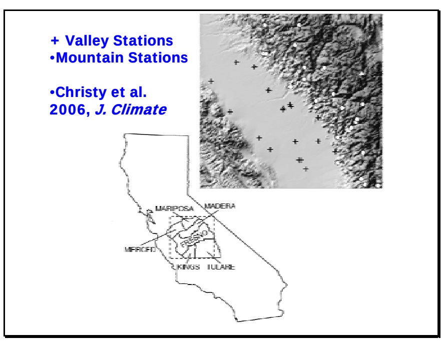
The earth's surface temperature has warmed in the past 120 years. The IPCC AR4 2007 states the warming of the surface temperature in the past century is "unequivocal." A more encompassing statement would have been to say that surface temperatures are always fluctuating on all time scales and that during the past century, warming has occurred.

Slide 10



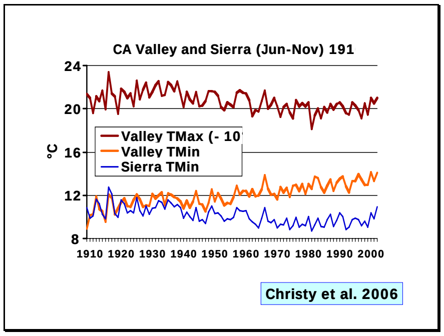
We now move to specific parts of the climate system to see evidence of change, but evidence which indicates attribution of the causes of that change is difficult. In other words, we want to know what is causing the changes. Above is Darwin Glacier (Fresno County, CA) showing significant ice loss. This is common for many of the small mountain glaciers in the western U.S. However, the mountain glaciers of the Western US are relatively young, commencing to form only 5,000 years ago when the earth's temperature began to fall after a long warm period (mid-holocene altithermal) from 9,000 to 5,000 years ago. This cooling was called the neoglacial. Thus, the glaciers we see receding now in all likelihood did not exist just 5,000 years ago. What is causing the loss of these small mountain glaciers?

Slide 11



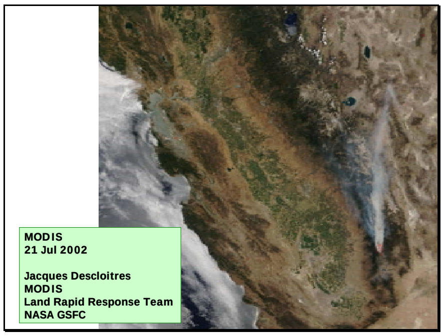
To understand whether temperature changes have occurred we constructed regional temperature records for the San Joaquin Valley (+) and the nearby Sierra Nevada Mountains (o). Darwin glacier is the triangle at the right side. There were 41 stations in all. We ultimately generated homogeneous temperature records since 1910 for the valley and the nearby Sierra Nevada mountains.

Slide 12



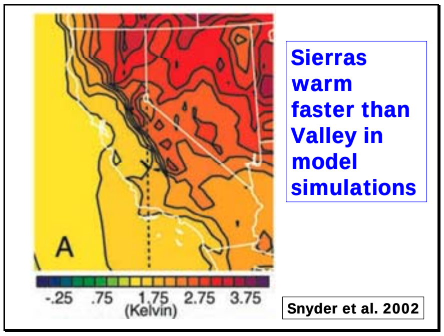
What was found was that the valley nighttime (TMin, orange) temperatures have warmed considerably while the Sierra TMin have not. This comparison demonstrates the likely impact of land-use changes on long-term temperature for this region, causing a warming since there were very different results of the Valley and the Mountains. Land-use changes like those in California's Central Valley are extensive and world-wide, especially in those locations where surface thermometers are used to compile global temperature values. This suggests such changes are a significant part of the warming seen in the global surface temperatures. Note also above that the daytime (TMax) has declined. One key result is that the Sierra temperatures have not risen at all, either day or night. So, the disappearing Fresno County glaciers are apparently doing so apart from an increase in temperature.

Slide 13



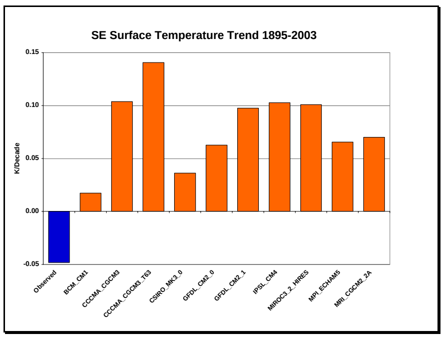
The San Joaquin Valley in the center is green with irrigated agriculture in July. The native July surface was a light, brown desert-like system, as still seen on the edges of the green farm fields in the photo above. The change from a light-colored, dry surface to a dark, moist, vegetated plain introduces a very different surface climate. With the darker color, more sunlight is absorbed and with moist ground, that energy can be stored during the day. At night, this energy can be released to the air, leading to nights that are warmer than would be the case in the original desert-like system. Additionally, the daytime temperatures will likely be cooler due to the fact the solar energy is being absorbed (not being used to raise the temperature) and that some evaporation from the moist ground and plants will occur. The results in the previous slide are consistent with the hypothesis that land-use changes have had a detectable impact on the valley temperatures.

Slide 14



The importance of the previous slides is shown here. Climate model projections, such as this one, indicate the Sierras should be warming more than the Valley if the enhanced greenhouse process is the dominant climate forcing. The results suggest the models are not yet capable of producing good greenhouse gas projections, but if they are capable, then the type of change seen in central California is not due to enhanced greenhouse gases. As a sidelight, if one wishes to return the climate of central California back to something like that of the 19th century, the valley should be depopulated and returned to a desert. Actions regarding CO2 emission reductions will have little impact on this region's temperature.

Slide 15



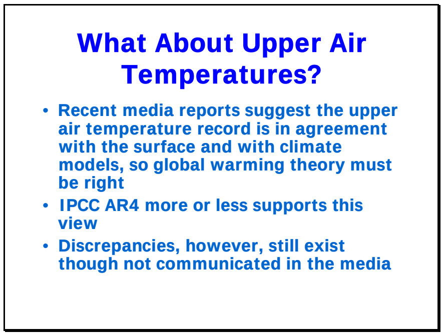
In another analysis, prepared for the National Assessment on climate change, a test was made to see how climate models which had created simulations of the last century compared with observations for the Southeastern U.S. over that time. All model projections showed warming. But in fact, the observations indicated a cooling trend since 1895. This and other evidence points to a weakness of climate models to generate reasonable regional simulations.

Slide 16

What About Upper Air Temperatures?

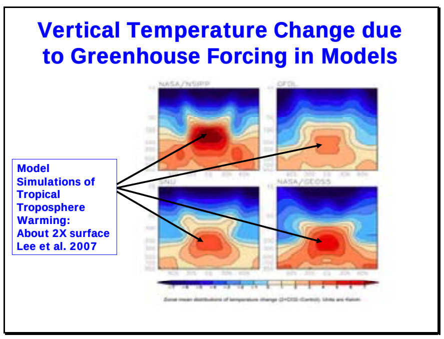
Upper air temperature trends are becoming a topic of vigorous debate. The reason is that the dominant signature of the enhanced greenhouse effect is a more rapid rise of temperatures in the upper air up to 10 km or so. But, knowing precisely what that temperature trend is has become an important issue.

Slide 17



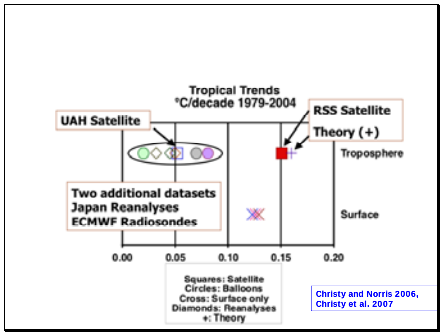
There have been several publications which attempt to reconstruct upper air temperature time series from which trends might be assessed. There has been some back-and-forth on this issue as some publications suggest upper air temperatures are indeed warming rapidly, while most datasets show very modest warming, even less than that of the surface. The AR4 came to some tentative conclusions, but was not definitive. The UAH satellite data in particular show less warming aloft than at the surface, both globally and in the tropics. However, the global average trends are within the margin of error, while the difference between the surface and upper air trends in the tropics is significant. Thus, a discrepancy exists.

Slide 18



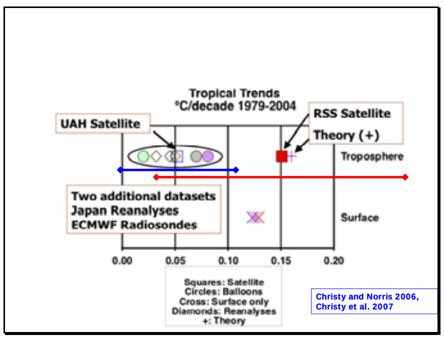
The tropical upper air is a key area to study. All climate models indicate that the strongest tropospheric signal of CO2 warming is found in the tropical upper atmosphere. In that region, models (which represent the theoretical understanding of climate) show warming of twice that of the surface. If the entire layer from the surface to about 300 hPa is averaged, then this layer is expected to warm at a rate about 1.3 to 1.5 times that of the tropical surface. This layer is the one measured by satellite, so satellite temperatures of the lower troposphere (LT) should show 1.3 to 1.5 more warming than at the surface in the tropics if greenhouse warming is the dominant cause of temperature changes according to model simulations. The tropics are important because models show this to be the place were the most dramatic signal of greenhouse warming should be detectable.

Slide 19



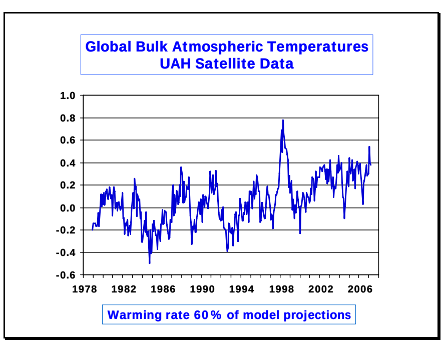
Now we introduce a bit of controversy. The diagonal crosses show the tropical surface trend from three surface datasets (about +0.125 C/decade). Most LT observations reveal trends quite a bit less than that (circled). The theory embodied in climate models is shown with the cross and nearby is one specific satellite result (RSS). What should you conclude? Here are 7 datasets (circled) indicating the tropical troposphere is not warming in the fashion suggested by climate models, but one dataset that does. I don't know about you, but my view is that the group of smaller trends, which are all independently constructed and often start with different data all together, should form the consensus.

Slide 20



The two papers cited here detail a number of analyses to determine the error range of the two satellite datasets shown above. These error bars were calculated from comparisons with independent balloon data of different types and homogenization techniques. The results show that the likely trend of the tropical troposphere is around +0.08 C/decade for this period where the two error bars overlap. This is inconsistent with the results from climate models (+0.17). What should one conclude since this test of the models was performed in the area of the climate system for which greenhouse warming should be detectable due to the large signal?

Slide 21



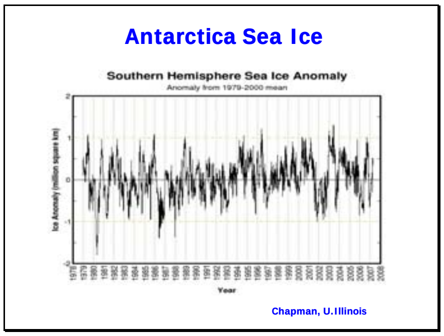
Here is the time series of UAH's lower tropospheric temperatures. This warming rate is about 60% of the climate model projections.

Slide 22

Cold Places?

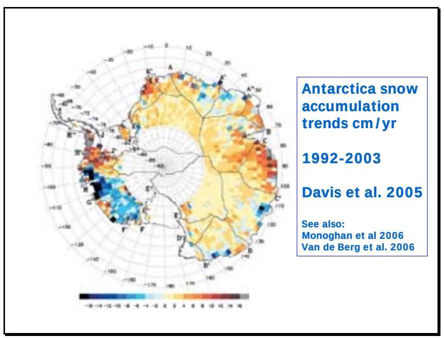
Because global warming at the surface is thought to impact cold places first and most obviously, we shall look there now.

Slide 23



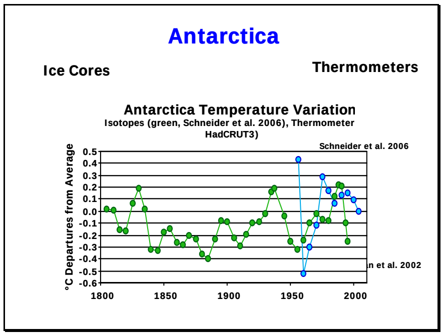
This is the sea ice extent for the southern hemisphere around Antarctica since 1978. This shows a slightly positive trend in sea ice extent with no hint of a long-term change. Whether sea ice is expanding or contracting though is not important for sea levels because the ice is already floating in the ocean. If it melts, it doesn’t change the level. For sea level to rise due to melting ice, the ice must be above the ocean, such as on Greenland or Antarctica.

Slide 24



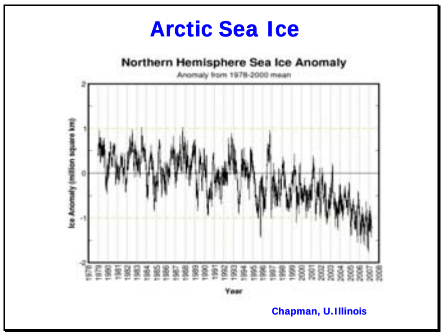
Moving now to the Antarctic continent, we see that some studies show the following result - that there is a net mass accumulation over Antarctica. As indicated before, snow and ice that accumulate on Antarctica and Greenland have an impact on sea level. If these places are accumulating snow and ice, that means the sea level will not be rising due to this. This particular study and others suggest Antarctica is not contributing to sea level rise. However, this is a hot area of research and there are other papers which indicate that the edges of part of Antarctica, mainly in the lower left of the figure above, counterbalance the accumulation in the main part of the continent with melting. In fact, some results show a small net loss of Antarctic ice, contributing to sea level rise of a couple of cm over a century. There is considerable uncertainty in the mass balance of Antarctica and Greenland. New results will no doubt keep the uncertainty alive.

Slide 25



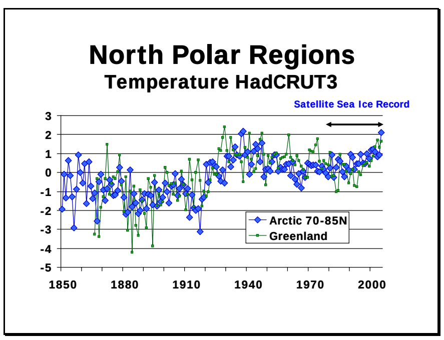
Antarctica surface temperatures have large variability, but show not trend. Indeed, the most recent decades indicate a declining trend. It doesn't look like temperature changes are causing changes in ice mass unless it is causing an accumulation of ice. In another point of view, even if the Antarctic and Greenland warm up, this will cause more snow to fall, not less.

Slide 26



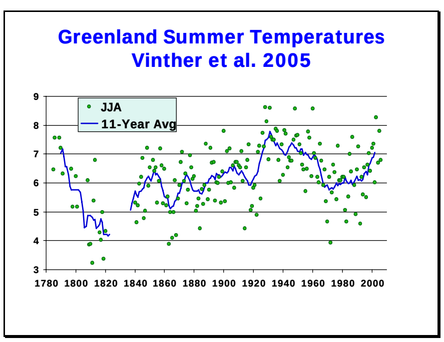
There has been a significant loss in Arctic sea ice. Temperatures have also risen over this time period as indicated in all of the datasets we have.

Slide 27



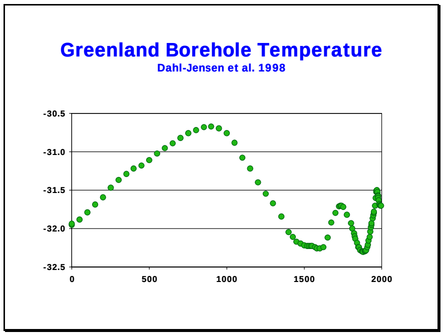
As can be seen here the period where the Arctic sea ice is retreating (1979 onward), we see a rising surface temperature. However, looking back to 1920 to 1940 you see a much more rapid rise to a temperature level even warmer than today. I wonder what all of the new satellites we have now would have seen back then?

Slide 28



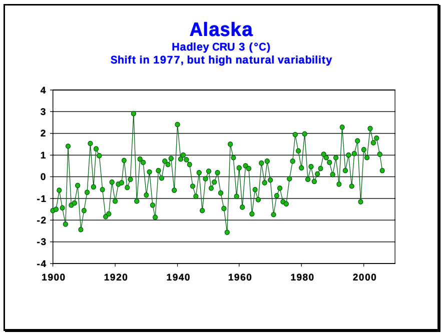
Greenland's temperature has risen in the past 15 years, but again, rises in temperature have occurred in the past and to levels higher than today without a dramatic change in Greenland's melting that we know of. Even the most recent estimates of the balance of Greenland's ice budget, where 3 years of data show a net melting, contributing to sea level rise of only 4 cm per century. Should one make a trend based on 3 years of data? There are a very few scientists who are claiming Greenland will melt rapidly in the near future causing seas to rise 5 to 25 meters, with 5 m reached by 2100 - 100 times what the trend over the past 3 years shows.

Slide 29



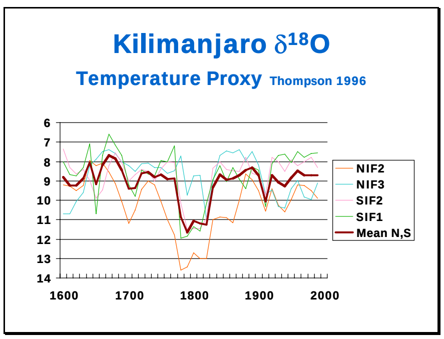
Going back over the last 2000 years we see that Greenland has been warmer than today for hundreds of years - yet no rapid melting was observed. Not shown is the temperature back 10,000 years. Greenland was actually over 2.5 °C warmer from 4,000 to 8,000 years ago than today … a very long period of greater warmth. Greenland didn't melt back then.

Slide 30



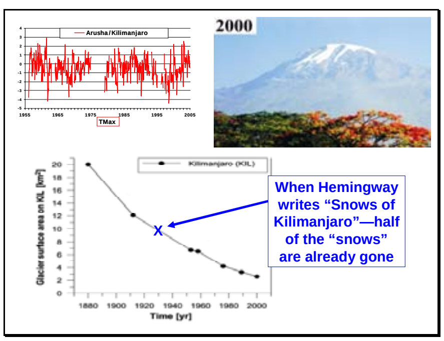
Alaska's temperature is quite variable with the warmest years in the 1920's and 1940. The last few years have been on a downward trend.

Slide 31



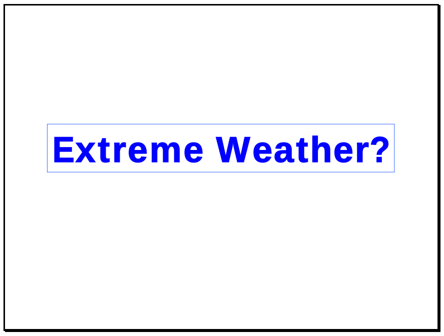
This is a time series of a temperature proxy for tropical glaciers. The main point to get from this is that tropical glaciers are terrible thermometers.

Slide 32



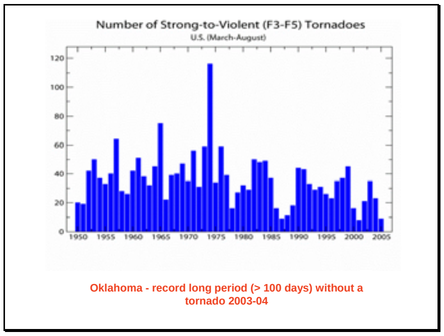
Actual temperature measurements of the daytime temperature in the Kilimanjaro area has not changed in over 50 years. The snow has been diminishing on Kilimanjaro since the first measurements were made over 100 years ago. The best explanation here is that changes in precipitation (not temperature) are causing the loss of snow and ice.

Slide 33



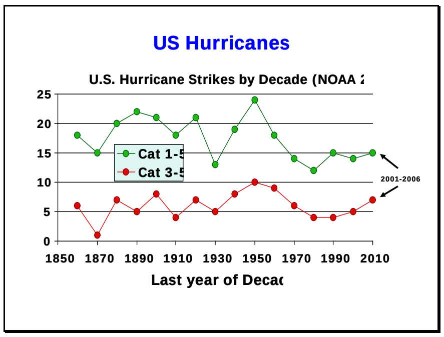
We hear much about extreme weather events as a result of human-caused global warming.

Slide 34



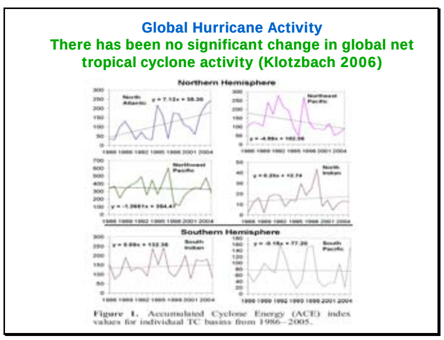
Tornadoes are not increasing.

Slide 35



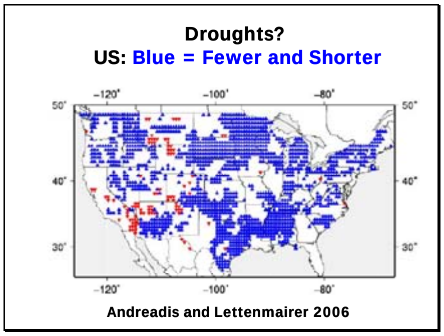
Hurricanes are not increasing. (Landsea 2007 has just published an update of this to show no change over this time period too.)

Slide 36



Globally, hurricanes are not increasing. These are different areas of the globe and all together the numbers show 90 to 100 hurricanes per year.

Slide 37



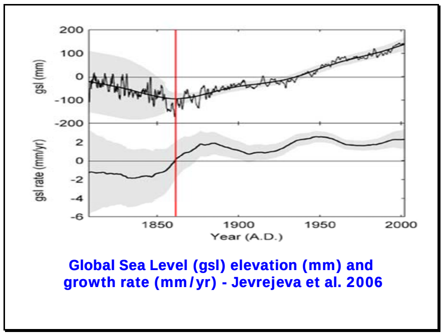
Droughts in the U.S. are becoming fewer and shorter. Overall, the past several slides point out that the type of weather that people really care about is not changing much at all. However, extremes do happen by definition. So, if we know the types of extremes that have happened in the past, can we make ourselves less vulnerable to them in the future? If something has happened before, there should be a relatively high probability it will happen again at some point.

Slide 38

Sea Level Rise?

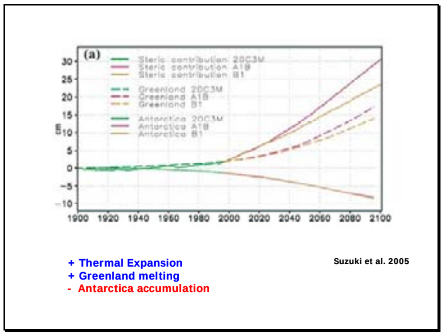
Will sea level rise at a dangerous rate? In the last 100 years the rate has been about 2 cm per century.

Slide 39



The current rate of 2 cm per century has been steady since the 19th century.

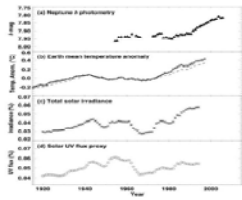
Slide 40



Model projections expect a “warming world” to slowly melt the ice in Greenland (raising sea level), cause accumulation in Antarctica (reducing sea level) and warm the oceans which will then expand a bit (raising sea levels). This is expected to cause a total sea level rise of about 30 to 40 cm by 2100. A couple of scientists, as mentioned earlier, think a tipping point will be reached that will cause Greenland to rapidly decay leading to a 5 m rise by 2100. We note here again that between 4000 and 8000 years ago, Greenland was over 2.5 °C warmer than today (sometimes being much more than that) without such catastrophic failure and sea level rise. The evidence overall indicates that sea level will continue to slowly rise until the next ice age begins, just as it did during the last interglacial period 130,000 years ago.

Slide 41

Neptune warming?



(a) represents the corrected visible light from Neptune from 1950 to 2006; (b) shows the temperature anomalies of the Earth; (c) shows the total solar irradiance as a percent variation by year; (d) shows the ultraviolet emission from the Sun (Source: Hammel and Lockwood (2007)).

A final observation that introduces a different idea of the cause of Earth's warming is shown here. Apparently, several planetary bodies in our solar system have shown recent warming (e.g. Mars). A proxy for Neptune's temperature (top) seems to match very well with the variations in solar output (Hammel and Lockwood, 2007). This is a preliminary result and has a number of cautionary notes. For example, Neptune's temperature is shown to lag behind the Earth/Sun relationship by 10 years because the assumption is that Neptune's ability to respond to solar changes is that slow. In any case, this and other intriguing results point to a solar connection as a component of the changing Earth temperatures on decadal scales.

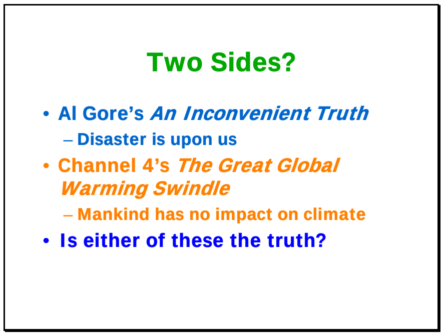
Slide 42

Evidence Thus Far

- Global surface and atmospheric temperatures are rising in a way somewhat inconsistent with model projections of greenhouse gas forcing
- Overall decline in ice mass, with sea level rise of 1" per decade
- Severe weather not becoming more frequent

If you had been completely ignorant of the enhanced greenhouse effect, would you conclude that humans were altering the climate system by that process? This leads us into what science really is.

Slide 43



Two videos regarding climate change have been popular lately, especially An Inconvenient Truth. BBC's Channel 4 produced a documentary, The Great Global Warming Swindle, in which the basic premise was that CO2 has essentially no impact on the climate at all. (Although Channel 4 did take a considerable look at political and social aspects of the climate change issue too.) These two are good examples of how science is not done. In both of these programs, a particular point of view was assumed to be correct at the start. From that point, information that was consistent with the particular view was utilized and promoted while information not consistent was ignored, belittled or twisted. This is what is done in a court of law to argue a case, because the goal in a legal case is for one side to win. In science, we construct hypothesis which are required to explain all of the information (observations). If something is not consistent, then the hypothesis must be revised. Science progresses not by structured court proceedings but by the almost "chaotic" publication of discoveries which address various hypotheses. Science can be a rather messy way to arrive at information in which one may have confidence.

You are not doing science if you start with a premise and seek to prove it by ignoring evidence to the contrary. The goal should be to start with the observations (ALL of the observations) and then try to explain them with a hypothesis that can be tested with new (but unknown to you) observations. Human-induced climate change is a hypothesis with both supportive evidence (not shown to any extent in this presentation) and unsupportive evidence. More must be done on this science - more and better observational systems are needed, better understanding of climate physics is required and improvements in model simulations need to be performed.

Slide 44

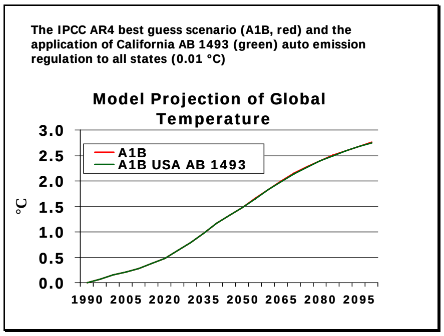
Main Point:

I don't see a disaster developing

But, suppose you do ....

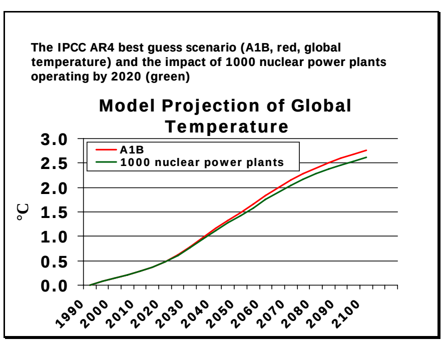
Finally, we hear much today about "doing something" about climate change. So, let's look at the final two slides and ask about policy.

Slide 45



For example, California has signed into law AB 1493 and several N.E. states have adopted it. The bill requires a 30% reduction in tail pipe emissions of CO_2 by 2016 for light duty vehicles (cars, light trucks). To determine the impact, the MAGICC tool (Wigley) was utilize in which the CO_2 emission reductions from AB 1493 were applied to a library of climate model simulations. The net impact, even if the entire country adopted this, is imperceptible, 0.01 °C by 2100 for the IPCC AR4 A1B scenario of emissions. We don't even have observing systems to measure such a result. So this bill will have no measurable impact on the climate system. (Recall that to have a measurable impact on central California climate, the area must be depopulated and returned to a desert - which has nothing to do with CO_2 emissions.)

Slide 46



To make even a small impact on projected temperatures, the above chart shows what would happen if 1000 new nuclear power plants began operating by 2020. People produce and use energy at a rate of about 14 terawatts. A typical nuclear power plant generates about 1.4 gigawatts. So to replace 10% of the current energy production and thus about 10% of CO_2 emissions, it would take about 1000 nuclear power plants. The net change in temperature with this scheme is about 0.15 °C by 2100 which is also a tiny amount, but it is now noticeable. (The 1000 nuclear power plants world wide is roughly equivalent to cutting U.S. emissions in half by 2020 … would the U.S. have a functioning economy if that were done?)

These last two slides illustrate a policy situation on which climate scientists are often called to give opinions (even though we are not trained as policy experts). As indicated, tweaking current transportation and energy systems to reduce CO_2 by fractional amounts will have no discernable impact on the climate (whatever the climate might do in the future) and will have high costs. To have a major impact on CO_2 emissions, a massive change to non-emitting technology (I.e. nuclear) is required.

So, here are two policy questions, one technology and the other infrastructure: (1) should money be spent trying to reduce emissions in current systems by fractional amounts, or should money be spent on the next generation of systems that emit little or no CO_2 to get them here sooner? (2) should money be spent adapting to changes that are being measured as they happen (or that are likely to happen because they've happened before like the devastating drought of the 1930s), or should infrastructure by built based on predictions of how the climate system might evolve as depicted by some climate models (i.e. guessing where the droughts will be)?

And don't forget this - what would you recommend to congress knowing that when energy prices are forced upward, the result is what is called a regressive tax - its greatest impact falls on the poorest people? This goes back to the early slide noting that energy technology has had a spectacular impact on extending and enhancing human life. People want energy because it makes their lives much better, and the poorer you are, the greater impact affordable energy will have on your life.

These policy issues raise questions scientists have opinions on, but for which the underlying assumptions and data are rather ambiguous and diverse. Be very clear about your assumptions when dealing in the policy arena because various "experts" have various assumptions which then lead to very different conclusions. It's always best to have numbers rather than feelings on which to base assumptions.