

Testimony of DANIEL B. BOTKIN

Before the United States Senate Subcommittee on Clean Air and Nuclear Safety

“Climate Change: The Need to Act Now.”

June 18, 2014 at 10:00 A.M.

Since 1968, I have published research on theoretical global warming, its potential ecological effects, and the implications for people and biodiversity. Some examples: In 1970, I developed the first computer model of forests used in many versions around the world from then to the present to forecast possible climate change effects on forests. In the 1980s, one of my graduate students added world vegetation to a major climate model. In 2010, I published a paper comparing century Arctic sea ice extent in the nineteenth with that at the end of twentieth century. I have a paper in press giving the first statistically valid estimates of forest carbon sequestering for large areas of the Earth.

I have spent my career trying to help conserve our environment and its great diversity of species. Some examples: When the Marine Mammal Protection Act was passed in 1973, the Commission asked me to analyze the law and explain its key concepts both ecologically and legally; I served on a California State Committee to advise what to do about the then 22 condors remaining in the wild; Under a special bill passed by the Oregon State Legislature, I directed a five year study of the relative effects of forest practices on salmon; Under a special bill passed by the California State Legislature, I directed a study concerning Mono Lake, whose supply of fresh water had been completely diverted to Los Angeles: at the request of the city of Los Angeles, I wrote a report concerning the use of trees, shrubs and other vegetation in a city in a semi-arid environment; I have advised the Scientific Committee of the International Whaling Commission; served as the U. S. representative of the International Union for the Conservation of Nature. I have published 14 books about nature and people including one of the leading environmental science textbooks.

I have always attempted to maintain an objective, intellectually honest, scientific approach in the

best tradition of scientific endeavor and have been dismayed and disappointed in recent years that this subject has been converted into a political and ideological debate. I have colleagues on both sides of the debate and believe we should work together as scientists instead of arguing divisively about preconceived, emotionally-based “positions.” I hope my testifying here will help lead to a calmer, more rational approach to dealing with not only climate change but also other major environmental problems. The IPCC 2014 report and the White House Climate Change Assessment do not have this kind of rational discussion we should be having. I would like to tell you why.

The IPCC 2014 report is actually a series of reports, each long, complex in organization, and extensive in scope. The White House Report is 881 pages. Since it’s not possible to discuss these documents thoroughly in detail today, I will highlight some of my thoughts for you here as they relate to the reports, hoping to bring a saner, more sober approach to this highly charged issue.

To characterize where we are with these reports and this issue, I would like to quote James R. Schlesinger, the first U.S. Energy Secretary, who said: “*We have only two modes — complacency and panic.*”—commenting on the country’s approach to energy (1977).

Now to my major points.

1. **I want to state up front that we have been living through a warming trend driven by a variety of influences.** However, it is my view that this is not unusual, and contrary to the characterizations by the IPCC and the National Climate Assessment, these environmental changes are neither apocalyptic nor irreversible.
2. **My biggest concern is that both the reports present a number of speculative, and sometimes incomplete, conclusions embedded in language that gives them more scientific heft than they deserve.** The reports are “scientific-sounding” rather than based on clearly settled facts or admitting their lack. Established facts about the global environment exist less often in science

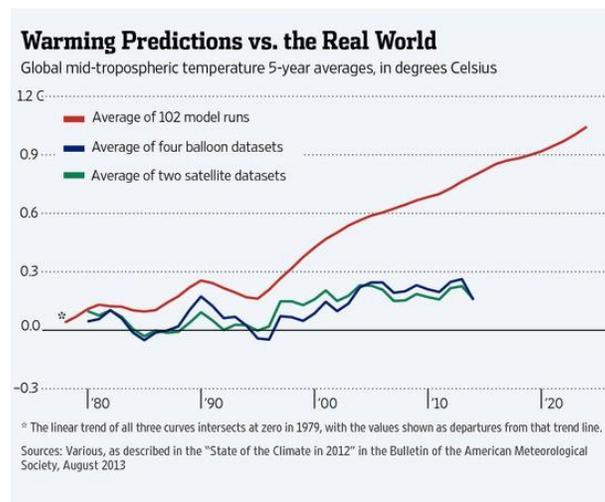
than laymen usually think.

3. **HAS IT BEEN WARMING? Yes, we have been living through a warming trend, no doubt about that.** The rate of change we are experiencing is also not unprecedented, and the “mystery” of the warming “plateau” simply indicates the inherent complexity of our global biosphere. Change is normal; life on Earth is inherently risky. It always has been. The two reports, however, makes it seem that environmental change is apocalyptic and irreversible. It is not.
4. **IS CLIMATE CHANGE VERY UNUSUAL? No, it has always undergone changes.**
5. **ARE GREENHOUSE GASES INCREASING? Yes, CO2 rapidly.**
6. **IS THERE GOOD SCIENTIFIC RESEARCH ON CLIMATE CHANGE? Yes, a great deal of it.**
7. **ARE THERE GOOD SCIENTISTS INVOLVED IN THE IPCC 2014 REPORT?** Yes, the lead author of the Terrestrial (land) Ecosystem Report is Richard Betts, a coauthor of one my scientific papers about forecasting effects of global warming on biodiversity.
8. **ARE THERE SCIENTIFICALLY ACCURATE STATEMENTS AT PLACES IN THE REPORT? Yes, there are.**
9. **What I sought to learn was the overall take-away that the reports leave with a reader.** I regret to say that I was left with the impression that the reports overestimate the danger from human-induced climate change and do not contribute to our ability to solve major environmental problems. I am afraid that an “agenda” permeates the reports, an implication that humans and our activity are necessarily bad and ought to be curtailed.
10. **ARE THERE MAJOR PROBLEMS WITH THE REPORTS? Yes, in assumptions, use of data, and conclusions.**
11. **My biggest concern about the reports is that they present a number of speculative, and**

sometimes incomplete, conclusions embedded in language that gives them more scientific heft than they deserve. The reports, in other words, are "scientific- sounding," rather than clearly settled and based on indisputable facts. Established facts about the global environment exist less often in science than laymen usually think.

12. **The two reports assume and/or argue that the climate warming forecast by the global climate models is happening and will continue to happen and grow worse. Currently these predictions are way off the reality** (Figure 1). Models, like all scientific theory, have to be tested against real-world observations. Experts in model validation say that the climate models frequently cited in the IPCC report are little if any validated. This means that as theory they are fundamentally scientifically unproven.

13. **Figure 1: Climate model forecasts compared to real world temperature observations** (From John Christy, University of Alabama and Alabama State Climatologist. Reproduced with permission from him.)



14. **The reports suffer from the use term "climate change" with two meanings: natural and human-induced. These are both given as definitions in the IPCC report and are not distinguished in the text and therefore confuse a reader.** (The White House Climate Change

Assessment uses the term throughout including its title, but never defines it.) There are places in the reports where only the second meaning—human induced—makes sense, so that meaning has to be assumed. There are other places where either meaning could be applied.

- a. In those places where either meaning can be interpreted, if the statement is assumed to be a natural change, then it is a truism, a basic characteristic of Earth's environment and something people have always known and experienced. If the meaning is taken to be human-caused, then in spite of the assertions in the report, the available data do not support the statements.

15. Some of the reports' conclusions are the opposite of those given in articles cited in defense of those conclusions. For example, the IPCC 2014 Terrestrial Ecosystem Report states that “there is medium confidence that rapid change in the Arctic is affecting its animals. For example, seven of 19 subpopulations of the polar bear are declining in number” citing in support of this an article by Vongraven and Richardson, 2011. That report states the contrary, that the “decline’ is an illusion.

In addition, I have sought the available counts of the 19 subpopulations. Of these, only three have been counted twice; the rest have been counted once. Thus no rate of changes in the populations can be determined. The first count was done in 1986 for one subpopulation.¹

On May 22, Vongraven, a member of the international team that created these estimates, stated that the polar bear population size, “never has been an estimate of total abundance in a scientific sense, but simply a qualified guess given to satisfy public demand...the range given for total global population should be viewed with great caution as it cannot be used to assess population trend over the long term.” The U. S. Marine Mammal Commission, charged with the conservation of this species, acknowledges “*Accurate estimates of the current and historic sizes of polar bear stocks are*

difficult to obtain for several reasons—the species ‘inaccessible habitat, the movement of bears across international boundaries, and the costs of conducting surveys.’”²

According to Dr. Susan Crockford, “out of the 13 populations for which some kind of data exist, five populations are now classified by the PBSG [IUCN/SSC Polar Bear Specialist Group] as ‘stable’ (two more than 2009), one is still increasing, and three have been upgraded from ‘declining’ to ‘data deficient’ That leaves four that are still considered ‘declining’ - two of those judgments are based primarily on concerns of overhunting, and one is based on a statistically insignificant decline that may not be valid and is being reassessed (and really should have been upgraded to ‘data deficient’). That leaves only one population – Western Hudson Bay – where PBSG biologists tenaciously blame global warming for all changes to polar bear biology, and even then, the data supporting that conclusion is still not available.”³

16. Some conclusions contradict and are ignorant of the best statistically valid

observations. For example, the Terrestrial Ecosystems Report states that “terrestrial and freshwater ecosystems have sequestered about a quarter of the carbon dioxide emitted to the atmosphere by human activities in the past three decades (high confidence).” I have done the first statistically valid estimate of carbon storage and uptake for any large area of Earth’s land, the boreal forests and eastern deciduous forest of North America, and subtropical forests in Queensland, Australia. The estimates of carbon uptake by vegetation used by IPCC and in major articles cited by the reports are based on what can best be called “grab samples,” a relatively small number of studies done at a variety of times using a variety of methods, mainly in old- growth areas. The results reported by IPCC overestimate

carbon storage and uptake by as much as 300 percent.⁴

- 17. The IPCC Report for Policymakers on Impacts, Adaptation, and Vulnerability repeats the assertion of previous IPCC reports that “large fraction of species” face “increase extinction risks” (p15). Overwhelming evidence contradicts this assertion.**

And it has been clearly shown that models used to make these forecasts, such as climate envelope models and species-area curve models, make incorrect assumptions that lead to erroneous conclusions, over-estimating extinction risks. Surprisingly few species became extinct during the past 2.5 million years, a period encompassing several ice ages and warm periods.⁵ Among other sources, this is based on information in the book *Climate Change and Biodiversity* edited by Thomas Lovejoy, one of the leaders in the conservation of biodiversity.⁶ The major species known to have gone extinct during this period are 40 species of large mammals in North America and Northern Europe. (There is a “background” extinction rate for eukaryotic species of roughly one species per year.)

- 18. THE REPORTS GIVE THE IMPRESSION THAT LIVING THINGS ARE FRAGILE AND RIGID, unable to deal with change. The opposite is the case. Life is persistent, adaptable, and adjustable.**

- 19. STEADY-STATE ASSUMPTION: There is an overall assumption in the IPCC 2014 report and the White House Climate Change Assessment that all change is negative and undesirable – that it is ecologically and evolutionarily unnatural, bad for populations, species, ecosystems, for all life on planet Earth, including people. This is the opposite of the reality.** The environment has always changed and is always changing,

and living things have had to adapt to these changes. Interestingly, many, if not most, species that I have worked on or otherwise know about require environmental change.⁷

20. The IPCC Summary for Policy Makers on Impacts, Adaptation, and Vulnerability

makes repeated use of the term “irreversible” changes. A species going extinct is irreversible, but little else about the environment is irreversible. The past confirms this. Glaciers have come and gone repeatedly. The Northwest Passage of North America has gone and come again. The average temperature has greatly exceeded the present and forecasted and has declined only to rise again.

- a. Implicit in this repeated use of irreversible is the belief that Earth’s environment is constant — stable, unchanging — except when subjected to human actions. This is obviously false from many lines of evidence, including the simple experience of all people who have lived before the scientific-industrial age and those who live now and so such work as farm, manage rivers, wildlife and forests.

The extreme over-emphasis on human-induced global warming has taken our attention away from many environmental issues that used to be front and center but have been pretty much ignored in the 21st century. By my count there are ten issues, including global warming. I know it is easier for people to focus on just one issue at a time and ten seems overwhelming, but they can all be part of, and can be cast in terms of, biodiversity and sustainability. A singular focus on climate change as the driver of the other nine obscures the best solutions to the full suite of environmental challenges we face. In terms of “the need to act now” it is on these issues that we should focus, with the concern with a possible global warming prioritized properly with that group.

Environmental Issues that need our attention now

- 1. Energy**
- 2. Fresh water**
- 3. Habitat destruction**
- 4. Invasive-species control**
- 5. Direct threats to Endangered species**
- 6. Pollution by directly toxic substances**
- 7. Fisheries**
- 8. Forests**
- 9. Phosphorus and other essential minerals**

The Terrestrial report in a sense acknowledges this, for example by stating: “*Climate stresses occur alongside other anthropogenic influences on ecosystems, including land-use changes, nonnative species, and pollution, and in many cases will exacerbate these pressures (very high confidence).*”

21. Do the problems with these reports mean that we can or should abandon any concerns about global warming or abandon any research about it? Certainly not, but we need to put this issue within an appropriate priority with other major here-and-now environmental issues that are having immediate effects.

22. I reviewed and provided comments on both the IPCC 2014 report and the draft White House's National Climate Change Assessment and, unfortunately, it appears that these issues have not been addressed in the final assessment. For example in regard to the White House Report, I stated:

- a. "The executive summary is a political statement, not a scientific statement. It is filled with misstatements contradicted by well-established and well-known scientific papers."
- b. "Climate has always affected people and all life on Earth, so it isn't new to say it is 'already affecting the American people.' This is just a political statement."

- c. "It is inappropriate to use short-term changes in weather as an indication one way or another about persistent climate change."

WHAT HAS GONE WRONG AND HOW TO FIX IT

1. **Rather than focus on key, specific and tractable aspects of climate-change science, the long-term approach throughout the 20th century was to try to create *de nova* a complete model of the climate.**
2. **This approach has been taken despite a lack of focus on monitoring key variables over time in statistically and scientifically valid ways, e. g. carbon sequestering by forests; polar bear population counts.** As a result, there is an odd disconnect between theory and observation. The attempt to create complete models of every aspect of climate has meant that many factors had to be guessed at, rather than using the best scientific methods. Too many guesses, too little checking against real, observed effects.
3. **Both reports are the result of a very large number of people doing long reviews of the scientific literature. This easily leads to people being so overburdened that they misinterpret specific papers, fail to understand where the major observational gaps are, and have trouble making an accurate list of citations and all sources of information.** The fundamental IPCC and White House Climate Change Assessment approach has been to gather a huge number of scientists from a large number of disciplines, on the assumption that a kind of crowd approach to what can be agreed on is the same as true scientific advance. While this might seem a reasonable and effective approach, there is some danger in relying on this "crowd-sourced" model of information sharing. Groups of people, particularly when credentialed "experts" are involved, are very prone to a condition called an "information cascade" in which error is compounded by group

think, assumptions become unchallenged “fact” and observations play second fiddle to unchallenged models. The excellent scientists involved with the IPCC reports are no less prone to this than the excellent scientists who relied on Aristotelian models of a geocentric universe. Entrenched beliefs are hard to extricate, even amongst supposedly rational thinkers. This is probably in part responsible for the problems listed with the White House Climate Assessment report’s table of Biological Effects, discussed later.

4. **What a scientist discovers is different from what a scientist says. The first is science, the second is opinion.** Have small groups of scientists work on this problem, no more than can easily argue with one another, that is less than 20 and preferably even smaller, representing the primary disciplines. Divide the problem into areas, rather than try to answer all questions in one analysis. I have used this approach in my own work and found it to be successful.^{8, 9}
5. **The desire to do good has ironically overridden the desire to do the best science.**
6. **Under the weight of this kind of crowd rule and approach, some specific alternative approaches to the science of climate change, have not been allowed to rise to the surface.**
7. **Among the approaches that would improve climate science:**
 1. Return to the former reliance on science done by individuals and small groups with a common specific interest and focus.
 2. Change the approach from trying to make a complete, definitive model of every aspect of climate to a different level. See kinds of models that explore specific possibilities and phenomena.
 3. Get out of the blame game. None of the above suggestions can work as long as

global warming remains a moral, political, ideologically dominated topic, with scientists pushed into, or at least viewed as, being either for or against a single point of view.

9. **We need to focus again on major environmental Issues that need our attention now** (see the list above).

10. **ARE THERE EXAMPLES OF THE KIND OF RESEARCH I BELIEVE WE NEED MORE OF? YES.**

- a. NASA Carbon Monitoring System (CMS)
- b. Hubbard Brook Ecosystem Study
- c. Whooping Crane monitoring, e.g. of an endangered species
- d. In-place monitoring on carbon flux, being done by the USGS in the Great Cypress Swamp, Florida.
- e. Many others.

NOTES For the general discussion of both the IPCC 2014 and the White House Climate Change Assessment. (A second section dealing directly with the White House Assessment has its own note section.)

1. IUCN Summary of polar bear population status per 2013 <http://pbsg.npolar.no/en/status/status-table.html>
2. <http://www.mmc.gov/species/pdf/ar2000polarbear.pdf> P. 91.
3. Crockford, S., 2014. Polar Bear Science website <http://polarbearsience.com/2014/03/20/polar-bear-status-changes-in-2013-deconstructed-with-a-map-to-the-good-news/>
4. Botkin, D. B. and L. Simpson, 1990, Biomass of the North American Boreal Forest: A step toward accurate Global Measures: *Biogeochemistry* 9:161-174; Botkin, D. B., Simpson, L. G., and H. J. Schenk, 1992, Estimating Biomass, *Science Letters*. Vol. 257, No. 5067. (Jul. 10, 1992), pp. 146-147; Botkin, D. B., Simpson, L. G., and R. A. Nisbet, 1993, Biomass and Carbon Storage of the North American Deciduous Forest, *Biogeochemistry* 20: 1-17; Botkin, D.

B., Ngugi, M.R., D. Doley (submitted) “Statistically Valid Estimates and Accurate Forecasts of Forest Biomass and Carbon Sequestration: A Forty-Five Year Quest.” Keynote speech at IUFRO Forest Biomass Conference, October 7, 2013, to be published in *Drewno (Wood) Journal*.

5. Botkin, D. B., Henrik Saxe, Miguel B. Araújo, Richard Betts, Richard H.W. Bradshaw, Tomas Cedhagen, Peter Chesson, Margaret B. Davis, Terry P. Dawson, Julie Etterson, Daniel P. Faith, Simon Ferrier, Antoine Guisan, Anja Skjoldborg Hansen, David W. Hilbert, Craig Loehle, Chris Margules, Mark New, Matthew J. Sobel, and David R.B. Stockwell. (2007). “Forecasting Effects of Global Warming on Biodiversity.” *BioScience* 57(3): 227-236.

6. Lovejoy, T. E., Lee Hannah, editors. (2005). *Climate Change and Biodiversity*. New Haven, Yale University Press.

7. Botkin, D. B., 2012, *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered* (Oxford University Press, New York, hardback and ebook, September 14, 2012).

8. Botkin, D.B., W.S.Broecker, L. G. Everett, J. Shapiro, and J. A. Wiens, 1988, *The Future of Mono Lake*, California Water Resources Center, University of California, Riverside, Report #68.

9. Botkin, D. B., Henrik Saxe, Miguel B. Araújo, Richard Betts, Richard H.W. Bradshaw, Tomas Cedhagen, Peter Chesson, Terry P. Dawson, Julie Etterson, Daniel P. Faith, Simon Ferrier, Antoine Guisan, Anja Skjoldborg Hansen, David W. Hilbert, Craig Loehle, Chris Margules, Mark New, Matthew J. Sobel, and David R.B. Stockwell. 2007 "Forecasting Effects of Global Warming on Biodiversity." *BioScience* 57(3): 227-236.

SPECIFIC REVIEW OF *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program

Jerry M. Melillo, Terese (T.C.) Richmond, and Gary W. Yohe, Eds.

841 pp. doi:10.7930/JOZ31WJ2.

[Note regarding my connections with Jerry M. Melillo, one of the three primary editors of this report: When I was on the faculty of the Yale School of Forestry and Environmental Studies, Jerry Melillo was a graduate student working on his doctorate and we interacted frequently. Beginning in 1975, Jerry Melillo and I worked at the Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA, and we published four scientific papers together, listed at the end of this document.¹

COMMENTS ON THE ASSESSMENT

GENERAL COMMENTS:

The opening statement of the Assessment (p.1), reproduced here, is characteristic of the entire Assessment in that it violates one of the basic principles of good climatology --- never use short-term weather changes as proof of climate change. Climatologists I have worked with over the decades have said this repeatedly. In 1962, when I was a graduate student at the University of Wisconsin working under a science writing fellowship, I spoke with Reed Bryson, said to be the father of the International Geophysical Year and the person who persuaded Richard Keeling to begin measuring atmospheric carbon dioxide concentration on Mauna Loa, Hawaii. At that time Earth had been undergoing a global cooling since about 1940. At first Professor Bryson said “if present trends continue, we are entering a new ice age.” But when I drafted a press release that quoted him so, he thought about it carefully and told me that we could not make that statement, because this was just a short- term weather event.

In the 1980s, I worked closely with climatologist Stephen Schneider and we often gave talks at the same events. Steve, one of the leaders of the modern concern about a possible human-induced global warming, also said that you should never use short-term weather events to infer climate change. I agreed with these experts, and therefore was taken aback by the overall tone of the new White House Climate Change Assessment, which begins: “Climate change, once considered an issue for a distant future, has moved firmly into the present. Corn producers in Iowa, oyster growers in Washington State, and maple syrup producers in Vermont are all observing climate-related changes that are outside of recent experience. So, too, are coastal planners in Florida, water managers in the arid Southwest, city dwellers from Phoenix to New York, and Native Peoples on tribal lands from Louisiana to Alaska. This National Climate Assessment concludes that the evidence of human-induced climate change continues to strengthen and that impacts are increasing across the country.

Based on what my climatologist colleagues had always told me, the Assessment should have begun instead by stating: “Corn producers in Iowa, oyster growers in Washington State, and maple syrup producers in Vermont are all observing weather-related changes” outside of their

personal recent experience. So, too, are coastal planners in Florida, water managers in the arid Southwest, city dwellers from Phoenix to New York, and Native peoples on tribal lands from Louisiana to Alaska.”

The Assessment concludes that opening paragraph by stating: *This National Climate Assessment concludes that the evidence of human-induced climate change continues to strengthen and that impacts are increasing across the country.*

Americans are noticing changes all around them. Summers are longer and hotter, and extended periods of unusual heat last longer than any living American has ever experienced. Winters are generally shorter and warmer. Rain comes in heavier downpours. People are seeing changes in the length and severity of seasonal allergies, the plant varieties that thrive in their gardens, and the kinds of birds they see in any particular month in their neighborhoods (p.1).

These opening paragraphs and several that follow directly communicate to the reader, both lay and professional, that human-induced global warming is an immediate disaster. For example:

Other changes are even more dramatic. Residents of some coastal cities see their streets flood more regularly during storms and high tides. Inland cities near large rivers also experience more flooding, especially in the Midwest and Northeast. Insurance rates are rising in some vulnerable locations, and insurance is no longer available in others. Hotter and drier weather and earlier snowmelt mean that wildfires in the West start earlier in the spring, last later into the fall, and burn more acreage. In Arctic Alaska, the summer sea ice that once protected the coasts has receded, and autumn storms now cause more erosion, threatening many communities with relocation.

Scientists who study climate change confirm that these observations are consistent with significant changes in Earth’s climatic trends. Long-term, independent records from weather stations, satellites, ocean buoys, tide gauges, and many other data sources all confirm that our nation, like the rest of the world, is warming. Precipitation patterns are changing, sea level is rising, the oceans are becoming more acidic, and the frequency and intensity of some extreme weather events are increasing (p. 1).

To be scientifically accurate, these paragraphs should instead have been written (my changes noted by underlining): *Other weather changes are even more dramatic. Residents of some coastal cities see their streets flood more regularly during storms and high tides. Inland cities near large rivers also experience more flooding, especially in the Midwest and Northeast. Insurance rates are rising in some vulnerable locations, and insurance is no longer available in others. Hotter and drier weather and earlier snowmelt mean that wildfires in the West start earlier in the spring, last later into the fall, and burn more acreage. In Arctic Alaska, the summer sea ice that once protected the coasts has receded, and autumn storms now cause more erosion, threatening many communities with relocation. Scientists who study weather and climate change point out that short-term, including several decades and longer, changes in weather do not confirm that these observations are consistent with significant changes in Earth’s climatic trends.*

These opening statements are directly followed by: *Many lines of independent evidence*

demonstrate that the rapid warming of the past half-century is due primarily to human activities. The observed warming and other climatic changes are triggering wide-ranging impacts in every region of our country and throughout our economy. Some of these changes can be beneficial over the short run, such as a longer growing season in some regions and a longer shipping season on the Great Lakes. But many more are detrimental, largely because our society and its infrastructure were designed for the climate that we have had, not the rapidly changing climate we now have and can expect in the future. In addition, climate change does not occur in isolation. Rather, it is superimposed on other stresses, which combine to create new challenges (p. 1). **The assertions in this paragraph are based on the forecasts from climate models and from temperature records. However, Figure 1 shows that the climate models greatly exaggerate the rate and amount of temperature change and are not making forecasts that come even close to fitting the data. Furthermore, Figure 1 also shows that the average Earth temperature in the past 30 years has changed very little if at all, contradicting the assertions on the first page of the Assessment.**

The Assessment further attributes the supposed climatic warming to human activities that are releasing greenhouse gases, especially carbon dioxide, into the atmosphere. Therefore the claimed disaster is our fault. But recent evidence shows that temperature change is not tracking the increase in carbon dioxide. The gas has increased from 370 ppm to just over 400ppm, 8 percent, between year 2000 and year 2014 (Figure 2), while the temperature has changed either only slightly or not at all, depending on how one does the analysis (Figure 3). Instead, temperature change tracks closely changes in the energy output from the sun (Soon, W. and D. R. Legates, *Solar irradiance modulation of Equator-to-Pole (Arctic) temperature gradients: Empirical evidence for climate variation on multi-decadal timescales*. Journal of Atmospheric and Solar-Terrestrial Physics, 2013. **93**: p. 45-56.)

Figure 2. Mauna Loa Observatory CO₂ measurements

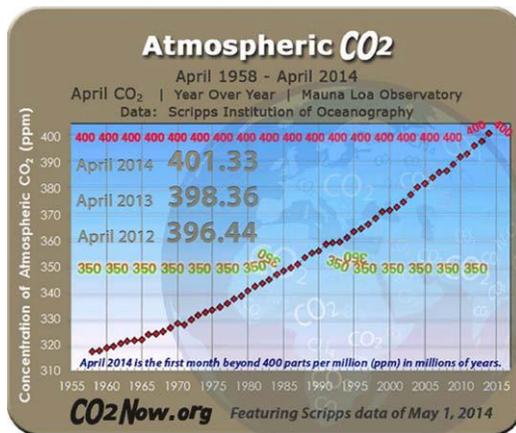
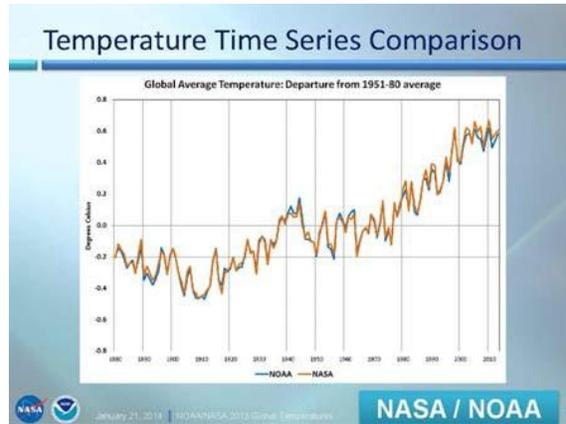


Figure 3. Earth Surface Temperature Departure from 1950-1980 Average



The current evidence from scientific observations shows that Earth’s temperature has not changed very much, if at all, since the start of the new century, while carbon dioxide has increased considerably.

Given these facts, the basic opening assertions of the new U.S. Climate Change Assessment are about a hypothetical world, not a real world, and must be taken as a “what if” rather than “what is”. Therefore the dire consequences forecast in the Assessment cannot be taken as reliable, nullifying many, if not most, of the ecological and biological implications the Assessment makes heavy use of.

The time available to write and the space available to publish as written testimony prevent a comprehensive, detailed review of the entire White House Climate Change Assessment. As a result, I have used as an example of the kinds of problems throughout the Assessment the table appearing on pages 204-5, *Biological Responses To climate Change*. As an ecologist, I have taken that table and reorganized it. This reorganization follows.

Although the document is titled “Climate Change Assessment,” the term “climate change” is not defined and is in fact used with two meanings, natural and human-induced. There are places in the Assessment where only the second meaning makes sense, so that meaning has to be assumed. There are other places where either meaning could be applied. In those places where either meaning can be interpreted, if the statement is assumed to be a natural change, then it is a truism, a basic characteristic of Earth’s environment and something people have always known and experienced. If the meaning is taken to be human-caused, then in spite of the assertions in the Assessment, the available data do not support the statements.

For example, the Assessment’s section titled *CLIMATE CHANGE AND THE AMERICAN PEOPLE* begins with the statement: *Climate change, once considered an issue for a distant future, has moved firmly into the present. Corn producers in Iowa, oyster growers in*

Washington State, and maple syrup producers in Vermont are all observing climate-related changes that are outside of recent experience.

If this is to be interpreted as natural, then people have frequently in history experienced “climate-related changes that are outside of [their] recent experiences,” as the Medieval Warming and Little Ice Age demonstrate,^{2, 3, 4} and therefore it is not unusual nor unexpected in ordinary life. If this is to be interpreted to be human-induced, then the evidence just discussed demonstrates that this kind of change cannot be attributed to human actions and therefore the statement is false.

ANALYSIS OF THE CLIMATE CHANGE IMPACTS ASSESSMENT TABLE OF ECOLOGICAL EFFECTS, titled Biological responses to climate change (Assessment’s pages 204-205)

The Assessment presents a list of 30 biological responses to climate change. Since this is my particular area of expertise, I have analyzed this list and sorted the items into the following categories: **Where the Assessment is wrong** based on my understanding (10 items); **Improvements** (12 items); **Declines** (which can be taken as worsening) (No items); **Predicted from Climate Models**, Therefore Not Fact, especially given the failure of climate models to forecast with any reliability Earth’s increase in temperature since the 1990s (see figure 1) (3 items); and **Unlikely or Unsupported Statement** (5 items). **Within the context of the Assessment, this table comes across as meaning to demonstrate more very negative effects of a human-induced global warming, but since upon analysis none of the 30 appears to be a legitimately supported decline that might occur under a hypothetical global warming or have been directly observed, this table in fact is an argument against the overall message of the Assessment.**

(The number that appears at the beginning of each entry is the number in the Assessment’s list. The numbers following each of the Assessment’s entry are the citation number as listed in the Assessment. The Assessment’s statements are in italics; my comments appear in plain font.)

ASSESSMENT IS WRONG

1. *21. Seedling survival of nearly 20 resident and migrant tree species decreased during years of lower rainfall in the Southern Appalachians and the Piedmont areas, indicating that reductions in native species and limited replacement by invading species were likely under climate change.*¹³⁴ Since the climate models are admittedly weak about changes in rainfall, this statement has no relevance to purported human-induced global warming.
2. *27. Water temperature data and observations of migration behaviors over a 34-year time period showed that adult pink salmon migrated earlier into Alaskan creeks, and fry advanced the timing of migration out to sea. Shifts in migration timing may increase the potential for a mismatch in optimal environmental conditions for early life stages, and continued warming trends will likely increase pre-spawning mortality and egg mortality rates.*⁸⁷ Salmon have evolved and are adapted to environmental change.
3. *3. Conifers in many western forests have experienced mortality rates of up to 87% from warming-induced changes in the prevalence of pests and pathogens and stress from drought.*¹¹⁸ Important causes of the mortality of trees in western forests are: fire suppression, which promotes insect and disease outbreaks, and from introduced

- (invasive) insects and diseases.
4. 8. *Warmer and drier conditions during the early growing season in high-elevation habitats in Colorado are disrupting the timing of various flowering patterns, with potential impacts on many important plant-pollinator relationships.*⁷⁷ “Disrupting” is a politically loaded term. The scientific term would be “changed” and this is a good sign, showing the adaptability of species to changing environments.
 5. 12. *Variation in the timing and magnitude of precipitation due to climate change was found to decrease the nutritional quality of grasses, and consequently reduce weight gain of bison in the Konza Prairie in Kansas and the Tallgrass Prairie Preserve in Oklahoma.*¹²⁴ Results provide insight into how climate change will affect grazer population dynamics in the future. This is stated in a way that is not open to scientific evaluation. No doubt lower rainfall has negative effects, but the statement is “variation.” In fact, the publication cited (Craine et al., 2008)⁵ states that “Greater late-summer precipitation increased bison weight gain . . . “greater midsummer precipitation decreased weight gain.” This is a scientifically interesting result for those focused on wildlife in grasslands, but it is neither a negative nor positive in terms of global warming, because the forecasting models are weakest in forecasting rainfall even annually, let alone seasonally. Therefore these results cannot be taken as negative (nor positive) effects of a global rise in average temperature.
 6. 10. *Cutthroat trout populations in the western U.S. are projected to decline by up to 58%, and total trout habitat in the same region is projected to decline by 47%, due to increasing temperatures, seasonal shifts in precipitation, and negative interactions with nonnative species.*⁸ Stresses on Cutthroat extend considerably beyond climate change and have to do with fishing intensity, water diversions and other habitat changes, such as competition from introduced, invasive species such as lake trout and rainbow trout.⁶
 7. 28. *Warmer springs in Alaska have caused earlier onset of plant emergence, and decreased spatial variation in growth and availability of forage to breeding caribou. This ultimately reduced calving success in caribou populations.*¹³⁸ The implication is that warming will necessarily have a negative effect on caribou, but the paper cited (Post et al., 2008) actually is much more cautious, stating “it is highly relevant to herbivore ecology to consider the manner in which warming will alter spatial patterns of plant phenology at more immediate spatial scales than that of the regional landscape. The paper concludes, cautiously: “Large herbivores prefer newly emergent forage, presumably owing to the high digestibility and nutrient content of young plant tissues . . . future warming could conceivably impair the ability of herbivores such as caribou to forage selectively, with adverse consequences for their productivity. We suggest, therefore, that it is highly relevant to herbivore ecology to consider the manner in which warming will alter spatial patterns of plant phenology at more immediate spatial scales than that of the regional landscape.”⁷

There is again an inherent assumption that a steady-state between living things and climate is natural and necessary for a species’ persistent. Wildlife population can and do adjust to changes, but this can take some time. See the examples of current adjustments, which I have added below this table. Give the populations a little time to adjust.

8. *26 Changes in female polar bear reproductive success (decreased litter mass and numbers of yearlings) along the north Alaska coast have been linked to changes in body size and/or body condition following years with lower availability of optimal sea ice habitat.*¹³⁷ There is evidence that polar bears are adjusting by feeding more on terrestrial prey. Contrary to the publicity about polar bears, there is little information demonstrating any statistically, scientifically valid decline in polar bear populations. I have sought the available counts of the 19 subpopulations. Of these, only three have been counted twice; the rest have been counted once. Thus no rate of change in the population is possible. The first count was done 1986 for one subpopulation.⁸
9. *7. Quaking aspen-dominated systems are experiencing declines in the western U.S. after stress due to climate induced drought conditions during the last decade.*¹²² Anderegg, W. R. L., J. M. Kane, and L. D. L. Anderegg, 2012: *Consequences of widespread tree mortality triggered by drought and temperature stress. Nature Climate Change, 3, 30-36, doi:10.1038/nclimate1635.* Given the failure of the climate models to predict temperature change and the observed lack of a significant recent rise in temperature, it is incorrect to refer to this as a “climate induced” drought. Moreover, a thousand year tree-ring study shows that deep droughts are characteristic of California. Meteorologist Martin P. Hoerling wrote on March 8, 2014 that “At present, the scientific evidence does not support an argument that the drought there is appreciably linked to human-induced climate change.” Hoerling is a research meteorologist, specializing in climate dynamics, at the Earth System Research Laboratory of the National Oceanic and Atmospheric Administration, and the White House's National Climate Assessment cites many of Hoerling's papers, including figure 20.4 “Longer Frost-free Season Increases Stress on Crops,” so his work is respected by the authors.
10. *9. Population fragmentation of wolverines in the northern Cascades and Rocky Mountains is expected to increase as spring snow cover retreats over the coming century.*¹²³ The paper cited, Dawson et al. (2011)⁹, does not mention wolverines. And contrary to making a highly negative statement, the paper states *Populations of many species have persisted in situ at individual sites since the last glacial maximum (toleration) and many have undergone habitat shifts, moving short distances (1 to 10 km) to sites with different aspects, slopes, elevations, and other attributes as the environment changed. Migrations of 100 to 1000 km are well documented for many species.*

IMPROVEMENTS

1. *2. Northern flickers arrived at breeding sites earlier in the Northwest in response to temperature changes along migration routes, and egg laying advanced by 1.15 days for every degree increase in temperature, demonstrating that this species has the capacity to adjust their phenology in response to climate change.*¹¹⁷
2. *11. Comparisons of historical and recent first flowering dates for 178 plant species from North Dakota showed significant shifts occurred in over 40% of species examined, with the greatest changes observed during the two warmest years of the study.*⁷⁵
3. *14. Migratory birds monitored in Minnesota over a 40-year period showed significantly earlier arrival dates, particularly in short-distance migrants, indicating that some species are capable of responding to increasing winter temperatures better than*

- others.126.*
4. *15. Up to 50% turnover in amphibian species is projected in the eastern U.S. by 2100, including the northern leopard frog, which is projected to experience poleward and elevational range shifts in response to climatic changes in the latter quarter of the century.127*
 5. *16. Studies of black ratsnake (Elaphe obsoleta) populations at different latitudes in Canada, Illinois, and Texas suggest that snake populations, particularly in the northern part of their range, could benefit from rising temperatures if there are no negative impacts on their habitat and prey.128*
 6. *17. Warming-induced hybridization was detected between southern and northern flying squirrels in the Great Lakes region of Ontario, Canada, and in Pennsylvania after a series of warm winters created more overlap in their habitat range, potentially acting to increase population persistence under climate change.129*
 7. *18. Some warm-water fishes have moved northwards, and some tropical and subtropical fishes in the northern Gulf of Mexico have increased in temperate ocean habitat.130 Similar shifts and invasions have been documented in Long Island Sound and Narragansett Bay in the Atlantic.131*
 8. *23. Over the last 130 years (1880-2010), native bees have advanced their spring arrival in the northeastern U.S. by an average of 10 days, primarily due to increased warming. Plants have also showed a trend of earlier blooming, thus helping preserve the synchrony in timing between plants and pollinators.135*
 9. *24. In the Northwest Atlantic, 24 out of 36 commercially exploited fish stocks showed significant range (latitudinal and depth) shifts between 1968 and 2007 in response to increased sea surface and bottom temperatures.55*
 10. *25. Increases in maximum, and decreases in the annual variability of, sea surface temperatures in the North Atlantic Ocean have promoted growth of small phytoplankton and led to a reorganization in the species composition of primary (phytoplankton) and secondary (zooplankton) producers.136*
 11. *29. Many Hawaiian mountain vegetation types were found to vary in their sensitivity to changes in moisture availability; consequently, climate change will likely influence elevation-related vegetation patterns in this region.139*
 12. *5. In response to climate-related habitat change, many small mammal species have altered their elevation ranges, with lower-elevation species expanding their ranges and higher-elevation species contracting their ranges.120*

DECLINES

None.

PREDICTED FROM CLIMATE MODELS, THEREFORE NOT FACT

1. *30. Sea level is predicted to rise by 1.6 to 3.3 feet in Hawaiian waters by 2100, consistent with global projections of 1 to 4 feet of sea level rise (see Ch. 2: Our Changing Climate, Key Message 10). This is projected to increase wave heights, the duration of turbidity, and the amount of re-suspended sediment in the water; consequently, this will create potentially stressful conditions for coral reef communities.140*
2. *6. Northern spotted owl populations in Arizona and New Mexico are projected to decline*

during the next century and are at high risk for extinction due to hotter, drier conditions, while the southern California population is not projected to be sensitive to future climatic changes.¹²¹

3. 19. Global marine mammal diversity is projected to decline at lower latitudes and increase at higher latitudes due to changes in temperatures and sea ice, with complete loss of optimal habitat for as many as 11 species by midcentury; seal populations living in tropical and temperate waters are particularly at risk to future declines.¹³²

UNLIKELY CORRELATION OR UNSUPPORTED STATEMENT

1. 13. (a and b) Climatic fluctuations were found to influence mate selection and increase the probability of infidelity in birds that are normally socially monogamous, increasing the gene exchange and the likelihood of offspring survival. ¹²⁵
2. 20. Higher nighttime temperatures and cumulative seasonal rainfalls were correlated with changes in the arrival times of amphibians to wetland breeding sites in South Carolina over a 30-year time period (1978-2008).¹³³ Of course. The time period precedes any possible effect of human-induced global warming, and the effect is a truism. Rainfall will affect amphibians. Since the climate models are admittedly weak about changes in rainfall, this statement has no relevance to purported human-induced global warming.
3. 22. *Widespread declines in body size of resident and migrant birds at a bird-banding station in western Pennsylvania were documented over a 40-year period; body sizes of breeding adults were negatively correlated with mean regional temperatures from the preceding year.*⁸⁵ The citation for this statement is NatureServe, cited 2012: Ecosystem-based Management Tools Network. [Available online at www.ebmtools.org]. This is a general website. I used its search option and did not find bird-banding nor Pennsylvania, nor any reference to a study of bird-banding in Pennsylvania.
4. 4. *Butterflies that have adapted to specific oak species have not been able to colonize new tree species when climate change-induced tree migration changes local forest types, potentially hindering adaptation.*¹¹⁹ . The citation 119 in the Assessment is Aumen, N., L. Berry, R. Best, A. Edwards, K. Havens, J. Obeysekera, D. Rudnick, and M. Scerbo, 2013: Predicting Ecological Changes in the Florida Everglades Under a Future Climate Scenario, 33 pp., U.S. Geological Survey, Florida Sea Grant, Florida Atlantic University. [Available online at http://www.ces.fau.edu/climate_change/ecology-february-2013/PECFEFCS_Report.pdf]. I searched this report and found no mention of butterflies. This is probably an inadvertent editing error and the authors of the Assessment meant to refer to some other paper, but since this is the actual listing, the statement is unsupported.
5. 1. *Mussel and barnacle beds have declined or disappeared along parts of the Northwest coast due to higher temperatures and drier conditions that have compressed habitable intertidal space.*¹¹⁶. The citation listed is Burke, L., L. Reytar, M. Spalding, and A. Perry, 2011: Reefs at Risk Revisited. World Resources Institute, 130 pp. [Available online at http://pdf.wri.org/reefs_at_risk_revisited.pdf]. I searched this citation and did not find any mention of the words mussel or barnacle and the only mention of “northwest” was “northwestern Hawaii.” Again this is likely a typographic error, but no other statement in the Assessment brought me to a relevant paper either, so the statement

is unsupported by the report.

SOME OTHER EXAMPLES OF SPECIFIC STATEMENTS THAT ARE INCORRECT, OR OVERSTATED, OR LIMITED TO A FEW SPECIFIC CASES, OR OTHERWISE OF DOUBTFUL GENERALITY

Given the length of the just-released White House Climate Change Assessment and the time available to review it, I am able to consider only a few examples of other specific problems with the Assessment. I have focused on those that have to do with biological factors. These, however, are representative of problems throughout the Assessment. (Once again, the material in italics is quotes from the Assessment; the material in standard font is my text.)

Cores from corals, ocean sediments, ice records, and other indirect temperature measurements indicate the recent rapid increase of ocean temperature is the greatest that has occurred in at least the past millennium and can only be reproduced by climate models with the inclusion of human-caused sources of heat-trapping gas emissions (p. 559). As we saw earlier, the climate models are not coming even close to forecasting air temperature change, and therefore could not be expected to forecast accurately changes in ocean temperature, so it is not correct to say that something "can only be reproduced by climate models with the inclusion of human-caused sources of heat-trapping gas emissions."

Warmer air and ocean temperatures are also causing the continued, dramatic decline in Arctic sea ice during the summer (panel D) (p. 560). We published a paper comparing Arctic sea ice extent in the nineteenth century, using historical records from ships hunting the bowhead whale, with those in recent times.¹⁰ In this paper we wrote, "Records from May indicate that end-of-winter sea-ice extent in the Bering Sea during the mid-19th century closely resembled that in the 1972–82 data. However, the historical data reveal that sea ice was more extensive during summer, with the greatest difference occurring in July. This pattern indicates a later and more rapid seasonal retreat." While the statement in the White House Climate Change Assessment is not contradicted by our paper, the limited statement (about the summer) in the Assessment once again paints a dire picture to the average reader, whereas our work suggests that in fact the sea ice extent recovered over winter, and changes in arctic sea ice are more complicated than the Assessment implies. The problem here is a matter of tone and communication.

Key Message 4: Seasonal Patterns: Timing of critical biological events—such as spring bud burst, emergence from overwintering, and the start of migrations—has shifted, leading to important impacts on species and habitats (p.201). The implication here is that this is entirely negative for life on Earth and will forever be so. But on the contrary, the environment has always changed and is always changing, and living things have had to adapt to these changes.

Interestingly, many, if not most, species that I have worked on or otherwise know about require environmental change, including salmon and sequoia trees.^{11 12}

Two of the longest studies of animals and plants in Great Britain show that at least some species are adjusting to recent weather changes in “timing of critical biological events, such as spring bud burst, emergence from overwintering.” For example, a 47-year study of the bird *Parus major* (one of the longest monitoring of any bird species) shows that these birds are responding behaviorally to recent weather changes. A species of caterpillar that is one of the main foods of this bird during egg-laying has been emerging earlier as spring temperatures have risen. In response, females of this bird species are laying their eggs an average of two weeks earlier.¹³

The second study, one of the longest experiments about how vegetation responds to temperature and rainfall, shows that long-lived small grasses and sedges are highly resistant to climate change. The authors of the study report that changes in temperature and rainfall during the past 13 years “have had little effect on vegetation structure and physiognomy.”¹⁴

Of course with any environmental change, not all species will do well. This has always been the case, and is consistent with Darwinian evolution and with ecological knowledge. Black guillemots (*Cepphus grylle*), birds that nest on Cooper Island, Alaska, illustrate that some species are having difficulties adjusting to climate change. (However, black guillemots in their entire range are not a threatened or endangered species. It is only their abundance on Cooper Island that has declined.)

The problem has been that temperature increases in the 1990s caused the sea ice to recede farther from the island each spring. The parent birds feed on Arctic cod found under the sea ice and must then return to the nest to feed their chicks, who are not yet mature enough to survive on their own. For the parents to do this, the distance from feeding grounds to nest must be less than about 30 km, but in recent years the ice in the spring has been receding as much as 500–800 km (300–500 mi) from the island. As a result, the black guillemots on the island have lost an important source of food. The birds have sometimes targeted sculpin, which is not as abundant as cod.¹⁵

But the real problem these Cooper Island birds face today is egg predation by polar bears. With less sea ice during this time period, bears have gone ashore and eaten young birds. In 2009, of the 180 guillemots that hatched, only one on the island fledged (flew away). The solution to this has been to build bear-proof nesting boxes for the birds. In 2010, bear-proof nesting boxes resulted in about 100 birds that fledged.

Two points emerge here. One is that living things do in fact often adjust to changes in the timing of climate events; if not, there would be little or no life on Earth. The second is that the real problem black guillemots face is here-and-now predation, which can be and has been dealt with and does not require a single focus on whether or not the climate change was human-induced.

Chapter 7, *Forests*, opens with this:

Key Messages

1. Climate change is increasing the vulnerability of many forests to ecosystem changes and tree mortality through fire, insect infestations, drought, and disease outbreaks.

As I noted before, the Assessment suffers from the use of the term “climate change” with two meanings: natural and human-induced. The implication in this key message is that the forest problems are the result of human-induced climate change, but as I have made clear, both the

failure of the models and the failure of temperature change to closely track CO₂ make this key statement false. Furthermore, it is well known that (1) forest wildfires are largely due to long-term suppression of fires in the twentieth century, which allowed the buildup of excessive fuel; and (2) that insect infestations and disease outbreaks are heavily the result of introduced species and the failure to remove dead and decaying timber from forests. In addition, this key statement is another example where recent weather patterns are said to represent and prove human-induced global warming, which I pointed out at the beginning is incorrect.

Key Message 2. *U.S. forests and associated wood products currently absorb and store the equivalent of about 16% of all carbon dioxide (CO₂) emitted by fossil fuel burning in the U.S. each year. Climate change, combined with current societal trends in land use and forest management, is projected to reduce this rate of forest CO₂ uptake.*

As explained in my review of the IPCC 2014 report, the estimates of carbon uptake by vegetation used by IPCC and in major articles cited by the reports are based on what can best be called “grab samples,” a relatively small number of studies done at a variety of times using a variety of methods, mainly in old-growth areas. The results reported by IPCC overestimate carbon storage and uptake by as much as 300%.¹⁶ Therefore this is an unreliable statement.

As I stated at above, these are representative examples of problems that exist throughout the Climate Change Assessment.

NOTES For the White House Climate Change Assessment

1. Publications by myself and J. M. Melillo: Aber, J.S., D.B. Botkin and J.M. Melillo, 1978, Predicting the effects of different harvesting regimes on forest floor dynamics in northern hardwoods, Canad. J. Forest Research 8: 306 - 315.; Aber, J.D., D.B. Botkin and J.M. Melillo, 1979, Predicting the effects of different harvesting regimes on productivity and yield in northern hardwoods, Canadian J. Forest Research 9: 10 - 14.; Aber, J.S., G.R. Hendrey, D.B. Botkin, A.J. Francis, and J.M. Melillo, 1980, Simulation of acid precipitation effects on soil nitrogen and productivity in forest ecosystems, Brookhaven National Laboratory Publications BNL 28658, Associated Universities, Inc, N.Y. Botkin, D.B., J.M. Melillo and L.S. Wu, 1981, “How ecosystem processes are linked to large mammal population dynamics,” pp. 373 - 387. In: C.W. Fowler and T. Smith, eds. *Population Dynamics of Large Mammals*, John Wiley and Sons, NY.; Aber, J.D., G.R. Hendrey, A.J. Francis, D.B. Botkin and J.M. Melillo, 1982, Potential effects of acid precipitation on soil nitrogen and productivity of forest ecosystems, pp. 411 - 433, In: F.M. D'itri, ed., *Acid Precipitation: Effects on Ecological Systems*. Ann Arbor Science, MI.

2. Le Roy Ladurie, E., *Times of Feast, Times of Famine: A History of Climate Since the Year 1000.*, 1971, Garden City, N.Y: Doubleday & Co. 426pp.

3. Botkin, D. B., 2012, *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered* (Oxford University Press, New York, hardback and ebook, September 14, 2012)

4. Botkin, D. B., and E. A. Keller, 2014. *Environmental Sciences: Earth as a Living Planet* (John

Wiley, New York).

5. Craine, J. M., E. G. Towne, A. Joern, and R. G. Hamilton, 2008: Consequences of climate variability for the performance of bison in tallgrass prairie. *Global Change Biology*, 15, 772-779, doi:10.1111/j.1365-2486.2008.01769.x.

6. Vos, D., "Going Native." *Wildlife Reviews*, 2006. Spring: p. 25-28.

7. Post, E., C. Pedersen, C. C. Wilms, and M. C. Forchhammer, 2008: Warming, plant phenology and the spatial dimension of trophic mismatch for large herbivores. *Proceedings of the Royal Society B: Biological Sciences*, 275, 2005-2013, doi:10.1098/rspb.2008.0463. [Available online at <http://rspb.royalsocietypublishing.org/content/275/1646/2005.full.pdf+html>]

8. IUCN Summary of polar bear population status per 2013
<http://pbsg.npolar.no/en/status/status-table.html>

9. Dawson, T.P., S. T. Jackson, J. I. House, I. C. Prentice, and G. M. Mace, *Beyond predictions: Biodiversity conservation in a changing climate*. . *Science*, 2011. **332**: p. 53-58.

10. Mahoney, Andrew R., John R. Bockstoce, Daniel B. Botkin, Hajo Eicken, and Robert A. Nisbet. 2011, "Sea Ice Distribution in the Bering and Chukchi Seas: Information from Historical Whaleships' Logbooks and Journals," *Arctic*. 64, (4): 465 – 477. (DECEMBER 2011).
11. Botkin, D. B., and E. A. Keller. 2014. (9th edition) *Environmental Sciences: Earth as a Living Planet* (John Wiley, New York).
12. Botkin, D. B., 2012, *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered* (Oxford University Press, New York, hardback and ebook, September 14, 2012).
13. Charmantier, A., Robin H. McCleery, Lionel R. Cole, Chris Perrins, Loeske E. B. Kruuk, Ben C. Sheldon, *Adaptive Phenotypic Plasticity in Response to Climate Change in a Wild Bird Population*. *Science* 2008. **320**(5877): p. 800-803.
14. Grime, J.P., Jason D. Fridley, Andrew P. Askew, Ken Thompson, John G. Hodgson, and Chris R. Bennett, *Long-term resistance to simulated climate change in an infertile grassland*. *PNAS*, 2008. **105**(29): p. 10028-10032.
15. Divoky, G. 2011. Black Guillemots in a melting Arctic: Responding to shifts in prey, competitors, and predators. *Transcription*, pages 125–130 in R. T. Watson, T. J. Cade, M. Fuller, G. Hunt, and E. Potapov (Eds.). *Gyrfalcons and Ptarmigan in a Changing World*, Volume I. The Peregrine Fund, Boise, Idaho, USA. <http://dx.doi.org/10.4080/gpcw.2011.0112>
16. Botkin, D. B., and L. Simpson, 1990, Biomass of the North American Boreal Forest: A step toward accurate Global Measures: *Biogeochemistry* 9:161-174; Botkin, D. B., Simpson, L. G., and H. J. Schenk, 1992, Estimating Biomass, *Science Letters*. Vol. 257, No. 5067. (Jul. 10, 1992), pp. 146-147; Botkin, D. B., Simpson, L. G., and R. A. Nisbet, 1993, Biomass and Carbon Storage of the North American Deciduous Forest, *Biogeochemistry* 20: 1-17; Botkin, D. B., Ngugi, M.R., D. Doley (submitted). "Statistically Valid Estimates and Accurate Forecasts of Forest Biomass and Carbon Sequestration: A Forty-Five Year Quest." Keynote speech at IUFRO Forest Biomass Conference, October 7, 2013, to be published in *Drewno (Wood) Journal*.