Anthropogenic Global Warming Science Assessment Report

The Right Climate Stuff Research Team

April, 2013

Introduction

The Right Climate Stuff (TRCS) research team is a group of engineers and scientists, most of whom are retired NASA Johnson Space Center employees, who have successfully worked together on manned space projects since the early days of the Apollo Program. Although climate science is not one of our technical specialties, the required expertise in physics, chemistry, geology, meteorology, biology, data analysis and interpretation, and complex systems modeling, is similar to our collective academic training and experience gained through our typical 40 - 50 years of experience working in our nation's space program. Our natural interest in the Anthropogenic Global Warming (AGW) controversy led to invitations to guest speakers on the subject at our occasional NASA retiree organization meetings. Responding to additional interest generated from these guest speakers, our NASA retiree organization hosted two Symposiums on global warming topics during September and October 2011, featuring speakers on either side of the AGW debate. These symposiums generated even more interest in climate science and motivated self-study of the science and related data by some of our colleagues.

In February 2012, we organized TRCS research team to coordinate and share our individual studies of climate science. We were motivated by the public and political controversy fostered by alarming predictions of impending catastrophic anthropogenic global warming by NASA's current leadership of climate science research at the Goddard Institute for Space Studies (GISS). Many of us felt these alarming and premature predictions of a climate disaster with so little empirical data to support these claims, would eventually damage NASA's reputation for excellent and objective science and engineering achievement. Some members of our TRCS team, as well as a wider population of NASA retirees, signed two letters sent to the NASA Administrator expressing our concerns about alarming public statements regarding catastrophic AGW by NASA leaders of climate research. These letters expressed concern that such statements by high NASA officials would be interpreted by the general public as official positions of NASA, and that such statements did not result from a wider NASA internal and external review and scientific debate that our nation has come to expect from official NASA positions on controversial issues.

Because of our past successes, working in a team environment to achieve difficult objectives, our TRCS team were confident that we had or could recruit the requisite expertise in all required scientific disciplines to study published climate research and available significant data to form an independent, objective assessment regarding the alarming and controversial claims of catastrophic AGW. We invited others with interest and expertise to join our team and to share what they had learned from their previous individual studies of the scientific issues involved. In particular, the Texas State Climatologist, Dr. John Nielson-Gammon[1], agreed to work with us on this project and has been an invaluable resource in recommending peer-reviewed research for us to consider and in helping to

[1] Professor of Meteorology, Department of Atmospheric Sciences, Texas A&M University; Texas State Climatologist since 2000.

moderate our discussions regarding critical reviews of available research papers. He has done an excellent job of defending the main stream climate science viewpoints on the AGW issue, and we are identifying the unsettled scientific issues that require further study and definition.

In addition to our study of peer-reviewed research, we have been fortunate to have several nationally known climate researchers make presentations of their research findings and scientific positions to our group. As we proceed further with this project, we welcome similar presentations from scientists on both sides of the AGW controversy.

There are many fascinating aspects of climate science and various hypotheses to pursue that might explain what we can observe in the data, and that interest different members of our group to varying degrees. However, we decided that we would focus our initial TRCS team technical investigation on the most pressing question facing our public policy decision-makers, "To what extent can human-related releases of CO2 into the atmosphere cause earth surface temperature increases that would have harmful effects?" This is a summary report of what we believe to be true with high confidence at this point in our investigation.

Note: This diversity of opinion would be essentially academic had not many in the climate science community chosen to engage in direct advocacy to influence public policy on a global scale. This advocacy, particularly at the UN level, portends toward massive carbon-tax wealth-transfer payments, which would lower the standard of living in developed economies, and threatens the rise of underdeveloped economies out of poverty, i.e., it can be said with a high assessed confidence that the “cost” portion of the cost-benefit analysis to mitigate CO2 emissions will be excessive, crowding out more productive ways to spend the money. The legitimacy of the Carbon-based AGW hypothesis is thus rightly subject to public challenge.

The Question

"To what extent can human-related releases of CO2 into the atmosphere cause earth surface temperature increases that would have harmful effects?”

This is actually a two part question, the first of which relates to temperature increases (an objective question) and the second of which relates to harmful effects (subjective question.)

To answer the first question, the induced warming from additional CO2 must first be separated from other things that induce warming. These “other things” include both natural and human-induced perturbations besides CO2. And then the warming from “human-related”, a.k.a. anthropogenic CO2 (~3.5% of the total), must be teased away from the 96.5% of CO2 that is emitted from natural sources. Finally, any mitigating cooling responses to a warming earth, be they natural or anthropogenic, e.g. sulphate aerosols from fossil fuel combustion, must be factored into the equation.

To address the immediate questions that typically come up regarding the CO2 origins, we recommend the paper by one of our members, Dr. Don Bogard on *Global CO2 Inventories* at the TRCD website[2]

[2] http://therightclimatedata.com/Documents/Intro/A_Global%20CO2%20Inventories_DB.pdf

and the USGS Fact Sheet 2008-3097[3]. To paraphrase, although only a few % of the CO2 presently in the atmosphere is human-caused, the ~39% increase in atmospheric CO2 (from ~280 to ~390 ppm) over the past century correlates to the estimated amount of fossil fuel burned over this period. The CO2 exchange among the atmosphere, oceans, soils, and plants have substituted most of the human-caused atmospheric CO2 for CO2 in these other reservoirs. A more uncertain issue is related to the fact that CO2 exchanges among these reservoirs per year are much larger than the CO2 added by humans. This raises the question of how well we understand changes that are occurring in the rates of these CO2 exchanges. A relatively small uncertainty here could be significant compared to the rate of fossil fuel addition.

After addressing the first part of the topic question, the "harmful effect" temperature threshold must be defined. This, of course, requires a cost-benefit analysis, a process which is fraught with subjective judgments. The earth has warmed and then cooled many times in the past. So it is clear that natural processes have worked to prevent the earth from reaching a warming level harmful to the ecologies that humans and our pre-sapien ancestors have lived in, though in smaller numbers and with less fixed infrastructure. Anthropogenic CO2 emissions and any amplification factors induced by higher anthropogenic CO2 is known as Carbon-based Anthropogenic Global Warming[4]. The challenge then is to show when Carbon based AGW will have sufficiently increased to induce more harm than benefit. This issue will be addressed in another study.

Induced Warming From Additional CO2

With respect to this topic, our bullet point conclusions are:

- **Carbon-based AGW science is not settled.** This refers only to the Carbon or CO2 role in induced warming
- **Natural processes dominate climate change (although many are poorly understood).**
- **Non-Carbon-based AGW anthropogenic forcings are significant.** These include land use change, Urban Heat Island (UHI) effect, black carbon, and aerosols.
- **Carbon-based AGW impact appears to be muted.** Other sources are not necessarily muted; the impacts of changing solar activity, El Nino/La Nina-southern oscillation (ENSO), Pacific Decadal Oscillation (PDO), Atlantic Multidecadal Oscillation (AMO), black carbon, etc., are observable.
- **Empirical evidence for Carbon-based AGW does not support catastrophe.**

[3] http://pubs.usgs.gov/fs/2008/3097/pdf/CarbonFS.pdf
[4] The origin of the acronym CAGW is not clear and is inconsistently used in climate science discussions. AGW is not restricted to the impact of CO2 and methane, but also includes aerosol emissions, land use change and the Urban Heat Island effect. Some consider the "C" in CAGW to represent Catastrophic, e.g. net harmful, but this convention does not clearly acknowledge the contribution of factors other than greenhouse gases. Hence, we will avoid this acronym in this paper.

- **The threat of net harmful total global warming, if any, is not immediate and thus does not require swift corrective action.**
- **The US Government Is Over-Reacting to Concerns About Anthropogenic Global Warming.**

Is the Carbon-based AGW Science "Settled"?

Note that this topic is addressed only at the likely validity of the science that purports that an increase of global average temperature due to CO2 ppm doubling from 280 ppm to 560 ppm will be between 2 and 4.5 ^{O}C. (There are additional factors such as whether there is a real potential, in an economic sense, to generate that much CO2 based on the likely production of recoverable fossil fuels, but that is a separate issue and not one of pure science. In any case, estimates for the time required for this doubling to occur vary significantly, with many greater than 100 years, but at least one rough estimate taking as low as 55 years if the average CO2 ppm increase rate since 1950 were to continue and ~75 years if the present rate (~2 ppm/year) continues.)

We have reviewed the main stream climate science arguments that generally support the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) reports that a doubling of CO2 concentration in our atmosphere will lead to a 2.0–4.5 ^{O}C increase (the "climate sensitivity") in the earth's global average surface temperature. We have also reviewed scientific hypotheses, analyses, and rational arguments that refute the claims that increasing CO2 levels in our atmosphere can cause such large increases in the earth's annual global average temperatures. While it can be shown that the pure radiative effect of a doubling of CO2 concentration from 280 ppm to 560 ppm would produce ~1.2 ^{O}C, the rest of the above estimate is a function of uncertain feedback effects.

From IPCC AR4 Box 10.2 -

> *"The likely range for equilibrium climate sensitivity was estimated in the TAR (Technical Summary, Section F.3; Cubasch et al., 2001) to be 1.5°C to 4.5°C. The range was the same as in an early report of the National Research Council (Charney, 1979), and the two previous IPCC assessment reports (Mitchell et al., 1990; Kattenberg et al., 1996). These estimates were expert assessments largely based on equilibrium climate sensitivities simulated by atmospheric GCMs coupled to non-dynamic slab oceans. The mean ±1 standard deviation values from these models were 3.8°C ± 0.78°C in the SAR (17 models), 3.5°C ± 0.92°C in the TAR (15 models) and in this assessment 3.26°C ± 0.69°C (18 models).*
>
> *Considerable work has been done since the TAR (IPCC, 2001) to estimate climate sensitivity and to provide a better quantification of relative probabilities, including a most likely value, rather than just a subjective range of uncertainty. Since climate sensitivity of the real climate system cannot be measured directly, new methods have been used since the TAR to establish a relationship between sensitivity and some observable quantity (either directly or through a model), and to estimate a range or probability density function (PDF) of climate sensitivity consistent with observations. These methods are summarized separately in Chapters 9 and 10, and here we synthesize that information into an assessment. The information comes from two main categories: constraints from past climate change on various time scales, and the spread of results for climate sensitivity from ensembles of models."*

While the term “climate sensitivity” is generally used in the main stream climate science literature to denote an increase in the earth's global average surface temperature due to a doubling of the current CO2 concentration in our atmosphere, that sensitivity is a function of both the amount of CO2 in the atmosphere and, more importantly, the direct feedback mechanisms of atmospheric water vapor changes and cloud formation and distribution. Our current assessment is that this scientific debate regarding critical aspects of the AGW hypothesis will continue until the fundamental physics of the overall climate system response to higher CO2 levels is fully understood and more physical evidence becomes available to provide more convincing proof to support one side or the other.

Many in the climate science community espouse that they are able to define the harmful effect threshold level of CO2 from both empirical data and modeling results. For example:

- The faculty of the Dept. of Atmospheric Sciences of Texas A&M University, agree with the recent reports of the Intergovernmental Panel on Climate Change (IPCC) that:
    1. It is virtually certain that the climate is warming, and that it has warmed by about 0.7 ^{o}C over the last 100 years.
    2. It is very likely that humans are responsible for most of the recent warming.
    3. If we do nothing to reduce our emissions of greenhouse gases, future warming will likely be at least two degrees Celsius over the next century.
    4. Such a climate change brings with it a risk of serious adverse impacts on our environment and society.[5]
- James Hansen, recently retired from NASA's Goddard Institute of Space Studies (GISS), has stated that "*Air temperatures of the last quarter-century have been unprecedented for at least the past two thousand years*.", "*The atmosphere's current CO_2 concentration is greater than it may have been for tens of millions of years*." and "*The earth is close to dangerous climate change, to tipping points of the system with the potential for irreversible deleterious effects.*"[6]
- Richard Alley of Penn State has said that, "*Our high assessed confidence that the recent warming is mostly human-driven, and that the costs will become large if the warming becomes large, do not primarily rest on how much warmer or colder today is than some particular time in the past, or even how fast the recent changes are relative to those in the past*."[7] This brings into question the basis of the "high assessed confidence" of the anthropogenic dominance in historic cause **and** that whether there is a basis for "high assessed confidence" that the "costs" will become large.

Such sentiment is loosely categorized as being of the "warmist" camp.

But the alarm is not universal. Indeed, Dr. Richard Lindzen, the Alfred P. Sloan Professor of Atmospheric Sciences at the Massachusetts Institute of Technology, stated "*The notion of a static, unchanging climate is foreign to the history of the earth or any other planet with a fluid envelope*."; " *The fact that the developed world went into hysterics over changes in global mean temperature*

[5] http://atmo.tamu.edu/weather-and-climate/climate-change-statement

[6] 26 April 2007 testimony to the Select Committee of Energy Independence and Global Warming of the U. S. House of Representatives entitled "Dangerous Human-Made Interference with Climate" http://www.columbia.edu/~jeh1/2007/Testimony_20070426.pdf

[7] Comments on the blog DOT Earth, http://dotearth.blogs.nytimes.com/2013/03/07/scientists-find-an-abrupt-warm-jog-after-a-very-long-cooling/

anomaly of a few tenths of a degree will astound future generations.", and " *Such hysteria simply represents the scientific illiteracy of much of the public, the susceptibility of the public to the substitution of repetition for truth, and the exploitation of these weaknesses by politicians, environmental promoters, and, after 20 years of media drum beating, many others as well.*[8] Dr. Lindzen reflects the views of scientific thinkers who are skeptical that the impact of Carbon-based AGW will be significant.

And then there is a group of "lukewarmers", who contend that the data suggest that human activities produce CO2 emissions that induce discernable, but not alarming, warming of the globe. Typical of this camp is Dr. Roger A. Pielke, Sr.[9], who has frequently stated that: "*The focus on just* CO_2 *as the dominate human climate forcing is too narrow. Natural variations are still quite important. Human influence is significant, but it involves a diverse range of first-order climate forcings, including, but not limited to the human input of* CO_2." [These other human forcings include] "*emission of aerosols into the atmosphere, land management and land cover change*."

From such diverse interpretation of the data by climate scientists, **one must conclude, with a high assessed confidence, that the science of Carbon-based AGW is not settled.**

At the crux of these differences in scientific opinion is the extremely difficult task of separating atmospheric CO2 effects from poorly understood natural climate cycle effects, some with cycle periods that appear to last for hundreds or thousands of years. The most accurate global temperature history from thermometers only extends back to about 1850 AD, that coincidently is about the time measureable increases in atmospheric CO2 levels due to human activity are recorded. Those scientists who attribute most of the global temperature rise of the last century to atmospheric CO2 increases, discount the possibility that most of the observed warming could be due to natural climate cycles. The proven answer to this "human or natural causes" scientific debate question will require more data. Recent relatively flat to decreasing global average temperature data trends of the last 15 years indicate natural climate effects have prevented the hypothesized CO2 effects from warming the planet, and therefore are also just as significant. The tendency of the "warmist" camp to describe global average temperatures of the last 15 years as some of the "warmest on record", ignores paleo-climate data of the last 10,000 years, and can also be easily explained by the possibility of natural climate cycles that could be reaching a peak in their warming and cooling cycles. The next 10-15 years of global temperature data will be extremely important in resolving the relative magnitudes of human vs. natural climate cycle causes of the observed global warming over the last century and for obtaining more accurate projections of global average temperature trends for the future.

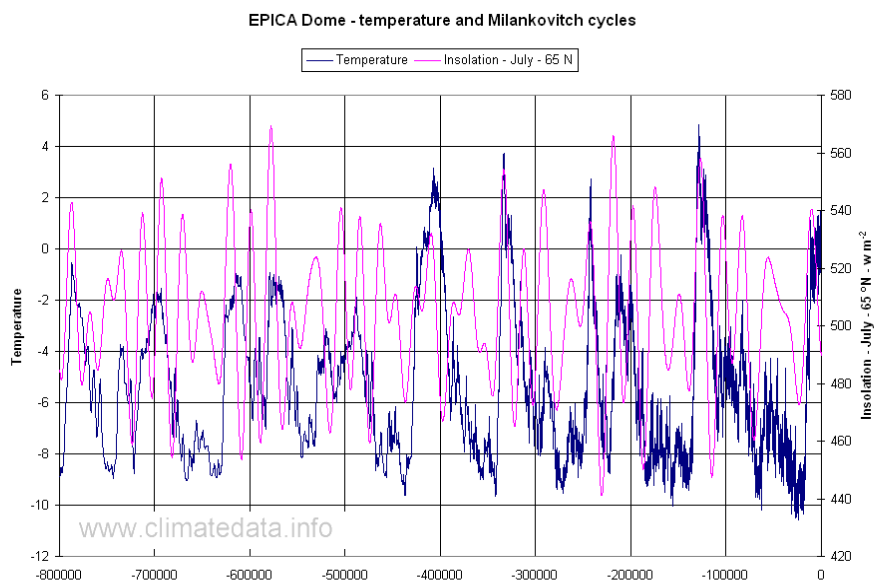
[8] July 26, 2009

[9] Senior Research Scientist at CIRES, emeritus professor of the Department of Atmospheric Science at Colorado State University, retired.

Natural Processes Dominate Climate Change (although many are poorly understood).

We first consider “other factors that cause warming (or cooling)”.

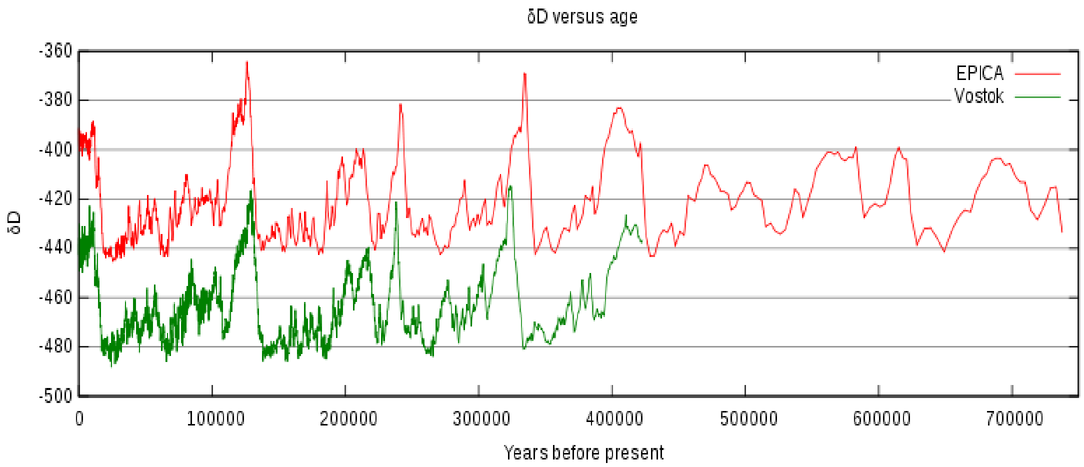
The theoretical[10] portion of climate science recognizes that the climate on earth is dominated by the sun, the earth’s varying position relative to the sun in its orbit around the sun, the varying albedo (reflectivity) of the earth, and the water cover of our planet. In the relatively recent ~one million years of the past, the earth has been in an ice age exemplified by glacial periods with enormous ice sheets covering most of the Northern Hemisphere (NH) that resulted in oceans being ~120 meters below the present sea level, interspersed by warming periods where most of the ice sheets melted and sea levels rose. As discerned from ice core proxies, these cycles lasted about 100,000 years, with the glacial periods being about 70,000 to 90,000 years and the interglacial periods lasting about 10,000 to 30,000 years.



This figure is from www.climatedata.info.[11]

[10] Per the National Academy of Sciences a theory is “A plausible or scientifically acceptable, well-substantiated explanation of some aspect of the natural world; an organized system of accepted knowledge that applies in a variety of circumstances to explain a specific set of phenomena and predict the characteristics of as yet unobserved phenomena.”

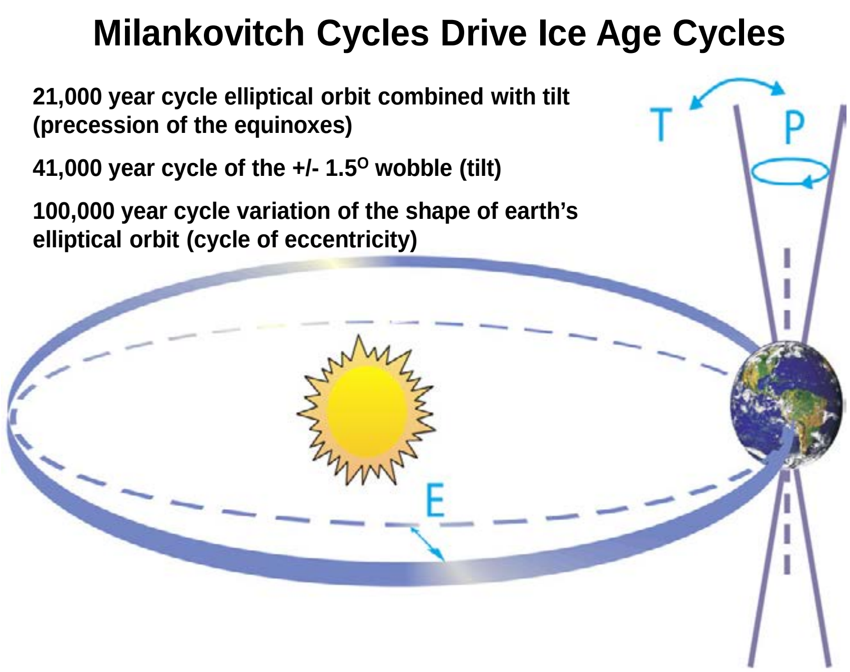
[11] http://www.climatedata.info/Proxy/Proxy/datasources.html. 29Mar13. “The figure “EPICA dome and temperature Milankovitch cycles” is based on ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/antarctica/epica_domec/edc3deuttemp2007.txt (Reference : Jouzel, J., et al. 2007.EPICA Dome C Ice Core 800KYr Deuterium Data and Temperature Estimates.). The complementary Milankovitch cycle data were based on a series files bein1.dat to bein11.dat downloaded from http://www1.ncdc.noaa.gov/pub/data/paleo/climate_forcing/orbital_variations/berger_insolation/ and processed by ourselves for the required month and latitude.



Delta deuterium data from the European Project for Ice Coring in Antarctica (EPICA) ice core deep drilling at Concordia Station at Dome C, compared to similar results from the Vostok Station, reflect the approximately 100,000 year glacial-interglacial cycles.[12]

These cycles were predicted by Serbian geophysicist and astronomer Milutin Milanković, who worked on them during his First World War internment. Milanković mathematically theorized that variations in eccentricity, axial tilt, and precession of the Earth's orbit determined climatic patterns on Earth through orbital forcing.

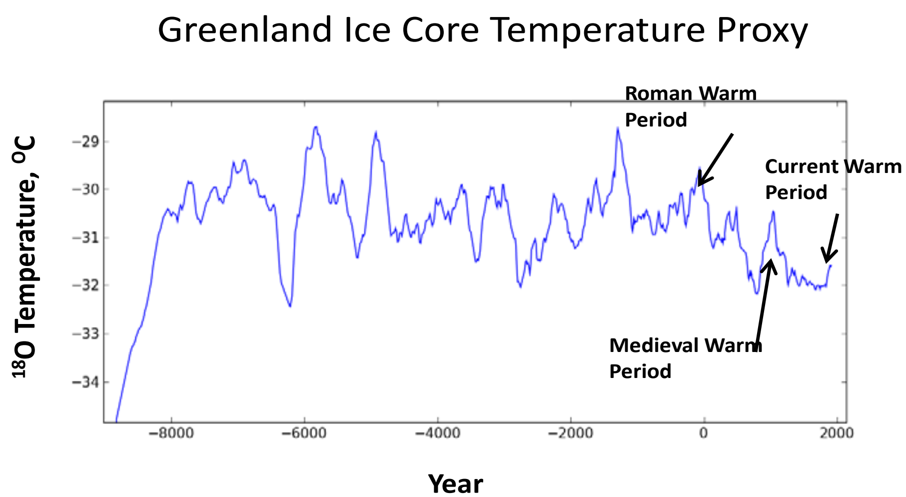
Schematic of the Earth's orbital changes (Milankovitch cycles) that drive the ice age cycles. 'T' denotes changes in the tilt (or obliquity) of the Earth's axis, 'E' denotes changes in the eccentricity of the orbit (due to variations in the minor axis of the ellipse), and 'P' denotes precession, that is, changes in the direction of the axis tilt at a given point of the orbit. Source: Rahmstorf and Schellnhuber (2006). Copied from http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter6.pdf, page 449. When the orbit is highly elliptical, one hemisphere will have hot summers and cold winters; the other hemisphere will have warm summers and cool winters. When the orbit is nearly circular, both hemispheres will have similar seasonal contrasts in temperature. The change in radiation from E is less than 0.2%, but this is enough to affect ice sheets. Today, the tilt is 23.5°, it varies between 21.6° and 24.5°.



This Milankovitch cycle is defined by the tilt, wobble, and eccentricity of the earth, and it explains these major glacial-interglacial cycles.

[12] http://en.wikipedia.org/wiki/European_Project_for_Ice_Coring_in_Antarctica

EPICA ice core data indicate that the globe was about 2 ^{O}C warmer at the peak of the last interglacial period, the Eemian, than the peak of the current interglacial, the Holocene. The peak temperature of



greenland/summit/gisp2/isotopes/gisp2_temp_accum_alley2000.txt

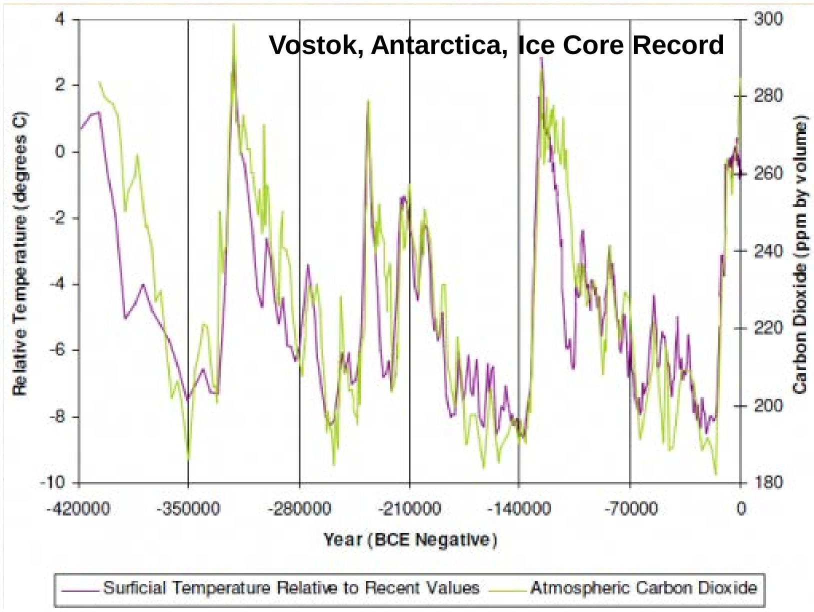
the Holocene, our current interglacial period, occurred about eight thousand years ago and was about 2 ^{O}C warmer than present in parts of the northern hemisphere per oxygen 18 isotope measurements, and globally perhaps 0.2 ^{O}C warmer per an ensemble of 73 paleo-thermometer proxies.[13]

Thus, during the cycles of, at least, the last four glacial periods the temperature changes always preceded changes in atmospheric CO2 levels. The IPCC 4th assessment report, page 444, states that the lag in CO2 increases that follow temperature increases is about 800 years. It is argued by some that, while this lag appears to be valid, the resultant warming of the oceans induces CO2 outgassing that amplifies the warming effect. While this may be true, it does not explain the factors that induced the warming periods or the factors that induced the following cooling phases whereupon the CO2 level decline begins after the temperature drops. Ergo, CO2 does not appear to be the throttle that controlled the temperature cycles of the last 700,000 years. Rather, the Milankovitch theory describes that temperature rheostat.

It is noteworthy that we are about 4,000 years past the peak insolation of this current Milankovitch cycle, and are thus into an overall cooling phase leading to the next glaciation. It is obvious from such data as the Greenland GISP2 proxy temperature data plotted above that the path toward cooler global temperature is not smooth, but rather is punctuated by abrupt episodes of warming lasting a few centuries, such as the Roman Warming Period (RWP) around 0 AD and the Medieval Warming Period (MWP) lasting from about AD 950 to 1250. The reasons for theses warming episodes are not known. Thus, there is no justification to discount these unknown warming factors from affecting our current warming period that began at the end of the Little Ice Age (LIA) but before atmospheric CO2 began to

[13] A Reconstruction of Regional and Global Temperature foe the Past 11,300 Years, Shaun A. Marcott, Jeremy D. Shakun, Peter U. Clarke, Alan c. Mix; *Since,* 8 March 2013; volume 339

rise after 1850.[14] This part of climate science is not settled.



It is becoming increasingly apparent that variations of solar activity likely played a part in the RWP, the MWP, and the LIA. The correlation of solar activity and the Earth's temperature is strong, but short-term irradiation variations are, by themselves, insufficient to explain temperature swings. Amplification factors are required, possibly such as increased galactic cosmic radiation reaching the earth's atmosphere during lulls in solar activity, which in turn induce increased cloud albedo that cools our planet; and vice versa during periods of high solar activity[15] (such as occurred during the last half of the 20th century).[16]

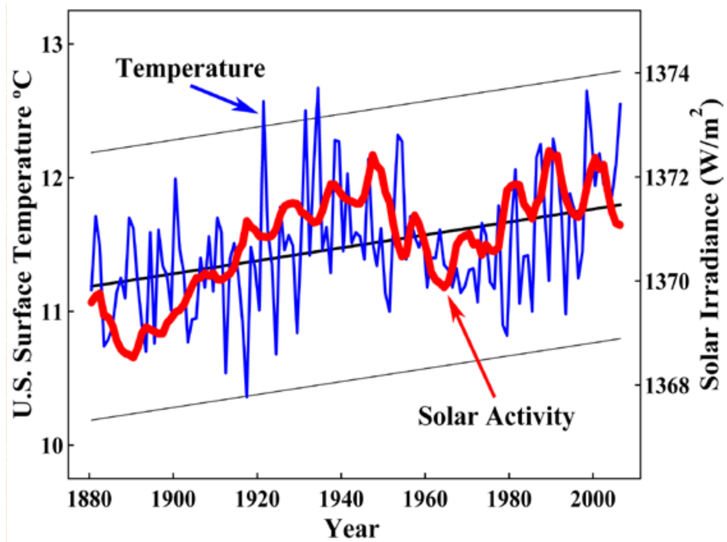
It has been estimated that a five percent change in global low-level cloud cover equates to a temperature change of about 0.35 ^{o}C[17], where more cloud cover results in reduced temperature.

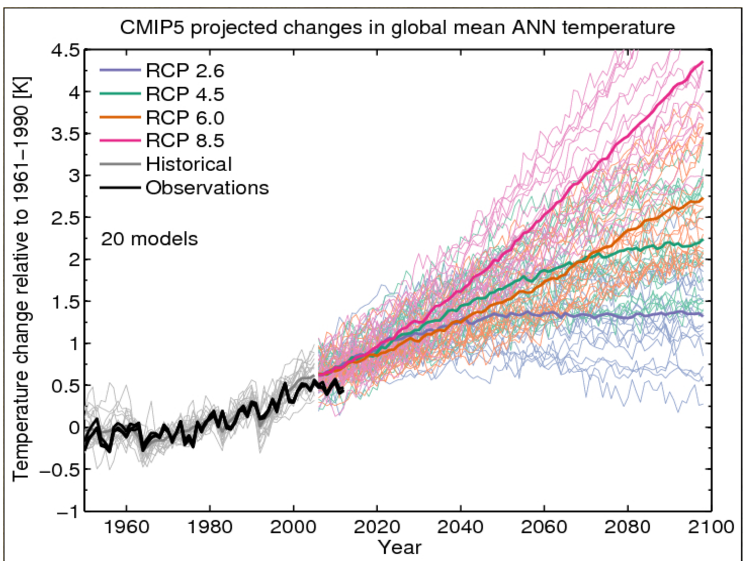
It is increasingly obvious that natural cycles over periods of years, decades and centuries influence the global temperature. John Christy and colleagues discuss some of these many natural cycles.[18] Among these cycles are the prominent ocean-atmospheric coupled oscillations of the El Nino Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Atlantic Multi-decadal Oscillation (AMO). Little is known about the cause of these cycles, but it is apparent that when their warm phases coincide, extra warmth is added to the atmosphere. Indeed this was the case in the latter part of last century. Likewise, an overlapping of their cool phases could mask any warming from increases of atmospheric CO2, especially when combined with the quiet sun of our current solar cycle 24, as might be happening now. Evidence for strong correlation between the 60-year AMO and Central England

[14] http://en.wikipedia.org/wiki/Little_Ice_Age
[15] J. Svensmark, M. B. Enghoff, and H. Svensmark; 2012, Effects of cosmic ray decreases on cloud microphysics; www.atmos-chem-phys-discuss.net/12/3595/2012/ doi:10.5194/acpd-12-3595-2012
[16] Chart from Robinson, et al, "Environmental Effects of Increased Atmospheric Carbon Dioxide", Journal of American Physicians and Surgeons, (2007)
[17] http://www.climate4you.com/ClimateAndClouds.htm#LowCloudCoverVersusGlobalSurfaceTemperature
[18] Karl et al., 2006; Temperature Trends in the Lower Atmosphere; Chapter 2; Christy et al.;

temperature is provided by Tung and Zhou; 2013[19]. Judith Curry, on her blog Climate Etc., concludes: "*It looks like the AMO may have peaked, and we remain in the cool phase of the PDO with a predominance of La Nina events expected (unlikely to see a return to do El Nino dominance in the next decade). I predict we will see continuation of the 'standstill' in global average temperature for the next decade, with solar playing a role in this as well.*"[20]

This chart correlates solar irradiance with US surface temperature over the period 1880 - 2008 or so.





This chart plots various model outputs of global temp anomaly with observations. The observations of the last few years clearly are deviating downward from the projections.

That standstill in global average temperature started about 1998, after the strong El Nino of that year; it can be seen in the flatness of the observations post 1998 in the figure above.[21] Notice that the model projections, which range from a gain of ~1.4 ^{o}C to almost 4.5 ^{o}C by 2100, are all above the current

[19] Ka-Kit Tung and Jiansong Zhou; Using data to attribute episodes of warming and cooling in instrumental records; PNAS; www.pnas.org/cgi/doi/10.1073/pnas.1212471110

[20] http://judithcurry.com/2013/01/16/hansen-on-the-standstill/

[21] http://www.climate-lab-book.ac.uk/

trend. This suggests that something is amiss in the physics of the models, perhaps unaccounted for dampening by solar and/or "oscillation" effects. Ed Hawkins, of the University of Reading, who created this figure, notes about the spread of the climate sensitivity in the above models, that the most sensitive simulations being less likely, i.e. projections based on a high amplification of CO2 warming are not likely. It's not as bad as the IPCC thought.

Non-Carbon-based AGW Anthropogenic Forcings Are Significant.

As Dr. Pielke, Sr. frequently states, man's activities produce aerosols, change biomass and thus the hydrology of large swaths of the globe's land surface, and create islands of urban heat, all being factors that affect climate and the measurement of climate change.

In the IPCC TAR4, the net impact of aerosols was thought to be a cooling effect of -0.5 W/m2 which would cool the earth about -0.11 ^{O}C. Myher, 2009, suggests that black carbon, an aerosol that warms, has been more abundant than previously thought, reducing the net aerosol impact to -0.3 W/m2. Bond, 2013, asserts that black carbon is the second largest man-made contributor to global warming, resulting in a warming of 1.1 W/m^2, and its influence on climate has been greatly underestimated.[22] The conclusion here is that any increased warming attribution from black carbon reduces some of the warming assigned to anthropogenic CO2 and methane. The good news is that mitigation of black carbon emissions is economically viable with current technology, and will likely be applied because of known health threats from black carbon particulate matter.

The IPCC AR5 working groups have been assessing research for some time now and the second draft was unofficially published circa December 2012. While changes could be made between now and its formal publishing date (nearly a year from now), there is interesting content. From J Curry's 12/19/12 blog related to the AR5 draft report - http://judithcurry.com/2012/12/19/climate-sensitivity-in-the-ar5-sod/ :

Here is a quick summary of the issue: The effects of aerosols on clouds consist of three linked elements. Increased numbers of aerosols provide additional locations for droplet nucleation and, all else being equal, result in clouds with more and smaller droplets hence being more reflective to solar radiation (a cooling effect). The increased number of smaller droplets is hypothesized to hinder the formation of rain because more smaller droplets do not collide and coalesce into precipitation as efficiently. Suppression of precipitation leads to longer lived clouds that reflect solar radiation back to space. While this sequence aerosol-cloud effects is easily understood and widely accepted, in many cloud systems the cloud dynamics has a dominant effect over aerosol/microphysical effects, and there is scant observational evidence for a large value of aci (aerosol-cloud interactions) in real clouds. Climate models that include these aerosol-cloud interactions fail to include a number of buffering responses, such as rainfall scavenging of the aerosols and compensating dynamical effects (which would reduce the magnitude of the aci cooling effect).

So, recent research is narrowing the range of uncertainty of the aci, and overall reducing the magnitude of the aci effect. But most climate models still include the inappropriately large values of

[22] Bond, et al. 2013; Bounding the role of black carbon in the climate system: A scientific assessment; Journal of Geophysical Research: Atmospheres Accepted Articles, Accepted manuscript online: 15 JAN 2013

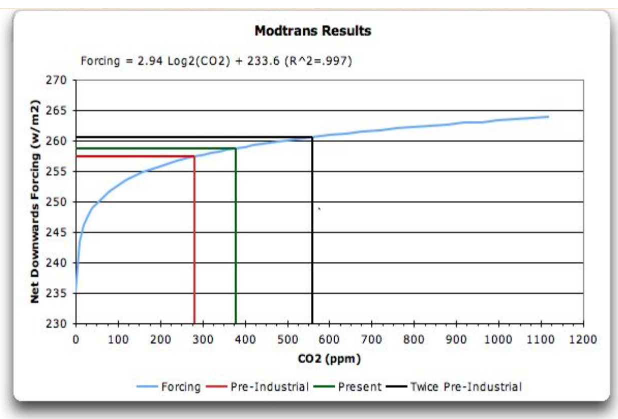
aci. It is difficult to then avoid the conclusion that the model-based sensitivity analyses (and observationally based analyses that use large values of aci) produce GHG equilibrium sensitivity values that are too large.

The impact of warming from land use change on the global earth temperature is difficult to assess, but the effects are recorded in ground-based thermometers and become part of the global temperature calculation. Warming from anthropogenic changes in the land thus diminishes that attributed to non-water greenhouse gases.

Carbon-based AGW Impact appears to be muted.

The physics of warming by atmospheric CO2 is well established, and it is generally agreed that a doubling of atmospheric CO2 from preindustrial levels would add about 1 ^{O}C to the earth's warmth. This relationship is logarithmic, and was described by Svante Arrhenius in 1896. The gain of ~4 W/m2 shown on this figure equates to about 1 ^{O}C. The issue in dispute is the amount of amplification that would come from humidification of a warmer mid-to-upper troposphere. Significant research is focused on this problem, but the answer at present is far from clear.

<u>The Logarithmic Effect of Carbon Dioxide</u>. **Willis Eschenbach, 2006**



Indicative of the controversy is the exchange on this issue between Andrew Dessler of Texas A&M University, and Roger Pielke, Sr.[23] In a guest post on Dr. Pielke, Sr's. blog Climate Science[24], Professor Dessler states: "*... we can conclude with extremely high confidence that the water vapor feedback is strong and positive (I would categorize it, in the IPCC's parlance, as being unequivocal). And I would categorize it as very likely that models are accurately simulating this phenomenon.*", and " *Given this, the most likely outcome of a business-as-usual emissions scenario is significant warming of several degrees Celsius*."

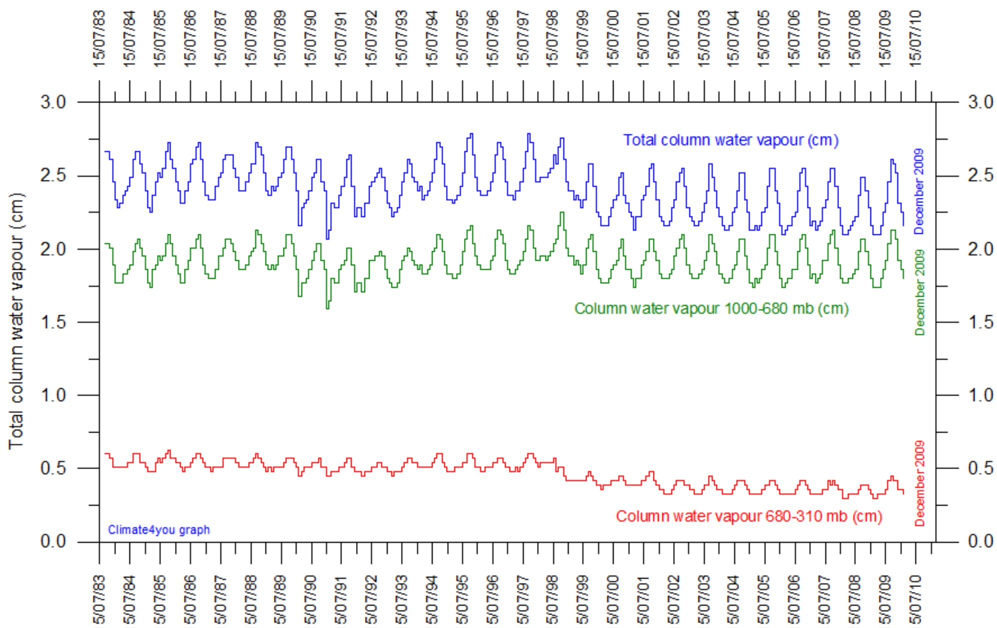
Dr. Pielke responds: "*There are also studies which do not show a concurrent warming and moistening of the atmosphere, at least on the regional scale*"; see Wang, J.-W., K. Wang, R.A. Pielke, J.C. Lin, and T. Matsui, 2008: <u>Towards a robust test on North America warming trend and precipitable water content increase</u>. Geophys. Res. Letts., 35, L18804, doi:10.1029/2008GL034564, which concludes: "*Student's t tests showed that the [lower troposphere temperature] from 1979 to 2006 was significant and positive; however, the [perceptible water vapor] and [total perceptible water content] were not. This suggests that atmospheric temperature and water vapor trends do not*

[23] Senior Research Scientist at CIRES, emeritus professor of the Department of Atmospheric Science at Colorado State University, retired

[24] http://pielkeclimatesci.wordpress.com/2010/01/06/guest-post-by-andrew-dessler-on-the-water-vapor-feedback/?preview=true&preview_id=3835&preview_nonce=6c212e614d

follow the conjecture of constant relative humidity."

The IPCC TR4 summary conflicts with column water vapor data from *The International Satellite Cloud Climatology Project (ISCCP)*, and is graphically presented below. The figure, extracted from the blog site of Ole Humlum, http://www.climate4you.com/, clearly shows a stable water column at low elevations, but a slightly decreasing water content in the important mid-to-upper troposphere. Note that these data encompass more recent measurements through July, 2010.



The caption for this satellite-based figure is: "The upper graph (blue) in the diagram above shows the total amount of water in the atmosphere. The green graph shows the amount of water in the lower troposphere between 1000 and 680 mb, corresponding to altitudes up to about 3 km. The lower red graph shows the amount of water between 680 and 310 mb, corresponding to altitudes from about 3 to 6 km above sea level. The marked annual variation presumably reflects the asymmetrical distribution of land and ocean on planet Earth, with most land areas located in the northern hemisphere. The annual peak in atmospheric water vapour content occur usually around August-September, when northern hemisphere vegetation is at maximum transpiration. The annual moisture peak occurs simultaneously at different levels in the atmosphere, which suggests an efficient transport of water vapour from the planet surface up into the troposphere."

Clearly, the science of troposphere humidification is not settled.

Perhaps the most difficult problem to assess is the response of cloud cover to a warming atmosphere. Low-level clouds reflect sunlight and produce a net cooling; increasing cloud cover with a warming atmosphere would mitigate moisture amplification of temperature. Yet the understanding of the response of cloud development is poorly known. From IPCC AR4, WG1, para 8.6.3.2: *"....cloud feedbacks remain the largest source of uncertainty in climate sensitivity estimates*."

From *Effect of land albedo, CO2, orography, and oceanic heat transport on extreme climates*, **V.** Romanova, et. al., 2006, a sensitivity study paper on land albedo, atmospheric CO2, orography and oceanic heat transport:

> *"Fraedrich et al. (1999) and Kleidon et al. (2000) used a general circulation model to investigate the land albedo effect of homogeneous vegetation extremes – global desert and global forest. It was found that the dominant signal is related to changes in the hydrological cycle and that the altered water and heat balance at the surface has a potential impact on regional climate. Kubatzki and Claussen (1998) and Wyputta and McAvaney (2001) showed that during the Last Glacial Maximum (LGM) the land albedo increased by 4% due to vegetation changes. In addition to this, the influence of the mountain chains and highly elevated glaciers with strong ice albedo feedback leads to large climate anomalies and an alteration of the atmospheric circulation and precipitation patterns (Lorenz et al., 1996; Lohmann and Lorenz, 2000; Romanova et al., 2005).*

From *Boreal forests, aerosols and the impacts on clouds and climate*, Spracklen, et. al., 2008

> *"Previous studies have concluded that boreal forests warm the climate because the cooling from storage of carbon in vegetation and soils is cancelled out by the warming due to the absorption of the Sun's heat by the dark forest canopy. However, these studies ignored the impacts of forests on atmospheric aerosol. We use a global atmospheric model to show that, through emission of organic vapours and the resulting condensational growth of newly formed particles, boreal forests double regional cloud condensation nuclei concentrations (from approx. 100 to approx. 200 cm-3). Using a simple radiative model, we estimate that the resulting change in cloud albedo causes a radiative forcing of between -1.8 and -6.7 Wm-2 of forest. This forcing may be sufficiently large to result in boreal forests having an overall cooling impact on climate. We propose that the combination of climate forcings related to boreal forests may result in an important global homeostasis. In cold climatic conditions, the snow–vegetation albedo effect dominates and boreal forests warm the climate, whereas in warmer climates they may emit sufficiently large amounts of organic vapour modifying cloud albedo and acting to cool climate."*

From *Radiative forcing and albedo feedback from the Northern Hemisphere cryosphere between 1979 and 2008*, Flanner, et. al., :

> *"The extent of snow cover and sea ice in the Northern Hemisphere has declined since 1979, coincident with hemispheric warming and indicative of a positive feedback of surface reflectivity on climate. This albedo feedback of snow on land has been quantified from observations at seasonal timescales, and century-scale feedback has been assessed using climate models. However, the total impact of the cryosphere on radiative forcing and albedo feedback has yet to be determined from measurements. Here we assess the influence of the Northern Hemisphere cryosphere on Earth's radiation budget at the top of the atmosphere—termed cryosphere radiative forcing—by synthesizing a variety of remote sensing and field measurements. We estimate mean Northern Hemisphere forcing at -4:6 to -2.2Wm-2, with a peak in May of -9.0+/-2.7Wm-2. We find that cyrospheric cooling declined by 0.45Wm-2 from 1979 to 2008, with nearly equal contributions from changes in land snow cover and sea ice. On the basis of these observations, we conclude that the albedo feedback from the Northern*

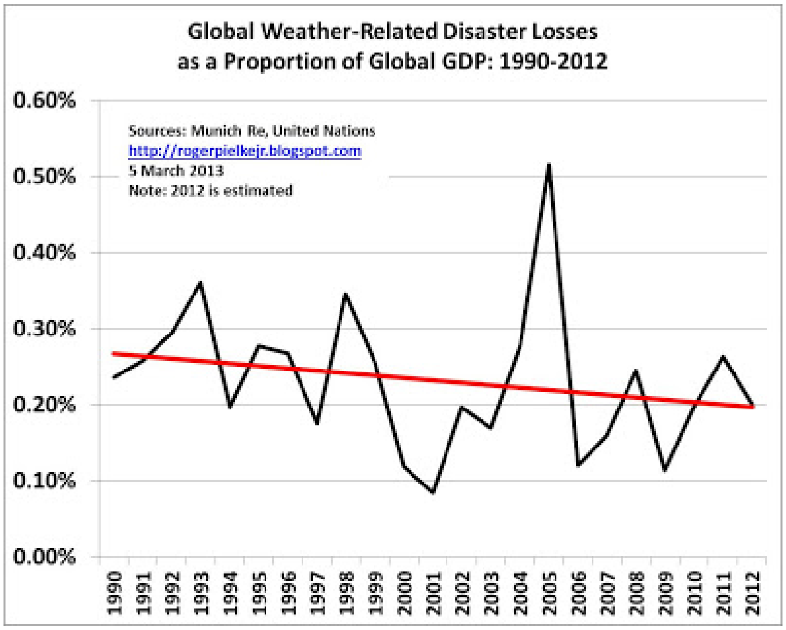
Hemisphere cryosphere falls between 0.3 and 1.1Wm^{-2} K^{-1}, substantially larger than comparable estimates obtained from 18 climate models."

An inference one can draw from this latter paper is that if there is indeed less albedo reflectivity in the NH, it's even more difficult to explain flat global average temperature profile over the last 10-15 years.

Empirical evidence for Carbon-based AGW does not support catastrophe.

Although the term "catastrophe" has been bandied about (in the climate change context) in some places, it is usually not in scientific papers as a scientific outcome. Like many such words popularized to engender anxiety about possible futures, its meanings are mostly in the eye of the beholder if one gets beyond the emotional content and begins to ask for specific instances. If you or a loved one was lost due to the tsunami in Japan in 2011, it was a catastrophe to you. But if you were a penguin in Antarctica, or a random child in Chad, it meant nothing to you. Closer to home, was hurricane Sandy of 2012 the same order of catastrophe as the 1900 hurricane that struck Galveston (6000-8000 killed out of a population of ~40,000) - was it (Sandy) a catastrophe at all? By whose reckoning?

A dictionary definition is "an event causing great and often sudden damage or suffering." Somewhere there must be a direct connection of 2-4.5 ^{o}C average warming to something "catastrophic" worldwide. So far, we have seen no specific papers alluding to anything so specific. The two lines of threat typically brought up are (1) significantly increased "extreme" weather events (e.g., droughts, tornados, hurricanes) and (2) rising sea level. Though the media often trumpet some year's tornado population or flood incidents or similar weather events, there is no hard evidence of anything that has not been seen before, and well before, the last few decades. The chart to the right [25] shows global weather related "disaster" losses from 1990 to ~2012.



As to sea level rise, the only real sources of significant sea level rise are the Greenland ice sheets and those in Antarctica. There are no known projections for either to produce large meltwater amounts in less than centuries.

"Catastrophe" is not the correct adjective in the context of Carbon-based AGW.

[25] http://rogerpielkejr.blogspot.com/ - April 08, 2013

The threat of net harmful total global warming, if any, is not immediate and thus does not require swift corrective action.

Global average surface temperatures have remained relatively steady at about 1 deg C above the 10,000 year average for the last 14 years and have stayed below the 1998 temperature peak that was anomalously high due to a strong Pacific Ocean El Nino event that year. During the ensuing14 years, the atmospheric CO2 concentration has continued to increase, as measured at the Mauna Loa station (and other locations). Therefore, one can conclude from the last 14 years of data, that factors other than CO2 are having compensating effects at least as large as the theorized warming effects of increasing CO2 levels.

Typically, when the earth warms, surface temperatures at high latitudes in the Northern Hemisphere (NH) increase much more than the tropical latitudes and Southern Hemisphere temperatures, probably due to the ratio of land to ocean areas of the respective hemispheres. Warming at these higher NH latitudes has many beneficial aspects. The initial concern if NH temperatures start to rise again due to any cause, would be the potential for a gradual sea level rise due to gradual melting and net loss of ice mass of the Greenland Ice Sheet, since Greenland has by far the largest ice mass north of the Arctic Circle. It is the time frame over which significant changes could occur that is of most concern for the earth's population to be able to adapt to any sea level changes. Melting of floating ice as in the Arctic Ocean does not contribute to sea level rise, and melting of the much smaller glaciers and ice fields, other than Greenland, would not contribute to significant global sea level rise.

Just as the current global average temperature fluctuations are well within the temperature variation history of the last 10,000 years, ice volume changes on Greenland should also be assessed against the backdrop of the long 10,000 year stable history of Greenland's ice volume. Following historical trends, further warming in the Arctic region would probably lead to heavier average yearly snow fall rates on Greenland. We do acknowledge that current monitoring also suggests that the heavier average yearly snow fall rates have been insufficient to offset any sea level rise from the yearly melt-water runoff. Indeed, the heavier average yearly snow fall rates have been insufficient to maintain a constant rate of net ice loss from Greenland. Observations indicate that, despite increased snow fall, the rate of ice loss from Greenland is accelerating[26]. However, these things also occur over centuries. Ice core data from Greenland available at the NOAA web site indicate a long term trend in ice volume increase but with periods of a few hundred years where ice volume contracted slightly before resuming the long term trend of ice volume increase. The net ice volume on Greenland should be monitored closely to obtain an accurate forecast of any detrimental sea level changes because of NH temperature change.

The vastly larger Antarctic ice sheet contains 90 percent of the earth's fresh water reserves. Only relatively small areas of its Western ice shelf and primary peninsula with non-floating ice exposed to water beneath, presents any potential threat to rapid sea level rise. Based on established historical trends over millions of years, this threat is insignificant in this era of climate change controversy. Air temperatures over the interior of Antarctica remain below freezing at all times of the year and the vast majority of Antarctica's ice mass is locked onto the land beneath. The condition of these western ice shelves has been a focused area of study and should continue to provide early warning of any significant global sea level rise. Study of ocean currents that would allow or prevent warmer water to

[26] http://www.arctic.noaa.gov/reportcard/greenland_ice_sheet.html

threaten the ice shelves of Antarctica should also be a critical area of study.

Regardless of what future global temperatures will do, changes should be gradual enough to allow sufficient time for adaptation to these changes. Therefore, there is no need to address these concerns in hasty, knee jerk public policy changes without a more complete understanding of root causes of the small temperature changes we have experienced over the last 10,000 years that had nothing to do with CO_2 levels in the atmosphere. We have time to improve climate models, get them validated, and only then use them in critical decision-making.

Our US Government Is Over-Reacting to Concerns About Anthropogenic Global Warming.

The global average temperature trends of the last 15 years since temperatures peaked in 1998, do not indicate an immediate problem that is definitely getting worse and requiring immediate action. A potential global warming issue has been identified that should be treated as a potential problem for which root cause is not definitely known. Our training and experience tells us that such potential problems should be monitored by gathering critical data to provide a more complete problem definition that will enable proof of root cause to be established. If global average temperatures do not continue to rise more than 1 ^{o}C above present levels (only time will tell), then a global warming problem requiring immediate corrective action does not exist. Even if increased CO_2 concentrations in the atmosphere can be proved to cause significant and detrimental warming of the atmosphere, curtailment of global CO_2 emissions is not the only possible, or even preferable, solution to mitigate any detrimental effects from a rise in the earth's surface temperature. Indeed, there are no demonstrated and cost-effective alternatives to fossil fuel use over a period of decades.

Given the importance of CO_2 to life on this planet; the large naturally occurring CO_2 exchanges between land masses, oceans and atmosphere; the relatively small amounts of anthropogenic CO_2 compared to naturally occurring CO_2 in our atmosphere, and the lack of conclusive proof that anthropogenic CO_2 can cause significant detrimental global warming, we find it scientifically embarrassing that the US Environmental Protection Agency (EPA) has made a "determination" that CO_2 is a "pollutant" that it must control. In our opinion, this was clearly a political decision, using too broadly worded legislation passed back in 1970. This is not just our limited group's opinion; in one of the hearings before the Court of Appeals, the Court said, in effect, that if Congress wants to write an absurd law, it is free to do so[27].

An interesting potential problem regarding human influences on global warming has been postulated. The situation should be addressed as a potential problem requiring further study and research, not a crisis requiring immediate corrective action. In our disciplined approach to problem solving in the manned space program, a problem is defined in terms of a significant deviation from the expected norm requiring a determination of root cause so that good decisions can be made regarding how to cope with the problem. In our experience and training, changes in global average temperatures in the last 150 years cannot even be defined to be a problem for which root cause must be determined, since a

[27] http://blog.chron.com/climateabyss/2012/06/why-epa-regulating-greenhouse-gases-is-absurd-and-why-it-doesnt-matter/

significant unexpected, or even undesirable, deviation from past climate behavior has not occurred. We believe that understanding the earth's climate system is a worthy objective for scientific research. However, it may not be more important than other research opportunities competing for available research funding that could provide a greater benefit to our nation. A more rational process for allocation of research funds without the constant media hype of an AGW crisis is needed.

Conclusions and Recommendations

Our main objective of determining to what extent CO2 concentrations in our atmosphere can cause detrimental global warming has led us to an objective conclusion that this issue is not settled science. Unfortunately, the scientific progress on this issue has been corrupted by political and special interest influences that determine where our research dollars get spent. Political influences in government sponsored research have focused climate change research on CO2 rather than a broader range of factors that need better definition.

Our recommendation would be to take the time required to improve our knowledge of the critical factors driving temperature prediction uncertainty before attempting to make critical high-economic-impact public policy decisions of doubtful effectiveness based on projections of unvalidated computer simulations. We find no convincing evidence indicating our planet is in a climate crisis. From a historical perspective, temperature variations we have experienced since the dawn of the Industrial Age are well within the earth's temperature fluctuations of the last 10,000 years, as well as the more recent 2000 years since the Roman Warm Period. The earth's global average temperature has varied by as much as +/- 2 ^{o}C of the 10,000 year average while CO2 levels in our atmosphere were relatively constant during the same 10,000 year period. The earth's surface temperature has remained within +/- 1 ^{o}C of this 10,000 year average since CO2 concentrations in the atmosphere have started to rise during the Industrial Age. There is no impending climate disaster that requires immediate corrective action. In the face of model prediction uncertainty, that is the primary source of alarm, we should continue to be anchored to the stable climate data of the last 10,000 years and assess recent temperature trends against the backdrop of these very stable temperatures.

We encourage more government sponsored climate change research to remove critical areas of prediction uncertainty. However, we recommend a broader study of all important climate variables and less concentration on CO2 effects in studies using only predictions of unvalidated models. Until models can be improved beyond their present state of effectiveness, and validated with empirical data covering the vast array of variables in physical, chemical and biological processes that they attempt to simulate over time, numerous studies with unvalidated computer simulations have questionable scientific benefits. Eco-engineering solutions for cooling and warming the planet should be studied as well as methods and cost estimates to adapt to a changing climate that we currently do not understand with sufficient precision to try to control.

Additional Considerations

Computer Models Need To Be Validated Before Being Used In Critical Decision-Making.

While TRCS veterans of our nation's manned space program have gained a healthy respect for the usefulness of simple, as well as, complex models throughout our careers, we also know it is critical to first validate the models before using them in critical design or operational decisions with potentially severe unintended consequences. Climate simulation models have not been validated through the normal rigorous process of comparing many aspects of model predictions to physical data to determine their accuracy and utility for critical decision making.

The actual earth surface temperature response to CO2 emissions cannot be validated in the models if important naturally occurring climate change mechanisms are not modeled accurately. This is because any measured land and ocean surface temperature changes in the future used to validate the model predictions, must be shown to accurately agree with predicted contributions of all major climate variables simulated such as, coupled ocean-atmosphere oscillations such as the El Nino-Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO), and the Atlantic Multi-decadal Oscillation (AMO), ocean currents (both lateral and vertical), ocean salinity profiles, cloud cover, atmospheric temperature distribution, water vapor content of the atmosphere, precipitation patterns and amounts, ice accumulation and loss patterns, effects of unpredicted major volcanic eruptions, land use changes, plant growth changes due to increased CO2 concentration in the atmosphere, snow cover extent, etc.

Model validation requirements and protocols should be established. The actual model validation process will require decades. Once the models can be improved to ensure confident and useful prediction accuracy, it will take at least 20 - 30 years to acquire the data that can prove that they can produce accurate results in all of the many important and inter-related parameter variations they predict.

In the meantime, we recognize that there is some value in the model outputs if used wisely. Some decision-making considerations can be based on a combination of observations and model output. Present-day models can simulate some things well and some things poorly. There’s no reason not to take advantage of their strengths and use observations to constrain their weaknesses.

For example, an aspect of the atmosphere modeling that appears to be presently poor at simulating is the global distribution of cloud cover. As long as the different cloud cover simulations of climate models span the observed distribution and behavior of cloud cover, however, the range of atmospheric simulations likely span reality.

As another example, models are very poor at simulating ice sheet changes. This problem is circumvented by determining the range of possible ice sheet behavior according to recent and paleo-climate observations and incorporating that range into climate models. The range of solutions that result tells us the importance (or unimportance) of realistically simulating ice sheet behavior and simultaneously determines the believable range of climate simulations.

The paper by J. A. Curry and P. J. Webster in the December 2011 American Meteorological Society's journal *Climate Science and the Uncertainty Monster*[28] is a well written synopsis of uncertainty in various aspects of climate science and particularly of the modeling in this area. An excerpt from the modeling area is illustrative:

[28] http://journals.ametsoc.org/doi/pdf/10.1175/2011BAMS3139.1

"A serious challenge to improving complex nonlinear models is that model complexity and analytic impenetrability precludes the precise evaluation of the location of parameter(s) that are producing the prediction error (Lenhard and Winsberg 2010). For example, if a model is producing shortwave surface radiation fluxes that are substantially biased relative to observations, it is impossible to determine whether the error arises from the radiative transfer model, incoming solar radiation at the top of the atmosphere, concentrations of the gases that absorb shortwave radiation, physical and chemical properties of the aerosols in the model, morphological and microphysical properties of the clouds, convective parameterization that influences the distribution of water vapor and clouds, and/or characterization of surface reflectivity. Whether a new parameterization module adds to or subtracts from the overall reliability of the model may have more to do with some entrenched features of model calibration than it does with that module's fidelity to reality when considered in isolation."

One other excerpt should lead us all to be always questioning:

What we observe is not nature itself, but nature exposed to our method of questioning.

—Werner Karl Heisenberg