Review of Recent Science on Climate Change

In Light of EPA's Proposed

Reliance on 2009 Endangerment Finding

to Set CO_2 New Source

Performance Standards

20000804v1

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1. INTRODUCTION

EPA's proposed New Source Performance Standards for carbon dioxide emissions from new fossil fuel-fired electric generating units states that EPA does not have to make a new "endangerment finding" regarding the health and welfare impacts of such emissions in order to promulgate such standards. EPA offers a primary rationale for its position in this regard and also two alternatives. Under EPA's first alternative, it would conclude that such emissions pose a danger to the public health and welfare based on its 2009 endangerment finding that was made in the context of EPA's issuance of motor vehicle greenhouse gas emission standards and the Technical Support Document (TSD) that EPA issued in connection with that endangerment finding. Under EPA's second alternative, EPA would rely on such 2009 endangerment finding as well as its denial of petitions to reconsider that finding and two more recent reports of the National Research Council (NRC). However, EPA would not, under either alternative, reconsider in this proceeding its 2009 endangerment finding in light of new science other than the NRC reports nor would it make a new endangerment finding in support of its proposed rule. See *Standards of Performance for Greenhouse Gas Emissions for New Stationary Sources: Electric Utility Generating Units*, 77 Fed. Reg. 22,392, 22,411-13 (Apr. 13, 2012).

The report below is intended to show that there is a wealth of new science that requires EPA to exercise its judgment in determining whether greenhouse gas emissions pose a danger to the public health and welfare. The report shows that the two NRC reports do not, as EPA asserts, reflect an "independent" and additional confirmation of EPA's 2009 endangerment finding. Instead, those reports draw from the same sources as EPA did, namely the work of the International Panel on Climate Change (IPCC) and U.S. Global Change Research Program (USGCRP). The IPCC 2007 report (AR4) includes papers available through May 2006 and the USGCRP 2009 report includes papers available through August 2008. Thus, both EPA's 2009 endangerment finding and the two NRC reports are based on science that is no longer current.

As described below, more recent science undermines key conclusions of the 2009 endangerment finding, particularly on the validity of models on which that finding (and the work of the IPCC, USGCRP and the NRC) are based. It also undermines key EPA conclusions as to climate impacts that EPA foresees for the United States as set forth in Chapter 3 of EPA's Regulatory

Impact Analysis (RIA) in support of its proposed rule. The report below shows that many of these conclusions are inconsistent with new science. The discussion below necessarily cites some older material to put the discussion of new science in context. But the central conclusion of the report is that new peer-reviewed evidence and current data have emerged that EPA must address if it is going to extend its greenhouse regulations into additional areas.

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2. RELIANCE ON NRC REPORTS

2.1 NRC process is not transparent

The NRC process for preparing its reports fails to meet the basic test of transparency. As stated by the NRC:

> The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

2.2 The NRC Reports are not "independent"

It is clear from the 2010 NRC report "Advancing the Science of Climate Change" that it is not an "independent" assessment, as the EPA asserts. The EPA backs its assertion of "independence" with the highly selective quote (reproduced below) that, out of context, gives the appearance that the NRC has arrived at its conclusions independently, and that they are "consistent" with the other assessment reports. But that is not the case at all. In fact, the NRC describes its report as follows (in the Preface of the report "Advancing the Science of Climate Change", page ix):

> In addition to drawing on the new scientific results being published nearly every week, we were aided in this task by the final U.S. Global Change Research Program (USGCRP) Synthesis and Assessment Product *Global Climate Change Impacts in the United States* (USGCRP, 2009a), the recent National Research Council (NRC) report *Restructuring Federal Climate Research to Meet the*

> *Challenges of Climate Change* (NRC, 2009k), and the four volumes of the fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC, 2007a-d).

There is no definition of the term "independent" which includes being "aided" by other reports—especially the very same set of reports that the NRC report is supposed to be "independent" of. In fact, the on-line dictionary, dictionary.com, defines "independent" as "not relying on another or others for aid or support" (http://dictionary.reference.com/browse/independent). As such, the EPA is incorrect in describing the NRC reports as representing "another independent and critical inquiry of the state of climate change science, separate and apart from the previous IPCC, NRC, and USGCRP assessments."

How much the NRC reports were "aided" by previous assessment reports of the USGCRP and the IPCC is clear from the numerous citations of those reports for the major conclusions of the NRC report. Additionally, while the NRC claims to draw on "new scientific results being published nearly every week" in actuality, there is very little of the new and influential research that has been published since the release of the IPCC AR4 and USGCRP assessments that is included in the NRC reports. In some cases, the fact that the NRC reports were produced in such close temporal proximity to the USGCRP report limits the new science available for inclusion, and in other cases, it seems that the NRC selectively ignores scientific research that runs counter to the contents of the USGCRP and IPCC reports upon which it is primarily based.

Some examples of key research areas where of the lack of inclusion of new and influential research by the NRC and the strong reliance on the IPCC and the USGCRP reports by the NRC are illustrated by the following from the 2010 NRC report. The same is the case for the 2011 NRC report.

- The primary reference cited by the NRC to back the conclusions of the "Climate Forcing" section (p. 189-200) of "Advancing the Science of Climate Change" is Forster et al., 2007—which is Chapter 2 of the IPCC AR4 WGI report. In this section, the NRC fails to include the results of the new and influential study by Ramanathan and Carmichael (2009) in which it is shown the cumulative warming impact from human black carbon (soot) emissions (not a GHG) is much larger than described by the IPCC. The Ramanathan and Carmichael (2009) result implies that the warming effect of GHG emission is less than previous assessments (such as the IPCC) have assigned to it.

- A primary reference cited by the NRC to back is findings reported in the "Climate Feedbacks and Sensitivity" section (p. 200-201) is Hegerl et al., 2007—which is Chapter 9 of the IPCC AR4 WGI report. Many of the other references were either dated and/or included in Hegerl et al., 2007. Absent from the NRC report is a large and growing collection of new and influential research findings which show that the estimates of climate sensitivity are much better constrained (especially on the high end) than reported in the IPCC AR4 (Annan and Hargreaves, 2009; Pueyo, 2011; Schmittner et al., 2011; Olson et al., 2012) and including central estimates for the climate sensitivity that fall beneath the IPCC AR4 central estimate of 3.0°C that was repeated by the NRC (Annan and Hargreaves, 2009; Lindzen and Choi, 2011; Pueyo, 2011; Schmittner et al., 2011). This new research greatly lessens the expectations for a large future temperature rise resulting from human GHG emissions.

- The NRC section "Attribution of Observed Climate Change to Human Activities" (p. 214-216) is replete with references to IPCC and USGCRP assessments. Of the 10 items included in the NRC's bullet list. The large majority are based on direct citations of IPCC AR4 Chapters or previous (and somewhat dated) NRC reports.

- The section "Projections of 21st Century Climate" (p. 221-224) future projections of climate from climate models relies virtually exclusively on the results presented in the IPCC and USGCRP assessments.

- The section on "Causes of Sea Level Rise" (p. 238-243) fails to include any of a growing list of recent publications which find that the pumping of groundwater for irrigation and other uses is growing rapidly across the world, and that this water, once stored in deep aquifers is now ending up in the oceans and contributing a sizeable fraction to the observed sea level rise. Recent estimates are between 15 and 40% (and growing) of the current observed rate of sea level rise is being contributed by continental “dewatering” (Wada et al., 2010; Konikow, 2011; Wada et al., 2012; Pokhrel et al., 2012). These recent findings are in stark contrast to the NRC report which states that:

> There are additional contributions to sea level rise from other human activities such as wetland loss, deforestation, and the extraction of groundwater for irrigation and industrial use. While estimates of the size of these sources are somewhat uncertain, they are believed to be small relative to land ice melting and may be partially offset by the increased storage of water behind dams and in other surface reservoirs over the past century and a half (e.g., Chao et al., 2008).

- Clearly, the NRC report is out-of-date on the issue as to the causes of and contribution to recent sea level rise. In fact, the reported “acceleration” of sea level rise in recent decades can fully be explained by an “acceleration” of groundwater extraction around the globe (Wada et al., 2012).

- The section on “Projections of Future Sea Level Rise” (p. 243-245) makes inadequate mention of a growing list of new and influential publications which find that glacier processes in Greenland do not lend support a rapid and sustained increase in ice discharge from the Greenland ice sheet and thus do not support a large contribution of sea level rise from Greenland this century (e.g., van de Wal et al., 2008; Nick et al., 2009; Schoof, 2010; Bjørk et al., 2012). Without fully considering these scientifically important results, it is impossible to make an accurate assessment of the current sea level rise projections and gives rise to an overestimation of the future rate of sea level rise.

- The section on Public Health: Extreme Temperatures and Thermal Stress (P. 311-313), includes virtually none of a large number of influential publications that clearly and unequivocally demonstrate that populations readily adapt to heat waves (e.g., Davis et al., 2003; Barnett, 2007; Gosling et al., 2009; Kalkstein et al;, 2010). The results of these studies, and others like them, suggest that if heat waves were to increase in frequency and intensity in the future, a declining population sensitivity would almost certainly be the result. Without adequately accounting for adaptation, both autonomous and planned, projections of negative health-related impacts from increasing heat waves are not robust and inaccurate. The NRC report is grossly incomplete on this topic.

These examples are not intended to be a comprehensive documentation of all the instances of NRC's direct reliance on the IPCC and USGCRP report, but are more than sufficient to demonstrate that the NRC reports, "Advancing the Science of Climate Change" are by no means "independent" of the IPCC and/or USGCRP assessment reports. Nor are these examples isolated instances. The NRC readily admits that the report relies heavily on the IPCC and USGCRP reports, as is clearly apparent from a simple perusal of the NRC report and its numerous citations of the IPCC and USGCRP reports to base its conclusions. Additionally, many of the examples listed above show that the NRC did not address a number of new and influential scientific research results.

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Barnett, A.G., 2007. Temperature and cardiovascular deaths in the U.S. Elderly: Changes over time. *Epidemiology*, 18, 369-372.

Bjørk, A. A., et al., 2012. An aerial view of 80 years of climate-related glacier fluctuations in southeast Greenland. *Nature Geoscience*, 5, 427-432, doi:10.1038/NGEO1481.

Davis, R.E., P.C. Knappenberger, P.J. Michaels, and W.M. Novicoff, 2003. Changing heat-related mortality in the United States. *Environmental Health Perspectives*, 111, 1712–1718.

Gosling, S.M., et al., 2008. Associations between elevated atmospheric temperature and human mortality: a critical review of the literature. *Climatic Change*, doi_10.1007/s10584-008-9441-x

[1] The list of references throughout this report includes those cited and additional references for context.

Kalkstein, L.S., S. Greene, D.W. Mills, and J. Samenow, 2010. An evaluation of the progress in reducing heat-related human mortality in major U.S. cities. *Natural Hazards*, doi:10.1007/s11069-010-9552-3

Konikow, L., 2011. Contribution of Global Groundwater Depletion Since 1900 to Sea-Level Rise. *Geophysical Research Letters*, 38, L17401, doi:10.1029/2011GL048604.

Lindzen, R.S., and Y-S. Choi, 2011. On the observational determination of climate sensitivity and its implications. *Asia-Pacific Journal of Atmospheric Sciences*, 47, 377-390.

Nick, F. M., et al., 2009. Large-scale changes in Greenland outlet glacier dynamics triggered at the terminus. *Nature Geoscience*, 2, 110-114, DOI:10.1038/ngeo394.

Olson, R., et al., 2012. A climate sensitivity estimate using Bayesian fusion of instrumental observations and an Earth System model. *Journal of Geophysical Research*, 117, D04101, doi:10.1029/2011JD016620,

Pokhrel, Y.A. et al (2012) Model estimates of sea-level change due to anthropogenic impacts on terrestrial water storage. *Nature Geoscience*, doi:10.1038/ngeo1476

Pueyo, S., 2011. Solution to the paradox of climate sensitivity. *Climatic Change*, doi:10.1007/s10584-011-0328-x.

Ramanathan V., and G. Carmichael, 2009. Global and regional climate changes due to black carbon. *Nature GeoScience*, 1, 221-227.

Schmittner, A., et al., 2011. Climate sensitivity estimated from temperature reconstructions of the Last Glacial Maximum. *Science*, 334, 1385-1388, doi: 10.1126/science.1203513

Schoof, C., 2010. Ice-sheet acceleration driven by melt supply variability. *Nature* 468, 803-805.

van de Wal, R. S. W., et al., 2008. Large and rapid melt-induced velocity changes in the ablation zone of the Greenland ice sheet. *Science*, 321, 111-113.

Wada, Y., et al. 2010. Global Depletion of Groundwater Resources. *Geophysical Research Letters*, 37, L20402, doi:10.1029/2010GL044571.

Wada, Y., et al., 2012. Past and future contribution of global groundwater depletion to sea-level rise. *Geophysical Research Letters*, 39, L09402, doi:10.1029/2012GL051230.

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3. FLAWED EPA AND IPCC PROCESS

3.1 The IPCC review process deficiencies invalidate the IPCC AR4 as a basis for US policymaking

The IPCC process is compromised by arbitrary author selection procedures, conflicts of interest in which IPCC-selected authors review their own work and that of their critics, weak peer review procedures and the lack of a requirement to document the full range of opposing views. The EPA Inspector General report set out peer review requirements required by the Information Quality Act (also known as the Data Quality Act (DQA)) that disqualify IPCC products for the proposed rule.

When the EPA released its Proposed Endangerment Finding on greenhouse gases in April 2009 and its final Endangerment Finding in December 2009 it did not conduct any internal evaluation of the science, instead relying on the IPCC assessment:

> However, the [EPA] Administrator is relying on the major assessments of the USGCRP, IPCC, and NRC as the primary scientific and technical basis of her endangerment decision for a number of reasons. …these assessment reports undergo a rigorous and exacting standard of peer review by the expert community, as well as rigorous levels of U.S. government review and acceptance.

> Individual studies that appear in scientific journals, even if peer reviewed, do not go through as many review stages, nor are they reviewed and commented on by as many scientists. The review processes of the IPCC, USGCRP, and NRC (explained in fuller detail in the TSD and the Response to Comments document, Volume 1) provide EPA with strong assurance that this material has been well vetted by both the climate change research community and by the U.S. government. (74 Fed.Reg. 66,510, 66,511 (Dec. 15, 2009))

This description is inaccurate, as the IPCC Lead Authors of Working Group reports have authority without recourse to override reviewer comments, and even to rewrite the text after the review process has closed. Consequently the review process is much weaker than that which occurs in normal academic journals, where neither of these practices are allowed.

In September 2010, the Office of the Inspector General (OIG) of the EPA issued a finding[2] that the TSD was a highly influential scientific assessment and therefore the EPA was required to conduct its own peer review, rather than relying on the review undertaken by the IPCC. The OIG directed the EPA to take corrective action but the EPA has not done so.

The OIG report (p. 11) also listed a key condition for evaluating whether another party's peer review processes is adequate for a highly influential scientific assessment. The EPA:

> . . . should examine closely the particulars of the peer review to ensure independence and a conscious effort to incorporate the peer reviewers' comments into the final work product. If there are perceived, or real, conflicts of interest, this may preclude the use of that peer review and, in those instances, another peer review would be needed."

The EPA had told the OIG:

[2] http://www.epa.gov/oig/reports/2011/20110926-11-P-0702.pdf

> . . .the TSD consisted only of science that was previously peer reviewed and that these reviews were deemed adequate under the Agency's policy. (OIG Report p. 13)

EPA's assertion is incorrect, however. The IPCC selects authors who are not independent, indeed who are in conflicts of interest in the sense that they review their own work and that of their critics. IPCC procedures allow authors arbitrary authority to ignore reviewer comments and rewrite text after the close of peer review.

3.2 IPCC Structure

There are three administrative tiers in the IPCC.[3]

(i) The top level is called the Panel, consisting of representatives of the 195 member states, who meet in periodic plenary sessions to make decisions and review ongoing work. The documentary record shows[4] that Panel members provide only cursory and superficial input into IPCC operations, few members participate in the Assessment review process and most were not engaged with the recent reform process. For all practical purposes, the IPCC is directed and controlled by the IPCC Bureau.

(ii) The IPCC Bureau (assisted by a 10-member IPCC Secretariat), is an administrative body elected by the Panel, consisting of a Chair (currently Rajendra Pachauri), Vice Chairs, the Working Group Co-Chairs, and other Bureau members. The current Bureau consists of 30 members elected at a meeting of the Panel in Geneva in September 2008.[5] 28 members are attached to the three Working Groups and 2 are Co-Chairs of the Task Force on Greenhouse Gas Inventories, which has its own 14-member Bureau. The 30-member Bureau and Secretariat have significant influence over the flow of information to the Panel, by structuring and presiding over the plenary meetings and overseeing the production of reports.

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[3] This is based on the IPCC organizational chart at http://www.ipcc.ch/organization/organization_structure.shtml.

[4] See McKitrick, Ross R. "What Is Wrong With The IPCC? Proposals For a Radical Reform." Global Warming Policy Foundation Report 4, 2010. This and the next 3 sections are based on that document.

[5] See report at http://www.ipcc.ch/meetings/session30/doc5.pdf.

(iii) The next tier is divided into three Working Groups and one Task Force, where the work of preparing reports is conducted. Working Group Lead Authors are selected by the Bureau. Each Working Group produces a contribution to an assessment report, commonly known as IPCC Reports.

The Bureau has complete control over the selection of Coordinating Lead Authors (CLAs) and Lead Authors (LAs) for the Working Groups. The CLAs and LAs then select contributors (CAs) at their own discretion to provide content to the chapters. While the Bureau recruits CLAs and LAs from lists provided by member governments, it is not limited to the names on those lists, instead it is allowed under IPCC rules to select anyone it wants.

One way that the IPCC's control over author selection could lead to biases in the assessment process is that authors can be selected who are in an intellectual conflict of interest, whereby authors of key sections are in the position of assessing their own work and that of their critics. Some examples include:

- In the 2001 IPCC Report, Michael Mann was Lead Author of the paleoclimate chapter that assessed his own hockey stick graph and that of rival teams, and he steered the decision to give it prominence and suppress contradictory information in another graph by Briffa et al.

- In the 2007 IPCC Report, Phil Jones of the CRU was Lead Author of the chapter that assessed, among other things, the quality of CRU data and the work of teams that had found evidence that it is contaminated with a warm bias. He kept the critical information out of drafts shown to reviewers and then participated in inserting text after the close of peer review that dismissed this evidence on the basis of a fabricated statistical test.

- The Lead Authors of IPCC 2007 Chapter 9 that critically assess the findings of "signal detection" literature, on which basis the attribution of climate change to GHG's is made, are themselves the authors of most of the signal detection studies on which their conclusions rest. This includes Gabriele Hegerl, Francis Zwiers, Peter Stott, Nathan Gillett, Myles Allan, Richard Betts, Reto Knutti and Simon Tett.

- Lead Author selection is done behind closed doors using an opaque process that was much-criticized during the review of IPCC procedures conducted by the InterAcademy Council (IAC) in 2010.[6] The author selection criteria have since been revised slightly, without introducing any substantial changes, in response to the IAC review recommendations. There is a requirement to ensure representation of a wide range of views, but it is worded so weakly that it is in effect a dead letter:

  > The composition of the group of Coordinating Lead Authors and Lead Authors for a section or chapter of a Report shall reflect the need to aim for a range of views, expertise and geographical representation.

In May 2011 the Panel responded to criticism by changing the wording from "shall reflect the need to aim for a range of views" to "shall aim to reflect a range of scientific, technical and socio-economic views,"[7] which is clearly a trivial change.

The centralized nature of the author selection process, and the absence of a meaningful requirement to include proponents of the full range of scientific views, means that the IPCC Bureau can predetermine the content of the report by selecting of CLAs and LAs they know to be committed to a particular point of view. IPCC Chairman Rajendra Pachauri denies that the author selection procedure is biased. In a 2007 interview he described the process in very idealized terms:

> These are people who have been chosen on the basis of their track record, on their record of publications, on the research that they have done. …They are people who are at the top of their profession as far as research is concerned in a particular aspect of climate change.[8]

[6] http://reviewipcc.interacademycouncil.net/
[7] See http://www.ipcc.ch/meetings/session33/ipcc_p33_decisions_taken_procedures.pdf p. 2.
[8] http://www.rediff.com/news/2007/jun/05inter.htm

But it is easy to find counterexamples that undermine this description.[9] A recent case is Sven Teske, a climate campaigner for Greenpeace who was selected by the IPCC as a Lead Author for its recent report on renewable energy (SRREN), which led to a non peer-reviewed Greenpeace report he coauthored becoming the basis for central claims in the report, which were subsequently highlighted in the press release announcing its publication.

Another particularly notable case is Sari Kovats, who was selected to serve as an IPCC Contributing Author in 1994 when she was 25 years old, had no Ph.D. and no academic publications, and was just starting a job as a research assistant at the London School of Hygiene and Tropical Medicine.[10] She began a part-time Ph.D. program in 2001, at which time she was promoted to a term as an IPCC Lead Author. The IPCC Bureau appointed her a third time as Lead or Contributing Author for a total of four chapters of the AR4, as well as expert reviewer. Her Ph.D. thesis wasn't completed until three years after the AR4 was published.[11]

These are not isolated cases. Past IPCC authors made many submissions to the IAC Review panel,[12] expressing concerns about the extent to which LAs are selected on political rather than scientific grounds. A common complaint was that the mandate to obtain geographic balance led to inclusion of many incompetent and untrained scientists, and political considerations often seemed to rank above scientific credentials.[13] Here are some excerpts from complaints filed by IPCC Lead Authors themselves about some of the people they were teamed with:

> There are far too many politically correct appointments, so that developing country scientists are appointed who have insufficient scientific competence to do anything useful. This is reasonable if it is regarded as a learning experience, but in my chapter in AR4 we had half of the [lead authors] who were not competent.

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[9] The material on lead author selection is drawn from Laframboise, Donna (2011) *The Delinquent Teenager Who Was Mistaken for the World's Top Climate Scientist* Toronto: Amazon.

[10] http://www.webcitation.org/5xEHr8hDh

[11] See Donna Laframboise, http://nofrakkingconsensus.com/2011/03/16/the-strange-case-of-sari-kovats/ for a more detailed examination of the circumstances of this author's appointment.

[12] Available online at http://reviewipcc.interacademycouncil.net/Comments.pdf.

[13] See Laframboise (2011, op. cit.) for more excerpts and discussion.

The most important problem of the IPCC is the nomination and selection of authors and Bureau Members. Some experts are included or excluded because of their political allegiance rather than their academic quality. Sometimes, the “right” authors are put in key positions with generous government grants to support their IPCC work, while the “wrong” authors are sidelined to draft irrelevant chapters and sections without any support.

The whole process… [is] flawed by an excessive concern for geographical balance. All decisions are political before being scientific.

…it is clearly noticeable that the [author nomination] process occasionally brings authors with poor knowledge or poor motivation into [lead author] positions.

… I have experienced the addition of lead authors or [contributing] authors during the process who often seem to come with a political mandate – generally from developed countries and as such they can be very disruptive – let alone the dubious nature of the science they contribute!

Since I have been selected for several IPCC reports, I have no personal prejudice (or grouse) on the process. However, regarding the selection of Lead Authors, I am more worried since the distortions, opaqueness and arbitrariness that is lately creeping into the process seems alarming. It seems that knowledge and scientific contributions are increasingly at discount in selection of authors compared to the personal connections, affiliations and political accommodations.

IPCC works hard for geographic diversity. This is one valuable criterion, but it is not sufficient to choose a lead author. The result is that some of the lead authors (generally although not always from developing countries) are clearly not qualified to be lead authors and are unable to contribute in a meaningful way to the writing of the chapter.

> The team members from the developing countries (including myself) were made to feel welcome and accepted as part of the team. In reality we were out of our intellectual depth as meaningful contributors to the process.

These comments, and many more like them, came from past IPCC Lead Authors themselves, indicating that Pachauri's description of the author selection process is clearly untrue. He also failed to point out the most significant loophole in the process, namely that CLAs and LAs have a free hand in selecting Contributing Authors, who provide much of the text.

> **3.3 The Coordinating Lead Authors and Lead Authors selected by the Working Group/Task Force Bureau may enlist other experts as Contributing Authors to assist with the work**

This aspect of the process neutralizes the already weak requirements for balance, since no requirements for balance are imposed on the CA selection process—in fact no requirements of any kind are imposed on it. The IPCC does not even have to release the list of CAs during the report-writing process, the rules only stipulate that CAs should be named in the final, published report.

Another illustration of the problems in the IPCC author selection process is the influence given to authors who are members of or advisors to the environmental activist organization World Wildlife Fund (WWF)[14]:

- 28 out of 44 chapters of the AR4 Working Group Reports had at least one author who is a campaign advisor for the World Wildlife Fund (WWF);

- WWF campaign advisors were involved in writing all 20 chapters of the Working Group II report and 6 of 11 chapters of the Working Group I report;

- WWF campaign advisors served as Coordinating Lead Authors for 15 of the 44 chapters in the AR4, and in three cases both the CLA's were WWF advisors;

[14] This information is documented in Laframboise (2011).

- In one chapter, 8 of the authors were WWF campaign advisors.

This remarkable overlap between the IPCC and a powerful environmental activist organization cannot credibly be viewed as mere coincidence, and instead reveals a political bias in the author selection process, confirming the complaints heard by the IAC on this matter.

3.4 IPCC Report-Writing Process

The IPCC writing procedures involve preparing a series of versions of the report. A first version (the so-called Zero Order Draft) is prepared by the LAs and CLAs, drawing upon contributions from CAs. This is worked up into the First Order Draft which is then sent out for Expert Review.

Selection of Expert Reviewers is generally open, and people can nominate themselves. Review comments are sent to the IPCC Secretariat, which provides them to chapter authors. Review Editors are supposed to ensure that all comments are taken into account. After this the Second Order Draft is released for another round of expert review and a round of government review. After these comments are received the report is returned to the Lead Authors for another complete rewrite prior to submission to the IPCC Bureau. This final draft is not itself subject to expert review.

The IPCC rules state[15] that Review Editors should supply annexes that explain significant unresolved differences of opinion. But no such annexes have ever been produced. This is an essential requirement for the independent Data Quality review that EPA should have conducted.

One of the most contentious disputes in the AR4 between LAs and reviewers concerned the paleoclimate chapter, in particular the hockey stick. There were deep, unresolved disagreements between reviewers and LAs on how this matter should be presented.[16] Yet no annex was produced, and the Review Editors signed off on the Chapter nonetheless. In 2008, a UK citizen named David Holland sought information about how one of the Chapter 6 Review Editors (John

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[15] See http://ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a.pdf section 5.

[16] Documented in Holland, David (2007) "Bias and Concealement in the IPCC Process: The "Hockey Stick" Affair and Its Implications." *Energy and Environment* Volume 18, Numbers 7-8, December 2007 , pp. 951-983(33).

Mitchell of the UK Met Office) had handled the controversies over the Mann et al. hockey stick. As part of his inquiries, Holland submitted a Freedom of Information Act request to the Met Office. The documents released in reply contained an email from IPCC Chair Susan Solomon to Mitchell[17] advising Mitchell on the limitations of his responsibilities as Review Editor. The email was dated March 14, 2008, and stated, in part:

> The review editors do not determine the content of the chapters. The authors are responsible for the content of their chapters and responding to comments, not REs. Further explanations, elaboration, or re-interpretations of the comments or the author responses, would not be appropriate.

Taking these points together, it is clear that RE's do not have the authority to stop Lead Authors who are determined to make arbitrary decisions about chapter content. For this reason the IPCC review process is fundamentally unlike the academic peer review process, in which the editor has the final right to accept or reject a paper and its contents based on review comments. Because the IPCC gives Lead Authors the final right to determine the content of their own chapters the EPA Administrator was wrong to declare the IPCC review process to be "rigorous and exacting," and the criteria cited by the EPA OIG are not met, implying that "this may preclude the use of that peer review and, in those instances, another peer review would be needed."

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[17] Contained in emails from IPCC Review Editor Brian Hoskins that were released to Mr. David Holland in response to a UK Freedom of Information Act request, ICO decision notice FER0239225.

4. CLIMATE MODELS: INACCURACIES, INADEQUACIES, AND FAILURES

4.1 Climate models are unable to represent accurately the atmospheric response to GHG's

In the 2009 endangerment finding, EPA concluded that one of three lines of evidence supporting the endangerment finding comes from climate models. But new science has emerged showing that the models are in serious error where it matters most, in the tropical troposphere.

A key region for modeling the climatic response to greenhouse gases is the vast section of atmosphere in the tropics up to an altitude of 16 km, spanning 20 degrees North to 20 degrees South of the equator. Ever since the first climate models were produced, and in all the modeling work done since, including for the IPCC in its 2007 Report, the theory of amplified greenhouse gas-induced warming implies that warming trends should reach a maximum there, specifically in the mid- and upper-troposphere over the tropics. As emphasized in Fu et al. (2011, p. 1):[18]

> This feature [enhanced warming in the tropical upper troposphere] has important implications to the climate sensitivity because of its impact on water vapor, lapse rate, and cloud feedbacks… It is therefore critically important to observationally test the GCM-simulated maximum warming in the tropical upper troposphere.

A recent survey article by Thorne et al. (2011)[19] summarizes the point as follows:

> Since the earliest attempts to mathematically model the climate system's response to human-induced increases in greenhouse gases, a consistent picture of resulting atmospheric trends has emerged. The surface and troposphere (the lowest 8—12 km) warm with a local maximum trend in the upper levels in the tropics, while the stratosphere above cools.

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[18] Fu, Qiang, Syukuro Manabe and Celeste M. Johanson (2011) "On the warming in the tropical upper troposphere: Models versus observations" *Geophysical Research Letters* VOL. 38, L15704, doi:10.1029/2011GL048101, 2011.

[19] Thorne, P. W., J. R. Lanzante, T. C. Peterson, D. J. Seidel, and K. P. Shine (2011), Tropospheric temperature trends: History of an ongoing controversy, Wiley Interdisciplinary Rev. Clim. Change, 2, 66–88, doi:10.1002/wcc.80.

The IPCC also emphasizes that,[20] according to climate model predictions, warming due to greenhouse gases reaches a maximum in the upper troposphere over the tropics, and that all model runs suggest this pattern ought to be observable in current data.

Fu et al. 2011 point out that, since the 1970s, the trend has been for models to predict a larger and larger differential between the warming rate in the tropical lower troposphere compared to the tropical mid- or upper-troposphere. Hence as the theory of greenhouse induced-warming has developed over recent decades, the expectation of enhanced warming in the tropical troposphere has emerged as a central prediction.

But there is considerable empirical evidence that no such warming "hotspot" has been observed since the advent of satellite monitoring in 1979. Many commenters on the EPA endangerment finding pointed to the empirical evidence that the combined records from weather balloons and satellites does not support the model predictions of amplified warming in the tropical troposphere.[21] A significant discrepancy between models and observations on this point would imply a major failure on the part of climate models, directly undermining the soundness of, among other things, the EPA's position. Indeed the 2006 CCSP Report on surface and satellite records, mentioned above, pointed to this problem, as follows:

> A potentially serious inconsistency, however, has been identified in the tropics. Figure 4G shows that the lower troposphere warms more rapidly than the surface in almost all model simulations, while, in the majority of observed data sets, the surface has warmed more rapidly than the lower troposphere. In fact, the nature of this discrepancy is not fully captured in Fig. 4G as the models that show best agreement with the observations are those that have the lowest (and probably unrealistic) amounts of warming.

(Wigley et al. 2006, p. 11)

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[20] IPCC WGI pp. 763-764; also Figure 9.1.

[21] http://www.epa.gov/climatechange/endangerment/comments/volume3.html

In 2007, papers by two teams of authors (Christy, Norris, Spencer and Hnilo, and Douglass, Christy, Pearson and Singer) showed that observed data sets contained much less warming than even the lowest model-based predictions. The Douglass et al. paper[22] specifically asserted that the model-data discrepancy is statistically significant. The EPA Response to comments on the Endangerment Finding (3-7) reveals some hesitation on their part concerning this matter:

> EPA is aware of the emerging literature on this issue and the challenges in identifying the anthropogenic fingerprint in the tropics. The TSD's characterization of this issue is consistent with the assessment literature as well as the most recent studies, which find that when uncertainties in models and observations are properly accounted for, newer observational data sets are in agreement with climate model results.

The EPA responded to the evidence in the Douglass et al. paper by citing three sources. First, they refer to a paper by Haimberger et al. (2008)[23] which uses a weather balloon series called RAOBCORE version 1.4, which apparently agrees with some model projections. However, Haimberger has since revised the RAOBCORE version 1.4 data to remove a spurious warming influence from an input data source.[24] The trend in the lower tropical troposphere in RAOBCORE 1.4 set is now 0.117 degrees C per decade whereas the average predicted trend in climate models for the same region is 0.272 degrees C per decade, more than twice as high. Clearly this data set cannot be the basis for setting aside the commenters' concerns about models overstating warming.

The second paper cited by the EPA is Allen and Sherwood (2008),[25] who use windspeed data collected by weather balloons to infer temperature trends. They find higher trends than studies

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[22] Douglass, D. H., J. R. Christy, B. D. Pearson, and S. F. Singer (2008), A comparison of tropical temperature trends with model predictions, Int. J. Climatol., 28, 1693–1701, doi:10.1002/joc.1651.
[23] Haimberger, L., C. Tavolato, and S. Sperka (2008), Towards elimination of the warm bias in historic radiosonde records—Some new results from a comprehensive intercomparison of upper air data, J. Clim., 21, 4587–4606, doi:10.1175/2008JCLI1929.1.
[24] The problem apparently was in the ERA-40 reanalysis data.
[25] Allen, R. J., and S. C. Sherwood (2008), Warming maximum in the tropical upper troposphere deduced from thermal winds, Nat. Geosci., 1,399–403, doi:10.1038/ngeo208.

using thermometers to measure temperature trends. The EPA does not provide a discussion of the problems associated with using wind data to infer temperatures. A 2010 paper by John Christy and 8 coauthors[26] in the journal Remote Sensing points out that until the advent of modern GPS systems, weather balloons tended to drift out of radio range at high altitudes on the windiest days, leading to an artificial depression of the highest windspeeds in the earlier years of the record, introducing a known source of bias in the trend over time. Also, windspeed data is very limited in the tropics compared to temperature data, and as Christy et al. point out, the temperature trend calculations by Thorne et al. imply windspeeds in the interpolated regions would have to be much higher than those observed in regions that do have data. Consequently, it was inappropriate for the EPA to place greater reliance on this study than on the many studies using direct temperature observations, especially since its method is new and rather speculative.

The third study cited by the EPA, and arguably the one that is key to their position, is a 2008 paper by Ben Santer et al.,[27] asserting that uncertainties in climate models and observations are sufficiently large with regards to trends in the tropical troposphere as to rule out a finding of inconsistency. They reach this conclusion by arguing that Douglass et al. used an incorrect statistical methodology to compare modeled and observed trends, and in the Santer et al. analysis they propose a slight improvement in methods, which they apply to data ending in 1999. They report the uncertainties in the model trends to be sufficiently large as to partially overlap with the uncertainties in the observed trends, leading Santer et al. to conclude that the models-data differences are not statistically significant.

A subsequent paper, McKitrick, McIntyre and Herman (2010),[28] showed that the Santer et al. conclusions fail on two grounds. First, neither Douglass et al. nor Santer et al. used appropriate statistical modeling techniques for comparing trends in data sets of the kind under dispute.

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[26] Christy, John, et al. (2010) “What Do Observational Datasets Say about Modeled Tropospheric Temperature Trends since 1979?” Remote Sensing 2010, 2, 2148-2169; doi:10.3390/rs2092148.

[27] Santer, B. D., et al. (2008), Consistency of modelled and observed temperature trends in the tropical troposphere, Int. J. Climatol., 28, 1703–1722, doi:10.1002/joc.1756.

[28] McKitrick, Ross R., Stephen McIntyre and Chad Herman (2010)Panel and Multivariate Methods for Tests of Trend Equivalence in Climate Data Sets. *Atmospheric Science Letters* DOI: 10.1002/asl.290.

McKitrick et al. applied two different state of the art statistical methods for trend comparisons, both of which are well-established in the econometrics literature. Second, they extended the data up to the end of 2009 (the maximum extent available at the time of the analysis). Ending the data at 1999, as Santer et al. did, biases the results because there was a large El Nino event in 1998, temporarily boosting the observed trend so much that it appears to match models.

McKitrick et al. found that on the full sample up to 2009, the satellite and weather balloon data sets were not significantly different from each other, but were significantly different from models. In particular, the models predicted two to four times more warming, on average, than is observed in the data, and the differences are statistically very significant.

In light of these updated findings, the EPA's reliance on Santer et al. (2008) is unsound, as is their claim that when uncertainties in models and observations are properly accounted for, newer observational data sets are in agreement with climate model results.

Furthermore, when McKitrick et al. did their analysis on a sample ending in 1999, to match that of Santer et al., they found the model-observation difference marginally significant, an indication of the bias in the Santer et al. method. But in that case they also noted that there is no significant warming trend in the balloon and satellite series when the data are truncated at 1999, something not mentioned by the EPA in its reliance on the Santer et al. results. When the data are extended up to 2009, some of the observational series indicate a significant warming trend, but it is very small compared to model predictions, and the model-observation discrepancy is statistically significant. Thus McKitrick et al. confirm the 2006 observation of the CCSP Report of a "potentially serious inconsistency" between models and data.

The continuing importance of this issue is attested by the Thorne et al. (2010) review, which points out that if observations fail to support the tropospheric warming projected by models this would have "fundamental and far-reaching implications for understanding of the climate system." The Thorne et al. review article asserts that the models and observations are in general agreement, but like the TSD it relies for this conclusions entirely on the Santer et al. study and makes no mention of the McKitrick et al. findings. EPA must reverse its conclusion regarding the "skill" of the models.

4.2 Other indications of climate model failure

Fu et al. (2011) found that not only do the IPCC climate models exaggerate warming at the surface and each layer above, but they also exaggerate the rate of amplification of warming with height. Fyfe et al. (2011)[29] sought to replicate the 1961-2006 observed global average surface temperature using a prominent climate model, allowing their model to re-initialize with observed outcomes every five years. They reported having to apply repeated corrections to the model trend since it regularly drifts away from reality: "

> Since observation-based and model-based climates tend to differ, hindcasts which are initialized to be near the observations tend to drift towards the model climate. For short term hindcasts this is accounted for by removing the mean bias. However, for longer term decadal hindcasts a linear trend correction may be required if the model does not reproduce long-term trends. For this reason, we correct for systematic long-term trend biases following a procedure detailed in the auxiliary material.

Kaufmann and Stern (2004)[30] analysed climate model predictions of the global surface average temperature and asked whether the model had any more information in it than a small number of GCM input series, namely observations on greenhouse gas concentrations, solar irradiance, volcanic dust and atmospheric aerosols, rescaled to represent forcing units on temperature change processes. They could not reject the hypothesis that the GCM added no information to the forecast other than that inherited from the observed forcing series. In other words, the detailed structure of the climate model was itself uninformative; the only information was contained in the input data.

The study by Paltridge et al. (2009) is very important on this topic as well. A key mechanism in climate models for amplifying warming is a projected increase in the concentration of water

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[29] Fyfe, J.C., G.J. Boer, G. J., V. Kharin, W. S. Lee, W. J. Merryfield, and K. von Salzen (2011) "Skillful predictions of decadal trends in global mean surface temperature" *Geophysical Research Letters* VOL. 38, L22801, doi:10.1029/2011GL049508, 2011

[30] Kaufmann, Robert K. and David I. Stern (2004) "A Statistical Evaluation of Atmosphere - Ocean General Circulation Models: Complexity vs. Simplicity." Rensselaer Polytechnic Institute Department of Economics Working Paper 0411, May 2004.

vapor in the tropical troposphere, but the data shows water vapor levels trending downwards over the past 35 years. Changes in temperature and precipitation cannot be accurately forecast at the regional level AR4 claims that changes in temperature and precipitation can be accurately forecast at the regional level, but there is no defense of this point in the AR4. Testing of the spatial pattern of regional trends is not done, or is only done using informal visual comparisons. Recent literature shows models fail to explain spatial trend patterns in both temperature and precipitation.

4.3 IPCC and CCSP silence on "regional skill" of models

The discussion of the evaluation of climate models in AR4 Chapter 8 is dominated by a priori process checks, that is, whether certain known meteorological processes are coded into the models. Model evaluation at regional levels focuses on static reproduction tests, that is, the ability to reproduce the distribution of mean temperature and precipitation levels, and diurnal temperature ranges, but not temperature trends, around the world. In essence, models are tested on whether they get cold poles and hot tropics. But success on this measure, to the extent it is achieved, is not an indication of accurate ability to forecast the spatial pattern of trends over time, that is, to put warming where warming has been observed and cooling where cooling has been observed. The IPCC report notes (p. 594) that relatively few studies have looked at whether empirical fidelity between model simulations of historical periods and observations improves the accuracy of climate trend forecasts. Gleckler et al. (2008)[31] note that the ability of a climate model to replicate a mean climate state has little correlation to measured fidelity on interannual trend measures.

Knutti (2008)[32] argues that testing model accuracy over both space and time is necessary for evaluating their credibility. A little over a decade ago, Berk et al. (2001)[33] warned that quantitative comparison of model outputs to observed data was rare and "relies very heavily on

[31] Gleckler, P. J., K. E. Taylor, and C. Doutriaux (2008), "Performance metrics for climate models," *J. Geophys. Res.*, *113*, D06104, doi:10.1029/2007JD008972.
[32] Knutti, R. (2008) "Why are climate models reproducing the observed global surface warming so well?" *Geophysical Research Letters* 35, L18704, doi:10.1029/2008GL034932, 2008.
[33] Berk, Richard A., Robert G. Fovell, Frederic Schoenberg and Robert E. Weiss (2001) "The use of statistical tools for evaluating computer simulations." *Climatic Change* 51: 119-130.

eyeball assessments" (Berk et al p. 126). Since then, neither the 2007 IPCC report nor the Climate Change Science Program 2008 review of climate models[34] provided quantitative tests of how well climate models reproduce the spatial pattern of temperature trends in recent decades, relying instead on "eyeball assessments." This validation of the models is a key element of the DQA requirements that EPA was obligated to independently confirm.

AR4 Chapter 9 presents a diagram and accompanying discussion (Figure 9.6, pp. 684-686) of the averaged output from 58 GCM runs and the spatial pattern of temperature trends over land from 1979-2005, comparing model runs under the assumption that greenhouse gases do not warm the climate versus runs that assume they do. It is asserted that the latter assumption fits the data better, but no quantitative evidence is provided. CCSP (2008) presents a visual comparison of the fit between observed trend patterns over 1979-2003 and those generated by a single model, the GISS ModelE. Again the discussion is entirely qualitative—readers are given no statistical scores testing whether the model attains statistically significant validity.

CCSP (2008) reports a 95-98% correlation between modeled and observed temperatures over space and time. However this is not a test of regional trend accuracy. The underlying study is Covey et al. (2003).[35] The tests were not of historical reproduction of observations, but instead a historical, no-forcing control runs. Covey et al. were merely testing the ability to reproduce the annual temperature range in each region. They compared the 12 monthly means from GCM control runs on a gridcell-by-gridcell basis to late 20th century monthly means in CRU data. The models did a good job reproducing the spatial pattern of the mean across grid cells, the amplitude of the seasonal cycle within each grid cell and the different seasonal amplitudes across grid cells. However the ability to predict trends in the gridded monthly or annual means over time in response to observed forcing changes was not tested.

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[34] CCSP (2008): *Climate Models: An Assessment of Strengths and Limitations*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Bader D.C., C. Covey, W.J. Gutowski Jr., I.M. Held, K.E. Kunkel, R.L. Miller, R.T. Tokmakian and M.H. Zhang (Authors)]. Department of Energy, Office of Biological and Environmental Research, Washington, D.C., USA, 124 pp

[35] Covey, C., K.M. AchutaRao, U. Cubasch, P. Jones, S.J. Lambert, M.E. Mann, T. J. Phillips, K.E. Taylor (2003) "An overview of results from the Coupled Model Intercomparison Project." *Global and Planetary Change* 37 103—133.

4.4 Other reported test results indicate serious problems with the IPCC models

Knutson et al. (2006)[36] present a comparison of the spatial trend pattern between an ensemble average of simulations from a single model for 1949—2000 and corresponding observations. In their Figure 5d (p. 1635) the differences are denoted as significant or not based on a t-test. They report that in 31% of the locations, the t-statistic rejects the hypothesis that the modeled and observed trends are the same. However, the apparent failure to reject differences elsewhere does not imply that the models are accurate. Consider for example, a test for different trends among two lists of random numbers. A t-test would typically fail to reject such a difference, but that does not imply that one explains the other. Jun et al. (2008, Figure 7) contrast observed and model trends but the significance of the mismatches is not reported.

McKitrick and Nierenberg (2010), cited above, found that a vector of socioeconomic variables had significant explanatory power for the spatial pattern of temperature trends over land. But the GISS-E climate model, as well as an average formed over all climate models used for the AR4, failed to reproduce the correlation pattern and typically generated the opposite pattern to that observed in the data. They also found that models exhibit a regional pattern of spatial autocorrelation in temperature trends that is not found in a regression model using observational data. While the focus of that study was on detecting non-climatic contamination of surface temperature data, the implication is equally relevant to the present discussion, namely that climate models have been shown to fail to predict the spatial pattern of warming and cooling trends over land, whereas a simple model using data on the spatial pattern of socioeconomic activity has been shown to successfully predict such a pattern.

McKitrick and Tole[37] (2012) evaluated three categories of variables for explaining the spatial pattern of warming and cooling trends over land: predictions from 22 general circulation models (GCMs) used by the IPCC for the AR4; geographical factors like latitude and pressure; and

[36] Knutson, T. R.; Delworth, T. L.; Dixon, K. W.; Held, I. M.; Lu, J.; Ramaswamy, V.; Schwarzkopf, M. D.; Stenchikov, G.; Stouffer, R. J (2006) "Assessment of Twentieth-Century Regional Surface Temperature Trends Using the GFDL CM2 Coupled Models." *Journal of Climate* **19**, 1624–1651.

[37] McKitrick, Ross R. and Lise Tole (2010) "Evaluating Explanatory Models of the Spatial Pattern of Surface Climate Trends using Model Selection and Bayesian Averaging Methods" *Climate Dynamics,* accepted.

socioeconomic influences on the land surface and data quality. The IPCC assumes that the GCMs have all the relevant explanatory power, though the geographical variables may account for some. As explained in Section 2, the IPCC strongly insists that socioeconomic measures have no explanatory power, a position also maintained by the EPA. Statistical tests showed that each of the three classes of variables have at least some explanatory power, though 20 of 22 GCMs individually contribute either no significant explanatory power or yield a trend pattern negatively correlated with observations. Further testing showed that socioeconomic variables have considerable unique explanatory power. While in 20 of 22 cases the data do not reject the hypothesis that any apparent explanatory power of the climate model is spurious and can be dropped, in all 22 cases the probability that the socioeconomic variable can be dropped is less than 1 in 200,000. McKitrick and Tole used advanced computational methods to examine all possible linear combinations of explanatory variables, yielding coefficient estimates and uncertainty distributions robust to cherry-picking effects. The results show that even if climate models are allowed to be used individually or in any linear combinations with each other, only three of the 22 GCMs would ever exhibit any explanatory power, and the use of socioeconomic measures of temperature data contamination is essential for yielding a valid model of the spatial pattern of trends in land surface temperature records. The three models that were not rejected outright are from the Russian Institute for Numerical Mathematics (INM 3.0), the Beijing Institute for Atmospheric Physics (IAP FGOALS 1.0g) and the National Center for Atmospheric Research (CCSM 3.0). Climate models from Norway, Canada, Australia, Germany, France, Japan and the UK, as well as American models from GFDL, NOAA and GISS, fail to exhibit any explanatory power for the spatial pattern of surface temperature trends in any test, alone or in any combination. The findings thus show both that the evidence of temperature data contamination is robust and that most climate models fail to provide meaningful data for the purpose of establishing EPA findings.

Some other relevant studies in recent years are shown below.

- Koutsoyiannis, D., A. Efstratadis, N. Namassis and A. Christofides (2008) "On the credibility of climate predictions" *Hydrological Sciences*, 53(4) August 2008.

Abstract Geographically distributed predictions of future climate, obtained through climate models, are widely used in hydrology and many other disciplines, typically without assessing their reliability. Here we compare the output of various models to temperature and precipitation observations from eight stations with long (over 100 years) records from around the globe. The results show that models perform poorly, even at a climatic (30-year) scale. Thus local model projections cannot be credible, whereas a common argument that models can perform better at larger spatial scales is unsupported.

- nagnostopoulos, G. G., D. Koutsoyiannis, A. Christofides, A. Efstratiadis & N. Mamassis (2010). "A comparison of local and aggregated climate model outputs with observed data." *Hydrological Sciences Journal*, 55(7) 2010.

Abstract We compare the output of various climate models to temperature and precipitation observations at 55 points around the globe. We also spatially aggregate model output and observations over the contiguous USA using data from 70 stations, and we perform comparison at several temporal scales, including a climatic (30-year) scale. Besides confirming the findings of a previous assessment study that model projections at point scale are poor, results show that the spatially integrated projections are also poor.

- Stephens, G. L., T. L' Ecuyer, R. Forbes, A. Gettlemen, J.-C. Golaz, A. Bodas-Salcedo, K. Suzuki, P. Gabriel, and J. Haynes (2010), "Dreary state of precipitation in global models," J. Geophys. Res., 115, D24211, doi:10.1029/2010JD014532.

Abstract New, definitive measures of precipitation frequency provided by CloudSat are used to assess the realism of global model precipitation. The character of liquid precipitation (defined as a combination of accumulation, frequency, and intensity) over the global oceans is significantly different from the character of liquid precipitation produced by global weather and climate models. Five different models are used in this comparison representing state-of-the-art weather prediction models, state-of-the-art climate models, and the emerging

> high-resolution global cloud "resolving" models. The differences between observed and modeled precipitation are larger than can be explained by observational retrieval errors or by the inherent sampling differences between observations and models. We show that the time integrated accumulations of precipitation produced by models closely match observations when globally composited. However, these models produce precipitation approximately twice as often as that observed and make rainfall far too lightly. This finding reinforces similar findings from other studies based on surface accumulated rainfall measurements. The implications of this dreary state of model depiction of the real world are discussed.

Fildes and Kourentzes (2011)[38] used standard forecasting evaluation tests to compare the validity of GCM regional temperature forecasts over 1—10 year-ahead horizons. The testing approach compares a forecasting system against an uninformative "random walk" alternative consisting simply of using the last period's value as the forecast for the next period's value. The resulting score ranges from 0 for a perfect forecast up to 1.0 for a forecast method that is no better than the random alternative. A forecasting method receiving a score above 1.0 is deemed worse than uninformed guesses. Simple statistical models typically yielded scores between 0.805 and 0.973, indicating slight improvements on the random walk, though in some cases their scores went above 1.0, in one case as high as 1.762. The GCMs did extremely poorly, however, with scores ranging from 2.386 to 3.732, indicating a complete failure to provide valid forecast information at the regional level. The authors comment (p. 990):

> This implies that the current GCM models are ill-suited to localised decadal predictions, even though they are used as inputs for policy making.

In sum the IPCC and CCSP(USGCRP) do not present evidence to support the view that regional temperature and precipitation forecasts are accurate, and furthermore what testing has been done in recent years has shown poor results. This failure is a fatal flaw in EPA's "line of evidence" justification for the proposed rule.

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[38] Fildes, Robert and Nikolaos Kourentzes (2011) "Validation and Forecasting Accuracy in Models of Climate Change *International Journal of Forecasting* 27 968-995.

4.5 Model Cannot Predict increased extreme weather events in the U.S. from Climate Change

Since climate models are not able to predict temperature and precipitation at regional levels, the ability of the models to predict extreme weather in the U.S. is purely speculative. The InterAcademy Council (IAC) found the work of IPCC WG2, which looks at the impacts of climate change, to be full of unsubstantiated conclusions. The IAC was deeply critical of the way the IPCC, particularly Working Group II, handled and reported on uncertainty, especially in regards to statements about the impacts of climate change. Since Working Group II handles the topic of impacts, this is directly pertinent to the endangerment question. The IAC said:

> The Working Group II Summary for Policy Makers in the Fourth Assessment Report contains many vague statements of “high confidence” that are not supported sufficiently in the literature, not put into perspective, or are difficult to refute.

(p. 37)

The IAC found that the guidance for explaining uncertainty is not itself adequate, and is often not followed anyway (p. 4).

> Many of the 71 conclusions in the “Current Knowledge about Future Impacts” section of the Working Group II Summary for Policy Makers are imprecise statements made without reference to the time period under consideration or to a climate scenario under which the conclusions would be true….In the Committee’s view, assigning probabilities to imprecise statements is not an appropriate way to characterize uncertainty. If the confidence scale is used in this way, conclusions will likely be stated so vaguely as to make them impossible to refute, and therefore statements of “very high confidence” will have little substantive value.

(pp. 33-34).

More generally, the IAC noted that in some cases

> [IPCC] authors reported high confidence in statements for which there is little evidence, such as the widely-quoted statement that agricultural yields in Africa might decline by up to 50 percent by 2020. Moreover, the guidance was often applied to statements that are so vague they cannot be falsified. In these cases the impression was often left, quite incorrectly, that a substantive finding was being presented.

(p. 36)

The IAC concluded that “many of the conclusions in the “Current Knowledge about Future Impacts” section of the Working Group II Summary for Policy Makers are based on unpublished or non-peer-reviewed literature” (p. 33). They also found that many conclusions stated with “High Confidence” by Working Group II had little or no scientific basis:

> [By] making vague statements that were difficult to refute, authors were able to attach “high confidence” to the statements. The Working Group II Summary for Policy Makers contains many such statements that are not supported sufficiently in the literature. (p. 4).

The IAC concludes that had Working Group II used a level-of-understanding scale, rather than their “confidence” scale, it would have made clear the “weak evidentiary basis” for many of their conclusions (p. 33).

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Allen, R. J., and S. C. Sherwood (2008), Warming maximum in the tropical upper troposphere deduced from thermal winds, Nat. Geosci., 1,399–403, doi:10.1038/ngeo208

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CCSP (2008): Climate Models: An Assessment of Strengths and Limitations. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Bader D.C., C. Covey, W.J. Gutowski Jr., I.M. Held, K.E. Kunkel, R.L. Miller, R.T. Tokmakian and M.H. Zhang (Authors)]. Department of Energy, Office of Biological and Environmental Research, Washington, D.C., USA, 124 pp

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5. RECENT TEMPERATURE TRENDS - ARCTIC

The endangerment finding TSD points to Arctic warming as evidence of anthropogenic climate change. But new studies show more significant Arctic warming in the past.

Wood et al. (2010) constructed a two-century (1802–2009) instrumental record of annual surface air temperature within the Atlantic-Arctic boundary region, using data obtained from recently published (Klingbjer and Moberg, 2003; Vinther et al., 2006) and historical sources (Wahlen, 1886) that yielded ―four station-based composite time series that pertain to Southwestern Greenland, Iceland, Tornedalen (Sweden) and Arkhangel‘sk (Russia). This operation added 76 years to the previously available record, the credibility of which result, in Wood et al.‘s words, is supported by ice core records, other temperature proxies, and historical evidence.

In examining the record, the U.S. and Icelandic researchers found “an irregular pattern of decadal-scale temperature fluctuations over the past two centuries, of which the early twentieth-century warming (ETCW) event which they say began about 1920 and persisted until mid-centurywas by far the most striking historical example.” Wood et al. write, “as for the future, with no other examples in the record quite like the ETCW, we cannot easily suggest how often—much less when—such a comparably large regional climate fluctuation might be expected to appear.”

Nevertheless, they say that if past is prologue to the future, it would be reasonable to expect substantial regional climate fluctuations of either sign to appear from time to time, and therefore singular episodes of regional climate fluctuation should be anticipated in the future. This implies any rapid warming that may subsequently occur within the Atlantic-Arctic boundary region need not be due to rising greenhouse gas concentrations, as it could be caused by the same unknown factor that caused the remarkable ETCW event.

Wood and Overland (2010) write, the recent widespread warming of the earth‘s climate is the second of two marked climatic fluctuations to attract the attention of scientists and the public since the turn of the 20th century, and that the first of these the major early 20th century climatic fluctuation (~1920–1940) has been the subject of scientific enquiry from the time it was detected in the 1920s. In addition, they write, the early climatic fluctuation is the features of the present warming that has been felt so strongly in the Arctic.

To learn more about the nature of both warmings, Wood and Overland reviewed what is known about the first warming through what they describe as a rediscovery of early research and new assessments of the instrumental record, which allowed them to compare what they learned about the earlier warming with what is known about the most recent one. With respect to the first of the two warmings, the U.S. researchers say there is evidence that the magnitude of the impacts on glaciers and tundra landscapes around the North Atlantic was larger during this period than at any other time in the historical period.

In addition, they report, the ultimate cause of the early climatic fluctuation was not discovered by early authors and remains an open question, noting all of the leading possibilities recognized today were raised by the 1950s, including internal atmospheric variability, anthropogenic greenhouse gas (CO2) forcing, solar variability, volcanism, and regional dynamic feedbacks (e.g. Manley, 1961). However, they note, greenhouse gas forcing is not now considered to have played a major role (Hegerl et al., 2007). Thus they suggest the early climatic fluctuation was a singular event resulting from intrinsic variability in the large-scale atmosphere-ocean-land system and that it was likely initiated by atmospheric forcing.

Wood and Overland conclude the early climatic fluctuation is best interpreted as a large but random climate excursion imposed on top of the steadily rising global mean temperature associated with anthropogenic forcing. However, it could just as easily be concluded that the steadily rising global mean temperature was Earth's natural recovery from the global chill of the Little Ice Age.

White et al. (2010) published a comprehensive review of past climate change in Earth's north polar region. They began their work by describing how processes linked with continental drift have affected atmospheric circulation, ocean currents, and the composition of the atmosphere over tens of millions of years and how a global cooling trend over the last 60 million years has altered conditions near sea level in the Arctic from ice-free year-round to completely ice covered. They also report variations in Arctic insolation over tens of thousands of years in response to orbital forcing have caused regular cycles in turn, this glacial-interglacial cycling was punctuated by abrupt millennial oscillations, which near the North Atlantic were roughly half as large as the glacial-interglacial cycles.

Finally, they note the current interglacial, the Holocene, has been influenced by brief cooling events from single volcanic eruptions, slower but longer lasting changes from random fluctuations in the frequency of volcanic eruptions, from weak solar variability, and perhaps by other classes of events. In comparing the vast array of past climate changes in the Arctic with what the IPCC claims to be the unprecedented anthropogenic-induced warming of the past several decades, White et al. conclude, thus far, human influence does not stand out relative to other, natural causes of climate change.

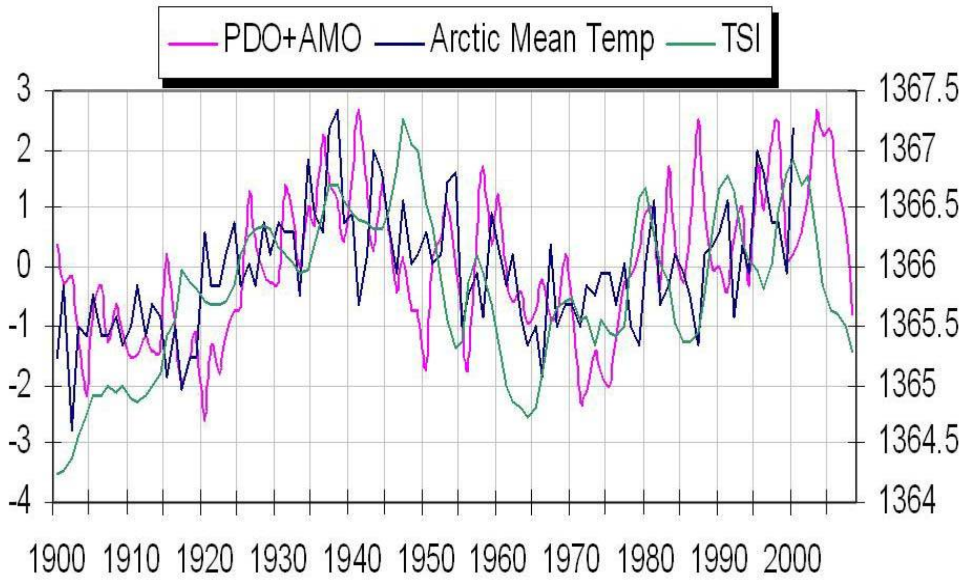


Figure. *Annual Standardized Pacific Decadal Oscillation, Atlantic Multidecadal Oscillation (NOAA ESRL (http://www.esrl.noaa.gov/psd/data/climateindices/list/) Arctic Mean Annual Temperatures (Polyakov, IARC UAF), TSI (Hoyt-Schatten-Wilson).*

In fact, they state, the data clearly show that strong natural variability has been characteristic of the Arctic at all time scales considered, and they reiterate the data suggest that the human influence on rate and size of climate change thus far does not stand out strongly from other causes of climate change. Ladd and Gajewski (2010) evaluate the position of the Arctic front defined as the semi-permanent, discontinuous front between the cold Arctic air mass and the intermediate Polar air mass, bounded in the south by the Polar Front (Oliver and Fairbridge, 1987) based on gridded data obtained from the National Center for Environmental Prediction/National Center for Atmospheric Research reanalysis (NNR) for each July between 1948 and 2007, and from 1958 to 2002 using data from the European Centre for Medium-Range Weather Forecasts ERA-40, as well as the period 1948-1957 for comparison with the results of Bryson (1966). The two researchers report the position of the July Arctic front varies significantly through the period 1948–2007, but they find it does so with a mean position similar to that found by Bryson (1966), which close similarity, as they describe it, is striking, given that the Bryson study was completed over 40 years ago.

This front is in the part of the world that theory and computer models predict should be warming faster than nearly all other parts of the globe. If the IPCC's claim were true that the Earth warmed at a rate and to a level that was unprecedented over the past two millennia, it is highly unlikely the Arctic front would have remained stationary for more than four decades.

Box et al. (2009), using a set of 12 coastal and 40 inland ice surface air temperature records in combination with climate model output, identified long-term (1840–2007) monthly, seasonal, and annual spatial patterns of temperature variability over a continuous grid covering Greenland and the inland ice sheet. They then compared the 1919–32 and 1994–2007 warming episodes‖ and made a comparison of Greenland ice sheet surface air temperature temporal variability with that of the Northern Hemisphere average, obtaining the near-surface air temperature history of Greenland reproduced Figure 2, along with the corresponding history of Northern Hemispheric near-surface air temperature. Based on the results depicted in the figure, the four researchers determined the annual whole ice sheet 1919–32 warming trend is 33% greater in magnitude than the 1994–2007 warming, and in contrast to the 1920s warming, the 1994–2007 warming has not surpassed the Northern Hemisphere anomaly. They note, an additional 1.0°–.5°C of annual mean warming would be needed for Greenland to be in phase with the Northern Hemisphere pattern. Thus there does not appear to be anything unusual, unnatural, or unprecedented about the nature of Greenland's 1994–2007 warming episode. It is much less impressive than the 1919–1932 warming, and it is even less impressive when it is realized that the atmosphere's CO_2 concentration rose by only about 5 ppm during the earlier period of stronger warming but by fully 25 ppm (five times more) during the later period of weaker warming.

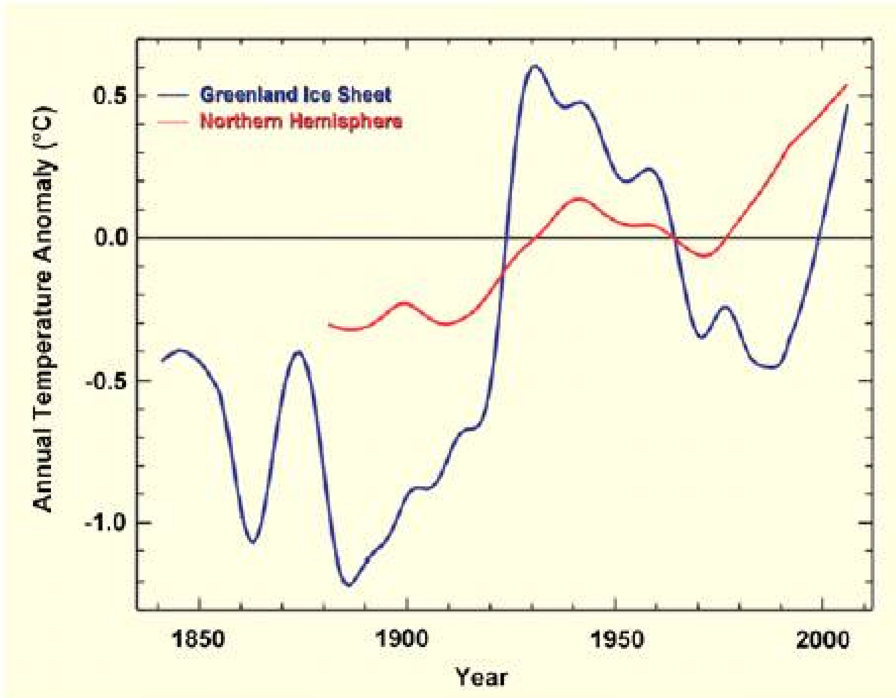


Figure. *Low-pass-filtered Greenland and Northern Hemispheric near-surface air temperature anomalies with respect to the 1951-1980 base period vs. time. The Greenland temperatures were constructed from a set of 12 coastal and 40 inland ice surface air temperature records in combination with climate model output. Adapted from Box et al. (2009).*

Anders Bjørk (2012) at the University of Copenhagen and his colleagues used long-forgotten aerial photographs of Greenland from the 1930s, rediscovered in a castle outside Copenhagen to construct a history of glacier retreat and advance in the area. The work aims to provide a deeper understanding of how climate change has affected ice loss and glacier movements over the past 80 years. Most studies of Greenland's glaciers have been done only since imaging satellites became available in the 1970s, so the data are relatively short-term. But using photographs from 1930s aerial surveys of the southeast coast of Greenland, together with US military aerial shots from the Second World War and recent satellite images, Bjørk and his colleagues have been able to observe changes at high spatial resolution from a period in which few glacier measurements were previously available.

Analysis of the images reveals that over the past decade, glacier retreat was as vigorous as in a similar period of warming in the 1930s.

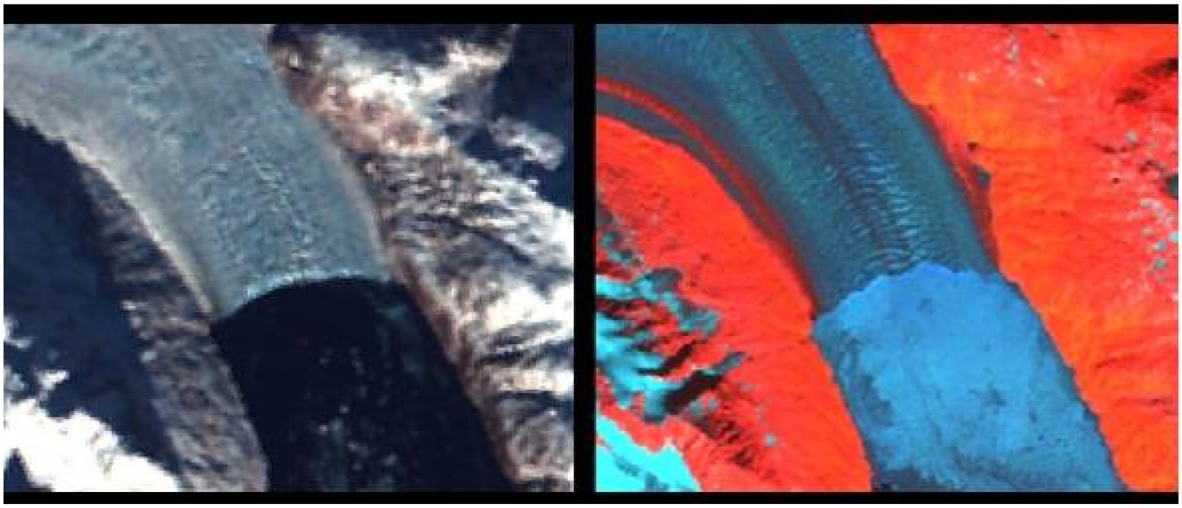


Figure. *The US Landsat Earth-observation programme has been providing researchers with a steady stream of satellite observations since 1972. To fill in the gap since the last aerial photographs, Bjørk and his colleagues gained access to recently declassified images from US intelligence satellites from 1965. Pictured are false-colour composites showing the combined outlet of the Rimfaxe and Guldfaxe glaciers. Left: 1972 image taken by Landsat 1; right, 2010 image taken by Landsat 7, the most recent Landsat satellite. NASA Goddard Space Flight Center/US Geological Survey.*

A team of scientists, Zdanowicz et al (2012), analyzing the summer water melt rate for the Penny ice cap determined its 2010 temperatures were consistent with temperatures of 3,000 years ago - meaning, that current temps are significantly below those of both the Roman and Minoan warming spans.

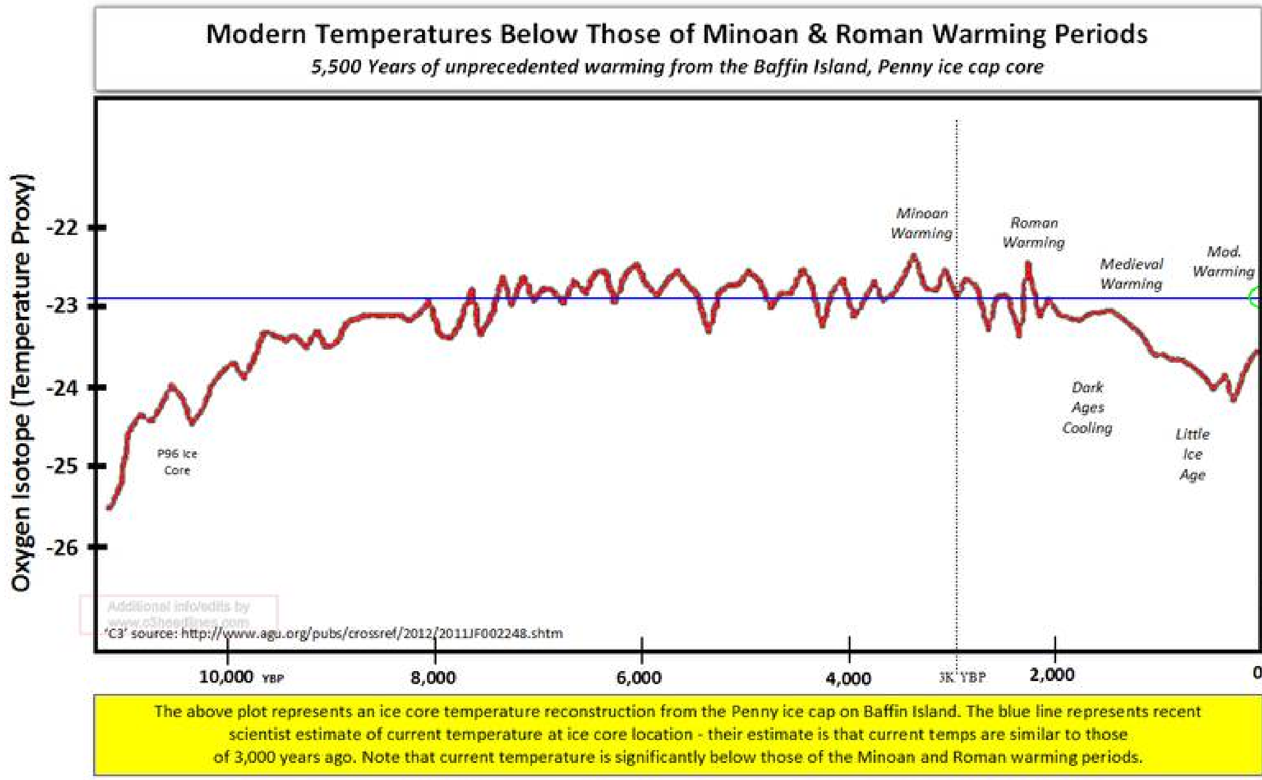
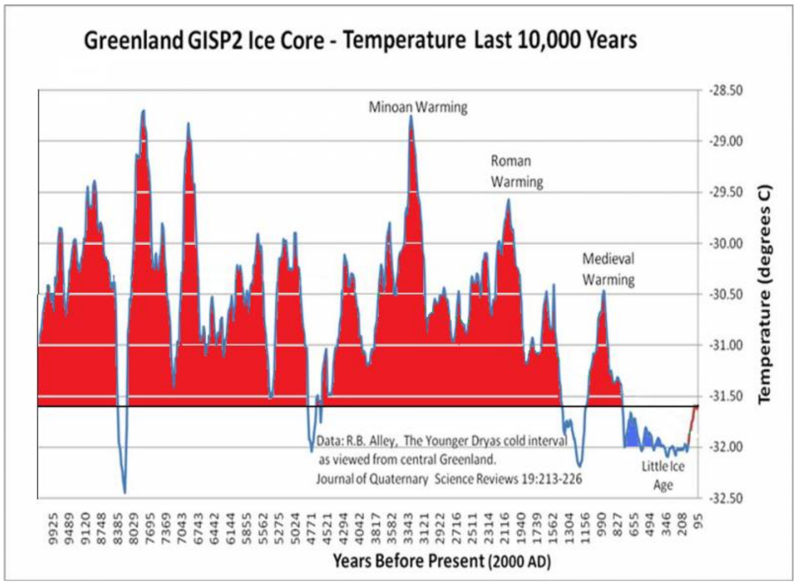


Figure. *Ice core temperature reconstruction from the Penny Ice Cap on Bafffin Island. (Zdanowicz et al 2012).*

Zdanowicz et al. found: "At latitude 67°N, Penny Ice Cap on Baffin Island is the southernmost large ice cap in the Canadian Arctic, yet its past and recent evolution is poorly documented. Here we present a synthesis of climatological observations, mass balance measurements and proxy climate data from cores drilled on the ice cap over the past six decades (1953 to 2011). We find that starting in the 1980s, Penny Ice Cap entered a phase of enhanced melt rates related to rising summer and winter air temperatures across the eastern Arctic. Presently, 70 to 100% (volume) of the annual accumulation at the ice cap summit is in the form of refrozen meltwater. Recent surface melt rates are found to be comparable to those last experienced more than 3000 years ago. Enhanced surface melt, water percolation and refreezing have led to a downward transfer of latent heat that raised the subsurface firn temperature by 10°C (at 10 m depth) since the mid-1990s. This process may accelerate further mass loss of the ice cap by pre-conditioning the firn for the ensuing melt season. Recent warming in the Baffin region has been larger in winter but more regular in summer, and observations on Penny Ice Cap suggest that it was relatively uniform over the 2000-m altitude range of the ice cap. Our findings are consistent with trends in glacier mass loss in the Canadian High Arctic and regional sea-ice cover reduction, reinforcing the view that the Arctic appears to be reverting back to a thermal state not seen in millennia."

This agrees also with the Greenland GISP2 Ice Core data (Alley, 2000) which also shows temperatures below that of the Minoan, Roman and Medieval Warm Periods.



The Minoan Warming Period occurred ~ 3000 years ago

Figure. *Greenland GISP2 Ice Core temperatures for the last 10,000 years (Alley, 2000).*

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6. EXTREME EVENTS

6.1 Drought

New studies show that EPA's statements on droughts need to be reexamined. Past droughts have been more severe and with greater frequency making EPA's predictions of the future inaccurate and inflammatory.

Chapter 3 of EPA's RIA describes climate related drought:

> With higher temperatures, the water-holding capacity of the atmosphere and evaporation into the atmosphere increase, and this favors increased climate variability, with more intense precipitation and more droughts.

The 2009 Endangerment Finding is more specific, for example, stating:

> Warmer temperatures and decreasing precipitation in other parts of the country, such as the Southwest, can sustain and amplify drought impacts.

and,

> The Administrator also notes that scientific literature clearly supports the finding that drought frequency and severity are projected to increase in the future over much of the United States.

During the public comment period for the Endangerment Finding, the EPA was repeatedly challenged about its drought findings. Here is a comment and EPA's Response discussing the support for EPA's findings about drought:

Comment (4-31):

One commenter (3136.1) objects to a statement in the TSD, asking "Why will soils be drier given increasing precipitation and cloud cover (the latter of which mitigates against higher evaporation)? Because a model says so? When, in reality, over the last 100 years, precipitation increases have been far greater than evapotranspiration across the U.S.?

Response (4-31):

The commenter objects to the statement in Section 8 of the TSD that "The IPCC (Field et al., 2007) reported with very high confidence that in North America disturbances like wildfire are increasing and are likely to intensify in a warmer future with drier soils and longer growing seasons.

Changes in soil moisture, and therefore dryness, are a function of the difference between water gain and water loss. Increased temperatures increase evaporation, and therefore, all other things being equal, should lead to increased dryness. However, increased precipitation (which increases water input, minus runoff losses) and increased cloudiness (which should decrease evaporative losses) can both reduce dryness. Therefore, future dryness will be a function of future temperature, precipitation, and cloudiness, among other variables.

The commenters provided a reference, McCabe and Wolock (2002), to support the claim that "precipitation increases have been far greater than evapotranspiration." We reviewed this paper, which found that "[t]rends in annual surplus and annual deficit suggest that the eastern US has become slightly wetter and the western US has become slightly drier during the period 1895–1999." In contrast to the assertion by the commenter that precipitation increases were "far greater" than evapotranspiration, the paper uses the term "slight" to describe the increase in annual surplus across the country, as well as finding drying in the western United States. As shown by the slight drying of the western United States, it does not follow that "increasing precipitation" implies an even distribution of precipitation geographically or temporally, or that increasing total precipitation will counteract the increased dryness projected for certain regions and seasons. As stated in Karl et al. (2009), "While it sounds counterintuitive, a warmer world produces both wetter and drier conditions. Even though total global precipitation increases, the regional and seasonal distribution of precipitation changes, and more precipitation comes in heavier rains (which can cause flooding) rather than light events.

Other observational studies support the contention that a warmer future can have drier soils in some regions or some seasons despite higher levels of national precipitation. The IPCC states that historically, "[d]espite the overall national trend towards wetter conditions, a severe drought has affected the southwest United States from 1999 through 2008 (see Section 4(l)), which is indicative of significant variability in regional precipitation patterns over time and space." Karl et al. (2009) found that increased extremes of summer dryness and winter wetness consistent with future projections have already been observed, not just modeled. Moreover, Jansen et al. (2007) found that some evidence suggests that during the past 2000 years, warmer than average summer temperatures were associated with particularly extensive, severe, and frequent droughts.

Model projections find that decreases in precipitation are actually likely in subtropical regions and the southwestern United States, even though precipitation is expected to increase globally. Karl et al. (2009) report model projections of future precipitation in the United States generally indicate northern areas will become wetter, and southern areas, particularly in the West, will become drier. Karl et al. also find that "[p]rojected increases in precipitation are unlikely to be sufficient to offset decreasing soil moisture and water availability in the Great Plains due to rising temperatures and aquifer depletion.

Therefore, we do not find that either observational data or model projections contradict the IPCC conclusions on the contributions of drier soils in a warmer future.

The science of drought, especially over the Southwestern U.S., has evolved considerably since the EPA's 2009 endangerment finding and recent scientific literature shows that not only does climate change as a result from human GHG emissions play only a minor role in the observed changes to the large-scale atmospheric circulation features which control, to some extent, the climate of the Southwest, but that when fine-scale terrain features are included in climate models, the projected declines in precipitation across the Southwest are greatly reduced. Further, evidence continues to mount indicating that the current extended period of drought in the Southwest has natural analogues. In combination, the new science indicates that the EPA's findings on drought are outdated and incomplete, and require a reassessment.

An influential new paper by Allen et al., (2012) documents that black carbon aerosols and tropospheric ozone together have been the primary cause of the northward expansion of the tropics—a substantial mechanism for drying the Southwest, and one which has been proposed to have been primarily driven by GHG emissions according to the science relied on by the EPA (highlighted section above). In the Response quoted above, the EPA makes reference to Karl et al. (2009), which is the synthesis report of the USGCRP. Karl et al. (2009) at various places describes anticipated changes in future precipitation. Here is one such example (from the Global Climate Change chapter, p. 24):

> ***Changing precipitation patterns***
>
> Projections of changes in precipitation largely follow recently observed patterns of change, with overall increases in the global average but substantial shifts in where and how precipitation falls.90 Generally, higher latitudes are projected to receive more precipitation, while the dry belt that lies just outside the tropics expands further poleward,96,97 and also receives less rain. Increases in tropical precipitation are projected during rainy seasons (such as monsoons), and especially over the tropical Pacific. Certain regions, including the U.S. West (especially the Southwest) and the Mediterranean, are expected to become drier. The widespread trend toward more heavy downpours is expected to continue, with precipitation becoming less frequent but more intense.90 More precipitation is expected to fall as rain rather than snow.

In Karl et al. (2009) reference “96” is to Seidel et al. (2008) which is a paper describing the observed expansion of the tropics and points to climate change from GHG emissions as at least part of the cause. In Karl et al. (2009) reference “97” is to another USGCRP report, Cook et al. (2008), a chapter in Abrupt Climate Change, Synthesis and Assessment Product 3.4. From that report (p. 9) comes the following:

> There is no clear evidence to date of human-induced global climate change on North American precipitation amounts. However, since the IPCC AR4 report, further analysis of climate model scenarios of future hydroclimatic change over North America and the global subtropics indicate that subtropical aridity is likely to intensify and persist due to future greenhouse warming. This projected drying extends poleward into the United States Southwest, potentially increasing the likelihood of severe and persistent drought there in the future. If the model results are correct then this drying may have already begun, but currently cannot be definitively identified amidst the considerable natural variability of hydroclimate in Southwestern North America.

Clearly, a GHG emissions-induced expansion of the tropics, pushing subtropical aridity northwards over the Southwestern U.S. is one of the primary mechanisms underlying the EPA’s finding for more drought in the U.S. Southwest (including potentially an influence on current conditions).

The new Allen et al. (2012) paper disputes this drought mechanism. According to Allen et al. (2012):

> Observational analyses have shown the width of the tropical belt increasing in recent decades as the world has warmed. This expansion is important because it is associated with shifts in large-scale atmospheric circulation and major climate zones. Although recent studies have attributed tropical expansion in the Southern Hemisphere to ozone depletion, the drivers of Northern Hemisphere expansion are not well known and the expansion has not so far been reproduced by climate models. Here we use a climate model with detailed aerosol physics to show that

> increases in heterogeneous warming agents—including black carbon aerosols and tropospheric ozone—are noticeably better than greenhouse gases at driving expansion, and can account for the observed summertime maximum in tropical expansion. Mechanistically, atmospheric heating from black carbon and tropospheric ozone has occurred at the mid-latitudes, generating a poleward shift of the tropospheric jet, thereby relocating the main division between tropical and temperate air masses. Although we still underestimate tropical expansion, the true aerosol forcing is poorly known and could also be underestimated. Thus, although the insensitivity of models needs further investigation, black carbon and tropospheric ozone, both of which are strongly influenced by human activities, are the most likely causes of observed Northern Hemisphere tropical expansion.

Black carbon and tropospheric ozone are not included in the EPA's mix of long-lived and directly-emitted greenhouse gases. Thus, the mechanism described by Allen et al. (2012) for expanding the tropics and drying the Southwest does not result from the gases for which the EPA has made its Endangerment Finding. To ascribe the (present and future) drying of the Southwest to the mix of six GHGs, as does the EPA, is thus incorrect. According to Allen et al. "our results point to anthropogenic pollutants other than CO2 rather than global warming as the culprit in recent Northern Hemisphere tropical expansion." A reassessment by the EPA in light of this new science is in order.

Additionally, new research has shown that the coarseness of the spatial resolution of general circulation models (GCMs) limits their ability to capture the precipitation mechanisms of the Southwest which are to a large degree governed by small-scale terrain features. In a series of recent studies, Gao et al. (2011, 2012) have used a higher-resolution regional climate model (RCM) that contains detailed representation of the complex terrain of the Southwestern U.S. Gao et al. (2011, 2012) find that by including the terrain features at a finer scale, the regional climate models were better able to capture the small scale and transient features of the weather that were responsible for precipitation. In doing do, the RCM produced less precipitation vulnerability to future climate changes than did the GCMs. Gao et al. (2011) showed that the enhanced resolution of RCMs allowed them to better simulate the snow accumulation and ablation at high elevations and consequently "runoff in the Colorado River Basin is less susceptible to a warming climate in RCMs than in GCMs." And in Gao et al., (2012), the researchers reported:

> The ability of RCMs to better resolve transient eddies and their interactions with mountains allows RCMs to capture the response of transient flux convergence to changes in stability. This leads to reduced susceptibility to hydrological change in the RCMs compared to predictions by GCMs.
>
> In summary, this study suggests that limitations in how GCMs represent terrain and its effects on moisture convergence have important implications for their ability to project future drying in the SW where mountains play an important role in the regional water cycle.

It is important to contrast the Gao et al. (2012) results with the findings of the USGCRP report which reported that "In response to increased concentration of GHGs, the semi-arid regions of the Southwest are projected to dry in the 21st century, with the model results suggesting, if they are correct, that the transition may already be underway (Seager et al., 2007)." Using the higher resolution RCM with detailed terrain features, Gao et al. (2012) found enhanced transient moisture convergence in the Southwest relative to the coarser resolution GCMs such as those used in primary reference of the USGCRP, Seager et al. (2007), the result of which, as reported by Gao et al. (2012) is that "[t]his enhanced convergence leads to reduced susceptibility to hydrological change in the RCMs compared to GCMs.

And in addition to the modeling work described above, there has been an accumulation of observational evidence that the droughts experienced across the U.S.—even during the period of increasing global temperatures—have not exceeded historical analogs and thus do not distinctly bear signs of having been induced by human GHG emissions. For instance, Cook et al. (2009) find that the current extended drought in the Southwestern U.S. has not exceeded the severity of two 20th century droughts—themselves which pale in comparison to "megadroughts" which have occurred in the region over the past millennium. Cook et al. (2009) write "While severe, this turn of the century drought has not yet clearly exceeded the severity of two exceptional droughts in the 20th century. So while the coincidence between the turn of the century drought and projected drying in the Southwest is cause for concern, it is premature to claim that the model projections are correct."

Similar results showing that past droughts were far greater than recent droughts in the West were recently reported by Wise (2011), and in the Midwest Corn Belt by Stambaugh et al., (2011). Other new research confirms the strong role of natural influences such as solar output (Springer et al., 2008), patterns of Atlantic and Pacific sea surface temperatures (Sheffield et al., 2009), and ENSO variability (McCabe et al., 2010). McCabe et al. (2010) finds that while there has been a recent increase in the length of dry events across the Southwestern U.S., that the increase does not overwhelm the general trend towards long-term wetter conditions. According to McCabe et al. (2010):

> Little evidence of long-term positive trends in dry event length in the southwestern United States is apparent in the analysis of daily WBAN precipitation data. During the mid-1990s to late 1990s, drought conditions began in the southwestern United States and persisted in the 21st century. This drought has resulted in positive trends in dry event length for some sites in the southwestern United States. However, most of the statistically significant trends in the number of dry days and dry event length are negative trends for water years and cool seasons.
>
> …Since the mid-1970s, El Niño events have been more frequent, and this has resulted in increased precipitation in the southwestern United States, particularly during the cool season. The increased precipitation is associated with a decrease in the number of dry days and a decrease in dry event length.

Taken together, the results from more refined models and multiple, influential studies of the reasons behind the recent drought conditions in the Southwest U.S.—reasons which do not feature human GHG emissions—make a clear and unequivocal case for the EPA to conduct a reassessment of its findings concerning the nature and causes of current and future droughts across the Southwestern U.S.

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6.2 Cyclones and Hurricanes/Tropical Cyclones (Hurricanes)

Chapter 3 of EPA's RIA has this to say about tropical cyclones:

> Increases in tropical cyclone intensity are linked to increases in the risk of deaths, injuries, waterborne and food borne diseases, as well as post-traumatic stress disorders. Drowning by storm surge, heightened by rising sea levels and more intense storms (as projected by IPCC), is the major killer in coastal storms where there are large numbers of deaths. Flooding can cause health impacts including direct injuries as well as increased incidence of waterborne diseases.

In the 2009 endangerment finding, the EPA recognized that the future frequency of Atlantic basin tropical cyclones is uncertain and dependent on a number of future climate conditions that themselves are uncertain. In fact, the sign (i.e., an increase or a decrease) of many of the individual influences, as well as the comprehensive effect on tropical cyclones frequency varied from climate model to climate model. Thus, the EPA in its TSD concluded that "frequency changes in tropical cyclones are currently too uncertain for confident projections." Consequently, the EPA focused on changes to the intensity of tropical cyclones, concluding that, "Based on a range of models, it is likely that tropical cyclones (tropical storms and hurricanes) will become more intense, with stronger peak winds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures." Such a finding is reflected in the RIA as quoted above and the basis for the listed associated negative consequences.

However, new research on past tropical cyclone behavior sheds uncertainty on future changes in tropical cyclone intensity and the influence that human greenhouse gas emissions may have (Landsea et al., 2010; Vecchi et al., 2011; Villarini et al., 2011; Hagen and Landsea, 2012); new research on hurricane modeling lessens the certainty of the direction of future changes in intensity and establishes that intensity and frequency are interrelated (Knutson et al., 2010; Zhao and Held, 2010); and new research on the tracking behavior of tropical cyclones calls into question whether projections of future storm intensity are alone sufficient to threaten public health and welfare (Murakami and Wang, 2010; Wang et al., 2011, Murakami et al., 2012; Raible et al., 2012). Additionally, research shows that changing demographics of coastal communities makes disentangling the impacts of human greenhouse gas emissions from other sources of impacts on the future evolution of vulnerabilities to tropical cyclones exceedingly difficult if not impossible prior to at least the late 21st century (Compton et al., 2011; Willoughby, 2012). Together, this collection of new and influential scientific research undermines the EPA's conclusions regarding future hurricanes and their impacts as reflected in the TSD of the endangerment finding and requires a re-evaluation of the best available science.

Numerous recent studies looking into how changes in observational technologies impact the observational history of Atlantic basis tropical cyclones have found that the number of small storms (Villarini et al., 2011), short-lived storms (Landsea et al., 2011), total storms (Landsea, 2007; Vecchi and Knutson, 2011), and major hurricanes (Hagen and Landsea, 2012) have been underestimated prior to the era of satellite coverage. As a consequence, long-term trends in the total number of tropical cyclones as well as the number of major hurricanes are unreliable unless changes in observational technologies are accounted for. Most evidence (from the above cited papers) indicates that a proper accounting of the impacts of observational changes over time will result in the reduction or elimination of the century-scale upward trend in both the annual total as well as the annual count of major hurricanes in the Atlantic basin. Thus, a century-long period of "global warming" appears to have had neither a detectable impact on the total frequency of tropical cyclones in the Atlantic basin, nor on the frequency of major (intense) hurricanes. Such evidence suggests that future intensity changes resulting from anthropogenic global warming will be minimal if even detectable. New research involving climate model projections of future hurricane intensity is beginning to reach a similar conclusion.

Zhao and Held (2010) investigated changes in tropical cyclone characteristics under greenhouse warming and found that a changes in storm intensity are comprised of two components, one which is closely (positively) related to changes in storm frequency and the other is an intrinsic intensity increase. Across climate models, the authors found that while greenhouse warming increases the intrinsic intensity of hurricanes, that greenhouse warming drives down the frequency of storms of all intensity. And that in combination, while the model ensemble average indicates a slight increase in intensity, the model range encompassed both increases and decreases. Zhao and Held (2010) emphasize that the results are dependent on model errors:

> We emphasize that because of the potential competing effects between changes in total storm frequency (dN) and changes in intensity probability distribution (dP) in a greenhouse gas–warmed climate, model errors in predicting both dN and dP will impact the overall projection of intense hurricanes.

This conclusion is similar to that of another comprehensive review of changing tropical cyclones under greenhouse warming (Knutson et al., 2010) which found only "limited" confidence in net intensity increases, since projections of increased intensity had to be tempered by projections of decreasing frequency. According to Knutson et al. (2010):

> We judge that a substantial increase in the frequency of the most intense storms is more likely than not globally, although this may not occur in all tropical regions. Our confidence in this finding is limited, since the model-projected change results from a competition between the influence of increasing storm intensity and decreasing overall storm frequency.

Zhao and Held (2010) specifically note that the results of another recent investigation (Bender et al., 2010) which found large increases in the frequencies of category 4 and 5 hurricanes in the Atlantic might be overestimates resulting from an inaccurate representation of historical storm behavior.

Thus, based on modeling studies, there are significant uncertainties in climate model projections of future intensity changes (with some models indicating declines)—a situation not dissimilar to the one concerning changes in overall tropical cyclone frequencies, which the EPA recognized as being "currently too uncertain for confident projections."

But even if the EPA continues to consider the uncertainties in projections of future tropical cyclone intensity to be small enough to justify their conclusion that future increases in intensity are “likely”, it still must consider whether the “likely” intensity increase will increase the threat to the U.S.—as such a conclusion does not directly follow. For instance, several recent papers (Murakami and Wang, 2010; Wang et al., 2011; Murakami et al., 2012; Raible et al., 2012) lend evidence that this may not be the case.

Murakami and Wang (2010) compared the tracks of Atlantic basin tropical cyclones generated from a high resolution general circulation model (MRI/JMA AGCM v3.1) for a 25-yr simulation of the present day with those of the future under the SRES A1B emissions scenario. They found a significant eastward shift in the tropical cyclone genesis region in the Atlantic Ocean. This eastward shift had the impact of decreasing the frequency of storms which tracked into the U.S. Southeast Atlantic and Gulf coasts and reducing the probability of landfall, while only slightly increasing the influence of tropical cyclones on the northeastern U.S. In follow-up work using a newer version of the high resolution climate model (MRI/JMA AGCM v3.2), Murakami et al. (2012), find that overall, the frequency of tropical cyclones approaching the U.S. coastline declines by nearly 20% while the average maximum intensity of storm approaching the coast increases by less than 0.5 m/s.

In other work, Wang et al. (2008) established that the size of the Atlantic Warm Pool (AWP) plays a strong role in hurricane activity in the Atlantic Ocean. The size of the AWP is influenced by annual-to-multiannual ENSO variability, the multi-decadal variability of the Atlantic Multidecadal Oscillation (AMO) and a general overall “global warming” (which leads to a larger AWP). Larger AWPs are associated with more intense Atlantic hurricanes. However, in a follow-up study, Wang et al. (2011) investigated the relationship between AWP size and U.S. landfalling hurricanes. Wang et al. (2011) found that while large AWPs were associated with more storms, large AWPs also altered atmospheric steering currents such the storms which did form had a tendency to recurve northwards and remain out to sea without making landfall in the U.S. Conversely, in years with small AWPs—a condition not favored by global warming—storms were steered more towards the southeastern U.S. Atlantic coast and Gulf of Mexico.

Most recently, Raible et al. (2012) examined insurance loss potentials from changes in Atlantic hurricanes as projected in future climate scenarios. Using the projections from the ECHAM5 climate model, Raible et al. (2012) find “a decrease in insured losses in the future for the entire United States” and that “although the number of major hurricanes increases, the insured losses do not increase in the United States, reflecting to some extent the changes in track density over the region.” Using the MRI/JMA AGCM v3.1 model, Raible et al. (2012) find “an increase in insured loss…being dominated by weaker changes in trajectories in conjunction with a general intensification.” Based upon the newly reported results of the updated MRI/JMA AGCM v3.2 model (Murakami et al., 2012—as described above), it is likely that had Raible et al. (2012) had those results available, the increases in insurance losses would likely lessen, or perhaps even change sign entirely. Raible et al. (2012) have this to say about assessing future insured losses in the U.S. from future hurricanes:

> In conclusion, it is necessary to analyze different model simulations in US regions to assess the uncertainty of future changes. Based on our study, a conclusive statement about future loss potentials in the Eastern US cannot be drawn. The study, therefore, demonstrates and highlights the current limitations of the use of scenario simulations based on state-of-the-art, high-resolution global models as input for insurance loss models.

The above studies (Murakami and Wang, 2010; Wang et al., 2011, Murakami et al., 2012) show that even if human greenhouse gas emissions were to increase the intensity of hurricanes, the same changes may reduce the frequency of those hurricanes making landfall along the U.S. coast—interestingly, with the conclusion of the 2011 hurricane season, it has now been more than 2,321 days since the last major hurricane made landfall in the U.S. (hurricane Wilma in 2005)—a new record for the number of days between major hurricane landfalls in the U.S. (Weinkle et al., 2012).

The net result from climate change resulting from human greenhouse gas emissions could be a reduction in the threat to Americans health and welfare posed by hurricanes (Raible et al., 2012), especially once the threat from hurricanes is properly normalized to account for changing population demographics—a factor which has been primarily responsible for the observed steep increase in hurricane-related damages (Pielke Jr., et al., 2008; Willoughby, 2012) and will continue to drive up damages in the future (Pielke Jr., 2007). Once the influence of changing demographics and wealth has been accounted for in historical loss estimates, researchers find no evidence for an anthropogenic global warming impact on the magnitude of observed hurricane-related damage in the U.S. since the beginning of the 20th century (Pielke Jr. et al., 2008; Willoughby, 2012). And based on the high level of noise in the loss data it is unlikely that whatever signal (if any) global warming may induce will be undetectable for most of the 21st century (Compton et al., 2011; Willoughby, 2012). According to Willoughby (2012):

> Hurricane deaths and destruction in the Unites States are convolutions of numbers and intensities of hurricanes crossing the shoreline, increasing population and development, and measures taken to mitigate effects. None of these factors is necessarily constant over time…. This analysis reveals no trend attributable to anthropogenic global warming. It is consistent with the tentative consensus (Bender et al. 2010; Knutson et al. 2010) among TC meteorologists that global warming is a real threat that will ultimately increase numbers and intensities of the strongest hurricanes (if not total numbers of TCs), but the signal is unlikely to be detectible above random variations before the late 21st century.

And as shown in the papers cited above the "tentative consensus" that global warming poses a "real threat" by increasing the frequency and intensity of the strongest hurricanes is growing thinner as new science comes in. As all the above referenced studies indicate, the future behavior of Atlantic tropical cyclones will be determined by a complex interplay between natural and anthropogenic influences. No clear picture has yet to emerge regarding the change in threat to the public health and welfare of Americans as a result of changes in frequency, intensity, or preferred tracking of Atlantic tropical cyclones as a result of human greenhouse gas emissions.

The EPA's confidence in an increasing threat—which inadequately relies only on its assessment of potential changes in intensity—is shown to be based on incomplete information. The best, most current most influential science indicates that the EPA's findings must be re-evaluated.

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6.3 Precipitation: Variability/Extremes

Chapter 3 of EPA's RIA has this to say about precipitation extremes:

> Increases in the frequency of heavy precipitation events are associated with increased risk of deaths and injuries as well as infectious, respiratory, and skin diseases. Floods are low-probability, high-impact events that can overwhelm

> physical infrastructure, human resilience, and social organization. Flood health impacts include deaths, injuries, infectious diseases. . .

This statement follows from the TSD of the 2009 Endangerment Findings which, in the Executive Summary states:

> Observations show that changes are occurring in the amount, intensity, frequency and type of precipitation. Over the contiguous U.S., total annual precipitation increased by 6.5% from 1901-2006. It is likely that there have been increases in the number of heavy precipitation events within many land regions, even in those where there has been a reduction in total precipitation amount, consistent with a warming climate.

and,

> Intensity of precipitation events is projected to increase in the U.S. and other regions of the world. More intense precipitation is expected to increase the risk of flooding and result in greater runoff and erosion that has the potential for adverse water quality effects.

However, changes in heavy rainfall are influenced by a large array of factors besides GHG emissions—factors which produce results that may masquerade as being from GHG emissions. For instance, it has been documented that water impoundments (e.g., reservoirs), urban areas, agriculture, anthropogenic aerosol emissions, and natural variability can enhance local rainfall intensity and amounts. These influences are similar in character to that which has been hypothesized to occur as a result of an increase in atmospheric GHG concentrations. If these other scientifically documented influences on precipitation characteristics are not properly accounted for and properly assessed, too much influence will be improperly apportioned to GHG increases—it is unclear that the EPA has properly considered these other influences. For instance, in the EPA's Response to Comments on the TSD for the endangerment finding is found this exchange:

Comment (4-58):

> One commenter (7037) references Shepherd (2005), and writes that the article conveys the view that "Increased precipitation, not drought, is possible over urban areas because of the presence of the urban heat island coupled with a moister and more unstable atmosphere, resulting in more wet deposition."

Response (4-58):

> We agree that the microclimate in urban areas differs from that of neighboring rural areas, and that observational studies have linked urban effects to precipitation increases over background values. This is discussed in the AR4 (Trenberth et al., 2007), which we cite in the TSD. Trenberth et al. (2007) states that "Urban effects can lead to increased precipitation (5 to 25% over background values) during the summer months within and 50 to 75 kilometers (km) downwind of the city." Thus, because the IPCC is aware of and discusses this effect, the large-scale precipitation projections which we cite in the TSD are not called into question by the commenter's point, and the TSD's discussion of precipitation projections is reasonable and sound.

The EPA seems to recognize that influences other than GHG emissions can impact precipitation characteristics (in this case, the urban environment), but defers to the IPCC AR4 as being "aware of" the effect. But, since the publication of the IPCC AR4, there has been a lot of new and influential scientific research that has appeared in the scientific literature that has investigated in more depth other influences on the characteristics of precipitation. Many of these new papers, described below, indicate that separating an effect of human GHG emissions from many other types of anthropogenic influences on heavy precipitation events is difficult if not impossible at this time, making assessments of the magnitude of the human GHG influence (like those in the IPCC AR4 and thus the EPA's Endangerment Finding) outdated, unreliable, and in need of revision.

For example, in a major research effort investigating the influence of water impoundments on precipitation, Degu et al. (2011) examined the meteorological influence of 92 large dams across the U.S. They found that in certain climate types, that large dams produce spatial gradients in convective available potential energy (CAPE), specific humidity, and surface evaluation in the regions near the reservoirs. The authors report that "[b]ecause of the increasing correlation between observed CAPE and extreme precipitation percentiles, our findings point to the possibility of storm intensification in impounded basins of the Mediterranean and arid climate of the United States." And while, at first pass, this effect may seem limited in scope, the authors are quick to remind us that "Today, there are more than 70,000 dams in the US capable of storing a volume of water almost equaling one year's mean runoff" and that "[g]iven that land cover is a first order forcing on local climate change, the historical chronology of irrigation patterns and other land cover types around multi-purpose reservoirs needs to be investigated with an atmospheric model to understand how heavy storms are physically modified (become more/less frequent or altered in average intensity)."

Another recent paper investigated the impact of irrigation on precipitation characteristics over the large region of the U.S. Great Plains. DeAngelis et al. (2010) studied the precipitation changes observed over and downwind of the Ogallala aquifer that underlies much of the Great Plains (from Nebraska south to northern Texas) and its relationship to the rapid post-WWII expansion of irrigation. DeAngelis et al. (2010) describe their findings:

> A long-term record of station and gridded precipitation observations covering the entire 20th century shows that July precipitation increased 15–30% in a broad region downwind of the Ogallala Aquifer, stretching from eastern Kansas through Indiana…. While the July precipitation increase was only statistically significant in a region far downwind of the Ogallala, the timing and spatial distribution of the broad precipitation increase is overall consistent with our hypothesis that Ogallala irrigation may have enhanced the regional precipitation.

The DeAngelis et al. (2010) results were heavily citied in another new and influential research paper by Groisman et al. (2012) which examined trends and causes of heavy precipitation events in the central U.S. The authors found up to a 40% increase in the frequency of days and multiday extreme rain events during the past several decades. Groisman et al. (2012) state that while "there are good reasons to expect that some of the observed changes in intense precipitation over extratropical land areas (including the central United States) are part of the global climatic change" that "in parallel, there were large-scale land use changes over the central United States and its adjacent areas that could also shift the regional water budget in the same direction." The authors go on to state that "More comprehensive studies will be required to perform a special study to separate climatic and local anthropogenic factors in any attribution of causality…. [a] combination of global and regional climate and hydrological modeling driven by well-documented external anthropogenic forcing (that includes, in addition to global factors, regional land use and water management changes) can be a way to perform this attribution study" –a study that the authors note is "easy to envision" but "extremely laborious to do."

Additionally, evidence continues to mount that urban areas have a significant, and large-scale influence on precipitation characteristics, including increasing the frequency and magnitude of intense precipitation events. Specific demonstrations of this have been made for Atlanta (Shem and Shepherd, 2008), Indianapolis (Nyogi et al., 2011), Houston (Shepherd, 2010), Oklahoma City (Hand and Shepherd, 2009), and other cities and countries around the world (e.g. Mitra et al., 2011). Ashley et al. (2011) analyzed radar data from multiple cities across the Southeastern U.S. and found that their results "illustrate substantive evidence of urban effects on thunderstorm frequency and severity for major cities as well as evidence of non-urban LULC effects at a control site." Ashley go on to note the consequences of continued urbanization into the future on convective precipitation events:

> As urban cities continue to grow into the 21st Century, so will the convective feedbacks and, in return, enhanced thunderstorm risk they engender. When this risk is juxtaposed with elevated physical vulnerability created by urban infrastructure (e.g., impervious surfaces, outdated and aging storm drainage infrastructure, etc.), as well as the social vulnerability due to a concentration of millions of people and their assets into these centers, devastating consequences can result.

And perhaps the cutting edge area which is most rapidly growing and which has seen the publication of several influential scientific papers concerns the influence of anthropogenic aerosol emissions on the intensity of precipitation events. A major and influential scientific research article was published in 2012 on the topic by Koren et al. The abstract of their paper is both instructive at setting the stage for their work as well as for summarizing their findings:

> Atmospheric aerosols affect cloud properties, and thereby the radiation balance of the planet and the water cycle. However, the influence of aerosols on clouds, and in particular on precipitation, is far from understood, and seems to depend on factors such as location, season and the spatiotemporal scale of the analysis. Here, we examine the relationship between aerosol abundance and rain rate—a key factor in climate and hydrological processes—using rain data from a satellite-based instrument sensitive to stronger rain rates (Tropical Rainfall Measuring Mission, TRMM), aerosol and cloud property data from the Moderate Resolution Imaging Spectroradiometer onboard the Aqua satellite and meteorological information from the Global Data Assimilation System. We show that for a range of conditions, increases in aerosol abundance are associated with the local intensification of rain rates detected by the TRMM. The relationship is apparent over both the ocean and land, and in the tropics, subtropics and mid-latitudes. Further work is needed to determine how aerosols influence weaker rain rates, not picked up in the analysis. We also find that increases in aerosol levels are associated with a rise in cloud-top height. We suggest that the invigoration of clouds and the intensification of rain rates is a preferred response to an increase in aerosol concentration.

Continuing this line of research using satellite measurements, Heiblum et al. (2012) in their paper "New evidence of cloud invigoration from TRMM measurements of rain center of gravity" show that "for the majority of cases, high [aerosol optical depth] values are correlated with higher [rain vertical profiles' center of gravity] and larger [rain spread], indicating significant invigoration of the rain vertical distribution by aerosols." They specifically note that "[a]lthough we see an indication of invigoration in all regions, the results are more prominent in cases favoring deeper convective clouds, such as the South East US (SEUS)… during summer months."

Fan et al. (2012), noting that "the interactions of aerosols with clouds…constitute the largest uncertainty in climate forcing and projections" used high-resolution model simulations to elucidate how aerosols change intensive intensity, diabatic heating and regional circulation. They found that the "increased rain frequency for the heavy rain and the decreased rain frequency for the light rain in the polluted environment studied in the past studies are also seen here when aerosols significantly invigorate convection."

Studies which focused specifically on the United States also found significant influences of human aerosol emissions and enhancement of extreme precipitation events. A series of studies (Bell et al., 2008; Bell et al., 2009; Rosenfeld and Bell, 2011) documented that severe weather (including thunderstorms, hail, tornadoes, intense rainfall) show a mid-week peak that is associated with increased aerosol emissions during the work week relative to the weekends. From Bell et al. (2008), "Based on the substantial amount of research documenting the influence of aerosols on cloud development and the weekly variation in aerosol concentrations, this evidence strongly suggests that air pollution invigorates storms in areas with large vertical instability, such as occurs over land in the summer, when there is an ample supply of moisture." And in an influential study of the impacts of aerosols on precipitation intensity, Li et al. (2011) reported a strong association between atmospheric aerosol loading and extreme precipitation for the U.S. Great Plains. According to one of the study's authors, Daniel Rosenfeld, "The probability of heavy rain is increased by 50 percent from clean to dirty conditions, whereas the chance of light rain is reduced by 50 percent," The implications are global in scale according to Li et al. (2011):

> Using an unprecedented set of extensive measurements collected over a 10-year period at the ARM SGP site, strong long-term aerosol effects are revealed. A strong aerosol invigoration effect on convection is observed in summer, leading to higher cloud tops for mixed-phase clouds with low bases. The precipitation frequency is found to increase with increasing concentration of condensation nuclei for clouds with high water contents but decreases for clouds with low water contents. The findings concerning the effects of aerosols on both clouds and

> precipitation have numerous implications for climate studies, and even have economic consequences.
>
> The invigoration-induced upward motion can change regional circulation patterns, which can potentially alter larger-scale circulations and affect global climate…
>
> The findings presented here imply a potentially adverse impact on sustainable development over regions vulnerable to extreme meteorological events such as drought or flooding. Even if total rainfall amounts remain intact, changes in the frequency of light and heavy rains as found here would have consequences in terms of water usage efficiency, a key factor for life and agriculture.

According to the press release accompanying the Li et al. (2011) article, "t]he research provides the first clear evidence of how aerosols— soot, dust and other small particles in the atmosphere— can affect weather and climate; and the findings have important implications for the availability, management and use of water resources in regions across the United States and around the world," and that "[t]his work confirms what previous cloud modeling studies had suggested, that although clouds are influenced by many factors, increasing aerosols enhance the variability of precipitation, suppressing it when precipitation is light and intensifying it when it is strong. This complex influence is completely missing from climate models, casting doubt on their ability to simulate the response of precipitation to changes in aerosol pollution."

And not to be overlooked, there is an influence of natural variability on observed precipitation trends, including intensity. For instance, Chu et al. (2010) looked at trends in extreme precipitation across the Hawaiian Islands and reported "a reduction in the probability of moderate and high precipitation intensity accompanied by an increase in light intensity, shorter annual total number of days with daily precipitation greater than 25.4 mm, and smaller annual maximum consecutive 5-day precipitation amounts." These trends were found to be associated with variability in the Southern Oscillation Index. And in examining spatial patterns of trends in precipitation intensity across the continental U.S., Balling and Goodrich (2012) reported that while "[o]ur analyses of daily precipitation records from the conterminous USA reveal that during a time the Earth warmed (1975–2009), precipitation intensity appears to have increased at a continental scale," that "[g]iven the complexity of the spatial patterns in precipitation intensity trends along with a significant link to [Atlantic decadal Oscillation], making any direct link between anthropogenic changes in atmospheric composition and increases in precipitation intensity must be done with caution."

Clearly, new research indicates a much more complex system of interplay between non-GHG anthropogenic alteration to the environment, natural variability, and precipitation intensity than was recognized by the EPA in its TSD for the endangerment finding. In light of the new findings that reservoirs, irrigation, urban environments, and aerosols can act to increase the frequency and intensity of extreme precipitation events over large spatial scales—and over regions where intensity increases have been observed—it is imperative that the EPA revisit and reassess its conclusions regarding human GHG emissions and their actual and potential impact on intense precipitation events.

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6.4 Storm Surge

Chapter 3 of EPA's RIA makes this reference to endangerment as a result of storm surge:

> Although increases in mean sea level over the 21st century and beyond will inundate unprotected, low-lying areas, the most devastating impacts are likely to be associated with storm surge. Superimposed on expected rates of sea level rise, projected storm intensity, wave height, and storm surge suggest more severe coastal flooding and erosion hazards. Higher sea level provides an elevated base for storm surges to build upon and diminishes the rate at which low-lying areas

> drain, thereby increasing the risk of flooding from rainstorms. In New York City and Long Island, flooding from a combination of sea level rise and storm surge could be several meters deep. Projections suggest that the return period of a 100-year flood event in this area might be reduced to 4–60 years by the 2080s. Additionally, some major urban centers in the United States, such as areas of New Orleans are situated in low-lying flood plains, presenting increased risk from storm surges.

Recent and influential scientific literature provides evidence that there is large natural variability in the characteristics of the surge-producing storms themselves that typically dominate over any changes that can be related to a changing climate. Consequently, the potential impacts from storm surges themselves will largely be determined by the rate of local sea level rise—not by changes in relative surge characteristics.

Storm surge is dependent on the strength, position, and speed of movement of a coastal or near-coastal tropical or extra-tropical storm system. Storm surge adds to the underlying state of the ocean level as determined by the average height of the sea level and the lunar tidal cycle. If storm characteristics were to evolve under increasing greenhouse gas concentrations such that they were to become more favorable to producing large storm surges, the portions of the U.S. would become more vulnerable to disruption from the effects of periodic high water levels over and above those which would accompany a rise in relative sea level. However, observations show that few if any trends exist in the key storm characteristics for producing storm surge—instead, the observational record is marked by a high degree of natural variability characteristic of the underlying climate rather than climate change.

Along the Gulf Coast, storm surges are most often associated with warm season tropical cyclones, while the East Coast is subject to storm surges produced both by tropical cyclones as well as by cold-season extratropical coastal storms (aka nor'easters). Both Atlantic tropical cyclones and East Coast extratropical storms are affected by large scale atmosphere/ocean circulation patterns such as El Nino/La Nina (ENSO) and the Atlantic Multidecadal Oscillation. Extratropical storms are also influenced by ENSO and the North Atlantic Oscillation. While natural variability has been documented in all of these patterns in both observations and climate models, there has been observed no overall, long-term trend that could be related to global warming.

For nor'easters along the U.S. East Coast, storm surges and damage to coastal property are enhanced by slow moving storm systems. However, long-term studies indicate that there has been no overall change in the average speed of movement of these storms since at least the 1950s (Bernhardt and DeGaetano, 2012). Nor has there been any increases in wave height associated with these storms since at least the mid-1970s (Komar and Allan, 2008). The frequency of nor'easters has remained unchanged (Hirsh et al., 2001). Consequently, there has been no change in the number of storm surge events along the East Coast once local sea level rise has been accounted for (Zhang et al., 2000; Sweet and Zervas, 2011). Multiple studies identify ENSO and the NAO as being a strong drivers in the natural variability of many characteristics of nor'easters (Hirsh et al., 2001; Eichler and Higgins, 2006; Sweet and Zervas, 2011; Bernhardt and DeGaetano, 2012.)

The picture is much the same for tropical cyclones. Natural variations in the track, intensity, and frequency characteristics dominate any long-term trend and can be related to natural climatological drivers (Klotzbach, 2011; Villarini et al., 2012). Changing observational technologies can impart a false (i.e., non-climatological) trend in the tropical cyclone data sets that is often misinterpreted as being related to anthropogenic climate change (Villarini et al., 2011; Hagen and Landsea, 2012). Care must be taken to avoid this mistake. Additionally, damage assessments from tropical cyclones often fail to account for changes in population and wealth when determining long-term trends and trying to relate them to the changes in storm characteristics (Pielke and Landsea, 1998). When changing demographics are properly incorporated, there has been no long-term change in the magnitude of tropical cyclone damage which includes that from storm surge (Pielke et al., 2008; Willoughby, 2012).

As discussed at length in the comments on potential changes in hurricane number, intensity and track characteristics, current model-based projections regarding the future behavior of tropical cyclones are both complex and evolving and do not provide robust evidence that any changes that may or may not take place will be such as to increase the threat from storm surge from tropical cyclones. For example, some models project that the preferred storm track will change in such a ways as to keep storms more often out to sea (Murakami and Wang, 2010; Wang et al., 2011; Murakami et al., 2012)—a trend which would lead to less and/or rarer occurrence of storm surges of any particular level (i.e. increase the return intervals).

All this is not to say that damages, both potential and observed, from storm surge are not on the rise or that that will not continue to grow in the future. But that the increase is not being driven by anthropogenic emissions of greenhouse gases, but rather by elements of the natural climate coupled with large and growing coastal development.

Projections of potential changes to tropical and extratropical storm characteristics responsible for producing storm surge are neither large nor consistent enough to make reliable guides for assessing potential endangerment to the public health and welfare. The observed climate indicates no such trends over the period of rapid build-up of atmospheric greenhouse gases and projected changes are neither large nor consistent. Therefore, future impacts from storm surge resulting from climate change will likely be dictated by the degree of local sea level rise, rather than by changes in the characteristics of surge-producing storm characteristics.

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6.5 Wildfires

Chapter 3 of EPA's RIA discussed wildfires in several instances:

> According to the science assessment reports on which the Administrator relied for the 2009 Finding, climate change has very likely increased the size and number of wildfires, insect outbreaks, and tree mortality in the Interior West, the Southwest, and Alaska, and will continue to do so.

and,

> Changes in plant species composition in response to climate change can increase ecosystem vulnerability to other disturbances, including wildfires and biological invasion. Disturbances such as wildfires and insect outbreaks are increasing in the United States and are likely to intensify in a warmer future with warmer winters, drier soils and longer growing seasons.

As the EPA recognized in its TSD (and Response to Comments) for its 2009 endangerment finding, the frequency and severity of wildfires in the U.S. (including Alaska) fluctuates naturally in time and space. Further, the EPA recognizes that forest management practices play a role in fire statistics. In the time since the TSD, new research has been published which shows that as climate models increase in resolution, they produce less future moisture stress across the Southwestern U.S. Additionally, new research into natural variability projects an increase in wildfire outbreak as a result of the current (and near future) state of climate oscillations in the Atlantic and Pacific oceans—a trend which would complicate identification of a human GHG signal. As too does the increasing human presence in wildfire prone regions. The result is that the influence of human GHG emissions is difficult, if not impossible, to tie down and making assessments of future behavior of wildfire across the U.S. are fraught with uncertainty and unreliability.

Since the TSD, new research has been published further demonstrating the large role played by of natural variability—specifically multi-annual and multidecadal oscillations in the Atlantic and Pacific oceans—in governing the climate and wildfire regimes of the U.S. Southwest. For example, Schoennagel et al. (2007) examined fire/climate associations in a Southern Rocky Mountain site in western Colorado. They found that while there is uncertainty in regional-scale GHG-driven climate changes related to fire, that there are certainly strong natural influences that, at least for the next several decades, have become aligned to produce a greater frequency of wildfire:

> Overall, because fires are synchronous at supra-annual to multidecadal time scales with warm AMO [Atlantic Multidecadal Oscillation] events, particularly when combined with cool ENSO and PDO phases, this suggests that we may be entering a qualitatively different fire regime in the next few decades due to the recent shift in 1998 to a likely long-term warm AMO phase. Although uncertainty remains regarding the effects of CO2-induced warming at regional scales, given the multidecadal persistence of the AMO there is mounting evidence that the recent shift to the positive phase of the AMO will promote higher fire frequencies in the region.

In addition to increased fire frequency as a result of the alignment of natural influences, there is an ever-growing presence of humans in wildfire prone areas. This increasing presence has the effect of both increasing the number of wildfires (more than half of wildfire are now being initiated by humans) and increasing the loss from wildfires. According to Litschert et al. (2012) “Property losses from wildfires are increasing as rural land is developed; indeed, 39% of houses in the conterminous US are now in the wildland–urban interface.” In other research, Bartlein et al. (2008) examined the different characteristics (seasonality, location, etc.) between lightning-initiated wildfires and those started by humans. They analyzed 332,404 fire start records between 1986 and 1996, including 116,489 fires caused by lightning and 197,617 fires caused by humans west of 102°W. They noted that the seasonality of fires was stronger from naturally set fires than from fires started by humans. The net result is that, "Human-caused fires, on the other hand, display a less well-defined annual cycle and tend to lengthen the overall fire season." Lengthening the fire season is one of the ways that human GHG emission-induced climate change has been proposed to alter wildfire characteristics (see p. 92 of the EPA's Endangerment TSD where it is stated that "[f]urthermore, increased temperature in the future will likely extend fire seasons throughout the western United States, with more fires occurring earlier and later than is currently typical...". That Bartlein et al. (2008) find that the expanding human presence in wildfire prone regions produces a demonstrable and similar effect means that a GHG-induced climate change impact may be mis-identified—both presently and in the future.

The expectation for increases in wildfires in the Southwestern U.S. are driven by climate models which project warmer and drier conditions in the future. However, there is mounting evidence that wildfire regimes are more complex than the warmer/ drier conditions equates to more fires hypothesis. In a new paper, Roos and Swetnam (2012) reconstructed wildfire frequency in Ponderosa pine forests across Arizona and New Mexico back more than 1,400 years. They found that the frequency of major fires was unchanged between the warm/dry conditions associated with the Medieval Warm Period (a period from about 800 to 1300 A.D) and the cooler/wetter conditions of the Little Ice Age (1400 to 1850 A.D), and noted that rather than long-period climate shifts fire frequency was more related to decadal variability in precipitation regimes with large fires being associated with pluvial conditions (which lead to an accumulation of the fuel load) followed by several dry years. They note that the fire suppression policies put in place during the late 19th and continuing through the 20th century resulted in a "a duration of time with little to no local or regional fire activity [that] was truly anomalous in the entirety of the 1416 year record" and that the recent increase in large fires is a direct result of the increased fuel-load associated with the fire suppression policies. Had such policies not been put in place, the natural wildfire history of the 20th century would have looked much different, with large fires occurring throughout the period, rather than clumped in recent decades. Thus, the recent trend to more wildfires is not a result of anthropogenic climate change from GHG emissions, but rather from anthropogenic fire management policies.

And as to climate model projections themselves, research results indicate that as climate models become better refined, the model-projected declines in Southwestern precipitation become less, with the net result that the hydroclimate of the Southwest does not become as much drier as has been projected previously. The new results indicate a lessening of the threat for an increase in future wildfire occurrence.

Litschert et al. (2012) examined output downscaled from global climate models specifically chosen because they best modeled historic ESNO and PDO weather patterns across the Southwestern U.S.—key components driving wildfire characteristics. The downscaled output from the GCMs was fed into a fire model to project wildfires in the future under two different emissions scenarios. Although Litschert et al. (2012) found increases in wildfire occurrence under both scenarios, they noted the A2 scenario produced less of an increase than the B1 scenario even through the A2 scenario was a much warmer one, because the A2 scenario was a wetter one in the Southwest as well, and they postulated that as better modeling may reduce the uncertainty in the future. According to Litschert et al. (2012):

> If future precipitation is greater than in the recent past, as indicated by the climate model simulations for the A2 scenario, those precipitation increases can lessen, though not necessarily balance, the effects of temperature increases, thereby ameliorating the weather-based amplification of pressures on forest and wildfire managers. We must await improvements in climate modeling before we can remove this uncertainty about future precipitation and thus about future burned area.

In fact, high resolution regional climate models are already showing signs that future precipitation changes in the Southwest will not be as large as the coarser general circulation models (GCMs) project them to be. For example, Gao et al. (2011) using a regional climate model (RCM) with higher spatial resolution and better terrain features (features which play an important role in the region's precipitation climate) find that the enhanced resolution of RCMs allowed them to better simulate the snow accumulation and ablation at high elevations and consequently "runoff in the Colorado River Basin is less susceptible to a warming climate in RCMs than in GCMs." And in follow-on research, Gao et al. (2012) find that contrary to the results of GCMs which project increased dryness caused by "increased moisture divergence" (Seager et al., 2007—a central paper in the CCSP 3.4 report basing the TSD), Gao et al. find increased moisture convergence. According to the authors:

> The ability of RCMs to better resolve transient eddies and their interactions with mountains allows RCMs to capture the response of transient flux convergence to changes in stability. This leads to reduced susceptibility to hydrological change in the RCMs compared to predictions by GCMs.
>
> In summary, this study suggests that limitations in how GCMs represent terrain and its effects on moisture convergence have important implications for their ability to project future drying in the SW where mountains play an important role in the regional water cycle.

Together these two Gao et al. studies suggest that the future Southwest is considerably less threatened by water shortages from climate change than the USGCRP, IPCC, and EPA have assessed it to be.

And as to the associations between wildfire and insect outbreaks alluded to by the EPA, recent papers find the associations between very weak (Powell et al., 2012) and perhaps even negative (Simard et al., 2011). In a study of the relationships between mountain pine beetles and wildfire in the Yellowstone region, Simard et al. (2011) report that "the linkage of prior [mountain pine beetle] disturbance to future fire disturbance generally results in a dampening, rather than an amplification, of fire behavior and intensity." In a review of the topic, Hicke et al. (2012) conclude:

> Published studies suggest that bark beetle outbreaks can indeed affect fuels and fire behavior. The types of change, however, depend on the research question addressed, time since outbreak, and fuels or fire characteristic of interest,

suggesting that generalizations about the effects of bark beetle-caused tree mortality on fire characteristics are unwarranted.

As more studies performed and better models are developed, the complexity of the interactions of both natural and human presence is better exposed, and the future incidence of wildfire in the southwestern U.S. and its influences becomes less clear. A complete reassessment of the EPA's previous findings is compelled by these new scientific developments.

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7. SEA LEVEL RISE

Chapter 3 of the RIA states as follows as to sea level rise (SLR):

> The most vulnerable areas are the Atlantic and Gulf Coasts, the Pacific Islands, and parts of Alaska. Cities such as New Orleans, Miami, and New York are particularly at risk, and could have difficulty coping with the sea level rise projected by the end of the century under a higher emissions scenario. Population growth and the rising value of infrastructure increases the vulnerability to climate variability and future climate change in coastal areas. Adverse impacts on islands present concerns for Hawaii and the U.S. territories. Reductions in Arctic sea ice increases extreme coastal erosion in Alaska, due to the increased exposure of the coastline to strong wave action.

There is, however, no accelerated SLR anywhere in the vicinity of New York City. Gauge data from Houston & Deal (2006) show how most locations from Maine to Florida show either a small rise or even a deceleration in sea level rise.

NOAA's tide gauge at Battery Park, NY shows no acceleration since 1860 (See Figure below).

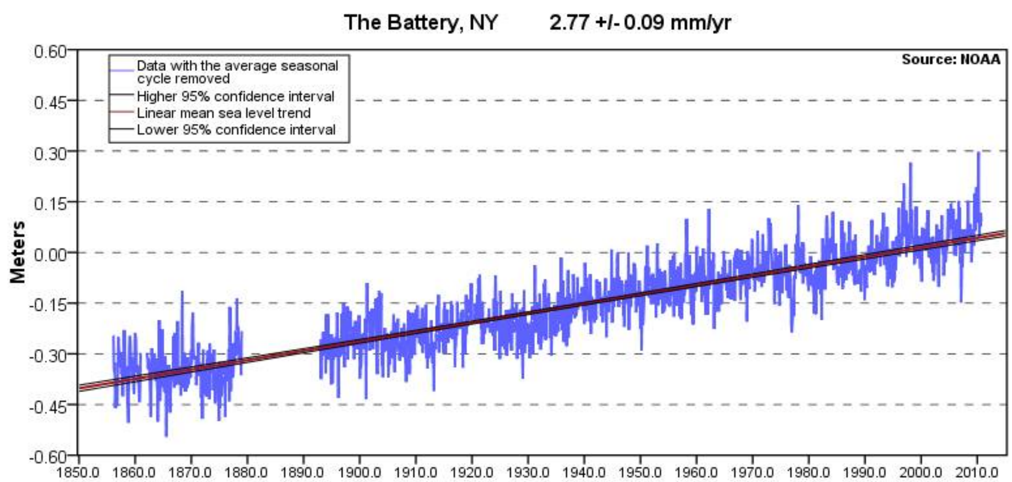

Figure. *NOAA Sea Level Data Battery Park, New York tidal gauge for 1860 through 2010.*

Cazanave (2008) shows that the vulnerable areas in the next few years do not include the U.S. Atlantic Coast.

The best guess value of SLR for the next 100 years is a relatively modest 23 cm +/− 5 cm which poses little threat to coastal areas of the world either at present or in future.

EPA has used the IPCC as a principal source, but apparently is unwilling to admit that the IPCC has steadily REDUCED its forecast of SLR. The IPCC (1995) climate change estimated SLR of about 50 cm by 2100. IPCC(2001) revised this estimate to about 37 cm. IPCC (2007) projects SLR to be between 14 and 43 cm (with a mean value of 29 cm) by 2100 under the A1B (greenhouse gas) emission scenario in which the earth's mean temperature is projected to rise between 2.3C and 4.1C by 2100.

7.1 Historical Perspective

It is now generally accepted that the global sea level increased by about 120 m as a result of de-glaciation that followed the last glacial maximum (LGM) about 21,000 years ago. By about 5000–6000 BP (Before Present), the melting of high-latitude ice mass was essentially completed (Douglas & Peltier 2002). Thereafter global sea level rise was small and appears to have ceased by 3000–4000 yr BP. Rates of global-averaged SLR over the last 1000 yr and prior to the twentieth century are estimated to be less than 0.2 mm/yr (Fleming et al 1998; Lambeck 2002). See Figure below.

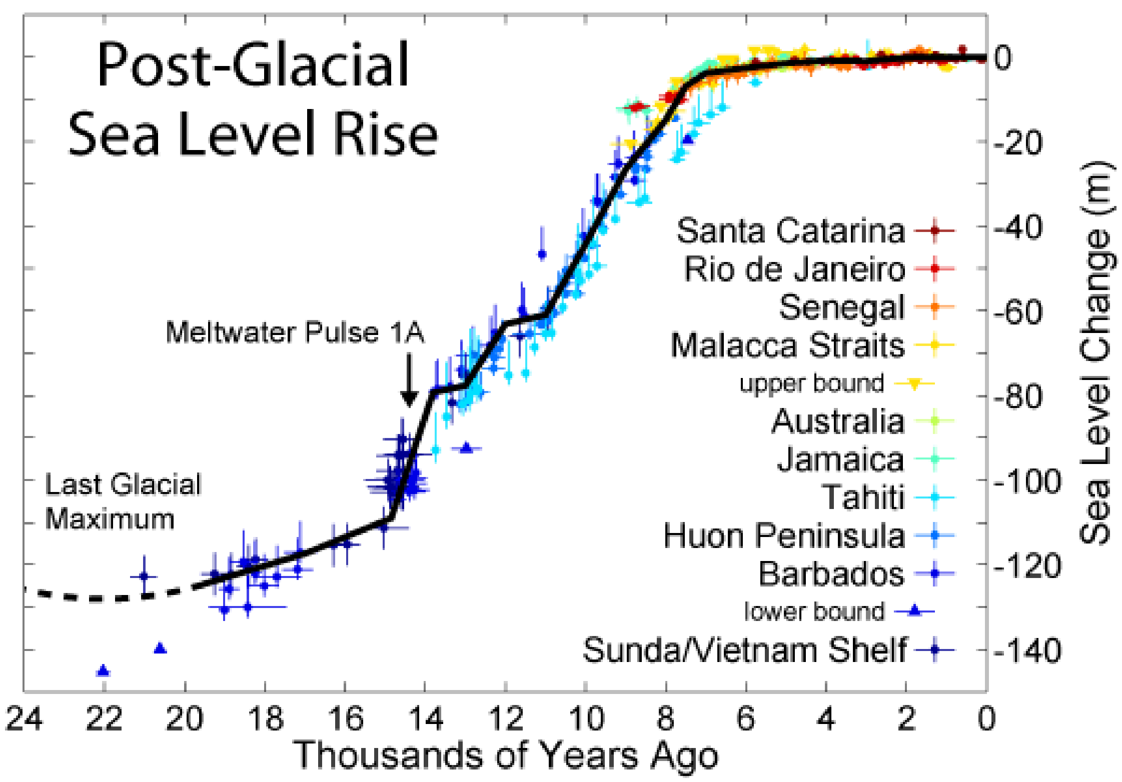

Figure. *Sea level rise since the end of the last glacial episode based on data from Fleming et al. 1998, Fleming 2000, & Milne et al. 2005.*

An empirical study by Holgate & Woodworth (2004) using 177 tide gauges divided into 13 regions with near global coverage obtains a value of 1.7 +/− 0.2 mm/yr over a 55-year period (1948–2002). Another study (Church et al 2004) estimates regional distribution of SLR for the period 1950–2000 by combining satellite altimeter data with historic tide gauge data. The study obtains a value of 1.8 +/− 0.3 mm/yr for the 51-year period (1950–2000) with a maximum value of over 2 mm/yr over the North Atlantic Ocean along a band running east-northeast from the US east coast.

Among major sources of uncertainty identified by Church et al are inadequate distribution of tide gauges particularly in the southern hemisphere, inadequate information on various geophysical signatures in the tide gauge data (e.g. glacial isostatic adjustment and tectonic activity) and relatively short duration of satellite altimetric data.

In a series of comprehensive studies, Peltier and coworkers (Peltier 1996, 1998, 2001; Douglas & Peltier 2002) have articulated the issue of GIA (Glacial Isostatic Adjustment) which refers to the gradual springing back of the earth's crust in response to the removal of the ice loads of the LGM which were at their maximum extents around 21000 yr BP. Peltier and his students (University of Toronto Canada) have developed a geophysical computer model which accounts for gravitational interaction between a spherical viscoelastic model of the solid earth and the surface mass load associated with the process of glaciation and deglaciation. This numerical model documents how the GIA is a slow process that decays exponentially at a rate determined by the (earth's) mantle viscosity. The GIA is still significant in the region around the Gulf of Bothnia (often referred to as Fennoscandia) which was covered with ice to a depth of several kilometers during the LGM and where the relative sea level is currently falling at a rate of 5–10 mm/yr as the land in that region continues to rebound.

In another comprehensive study, Munk (2002) examines the twentieth century sea-level rise enigma and assesses various geophysical forcing (like earth's rotation, polar wandering etc) as well as climate forcing (melting of glaciers, thermal expansion of water, El Nino events) on the SLR for the 20th century. Munk concludes that despite large error bars in SLR estimates, the traditional value of 1.5–2 mm/yr seems a reasonable estimate for the 20th century SLR.

7.2 Recent Global and Regional Studies

Since the publication of IPCC (2007) climate change documents, several studies have appeared on sea level rise and related issues. A few of the important recent studies are summarized below:

1. **Holgate (2007):** This study examines nine long and almost continuous sea-level records to obtain SLR estimates for the period 1904–2003. The rate of SLR was found to be larger in the first half of the 20th century (2.03 +/− 0.34 mm/yr 1904–1953) than in the second half of the century (1.45 +/− 0.34 mm/yr 1954–2003). According to Holgate (See Figure 3), the highest decadal rate of rise occurred in the decade centered on 1980 (5.31 mm/yr) while the lowest rate of rise occurred in the decade centered on 1964 (−1.49 mm/yr).

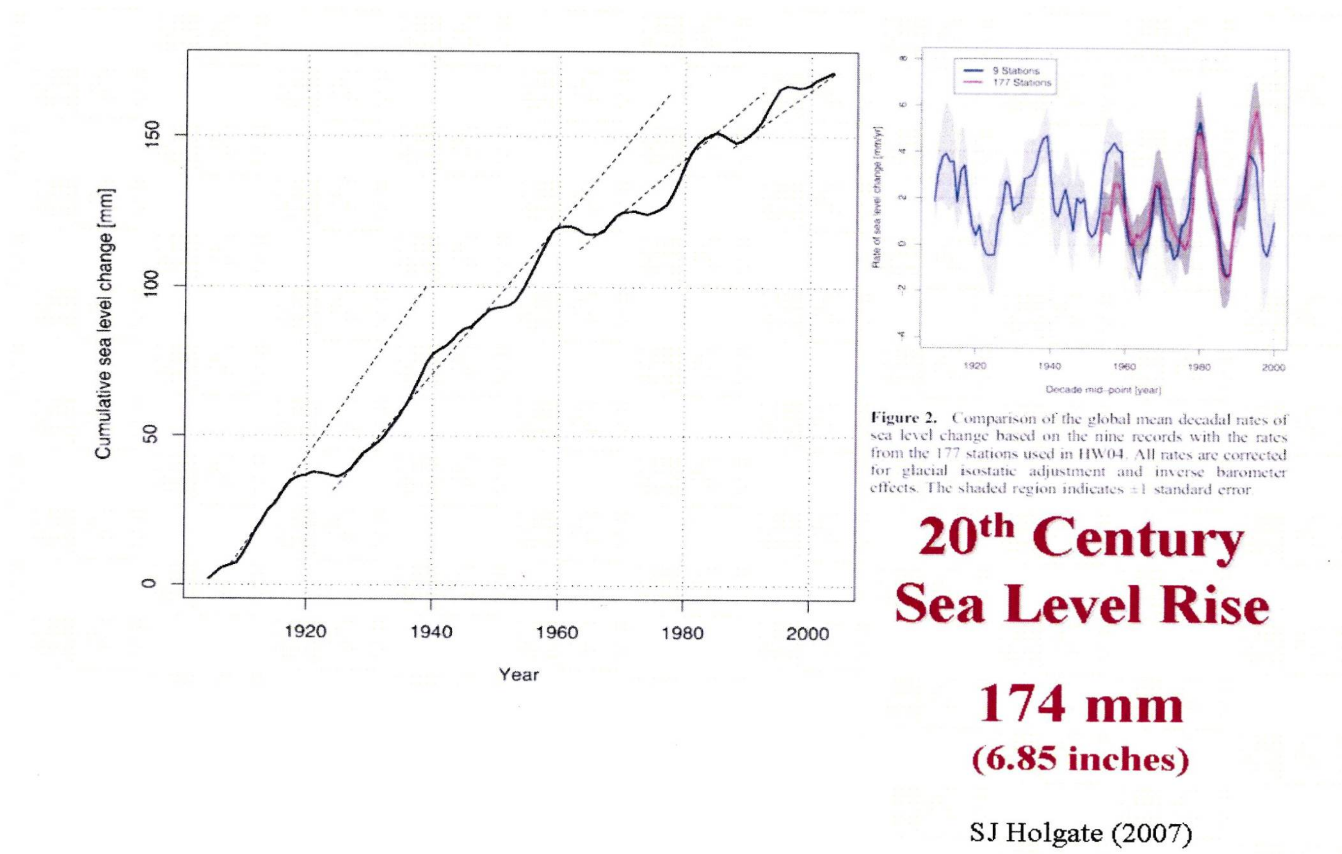

Figure. *The mean sea level record from the nine tide gauges over the period 1904-2003 based on the decadal trend values for 1907-1999. The sea level curve here is the integral of the rates presented in Figure 2.*

2. **Wunsch et al (2007):** This comprehensive study obtains regional estimates of sea level trends using over 100 million data points generated by a 23-layer general circulation model with a 1° horizontal resolution. The general circulation model uses many different types of data including salinity, sea surface temperature, satellite altimetry and Argo float profiles over a period 1993–2004. The study finds large regional variability, governed by thermal, salinity and mass redistribution contribution. Based on a careful analysis of such a large data base, the authors obtain a global mean value of SLR as 1.6 mm/yr which is about 60% of the pure altimetric estimate of 2.8 mm/yr, as mentioned earlier. The authors also identify several uncertainties and regional variations in the altimetric data and conclude that "it remains possible that the database is insufficient to compute sea level trends with the accuracy necessary to discuss the impact of global warming—as disappointing as this conclusion may be."

3. **Wopplemann et al (2008):** This study examines one of the world's longest tide gauge records, at Brest (France), and concludes that the Brest tide gauge is stable over the period 1889–2007. These authors further conclude that the sea level rise at Brest has been at a constant rate for over 100 years and as such the rise does not appear to be influenced by rapid increase in atmospheric CO2 of the last fifty years.

4. **Wenzel et al (2010):** confirms other studies of tide gauge records which show that there has been no statistically significant acceleration in sea level rise over the past 100+ years, in contrast to statements of the IPCC. Sea levels have been rising naturally since the end of the last major ice age 20,000 years ago, and the rate of rise began to decelerate about 8,000 years ago. On shorter timescales, but longer than the annual cycle, the basins sealevels are dominated by oscillations with periods of about 50-75 years and of about 25 years. Consequently, there are high (lagged) correlations between the single basins.

Note: The 1.56 mm/yr non-accelerating rate of sea level rise would result in sea levels 6 inches higher than the present in 100 years. The oscillations noted in this study correspond to the typical full and half-cycle lengths of the natural Pacific Decadal Oscillation and the natural 60-year climate cycle. The Pacific Decadal Oscillation warm phase has been shown to produce a marked temporary rise in global mean sea levels.

5. **Meyssignac et al (2012):** In this study the authors focus on the sea level trend pattern observed by satellite altimetry in the tropical Pacific over the 1993–2009 time span (i.e. 17 yr). The objective was to investigate whether this 17-yr-long trend pattern was different before the altimetry era, what was its spatio-temporal variability and what have been its main drivers.

"We try to discriminate the respective roles of the internal variability of the climate system and of external forcing factors, in particular anthropogenic emissions (greenhouse gases and aerosols). On the basis of a 2-D past sea level reconstruction over 1950–2009 (based on a combination of observations and ocean modelling) and multi-century control runs (i.e. with constant, preindustrial external forcing) from eight coupled climate models, we have investigated how the observed 17-yr sea level trend pattern evolved during the last decades and centuries, and try to estimate the characteristic time scales of its variability.

For that purpose, we have computed sea level trend patterns over successive 17-yr windows (i.e. the length of the altimetry record), both for the 60-yr long reconstructed sea level and the model runs. We find that the 2-D sea level reconstruction shows spatial trend patterns similar to the one observed during the altimetry era. The pattern appears to have fluctuated with time with a characteristic time scale of the order of 25-30 yr. The same behavior is found in multi-centennial control runs of the coupled climate models. A similar analysis is performed with 20th century coupled climate model runs with complete external forcing (i.e. solar plus volcanic variability and changes in anthropogenic forcing)."

"Results suggest that in the tropical Pacific, sea level trend fluctuations are dominated by the internal variability of the ocean–atmosphere coupled system. While our analysis cannot rule out any influence of anthropogenic forcing, it concludes that the latter effect in that particular region is still hardly detectable."

6. **Morner (2010):** Morner, an IPCC reviewer, said he was "astonished to find that not one of their 22 contributing authors on sea levels was a sea level specialist: not one." Morner discussed the realities of a number of countries and islands claimed to be doomed from climate change. He started with the Maldives, which some reports claim will be submerged in the next fifty years. Morner pointed out that the sea level around the Maldives has been much higher

before and actually fell 20 centimeters (7.8 inches) during the 1970s. He also asserted that sea levels have been stable for the past three decades:

In the last 2000 years, sea level has oscillated with 5 peaks reaching 0.6 to 1.2 m above the present sea level. From 1790 to 1970 sea level was about 20 cm higher than today. In the 1970s, sea level fell by about 20 cm to its present level. Sea level has remained stable for th e last 30 years, implying that there are no traces of any alarming on-going sea level rise. He reported this to the President of the Maldives in an open letter in 2009.

Morner (2009) from his Open Letter to the President of the Maldives

Therefore, we are able to free the Maldives (and the rest of low-lying coasts and island around the globe) from the condemnation of becoming flooded in the near future."

For Tuvalu, Morner (2010) found no recent trends. "Over and over again, I have tried to demonstrate (Mörner, 2007; 2010, 2011) that sea is not at all in a rising mode in Tuvalu judging from the only information there is; i.e. the tide gauge records. (See Figure below) The same has been done by others, especially Gray (2010)."

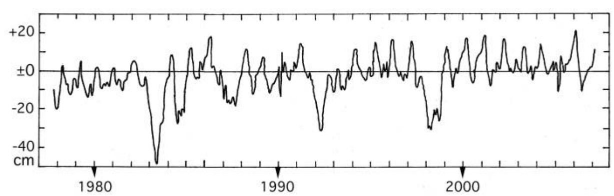

Figure. *Morner 2010 Tuvalu Sea Level Reconstruction from tidal gauges.*

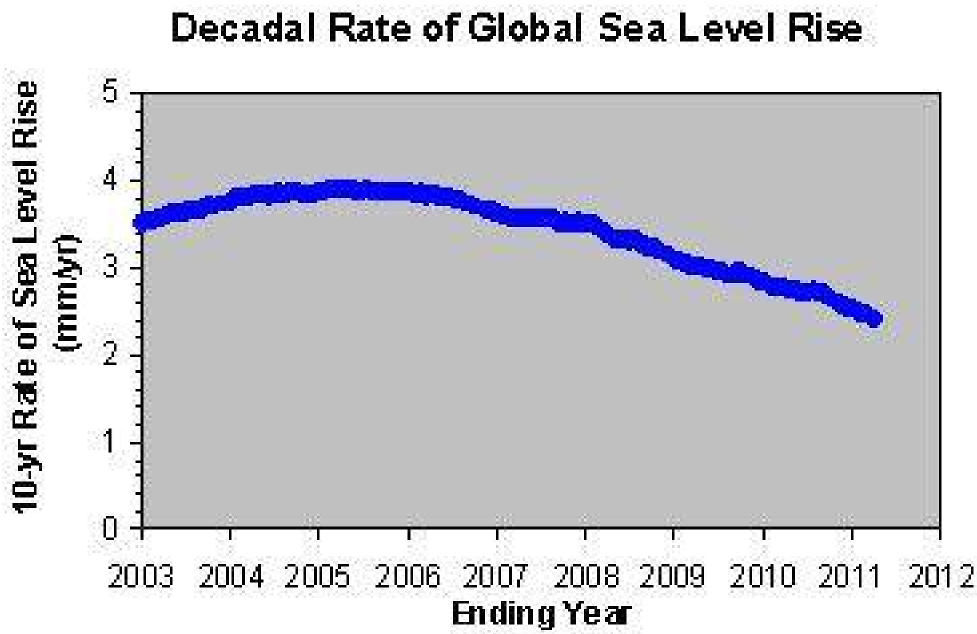

Figure. *The trend in the decadal rate of sea level rise as measured by the satellite-borne altimeters from 1993 through March 2011. Note that these data have been revised since the IPCC AR4 such that the rates of sea level rise do not correspond exactly to those reported by the IPCC in its AR4 (data source and information about the data revisions: University of Colorado Sea Level Research Group)*

7. **Moon et al (2012):** Earlier observations on several of Greenland's outlet glaciers, starting near the turn of the 21st century, indicated rapid (annual-scale) and large (>100%) increases in glacier velocity. Combining data from several satellites, we produce a decade-long (2000 to 2010) record documenting the ongoing velocity evolution of nearly all (200+) of Greenland's major outlet glaciers, revealing complex spatial and temporal patterns. Changes on fast-flow marine-terminating glaciers contrast with steady velocities on ice-shelf–terminating glaciers and slow speeds on land-terminating glaciers. Regionally, glaciers in the northwest accelerated steadily, with more variability in the southeast and relatively steady flow elsewhere. Intraregional variability shows a complex response to regional and local forcing. Observed acceleration indicates that sea level rise from Greenland may fall well below proposed upper bounds.

8. **Hannah et al (2012)**: The two New Zealand scientists report that "the average relative sea level rise calculated from the six newly derived trends was 1.7 ± 0.1 mm/year," a result that

they say "is completely consistent with the far more rigorous and conventional analyses previously undertaken for the four main ports using long-term tide gauge records." And they write that "in a global context, this average trend in relative sea level rise is also consistent with the results of Church and White (2011), who find a global average linear trend in secular sea level rise of 1.7 ± 0.2 mm/year from 1900-2009."

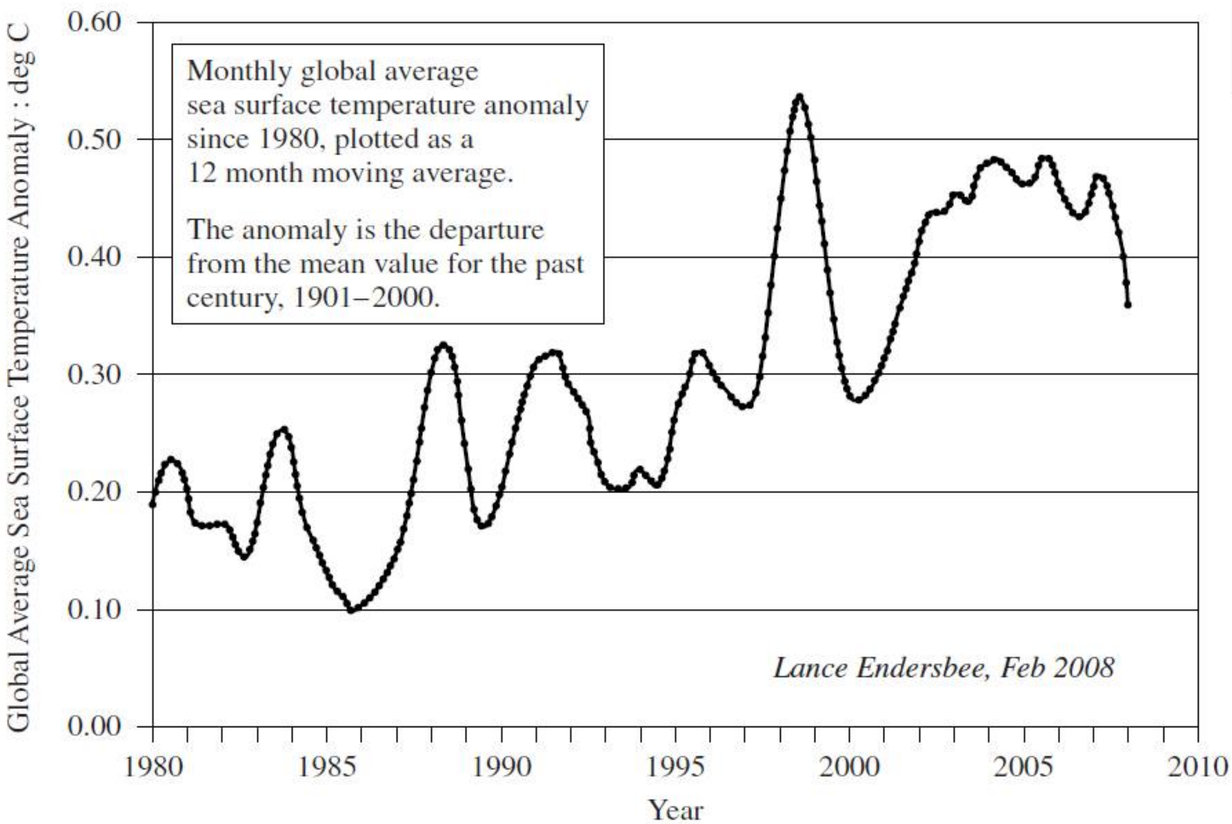

Figure. *Global average sea surface temperature anomalies plotted as a 12-month moving average. (Source: Lance Endersbee, Feb 2008)*

7.3 Sea Level Rise from Melting?

It is now well-established that the Arctic Basin temperature rose sharply in the 1920s and 1930s and the Arctic was at its warmest in 1935/36 during the first half of the twentieth century. Chylek et al (2005) compares the warming of the Arctic between 1920–1930 and 1995–2005 and demonstrates that the Arctic warmed at a faster rate in the 1920s than in the 1990s and in the first few years of the new millennium. In a related paper Vinther et al (2006) extend Greenland temperature records to 1874 using long-term temperature records from the Danish

Meteorological Institute. The paper further documents that the decades 1930s and 1940s were the warmest decades in Greenland and 1941 was the warmest year in the 135-year temperature record of Greenland.

Morner (2010) noted: “At the Last Ice, the huge ice caps over Europe and North America had their southern margins way down at mid latitudes (at Hamburg in Europe and at New York in North America). When climate changed, the ice melted at a very rapid rate. At Stockholm, for example, the ice margin was displaced northwards at a rate of about 300 m per year. Indeed, an enormous speed. Still, global sea level did not rise more than about 10 mm per year or 1 metre in a century. This rate sets the absolutely ultimate physically frame of any possible sea level rise today. Any claim exceeding this value must be classified as sheer nonsense. It is as simple as that. “

The Greenland Ice Cap did not melt during the postglacial hypsithermal (some 5000 to 8000 years ago), when temperature was about 2.5 C higher than today. Nor did it melt during the Last Interglacial when temperature was about 4C higher than today. As to time, it would take more than a millennium (with full thermal forcing) to melt the ice masses stored there. Dr. Richard Alley who has testified to Congress in 2010 about the threat of imminent demise of the Greenland ice sheet has provided analyses that should tell you we do not have a problem in Greenland. In fact, if anything, his data may be suggesting a movement towards a new ice age (Figure below).

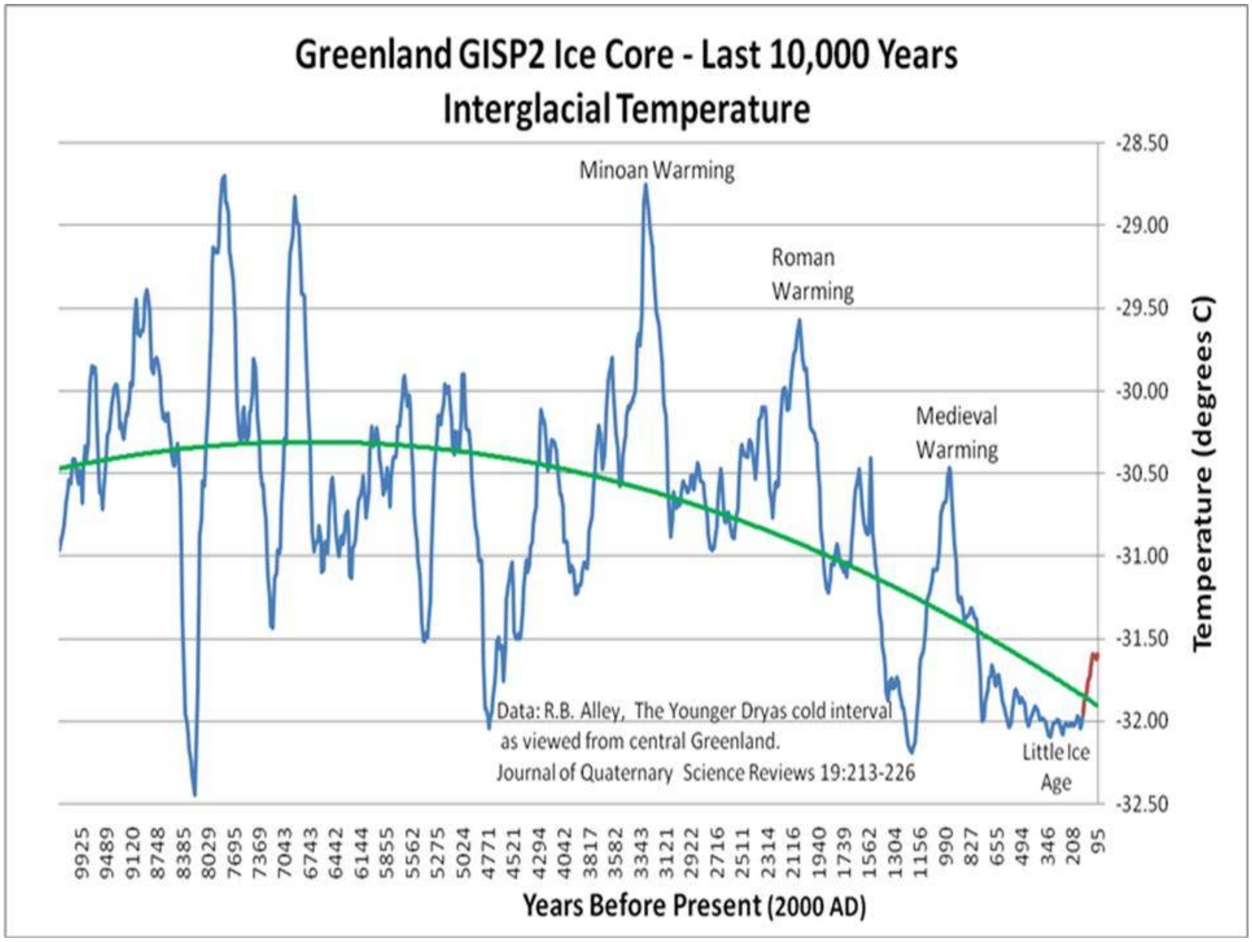

Figure. *Alley GISP2 Ice Core Temperatures during the Post Glacial Period, Journal of Quaternary Science Reviews, 19, 213-226*

Frances et al. (GRL 2007) showed how the warming in the arctic and the melting ice was related to warm water (+3C) in the Barents Sea moving slowly into the Siberian arctic and melting the ice. She also noted the positive feedback of changed "albedo" due to open water then further enhances the warming.

The International Arctic Research Center at the University of Alaska, Fairbanks showed how arctic temperatures have cycled with intrusions of Atlantic water - cold and warm. Frances 2007, confirmed a delayed response to warming in the Barents Sea with loss of ice in the arctic.

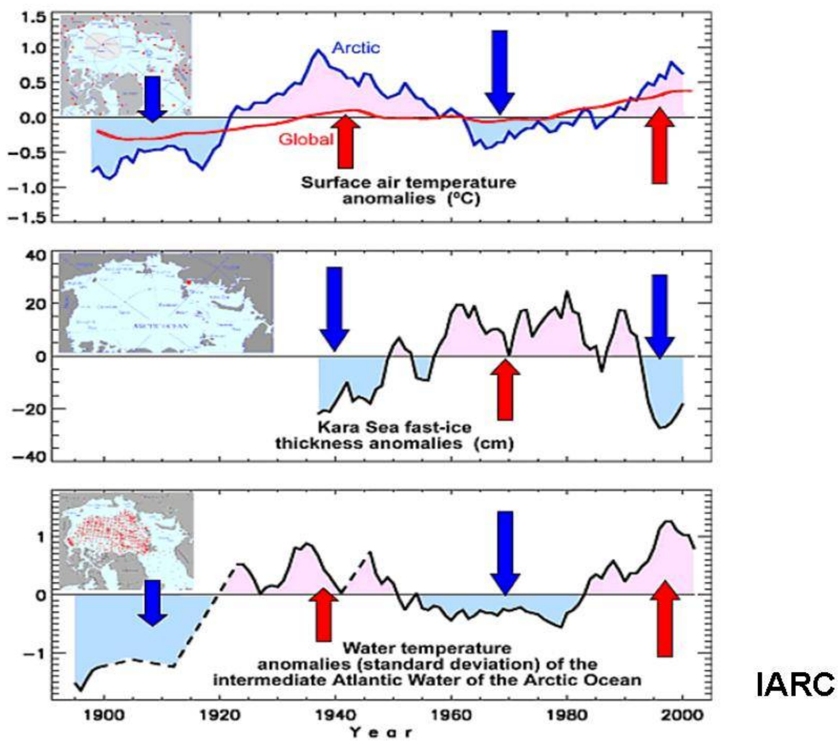

Figure. *Arctic and Global Temperature and Kara Sea Ice versus Atlantic intermediate water [Analysis](#) from International Arctic Research Center, Fairbanks*

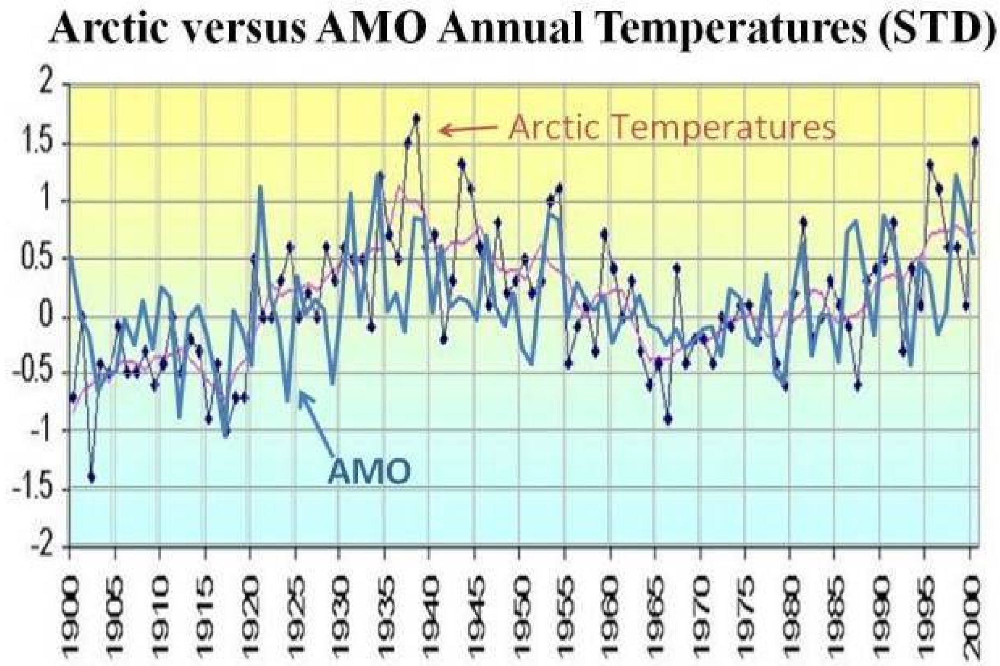

Figure. *Arctic temperatures Polyakov, IARC, UAF and AMO NOAA CDC (annual means)*

Note how the flip to warm of the Atlantic Multidecadal Oscillation(AMO) in 1995 began the latest cyclical decline of arctic ice.

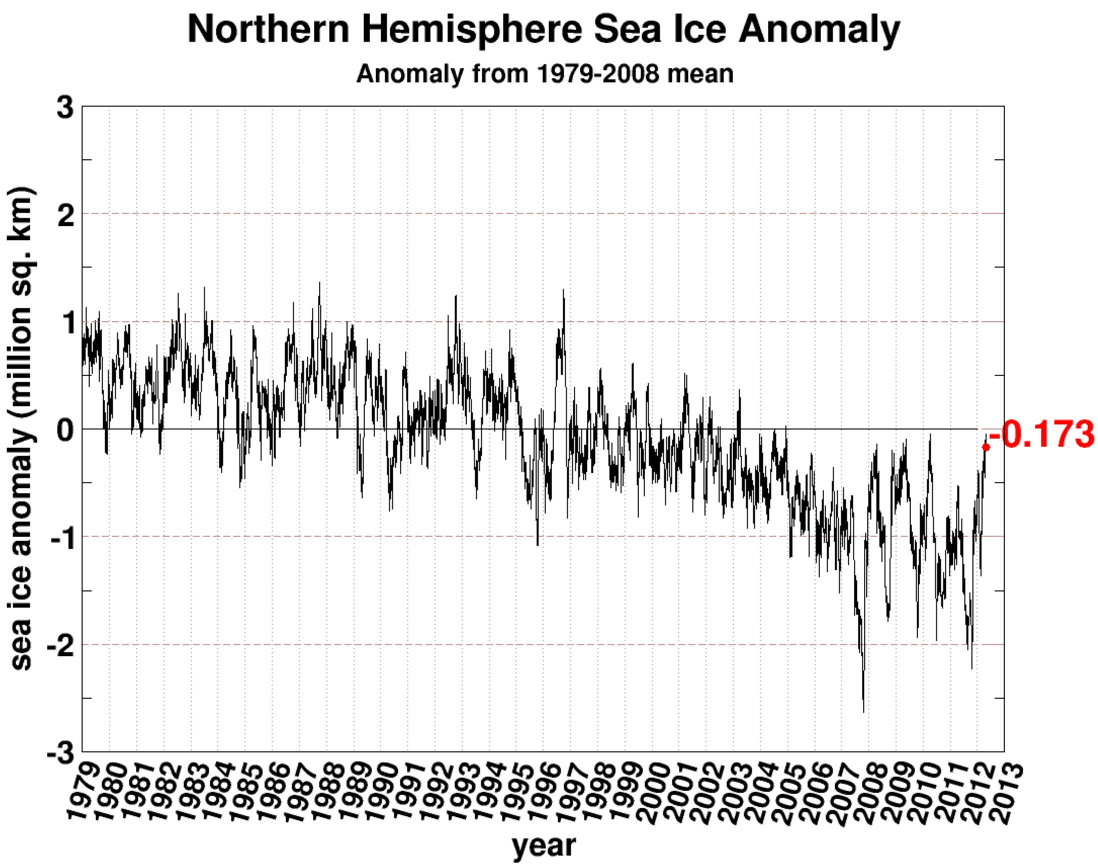

Figure. *Cryosphere Today, UIL, May 7, 2012 Northern Hemisphere Ice Extent Anomalies.*

Note how the ice has recovered in winters in recent years as the AMO has weakened (except for a spike in 2011). It actually was above normal this winter briefly and continues at the high end of the range the last decade.

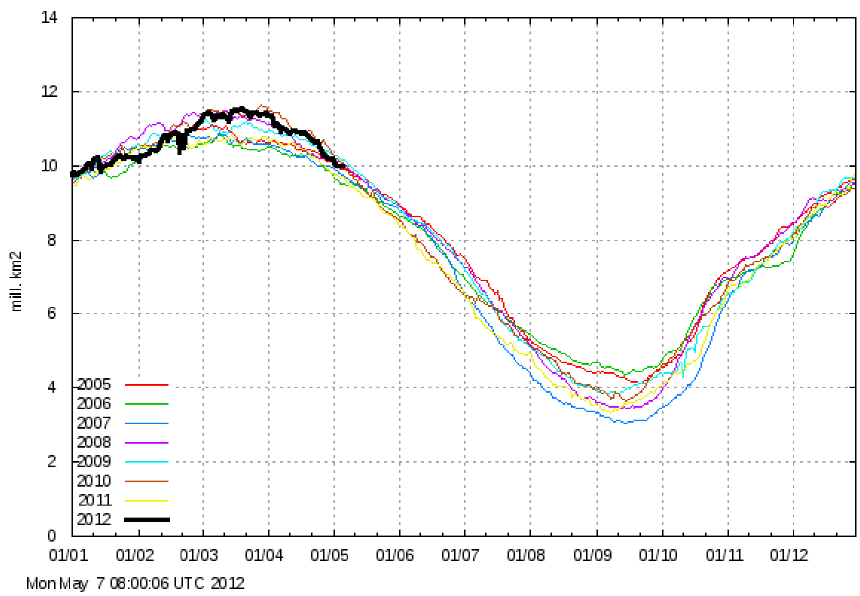

Figure. *Daily Ice Arctic extent 2005-2012 Source [DMI]*

The arctic ice extent is clearly closely related to the Atlantic ocean heat content as Juraj Vanovcan clearly shows in Figure below.

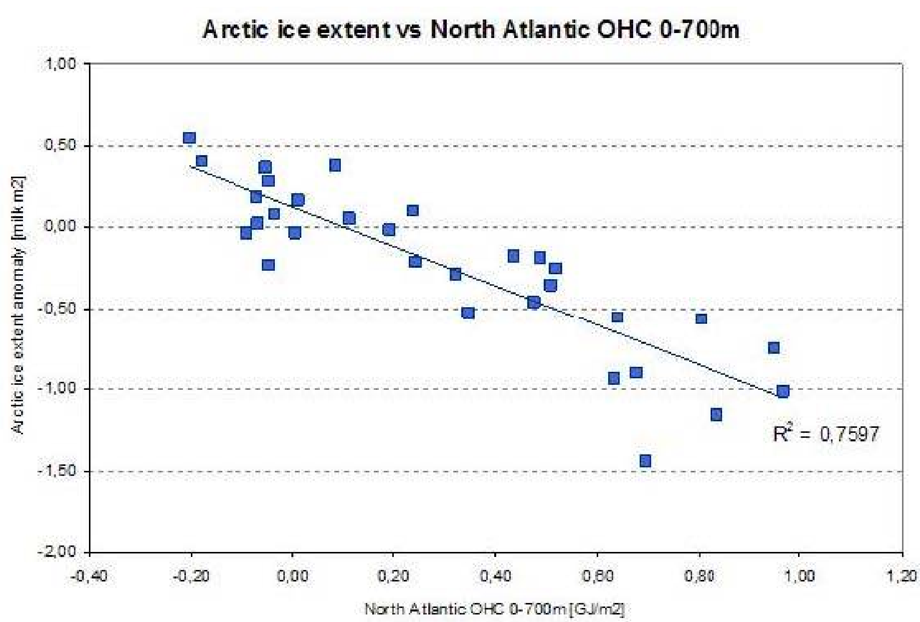

Figure. *Arctic Ice Extent versus North Atlantic Ocean Heat Content (NOAA)*

Source [Juraj Vanovcan]

In view of these observational studies, the Arctic icecap as well as the Greenland Ice Cap may have experienced rapid melting from 1920s through 1940s, but no estimate of any melt rates or of AAR were available due to lack of satellite remote sensing technology in the 1920s and 1930s. The observed worldwide SLR from about 1940 till 2008 is now known to be about 12 cm of which only about 6 to 8 cm rise can be attributed to the possible melting of Greenland Ice Cap together with other Arctic mountain ice caps (see Munk 2002).

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8. IPCC SPECIAL REPORT ON WEATHER EXTREMES (SREX)

The March 2012 "Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (SREX)" provides many striking indications of the lack of certainty around projections of worsening climatic conditions.

Attribution to human causation: IPCC SREX (p. 161) says:

> The AR4 concluded that it is more likely than not that anthropogenic influence has contributed to increases in the frequency of the most intense tropical cyclones (Hegerl et al., 2007). Based on subsequent research that further elucidated the scope of uncertainties in both the historical tropical cyclone data as well as the physical mechanisms underpinning the observed relationships, no such attribution conclusion was drawn in the recent WMO assessment (Knutson et al., 2010). The present assessment regarding detection and attribution of trends in tropical cyclone activity is similar to the WMO assessment (Knutson et al., 2010): the uncertainties in the historical tropical cyclone records, the incomplete understanding of the physical mechanisms linking tropical cyclone metrics to climate change, and the degree of tropical cyclone variability – comprising random processes and linkages to various natural climate modes such as El Niño – provide only low confidence for the attribution of any detectable changes in tropical cyclone activity to anthropogenic influences.

Drought frequency - IPCC SREX (page 170):

> From a paleoclimate perspective recent droughts are not unprecedented, with severe 'megadroughts' reported in the paleoclimatic record for Europe, North America, and Australia (Jansen et al., 2007). Recent studies extend this observation to African and Indian droughts (Sinha et al., 2007; Shanahan et al., 2009): much more severe and longer droughts occurred in the past centuries with widespread ecological, political, and socioeconomic consequences. Overall, these studies confirm that in the last millennium several extreme droughts have occurred (Breda and Badeau, 2008; Kallis, 2008; Büntgen et al., 2010). In North

America, there is medium confidence that there has been an overall slight tendency toward less dryness (wetting trend with more soil moisture and runoff; Table 3-2), although analyses for some subregions also indicate tendencies toward increasing dryness. This assessment is based on several lines of evidence, including simulations with different hydrological models as well as PDSI and CDD estimates (Alexander et al., 2006; Andreadis and Lettenmaier, 2006; van der Schrier et al., 2006a; Kunkel et al., 2008; Sheffield and Wood, 2008a; Dai, 2011). The most severe droughts in the 20th century have occurred in the 1930s and 1950s, where the 1930s Dust Bowl was most intense and the 1950s drought most persistent (Andreadis et al., 2005) in the United States, while in Mexico the 1950s and late 1990s were the driest periods. Recent regional trends toward more severe drought conditions were identified over southern and western Canada, Alaska, and Mexico, with subregional exceptions (Dai, 2011).

Climate extremes projections - IPCC SREX Page 11:

Confidence in projecting changes in the direction and magnitude of climate extremes depends on many factors, including the type of extreme, the region and season, the amount and quality of observational data, the level of understanding of the underlying processes, and the reliability of their simulation in models. Projected changes in climate extremes under different emissions scenarios generally do not strongly diverge in the coming two to three decades, but these signals are relatively small compared to natural climate variability over this time frame. Even the sign of projected changes in some climate extremes over this time frame is uncertain. For projected changes by the end of the 21st century, either model uncertainty or uncertainties associated with emissions scenarios used becomes dominant, depending on the extreme.

Disaster-related losses – IPCC SREX pp. 268-269:

There is high confidence, based on high agreement and medium evidence, that economic losses from weather- and climate-related disasters have increased

(Cutter and Emrich, 2005; Peduzzi et al., 2009, 2011; UNISDR, 2009; Mechler and Kundzewicz, 2010; Swiss Re 2010; Munich Re, 2011). A key question concerns whether trends in such losses, or losses from specific events, can be attributed to climate change. In this context, changes in losses over time need to be controlled for exposure and vulnerability. Most studies of long-term disaster loss records attribute these increases in losses to increasing exposure of people and assets in at-risk areas (Miller et al., 2008; Bouwer, 2011), and to underlying societal trends – demographic, economic, political, and social – that shape vulnerability to impacts (Pielke Jr. et al., 2005; Bouwer et al., 2007). Some authors suggest that a (natural or anthropogenic) climate change signal can be found in the records of disaster losses (e.g., Mills, 2005; Höppe and Grimm, 2009), but their work is in the nature of reviews and commentary rather than empirical research. Attempts have been made to normalize loss records for changes in exposure and wealth. There is medium evidence and high agreement that long-term trends in normalized losses have not been attributed to natural or anthropogenic climate change (Choi and Fisher, 2003; Crompton and McAneney, 2008; Miller et al., 2008; Neumayer and Barthel, 2011).

9. ECONOMIC LOSSES SFROM WEATHER EVENTS

There is an absence of trends in impacts attributable to natural or anthropogenic climate change for tropical and extratropical storms and tornados (Boruff et al., 2003; Pielke Jr. et al., 2003, 2008; Raghavan and Rajesh, 2003; Miller et al 2008; Schmidt et al., 2009; Zhang et al., 2009). Most studies related increases found in normalized hurricane losses in the United States since the 1970s (Miller et al., 2008; Schmidt et al., 2009; Nordhaus, 2010) to the natural variability observed since that time (Miller et al., 2008; Pielke Jr. et al., 2008). Bouwer and Botzen (2011) demonstrated that other normalized records of total economic and insured losses for the same series of hurricanes exhibit no significant trends in losses since 1900. The absence of an attributable climate change signal in losses also holds for flood losses (Pielke Jr. and Downton, 2000; Downton et al., 2005; Barredo, 2009; Hilker et al., 2009), although some studies did find recent increases in flood losses related in part to changes in intense rainfall events (Fengqing et al., 2005; Chang et al., 2009). For precipitation- related events (intense rainfall, hail, and flash floods), the picture is more diverse. Some studies suggest an increase in damages related to a changing incidence in extreme precipitation (Changnon, 2001, 2009), although no trends were found for normalized losses from flash floods and landslides in Switzerland (Hilker et al., 2009). Similarly, a study of normalized damages from bushfires in Australia also shows that increases are due to increasing exposure and wealth (Crompton et al., 2010).

> Increasing exposure of people and economic assets has been the major cause of long-term increases in economic losses from weather- and climate-related disasters (high confidence). The attribution of economic disaster losses is subject to a number of limitations in studies to date: data availability (most data are available for standard economic sectors in developed countries); type of hazards studied (most studies focus on cyclones, where confidence in observed trends and attribution of changes to human influence is low; Section 3.4.4); and the processes used to normalize loss data over time. Different studies use different approaches to normalization, and most normalization approaches take account of changes in exposure of people and assets, but use only limited, if any, measures of vulnerability trends, which is questionable. Different approaches are also used to handle variations in the quality and completeness of data on impacts over time. Finding a trend or 'signal' in a system characterized by large variability or 'noise' is difficult and requires lengthy records. These are all areas of potential weakness in the methods and conclusions of longitudinal loss studies and more empirical and conceptual efforts are needed. Nevertheless, the results of the studies mentioned above are strengthened as they show similar results, although they have applied different data sets and methodologies.

Many more such examples can be found. In light of the general failure of climate models to accurately make predictions at the regional level, and the admission of the IPCC that there is no evidence of trends in damages from extreme weather and/or a link to greenhouse gas emissions, the EPA's claim to know that greenhouse gas emissions will have specific, endangering effects on U.S. regions is groundless.

10. HEALTH

10.1 Heat-related Human Mortality

Chapter 3 of EPA's RIA has this to say about heat-related mortality:

> Regarding direct temperature changes, it has already been estimated that unusually hot days and heat waves are becoming more frequent, and that unusually cold days are becoming less frequent. Heat is already the leading cause of weather-related deaths in the United States. In the future, severe heat waves are projected to intensify in magnitude and duration over the portions of the United States where these events already occur. Heat waves are associated with marked short-term increases in mortality. Hot temperatures have also been associated with increased morbidity. The projected warming is therefore projected to increase heat related mortality and morbidity, especially among the elderly, young, and frail. The populations most sensitive to hot temperatures are older adults, the chronically sick, the very young, city dwellers, those taking medications that disrupt thermoregulation, the mentally ill, those lacking access to air conditioning, those working or playing outdoors, and socially isolated persons. As warming increases over time, these adverse effects would be expected to increase as the serious heat events become more serious.

Many of these statements and conclusions are controversial and challenged by other findings in the peer-reviewed scientific literature. Other statements and conclusions are based on methodologies that the IPCC find unacceptable—a situation that undermines EPA's claim that "[t]he major assessments by the U.S. Global Change Research Program (USGCRP), the Intergovernmental Panel on Climate Change (IPCC), and the National Research Council (NRC) served as the primary scientific basis for these effects."

The EPA produces a chain of events, which at first glance seems logical, but when the light of sound science is shined upon it, turns out to be scientifically, socially, and methodologically wrong.

The EPA's chain of events goes like this: "[h]eat waves are associated with marked short-term increases in mortality" and "[i]n the future, severe heat waves are projected to intensify in magnitude and duration over the portions of the United States where these events already occur" and thus "[t]he projected warming is therefore projected to increase heat related mortality and morbidity, especially among the elderly, young, and frail."

The reason this chain of events is incorrect, in that the EPA—by its own admission—refuses to consider the impacts of adaptation—a powerful force, both autonomous and planned—proven effective to reduce heat-related mortality even in the face of rising temperature. According to the 2009 endangerment finding,

> EPA considers adaptation and mitigation to be potential responses to endangerment, and as such has determined that they are outside the scope of the endangerment analysis.

Based on this stance, it is impossible for the EPA to arrive at a proper conclusion as to the public health impacts of potentially increasing heat waves.

The IPCC—an organization favored by the EPA for relying on in its endangerment finding—specifically and repeatedly makes this known:

> Predictions or estimates of likely future adaptations are an essential element of climate change impact and vulnerability assessment. The degree to which a future climate change risk is dangerous depends greatly on the likelihood and effectiveness of adaptations in that system. (IPCC, TAR, WGII, p.885*)*

and, more broadly,

> Estimates of likely future adaptations are essential parts of climate change impact models. Integrated assessment models also include assumptions about adaptations in the impact components (Leemans, 1992; Rotmans et al., 1994; Dowlatabadi, 1995; Hulme and Raper, 1995; West and Dowlatabadi, 1999). Some early studies of impacts assumed no adaptation (Tol et al., 1998), invoking the so-called "naive" or "dumb farmer" assumption. The "dumb farmer" assumption—which is not unique to agriculture—is a metaphor for any impacted agent that is assumed not to anticipate or respond to changed climate conditions but continues to act as if nothing has changed (Rosenberg, 1992; Easterling et al., 1993; Smit et al., 1996). By ignoring autonomous and planned adaptations, such studies do not distinguish between potential and residual net impacts and are of limited utility in assessing vulnerability.
>
> An alternative approach that is common in more recent impact modeling has been to assume levels of adaptation." (IPCC, TAR, WGII, p.886-887, emphasis added).

The IPCC, unlike, the EPA, recognizes the inherent role that adaptation plays is reducing human population's sensitivity the climate change, and considers evaluations which do not include adaptive responses to be "of limited utility"—and yet the EPA relies on such a methodology to based its Endangerment Finding which underlies these Proposed Performance Standards. This is unacceptable practice and requires a re-evaluation.

Examples of the effectiveness of adaptation in reducing heat-related mortality are commonplace in the scientific literature.

All heat related mortality is preventable (Ebi, 2012). The measures to do so are not overly complicated, nor are they particularly expensive. Simple heat wave awareness programs stressing proper clothing, proper hydration, and other behavioral modification have shown to be successful in reducing heat-related mortality (Das, 2011). Community responses such as programs to check on the elderly and the opening of temporary "cooling" centers have also proven quite effective (Palecki et al., 2001). And commonly available technology, such as air-conditioning, further reduces heat-related mortality (Davis et al., 2003b)—so long as it is in use.

Heat watch/warnings issued through the National Weather Service help announce when such measures should be enacted, resulting in lives saved (Ebi et al., 2004). Physiological adaptation also plays a role in reducing the population's sensitivity to extreme heat events (heat waves) (Gosling et al., 2008).

In locations in the U.S. where very high temperatures are commonplace the sensitivity to them is greatly reduced to such a degree that statistically speaking, heat-related mortality has been virtually eliminated (Davis et al., 2002; 2003a, 2003b). In cities where extreme heat events are less common, such as the upper Midwest and Northeast, a heat-related mortality signal is still present, although it has declined significantly in most large urban areas since the late-1960s/early 1970s (Davis et al., 2002; 2003a, 2003b).

In a multi-decadal study examining trends in heat-related mortality in six cities in the eastern U.S., Davis et al. (2002) noted significant declines from the mid-1960s through the late 1990 in population adjusted heat-related mortality in the cities in the northeastern U.S. (Boston, Philadelphia, New York) and found no statistically identifiable heat-related in the southern cities of Miami and Charlotte. Declines in heat-related mortality to levels that were no longer statistically significant were also reported in North Carolina by Donaldson et al. (2004). In studies which were expanded to include 28 major cities across the U.S., Davis et al. (2003a, 2003b) found the general patterns identified in Davis et al. (2002) to apply nearly nationwide—that is, declines in heat-related mortality were widespread across cities in the Midwest and Northeastern U.S., while statistically identifiable heat-related mortality had dropped to zero by the 1990s in most southern (warmer) U.S. cities. Davis et al. (2003b) noted that:

> In general, over the past 35 years, the U.S. populace has become systematically less affected by hot and humid weather conditions. All-causes mortality during heat stress events has declined despite increasingly stressful weather conditions in many urban and suburban areas. This relative "desensitization" of the U.S. metropolitan populace to weather-related heat stress can be attributed to a variety of factors, including improved medical care, infiltration of air conditioning, better public awareness programs relating the potential dangers of heat stress, and both human biophysical and infrastructural adaptations. Thus, heat-related mortality in

> the United States seems to be largely preventable at present… With respect to projections of future heat-related mortality that might arise from greenhouse-gas–induced warming, urban warming, or other factors, it is clear that these projections must incorporate the observed reductions in heat vulnerability.

The highlighted section closely mirrors similar recommendations by the IPCC—recommendations ignored by the EPA.

The decline in heat-related mortality across the U.S. has continued beyond the 1990s (the end of the period examined in the Davis et al. series of studies) and into the 21st century. Kalkstein et al. (2010) examined trends in heat-related mortality from extreme heat events (EHE) in 40 major U.S. cities using data extending to 2004 and reported that "Our results generally show a reduction in EHE-attributable mortality rates since 1996."

Kalkstein et al. (2010) saw room for extending the declines into the future, reporting "Our results indicate there is promise for further reductions in EHE-attributable mortality from the approximately 1300 excess deaths per summer we identify using data from the 1975–2004 period." And given the observed declines in heat-related mortality coupled with promise for the trends to continue into the future, Kalkstein et al. (2010) recommended "Our results also raise important questions with respect to…how EHE-attributable mortality should be estimated for future scenarios, notably for climate change projections."

The decline of heat-related mortality across the U.S. is apparent in elderly populations—populations which as especially vulnerable to high temperatures. Barnett (2007) examined daily cardiovascular mortality from elderly populations in 107 cities across the U.S. from 1987-2000 and noted that "Heat-related cardiovascular deaths in the elderly have declined over time, probably due to increased use of air conditioning, while increased risks with cold-related temperature persist."

Declines in the population's sensitivity to extreme temperature events can also be found in other area across the world—an indication that adaptation is a universal response and not specific to a few individual locations or instances. Further reason why the EPA is wrong to ignore it. Carson et al. (2006) examined trends in temperature related mortality in London, England and reported

> Heat deaths also diminished over the century. There was a progressive reduction in temperature-related deaths over the 20th century, despite an aging population. This trend is likely to reflect improvements in social, environmental, behavioral, and health-care factors and has implications for the assessment of future burdens of heat and cold mortality.

Donaldson and Keatinge (2008) found declines in heat-related mortality throughout the whole of England. Matzarakis et al. (2011) documented heat-related mortality declines in Vienna, Austria. Tan et al. (2007) found declines in Shanghai.

Most recently, Kyselý and Plavocá (2012) studied the impacts of heat waves across the Czech Republic and noted that future warming may have little impact on that country's heat-related mortality as adaptations outpace climate changes and that consideration of adaptation must be included in assessments of future impacts:

> Declining trends in the mortality impacts are found in spite of rising temperature trends…. The results suggest that climate change may have relatively little influence on heat-related deaths, since changes in other factors that affect vulnerability of the population are dominant instead of temperature trends. It is essential to better understand the observed nonstationarity of the temperature-mortality relationship and the role of adaptation and its limits, both physiological and technological, and to address associated uncertainties in studies dealing with climate change projections of temperature-related mortality.

Most importantly, the decline in sensitivity to heat events has occurred in the face of rising summer temperatures (Davis et al., 2002; 2003a, 2003b; Donaldson et al., 2004; Donaldson and Keatinge, 2008; Matzarakis et al., 2011; Kyselý and Plavocá, 2012). The role that rising temperatures or an increase in heat-wave frequency/intensity has played in the decline in heat-related mortality rates is unclear, although cases where effective response measures have been established prompted by the occurrence of a deadly heat wave have been documented both in the U.S. (Palecki et al., 2001; Weisskopf et al., 2002) and abroad (Tan et al., 2007; Fouillet et al., 2008). This would suggest that the occurrence of heat-waves themselves hasten the adaptive response and thus act to lower the population's sensitivity to future heat-waves. So long as extreme heat events occur with enough frequency to remain in the public's attention (and avoid the risk of forgetting the past—the establishment of heat watch/warning systems helps in this accord (Sheridan and Kalkstein, 2004 and updates; Ebi et al., 2004)), adaptive measures should remain in place and act to lower the heat-related mortality rate—just as is the case in those cities where high heat is commonplace. Therefore, it follows that an increase in the occurrence of heat waves should act to prompt a decline in the rate of heat-related mortality across the U.S.

In a very comprehensive review of the heat-related mortality literature, Gosling et al. (2008) stressed the importance of including adaptation (including biophysical acclimitization—an autonomous response which occurs without any intervention) when modeling future impacts of climate change:

> Adaptation includes physiological acclimatisation as well as a range of behavioural adaptations (e.g. dressing appropriately during hot weather) and technological adaptations (e.g. air conditioning or the introduction of heat health watch warning systems). Most temperature–mortality studies focus on modelling present relationships by time-series analysis (Páldy et al. 2005; Hajat et al. 2002, 2005; Davis et al. 2003a; O'Neill et al. 2003; Pattenden et al. 2003; Curriero et al. 2002; Gemmell et al. 2000; Danet et al. 1999; Ballester et al. 1997), meaning that predictions of future mortality based on them assume the relationship is stationary; i.e. that future temperature–mortality relationships will be identical to past ones. However, it has been shown that such time series are non-stationary in nature (Davis et al. 2002, 2003a, b) so that they cannot be easily applied to future scenarios of climate and demographic change. The effects of any potential adaptation to a changing climate imply that non-stationary models are required.

Again, in Gosling et al.'s review of the literature, they stress what is a seemingly universal viewpoint (everywhere, except at the EPA, that is) "The effects of any potential adaptation to a changing climate imply that non-stationary models are required."

As has been shown here, adaptation to heat waves is capable of eliminating heat-related mortality, and in fact has already been observed to have done so in many areas of the United States and has been leading to declines in heat-wave mortality in most others. Adaptation to heat waves also has the potential to produce the net effect of improving public health—in the face of, or even because of, intensifying heat waves. That the EPA does not even consider this possible (probable) outcome runs counter to the best and recommended scientific practices as reflected in the scientific literature as well as in the IPCC. Consequently, the EPA's judgments on heat-related mortality and public health/welfare are unacceptable for basing the proposed rule.

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10.2 Net Heat/Cold-related Human Mortality Changes

Chapter 3 of EPA's RIA has this to say about the topic of heat/cold-related mortality:

> Increases in temperature are also expected to lead to some reduction in the risk of death related to extreme cold. It is not clear whether reduced mortality in the United States from cold would be greater or less than increased heat-related mortality in the United States due to climate change. However, there is a risk that projections of cold-related deaths, and the potential for decreasing their numbers due to warmer winters, can be overestimated unless they take into account the effects of season and influenza, which is not strongly associated with monthly winter temperature. In addition, the latest USGCRP report (2009) refers to a study (Medina-Ramon and Schwartz, 2007) that analyzed daily mortality and weather data in 50 U.S. cities from 1989 to 2000 and found that, on average, cold snaps in the United States increased death rates by 1.6 percent, while heat waves triggered a 5.7 percent increase in death rates. The study concludes that increases in heat-related mortality due to global warming in the United States are unlikely to be compensated for by decreases in cold-related mortality.

This is a grossly incomplete picture of the prevailing scientific literature on this topic. In fact, a scientific paper has recently been published which directly and specifically refutes the findings of the Medina-Ramon and Schwartz (2007) cited by the EPA to support its conclusions.

Anderson and Bell (2009) investigated how heat, cold, and heat-waves affect mortality in the U.S. and found that the magnitude of the cold effect on mortality was similar to that of the heat effect. Anderson and Bell (2009) specifically contrasted their results with those of Medina-Ramon and Schwartz (2007), citing methodological weaknesses in the Medina-Ramon and Schwartz (2007) study:

> Heat and cold effects were similar in magnitude for absolute and relative estimates, which contrasts with earlier US studies finding larger heat effects than cold effects [Medina-Ramon and Schwartz, 2007; Chestnut et al., 1998]. We hypothesize that previous studies underestimated cold-related effects through use of shorter lags. Results agree with a European study finding mortality effects occurring days to weeks after cold exposure [Pattenden et al., 2003].

The methodological flaw of Media-Ramon and Schwartz (2007) of using too short a lag period when assessing cold-related deaths vs. heat-related deaths leads to an underestimation of the effects of the cold. In another cold vs. heat study, Deschênes and Moretti (2009) found that the net cumulative mortality impact of heat-waves was high within a few days after an excessive heat event, but subsequently dropped to zero after about 30 days due to the impacts of mortality displacement. Cold-related mortality exhibited a cumulative net increase during a 30 day period after cold exposure. According to Deschênes and Moretti (2009):

> Our findings indicate that increases in mortality caused by cold temperature are long lasting. We find evidence of a large and statistically significant permanent effect on mortality of cold waves. By contrast, the increases in mortality associated with heat waves are short lived. The increase in mortality that occurs in the days immediately following heat waves appears entirely driven by temporal displacement.

Thus, if exposure to cold temperatures was mitigated by a warming climate, the net impacts on human mortality would be an overall decline.

A similar result was found in recent study of 15 cities across nearby Canada. Martin et al. (2011) reported that projected cold-related mortality declines offset heat-related mortality increases in 11 of the 15 cities that they analyzed, although they pointed out a weakness in their model in that they did not consider changing relationships between temperature and mortality.

And most recently, Barreca (2011) accounted for changes in humidity as well as changes in temperature when assessing impacts on human mortality and found that "humidity, like temperature, is an important determinant of mortality." Barreca (2011) coupled observed mortality rates with Hadley CM3 climate-change predictions, and projected that "mortality rates will change very little on the aggregate for the United States by the end of the 21st century."

These studies contrast with the EPA's assertion that with a warming climate, increases in heat-related mortality will outpace decreases in cold-related mortality in the U.S.—despite these studies not adequately taking into account adaptation, which, as shown in a previous section of this report, has been observed to greatly reduce heat-related mortality.

Further, in Chapter 3 of the RIA, the EPA states that:

> In addition to impacts on heat-related mortality and air quality, there is also the potential for increased deaths, injuries, infectious diseases, and stress-related disorders and other adverse effects associated with social disruption and migration from more frequent extreme weather.

In a recent study specifically designed to analyze the impacts of migration from extreme weather events, Deschênes and Moretti (2009) find that people are actively moving away from the cold and into the heat—inducing, by choice, a change in their personal thermal climate similar in character to that projected to occur due to anthropogenic greenhouse gas emissions. Deschênes and Moretti (2009) conclude that this migration away from the cold has had profound impact towards reducing mortality in the U.S.

> We estimate the effect of extreme weather on life expectancy in the United States. Using high-frequency data, we find that both extreme heat and cold result in immediate increases in mortality. The increase in mortality following extreme heat appears mostly driven by near-term displacement, while the increase in mortality following extreme cold is long lasting. We estimate that the number of annual deaths attributable to cold temperature is 0.8% of average annual deaths in our sample. The longevity gains associated with mobility from the Northeast to the Southwest account for 4% to 7% of the total gains in life expectancy experienced by the U.S. population over the past thirty years. [emphasis added]

Recent science provides compelling evidence that the EPA's conclusions regarding cold/heat related mortality are out of date and must be re-evaluated and revised. As it stands now, the EPA's conclusions do not rest on the best available science.

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10.3 Health – Ozone Effects

Chapter 3 (p. 37) of the RIA states that climate change will worsen ozone pollution. That is incorrect. With or without climate warming, ozone will decline substantially in the future. The lesson of the past few decades is "higher temperatures, lower ozone." Ozone declined all over the U.S., with the greatest improvements occurring in the most polluted areas of the country. The ozone declines were due to reductions in ozone-precursor emissions. Already-adopted measures will eliminate the vast majority of remaining ozone-precursor emissions during the next few decades, resulting in continued ozone reductions, even if the climate warms in the future.

Both modeling and observations suggest that ozone-precursor reductions between the late 1990s and 2011 have already eliminated most of the "climate penalty". Since ozone-precursor emissions are dropping rapidly, whatever climate penalty remains will likely disappear within a decade or two, as most remaining ozone-precursor emissions are eliminated by already-adopted measures.

Past experience shows that reducing ozone-precursor emissions reduce ozone, regardless of whether the climate warms. EPA itself reports dramatic declines in ozone during the last few decades, despite climate warming over the same period. EPA's TSD for its endangerment finding states, "According to studies cited in Karl et al. (2009), the annual average temperature in the Northeast has increased by 2°F (1°C) (relative to a 1960-1979 base period) since 1970" (EPA 2009c). Nevertheless, EPA's own monitoring data demonstrate that ozone levels decreased dramatically during the same period, as shown in Figure 1. Figure 1 comes directly from EPA's own AirTrends website (http://www.epa.gov/airtrends/ozone.html, accessed June 10, 2012).

As the graph shows, from 1980-2010, average peak ozone levels decreased by 28 percent. Peak ozone levels improved even more in areas with the highest ozone levels. The top of the blue-shaded area represents the 90th percentile among all monitoring locations in the U.S. Note that the 90th percentile ozone level declined from about 125 ppb in 1980 down to about 80 ppb in 2010, a 36 percent decrease.

The Figures below show similar data over a longer time period and demonstrate continuing declines in ozone.

Overall, the lesson of the last 40 years is "higher temperatures, lower ozone." It is, of course, possible that ozone would have been even lower had the temperature not warmed. Regardless, the fact is that 2°F of warming did not prevent dramatic declines in ozone levels during the last 40 years. EPA never explains why we should expect the future to be the opposite of the past and does not even mention that past ozone levels declined dramatically despite warming of similar magnitude to what it predicts will occur between now and 2050.

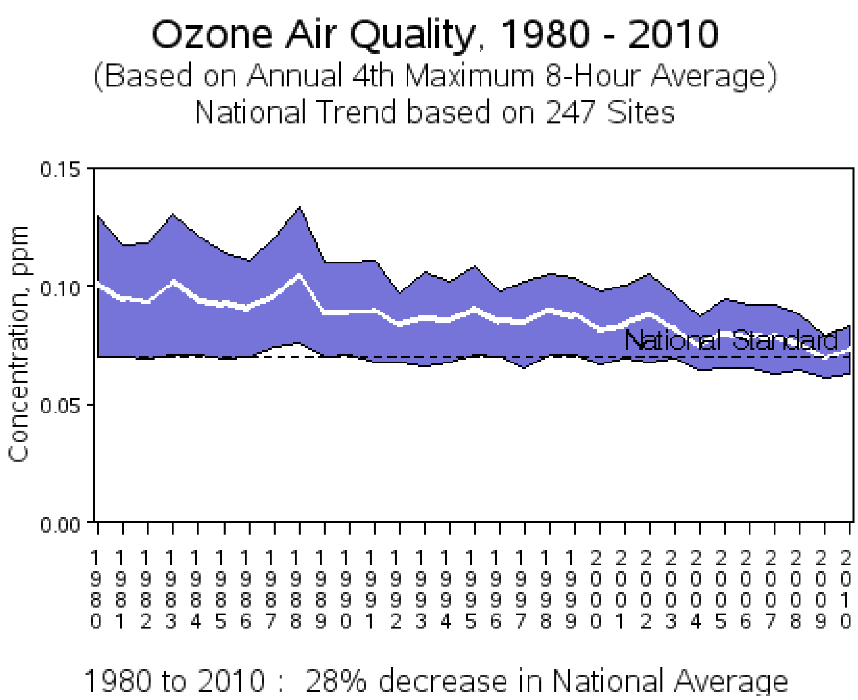


Figure. *National Trend in Peak Ozone Levels from 1980-2010*

Source: Graphic downloaded from http://www.epa.gov/airtrends/ozone.html (accessed June 12, 2012).

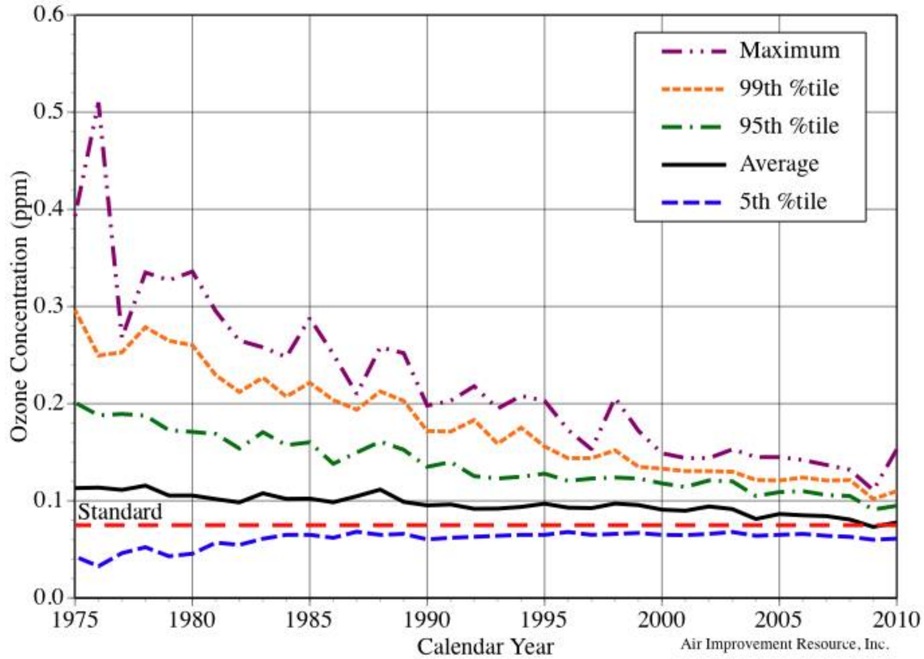


Figure. *Highest Annual 8-hour Ozone Concentrations for All U.S. Monitoring Locations from 1975-2010*

Source: Dennis Kahlbaum, Air Improvement Resource, using ozone monitoring data downloaded from EPA.

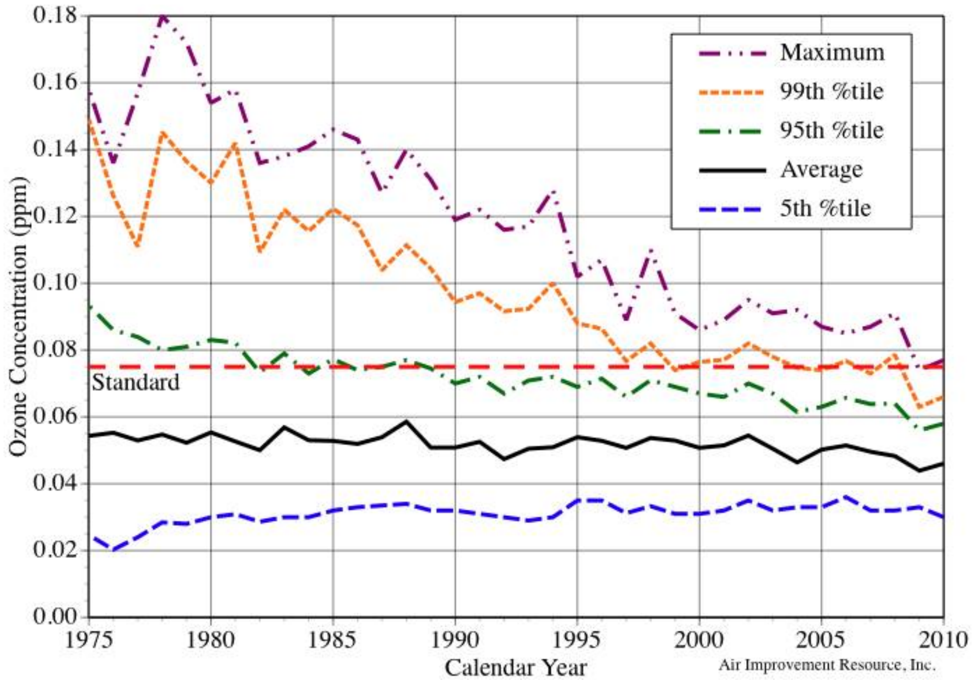


Figure. *June-August Average of Daily Peak 8-hour Ozone Concentrations for All U.S. Monitoring Locations from 1975-2010*

Source: Dennis Kahlbaum, Air Improvement Resource, using ozone monitoring data downloaded from EPA.

The fact that ozone has declined as the climate has warmed suggests that ozone levels are becoming less and less sensitive to temperature over time. One way to check this is by looking at the ratio of the number of ozone exceedance days each year to the number of hot days each year in a given city. Schwartz and Hayward (2008) did such an assessment for a number of U.S. cities representing major geographical areas of country and including cities with the highest ozone levels in the nation. The results are shown in Figure 4.

The Figure below shows the ratio of the number of days exceeding a given ozone level to the number of days exceeding 90ºF each year average over 10 cities. In the early 1980s, the number of 8-hour, 85 ppb ozone exceedances per hot day was around 0.6 to 0.8. By the mid-2000s, the ratio had dropped to about 0.15 to 0.3. The improvement was even more dramatic for the higher ozone levels probed by the old 125 ppb, 1-hour standard. Between 1982 and 2005, the number of 1-hour exceedance days per hot day dropped from 0.3 to near zero. In other words, ozone levels have been becoming steadily less and less sensitive to temperature. The fact that ozone levels have continued to decline in the years since 2005 shows that this downward trend in the sensitivity of ozone levels to temperature has continued.

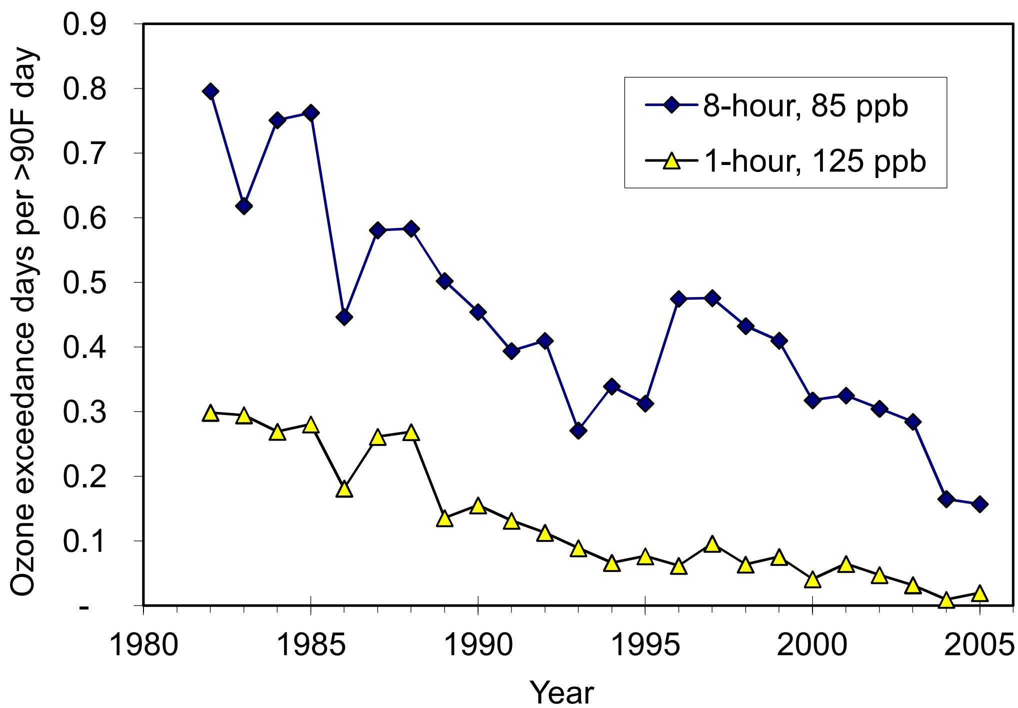


Figure. *Trend in the Ratio of Days per Year Exceeding A Given Ozone Level to Days per Year With Temperature Greater Than 90°F*

SOURCES: Air pollution data were downloaded from EPA's Air Quality System (AQS) database, http://www.epa. gov/ttn/airs/airsaqs/detaildata/downloadaqsdata.htm and http://www.epa.gov/ttn/airs/airsaqs/archived% 20data/downloadaqsdata-o.htm (accessed November 27, 2006). Temperature data were downloaded from the National Climatic Data Center, Summary of the Day (Data Set TD-3200), http://ncdc.noaa.gov (accessed October 3, 2006).

NOTES: Figure is based on ozone and temperature data for ten metropolitan areas: Atlanta, Baltimore, Charlotte, Chicago, Cincinnati, Houston, Los Angeles, Nashville, New York, and Philadelphia. Ozone exceedance days for a given metropolitan area were calculated as the average number of exceedance days each year for all monitoring sites in an area with continuous data. This was then divided by the number of days each year with peak temperature greater than 90°F. The graph gives the average ratio across the ten metropolitan areas. The year 1982 was the earliest time period for which all of the cities had at least one continuously operated monitoring site.

Indeed, EPA itself presents data showing that ozone is becoming less and less sensitive to temperature. The Figure below was downloaded from the EPA Region 1 (New England) web site. It shows the number of ozone exceedance days in New England from 1983 to 2011 based on both the 85 ppb 8-hour ozone standard and the new 75 ppb 8-hour ozone standard.

First, note that the number of ozone exceedance days has substantially declined. Exceedances of the 85 ppb threshold decreased from about 40 to 50 days per year in the late 1980s down to about 5 to 10 days per year during the last few years. Likewise, exceedances of the 75 ppb threshold dropped from about 55 to 70 days per year down to about 15 to 30 days per year over the same period.

Second, note that ozone levels are becoming much less sensitive to temperature. The graph shows that 1983, 2002, and 2010 all had about 39 days of at least 90°F, yet the number of 75 ppb ozone exceedance days dropped from 115 to 55 to 30 for the three time periods, respectively. Likewise, the number of 85 ppb exceedance days dropped from 90 to 43 to 10, respectively. In other words, given similarly hot summers, the number of 75 ppb and 85 ppb ozone exceedance days dropped 74 percent and 89 percent, respectively. And this is in the Northeast—the region EPA says is among the most sensitive to the effects of temperature on ozone. Once again, this suggests that temperature is a minor factor when compared with reductions in ozone precursors.

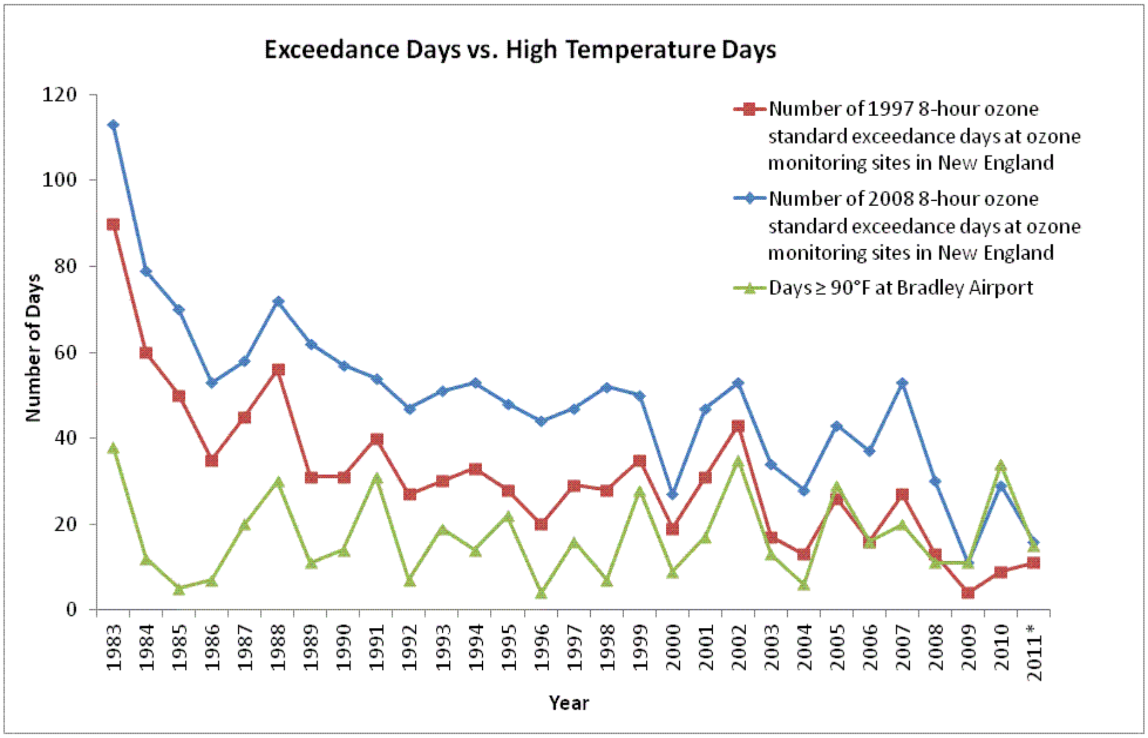
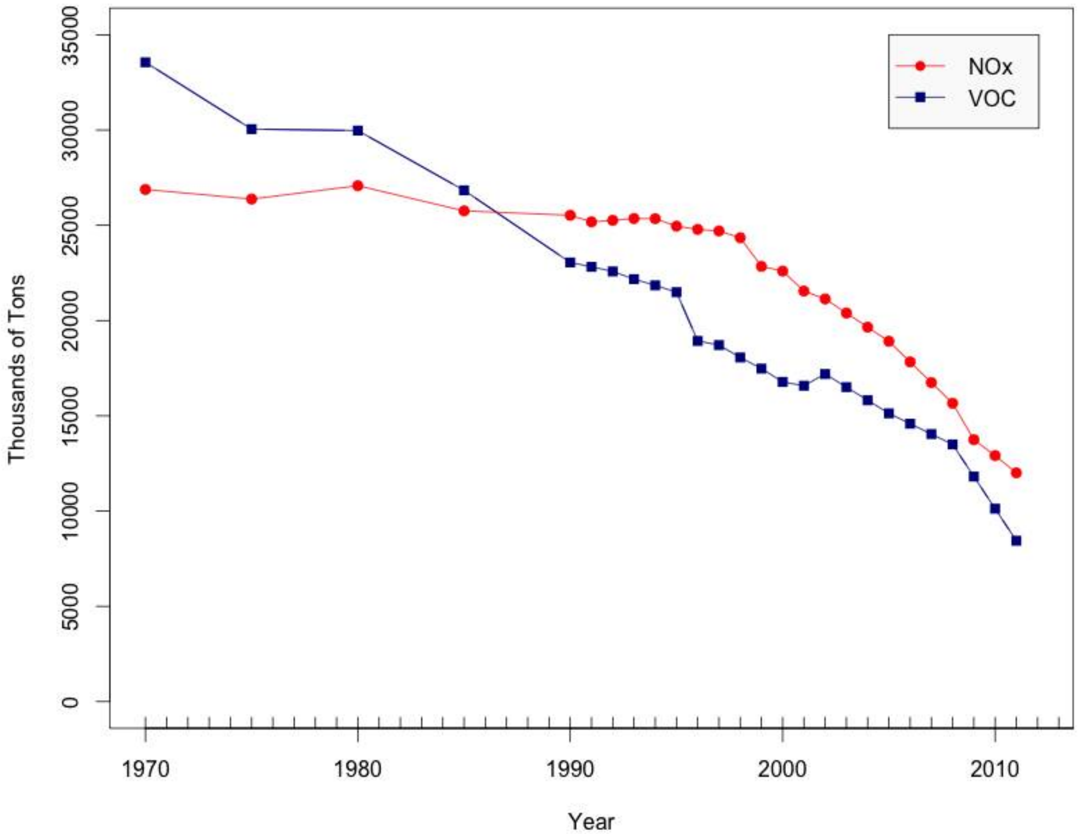


Figure. *Trend in Number of Ozone Exceedance Days vs. High Temperature Days in the New England Region.*

Source: EPA Region 1 (New England) web site: http://www.epa.gov/region1/airquality/graph.html (accessed June 13, 2012).

Note: Over time not only has the number of ozone exceedance days declined, the sensitivity of ozone to temperature has also declined. For example, in New England, since the early 1980s, the number of 75 ppb or 85 ppb ozone exceedance days during hot summers has dropped by 74 percent and 89 percent, respectively.

Recent studies also suggest that reductions in ozone precursors make ozone levels less sensitive to temperature. For example, Bloomer et al. (2009) concluded, based on observations of the real-world response of ozone to NOx reductions, that a 43 percent reduction in NOx emissions from power plants reduced the "climate penalty"—the amount by which ozone increases per degree of increase in temperature—by 31 percent, from 3.2 ppb ozone/°C to 2.2 ppb ozone/°C.



Source: EPA, "1970 - 2011 Average annual emissions, all criteria pollutants," http://www.epa.gov/ttnchie1/trends/ (accessed June 13, 2012).

Note: NOx and VOC emissions have been declining rapidly. The rate of decline has been accelerating in recent years.