Prepared 07-22-08

Analysis by Michael MacCracken of the paper

"Environmental Effects of Increased Atmospheric Carbon Dioxide" by Arthur B. Robinson, Noah E. Robinson, and Willie Soon

(published in *Journal of American Physician and Surgeons* (2007) 12, 79-90)

Summary

Expanding on a paper first presented ten years ago, the authors present a summary of climate change science that finds fault with nearly all of the internationally peer-reviewed findings contained in the comprehensive scientific assessments of the Intergovernmental Panel on Climate Change (IPCC). In particular, the authors find fault with IPCC's conclusions relating to human activities being the primary cause of recent global warming, claiming, contrary to significant evidence that they tend to ignore, that the comparatively small influences of natural changes in solar radiation are dominating the influences of the much larger effects of changes in the atmospheric greenhouse gas concentrations on the global energy balance. After many scientific misstatements and much criticism of IPCC science, the authors conclude with a section on the environment and energy that argues for construction of 500 additional nuclear reactors to provide the inexpensive energy needed for the US to prosper and to end importation of hydrocarbon fuels (particularly petroleum). Taking this step, along with the beneficial effects of the rising CO_2 concentration, will, they argue in complete contrast to the prevailing scientific views, create a "lush environment of plants and animals" that our children can enjoy.

Background

In early 1998, following the negotiation of the Kyoto Protocol in late 1997, the late Dr. Frederick Seitz, past president of the U.S. National Academy of Sciences and president emeritus of Rockefeller University, widely distributed a letter presenting for consideration an article entitled "Environmental Effects of Increased Atmospheric Carbon Dioxide." The authors of this article were Arthur B. Robinson of the Oregon Institute of Science and Medicine (OISM), Willie Soon and Sallie L. Baliunas, both of the Harvard-Smithsonian Center for Astrophysics, and Zachary Robinson, also of OISM. The article was composed and formatted to appear as if it had been published in the *Proceedings of the National Academy of Sciences* (PNAS), even though, at the time it had not yet been published by any journal, much less by PNAS. The impression that the article was endorsed by the National Academy of Sciences (NAS) was so strong, however, that it led the NAS to take the exceptional action of disassociating itself from the article and the science that the article contained (NAS, 1998).

Basically, the article, which was later published in non-mainline journals as Robinson et al. (1998) and Soon et al. (1998), took strong exception to the findings and international consensus on science presented in the assessments of the Intergovernmental Panel on Climate Change (IPCC), which relied on literature that had been published in peer-reviewed journals. As

documented in an analysis that I prepared in early 1998 (see appendix), the arguments and findings presented seemed to be strongly contradicted by the scientific findings summarized by the IPCC.

Using the supposed article as partial justification, Seitz's letter also circulated a relatively brief petition that, for scientific, economic, and other reasons, expressed opposition to US concurrence with the Kyoto Protocol. Although there was really no basis for drawing the conclusion, the packaging of the letter, the article and the petition created the impression, quite possibly intentionally, that signing the petition also indicated agreement with the findings in the attached article, suggesting, in turn, that there were many qualified people that fundamentally disagreed with the IPCC's scientific assessments. Although it is not clear what role the article played in gaining agreement with the petition (one could agree with the petition while still agreeing with the IPCC's findings), roughly 17,000 names of supposedly qualified scientists and other experts were listed as having signed the petition over the ensuing few months. Among those listed were a few well-known scientists, but also a few who were clearly not experts on the subject matter (e.g., the names of the Spice Girls were listed); many others whose names were listed were not recognized as having published in the climate change peer-reviewed literature.

More detailed reviews of this and related efforts to discredit the IPCC science and create doubt about global warming are presented at http://en.wikipedia.org/wiki/Oregon_Petition#cite_note-seitz-7 and http://www.realclimate.org/index.php/archives/2007/10/oregon-institute-of-science-and-malarkey/, among others.

The 2007 Version of the Article

In late 2007, apparently following the publication of the Fourth Assessment Report of the IPCC earlier in the year (IPCC, 2007a, 2007b, 2007c, 2007d), Arthur Robinson, Noah Robinson (another son of Arthur Robinson), and Willie Soon published an article with the same title and in the same format as the 1998 article, although this updated version of the article is now 50% longer. The article (Robinson et al., 2007) was published in the *Journal of American Physicians and Surgeons*, a journal not known for being a publication that would impose the type of independent and high quality peer-review required of the major journals and that is conducted as part of the IPCC review process. The affiliation for all the authors was listed as OISM, an institution not generally recognized as a leading climate change research center, as described in a number of sites on the Web.

In October 2007, with one day's warning, I was invited to come to the 11th annual Telecosm meeting organized by Steve Forbes and George Gilder and to respond to a presentation of the updated Robinson et al. paper by Arthur Robinson and his son Noah. Believing that the mainline scientific views should be presented to the attendees of such a prestigious meeting, I accepted, venturing, as Steve Forbes later put it, 'into the lion's den.' While it remains surprising to me that so much attention and confidence could be put into the claims of these authors versus the authoritativeness of the IPCC findings, I did agree to participate. This note describes the many problems with the science that I identified while preparing for that presentation and in listening to the presentations of the Robinsons at the conference. I am devoting time to preparing this

compilation of scientific criticisms because this has apparently not been systematically done,[1] presumably because the views seem so out of the mainstream that no attention will be paid to them. I only wish that were the case, for those attending the Telecosm conference seemed to give them significant credence.

General Comments on the 2007 Paper

Before offering a section by section analysis, a few observations about the general style and tone of the article (and their oral presentation):

1. The Robinson et al. (2007) paper covers a lot of ground. There are quite a number of points where their presentation of the science is correct, and I will not comment on these points. The article also contains a number of mainly political statements, which I will also let pass, focusing instead on critiquing the science and not personal preferences.
2. It is generally inappropriate in scientific, or other, papers to be inferring, ascribing, and then criticizing the motives and political views to others. To the extent that this is done, it suggests the author is pushing an individual agenda rather than simply explaining the science. Again, I will try to stick to the scientific issues.
3. Scientific papers are supposed to be based on inferences drawn from the historical record, experiments, theoretical analyses based on fundamental physical laws (and this includes modeling), relevant analogues, consistency across different systems (e.g., across different planetary atmospheres), etc. Arguments need to be soundly based, not relying on belief, but on rational and internally consistent explanations. Alternative explanations that are introduced need to be considered across the same breadth of evidence as the mainline explanations (e.g., taking exception to the greenhouse effect needs to be explained in the context of not just the Earth's atmosphere, but those of Venus and Mars, in results from Earth's paleoclimatic history, in laboratory experiments, etc.). Because science has been building a solid and interlocked explanation and not a house of cards, the suggestion that one aspect of the explanation is less certain than indicated does not, even if the criticism is true, cause the whole explanation to collapse. In general, analyses and findings presented in the Robinson et al. (2007) paper, as in the earlier paper, fail to expose their explanations to the full range of evidence and to come up with an alternative, self-consistent explanation.
4. Scientific papers typically explain the extent of and reasons for uncertainty in the arguments being made by the author(s), and not just in the views of other scientists. This paper makes quite a few assertions and offers considerable speculation supporting the authors' views without indicating providing the supporting evidence and indicating the uncertainties concerning often controversial lines of evidence. Assertion, and especially bold assertion and repetition, do not make a statement true. The authors of the Robinson et al. (2007) paper generally fail to apply the same level of scrutiny to their own arguments as they apply to the arguments of others.
5. In science, correlations are interesting, but they do not prove causality. The authors indicate a recognition of this, although they frequently fail to adhere to this principle, and in addition, they also assert that a lack of correlation disproves a point. This last assertion

[1] For example, a compilation of comments sent in by some of those following realclimate.org is available at http://www.realclimate.org/index.php?title=OISM.

is just not the case, especially when there are multiple factors involved in, for example, affecting the radiation balance and the time lags in the system. Indeed, science seeks to find explanations that are physically consistent and do not violate fundamental principles (e.g., asserting that small forcings can cause large consequences while large forcings will have no effect at all).

6. Certainly, uncertainties exist in the explanations of the causes and extent of past and future changes in climate—indeed, uncertainty is inevitable and can never be completely removed. However, the presence of uncertainty does not make a finding wrong—indeed, even the most plausible explanations have uncertainties.
7. It is important to keep in mind that uncertainties work both ways. Scientific tradition and analysis techniques—and especially the IPCC process--lead to defining uncertainties broadly enough to cover all possibilities that cannot be definitively ruled out. As a consequence, there is typically a range in the uncertainties around a best estimate or most plausible estimate, recognizing that the actual value or answer (if there is indeed a narrow one—and this is not always the case for a chaotic system) could be more than or less than the specified value, so possibly making the change larger or smaller than the most plausible estimate.
8. The IPCC is a process for the international scientific community to come to a consensus; it does not have an agenda other than the task assigned to it by the international Conference of the Parties of the UN Framework Convention on Climate Change. In the IPCC process, the lead authors are chosen to be experts that are knowledgeable in their field and capable of fairly representing the range of recognized expert understanding. The chapters that are prepared are charged with fairly representing the full range of the up-to-date, peer-reviewed literature—narrowing the range of expert understanding only when there is good reason to suggest that this is justified by the sweep of current literature.
9. There are many ideas and findings in the literature that have been overtaken by newer research, so just because there was an article in the peer-reviewed literature some time ago or an out-dated argument is re-raised does not, without additional information and analysis, make the argument worth considering or worthy of inclusion in the latest assessments. The Robinson et al. (2007) article seems to frequently cite literature that is no longer considered to represent the level of understanding that has developed with the benefit of newer research.
10. The IPCC, being a process that involves developing consensus across a wide number of participants and reviewers, tends to be cautious in coming to conclusions and in ruling out of alternative explanations—thus, charging that the IPCC has too narrow a viewpoint really requires presenting arguments and alternative explanations with considerable care. What has been most apparent in considering the series of IPCC assessments is that the newest research findings are consistently leading to IPCC concluding that climate change is occurring more rapidly and intensely than indicated by the cautious findings in its previous assessment, so generally indicating that the situation is worsening.
11. IPCC's assessments are considered the most authoritative scientific summaries available. If one is going to pick and choose among their findings, as the Robinson et al. (2007) article does, then it is important to be especially rigorous in explaining the basis for taking exception--just saying one disagrees, whatever the level of one's expertise, needs to be explained thoroughly for the exception to be taken seriously. The Robinson et al. (2007) article does poorly in this regard.

12. Research on the climate change issue goes back many decades, and many smart people have been asking tough questions about it over this period—the questions this paper raises are not new, but have been asked and investigated many times. Through this effort, the underlying hypothesis that human-induced changes in atmospheric composition can cause significant changes in the climate has proven to be very solid. Asserting that some new criticism can overturn all that has been done fails to understand the depth and intensity of the testing and questioning. The notion of such human dominance has only prevailed recently, there being no other viable explanation for what is occurring.
13. Scientific papers tend to use cautious language without making value judgments or using value-laden words. This paper describes the hypothesis of human influence as "catastrophic," whereas the scientific question is whether it is valid or not. While it is fair to argue that higher confidence in the scientific findings about socially beneficial activities should be required before taking significant policy action, what the effect of a policy action might have on society is not relevant to evaluating the scientific likelihood of a particular outcome. The Robinson et al. (2007) paper, like the earlier one, tends to try to bias the scientific evaluation by intermixing fearful scenarios about what the consequences of particular policy actions could mean, when those are not nearly the only policy actions that could be taken.
14. Scientific review papers, such as this strives to be, try to be comprehensive in the references they use (or at least build upon those that IPCC uses, as their reviews are very comprehensive). Making narrow choices in the set of selected references, as is done here, rather than considering the findings of the full range in the literature, is not a characteristic of an authoritative scientific review.
15. Occam's Razor is a long-followed principle used in analysis of systems, particularly complex phenomena and systems. Basically it states that the explanation should be as simple and straightforward as possible, making the fewest assumptions. Physically based explanations are preferred over explanations based on undefined, imprecise, or immeasurable relationships. This principle also argues for preferring well-developed explanations over ones characterized by contradictions and assertions.

That the Robinson et al. (2007) paper evidences so many of these problems tends to obscure the technical aspects of many of its arguments. The specific comments in the next section provide an alternative, and even more critical, critique.

Specific Comments on the 2007 Paper by Robinson et al.

Abstract and throughout the article:

This review is not put in the context of the many other reviews by highly respected organizations that have come to quite different conclusions. The statements here are in many cases assertions with no qualifications indicated, and, based on assessments by many other highly qualified experts across many fields, are not backed up by the findings in this paper and cited in the abstract.

Summary Section:

First paragraph: The conclusions drawn by the leaders in Kyoto, Japan in December 1997 (and by such leaders at the 1992 Earth Summit in Rio de Janeiro and at many later meetings) have

been based on the evidence and findings presented in the assessments of scientific understanding prepared by IPCC and other authoritative bodies—not on fear.

Third paragraph and Figure 1: The text and the caption to Figure 1 focus on a record from the Sargasso Sea. The record shows no indication of uncertainties, and there is no reason to believe this record is typical for the world. Indeed, the very peaked nature of the record suggests that the location may be affected by shifts in currents or other problems—there is simply no way that the temperature of the whole world could just randomly shift by 2.5ºC over a couple of hundred years, as is suggested occurred at about 500 BC. Estimates for the past 1000 years and more developed by other scientists using various indicators from multiple proxy indicators suggest a different and much smoother record.

Whether the "Medieval Climate Optimum" and the "Little Ice Age" were an Atlantic Basin phenomenon or a simultaneous global occurrence is scientifically controversial. It is an unsupported assertion that the Earth would naturally have recovered from the Little Ice Age (we do not nearly adequately understand its cause to assert this) and it is an unsupported assertion that the recovery would still be continuing. The comparison to the record of what happened at Valley Forge, which is just another point and for which no uncertainties in the results are indicated, suggests a significant problem in the analysis. Valley Forge is on land and so it would be expected that it would have larger variations, especially over one winter, than would typically occur for an ocean point because the ocean's heat capacity buffers temperature changes. Yet, the fluctuation at Valley Forge was "only about 1º Centigrade" whereas the ocean temperature changes over century long periods was as much as 2ºC. Very odd.

Fourth paragraph and Figure 2: The curve for changes in glaciers appears to be mainly for Europe, which essentially has to be the case for that is where data are available. It is not at all clear that this record represents the average for the globe. More significantly, showing a correlation with hydrocarbon use, shows no recognition of the roles of other factors (e.g., other gases, sulfate aerosols, changes in solar radiation and volcanic eruptions, etc.) in affecting the climate, or of how emissions from the use of coal, oil, and gas accumulate in the atmosphere and exert their influence on the climate. The analysis also fails to recognize that in very cold areas, some warming leads to more snow (e.g., lake effects snows around the Great Lakes) and glaciers can expand (e.g., in much of Antarctica, and Scandinavia)—interpretations are not nearly so simple and linear.

Fifth paragraph and Figure 3: Were the atmospheric temperature regulated only by the Sun, it would be frightfully cold at night; even in the polar night, temperatures do not fall to absolute zero. Conditions result from the interactions of many factors—and the Earth's greenhouse effect, which depends on the atmospheric composition of water vapor and other gases, is absolutely essential to determining the present climate. As one measure of the importance, the infrared radiation emitted from the atmosphere back to the surface, integrated over the world and day-night cycle, is more than twice as much as the solar radiation absorbed at the surface. Regarding the plot of solar radiation, the solar activity that is shown is inferred from changes in sunspot numbers, and recent satellite observations indicate that the inversion overestimates the variations in the amount of solar radiation reaching the surface. Again, considering a correlation with use of hydrocarbons makes no sense for it leaves out the roles of other factors.

Sixth paragraph: The assertion that "Figure 1 is illustrative of most geographical locations" is simply not the case, and the references given here are very selective, especially in their

geographical coverage. Results from other than the Atlantic basin are far too sparse to justify the assertion that the "current *Earth* temperature is approximately 1ºC lower than during the Medieval Climate Optimum 1,000 years ago [emphasis added]." Indeed, the "Medieval Climate Optimum" is a term characterizing the climate of northern Europe.

Seventh paragraph, Figures 4-6: In that it is widely recognized that variability decreases as one averages over larger and larger areas, one would think the search for a correlation with solar radiation would involve searching for correlations with the global average temperature rather than using the record over a comparatively small region such as the US. While it is encouraging that the authors are arguing that changes in various factors can cause changes in the climate, asserting that variations in solar radiation (and, as noted above, the particular reconstruction is not consistent with recent satellite observations) are the dominant explanation for multidecadal temperature trends (and presumably for the so-called recovery from the Little Ice Age) allows no room for other factors to play a role (other factors would include volcanic eruptions, greenhouse gases, sulfate aerosols, land cover change, etc.).

The comparisons shown in Figure 6 are really of quite different things: the bar for "Earth Day-Night & Seasonal" is apparently the range between the maximum and minimum temperature anywhere on Earth at a given time or over the course of a season, irrespective of the characteristic of the location or of the role of other forcings (like the Sun going up and down and shifting over the seasons)—certainly the whole Earth does not change by this much. Similarly for the "Oregon Day-Night and Seasonal Temperature Range," comparing a range created by changes in the Sun's daily and seasonal cycle at a given point to changes in the average US temperature change over a century makes no sense at all.

Eighth paragraph: In that the loss of heat from the planet is proportional to the fourth power of the temperature (the Stefan-Boltzmann relationship), it makes no sense to equate a 0.5ºC temperature increase to a 0.21% change in absolute temperature; what matters is the energy flux, not the temperature. Drawing from Figure 5, a change in solar irradiance at the top of the atmosphere (that is, the flux coming at the Earth if looking directly at the Sun) of about 2 W/m^2 out of 1370 W/m^2 (so about 0.15%), leads to an increase in U.S. surface temperature of about 1ºC. But, this radiation (and the change in radiation) must be spread over the Earth (given that the Earth is a sphere), so divide by 4. In addition, about one-third of the incoming radiation is reflected by clouds, so, on a per square meter basis, Robinson et al. are suggesting that a change in absorbed solar radiation of 0.35 W/m^2 (and recent reconstructions of this change are smaller) is causing a change in temperature of 1ºC, giving a climate sensitivity of about 3ºC warming for an increase of 1 W/m^2. Atmospheric radiation models, which have been tested against laboratory experiments and performing in accord with observations for the atmospheres of Earth, Venus, and Mars, indicate that the increase in the CO_2 concentration alone that has been observed is contributing to an increase in the net downward flux at the tropopause (so at the top of the atmosphere-surface system) of about 1.6 W/m^2—so four to five times as much as the change in energy that the change in solar radiation is causing. Assuming, reasonably, that the response is proportional to the change in energy available (and it should not matter if the energy comes from a change in solar radiation or from a change in the downward radiation by greenhouse gases), the greenhouse gas induced change in radiation should have caused a current warming of about 5ºC —but the recent warming has been only about 0.8ºC. This inconsistency can only be resolved if: (a) the climate sensitivity is reduced from 3ºC per W/m^2 to about 0.8ºC per W/m^2 (IPCC actually considers a range from 0.55 to 1.25), so roughly by a factor of 4 from that given by Robinson

et al.; (b) the warming influences of all greenhouse gases and the warming and cooling influences of aerosols are considered; and (c) a lag in warming is created by the oceans and their quite large heat capacity. When this is done, results presented in IPCC's Fourth Assessment Report (AR4) indicate that, since the mid-19th century, there is very good consistency between the effects of the various climate-changing factors and the observed temperature changes, both at the global scale and over each continent.

Ninth paragraph and Figure 5: While the correlation may look impressive, it does not work out quantitatively, as explained in the discussion about the eighth paragraph—correlation is not necessarily causation, and, given that the two data sets are both flawed choices, the conclusion is simply not justified. In addition, because the temperature fluctuations are being caused by multiple factors, it makes no sense to simply compare them to the time history of fossil-fuel emissions.

Tenth paragraph: While people in a room might not notice a 0.5ºC change, there are many studies indicating that plant and animal species are responding to a temperature increase of this size. Indeed, referring back to Figure 1, Robinson et al. are suggesting that a 2ºC change is the difference between the warmth of the Medieval Climate Optimum and the depth of the Little Ice Age. In addition, paleotemperature data going back much further suggest that the temperature change from the present to a full ice age is only about 5-6ºC globally. While there are a number of problems with Figure 1, it does seem that the authors are indicating that, as other results show, a widespread and persistent temperature change of as little as 0.5ºC does indeed make a difference—and cannot simply be dismissed.

Eleventh paragraph, Figures 7-10: As noted earlier, there is no clear indication that the warming since the mid-19th century is a recovery from the Little Ice Age—the solar flux change alone seems unable to explain it if one uses the generally agreed climate sensitivity. Regarding Figure 7, not only is rainfall over the US increasing, but its average intensity is increasing. Regarding tornadoes, the database on tornados is controversial, generally being said to be showing an overall increase in number (whether due to more complete observation or changes in climate is undetermined), but there is no decrease in tornados occurring. Note that Figure 8 is for only the months March to August; in 2008, there were tornadoes in Wisconsin in January, so the full season needs to be considered. Regarding hurricanes and Figures 9 and 10, there is some indication that hurricanes are, on average, increasing in peak intensity and in destructive power over their lifetimes; changes in hurricane number are indeed uncertain.

Twelfth paragraph and Figures 11-12: The database on glacier shortening is quite limited until recent decades. Regarding sea level rise, contrary to the caption to Figure 11, the satellite record finds that sea level is currently rising at about *twice* the rate recorded by the coastal tide gauge network for the 20th century. As to the rise beginning before the increase in fossil-fuel use, it is important to remember that there are multiple factors that can contribute to sea level rise, including changes in land cover, damming of rivers, pumping of groundwater, etc., the time histories of each of which need to be considered. There are also multiple factors that can cause changes which would contribute to sea level rise, including the cooling influence of volcanoes and sulfate aerosols, that need to be considered before suggesting there is a contradiction with the finding that use of fossil fuels will lead to sea level rise.

Thirteenth paragraph: Supposed problems with simple correlations that are ignoring the influence of the many factors affecting the climate cannot be used to justify the assertion that "human use of hydrocarbons has not caused the observed increase in temperature." The IPCC

chapter on detection and attribution indicates clearly how the roles of the many factors can be fit together in a coherent, internally consistent manner.

Fourteenth paragraph: The assertion that the "extent and diversity of plant and animal life have both increased substantially during the past half-century" is very imprecise. There is no indication that there has been any increase at the global level—evolution does not work that fast. At the local level, there are regions with both increases and decreases. However, as climate change is shifting the boundaries of preferred ranges, increases in many locations are resulting from the unintended introduction of non-native and invasive species, often due to global transport of people and goods.

Fifteenth paragraph: Paleoclimatic data such as the ice cores from Greenland do make clear that the Earth's climate can change quite rapidly, including experiencing dramatic shifts over a few years. This has most often occurred when the Earth was colder than at present. The National Academy of Sciences carried out a very interesting study on the potential for abrupt changes (NAS, 2002). In addition, drilling of ice cores in Greenland indicates that it was only about 50% covered by ice during the last interglacial about 125,000 years ago when the global average temperature was roughly 1ºC higher than at present. Remnants of beaches on low-latitude islands from that time suggest that sea level peaked at 4-6 meters above its present level during that interglacial. Such a rise would be catastrophic for many coastal cities, especially if the change took place over a few centuries or faster.

Sixteenth paragraph: While further improvements in climate models are certainly needed, the se models have become quite sophisticated tools for studying the Earth system and climate change. In that the notion of modeling the atmosphere goes back to before the first computer, presumably computer technologies should also be said to be in their "infancy," so that is a rather inapt criticism.

That human activities are responsible for all of the CO_2 increase since preindustrial times has been determined from a number of studies of changes in carbon isotope concentrations over time—there is no indication that the change in the CO_2 concentration is due to natural causes. As to the effects being "benign," the changes have only just begun and there is no indication that increases in temperature, precipitation intensity, occurrence of drought and wildfire, melting of sea ice and glaciers, and sea level rise will continue to be benign.

Seventeenth through nineteenth paragraphs: It is certainly true that the combustion of fossil fuels provides many vital services to the world's population. Actions proposed to reduce global warming do not envision reducing these energy services—indeed, the scenarios for the future envision a significant increase in the energy services provided. What would change is the source of the energy for providing them and the efficiency with which they are provided. Quite a number of estimates of the economic cost of making the transition suggest that the cost would build over a few decades to be less than 1-2% of global GDP, which would be pretty much in the noise when spread over several decades (being equivalent to foregoing perhaps 4-6 months of global growth out of 50 years).

Twentieth paragraph: It is true that the climate has changed over recent centuries and longer, but by nowhere near as much as is projected for the 21st century if reliance on fossil fuels continues unabated. Over the past few centuries, society has become more and more attuned to the existing climate (e.g., buildings are designed for the current weather, coastal city locations are based on current sea level). The change in temperature projected for the 21st century is roughly half as much as occurred going from a glacial maximum to the present—the coming changes will be very significant.

Twenty-first paragraph: Every indication is that most of the major changes in climate over Earth's history were caused by some physical change—whether changes in the distribution and timing of solar radiation caused by cycling of the Earth's orbital parameters, volcanic eruptions, variations in solar output, freshwater outbreaks through ice dams, etc. The degree of background fluctuations is apparently quite small, with most changes in global climate being forced by identifiable changes in forcing factors. With human activities sharply changing atmospheric composition, large changes in climate seem inevitable based on the Earth's paleoclimatic history.

Section entitled "Atmospheric and Surface Temperatures"

First and second paragraphs: As indicated earlier, the interpretation of the climate of the last 1,000 years is controversial, and the Sargasso Sea temperature record does not reflect the variable global pattern of conditions. The suggestion of the temperature recovering from the Little Ice Age does not explain how it got perturbed and why it should recover.

Third paragraph: The claim that the "historical record does not contain any report of 'global warming' catastrophes" is simply not true. The Sahara desert and Mesopotamia were quite lush several thousand years ago as civilization dawned—the climate changed and they became quite arid. The Anasazi tribes of the southwestern US were doing quite well until the climate became much more arid, and they were scattered to the winds.

Fourth paragraph: Great care has been taken in putting together the hemispheric and global records. In any case, averaging over larger areas gives much more representative results than recording the conditions for a single point. The logic used by the authors is upside down.

Fifth and sixth paragraphs and Table 1: The locations covered by the cited analysis were mostly from the North Atlantic basin. The metaanalysis done in the reference cited did not require the changes to be simultaneous—just occurrence of even a short warm period during a several century interval. Given the natural spatial fluctuations of the climate, there is really little indication that the global climate played out as the authors suggest (NRC, 2006).

Seventh to tenth paragraphs: The coastal locations and elevations of Phoenician salt flats and Roman baths suggest that sea level was near constant for the few millennia preceding the mid-19th century, at which time sea level rise began. Contrary to the text, satellite data indicate that the rate of rise since 1993 has been about twice the rate in the century before that time (IPCC, 2007a), and newer data suggest an even higher rate of rise. Regarding the correlation to fossil fuel use, it fails to consider: (a) that other factors can affect sea level (including groundwater pumping, land clearing, reservoirs, etc.); and (b) the response of sea level to greenhouse gases is delayed by the time it takes to warm and then melt glaciers, and for heat to get absorbed in the ocean and be moved downward to cause thermal expansion. As to the correlations mentioned regarding Figure 12, there is no data shown for the temperature change over this period, despite the claim of a lag in the caption.

Eleventh to thirteenth paragraphs: Comments on much of this has been made earlier. Regarding Figure 15, it is also the case that irrigation in rural areas (and on golf courses) tends to reduce the temperature response. Indeed, one must be careful, and account for potential biases, and this has been done in compiling the global data sets (in addition, the oceans are warming, and no one lives there, so that is not an urban effect).

The argument at the end of these paragraphs that the best correlation is with solar radiation and not with fossil fuel use fails to consider either the quantitative issue of climate sensitivity discussed above or the roles of each of the various factors. For example, fossil fuel

use also led to emission of SO_2 that was chemically transformed to sulfate aerosol and exerted a strong cooling influence on the climate during the mid-20th century when the observed cooling was taking place.

Fourteenth to sixteenth paragraphs and Figure 14: Recent studies have provided a lot more insight into the issue of tropospheric versus surface temperature changes (e.g., Karl et al., 2006). Of major importance has been recognition of shortcomings in the observations, which have had to be corrected for several factors, including changes in the height and timing of the satellite orbits (the satellites measure radiance that is inverted, using a radiation model, to estimate temperature—satellites do not measure temperatures directly). Basically, the results here are out-of-date, being based on what have been found to be biases in the observations.

Seventeenth to nineteenth paragraphs: This is all argued based on correlations—not a causal factor explanation. The dismissal of the role of fossil fuel emissions by simple correlation neglects the roles of the many factors contributing to climate change and the complicated processes and time lags that are involved. In addition, satellite measurements have shown that the solar reconstruction is not correct (IPCC, 2007).

Twentieth and twenty-first paragraphs: Asserting that "non-correlation proves non-causality" is just non-sense. Multiple factors are involved in affecting the climate and relative magnitudes and timing and mechanisms matter—not simply correlations. Accepting the assertion that human hydrocarbon use is not affecting the climate violates Occam's Razor, for there is no explanation of how quite small solar variations can cause large climatic responses whereas comparatively large greenhouse gas-induced changes in heating have no effect. More than that, one has to explain how a reduction in solar radiation over recent decades is consistent with strong global warming. The assertion of self-consistency of the authors' explanation simply does not hold up, not only against the Earth's climate, but also in how planetary climates and Earth system history work.

Section entitled "Atmospheric Carbon Dioxide"

First paragraph: Listing the human contribution to CO_2 emissions here is rather misleading. The fossil fuel sources transfer carbon from being sequestered underground (where it has resided for many tens of millions of years) into the atmosphere-upper ocean-biosphere system, whereas the CO_2 that humans exhale is from carbon taken up by the land biosphere, so already in the atmosphere-upper ocean-biosphere system. Thus, the former increases the amount of carbon cycling in the active reservoirs, while the latter simply is part of the active exchanges taking place. Not differentiating is like failing to note the difference between new money coming into a mutual fund and the amount that is there being cycled through purchases and sales of stock.

Third paragraph: The recent rise in the CO_2 concentration has been definitively related to human activities by isotopic and other studies; this sentence is only acceptable because determining all the fluxes and terms "with certainty" (i.e., without any uncertainty) is not scientifically possible. With respect to past concentrations, over at least the last 750,000 years, ice core records indicate that the range has been from about 200 ppm during the coldest parts of glacial cycles to about 300 ppm during the warmest parts. Going back further, concentrations may have been 1500-2000 ppm during the much warmer Cretaceous, which ended about 65,000,000 years ago with the impact of a large asteroid that apparently ended the period of dinosaurs. Going back further in time makes little sense.

Fourth to sixth paragraphs: It is true that the increase in CO_2 lags the increase in temperature in the ice core records covering about the last 750,000 years. This is to be expected, and occurs because, for the natural climate system, warming caused by changes in the shape and characteristics of the Earth's orbit around the Sun cause a shift of carbon from the ocean to the atmosphere as the world warms (just as CO_2 comes out of a cold soda as it warms). Because of its greenhouse effect, the resulting release of CO_2 causes more warming and more out-gassing, thus creating a positive natural feedback mechanism. Combusting fossil fuels provides an alternative mechanism for the rise in the CO_2 concentration, but once there, the added CO_2 will cause additional warming just as happened during the glacial cycling.

Seventh through ninth paragraphs: This ratioing approach to estimating responses to the CO_2 concentration fails to recognize the roles of other factors (like changes in the Earth's orbital elements), the interplay of various processes, and the time it takes for the start of forcing to cause changes (e.g., for the oceans to warm). To keep track of all of these interactions requires quantitative models and the rigorous quantitative consistency they demand. When models are used, the outcomes the authors get can be explained as basically ill conceived; indeed, the climate system behaves as the IPCC has been suggesting and the physics explaining the ice-core record and human-induced warming are self-consistent.

Tenth and eleventh paragraphs: The authors are mixing up the lifetime of a particular CO_2 molecule in the atmosphere, which has been observed to be a few years based on bomb carbon-14 measurements, and the persistence time of the excess CO_2 added to the atmosphere-upper ocean-biosphere system that determines the atmospheric CO_2 concentration. Because this persistence time is determined by the slow rate that the additional carbon is transferred from the upper to the deep ocean, the half-life of the atmospheric persistence time is of order a century or more (it depends on the various gradients in concentration that are created, which means it depends to some extent on the rate of emission). Because the deep ocean is saturated, it cannot really accommodate all the CO_2, so once mixing through deep ocean waters occurs, the persistence time of the elevated CO_2 concentration is determined by the rate of removal of the excess CO_2 to the ocean sediments, and this is a very slow process, meaning that a fraction of the elevated concentration will persist not just for centuries, but for many millennia.

Twelfth paragraph: This comparison of human production of CO_2 to the amount in the total ocean was a criticism of the original Arrhenius hypothesis of 1896. It took until the observational studies of Revelle and Seuss in the 1950s to come to understand that the ocean is not well mixed, the deep ocean having a circulation time to the surface of about 1000 years. So, even if full uptake of the human contribution could occur (and the comparison should not be with the annual rate of emission, but with total emissions over time, which is now several hundred gigatons of carbon), the mixing the authors suggest would take millennia, and during the interval, the atmospheric concentration would be sharply elevated (just as is occurring). The authors mention that a "transient increase" will occur, and, indeed, that is what we are seeing, but the duration of the transient is very long.

Thirteenth paragraph: For scientists, how things happens matters. Understanding the "sources and amounts" is critical to getting beyond the unjustified correlations that this paper relies on.

Section entitled "Climate Change"

First paragraph: I am glad to see that the authors agree that a small change in temperature can cause important impacts (we apparently mainly disagree on the cause of the warming).

Second paragraph: Arctic sea ice has been decreasing very sharply. Antarctic sea ice is not decreasing (likely due to processes relating to ocean circulation in the Southern Ocean), but the ice sheet on Antarctica is losing mass, based on recent satellite evidence. In that it is ice in ice sheets that determines changes in sea level, that the Antarctic ice mass is decreasing is contributing to sea level rise.

Third paragraph: Indeed, diversity and plant mass are increasing in high elevations (and also in the Arctic), but as this happens, the species that were there are being pushed to extinction. So, locally, the variety of species goes up, but globally it goes down. And while new, hotter than ever environments are created, it is unlikely new species will evolve to fill in as fast as existing species are pushed to extinction. The net effect is projected to be a very large global loss of species, even as some regions have a greater variety of species than they did before.

Fourth through seventh paragraphs: Comments on these points have been made earlier. The claim that "[a]ll of the observed climate changes are gradual, moderate, and entirely within the bounds of ordinary natural changes" is belied by what is happening in the Arctic, where the remarkable changes are unprecedented for the peoples who have lived there for millennia. That the Greenland and Antarctic ice sheets are both starting to lose mass is an early indication of very large sea level rise in the coming decades and centuries.

Section entitled "Global Warming Hypothesis"

Second paragraph and Figure 18: With respect to the radiative influence of CO_2, it can seem minor when looked at from the surface and treating the troposphere as a single layer—from this perspective, water vapor looks dominant. However, the water vapor concentration drops off sharply with altitude, so that in the upper troposphere and stratosphere, CO_2 plays a very large role and water vapor's role is greatly reduced. The problem with Hypothesis 2 is that if this were the answer, there would be no way to explain the very large changes in climate that occurred over Earth history (much less the natural greenhouse effect and the climates of Mars and Venus).

The models cited by IPCC do not predetermine the response—they are based on fundamental physical relationships and some parameterizations that have a strong empirical basis. Based on these equations, the models generate the response—it is not something that is assumed, but emerges out of the physics. With respect to the processes described in the papers that are cited as leading to Hypothesis 2, all have a number of important shortcomings and no quantitative representation of them has succeeded in being able to explain the present seasonal cycle of climate over the Earth, much less climate change.

Third paragraph and Figure 19: Models do have uncertainties—like democracy, however, they are better than any of the alternative ways for understanding and projecting climate change, and they are much better and more rigorous than the correlation-based speculation relied on in this article. Models are quantitative and objective, are based on fundamental physical relationships, and represent the integral of scientific understanding of the climate system. They are constantly being tested and evaluated, and they show substantial agreement with observations. Figure 18 is seriously out of date and has grossly over-estimated the problems with models.

The comparison to the flux change for CO_2 doubling is inappropriate—the other bars (all apparently based on peak values at any single location on Earth) refer to what are generally called systematic errors (or offsets) that would be present in both a control and a perturbed model simulation, whereas the change in CO_2 would be present in only the perturbed simulation. There is no indication that the systematic errors have a significant effect on the calculation of the overall response of the climate to a perturbation (just as different mutual funds based on the same investment priorities tend to have the same response to a change in the market). Recognizing the importance of the uncertainties, scientific results are generally provided as bands of possibilities—a much more rigorous approach than the casual correlations relied on in the authors' analyses. With so much discussion of the complexities of the climate system, one would think the authors would be much more cautious in the assertion of their degree of understanding of it.

Fourth to sixth paragraphs: The authors keep focusing on simple correlations, showing no recognition of the competing effects of various factors or of the time scales involved in going from emission to response. Even if increasing solar radiance contributed to the warming up to the mid-20th century, since then solar radiation has been stable or decreasing, and yet the amount and rate of warming has increased. The looseness of their analysis seems to just ignore such inconsistencies.

Seventh paragraph: Of course, the change in climate is not based on the CO_2 influence alone—that is not how the Earth system works. When CO_2 is added to the atmosphere, it changes the radiation balance and this initiates changes in everything else—and this is why it takes models to keep track of the various interactions; simple correlations make no sense at all.

Eighth paragraph: The Sargasso Sea figure is for a single point; there is no basis for using this record alone as a global record of changes. Some of the changes likely result from small shifts in ocean currents that have little global effect—and these cannot be differentiated from the changes that indicate a global change. The conclusion is just totally unsupported. Even if the record here is correct, no evidence is presented for what is going on elsewhere (like the Anasazi civilization breaking apart due to drought in the southwestern United States).

Ninth paragraph: There is no basis here for differentiating the CO_2 and methane effects—the assertion of methane having no effect is simply not justified. In addition, the methane concentration has again started to rise, which is could contribute to an acceleration in the rate of warming.

Tenth paragraph: Climate models represent the integration of our understanding. Indeed, they are theoretical, but they have done quite well in explaining a range of situations (e.g., diurnal, seasonal, interannual, centennial, and glacial/interglacial variations). It is true that the situation we are facing with rapidly changing atmospheric composition is unprecedented, so we cannot be sure the models are correct—but there is virtually no justification for believing they are far off.

Eleventh paragraph: The climate models do not try to calculate the impacts—only the types of changes in climate that occur—the projected impacts are inferences about the future. Some of the impacts are very soundly based. For example, as the CO_2 concentration increases, more is dissolved in the ocean, and this changes the chemistry of the ocean, causing "ocean acidification;" observations indicate a change in the depth at which the calcium carbonate dissolves, and this change is consistent with the changing ocean acidity. Heat-caused deaths are not due to the slow rise in average temperature, but to the higher peak changes and longer duration of heat waves—and the associated failure to design cities so that people do not get

overheated. The final assertion is simply not scientifically justified—climate change cannot be dismissed by unsupported assertions such as made in this article.

Section entitled "World Temperature Control"

First paragraph: Global temperatures are controlled by the conditions of the climate system that influence the global energy balance, and human activities are affecting this, so the temperature is not controlled by natural processes alone.

Second paragraph: The present distribution of temperature is optimum largely because we have adapted to it over the past several centuries. Had the conditions been different, we would likely have tried to adapt to them and called that temperature optimal for society. The statement that "we can cool the Earth with relative ease" is totally unsubstantiated—actually, we have much more experience with adding greenhouse gases that can warm (and are warming) the Earth.

Third through fifth paragraphs: As volcanic eruptions make clear, increasing the loading of stratospheric aerosols does lead to a number of quite possibly important side effects. In addition to the cost estimates being mostly guesses, there has been virtually no study of the patterns of climate response if this is done. Further, and relevant to this article's point of view, all of the studies on this have been done with the very computer models that the authors find inadequate. Interestingly, the model results, at least to some extent, seem contrary to our understanding of how ice age cycling works (that is, it seems reasonable to expect that changes in solar radiation and changes in the CO_2 concentration might cause different patterns of climate change, but this is, somewhat surprisingly, apparently not the case).

With respect to the claim that "[w]orld energy rationing, on the other hand, would not work," the issue is not about energy used, but about how it is derived. Studies indicate that a significant part of the transition to non-fossil energy could be done for about 1-2% of GDP or less—this would hardly spell the end of civilization.

Section entitled "Fertilization by Plants"

First paragraph: The problem is that being at "ultimate equilibrium" takes many, many millennia, and in the interim we will have a very substantial non-equilibrium increase.

Second paragraph: While individual plants would absorb more, the degree of warming, drying, and increase in occurrence of fire may well limit the overall increase, which is what matters. In addition, the oceans are expected to be absorbing less CO_2 as warming increases their stability and reduces the upwelling of nutrient rich waters that supply the marine biological pump. As a result, the rise in the land biomass uptake is unlikely to be sufficient to moderate climate change. Further, at 600 ppm, ocean chemistry will be dramatically modified, basically starting to dissolve most coral formations.

Third paragraph: While the CO_2 concentration has risen, much of the rise has been recent so that the climate has yet to have the decades needed to fully adjust—we are seeing only part of the response. In addition, sulfate aerosols are offsetting some of the warming influence, but this effect would diminish if CO_2 emissions were diminished sufficiently to keep its concentration level.

Fourth paragraph: The claim that CO_2 enhances plant growth enough to substantially increase carbon storage assumes adequate water and nutrients. Also, the resulting biomass may well

be less nutritious to animals, and weeds and pests tend to respond much more than the desirable plants. In addition, fire incidence seems likely to go up.

Sixth through ninth paragraphs and Figures 23-24: The problem with the figure for calculating impacts is that it fails to make clear that the actual amount of biomass that is produced varies dramatically between the two cases—while the "not resource limited" case shows a smaller percentage growth, its actual increase in growth dominates the actual increase for the "resource limited" case—so, dryland farmers might well get a higher percentage increase, but their actual increase will be less than for farmers with rich soils and irrigation or precipitation, so the competitive disadvantage of dryland farmers will grow, not shrink.

Last sentence: Despite the essential role of CO_2 for life, under the Clean Air Act, human-created emissions of CO_2 are, by interpretation of the US Supreme Court, to be treated as are other air pollutants.

Section entitled "Environment and Energy"

Third paragraph: Reducing use of fossil fuels by 90% will clearly take time—it took time (and lots of subsidies, many still remaining) to build up to this level, and it will take time to change (and subsidies to renewables have been trivial in comparison). Economic studies by many groups suggest the cost of changing might grow over a few decades to no more than 1-2% of GDP (more argue less than more), not something that makes the goal unachievable if innovation and flexibility are encouraged.

Fifth paragraph: The assertion that there "are no climatological impediments to increased use of hydrocarbons" is true only if one captures the CO_2 that is created and sequesters it underground.

Rest of discussion: There is general agreement about the value of establishing a level playing field, but this requires not only removing subsidies, but also internalizing the environmental and social costs of each technology. For fossil fuels, this would include the costs of climate change, ecosystem impacts, etc. as well as the health and air pollution costs. Once that is done (and the proposed carbon tax or permit fee is one way of doing this), then the various technologies should be expected to compete. Right now, improvements in efficiency are generally viewed to be by far the least expensive option in the US—this is not giving up energy services, but getting them much more cost effectively. Beyond that, the US and other countries would likely most benefit from having a mix of technologies, each appropriate to fulfilling its special role in its region—there is no one answer for everywhere in the world.

Conclusions section

First through sixth paragraphs: The authors conclusion is in opposition to the carefully and thoroughly reviewed scientific assessments of the international community and the findings of all the major national academies of science of the world—that should give the authors some pause in their unqualified assertions.

References

Generally the references provided are from a quite small and carefully selected representation of scientists rather from the full international community—suggesting an unwillingness to be open to the full range of findings of the scientific community. The IPCC considers a much broader and more complete set, and has included consideration of the points raised in the references used to justify the points given in this paper and found them seriously wanting.

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Appendix: Draft comments by Michael MacCracken dated April 18-19, 1998 on the Robinson et al. version of the article. A version of the original article is posted at http://web.archive.org/web/20070713215304/http://www.oism.org/pproject/s33p36.htm (download the pdf of the article to have access to the original formatting, to which the comments below apply).

Comments on
"Environmental Effects of Increased Atmospheric Carbon Dioxide"
by A. R. Robinson, S. L. Baliunas, W. Soon, and Z. W. Robinson

Prepared by
Michael MacCracken
National Assessment Coordination Office

General Comment: This paper is filled with distortions, errors, and one-sided interpretations of the science and blithely presumes that because we have survived to the present, the future will bring no problems as the population rises, energy use rises, atmospheric composition changes, and the earth's natural systems are seriously and rapidly altered by human activities. While it is true that we do not know all, or maybe even most, answers to questions about the future, the international scientific community has come to the conclusion that virtually all the evidence is pointing in one direction and these authors, ignoring that literature and the international conclusions, pick and select and come to the exact opposite conclusion. Theirs is truly the style of argument of a defense attorney with a very weak case--the first line of defense is that man is not causing any change; their second is that man is certainly not causing an exaggerated set of changes they attribute to the other side; their third is that if changes do occur, all of the impacts will be positive and easy to deal with (but here they leave out whole categories of impacts from consideration); and their fourth line of defense is that even if adverse changes do occur, what is happening is for the long-term greater good of society whether society likes it or not. All of these lines of defense have been considered by the international scientific community in great detail and then their analyses have been reviewed broadly by experts and governments--and all of these supposed lines of defense fail. With unanimity, the cautiously stated summary for consideration by policymakers is that "the balance of evidence suggests a discernible human influence on global climate" and that "the probability is very low that these correspondences could occur by chance as a result of natural internal variability only. The vertical patterns of change are also inconsistent with those expected for solar and volcanic forcing." These conclusions stand unrefuted by this work.

Specific Comments

Page 1, Summary: (1) Computer climate modeling goes back three decades, and simulation capability is well beyond its infancy; (2) The statement that there has been no man-made warming trend is simply false--temperatures have warmed significantly over the last 100 years and more; (3) The satellite temperature record is very short, calibrations are being questioned, and it is influenced by factors other than the CO_2 increase--this analysis is simply incomplete and wrong; (4) Over the past 700 years, when CO_2 has been at its highest,

temperatures have been their warmest--this type of relationship is clearly evident throughout Earth's history, as evidenced in the geological record, ice cores, etc.; (5) While higher CO_2 concentrations may mean more overall global biomass (depending on how the climate and land surfaces are arranged), the plant life that exists is likely to be very different than we have become accustomed to.

Page 1, Rise in Atmospheric Carbon Dioxide: (1) "Total human CO_2 emissions" (presumably meaning emissions created by human activities) actually total about 6 GtC/yr from fossil fuel use and about 1 GtC/yr from biomass destruction--so total 7 and not 5.5 GtC/yr as indicated; (2) The additional flux that humans are adding to the atmosphere-ocean-land system is significant because it is adding to the overall total--comparing this addition to the annual fluxes between reservoirs is like comparing new money coming into the stock market to the total annual value of all trades of stock--it makes no sense to do this; (3) It is clear beyond all doubt (from isotopic studies, for example) that the additional CO_2 emissions created by human activities are the cause of the global atmospheric CO_2 increase--values have likely not been so high since well before the Pleistocene glaciations started a million or more years ago (ice core records demonstrate this convincingly for the last 400,000 years)--there is no reason based on natural processes why CO_2 concentrations should now suddenly be jumping in the absence of the human influence; (4) If warm temperatures alone caused CO_2 concentrations to rise, then the CO_2 levels should have been high during the Climatic Optimum of 6000-9000 years ago when the global average temperature was perhaps even a bit warmer than at present (a result of natural cyclic changes in the Earth's orbit around the Sun)--CO_2 concentrations were not elevated--the CO_2 increase is due to human activities.

Page 2, Atmospheric and Surface Temperatures: (1) Using temperature variations in the Sargasso Sea (Fig. 2) to suggest that global temperatures vary comparably is totally improper [and would be totally unsupported by the satellite evidence, were that even appropriate to use}--while temperatures can vary a lot locally as weather or ocean currents change, the global temperature is, except on rare occasions when the ocean currents change dramatically, determined by the relative constancy of the Sun's output and the composition of the atmosphere and other generally slowly varying factors; (2) We do not understand why the Little Ice Age (which mainly involved colder winters) occurred, so it is pure speculation to suggest that the natural climate would be warming in the absence of human activities--while there are some suggestions the Little Ice Age was caused by a period of low solar output that has since ended, the recovery from this would likely have been over by the 19th century, and we cannot say whether the natural climate would have been warming or cooling in the absence of human activities; (3) While global temperatures may have been warmer than at present during the past three millennia (the time of human history), the greater warmth of the global average temperature was likely less than a degree (Celsius) greater than at present--and possibly less; human induced warming will likely exceed this value early in the next century and keep on going much higher--that there have been no catastrophes for human society in the past (a very arguable point--consider the Indians of the western US, civilizations in the Middle East, etc.) should be no reassurance for the future; (4) satellite observations of the variations in incoming solar radiation [measurements which these authors would be expected to argue are the most accurate type of measurement] show that the variations in solar radiation are very small compared to the temperature change that is being

associated with it--in fact, the ratio of temperature change to (solar) energy change derived from the Little Ice Age recovery would suggest that the Earth's temperature should have responded to the CO_2 (and aerosol) increase by about 10ºC by now in that the relationship shown in Fig. 3 shows that the warming is apparently an instantaneous response to the change in energy--climate models show much LESS temperature response to CO_2 than does the "Little Ice Age" geophysical experiment to solar radiation, and the fact that the Little Ice Age energy change was due to solar radiation is really of little consequence because as soon as the solar energy is absorbed in the atmosphere or at the surface, it becomes heat energy just like the energy trapped by the greenhouse gases [that an ozone chemical mechanism may be activated by the solar energy change may be a slight amplification factor, but by no means as strong as is being suggested, for in making a comparison, one would have to then assume that the climate models are showing MUCH TOO MUCH responsiveness to greenhouse gases--how climate models could at once be much too sensitive to CO_2 and much too insensitive to solar radiation is not at all clear--and not explained by the authors; (5) The evaluation of the US temperature record to draw global conclusions is a flawed approach--there is no proof that the 1900 to 1940 warming was due to the Little Ice Age, especially since the period 1850-1900 was warmer than the period 1900-1910--this period was likely cool due to the occurrence of several major volcanic eruptions and the diminished solar radiation during this period, just as 1940 was warm due to reduced volcanic activity and increased solar radiation, along with increased CO_2; (6) global temperature records show the 1980s and 1990s to be the warmest decades since records began, and likely for many centuries, even though there was a major volcanic eruption in 1991 [it should be noted that the global cooling after the 1991 Pinatubo eruption did not cool temperatures to anywhere near the level following the 1883 Krakatau eruption or the several eruptions in the first decade of this century--quite suggestive evidence that there has been global warming]; (7) Use of balloon data prior to the mid 1960s as representative of global average temperatures is suspect due to the very limited number of stations (typically dozens)--in fact, many skeptics argue that the lack of global representativeness of the surface station network with its thousands of stations is why they focus on the satellite temperature record (even though it is not recording surface temperature)--now using the very early radiosonde record would seem to conflict with their contention about the surface network results.

Page 3, Atmospheric and Surface Temperatures (continued): (1) the satellite record is quite controversial for reasons other than the trend that it shows--it is made up from the observations of nine different satellites that must be joined together; tropospheric temperatures are not a measure of surface temperatures due to the presence of inversions and the adjustments caused by atmospheric circulation which are so large that they can cool the atmosphere when the surface warms; the atmospheric temperatures are affected differently than the surface temperatures by El Niños, volcanic eruptions, ozone depletion, etc.; the satellite measurements are not consistent with what has been happening in mountain regions where glaciers have been melting; etc.--in summary, the satellite temperature record requires further consideration, but it is not the most relevant measurement, it is not yet clear it is reliable, and it does not provide a refutation that the global average SURFACE temperature is increasing nor that models are flawed; (2) It is not yet clear that the radiosonde (balloon) measurements are independent of the satellite data in that radiosonde measurements have apparently been used to do some calibration and estimation of the bias terms in the satellite

record; (3) The satellite and surface measurements are of quite different temperatures--the day-to-day correlation of anomalies is near zero according to Christy--this is because of the presence of inversions, the fact that the atmosphere is responding dynamically in ways the surface cannot, etc.--the two measurements can give the opposite response over particular regions, they show very different statistical character for very good reason, they have very different diurnal responses--they are measurements of different quantities [sort of like saying that measurements of the surface of the ocean and of the deep ocean should be the same--they should not and they are not]; (4) the model predictions suggesting tropospheric temperatures should be warming as the authors suggest are for cases with only greenhouse gases--model calculations with ozone and sulfate aerosols effects and accounting for the natural effects of El Niños and volcanic eruptions give much lower warming rates (similar to observations).

Page 3: The Global Warming Hypothesis: (1) Without the natural greenhouse effect, the Earth would be much colder (much more than 14ºC), with the exact number depending on whether one keeps clouds, whether snow covers the Earth, etc.--the problem with the analyses by the other author showing a low climate sensitivity cannot explain how the Earth's climate has varied in the past as shown in geological records; (2) the large temperature increase attributed to IPCC predictions is for the effect of CO_2 in the absence of all other effects--but aerosols, ozone depletion, volcanoes, El Niños, etc. are all occurring; when these are accounted for, the observed and modeled warming are in good agreement.

Page 4, The Global Warming Hypothesis (cont.): (1) The comparison in Figure 10 is of apples and oranges--the uncertainties due to ocean fluxes (which is the case or only some models), heat flux, humidity, and clouds) are of systematic uncertainties that will affect both present and future climates, whereas the greenhouse term is a change in flux and will only affect the future [this comparison is sort of like comparing factors causing temperature variations in your house with no furnace and then with a furnace]; (2) while climate models are not perfect, they are based on quantitative physical laws that are substantially more reliable than qualitative association of one factor with another (such as length of the solar cycle with global temperature as was done in Figure 3); (3) Figure 11 is the temperature increase attributed that IPCC calculated for the effect of CO_2 in the absence of all other effects--but aerosols, ozone depletion, volcanoes, El Niños, etc. are all occurring; when these are accounted for, the observed and modeled warming are in good agreement, as shown by Wigley, et al.; (4) Atmospheric temperatures have risen substantially since the 1940s (single years should not be used in making climate comparisons--also, about one third of the net greenhouse gas and aerosol induced changes in the greenhouse effect occurred BEFORE 1940, so implying the temperature increase before that date is solely natural is simply incorrect; (5) There are no known feedbacks that can turn a warming influence into a cooling influence as suggested here--there are positive feedbacks that can make a positive effect larger and negative ones that can make it smaller--but still positive--than it might normally be--these authors do not understand the concept of negative feedbacks; (6) Climate models do many things very well--they are not perfect and will be improved as shortcomings are recognized--and even in the absence of climate models, paleoclimatic evidence clearly suggests the climate would warm as greenhouse gas concentrations increase, and by an amount similar to predictions by models; (7) The suggestion that total reliance should be

placed on empirical data is flawed on several counts: observations can be affected by many factors and so be hard to interpret clearly and correctly (many interpretations of observations confirm the greenhouse warming hypothesis); observing systems can be biased; and giving up all attempts to look into the future in favor of relying on trends of the recent past is like trying to swim upstream as you head toward a waterfall [or looking up as you enjoy your fall off the Empire State building}; (8) the IPCC has considered the full range of scientific literature on all of these arguments--and found them all wanting.

Pages 4 and 5, Global Warming Evidence: (1) There are many indicators of global warming: surface temperature, ground temperature, melting glaciers, rising sea level, rising atmospheric humidity, etc., etc. (2) While urban areas can lead to a false indication of warming, irrigation (of fields, golf courses, etc.) can lead to a false indication of cooling in rural regions--both types of bias have to be accounted for--in any case, urban warming cannot explain why the oceans are warming, glaciers are melting, ground temperatures are rising on all continents where measurements have been made; (3) The timing of the warming depends on the combined rise of CO_2 and aerosols--IPCC calculations are that about a third of the radiative forcing occurred by 1940, so part of the early warming was due to human influences--and since 1940, aerosols have gone up relatively more, countering some of the greenhouse gas warming influence--all factors together must be considered; (4) Figure 14 shows clearly why to be careful of using short records--the very low temperature in 1964 was due to the Mt. Agung volcanic eruption in 1963; the decline in 1992 and thereafter was due to the very large Mt. Pinatubo eruption--surface temperatures showed quite different patterns. The reasons these results were used and the explanation for all of this is carefully laid out in a Nature exchange of letters by Michaels and then by Santer et al.; (5) Note that the authors seem reluctant to show the surface temperature record since 1860--the longest and best scrubbed temperature record of all--it would refute all of their conclusions about the temperature history of the world.

Pages 5 and 6, Sea Level and Storms: (1) The IPCC does not use the term “catastrophe”--this is a term used by these authors to create a strawman to shoot at; (2) Sea level has been rising--just go see the islands in Chesapeake Bay that have been inundated since colonial times--the long-term record is very clear that sea level is rising--the notion of relying on the first, few year satellite measurements instead of the long-term tide gauge measurement record is very poor science; (3) The Antarctic has glacier streams that are decaying--the Larsen ice shelf being one; indeed, natural variations still seem dominant, but some losses seem inevitable--and in any case, mountain glaciers around the world are melting back and thermal expansion of the oceans will cause sea level rise in any case; (4) The IPCC does not say that hurricane frequency will increase--this is a strawman argument; (5) There is no indication the Middle Ages were 1ºC warmer than today globally--there is also no indication that we are still recovering from the Little Ice Age, if we ever were--this is all speculation about long-term trends using quite limited data and eyeball analysis, which are quite unreliable.

Pages 6 and 7, Fertilization of Plants: (1) This carbon cycle analysis is serious flawed--use of about 250-300 GtC of fossil fuels has raised CO_2 concentrations by about 80 ppmv--burning of about 1300 GtC over the next century (averaging about twice the rate of current use) will likely take us up another 350 ppmv to about 700 ppmv--the analysis these authors do is way

off of what has been happening; (2) The living biosphere now contains about 600 GtC above ground biomass, perhaps twice that below ground--these authors suggest the rate of increase could rise to a net absorption of about 10 GtC/yr compared to about 1 GtC/yr now--were one-third of it to be above ground--a conservative amount--this would lead to a 50% increase in 100 years--where would we put it all--there is little room for it in the forests, etc.--this is simply not possible--while one plant can grow better with more CO_2, there is not room for all plants to do so, especially as cities and farms take over the forests--and the carbon can get to below ground without there being plants above ground; (3) the current biospheric exchange (uptake and release by the terrestrial biosphere) is about 80 to 100 GtC/yr, and there is a net annual storage occurring of perhaps 2 GtC/yr, offset by 1 GtC/yr in deforestation--the notion that this could grow to perhaps 10 GtC/yr (or 5 times as much) when the biospheric exchange rate has increased only modestly, seems very unlikely to have accounted for the needs of plants in the real world for nutrients, water, etc.; (4) the increase in hardwoods in the US since 1950 is largely in the northeast, where farmland became forests--there is decreasing room for this to continue

Pages 7 and 8, Discussion: (1) While "catastrophic changes" is a loaded phrase, there is good evidence to support that the fraction and frequency of heavy rainfall events is increasing; that the meltback of mountain glaciers (which supply water for many cities) is occurring very rapidly, that insect vectors are spreading to new regions, and that global average temperatures are the warmest in many centuries--only the short, controversial satellite record, which is being misinterpreted by not accounting for the influences of other important factors, is cited as contrary evidence; (2) Warmer temperatures can bring some benefits, but they also allow disease vectors to spread, allow longer periods for development and attack of pests, melt permafrost, alter competitive pressures in ecosystems in ways that cause rapid changes, divert storms and raise snowlines in ways that affect water resources, cause sea level to rise, etc., etc.--the effects of warming are by no means benign; (3) There are many indications the Earth has warmed: surface temperatures, ground temperatures, and ocean temperatures are up; glaciers are melting back; sea level is rising; and on and on--and these changes are all consistent with predictions of how human-induced greenhouse gases and aerosols should cause the climate to change and contrary to the types of changes expected from natural variations and factors--we cannot absolutely prove it is the human influence, but it is very likely the human influence causing most of these changes; (4) Indeed, the world's biosphere will not die off from a higher CO_2 concentration, but it will be quiet different, and the changes will occur very rapidly--the key question is whether humans, with their many needs for resources from the natural world, can and want to accommodate to the many important and complex (and not always obvious) changes that will be occurring.

Further Information and Citations to Comments: The comments made here are generally consistent with the summary scientific findings presented in the IPCC assessments and reports. Providing detailed citations for such an obviously flawed article that shows little familiarity with the major scientific literature and that is so intent on pushing a particular view is simply not worth the time or effort.