PETITION
of
Derek Watkins & Kids vs Global Warming

to the

MISSISSIPPI DEPARTMENT OF ENVIRONMENTAL QUALITY

For the promulgation of a rule to strictly limit
and regulate fossil fuel carbon dioxide emissions,
and to establish an effective emissions reduction
strategy that will achieve an atmospheric concentration
no greater than 350 ppm of carbon dioxide by 2100.

Derek Watkins
[redacted]

Alec Loorz and Victoria Loorz
Kids vs Global Warming
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May 4, 2011

[*] Please send relevant correspondences to all petitioners

[1] Miss. Const. Art. 3, § 11.

[*] Derek Watkins is a citizen of Mississippi currently living in Oregon for school.

Derek Watkins & Kids vs Global Warming

May 4, 2011

Trudy Fisher, Executive Director
Mississippi Department of Environmental Quality
P.O. Box 2261
Jackson, MS 39225

Re: Petition For Promulgation of a Rule to Regulate Fossil Fuel Carbon Dioxide Emissions and to Establish an Effective Emissions Reduction Strategy That Will Achieve a Concentration of 350 ppm Atmospheric Carbon Dioxide by 2100.

REQUEST FOR PROMULGATION OF A RULE

Pursuant to the Mississippi Constitution Article 3, Section 11, the people have a right "to peaceable assemble and petition the government on any subject."[1] The petitioners, Derek Watkins and Kids vs Global Warming, hereby submit this petition for rulemaking on behalf of themselves, the citizens of Mississippi, and present and future generations of minor children. The petitioners respectfully request that the Department of Environmental Quality (hereinafter, the Department) promulgate a rule that requires the agency to take the following steps in order to protect the integrity of Earth's climate by adequately protecting our atmosphere, a public trust resource upon which all those in Mississippi rely for their health, safety, sustenance, and security:

(1) Ensure that carbon dioxide emissions from fossil fuels peak in the year 2012;
(2) Adopt a carbon dioxide emissions reduction plan that, consistent with the best available science as described in the attached report, reduces state-wide fossil fuel carbon dioxide emissions by at least 6% annually until at least 2050, and expands Mississippi's capacity for carbon sequestration;
(3) Establishes a state-wide greenhouse gas emissions accounting, verification and inventory and issues annual progress reports so that the public has access to accurate data regarding the effectiveness of Mississippi's efforts to reduce fossil fuel carbon dioxide emissions; and
(4) Adopt any necessary policies or regulations to implement the greenhouse gas emissions reduction plan, as detailed in sections (1) and (2) above.

Petitioner Derek Watkins is a citizen of Mississippi who was born in Picayune

[1] Miss. Const. Art. 3, § 11.

and lives in Hattiesburg.[*] He is 26 and is concerned about drought and rising sea levels. He believes the inability of his state to have a rational conversation about climate change is dangerous, and that it is important to take action to preserve a healthy earth for future generations. In 2050, when the worst effects of climate change are projected to be seen, Derek will be 65.

Petitioner Kids vs Global Warming is a non-profit organization committed to creating opportunities for youth to learn about the science and solutions of climate change, and then to take action that will reduce dependence on fossil fuels and influence the Ruling Generation to make good decisions now that impact the future of youth and generations to come. Kids vs Global Warming is a membership organization of youth from all over the country who are concerned about how climate change is affecting and will continue to affect them and their future. Kids vs Global Warming files this petition on behalf of its members. The State's failure to limit carbon dioxide emissions and ensure that they decline each year as we transition off of fossil fuels is injuring Kids vs Global Warming's members in ways that are germane to the organization's mission. Namely, the State is causing harm to and failing to protect the atmosphere on which KvGW's members rely for their health, well-being and survival.

The petitioners are youth, who represent the youngest living generation of public trust beneficiaries, and have a profound interest in ensuring that the climate remains stable enough to ensure their right to a livable future. A livable future includes the opportunity to drink clean water and abate thirst, to grow food that will abate hunger, to be free from imminent property damage caused by extreme weather events, and to enjoy the abundant and rich biodiversity on this small planet. The petitioners request the promulgation of the rule herein proposed[·] in order to protect their interest in a livable future, and an inhabitable Mississippi.

I. **STATEMENT OF REASONS**: The Department of Environmental Quality should grant this petition and promulgate the proposed rule for the following reasons:

A. THE SCIENCE UNEQUIVOCALLY SHOWS THAT ANTHROPOGENIC CLIMATE CHANGE IS OCCURRING AND IS THREATENING THE STABILITY OF THE GLOBAL CLIMATE.

1. According to the United States Global Change Research Program[2], global warming

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[*] Derek Watkins is a citizen of Mississippi currently living in Oregon for school.

[·] See App. I for specific language of the proposed rule.

[2] "The U.S. Global Change Research Program (USGCRP) coordinates and integrates federal research on changes in the environment and their implications for society." The organization's vision is to produce "[a] nation, globally engaged and guided by science, meeting the challenges of climate and global change." The organization is comprised of "[t]hirteen departments and agencies [that] participate in the USGCRP…steered by the Subcommittee on Global Change Research under the Committee on Environment and

is occurring and adversely impacting the Earth's climate.[3] The present rate of global heating is occurring as a result of human activities that release heat-trapping greenhouse gases (GHGs) and intensify the Earth's natural greenhouse effect, at an accelerated rate, thereby changing Earth's climate.[4] This abnormal climate change is unequivocally human-induced[5], is occurring now, and will continue to occur unless drastic measures are taken to curtail it[6]. Climate change is damaging both natural and human systems, and if unrestrained, will alter the planet's habitability.[7]

2. According to the United States Environmental Protection Agency (EPA), "[T]he case for finding that *greenhouse gases in the atmosphere endanger public health and welfare is compelling and, indeed, overwhelming*."[8] The EPA further stated in April 2009 that "[t]he evidence points ineluctably to the conclusion that *climate change is upon us* as a result of greenhouse gas emissions, that *climate changes are already occurring that harm our health and welfare, and that the effects will only worsen over time in the absence of regulatory action*."[9]

3. We human beings have benefitted from living on a planet that has been remarkably hospitable to our existence and provided conditions that are just right for human

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Natural Resources, overseen by the Executive Office of the President, and facilitated by an Integration and Coordination Office." http://www.globalchange.gov/about.

[3] UNITED STATES GLOBAL CHANGE RESEARCH PROGRAM (USGCRP), GLOBAL CLIMATE CHANGE IMPACTS IN THE UNITED STATES 13 (2009) *available at* http://downloads.globalchange.gov/usimpacts/pdfs/climate-impacts-report.pdf [hereinafter *Global Climate Change Impacts*] ("Human activities have led to large increases in heat-trapping gases over the past century. Global average temperature and sea level have increased, and precipitation patterns have changed.").

[4] *Id*. ("The global warming of the past 50 years is due primarily to human-induced increases in heat-trapping gases."); DEUTSCHE BANK GROUP CLIMATE CHANGE ADVISORS, CLIMATE CHANGE: ADDRESSING THE MAJOR SKEPTIC ARGUMENTS 9 (September 2010) *available at* http://www.dbcca.com/dbcca/EN/_media/DBCCAColumbiaSkepticPaper090710.pdf; Intergovernmental Panel on Climate Change (IPCC), *IPCC Fourth Assessment Report: Climate Change 2007 (AR4)*, 1.1 (2007) *available at* http://www.ipcc.ch/publications_and_data/ar4/syr/en/mains1.html#1-1.

[5] USGCRP, *Global Climate Change Impacts* at 12 (2009).

[6] *Id*. ("Future climate change and its impacts depend on choices made today."); IPCC, *AR4* 1.1 (2007) ("Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.").

[7] USGCRP, *Global Climate Change Impacts* at 12 (2009) ("Thresholds will be crossed, leading to large changes in climate and ecosystems.").

[8] Proposed Endangerment Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act, 74 Fed. Reg. 18886, 18904 (April 24, 2009)(to be codified in 40 C.F.R. Chapter 1) (emphasis added).

[9] *Id*.

life to expand and flourish.[10] The Earth is a "Goldilocks" planet with an atmosphere that has fewer GHGs than that of Venus (which is too hot), and more than that of Mars (which is too cold), which is just perfect for the life that has developed on planet Earth.[11]

4. GHGs in the atmosphere act like a blanket over the Earth to trap the heat that it receives from the sun.[12] More GHGs in the atmosphere means that more heat is being retained on Earth, with less heat radiating back out into space.[13] Without this greenhouse effect, the average surface temperature of our planet would be 0°F (-18°C) instead of 59°F (15°C).[14] Scientists have understood this basic mechanism of global warming since the late-nineteenth century.[15]

5. Human beings have significantly altered the chemical composition of the Earth's atmosphere and its climate system.[16] We have changed the atmosphere and Earth's climate system by engaging in activities that produce, or release GHGs in to the atmosphere.[17] Carbon dioxide (CO_2) is the key GHG, and there is evidence that its emissions are largely responsible for the current warming trend.[18] Although much of the excess carbon dioxide is absorbed by the oceans, plants and forests, the increase of GHG concentrations resulting from historic and present human activities has altered the Earth's ability to maintain the delicate balance of energy between that which it receives from the sun and that which it radiates back out into

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[10] John Abatzoglou et al., *A Primer on Global Climate Change and Its Likely Impacts*, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN 11, 15-22 (Joseph F. C. DiMento & Pamela Doughman eds., MIT Press 2007) ("The earth's climate system can be thought of as an elaborate balancing act of energy, water, and chemistry involving the atmosphere, oceans, ice masses, biosphere, and land surface.").

[11] JAMES HANSEN, STORMS OF MY GRANDCHILDREN 224-225 (2009); *See* John Abatzoglou et al., *A Primer on Global Climate Change and Its Likely Impacts*, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN at 23.

[12] John Abatzoglou et al., *A Primer on Global Climate Change and Its Likely Impacts*, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN at 22.

[13] *Id.* at 16-17.

[14] *Id*. at 17.

[15] *See id*. at 35 (describing the efforts of Swedish chemist Svante Arrhenius).

[16] Naomi Oreskes, *The Scientific Consensus on Climate Change*, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN 65, 93 (Joseph F. C. DiMento & Pamela Doughman eds., MIT Press 2007) ("We have changed the chemistry of our atmosphere, causing sea level to rise, ice to melt, and climate to change. There is no reason to think otherwise.").

[17] *Id*.

[18] *See* James E. Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?* 2 OPEN ATMOS. SCI. 217, 217-231 (2008).

space.[19]

6. The current CO_2 concentration in our atmosphere is about 390 ppm[20] (compared to the pre-industrial concentration of 280 ppm).[21] Current atmospheric GHG concentrations are likely the highest they have been in the last 800,000 years.[22]

7. Concentrations of other GHGs in the atmosphere have also increased from human activities. Atmospheric concentrations of methane, for example, have increased nearly 150% since the pre-industrial period.[23] Concentrations of nitrous oxide have also increased.[24]

8. Humans not only continue to add GHGs into the atmosphere at a rate that outpaces their removal through natural processes,[25] but the current and projected CO_2

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[19] John Abatzoglou et al., *A Primer on Global Climate Change and Its Likely Impacts*, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN 11, 15-22 (Joseph F. C. DiMento & Pamela Doughman eds., MIT Press 2007).

[20] NOAA, Atmospheric CO_2 : Monthly & Annual Mean CO_2 Concentrations (ppm), March 1958 – Present, *available at* http://co2now.org/Current-CO2/CO2-Now/Current-Data-for-Atmospheric-CO2.html (showing an atmospheric CO_2 concentration of 392.40 for March, 2011).

[21] IPCC, *AR4* at 37 ("The global atmospheric concentration of CO2 increased from a pre-industrial value of about 280ppm to 379ppm in 2005."); National Science and Technology Council, *Scientific Assessment of the Effects of Global Change on the United States* 2 (May 2008) [hereinafter *Scientific Assessment*], *available at* http://www.climatescience.gov/Library/scientific-assessment/Scientific-AssessmentFINAL.pdf ("The globally averaged concentration of carbon dioxide in the atmosphere has increased from about 280 parts per million (ppm) in the 18th century to 383 ppm in 2007."); Environmental Protection Agency (EPA), *Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act* 17 (December 9 2009) [hereinafter *TS Endangerment Findings*].

[22] Dieter Lüthi et al., *High-resolution carbon dioxide concentration record 650,000-800,000 years before present* 453 Nature 379, 379-382 (May 2008) *available at* http://www.nature.com/nature/journal/v453/n7193/full/nature06949.html (prior to this publication it was accepted atmospheric CO_2 record extended back 650,000 years, but now research indicates that the record can be extended 800,000 years, or two complete glacial cycles).

[23] EPA, *TS Endangerment Findings* at 18 ("The global atmospheric concentration of methane has increased from a pre-industrial value of about 715 parts per billion (ppb) to 1732 ppb in the early 1990s, and was 1782 ppb in 2007- a 149% increase from pre-industrial levels.").

[24] *Id*. at 19.

[25] *Id*. at ES-2 ("Atmospheric GHG concentrations have been increasing because anthropogenic emissions have been outpacing the rate at which GHGs are removed from the atmosphere by natural processes over timescales of decades to centuries.").

increase, for example, is about one hundred times faster than has occurred over the past 800,000 years.[26] This increase has to be considered in light of the lifetime of greenhouse gases in the atmosphere. In particular, a substantial portion of every ton of CO_2 emitted by humans persists in the atmosphere for as long as a millennium or more.[27] The current concentrations of GHGs in the atmosphere therefore, are the result of both historic and current emissions.

9. One key observable change is the rapid increase in recorded global surface temperatures.[28] As a result of increased atmospheric GHGs from human activities, based on fundamental scientific principles, the Earth has been warming as scientists have predicted.[29] The increased concentrations of greenhouse gases in our atmosphere, primarily CO_2,[30] have raised global surface temperature by 1.4°F (0.8°C) in the last one hundred to one hundred fifty years.[31] In the last thirty years,

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[26] Dieter Lüthi et al., *High-resolution carbon dioxide concentration record 650,000-800,000 years before present* 453 Nature 379, 379-382 (May 2008) *available at* http://www.nature.com/nature/journal/v453/n7193/full/nature06949.html.

[27] James E. Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?* 2 OPEN ATMOS. SCI. 217, 220 (2008); *See also* EPA, *TS Endangerment Findings* at 16 ("Carbon cycle models indicate that for a pulse of CO2 emissions, given an equilibrium background, 50% of the atmospheric increase will disappear within 30 years, 30% within a few centuries, and the last 20% may remain in the atmosphere for thousands of years."); John Abatzoglou et al., *A Primer on Global Climate Change and Its Likely Impacts*, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN 11, 29 (Joseph F. C. DiMento & Pamela Doughman eds., MIT Press 2007) ("Since CO2 has a lifetime of over one hundred years, these emissions have been collecting for many years in the atmosphere.").

[28] National Science and Technology Council, *Scientific Assessment* at 51; IPCC, *AR4* at 30; USGCRP, *Global Climate Change Impacts* at 19; EPA, *TS Endangerment Findings* 26-30; National Aeronautics and Space Administration (NASA) & Goddard Institute for Space Studies (GISS), *Global Surface Temperature*, http://climate.nasa.gov/keyIndicators/#globalTemp (illustrating the change in global surface temperatures) (last visited April 7, 2011).

[29] IPCC, *AR4* at 39; USGCRP, *Global Climate Change Impacts* at 13; EPA, *TS Endangerment Findings* at 48.

[30] EPA, *Climate Change – Science*, *available at* http://epa.gov/climatechange/science/index.html (August 19, 2010) (last visited April 7, 2011); EPA, *TS Endangerment Findings* at ES-1-2.

[31] EPA, *TS Endangerment Findings* at ES-2 ("Global mean surface temperatures have risen by 1.3 ± 0.32°F (0.74°C ± 0.18°C) over the last 100 years."); *See* J. Hansen et al., NASA & GISS, *Global Surface Temperature Change* (August 3, 2010); NASA, *Climate Change: Key Indicators*, http://climate.nasa.gov/keyIndicators (last visited April 7, 2011); John Abatzoglou et al., *A Primer on Global Climate Change and Its Likely Impacts*, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN 11, 15-22 (Joseph F. C. DiMento & Pamela Doughman eds., MIT Press 2007).

the acceleration of change has intensified as the Earth has been warming at a rate three times faster than that over the previous one hundred years.[32]

10. Because of year-to-year variations in these thermometer readings, as with daily readings, scientists compare temperature differences over a decade to determine patterns.[33] Employing this decadal scale, the surface of the planet has warmed at a rate of roughly 0.3 to 0.4°F (0.15 to 0.2°C) per decade since the late 1970s.[34] Global mean surface temperature has been decidedly higher during the last few decades of the twentieth century than at any time during the preceding four centuries.[35] Global surface temperatures have been rising dramatically since 1951, and 2010 tied for the hottest year on record.[36]

11. The dramatic increase of the average global surface temperature is alarming. By comparison, the global surface temperature during the last Ice Age was about 9°F (5°C) cooler than today.[37] It has become quite clear that the past several decades present an anomaly, as global surface temperatures are registering higher than at any point in the past 400 years (and for the Northern Hemisphere the past 1,000 years).[38]

12. The IPCC has observed that "[w]arming of the climate system is unequivocal."[39]

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[32] EPA, *TS Endangerment Findings* at 32 ("U.S. average annual temperatures (for the contiguous United States or lower 48 states) are now approximately 1.25°F (0.69°C) warmer than at the start of the 20th century, with an increased rate of warming over the past 30 years. The rate of warming for the entire period of record (1901–2008) is 0.13°F (0.072°C) per decade while the rate of warming increased to 0.58°F (0.32°C) per decade for the period 1979–2008."); USGCRP, *Global Climate Change Impacts* at 9.
[33] IPCC, *AR4* at 40.
[34] *See* NASA, *Climate Change: Key Indicators*, *Global Land-Ocean Temperature Index*, http://climate.nasa.gov/keyIndicators/#globalTemp (last visited April 7, 2011).
[35] The National Academies Press (Board on Atmospheric Sciences and Climate), *Surface Temperature Reconstructions for the Last 2,000 Years* 3 (2006), *available at* http://www.nap.edu/catalog.php?record_id=11676.
[36] NASA, *Global Climate Change – Global Surface Temperature*, http://climate.nasa.gov/keyIndicators/index.cfm#globalTemp (last visited April 10, 2011) ("Global surface temperatures in 2010 tied 2005 as the warmest on record."); NASA, *Global Climate Change*, http://climate.nasa.gov/ (last visited April 10, 2011) ("January 2000 to December 2009 was the warmest decade on record.").
[37] James E. Hansen & Makiko Sato, *Paleoclimate Implications for Human-Made Climate Change* 5 (January 18, 2011), *available at* http://www.columbia.edu/~jeh1/mailings/2011/20110118_MilankovicPaper.pdf (last visited April 10, 2011).
[38] USGCRP, *Global Climate Change Impacts* at 19.
[39] IPCC, *Summary for Policymakers*, *in* CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF

The United States EPA has recognized the scientific consensus that has developed on the fact of global warming and its cause; that the Earth is heating up due to human activities.[40]

13. Changes in many different aspects of Earth's climate system over the past century are consistent with this warming trend: based on straightforward scientific principles, human-induced GHG increases lead not only to warming of land surfaces[41], but also to the warming of oceans[42], increased atmospheric moisture levels[43], rises in the global sea level[44], and changes in rainfall[45] and atmospheric air circulation patterns that affect water and heat distribution.[46]

14. As expected (and consistent with the temperature increases in land surfaces), ocean temperatures have also increased.[47] This has led to changes in the ocean's ability to circulate heat around the globe; which can have catastrophic implications for the global climate system.[48] The average temperature of the global ocean has increased significantly despite its amazing ability to absorb enormous amounts of heat before exhibiting any signs.[49] In addition, the most significant indicator of the planet's energy imbalance due to human-induced GHG increases, is the long-term increase in global average ocean heat content over the last 50 years, extending down to several thousand meters below the ocean surface.[50]

15. As predicted, precipitation patterns have changed due to increases in atmospheric moisture levels and changes in atmospheric air circulation patterns; just another

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THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, at 1, 3, 22, 31 (S. Solomon et al. eds. 2007).

[40] EPA, *TS Endangerment Findings* at ES-2 ("Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. … Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in *anthropogenic* GHG concentrations.") (emphasis added).

[41] IPCC, *AR4* at 30.

[42] *Id*. at 72.

[43] USGCRP, *Global Climate Change Impacts* at 18; B.D Santer et al., *Identification of human-induced changes in atmospheric moisture content*, 104 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES, 15248, 15248-15253 (September 25, 2007).

[44] IPCC, *AR4* at 30.

[45] USGCRP, *Global Climate Change Impacts* at 18, 44.

[46] *Id.* at 42.

[47] IPCC, *AR4* at 30; EPA, *TS Endangerment Findings* at ES-2.

[48] USGCRP, *Global Climate Change Impacts* at 26.

[49] UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP), CLIMATE CHANGE SCIENCE COMPENDIUM 2009 at 26 (UNEP/Earthprint, 2009).

[50] S. Levitus et al., *Global ocean heat content 1955-2008 in light of recently revealed instrumentation problems* 36 J. GEOPHYSICAL RES. LETTERS L07608 (April 2009).

indicator that the Earth is warming.[51] As the Earth warms, moisture levels are expected to increase when temperature increases because warmer air generally holds more moisture.[52] In more arid regions, however, higher temperatures lead to greater evaporation.[53]

16. These changes in the Earth's water cycle increase the potential for, and severity of, severe storms, flooding and droughts.[54] Storm-prone areas are already experiencing a greater chance of severe storms, and this will continue.[55] Even in arid regions, increased precipitation is likely to cause flash flooding, and will be followed by drought.[56]

17. These changes are already occurring: Droughts in parts of the midwestern, southeastern, and southwestern United States have increased in frequency and severity within the last fifty years, coincident with rising temperatures.[57] In 2009, more than half of the United States received above normal precipitation; yet the southwestern United States (Arizona in particular) had one of its driest periods.[58]

18. Based on the laws of physics and the past climate record, scientists have concluded that precipitation events will increase globally, particularly in tropical and high latitude regions, while decreasing in subtropical and mid-latitude regions,[59] with longer periods between normal heavy rainfalls.[60]

19. Other changes consistent with climate modeling resulting from global warming have been observed not just in the amount, intensity, and frequency of precipitation but also in the type of precipitation.[61] In higher altitude and latitude regions, including in mountainous areas, more precipitation is falling as rain rather than snow.[62] With early snow melt occurring because of climate change, the reduction in snowpack can aggravate water supply problems.[63] In Northern Europe and the northeastern United States, a change in air currents -- caused by the warming Arctic -- brought severe snowstorms during the winters of 2009-2010 and

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[51] USGCRP, *Global Climate Change Impacts* at 13, 17, 21, 36, 42, 74.
[52] EPA, *TS Endangerment Findings* at 111.
[53] *Id.*
[54] *Id.*
[55] *Id.* at 120-121; USGCRP, *Global Climate Change Impacts* at 27.
[56] EPA, *TS Endangerment Findings* at 115.
[57] *Id.* at 145, 143, 148.
[58] *State of the Climate, 2009* at S138.
[59] EPA, *TS Endangerment Findings* at ES-4, 74.
[60] EPA, *TS Endangerment Findings* at 74.
[61] *Id.* at ES-2.
[62] USGCRP, *Global Climate Change Impacts* at 18, 45.
[63] *Id.* at 33

2010-2011.[64]

20. As expected global sea levels have also risen.[65] Sea levels have been rising at an average rate of 3.1 millimeters per year based on measurements from 1993 to 2003.[66] Though sea levels rose about 6.7 inches over the last century; within the last decade, that rate has nearly *doubled*.[67] Rising seas, brought about by melting of polar icecaps and glaciers, as well as by thermal expansion of the warming oceans, will cause flooding in coastal and low-lying areas.[68] The combination of rising sea levels and more severe storms creates conditions conducive to severe storm surges during high tides.[69] In coastal communities this can overwhelm coastal defenses (such as levees and sea walls), as witnessed during Hurricane Katrina.[70]

21. Sea level is not uniform across the globe, because it depends on variables such as ocean temperature and currents.[71] Unsurprisingly, the most vulnerable lands are low-lying islands, river deltas, and areas that already lie below sea level because of land subsidence.[72] Based on these factors, scientists have concluded that the threats to the United States from rising seas are the most severe on the Gulf and Atlantic Coasts.[73] Worldwide, hundreds of millions of people live in river deltas and vulnerable coastlines along the southern and western coasts of Asia where

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[64] NOAA, *Arctic Report Card: Update for 2010*, (December 10, 2010) (last visited April 7, 2011) http://www.arctic.noaa.gov/reportcard/atmosphere.html; NOAA, *The Future of Arctic Sea Ice and Global Impacts*, http://www.arctic.noaa.gov/future/index_impacts.html#event; *See also* Climate Science Watch, *Climatologist Ben Santer on the attribution of extreme weather events to climate change*, (December 29, 2010) (last visited April 9, 2011) http://climateprogress.org/2010/12/29/ben-santer-attribution-extreme-weather-events-to-climate-change/#more.

[65] USGCRP, *Global Climate Change* Impacts, at 9; EPA, *TS Endangerment Findings* at ES-3; IPCC, *AR4* at 30.
[66] IPCC, *AR4* at 30.
[67] NASA, *Climate Change: How Do We Know?*, *Sea Level Rise* (last visited April 9, 2011) http://climate.nasa.gov/evidence/#no4 (citing J.A. Church & N.J. White, *A 20th Century Acceleration in Global Sea Level Rise* (2006) 33 Geophysical Research Letters, L01602, doi: 10.1029/2005GL024826).
[68] EPA, *TS Endangerment Findings* at ES-7; USGRCP, *Global Climate Change Impacts* at 62-63.
[69] USGCRP, *Global Climate Change Impacts* at 109; EPA, *TS Endangerment Findings* at 75.
[70] EPA, *TS Endangerment Findings* at 86, 118.
[71] USGCRP, *Global Climate Change Impacts* at 25-26, 37.
[72] EPA, *TS Endangerment Findings* at 121.
[73] *Id*. at 128; USGCRP, *Global Climate Change Impacts* at 57.

rivers draining the Himalayas flow into the Indian and Pacific Oceans.[74]

22. In a comprehensive review of studies on sea level rise in the 21st century published by the British Royal Society, researchers estimated the probable sea level rise for this century between .5 and 2 meters (1 ½ to 6 ½ feet), continuing to rise for several centuries after that, depending on future CO_2 levels and the behavior of polar ice sheets.[75]

23. The IPCC estimates a 0.6-meter rise in sea level by 2100 under a worst-case scenario that does not include contributions from the accelerated flow of major ice sheets.[76] Some scientists predict a 2-meter rise in sea level by 2100 if present trends continue.[77] "Today, rising sea levels are submerging low-lying lands, eroding beaches, converting wetlands to open water, exacerbating coastal flooding, and increasing the salinity of estuaries and freshwater aquifers."[78] The impacts of rising sea levels can be seen in many coastal locations across the nation; along the Florida coast for instance, sea level is rising about 1 inch every 11-14 years.[79] This seemingly small rise in ocean levels is contributing to massive erosion, causing many homeowners to remove beachfront property, and has lead to a decline in the recreational value of beaches.[80] Other coastal states (such as Maryland and Louisiana) are also experiencing wetland loss due to rising sea levels.[81] Scientists have predicted that wetlands in the Mid-Atlantic region of the United States cannot withstand a 7-millimeter per year rise in sea levels.[82]

24. As expected, mountain glaciers, which are the source of freshwater for hundreds of millions of people, are receding worldwide because of warming temperatures.[83]

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[74] EPA, *TS Endangerment Findings* at 159; IPCC, *AR4* at 52.

[75] R.J. Nicholls et al., *Sea-level rise and its possible impacts given a 'beyond 4°C world' in the twenty-first century*, PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY 161-181, 168 (2011).

[76] IPCC, *AR4* at 45.

[77] M. Vermeer & S. Rahmstorf, *Global Sea Level Linked to Global Temperature*, 106 PROC. NATL. ACAD. SCI. 21527, 21531 (2009).

[78] USCCSP, *Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region* [hereinafter *Coastal Sensitivity to Sea-Level Rise*] 2 (Jan. 2009), *available at* http://www.epa.gov/climatechange/effects/coastal/pdfs/ccsp_front.pdf.

[79] EPA, *Saving Florida's Vanishing Shores* (March 2002) *available at* http://www.epa.gov/climatechange/effects/coastal/saving_FL.pdf.

[80] *Id*.

[81] USCCSP, *Coastal Sensitivity to Sea-Level Rise* at 3-4.

[82] *Id*. at 4.

[83] *See TS Endangerment Findings* at 111 ("Glaciers throughout North America are melting, and the particularly rapid retreat of Alaskan glaciers represents about half of the estimated loss of glacial mass worldwide.").

Today, Glacier National Park in Montana has twenty-five glaciers larger than twenty-five acres, down from one hundred and fifty in 1850.[84] The year 2009 marked the 19th consecutive year in which glaciers lost mass.[85] Mountain glaciers are in retreat all over the world, including Mt. Kilimanjaro in Africa, the Himalayas, the Alps (99% in retreat), the glaciers of Peru and Chile (92% in retreat), and in the United States.[86] In the Brooks Range of northern Alaska, all of the glaciers are in retreat and in southeastern Alaska 98% are in retreat.[87]

25. Although a minor contribution to sea level rise, the melting of mountain glaciers is particularly serious in areas that rely on snow melt for irrigation and drinking water supply.[88] In effect, a large snow pack or glacier acts as a supplemental reservoir or water tower, holding a great deal of water in the form of ice and snow through the winter and spring and releasing it in the summer when rainfall is lower or absent.[89] The water systems of the western United States (particularly in California) and the Andean nations of Peru and Chile, among other places, all heavily rely on these natural forms of water storage.[90] In addition to providing a more reliable water supply, the storing of precipitation as ice and snow helps moderate potential flooding.[91]

26. Yet as temperatures warm, not only will these areas lose this supplemental form of water storage, but also severe flooding is likely to increase (because when rain falls on snow, it accelerates the melting of glaciers and snow packs).[92] Ice is melting most dramatically at the poles.[93] Sea ice in the Arctic oceans is expected

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[84] United States Geological Survey (Northern Rocky Mountain Science Center), *Retreat of Glaciers in Glacier National Park* (June 2010), http://www.nrmsc.usgs.gov/research/glacier_retreat.htm.
[85] National Oceanic and Atmospheric (NOAA), *State of the Climate in 2009*, 91 BULL. AMER. METEOR. SOC. at S13 (2010).
[86] L. Thompson, *Climate Change: The Evidence and Our Options*, 33 THE BEHAVIOR ANALYST No. 2 (Fall) 153, 155-160 (2010); USGRCP, *Global Climate Change Impacts* at 18.
[87] L. Thompson, *Climate Change: The Evidence and Our Options*, 33 THE BEHAVIOR ANALYST No. 2 (Fall) 153, 158 (2010).
[88] IPCC, *AR4* at 49.
[89] *See* L. Thompson, *Climate Change: The Evidence and Our Options*, 33 THE BEHAVIOR ANALYST No. 2 (Fall) 153, 164 (2010).
[90] *See Id*. at 155 – 160, 164.
[91] EPA, *TS Endangerment Findings* at 111; USGRCP, *Global Climate Change Impacts* at 64.
[92] EPA, *TS Endangerment Findings* at 111.
[93] L. Thompson, *Climate Change: The Evidence and Our Options*, 33 THE BEHAVIOR ANALYST No. 2 (Fall) 153, 160 (2010) ("[P]olar ice sheets are slower to respond to temperature rise than the smaller mountain glaciers, but they too, are melting. . . . The loss of ice in the Arctic and Antarctic regions is especially troubling because these are the locations of the largest ice sheets in the world.").

to decrease and may even disappear entirely in coming decades.[94]

27. Beginning in late 2000, the Jakobshavn Isbrae Glacier (which has a major influence over the mass of the Greenland ice sheet), lost significant amounts of ice.[95] In August of 2010, an enormous iceberg (roughly ninety-seven square miles in size) broke off from Greenland.[96] Nine Antarctic ice shelves have also collapsed into icebergs in the last fifty years, (six of them since 1996).[97] An ice shelf roughly the size of Rhode Island collapsed in 2002, and an ice bridge collapsed in 2009, leaving an ice shelf the size of Jamaica on the verge of shearing off.[98] The 2002 collapse of the Larsen Ice Shelf, which had existed for at least 11,000 years, was "unprecedented in respect to both area and time."[99] The "sudden and complete disintegration" of the Larsen Ice Shelf took a *mere 35 days*.[100]

28. During the 2007-melt season, the extent of Arctic sea ice (frozen ocean water) declined precipitously to its lowest level since satellite measurements began in 1979.[101] By the end of 2010 Arctic sea ice was at the lowest level in the satellite record for the month of December.[102]

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94 EPA, *TS Endangerment Findings* at 120; USGCRP, *Global Climate Change Impacts* at 20-21 ("Studies published after the appearance of the IPCC Fourth Assessment Report in 2007 have also found human fingerprints in the increased levels of atmospheric moisture (both close to the surface and over the full extent of the atmosphere), in the decline of Arctic sea ice extent, and in the patterns of change in Arctic and Antarctic surface temperatures.").

95 GARY BRAASCH & BILL MCKIBBEN, EARTH UNDER FIRE 18-20 (2009); *See also* J.E. Box et. al., (NOAA) *Greenland*, ARCTIC REPORT CARD at 55 (Oct. 2010) ("A clear pattern of exceptional and record-setting warm air temperatures is evident at long-term meteorological stations around Greenland.").

96 NASA Earth Observatory, *Ice Island Calves Off Petermann Glacier* (Aug. 2010), http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=45112&src=eorss-nh.

97 Alister Doyle, *Antarctic Ice Shelf Set to Collapse Due to Warming*, Reuters (Jan. 19, 2009) http://www.reuters.com/article/idUSTRE50I4G520090119.

98 NASA Earth Observatory, *Wilkins Ice Bridge Collapse* (April 2009), http://earthobservatory.nasa.gov/IOTD/view.php?id=37806.

99 U.S. Geological Survey, *Coastal-Change and Glaciological Map of the Larsen Ice Shelf Area, Antarctica: 1940-2005* at 10 (2008) http://pubs.usgs.gov/imap/2600/B/LarsenpamphletI2600B.pdf

100 *Id*. at 10.

101 National Snow and Ice Data Center (NSDIC), Press Release, *Arctic Sea Ice Shatters All Previous Record Lows* (October 1, 2007), http://nsidc.org/news/press/2007_seaiceminimum/20071001_pressrelease.html (last visited April 9, 2011); EPA, *TS Endangerment Findings* at 27 ("Average arctic temperatures increased at almost twice the global average rate in the past 100 years.").

102 NSIDC, *Repeat of a negative Arctic Oscillation leads to warm Arctic, low sea ice extent*, ARCTIC SEA ICE NEWS & ANALYSIS, (January 5, 2011), http://nsidc.org/arcticseaicenews/2011/010511.html (last visited April 9, 2011).

29. Arctic sea ice plays an important role in stabilizing the global climate, because it reflects back in to space much of the solar radiation that the region receives.[103] In contrast, open ocean water absorbs much more heat from the sun, thus, amplifying human-induced warming and creating an increased global warming effect.[104] As arctic sea ice decreases the region is less capable of stabilizing the global climate and may act as a feedback loop (thereby aggravating global warming).[105]

30. Scientists have also documented an overall trend of sea-ice thinning.[106] The year 2010 also marked a record-low, spring snow cover in the Arctic since satellite observations first began in 1966.[107]

31. Similarly, there has been a general increase in permafrost temperatures and permafrost melting in Alaska and other parts of the Arctic (particularly in the last five years).[108] Scientists in Eastern Siberia and Canada have documented substantial methane releases as the permafrost melts.[109] Because much of the Arctic permafrost overlays old peat bogs, scientists believe (and are concerned) that the melting of the permafrost[110] may release methane that will further increase global warming to even more dangerous levels.[111]

32. Changes in these different aspects of Earth's climate system over the last century tell a coherent story: the impacts we see today are consistent with the scientific understanding of how the climate system should respond to GHG increases from human activities and how the Earth has responded in the past (reflected in such evidence as: ice cores that have trapped air from thousands and even a few million years ago, tree rings and seabed sediments that show where sea level was thousands and even millions of years ago).[112] Collectively, these changes cannot

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[103] EPA, *Climate Change Indicators in the United States*, 45 (2010), *available at* http://www.epa.gov/climatechange/indicators/pdfs/ClimateIndicators_full.pdf [hereinafter *Climate Change Indicators*]; *See also* EPA, *TS Endangerment Findings* at 40.

[104] EPA, *Climate Change Indicators* 52 (2010); USGCRP, *Global Climate Change Impacts* at 39.

[105] EPA, *Climate Change Indicators* 46 (2010).

[106] NOAA, *State of the Climate in 2009* at S114.

[107] NOAA, *Land*, ARCTIC REPORT CARD 29 (Oct. 2010), *available at* http://www.arctic.noaa.gov/reportcard/ArcticReportCard_full_report.pdf.

[108] *Id*.

[109] NOAA, *State of the Climate in 2009* at S116.

[110] USGCRP, *Global Climate Change Impacts* at 139, 142 ("The higher temperatures are already contributing to . . . permafrost warming.").

[111] *See* IPCC, *4.4.6 Tundra and Arctic/Antarctic* Ecosystems, CLIMATE CHANGE 2007: FOURTH ASSESSMENT REPORT, WORKING GROUP II, IMPACTS, ADAPTATION, AND VULNERABILITY 231 (2007).

[112] USGCRP, *Global Climate Change Impacts* at 26.

be explained as the product of natural climate variability or a tilt in the Earth's axis alone.[113] A large human contribution provides the best explanation of observed climate changes.[114]

33. These well-documented and observable impacts from the changes in Earth's climate system highlight that the current level of atmospheric CO_2 concentration has already taken the planet into a danger zone.[115] The Earth will continue to warm in reaction to concentrations of CO_2 from past emissions as well as future emissions.[116] Warming already in the pipeline is mostly attributable to climate mechanisms that slowly heat the Earth's climate system in response to atmospheric CO_2.[117]

34. The Earth's oceans play a significant role in keeping our atmospheric climate in the safe-zone.[118] The oceans constantly absorb CO_2 and release it back into the atmosphere at rates that maintain a balance.[119] Because we now release so much CO_2, the oceans have absorbed about one-third of the CO_2 emitted from human activity over the past two centuries.[120] This capacity has slowed global warming, but at a cost: the added CO_2 has changed the chemistry of the oceans, causing the oceans' average surface pH (a measurement of hydrogen ions) to drop by an average of .11 units.[121] Although this may seem relatively small, the pH scale is logarithmic, so that a reduction of only one unit means that the solution has in fact become ten times more acidic.[122] A drop of .1 pH units means that the concentration of hydrogen ions in seawater has gone up by 30% in the past two centuries.[123] If CO_2 levels continue to rise to 500 ppm, we could see a further drop of .3 pH units by 2100.[124]

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[113] *Id*.
[114] Susan Solomon et al., *Irreversible climate change due to carbon dioxide emissions,* 106 PNAS 1704, 1704 – 1709 (Feb. 10, 2009), *available at* www.pnas.org/cgi/doi/10.1073/pnas.0812721106 (last visited April 9, 2011).
[115] USGCRP, *Global Climate Change Impacts* at 23.
[116] EPA, *TS Endangerment Findings* at 26.
[117] FRED PEARCE, WITH SPEED AND VIOLENCE: WHY SCIENTISTS FEAR TIPPING POINTS IN CLIMATE CHANGE 101-104 (Beacon Press 2007); IPCC, *AR4* at 72.
[118] *See* EPA, *TS Endangerment Findings* at 16, 38.
[119] IPCC, *AR4* at 72.
[120] Inter-Agency Report, *Impacts of Ocean Acidification* at 1; *See also TS Endangerment Findings* at 38 ("[T]he total inorganic carbon content of the oceans increased by 118 ± 19 gigatonnes of carbon (GtC) between 1750 and 1994 and continues to increase.").
[121] EPA, *TS Endangerment Findings* at 38; Inter-Agency Report, *Impacts of Ocean Acidification* at 1.
[122] HARVEY BLATT, AMERICA'S ENVIRONMENTAL REPORT CARD 158 (MIT Press 2005).
[123] A. Ridgewell & D. Schmidt, *Past constraints on the vulnerability of marine calcifiers to massive carbon dioxide release*, 3 NATURE GEOSCIENCE 196, 196-200 (2010).
[124] IPCC, *AR4* at 52.

35. Ocean acidification harms animals that use calcium to build their shells, as well as single-celled organisms that are an essential part of the marine food chain.[125] This is because the acidified waters affect the structural integrity and survival of shell-building marine organisms such as corals and shellfish by effectively robbing them of the key chemical (carbonate ion) they need to build their skeletons.[126] It also adversely impacts some kinds of algae and single-celled organisms that use calcification processes for survival.[127] Some of these organisms comprise magnificent natural features, such as the White Cliffs of Dover.[128] Coral reefs are major habitats for ocean fauna; and calcifying algae and plankton are key components of the marine food chain.[129]

36. About 55 million years ago, the ocean absorbed a large amount of CO_2, likely due to a release of methane from the ocean floor that caused the Earth's temperatures to rise several degrees and led to the extinction of many species worldwide.[130] The absorption of so much CO_2 also led to the death of calcifying organisms on the seafloor.[131] It took over 100,000 years for the ocean to regain its normal alkalinity.[132] The current of level of CO_2 being taken in by the ocean decreases the ability of coral and other calcium-based marine life to produce their skeletons, which affects the growing of coral and thus coral reefs.[133] Other marine life, such as algae, also exhibit a reduced growing ability.[134] Thus, ocean acidification can disrupt the food chain, give non-calcium based creatures a competitive advantage, and limit the geographic reach of calcium based creatures.[135] In experiments, "[c]oral reef organisms have not demonstrated an ability to adapt to decreasing carbonate saturation state."[136] Finally, this disruption to the food web "could

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[125] EPA, *TS Endangerment Findings* at 38.
[126] USGCRP, *Global Climate Change Impacts* at 85.
[127] *Id*.
[128] Carl Zimmer, *An Ominous Warning on the Effects of Ocean Acidification*, Yale Environment360, (February 15, 2010), *available at* http://e360.yale.edu/feature/an_ominous_warning_on_the__effects_of_ocean_acidification/2241/ (last visited April 9, 2011).
[129] EPA, *Coral Reef Biological Criteria: Using the Clean Water Act to Protect a National Treasure* 3-1 (July 2010), *available at* http://www.epa.gov/bioindicators/pdf/EPA-600-R-10-054_CoralReefBiologicalCriteria_UsingtheCleanWaterActtoProtectaNationalTreasure.pdf (last visited April 9, 2011).
[130] [130] James C. Zachos et al., *Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum*, 308 SCIENCE 1611, 1611-1615 (June 10, 2005).
[131] *Id*.
[132] *Id*.
[133] Inter-Agency Report, *Impacts of Ocean Acidification* at 69.
[134] "Many of these organisms are important components of the marine food web." *Id.*
[135] *Id*.
[136] *Id*.

substantially alter the biodiversity and productivity of the ocean."[137]

37. The warming of oceans also contributes to the bleaching of corals.[138] Corals contain a tiny alga that provides them with food and that accounts for their color.[139] When the oceans warm, the algae give off toxins, and the corals, in order to survive the toxin, expel the algae, thereby bleaching the coral.[140] If the water temperature does not fall enough to permit algae to survive within the coral without releasing the toxin, the corals will eventually die.[141] There have been several severe episodes of coral bleaching in recent years.[142] With continued warming, the coral may not be able to survive.[143]

38. Changes in water supply and water quality will also impact agriculture in the US.[144] Additionally, increased heat and associated issues such as pests, crop diseases, and weather extremes, will all impact crop and livestock production and quality.[145] For example, climate change in the United States has produced warmer summers, enabling the mountain pine beetle to produce two generations of beetles in a single summer season, where it had previously only been able to produce one; in Alaska, the spruce beetle is maturing in one year when it had previously taken two years.[146] The expansion of the forest beetle population has killed millions of hectares of trees across the United States and Canada and resulted in millions of dollars lost from decreased timber and tourism revenues.[147]

39. Agriculture is extremely susceptible to climate changes and higher temperatures

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137 *Id.*

138 EPA, *TS Endangerment Findings* at 103; USGCRP, *Global Climate Change Impacts* at 148.

139 USGCRP, *Global Climate Change Impacts* at 84, 151-52; *See* EPA, *TS Endangerment Findings* at 138.

140 USGCRP, *Global Climate Change Impacts* at 84, 151-52.

141 *See id*.

142 *Id*. at 84.

143 *Id*.

144 USGCRP, *Global Climate Change* Impacts at 126; *See* United States Department of State (USDS), *U.S. Climate Action Report 2010, Fifth National Communication of the United States of America Under the United Nations Framework Convention on Climate Change* [hereinafter *U.S. Climate Action Report*] 87 (June 2010) *available at* http://www.state.gov/documents/organization/140636.pdf.

145 USDS, *U.S. Climate Action Report* at 87.

146 U.S. Climate Change Science Program (USCCSP), *Weather and Climate Extreme in a Changing Climate, Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands* [hereinafter *Weather and Climate Extremes*] 15 (June 2008) *available at* http://www.climatescience.gov/Library/sap/sap3-3/final-report/sap3-3-final-all.pdf.

147 *Id*.

generally reduce yields of desirable crops while promoting pest and weed[148] proliferation.[149] Global climate change is predicted to decrease crop yields, increase crop prices, decrease worldwide calorie availability, and by 2050 increase child malnutrition by 20%.[150] Climate change threatens global food security and so any effort to mitigate global warming is effectively promoting a secure food supply.[151]

40. Glacial and ice cap melting is one of the major causes of global sea level change.[152] When glaciers and ice caps melt, this adds water to the ocean.[153] Another cause is that as ocean water warms, it expands and takes up more space; therefore, ocean warming "has been observed in each of the world's major ocean basins, and has been directly linked to human influences."[154]

41. Human-caused fossil fuel burning and the resulting climate change are already contributing to an increase in asthma, cancer, cardiovascular disease, stroke, heat-related morbidity and mortality, food-borne diseases, and neurological diseases and disorders.[155] The World Health Organization has concluded, "the health effects of a rapidly changing climate are likely to be overwhelmingly negative".[156] Climate change is not only expected to affect the basic requirements for maintaining health (clean air and water, sufficient food, and adequate shelter) but is likely to present new challenges for controlling infectious disease and even "halt or reverse the progress that the global public health community is now making against many of

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148 USCCSP & USDA, *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity*, in *Synthesis and Assessment Product 4.3* at 59 ("Many weeds respond more positively to increasing CO_2 than most cash crops, . . . Recent research also suggests that glyphosate, the most widely used herbicide in the United States, loses its efficacy on weeds grown at CO_2 levels that likely will occur in the coming decades.").

149 International Food Policy Research Institute, *Food Policy Report: Climate Change-Impacts on Agriculture and Costs of Adaptation* vii (Oct. 2009).

150 *Id*.

151 *Id*. at ix ("Climate change will pose huge challenges to food-security efforts. Hence, any activity that supports agricultural adaptation also enhances food security.").

152 M. Sharp & G. Wolken, *Glaciers Outside Greenland*, *in* ARCTIC REPORT CARD 48 (October 18, 2010).

153 USGCRP, *Global Climate Change Impacts* at 18.

154 *Id*.

155 *See* The Center for Health and the Global Environment, Harvard Medical School, *Climate Change Futures: Health, Ecological, and Economic Dimensions* (November 2005) *available at* eetd.lbl.gov/emills/pubs/pdf/climate-change-futures.pdf; USGCRP, *Global Climate Change Impacts* at 96-98.

156 World Health Organization, *Climate and Health Fact Sheet* (July 2005), http://www.who.int/globalchange/news/fsclimandhealth/en/index.html.

these diseases."[157]

42. As the 2010 Russian summer heat wave graphically demonstrated, heat can destroy crops, trigger wildfires, exacerbate air pollution, and cause increased illness and deaths.[158] Similar impacts are occurring across the United States: the "number and frequency of forest fires and insect outbreaks are increasing in the interior West, the Southwest, and Alaska. Precipitation, streamflow, and stream temperatures are increasing in most of the continental United States. The western United States is experiencing reduced snowpack and earlier peaks in spring runoff. The growth of many crops and weeds is being stimulated. Migration of plant and animal species is changing the composition and structure of arid, polar, aquatic, coastal, and other ecosystems."[159] Up to 30% of the millions of species on our planet could go extinct following just a few tenths of a degree warming above present.[160] Large wildfires in the Western US have quadrupled in recent years, a result of hotter temperatures and earlier snowmelt that contributes to dryer soils and vegetation.[161]

43. Similarly, climate change is already causing, and will continue to result in, more frequent, extreme, and costly weather events (such as hurricanes).[162] The annual number of major tropical storms and hurricanes has increased over the past 100 years in North America, coinciding with increasing temperatures in the Atlantic sea surface.[163]

44. The changing climate also raises national security concerns, as "climate change will add to tensions even in stable regions of the world."[164] The United States may experience an additional need to accept immigrant and refugee populations as droughts increase and food production declines in other countries.[165] Increased

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[157] World Health Organization, *Protecting Health from Climate Change: Connecting Science, Policy, and People* 02 (2009), *available at* http://www.who.int/globalchange/publications/reports/9789241598880/en/index.html.
[158] *See* NOAA Earth System Research Lab, *The Russian Heat Wave 2010*, (September 2010) http://www.esrl.noaa.gov/psd/csi/moscow2010/.
[159] EPA, *TS Document* at 41 (*citing* USCCSP, Backlund et. al., 2008a).
[160] IPCC, *AR4*, *Working Group II: Impacts, Adaptation and Vulnerability- Magnitude of Impact*, *available at* http://www.ipcc.ch/publications_and_data/ar4/wg2/en/spmsspm-c-15-magnitudes-of.html.
[161] USGCRP, *Global Climate Change Impacts* at 95.
[162] *Id*. at 27 ("Many types of extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years.").
[163] National Science and Technology Council, *Scientific Assessment* at 7.
[164] The CNA Corporation, Military Advisory Board, *National Security and the Threat of Climate Change* 7 (2007), *available at* http://securityandclimate.cna.org/report/SecurityandClimate_Final.pdf (last visited April 10, 2011).
[165] *Id*.

extreme weather events (such as hurricanes) will also present an increased strain on foreign aid and call for military forces.[166] For instance, by 2025, 40% of the world's population will be living in countries experiencing significant water shortages, while sea-level rise could cause displacement of tens, or even hundreds, of millions of people.[167]

45. Paleoclimate data provides sobering evidence that major climate change can occur in decades, and that the consequences would be much more severe, and even disastrous, if a 2°C (3.6°F) change occurs over decades rather than hundreds of years.[168]

46. There are at least three reasons that the present, human-induced global warming is particularly significant. First, past global warming and cooling of a similar magnitude occurred before human civilization existed.[169] Second, global warming is happening far more rapidly than in past occurrences[170], giving both humans and other forms of life only a short time to adapt to the changes. Human civilization and the crops and foods on which it depends have developed within a very narrow set of climatic conditions.[171] With the human population so large, with civilization so complex, centered around coastal cities, and dependent on water supplies fed by distant ice and snow melt, and with the great disparities in wealth between and within countries and regions, it will be nearly impossible to adapt to all of the climate change impacts in the quick time-frame in which they will occur.[172]

47. Third, and perhaps most importantly, the climate change we are now experiencing

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[166] *Id*.
[167] *Id*. at 16.
[168] *See* James E. Hansen & Makiko Sato, *Paleoclimate Implications for Human-Made Climate Change* (January 18, 2011), *available at* http://www.columbia.edu/~jeh1/mailings/2011/20110118_MilankovicPaper.pdf (last visited April 10, 2011).
[169] *See* James E. Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?* 2 OPEN ATMOS. SCI. 217, 217-231 (2008).
[170] *Id*.
[171] J. Abatzoglou et al., *A Primer on Global Climate Change and Its Likely Impacts* 15, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN (Joseph F. DiMento & Pamela Doughman eds., MIT Press 2007).
[172] *See generally* United States Agency International Development (USAID), *Adapting to Climate Variability and Change: A Guidance Manual for Development Planning* (August 2007) (discussing difficulty of adapting to climate change) http://pdf.usaid.gov/pdf_docs/PNADJ990.pdf; *See also* USGCRP, *Global Climate Change Impacts* at 12 ("Climate change will combine with pollution, population growth, overuse of resources, urbanization, and other social, economic, and environmental stresses to create larger impacts than from any of these factors alone.").

is caused largely by human activity.[173] This means that unlike with respect to past climate change events, by changing our activities humans can mitigate or even halt this warming before it causes catastrophic and irreversible effects.[174] Stopping, or at least greatly curtailing, the activities that discharge greenhouse gases into the air, such as the burning of fossil fuels and deforestation, and encouraging activities that remove CO_2 from the atmosphere (such as reforestation), can greatly reduce and even end global warming and its accompanying consequences within the lifetimes of today's children.[175]

48. To protect Earth's climate for present and future generations, we must restore Earth's energy balance. The best available science shows that if the planet once again sends as much energy into space as it absorbs from the sun, this will restore the planet's climate equilibrium.[176] Scientists have accurately calculated how Earth's energy balance will change if we reduce long-lived greenhouse gases such as carbon dioxide.[177] Humans have altered Earth's energy balance[178] and are currently causing a planetary energy imbalance of approximately one-half watt[179]. We would need to reduce atmospheric carbon dioxide concentrations by about 40 ppm, in order to increase Earth's heat radiation into space by one-half watt, if other long-lived gases stay the same as today.[180] We must reduce atmospheric carbon dioxide concentration to 350 ppm to avoid the threats contained herein.[181]

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[173] *See* USGCRP, *Global Climate Change Impacts* at 20; EPA, *TS Endangerment Findings* 47-51; IPCC, *AR4* at 39.
[174] USGCRP, *Global Climate Change Impacts* at 107 ("By mid-century and beyond, however, today's emissions choices would generate starkly different climate futures: the lower the emissions, the smaller the climatic changes and resulting impacts.").
[175] *See Id*. at 12 ("Future climate change and its impacts depend on choices made today.").
[176] John Abatzoglou et al., *A Primer on Global Climate Change and Its Likely Impacts*, *in* CLIMATE CHANGE: WHAT IT MEANS FOR US, OUR CHILDREN, AND OUR GRANDCHILDREN 11, 15-22 (Joseph F. C. DiMento & Pamela Doughman eds., MIT Press 2007).
[177] JAMES HANSEN, STORMS OF MY GRANDCHILDREN 166 (2009) ("Also our best current estimate for the planet's mean energy imbalance over the past decade, thus averaged over the solar cycle, is about +0.5 watt per square meter. Reducing carbon dioxide to 350 ppm would increase emission to space 0.5 watt per square meter, restoring the planet's energy balance, to first approximation.").
[178] IPCC, *AR4* at 37 ("[T]he global average net effect of human activities since 1750 has been one of warming, with a radiative forcing of +1.6 [+0.6 to +2.4] W/m^2.").
[179] D.M. Murphy et. al., *An observationally based energy balance for the Earth since 1950* 114 J. GEOPHYSICAL RES. LETTERS D17107 (September 2009).
[180] JAMES HANSEN, STORMS OF MY GRANDCHILDREN 166 (2009); *See* James E. Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?* 2 OPEN ATMOS. SCI. 217, 217-231 (2008).
[181] *See* James E. Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?* 2 OPEN ATMOS. SCI. 217, 217 (2008) ("If humanity wishes to preserve a planet similar to that on which civilization developed and to which life on Earth is adapted, Paleoclimate

49. The best available science also shows that to protect Earth's natural systems, average global surface heating must not exceed 1° C this century.[182] To prevent global heating greater than 1° C, concentrations of atmospheric CO_2 must decline to less than 350 ppm this century.[183] However, today's atmospheric CO_2 levels are about 390 ppm[184] and are rising.

50. Atmospheric CO_2 levels are currently on a path to reach a climatic tipping point.[185] Absent immediate action to reduce CO_2 emissions, atmospheric CO_2 may reach levels as high as about 1000 ppm[186] and a temperature increase of up to 5° C by 2100.[187] Life on Earth as we know it, is unsustainable at these levels.

51. The Department has the present ability to curtail the environmental harms detailed above. Atmospheric CO_2 concentrations will decrease if people stop (or greatly reduce) their burning of fossil fuels.[188] The environmental harms and threat to human health and safety as described above can only be avoided if atmospheric CO_2 concentrations are immediately reduced. Any more delay risks irreversible and unacceptable consequences for youth and future generations.

52. Fossil fuel emissions must decrease rapidly if atmospheric CO_2 is to be returned to

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evidence and ongoing climate change suggest that CO_2 will need to be reduced from its current 385 ppm to at most 350 ppm.").

[182] James E. Hansen & Makiko Sato, *Paleoclimate Implications for Human-Made Climate Change* (January 18, 2011), *available at* http://www.columbia.edu/~jeh1/mailings/2011/20110118_MilankovicPaper.pdf (last visited April 10, 2011); *See also* IPCC, *AR4* at 48 ("For increases in global average temperature exceeding 1.5 to 2.5°C and in concomitant atmospheric CO_2 concentrations, there are projected to be major changes in ecosystem structure and function, species' ecological interactions and shifts in species' geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services, e.g. water and food supply.").

[183] *See* James E. Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?* 2 OPEN ATMOS. SCI. J. 217, 217-231 (2008); JAMES HANSEN, STORMS OF MY GRANDCHILDREN (2009).

[184] CO_2Now, *Earth's CO_2 Homepage*, Atmospheric CO_2 for March 2011, http://co2now.org/ (last visited April 10, 2011).

[185] JAMES HANSEN, STORMS OF MY GRANDCHILDREN 224 – 230, 260 (2009).

[186] IPCC, *AR4* at 66-67.

[187] IPCC, *AR4* at 46.

[188] HARVEY BLATT, AMERICA'S ENVIRONMENTAL REPORT CARD xiii (MIT Press, 2005) ("How can we stop this change in our climate? The answer is clear. Stop burning coal and oil, the sources of nearly all the carbon dioxide increase.").

a safe level in this century.[189] Improved forestry and agricultural practices can provide a net drawdown of atmospheric CO_2, primarily via reforestation of degraded lands that are of little or no value for agricultural purposes, returning us to 350 ppm somewhat sooner.[190] However, the potential of these measures is limited. Immediate and substantial reductions in carbon dioxide emissions are required in order to ensure that the youth and future generations of children inherit a planet that is inhabitable.

53. Because most fossil fuel CO_2 emissions will remain in the surface carbon reservoirs for millennia, it is imperative that fossil fuel CO_2 emissions be rapidly terminated, if atmospheric CO_2 is to be returned to a safe level in this century.[191] The failure to act promptly will not only increase the costs of future reductions, it will have irreversible adverse effects on the youth and all future generations, as detailed above.

54. To have the best chance of reducing the concentration of CO_2 in the atmosphere to 350 ppm by the end of the century and avoid heating over 1 degree Celsius over pre-industrial temperatures, the best available science concludes that atmospheric carbon dioxide emissions need to peak in 2012 and then begin to decline at a global average of 6% per year through 2050 and 5% per year through 2100. In addition, carbon sequestering forests and soils must be preserved and replanted to sequester an additional 100 gigatons of carbon through the end of the century.[192]

55. A zero- CO_2 U.S. energy system can be achieved within the next thirty to fifty years without acquiring carbon credits from other countries. In other words, actual physical emissions of CO2 from fossil fuels can be eliminated with technologies that are now available or reasonably foreseeable. This can be done at reasonable cost by eliminating fossil fuel subsidies and creating annual and long-term CO_2 reduction targets. Net U.S. oil imports can be eliminated in about 25 years, possibly less. The result will also include large ancillary health benefits from the significant reduction of most regional and local air pollution, such as high ozone and particulate levels in cities, which is mainly due to fossil fuel combustion.[193]

56. The approaches to transition to a renewable energy system and to phase out fossil fuels by about 2050 include: A single national cap on fossil fuel use that declines to zero by 2050 or a gradually rising carbon tax with revenues used to promote a zero- CO_2 emissions energy system and to mitigate adverse income-distribution

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[189] James E. Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?* 2 OPEN ATMOS. SCI. 217, 217 (2008) (discussing the need to reduce atmospheric carbon dioxide concentration to 350 ppm).
[190] *Id*. at 227.
[191] *See id*. at 211.
[192] See. App. II.
[193] Arjun Makhijani, Carbon-Free, Nuclear-Free: A Roadmap for U.S. Energy Policy (IEER Press and RDR Books, 2007)

effects; increasingly stringent efficiency standards for buildings, appliances, and motor vehicles; elimination of subsidies for fossil fuels, nuclear energy, and biofuels from food crops coupled with investment in a vigorous and diverse research, development and demonstration program (including smart grid and storage technologies, electrification of transportation, stationary fuel cells for combined heat and power, biofuels from aquatic weeds like microalgae, use of aquatic weeds like microalgae in integrated gasification combined cycle plants, and use of hydrogen-fueled passenger aircraft); banning new coal-fired power plants; adoption of a policy that would aim to have essentially carbon-free state, local, and federal governments, including almost all of their buildings and vehicles by 2030; and adoption of a gradually increasing renewable portfolio standard for electricity until it reaches 100 percent by about 2050.[194]

B. Climate Change is Already Occurring in the State of Mississippi and is Projected to Significantly Impact Mississippi in the Future.

57. Since 1970, temperatures in the Southeastern US have risen about 2 degrees (Fahrenheit) on average, with the greatest seasonal increase occurring during the winter months. By the year 2080, temperatures are expected to rise a further 4.5-9 degrees under both low and high emissions scenarios. [195]

58. The average annual temperature near Jackson, Mississippi has decreased approximately 2.1 degrees over the last century. In the current century, however temperatures at this same location are expected to follow southeastern trends, increasing by 2 degrees in the winter and summer, 3 degrees in the spring, and 4 degrees in the fall.[196]

59. The number of freezing days experienced in the Southeastern US has decreased by a full week.[197]

60. The number of extremely hot days (those exceeding 90 degrees) is expected to increase from 45-75 per year to 120-150 by the end of the current century.[198]

61. Average precipitation in the autumn months has increased by more than 30% over the last century; however, precipitation in the gulf coast states is projected to increase an average of 10%-15% in the summer and fall, and remain the same or

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[194] Arjun Makhijani, Carbon-Free, Nuclear-Free: A Roadmap for U.S. Energy Policy (IEER Press and RDR Books, 2007)
[195] USGCRP, *Regional Climate Impacts: Southeast* (2009)
[196] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[197] USGCRP, *Regional Climate Impacts: Southeast* (2009)
[198] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)

decrease in the winter and spring.[199]

62. An increase in the frequency and intensity of summer thunderstorms is predicted over the next several decades.[200]

63. The destructive capabilities of hurricane systems have increased since the 1970s, and are expected to further increase peak winds, storm surge height and strength, and rainfall intensity continuing into the current century. These increases are also associated with increased wave height and correlating increased hurricane power.[201]

64. The area of the Southeast region of the US that experiences drought conditions in the spring and summer has increased 12-14% since the 1970s. With higher temperatures predicted by climate change models, an increased rate of evaporation from plants and soils is expected to further increase the frequency, intensity, and duration of droughts in the summer months. [202]

65. During times of drought, fewer rainfall events, increased temperatures, and increases in the amount of time between rainfalls all limit ground water recharge. Increases in groundwater pumping for irrigation and municipal water needs will add further stress to already decreased ground and surface water resources. [203]

66. Increased evaporation combined with groundwater pumping during times of drought increases the likelihood of saltwater intrusion into shallow aquifers near the coast.[204]

67. Predicted increases in seasonal precipitation are expected to cause an increase in flooding in low-lying agricultural lands that are already subject to periodic inundation and flooding. This includes the floodplain areas of the Yazoo, Bog Black, and Tombigbee near Hattiesburg. The Pearl River is also prone to flooding in areas near Jackson, Columbia, and Picayune.[205]

68. With increases in summer runoff, it is also expected that there will be an increased

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[199] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[200] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[201] USGCRP, *Regional Climate Impacts: Southeast* (2009); NWF, *Global Warming and Mississippi* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[202] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[203] USGCRP, *Regional Climate Impacts: Southeast* (2009)
[204] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); USGCRP, *Regional Climate Impacts: Southeast* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[205] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)

surge of pollutants and toxicants washed into surface waters from nearby agricultural, urban, and industrial landscapes.[206]

69. Ecosystems are expected to experience an altered distribution of native plants and wildlife in response to climate changes. This includes the loss of threatened and endangered species due to invasive non-native species, as well as more frequent wildfires.[207]

70. Climate changes are expected to have significant impacts on forest ecosystems; and declines are expected, as they shift northward in response to changing climate conditions. These shifts could translate into shifts in community composition from existing stands to species more adapted to warmer climates, such as sub-tropical evergreens, and in many areas lead to increased grassland and pasture. [208]

71. Forest and plant growth may initially be stimulated by high levels of atmospheric CO_2, however these effects are expected to be temporary, and as toxic ground-level ozone increases there is expected to be a negative impact on forest and plant growth.[209]

72. Low soil moisture, thermal stress, and increased frequency of wildfires are expected to cause stress to forests and make them more prone to attack and infestation by forest pests, like the southern pine beetle.[210]

73. Temperature in streams is directly related to the amount of dissolved oxygen available to aquatic species. Increases in temperatures could decrease the oxygen availability in streams and lakes leading to fish kills and a general decline in biodiversity of aquatic species.[211]

74. Increased temperatures and incidence of drought are expected to cause drying of smaller, shallow lakes, ponds and wetlands, with the potential to cause extirpation (or local extinction) of plant and wildlife species. By the year 2080, climate change could reduce up to 91% of the wetlands in the Prairie Pothole region, which is one

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[206] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[207] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); NWF, *Global Warming and Mississippi* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[208] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); NWF, *Global Warming and Mississippi* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[209] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[210] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[211] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)

of the most important breeding grounds for waterfowl in North America. [212]

75. Sea level rise is expected to cause inundation, erosion, and a retreat of wetlands where no barriers exist to prevent it. The salinity of these wetlands, as well as saltwater marshes, estuaries and tidal rivers, is expected to increase, altering the ecosystems and decreasing survivorship of the plants and wildlife living there, including coastal fish and shellfish.[213]

76. The Gulf of Mexico zone of coastal hypoxia is expected to be increasingly and adversely affected by the impacts of climate change. The duration of the hypoxic season is expected to lengthen and be exacerbated by increased temperatures and increased volumes of runoff that contain hypoxic-inducing nutrients from both the Mississippi and Atchafalaya Rivers. Hypoxic conditions are unlivable for fish and other marine organisms.[214]

77. Changes in climate in Mississippi could cause the breeding ranges of 17 songbirds currently found in the state, including the American goldfinch and the scarlet tanager, to shrink or shift out of Mississippi completely.[215]

78. Higher temperatures and increased frequency and duration of heat waves are expected to cause an increase in the number of heat-related illnesses and deaths. Average heat index—the measure of comfort calculated from temperature and humidity—is expected to rise 10-25 degrees in annually, by the end of the century.[216]

79. Both upper and lower respiratory allergies are affected by local humidity. An increase in temperatures and precipitation is expected to exacerbate these conditions with a 2-degree increase in temperatures causing a significant increase in incidence and severity of respiratory allergies.[217]

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[212] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); NWF, *Global Warming and Mississippi* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[213] USGCRP, *Regional Climate Impacts: Southeast* (2009); USGCRG, *Coastal Ecosystems of the Gulf of Mexico and Climate Change* (1997); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[214] USGCRG, *Coastal Ecosystems of the Gulf of Mexico and Climate Change* (1997); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[215] NWF, *Global Warming and Mississippi* (2009)
[216] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[217] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); UCS, *Climate Change and the Gulf State: Mississippi* (2009)

80. Additionally, climate change is expected to increase the incidence and severity of water-borne disease outbreaks, including *E. coli*, cryptosporidiasis, and giardiasis.[218]

81. Increased temperature and humidity for much of the year, combined with milder winters in general, could cause population blooms for biting pests, such as mosquitoes. Increases in transmission of malaria and Eastern equine encephalitis is of special concern as the climate changes. [219]

82. Drought conditions may cause a reduction in the number of rodent predators (owls, coyotes, snakes, etc.), allowing for rat populations to increase. This is especially true during times of high rainfall, which increases the amount of food available to rat populations. Rats may carry diseases such as Hantavirus and leptospirosis, both of which benefit from warmer, moist conditions.[220]

83. Warmer water temperatures provide ideal conditions for the propagation of shellfish-borne diseases in coastal waters. Harmful algal blooms could also increase in duration and density, which can damage habitat, cause toxicity in humans and shellfish, and carry harmful bacteria, such as cholera.[221]

84. Increased hurricane activity in the Gulf of Mexico is expected to cause flooding in the coastal states. This is projected to cause an increase in related morbidity, mortality, mental health issues, and increase the incidence of water-borne disease outbreaks.[222]

85. Rising sea level is expected to cause more frequent flooding, erosion, and a retreat of coastal communities. Some low-lying areas will become permanently inundated, especially in the areas where land surface is sinking.[223]

86. Sea level rise and the subsequent increase in frequency and severity of storms increases the risk of salt-water intrusion into drinking water supplies, which can be

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[218] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[219] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[220] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[221] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[222] USGCRP, *Regional Climate Impacts: Southeast* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[223] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); NWF, *Global Warming and Mississippi* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)

costly and difficult to repair.[224]

87. Increase in hurricanes, storm surge and flooding, as well and frequency and severity of storm systems is expected to overwhelm current infrastructure, which is insufficient to withstand conditions projected to cause catastrophic damage. [225]

88. The cost of protecting the and maintaining the Mississippi coastline and using sand replacement, when considering anticipated sea level rise, is expected to cost $70-$140 million by 2100. [226]

89. With rising incidence of heat-induced illness and death, as well as projected risk to property as the effects of climate change are experienced over the next century, the availability of insurance is expected to decline, and the cost of obtaining insurance and necessary healthcare is expected to increase.[227]

90. Agricultural crop production is reliant on temperature, moisture, and atmospheric chemical compositions, and as such is sensitive to the variations associated with climate change. Production is expected to be greatly diminished by thermal stress and declining soil moisture, and as a result is expected to shift northward with climate conditions, making adaptation difficult for growers.[228]

91. Increases in atmospheric CO_2 may initially boost crop growth, but this is expected to be only temporary due to the toxic impacts of ground-level ozone on plant growth.[229]

92. Changing climate to warmer temperatures and milder winters will allow insect pests (such as locusts and aphids) and weed populations to proliferate more quickly and in higher numbers, adding to the stress on agricultural production.[230]

93. Overall, the agricultural industry could face crop yield losses as high as 22% for soybeans and 25% for cotton.[231]

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[224] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[225] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); NWF, *Global Warming and Mississippi* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[226] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[227] USGCRP, *Regional Climate Impacts: Southeast* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[228] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[229] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[230] UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[231] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)

94. Increased runoff, higher rates of evaporation, and increased reliance on irrigation and surface water withdrawal to meet water needs is likely to cause conflict between multiple states reliant on the same water resources. This is also likely to increase conflicts between agricultural, municipal and industrial users within the state of Mississippi.[232]

95. At temperatures above 90 degrees, cattle encounter heat stresses that adversely impact growth and production, and will only be exacerbated by concurrent increases in humidity. Additionally, with changes in forage availability, the cost of feed for cattle is expected to increase. Indoor livestock, such as poultry and swine, are expected to become increasing costly to maintain, as warmer temperatures will cause the cost of keeping facilities cool to increase as well.[233]

96. Transportation structures will face increased stress as temperatures increase and remain high for longer periods of time. It is expected that with climate changes there will be increase buckling of pavement and railways, bridge failures, and road washouts.[234]

97. Increases in the duration and severity of hypoxic conditions in the Gulf of Mexico are expected to negatively impact coastal fisheries. Coastal salinity changes due to increased freshwater runoff are expected to adversely impact commercial shrimp fisheries.[235]

98. Increased frequency of wildfires in response to longer periods between rainfall in the hottest months is expected to impair Mississippi's $7 billion per year timber industry. Moreover, a warming climate is predicted to cause an increased invasion of species that have little to zero commercial value, such as scrub oak.[236]

99. Loss of habitat and the supported wildlife could threaten the $1.5 million annually reported tourism dollars spend on hunting, fishing, and wildlife viewing activities in Mississippi.[237]

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[232] USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[233] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998)
[234] USGCRP, *Regional Climate Impacts: Southeast* (2009); USEPA, *Climate Change and Mississippi,* EPA Pub. No. 236-F-98-007m (1998); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[235] USGCRG, *Coastal Ecosystems of the Gulf of Mexico and Climate Change* (1997); UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[236] NWF, *Global Warming and Mississippi* (2009), UCS, *Climate Change and the Gulf State: Mississippi* (2009)
[237] NWF, *Global Warming and Mississippi* (2009); UCS, *Climate Change and the Gulf State: Mississippi* (2009)

C. THE PUBLIC TRUST DOCTRINE DEMANDS THAT THE STATE OF MISSISSIPPI ACT TO PRESERVE THE ATMOSPHERE AND PROVIDE A LIVABLE FUTURE FOR PRESENT AND FUTURE GENERATIONS OF MISSISSIPPI RESIDENTS.

100. There is no greater duty of parents than to provide for the protection and safety of their children. Likewise, there is no greater duty of our government than to ensure the protection and safety of its citizens, both born and yet to be born. As described above, the Earth's atmosphere is what has allowed humans to exist and flourish on this planet. But human activity has allowed the atmospheric equilibrium to become imbalanced, and now human life on Earth is in grave danger.

101. The atmosphere, essential to human existence, is an asset that belongs to all people. The public trust doctrine requires that as co-tenet trustee, the State of Mississippi and its agency the Department of Environmental Quality, holds vital natural resources in *trust* for both present and future generations of its citizens. These resources are so vital to the well being of all people, including the citizens of Mississippi, that they must be protected by this distinctive, long-standing judicial principle. The atmosphere, including the air, is one of the most crucial assets of our public trust.

102. The public trust doctrine holds government responsible, as perpetual trustee, for the protection and preservation of the atmosphere for the benefit of both present and future generations. Today the citizens of Mississippi are confronted with an atmospheric emergency.

103. If the Mississippi Department of Environmental Quality, as the trustee of the atmosphere (an essential and fundamental resource that belongs to all citizens of Mississippi), does not take immediate and extraordinary action to protect, preserve, and bring the Earth's atmosphere back into balance, then children in the State of Mississippi, and countless future generations of children, will suffer continually greater injuries and damaging consequences. If we, as a society, want to protect and keep the world safe for our children, including here in the great State of Mississippi, then the Department must immediately accept its fiduciary responsibility as mandated by its trustee obligation and adopt the rule proposed herein.

104. The public trust imposes a legal obligation on the Department to affirmatively preserve and protect the citizen's trust assets from damage or loss, and not to use the asset in a manner that causes injury to the trust beneficiaries, be they present or future. The sovereign trustee has an affirmative, fiduciary duty to prevent waste, to use reasonable skill and care to preserve the trust property, and to maintain trust assets. The duty to protect the trust asset means that the Department must ensure the continued availability and existence of healthy trust resources for present and future beneficiaries. This duty mandates the development and utilization of the trust resource in a manner consistent with its conservation and in furtherance of the

self-sufficiency of Mississippi.

105. Mississippi's fiduciary duty in this instance is defined by scientists' concrete prescriptions for carbon reductions. Scientists have clearly expressed the minimum carbon dioxide reductions that are needed, and requisite timelines for their implementation. Mississippi may not disclaim this fiduciary obligation, and is subject to an ongoing mandatory duty to preserve and protect this atmospheric trust asset.

106. The children in the State of Mississippi are already experiencing serious environmental, economic, physical, emotional and aesthetic injuries as a result of the State government's actions and inactions. If the Department fails to regulate and continues to contribute to this atmospheric crisis, then these injuries will only intensify and expand. A failure to immediately take bold action to protect and preserve Earth's safe climate-zone will cause irreparable harm to the citizens of Mississippi and others. Immediate state action is imperative.

107. Once certain tipping points of energy imbalance and planetary heating have been exceeded, we will not be able to prevent the ensuing harm. A failure to act soon may cause the collapse of the Earth's natural systems resulting in a planet that is largely unfit for human life. The responsibility to protect and preserve the atmosphere for the citizens of Mississippi is the duty of the Department. This mandate requires Mississippi to protect and preserve that which belongs to all of its citizens and not to allow uses of those assets in a way that causes injury and damage to its citizen beneficiaries.

108. If sovereign governments, including the State of Mississippi, do not immediately react to this crisis and act swiftly to reduce carbon dioxide emissions being released into the atmosphere, the environment in which humans and other life on Earth has thrived, will no longer exist. If Mississippi does not act immediately to reduce carbon dioxide emissions into the atmosphere, the youth of Mississippi and future generations of Mississippi's children will face a planet that may be largely uninhabitable.

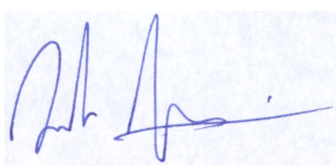
109. Mississippi must protect and preserve the planet for its children and future generations. The United States, and the State of Mississippi must lead the way and reduce its carbon dioxide emissions. The United States of America, including the State of Mississippi, not only has a large responsibility for currently harming the atmosphere, but it has the capacity and the technology to reduce emissions, as well as the will and obligation to protect its citizens. The rest of the world is looking to the United States to lead this effort. Without Mississippi's action the catastrophic collapse of natural systems is inevitable.

110. The shared atmosphere is a natural resource vital to human health, welfare, and survival. Atmospheric health is essential to all survival. Our atmosphere is a fundamental natural resource entrusted to the care of our governments, and the

State of Mississippi, in trust, for its preservation and protection as a common property interest. As a co-tenant trustee of this shared asset the Department has a fiduciary, and perpetual, affirmative duty to preserve and protect the atmosphere for the present citizens and future generations of the State as beneficiaries of this trust asset.

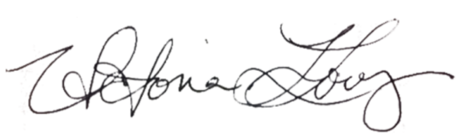
And so, for the reasons above, it is with utmost respect that Derek Watkins and Kids vs Global Warming hereby submit this petition on behalf of themselves, the citizens of the State of Mississippi, and present and future generations of minor children. The petitioners respectfully request that the Department of Environmental Quality promulgate a rule that requires the agency to take the necessary steps in order to protect the integrity of Earth's climate by adequately protecting our atmosphere, a public trust resource upon which all those who live in Mississippi rely for their health, safety, sustenance, and security.

Sincerely,



Derek Watkins
May 4, 2011

Alec Loorz
May 4, 2011



Victoria Loorz
May 4, 2011

Mandatory Statewide Carbon Dioxide Emissions Reduction Targets

(1)(a) The state must limit emissions of carbon dioxide to achieve the following emission reductions for Mississippi:

(i) Carbon dioxide emissions from fossil fuels must peak in 2012;

(ii) Starting in January 2013, statewide fossil fuel carbon dioxide emissions must be reduced by at least 6 percent per year;

(b) By January 1, 2012, the Department must adopt a greenhouse gas reduction plan that when implemented achieves the limits set forth in (1)(a);

(c) Consistent with this directive, the department shall take the following actions:

(i) Annual progress reports on statewide greenhouse gas emissions must be published annually on the Department's website for public review. These reports must include an accounting and inventory for each and every source of all greenhouse gas emissions within the state, without exception. This inventory and accounting must be verified by an independent, third-party. Annual reports must be posted to the Department's website and be made publicly available no later than December 31 of each year, beginning in the year 2012.

(ii) Track progress toward meeting the emission reductions established in this subsection, including the results from policies currently in effect, those that have been previously adopted by the state, and policies to be adopted in the future, and publicly report on that progress annually.

(2) By December 31st of each year beginning in 2011, the Department must report to the governor and the appropriate committees of the Senate and House of Representatives the total emissions of greenhouse gases for the preceding year, and totals in each major source sector. The Department shall ensure that reporting rules adopted under section (1)(c)(i) allow it to develop a comprehensive inventory of emissions of greenhouse gases from all sectors of the state economy.

(3) To the extent that any rule in this section conflicts with any other rule in effect, the more stringent rule, favoring full disclosure of emissions and protection of the atmosphere, governs.

The Case for Young People and Nature: A Path to a Healthy, Natural, Prosperous Future

James Hansen[1], Pushker Kharecha[1], Makiko Sato[1], Paul Epstein[2], Ove Hoegh-Guldberg[3], Peter Smith[4], Eelco J.Rohling[5], Karina von Schuckmann[6], James C. Zachos[7]

Abstract. We describe scenarios that define how rapidly fossil fuel emissions must be phased down to restore Earth's energy balance and stabilize global climate. A scenario that stabilizes climate and preserves nature is technically possible and it is essential for the future of humanity. Despite overwhelming evidence, governments and the fossil fuel industry continue to propose that all fossil fuels must be exploited before the world turns predominantly to clean energies. If governments fail to adopt policies that cause rapid phase-down of fossil fuel emissions, today's children, future generations, and nature will bear the consequences through no fault of their own. Governments must act immediately to significantly reduce fossil fuel emissions to protect our children's future and avoid loss of crucial ecosystem services, or else be complicit in this loss and its consequences.

1. Background

Humanity is now the dominant force driving changes of Earth's atmospheric composition and thus future climate on the planet. Carbon dioxide (CO_2) emitted in burning of fossil fuels is, according to best available science, the main cause of global warming in the past century. It is also well-understood that most of the CO_2 produced by burning fossil fuels will remain in the climate system for millennia. The risk of deleterious or even catastrophic effects of climate change driven by increasing CO_2 is now widely recognized by the relevant scientific community.

The climate system has great inertia because it contains a 4-kilometer deep ocean and 2-kilometer thick ice sheets. As a result, global climate responds only slowly, at least initially, to natural and human-made forcings of the system. Consequently, today's changes of atmospheric composition will be felt most by today's young people and the unborn, in other words, by people who have no possibility of protecting their own rights and their future well-being, and who currently depend on others who make decisions today that have consequences over future decades and centuries.

Governments have recognized the need to stabilize atmospheric composition at a level that avoids dangerous anthropogenic climate change, as formalized in the Framework Convention on Climate Change in 1992. Yet the resulting 1997 Kyoto Protocol was so ineffective that global fossil fuel emissions have since accelerated by 2.5% per year, compared to 1.5% per year in the preceding two decades.

Governments and businesses have learned to make assurances that they are working on clean energies and reduced emissions, but in view of the documented emissions pathway it is not inappropriate to describe their rhetoric as being basically 'greenwash'. The reality is that most governments, strongly influenced by the fossil fuel industry, continue to allow and even

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subsidize development of fossil fuel deposits. This situation was aptly described in a special energy supplement in the New York Times entitled 'There Will Be Fuel' (Krauss, 2010), which described massive efforts to expand fossil fuel extraction. These efforts include expansion of oil drilling to increasing depths of the global ocean, into the Arctic, and onto environmentally fragile public lands; squeezing of oil from tar sands; hydro-fracking to expand extraction of natural gas; and increased mining of coal via mechanized longwall mining and mountain-top removal.

The true costs of fossil fuels to human well-being and the biosphere is not imbedded in their price. Fossil fuels are the cheapest energy source today only if they are not made to pay for their damage to human health, to the environment, and to the future well-being of young people who will inherit on-going climate changes that are largely out of their control. Even a moderate but steadily rising price on carbon emissions would be sufficient to move the world toward clean energies, but such an approach has been effectively resisted by the fossil fuel industry.

The so-called 'north-south' injustice of climate disruption has been emphasized in international discussions, and payment of $100B per year to developing countries has been proposed. Focus on this injustice, as developed countries reap the economic benefits of fossil fuels while developing countries are among the most vulnerable to the impacts of climate change, is appropriate. Payments, if used as intended, will support adaptation to climate change and mitigation of emissions from developing countries. We must be concerned, however, about the degree to which such payment, from adults in the North to adults in the South, are a modern form of indulgences, allowing fossil fuel emissions to continue with only marginal reductions or even increase.

The greatest injustice of continued fossil fuel dominance of energy is the heaping of climate and environmental damages onto the heads of young people and those yet to be born in both developing and developed countries. The tragedy of this situation is that a pathway to a clean energy future is not only possible, but even economically sensible.

Fossil fuels today power engines of economic development and thus raise the standards of living throughout most of the world. But air and water pollution due to extraction and burning of fossil fuels kills more than 1,000,000 people per year and affects the health of billions of people **(**Cohen et al., 2005**)**. Burning all fossil fuels would have a climate impact that literally produces a different planet than the one on which civilization developed. The consequences for young people, future generations, and other species would continue to mount over years and centuries. Ice sheet disintegration would cause continual shoreline adjustments with massive civil engineering cost implications as well as widespread heritage loss in the nearly uncountable number of coastal cites. Shifting of climatic zones and repeated climate disruptions would have enormous economic and social costs, especially in the developing world.

These consequences can be avoided via prompt transition to a clean energy future. The benefits would include a healthy environment with clean air and water, preservation of the shorelines and climatic zones that civilization is adapted to, and retention of the many benefits humanity derives from the remarkable diversity of species with which we share this planet.

It is appropriate that governments, instituted for the protection of all citizens, should be required to safeguard the future of young people and the unborn. Specific policies cannot be imposed by courts, but courts can require governments to present realistic plans to protect the rights of the young. These plans should be consistent with the scientifically-established rate at which emissions must be reduced to stabilize climate.

Science can also make clear that rapid transition to improved energy efficiency and clean energies is not only feasible but economically sensible, and that rapid transition requires a steadily rising price on undesirable emissions. Other actions by governments are needed, such as

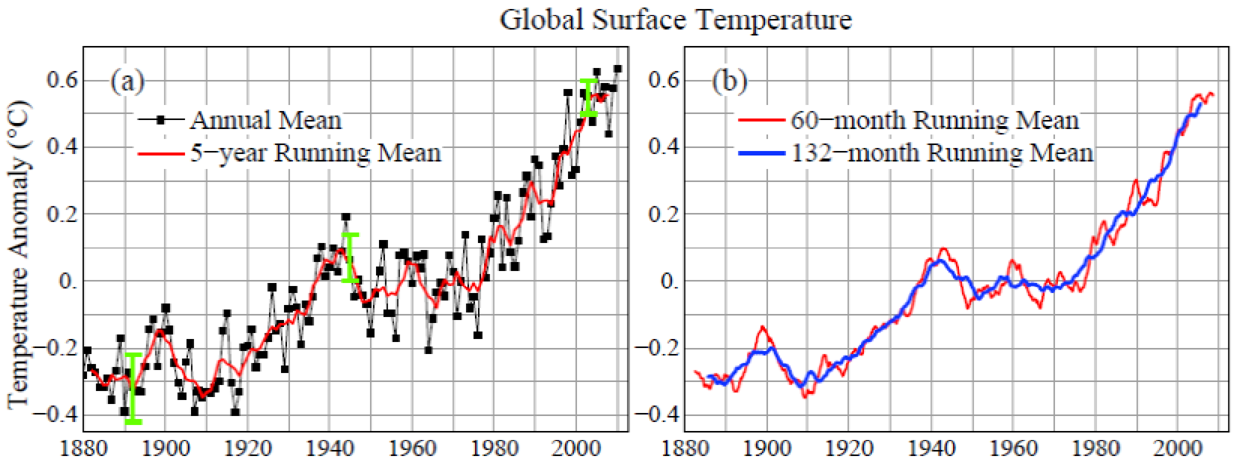

Figure 1. Global surface temperature anomalies relative to 1951-1980 mean for (a) annual and 5-year running means through 2010, and (b) 60-month and 132-month running means through March 2011. Green bars are 2-σ error estimates, i.e., 95% confidence intervals (data from Hansen et al., 2010).

enforcement of energy efficiency standards and investment in technology development. However, without the underlying incentive of a price on carbon emissions, such actions, as well as voluntary actions by concerned citizens, are only marginally effective. This is because such actions reduce the demand for fossil fuels, lower their price, and thus encourage fossil fuel use elsewhere. The price on carbon emissions, to be most effective, must be transparent and across-the-board, for the sake of public acceptance, for guidance of consumer decisions, and for guidance of business decisions including technology investments.

Here we summarize the emission reductions required to restore Earth's energy balance, limit CO_2 change to a level that avoids dangerous human-made interference with climate, assure a bright future for young people and future generations, and provide a planet on which both humans and our fellow species can continue to survive and thrive.

2. Global Temperature

Global surface temperature fluctuates chaotically within a limited range and it also responds to natural and human-made climate forcings. Climate forcings are imposed perturbations of Earth's energy balance. Examples of climate forcings are changes in the luminosity of the sun, volcanic eruptions that inject aerosols (fine particles) into Earth's stratosphere, and human-caused alterations of atmospheric composition, most notably the increase of atmospheric carbon dioxide (CO_2) due to burning of fossil fuels.

2.1. Modern Temperature

Figure 1(a) shows annual-mean global temperature change over the past century. The year-to-year variability is partly unforced chaotic variability and partly forced climate change. For example, the global warmth of 1998 was a consequence of the strongest El Nino of the century, a natural warming of the tropical Pacific Ocean surface associated with a fluctuation of ocean dynamics. The strong cooling in 1992 was caused by stratospheric aerosols from the Mount Pinatubo volcanic eruption, which temporarily reduced sunlight reaching Earth's surface by as much as 2 percent.

Figure 1(b) shows global temperature change averaged over 5 years (60 months) and 11 years (132 months), for the purpose of minimizing year-to-year variability. The rapid warming during the past three decades is a forced climate change that has been shown to be a consequence of the simultaneous rapid growth of human-made atmospheric greenhouse gases, predominately CO_2 from fossil fuel burning (IPCC, 2007).

The basic physics underlying this global warming, the greenhouse effect, is simple. An increase of gases such as CO_2 makes the atmosphere more opaque at infrared wavelengths. This added opacity causes the planet's heat radiation to space to arise from higher, colder levels in the atmosphere, thus reducing emission of heat energy to space. The temporary imbalance between the energy absorbed from the sun and heat emission to space, causes the planet to warm until planetary energy balance is restored.

The great thermal inertia of Earth, primarily a consequence of the 4-kilometer (2½ mile) deep ocean, causes the global temperature response to a climate forcing to be slow. Because atmospheric CO_2 is continuing to increase, Earth is significantly out of energy balance – the solar energy being absorbed by the planet exceeds heat radiation to space. Measurement of Earth's energy imbalance provides the most precise quantitative evaluation of how much CO_2 must be reduced to stabilize climate, as discussed in Section 2.

However, we should first discuss global temperature, because most efforts to assess the level of climate change that would be 'dangerous' for humanity have focused on estimating a permissible level of global warming. Broad-based assessments, represented by the 'burning embers' diagram in IPCC (2001, 2007), suggested that major problems begin with global warming of 2-3°C relative to global temperature in year 2000. Sophisticated probabilistic analyses (Schneider and Mastrandrea, 2005) found a median 'dangerous' threshold of 2.85°C above global temperature in 2000, with the 90 percent confidence range being 1.45-4.65°C.

The conclusion that humanity could readily tolerate global warming up to a few degrees Celsius seemed to mesh with common sense. After all, people readily tolerate much larger regional and seasonal climate variations.

The fallacy of this logic became widely apparent only in recent years. (1) Summer sea ice cover in the Arctic plummeted in 2007 to an area 30 percent less than a few decades earlier. Continued growth of greenhouse gases will likely cause the loss of all summer sea ice within the next few decades, with large effects on wildlife and indigenous people, increased heat absorption at high latitudes, and potentially the release of massive amounts of methane, a powerful greenhouse gas, presently frozen in Arctic sediments on both land and sea floor. (2) The great continental ice sheets of Greenland and Antarctic have begun to shed ice at a rate, now several hundred cubic kilometers per year, which is continuing to accelerate. With the loss of protective sea ice and buttressing ice shelves, there is a danger that ice sheet mass loss will reach a level that causes catastrophic, and for all practical purposes irreversible, sea level rise. (3) Mountain glaciers are receding rapidly all around the world. Summer glacier melt provides fresh water to major world rivers during the dry season, so loss of the glaciers would be highly detrimental to billions of people. (4) The hot dry subtropical climate belts have expanded, affecting climate most notably in the southern United States, the Mediterranean and Middle East regions, and Australia, contributing to more intense droughts, summer heat waves, and devastating wildfires. (5)) Coral reef ecosystems are already being impacted by a combination of ocean warming and acidification (a direct consequence of rising atmospheric CO_2), resulting in a 1-2% per year decline in geographic extent. Coral reef ecosystems will be eliminated with continued increase of atmospheric CO_2, with huge consequences for an estimated 500 million people that depend on the ecosystem services of coral reefs (Bruno and Selig, 2007; Hoegh-guldberg et al., 2007;

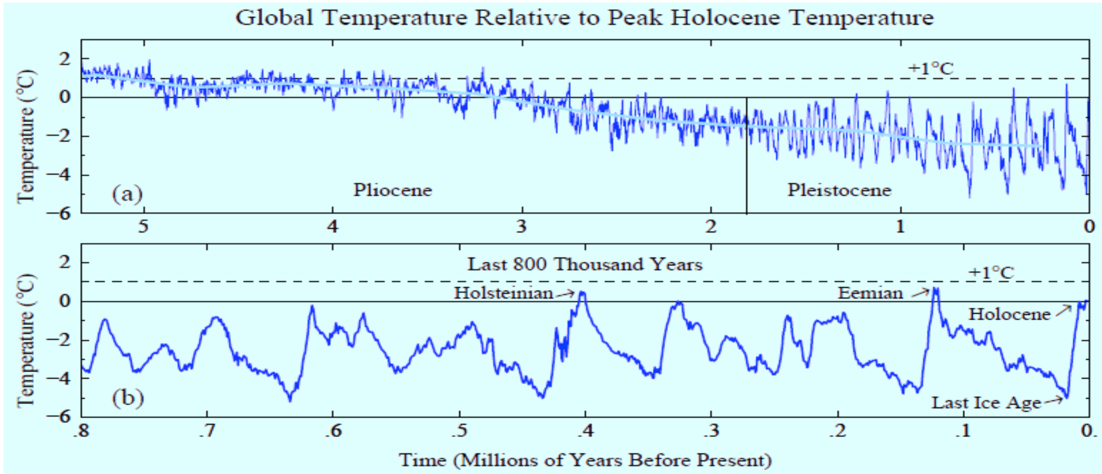

Figure 2. Global temperature relative to peak Holocene temperature (Hansen and Sato, 2011).

Veron et al., 2009). (6) So-called mega-heatwaves have become noticeably more frequent, for example the 2003 and 2010 heatwaves over Europe and large parts of Russia, each with heat-death tolls in the range of 55,000 to 70,000 (Barriopedro et al., 2011).
Reassessment of the dangerous level of global warming has been spurred by realization that large climate effects are already beginning while global warming is less than 1°C above preindustrial levels. The best tool for assessment is provided by paleoclimate, the history of ancient climates on Earth.

2.2. Paleoclimate Temperature

Hansen and Sato (2011) illustrate Earth's temperature on a broad range of time scales. Figure 2(a) shows estimated global mean temperature[8] during the Pliocene and Pleistocene, approximately the past five million years. Figure 2(b) shows higher temporal resolution, so that the more recent glacial to interglacial climate oscillations are more apparent.

Climate variations summarized in Figure 2 are huge. During the last ice age, 20,000 years ago, global mean surface temperature was about 5°C lower than today. But regional changes on land were larger. Most of Canada was under an ice sheet. New York City was buried under that ice sheet, as were Minneapolis and Seattle. On average the ice sheet was more than a mile (1.6 km) thick. Although it was thinner near its southern boundary, its thickness at the location of the above cities dwarfs the tallest buildings in today's world. Another ice sheet covered northwest Europe.

These huge climate changes were instigated by minor perturbations of Earth's orbit about the sun and the tilt of Earth's spin axis relative to the orbital plane. By altering the seasonal and geographical distribution of sunlight, the orbital perturbations cause small temperature change. Temperature change then drives two powerful amplifying feedbacks: higher temperature melts

[8] This estimate of global mean temperature is obtained from ocean sediments at many locations around the world (Zachos et al., 2001; Hansen et al., 2008). The composition of the shells of deep-sea-dwelling microscopic animals (foraminifera), preserved in ocean sediments, carry a record of ocean temperature. Deep ocean temperature change is about two-thirds as large as global mean surface temperature change for the range of climates from the last ice age to the present interglacial period; that proportionality factor is included in Figure 2.

ice globally, thus exposing darker surfaces that absorb more sunlight; higher temperature also causes the ocean and soil to release CO_2 and other greenhouse gases. These amplifying feedbacks have been shown, quantitatively, to be responsible for practically the entire glacial-to-interglacial temperature change.

In these slow natural climate changes the amplifying feedbacks (ice area and CO_2 amount) acted as slaves to weak orbital forcings. But today CO_2, global temperature, and ice area are under the command of humanity: CO_2 has increased to levels not seen for at least 3 million years, global temperature is rising, and ice is melting rapidly all over the planet. Another ice age will never occur, unless humans go extinct. A single chlorofluorocarbon factory can produce gases with a climate forcing that exceeds the forcing due to Earth orbital perturbations.

During the climate oscillations summarized in Figure 2, Earth's climate remained in near equilibrium with its changing boundary conditions, i.e., with changing ice sheet area and changing atmospheric CO_2. These natural boundary conditions changed slowly, over millennia, because the principal Earth orbital perturbations occur on time scales predominately in the range of 20,000 to 100,000 years.

Human-made changes of atmospheric composition are occurring much faster, on time scales of decades and centuries. The paleoclimate record does not tell us how rapidly the climate system will respond to the high-speed human-made change of climate forcings – our best guide will be observations of what is beginning to happen now. But the paleoclimate record does provide an indication of the eventual consequences of a given level of global warming.

The Eemian and Hosteinian interglacial periods, respectively about 130,000 and 400,000 years ago, were warmer than the Holocene, but global mean temperature in those periods was probably less than 1°C warmer than peak Holocene temperature (Figure 2b). Yet it was warm enough for sea level to reach mean levels 4-6 meters higher than today.

Global mean temperature 2°C higher than peak Holocene temperature has not existed since at least the Pliocene, a few million years ago. Sea level at that time was estimated to have been 15-25 meters higher than today. Changes of regional climate during these warm periods were much greater than the global mean changes.

How does today's global temperature, given the warming of the past century, compare with prior peak Holocene temperature? Holocene climate has been highly variable on a regional basis (Mayewski et al., 2004). However, Hansen and Sato (2011) show from records at several places around the globe that mean temperature has been remarkably constant during the Holocene. They estimate that the warming between the 1800s and the period 1951-1980 (a warming of ~0.25°C in the Goddard Institute for Space Studies analysis, Hansen et al., 2010) brought global temperatures back to approximately the peak Holocene level.

If the 1951-1980 global mean temperature approximates peak Holocene temperature, this implies that global temperature in 2000 (5-year running mean) was already 0.45°C above the peak Holocene temperature. The uncertainty in the peak Holocene temperature is a least several tenths of a degree Celsius. However, strong empirical evidence that global temperature has already risen above the prior peak Holocene temperature is provided by the ongoing mass loss of the Greenland and West Antarctic ice sheets, which began within the last 10-15 years. Sea level was stable for the past five to six thousand years, indicating that these ice sheets were in near mass balance. Now, however, both Greenland and West Antarctica are shedding ice at accelerating rates. This is strong evidence that today's global temperature has reached a level higher than prior Holocene temperatures.

The conclusion is that global warming of 1°C relative to 1880-1920 mean temperature (i.e., 0.75°C above the 1951-1980 temperature or 0.3°C above the 5-year running mean

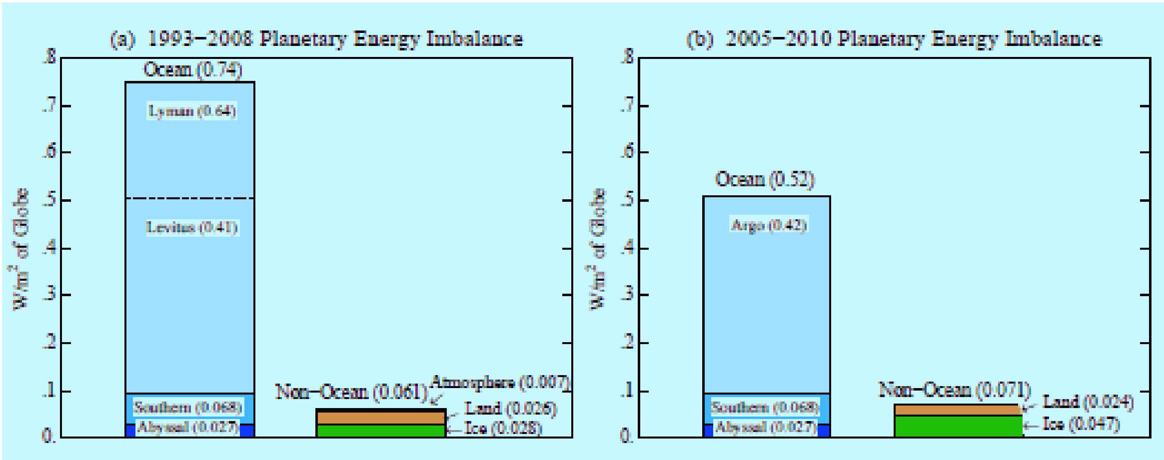

Figure 3. (a) Estimated planetary energy imbalance in 1993-2008, and (b) in 2005-2010. Data sources are given by Hansen et al. (2011).

temperature in 2000), if maintained for long, is already close to or into the 'dangerous' zone. The suggestion that 2°C global warming may be a 'safe' target is extremely unwise based on critical evidence accumulated over the past three decades. Global warming of this amount would be putting Earth on a path toward Pliocene-like conditions, i.e., a very different world marked by massive and continual disruptions to both society and ecosystems. It would be a world in which the world's species and ecosystems will have had no recent evolutionary experience, surely with consequences and disruptions to the ecosystem services that maintain human communities today. There are no credible arguments that such rapid would not have catastrophic circumstances for human well-being.

3. Earth's Energy Imbalance

Earth's energy balance is the ultimate measure of the status of Earth's climate. In a period of climate stability, Earth radiates the same amount of energy to space that it absorbs from incident sunlight. Today it is anticipated that Earth is out of balance because of increasing atmospheric CO_2. Greenhouse gases such as CO_2 reduce Earth's heat radiation to space, thus causing a temporary energy imbalance, more energy coming in than going out. This imbalance causes Earth to warm until energy balance is restored.

The immediate planetary energy imbalance due to an increase of CO_2 can be calculated precisely. It does not require a climate model. The radiation physics is rigorously understood. However, the current planetary energy imbalance is complicated by the fact that increasing CO_2 is only one of the factors affecting Earth's energy balance, and Earth has already partly responded to the net climate forcing by warming 0.8°C in the past century.

Thus authoritative determination of the state of the climate system requires measuring the planet's current energy imbalance. This is a technical challenge, because the magnitude of the imbalance is expected to be only about 1 W/m^2 or less, so measurements must have an accuracy that approaches 0.1 W/m^2. The most promising approach to achieve this accuracy is to measure ongoing changes of the heat content of the ocean, atmosphere, land, and ice on the planet.

The vast global ocean is the primary reservoir for changes of Earth's heat content. Because of the importance of this measurement, nations of the world launched a cooperative Argo float program, which has distributed more than 3000 floats around the world ocean

(Roemmich and Gilson, 2009). Each float repeatedly yoyos an instrument package to a depth of two kilometers and satellite-communicates the data to shore.

The Argo program did not attain planned distribution of floats until late 2007, but coverage reached 90% by 2005, allowing good accuracy provided that systematic measurement errors are kept sufficiently small. Prior experience showed how difficult it is to eliminate all measurement biases, but the exposure of the difficulties over the past decade leads to expectation that the data for the 6-year period 2005-2010 are the most precise achieved so far. The estimated standard error for that period, necessarily partly subjective, is 0.15 W/m^2.[9]

Smaller contributions to the planetary energy imbalance, from changes in the heat content of the land, ice and atmosphere, are also know more accurately in recent years. A key improvement during the past decade has been provided by the GRACE satellite that measures Earth's gravitational field with a precision that allows the rate of ice loss by Greenland and Antarctica to be monitored accurately.

Figure 3 summarizes the results of analyses of Earth's energy imbalance averaged over the periods 1993-2008 and 2005-2010. In the period 1993-2008 the planetary energy imbalance ranges from 0.57 W/m^2 to 0.80 W/m^2 among different analyses, with the lower value based on upper ocean heat content analysis of Levitus et al. (2009) and the higher value based on Lyman et al. (2010). For the period 2005-2010 the upper ocean heat content change is based on analysis of the Argo data by von Schuckmann and Le Traon (2011), which yields a planetary energy imbalance of 0.59 ± 0.15 W/m^2 (Hansen et al., 2011).

The energy imbalance in 2005-2010 is particularly important, because that period coincides with the lowest level of solar irradiance in the period since satellites began measuring the brightness of the sun in the late 1970s. Changes of solar irradiance are often hypothesized as being the one natural climate forcing with the potential to compete with human-made climate forcings, so measurements during the strongest solar minimum on record provide a conclusive evaluation of the sun's potential to reduce the planet's energy imbalance.

The conclusion is that Earth is out of energy balance by at least ~0.5 W/m^2. Our measured 0.59 W/m^2 for 2005-2010 suggests that the average imbalance over the 11-year solar cycle may be closer to 0.75 W/m^2.

This planetary energy imbalance is substantial, with implications for future climate change. It means that global warming will continue on decadal time scales, as the 0.8°C global warming so far is the response to only about half of the net human-made climate forcing.

Knowledge of Earth's energy imbalance allows us to specify accurately how much CO_2 must be reduced to restore energy balance and stabilize climate. CO_2 must be reduced from the current level of 390 ppm to 360 ppm to increase Earth's heat radiation to space by 0.5 W/m^2, or to 345 ppm to increase heat radiation to space by 0.75 W/m^2, thus restoring Earth's energy balance and stabilizing climate.

Earth's energy imbalance thus provides accurate affirmation of a conclusion reached earlier (Hansen et al., 2008), that the appropriate initial target level of atmospheric CO_2 to stabilize climate is "<350 ppm". This target level may need to be adjusted as it is approached, but, considering the time required to achieve a reversal of atmospheric CO_2 growth, more precise knowledge of the ultimate target for CO_2 will be available by the time CO_2 has been restored to a level approaching 350 ppm.

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[9] Barker et al. (2011) describe a remaining bias due to sensor drift in pressure measurements. That bias is reduced in the analysis of von Schuckmann and Le Traon by excluding data from floats on a pressure-bias black list and data from profiles that fail climatology checks, but errors remain and require further analysis.

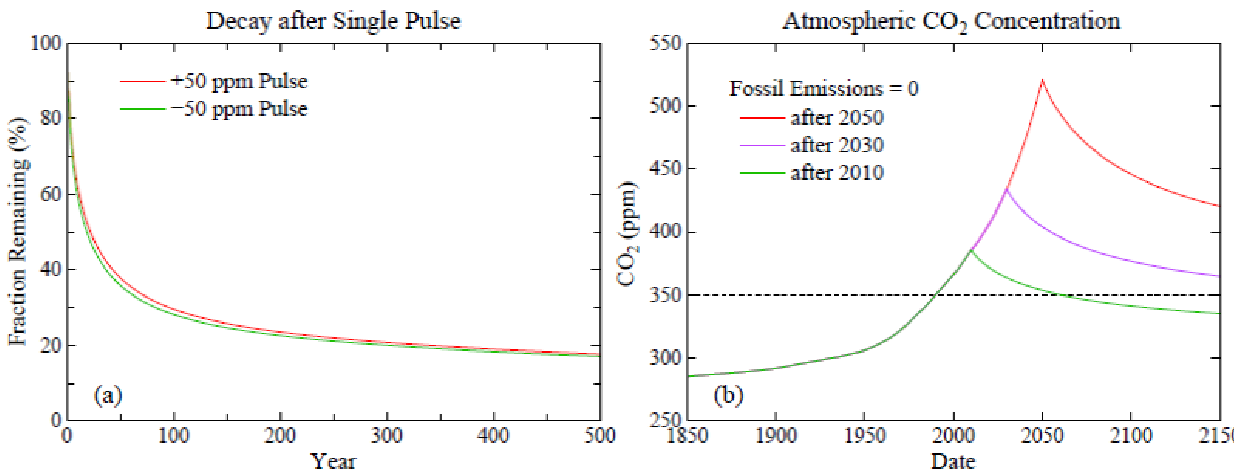

Figure 4. (a) Decay of instantaneous (pulse) injection and extraction of atmospheric CO_2, (b) atmospheric CO_2 if fossil fuel emissions terminated at end of 2011, 2030, 2050.

One reason that more precise specification than "<350 ppm" is inadvisable now is the uncertainty about the net effect of changes of other human-made climate forcings such as methane, other trace gases, reflecting aerosols, black soot, and the surface reflectivity. These forcings are smaller than that by CO_2, but not negligible.

However, the important point is that CO_2 is the dominant climate forcing agent and it will be all the more so in the future. The CO_2 injected into the climate system by burning fossil fuels will continue to affect our climate for millennia. We cannot burn all of the fossil fuels without producing a different planet, with changes occurring with a rapidity that will make Earth far less hospitable for young people, future generations, and most other species.

4. Carbon Cycle and Atmospheric CO_2

The 'carbon cycle' that defines the fate of fossil fuel carbon injected into the climate system is well understood. This knowledge allows accurate estimation of the amount of fossil fuels that can be burned consistent with stabilization of climate this century.

Atmospheric CO_2 is already about 390 ppm. Is it possible to return to 350 ppm or less within this century? Yes. Atmospheric CO_2 would decrease if we phased out fossil fuels. The CO_2 injected into the air by burning fossil fuels becomes distributed, over years, decades, and centuries, among the surface carbon reservoirs: the atmosphere, ocean, soil, and biosphere.

Carbon cycle models simulate how the CO_2 injected into the atmosphere becomes distributed among the carbon reservoirs. We use the well-tested Bern carbon cycle model (Joos et al., 1996)[10] to illustrate how rapidly atmospheric CO_2 can decrease.

Figure 4 (a) shows the decay of a pulse of CO_2 injected into the air. The atmospheric amount is reduced by half in about 25 years. However, after 500 years about one-fifth of the CO_2 is still in the atmosphere. Eventually, via weathering of rocks, this excess CO_2 will be deposited on the ocean floor as carbonate sediments. However, that process requires millennia.

It is informative, for later policy considerations, to note that a negative CO_2 pulse decays at about the same rate as positive pulse. Thus if we decide to suck CO_2 from the air, taking CO_2

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[10] Specifically, we use the dynamic-sink pulse-response function representation of the Bern carbon cycle model (Joos et al., 1996), as described by Kharecha and Hansen (2008) and Hansen et al. (2008).

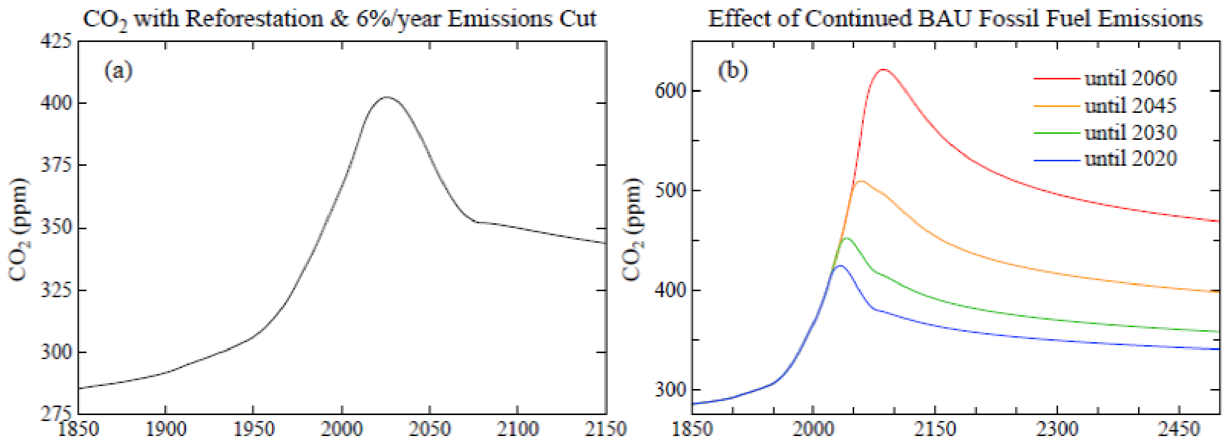

Figure 5. (a) Atmospheric CO_2 if fossil fuel emissions are cut 6% per year beginning in 2012 and 100 GtC reforestation drawdown occurs in the 2031-2080 period, (b) Atmospheric CO_2 with BAU emission increases until 2020, 2030, 2045, and 2060, followed by 5% per year emission reductions.

out of the carbon cycle, for example by storing it in carbonate bricks, the magnitude of the CO_2 change will decline as the negative increment becomes spread among the carbon reservoirs.

It is also informative to examine how fast atmospheric CO_2 would decline if fossil fuel use were halted today, or in 20 years, or in 40 years. Results are shown in Figure 4 (b). If emissions were halted in 2011, CO_2 would decline to 350 ppm at mid-century. With a 20 year delay in halting emissions, CO_2 returns to 350 ppm at about 2250. With a 40 year delay, CO_2 does not return to 350 ppm until after year 3000.

The scenarios in Figure 4 (b) assume that emissions continue to increase at the 'business-as-usual' (BAU) rate of the past decade (increasing by just over 2% per year) until they are suddenly halted. The results are indicative of how difficult it will be to get back to 350 ppm, if fossil fuel emissions continue to accelerate.

Do these results imply that it is implausible to get back to 350 ppm in a way that is essentially 'natural', i.e., in a way other than a 'geo-engineering' approach that sucks CO_2 from the air? Not necessarily. There is one other major factor, in addition to fossil fuel use, that affects atmospheric CO_2 amount: deforestation/reforestation.

Fossil fuel emissions account for about 80 percent of the increase of atmospheric CO_2 from 275 ppm in the preindustrial atmosphere to 390 ppm today. The other 20 percent is from net deforestation (here net deforestation accounts for any forest regrowth in that period). We take net deforestation over the industrial era to be about 100 GtC (gigatons of carbon), with an uncertainty of at least 50 percent (Stocker et al., 2011)[11].

There is considerable potential for extracting CO_2 from the atmosphere via reforestation and improved forestry and agricultural practices. The largest practical extraction is probably about 100 GtC (IPCC, 2001), i.e., equivalent to restoration of deforested land. Although complete restoration might appear to be unrealistic, 100 GtC uptake is probably feasible, because the human-enhanced atmospheric CO_2 level leads to an increase of carbon uptake by vegetation and soils. Competing uses for land – primarily expansion of agriculture to supply a growing world population – could complicate reforestation efforts. A decrease in the use of animal

[11] Net historical deforestation of 100 GtC and historical fossil fuel use yield good agreement with historical growth of atmospheric CO_2 (Figure S16 of Hansen et al., 2008), based on simulations with the Bern carbon cycle model.

products would substantially decrease the demand for agricultural land, as more than half of all crops are currently fed to livestock (Stehfest et al., 2009; UNEP, 2010).

We assume global reforestation (biospheric C uptake) of 100 GtC in our reforestation scenarios, with this obtained via a sinusoidal drawdown over the period 2031-2080. Alternative timings for this reforestation drawdown of CO_2 would have no qualitative effect on our conclusions about the potential for achieving a given CO_2 level such as 350 ppm.

Figure 5 (a) shows that 100 GtC reforestation results in atmospheric CO_2 declining to 350 ppm by the end of this century, provided that fossil fuel emissions decline by 6% per year beginning in 2013. Figure 5 (b) shows the effect of continued BAU fossil fuel emission (just over 2% per year) until 2020, 2030, 2045 and 2060 with 100 GtC reforestation in 2031-2080.

The scenario with emission cuts beginning in 2020 has atmospheric CO_2 return to 350 ppm at about 2300. If the initiation of emissions reduction is delayed to 2030 or later, then atmospheric CO_2 does not return to the 350 ppm level even by 2500.

The conclusion is that a major reforestation program does permit the possibility of returning CO_2 to the 350 ppm level within this century, but only if fossil fuel emission reductions begin promptly.

What about artificially drawing down atmospheric CO_2? Some people may argue that, given the practical difficulty of overcoming fossil fuel lobbyists and persuading governments to move rapidly toward post-fossil-fuel clean energy economies, 'geo-engineering' is the only hope. At present there are no large-scale technologies for air capture of CO_2, but it has been suggested that with strong research and development support and industrial scale pilot projects sustained over decades, it may be possible to achieve costs of about ~$200/tC (Keith et al., 2006).

At this rate, the cost of removing 50 ppm[12] of CO_2 is ~$20 trillion. However, as shown by Figure 4 (a), the resulting atmospheric CO_2 reduction is only ~15 ppm after 100 years, because most of the extraction will have leaked into other surface carbon reservoirs. The cost of CO_2 extraction needed to maintain a 50 ppm reduction on the century time scale is thus better estimated as ~$60 trillion.

In section 7 we note the economic and social benefits of rapidly phasing over to clean energies and increased energy efficiency, as opposed to continued and expanded extraction of fossil fuels. For the moment, we simply note that the present generation will be passing the CO_2 clean-up costs on to today's young people and future generations.

[12] The conversion factor to convert atmospheric CO_2 in ppm to GtC is 1 ppm ~ 2.12 GtC.

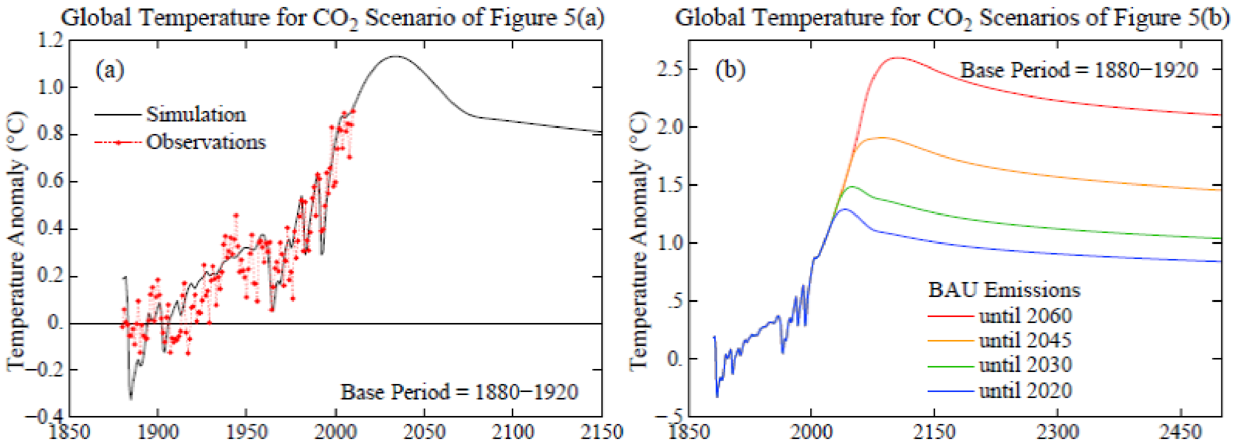

Figure 6. Simulated future global temperature for the CO_2 scenarios of Figure 5. Observed temperature record is from Hansen et al. (2010). Temperature is relative to the 1880-1920 mean. Subtract 0.26°C to use 1951-1980 as zero-point. Subtract 0.70°C to use 5-year running mean in 2000 as zero point.

5. Future Global Temperature Change

Future global temperature change will depend primarily upon atmospheric CO_2 amount. Although other greenhouse gases, such as methane and chlorofluorocarbons, contributed almost as much as CO_2 to the total human-caused climate forcings over the past century, CO_2 now accounts for more than 80 percent of the growth of greenhouse gas climate forcing (over the past 15 years). Natural climate forcings, such as changes of solar irradiance and volcanic aerosols, can cause global temperature variations, but their effect on the long-term global temperature trend is small compared with the effect of CO_2.

A simple climate response function can provide a realistic estimate of expected global temperature change for a given scenario of future atmospheric CO_2. Indeed, Hansen et al. (2011) show that such a function accurately replicates the results from sophisticated global climate models. In the simulations here we use the 'intermediate' response function of Hansen et al. (2011), which accurately replicates observed ocean heat uptake and observed temperature change over the past century, and we assume that the net change of other human-made climate forcings is small in comparison with the effect of CO_2.

One important caveat must be stressed. These calculations, as with most global climate models, incorporate only the effect of the so-called 'fast feedbacks' in the climate system, such as water vapor, clouds, aerosols, and sea ice. Slow feedbacks, such as ice sheet disintegration and climate-induced changes of greenhouse gases, as may occur with the melting of tundra and warming of continental shelves, are not included.

Exclusion of slow feedbacks is appropriate for the past century, because we know the ice sheets were stable and our climate simulations employ observed greenhouse gas amounts. The observed greenhouse gas amount includes any contribution from slow feedbacks. Exclusion of slow feedbacks in the 21st century is a dubious assumption, used in our illustrative computations only because the rate at which slow feedbacks come into play is poorly understood. However, we must bear in mind the potential for slow feedbacks to fundamentally alter the nature of future climate change, specifically the possibility of creating a situation in which continued climate change is largely out of humanity's control.

Slow feedbacks are thus one important consideration that helps to crystallize the need to keep maximum warming from significantly exceeding 1°C. With the current global warming of

~0.8°C evidence of slow feedbacks is beginning to appear, e.g., melting of tundra with release of methane (Walter et al., 2006), submarine methane release from dissociation of sea-bed gas hydrates in association with sea water temperature increase (Westbrook et al., 2009), and increasing ice mass loss from Greenland and Antarctica (Velicogna, 2009). The fact that observed effects so far are small suggests that these feedbacks may not be a major factor if maximum global warming is only ~1°C and then recedes.

On the other hand, if BAU CO_2 emissions continue for many decades there is little doubt that these slow feedbacks will come into play in major ways. Because the CO_2 injected into the air stays in the surface carbon reservoirs for millennia, the slow feedbacks surely will occur. It is only a question of how fast they will come into play, and thus which generations will suffer the greatest consequences.

There is thus strong indication that we face a dichotomy. Either we achieve a scenario with declining global CO_2 emissions, thus preserving a planetary climate resembling that of the Holocene or we set in motion a dynamic transition to a very different planet.

Can we define the level of global warming that would necessarily push us into such a dynamic transition? Given present understanding of slow feedbacks, we cannot be precise. However, consider the case in Figure 6 in which BAU emissions continue to 2030. In that case, even though CO_2 emissions are phased out rapidly (5% per year emission reductions) after 2030 and 100 GtC reforestation occurs in 2031-2080, the (fast-feedback) human-caused global temperature rise reaches 1.5°C and stays above 1°C until after 2500. It is highly unlikely that the major ice sheets could remain stable at their present size with such long-lasting warmth. Even if BAU is continued only until 2020, the temperature rise exceeds 1°C for about 100 years.

In contrast to scenarios with continued BAU emissions, Figure 6 (a) shows the scenario with 6% per year decrease of fossil fuel CO_2 emissions and 100 GtC reforestation in the period 2031-2080. This scenario yields additional global warming of ~0.3°C. Global temperature relative to the 1880-1920 mean would barely exceed 1°C and would remain above 1°C for only about 3 decades. Thus this scenario provides the prospect that young people, future generations, and other life on the planet would have a chance of residing in a world similar to the one in which civilization developed.

The precise consequences if BAU emissions continue several decades are difficult to define, because such rapid growth of climate forcing would take the world into uncharted territory. Earth has experienced a huge range of climate states during its history, but there has never been such a large rapid increase of climate forcings as would occur with burning of most fossil fuels this century. The closest analogy in Earth's history is probably the PETM (Paleocene-Eocene Thermal Maximum) in which rapid global warming of at least 5°C occurred (Zachos et al., 2001), probably as a consequence of melting methane hydrates (Zeebe et al., 2009). The PETM is instructive because it occurred during a 10-million year period of global warming, and thus the methane release was probably a feedback effect magnifying the warming.

Global warming that occurred over the period from 60 Mya (million years ago) to 50 Mya can be confidently ascribed to increasing atmospheric CO_2. That was the period in which the Indian subcontinent was moving rapidly through the Indian Ocean, just prior to its collision with Asia, when it began to push up the Himalayan Mountains and Tibetan Plateau. Continental drift over carbonate-rich ocean crust is the principal source of CO_2 from the solid Earth to the surface reservoirs of carbon.[13]

[13] The principal sink of CO_2, i.e., the mechanism that returns carbon to the solid Earth on long time scales, is the weathering process. Chemical reactions associated with weathering of rocks results in rivers carrying carbonate sediments that are deposited on the ocean floor.

The global warming between 60 Mya and 50 Mya was about 5°C, thus at a rate less than 1°C per million years. Approximately 55 Mya there was, by paleoclimae standards, a very rapid release of 3000-5000 GtC into the surface climate system, presumably from melting of methane hydrates based on the absence of any other known source of that magnitude. This injection of carbon and rapid additional warming of about 5°C occurred over a period of about 10,000 years, with most of the carbon injection during two 1-2 thousand year intervals. The PETM witnessed the extinction of almost half of the deep ocean foraminifera (microscopic shelled animals, which serve as a biological indicator for ocean life in general), but, unlike several other large warming events in Earth's history, there was little extinction of land plants and animals.

The important point is that the rapid PETM carbon injection was comparable to what will occur if humanity burns most of the fossil fuels, but the PETM occurred over a period that was 10-100 times longer. The ability of life on Earth today to sustain a climate shock comparable to the PETM but occurring 10-100 times faster is highly problematic, at best. Climate zones would be shifting at a speed far faster than species have ever faced. Thus if humanity continues to burn most of the fossil fuels, Earth, and all of the species residing on it, will be pushed into uncharted climate change territory, with consequences that are practically impossible to foresee.

6. Consequences of Continued Global Warming

The unparalleled rapidity of the human-made increase of global climate forcing implies that there are no close paleoclimate analogies to the current situation. However, the combination of paleoclimate data and observations of ongoing climate change provide useful insight.

Paleoclimate data serve mainly as an indication of likely long-term responses to changed boundary conditions. Observations of ongoing climate change provide information relevant to the rate at which changes may occur.

Yet we must bear in mind that some important processes, such as ice sheet disintegration and species extermination, have the potential to be highly non-linear. That means changes can be slow until a tipping point is reached (Lenton et al., 2008) at which more rapid change occurs.

Sea level. If all or most of the fossil fuels are burned global warming will be at least several degrees Celsius. The eventual sea level change in response to the global warming will be many meters and global coast lines will be transfigured. However, we do not know how rapidly ice sheets can disintegrate, because Earth has never experienced such rapid global warming.

During the most recent prior interglacial period, the Eemian, global mean temperature was at most of the order of 1°C warmer than the Holocene (Figure 2). During the Eemian sea level averaged 4-6 meters higher than today, there were several instances of sea level change by 1-2 meters per century, and sea level reached a peak level about 8 meters higher than today (Hearty and Neumann, 2001; Rohling et al., 2008; Kopp et al, 2009; Muhs et al., 2011). During the Pliocene, when global mean temperature may have been 2°C warmer than the Holocene (Figure 2), sea level was probably 15-25 meters higher than today (Dowsett et al., 1999, 2009; Naish et al., 2009).

Expected sea level rise due to human-caused climate change has been controversial partly because the discussion and the predictions of IPCC (2001, 2007) have focused on sea level rise at a specific date, 2100. Recent estimates of likely sea level rise by 2100 are of the order of 1 m (Vermeer and Rahmstorf, 2009; Grinsted et al., 2010). Ice-dynamics studies estimate that rates of sea-level rise of 0.8 to 2 m per century are feasible (Pfeffer et al., 2008) and Antarctica alone may contribute up to 1.5 m per century (Turner et al., 2009). Hansen (2005, 2007) has argued that BAU CO_2 emissions produce a climate forcing so much larger than any experienced in prior interglacial periods that a non-linear ice sheet response with multi-meter sea level rise may occur this century.

The best warning of an imminent period of sustained nonlinear ice sheet loss will be provided by accurate measurements of ice sheet mass. The GRACE satellite, which has been measuring Earth's gravitational field since 2003 reveals that the Greenland ice sheet is losing mass at an accelerating rate, now more than 200 cubic kilometers per year, and Antarctica is losing more than 100 cubic kilometers per year (Sorensen and Forsberg, 2010; Rignot et al., 2011). However, the present rate of sea level rise, 3 cm per decade, is moderate, and the ice sheet mass balance record is too short to determine whether we have entered a period of continually accelerating ice loss.

Satellite observations of Greenland show that the surface area with summer melting has increased over the period of record, which extends back to the late 1970s (Steffen et al., 2004; Tedesco et al., 2011). Yet the destabilizing mechanism of greatest concern is melting of ice shelves, tongues of ice that extend from the ice sheets into the oceans and buttress the ice sheets, limiting the rate of discharge of ice to the ocean. Ocean warming is causing shrinkage of ice shelves around Greenland and Antarctica (Rignot and Jacobs, 2002).

Loss of ice shelves can open a pathway to the ocean for portions of the ice sheets that rest on bedrock below sea level. Most of the West Antarctic ice sheet, which alone could raise sea level by 6 meters, is on bedrock below sea level, so it is the ice sheet most vulnerable to rapid change. However, parts of the larger East Antarctic ice sheet are also vulnerable. Indeed, satellite gravity and radar altimetry reveal that the Totten Glacier of East Antarctica, fronting a large ice mass grounded below sea level, is already beginning to lose mass (Rignot et al., 2008)

The important point is that uncertainties about sea level rise mainly concern the timing of large sea level rise if BAU emissions continue, not whether it will occur. If all or most fossil fuels are burned, the carbon will be in the climate system for many centuries, in which case multi-meter sea level rise should be expected (e.g., Rohling et al., 2009).

Children born today can expect to live most of this century. If BAU emissions continue, will they suffer large sea level rise, or will it be their children, or their grandchildren?

Shifting climate zones. Theory and climate models indicate that subtropical regions will expand poleward with global warming (Held and Soden, 2006; IPCC, 2007). Observations reveal that a 4-degree latitudinal shift has occurred already on average (Seidel and Randel, 2006), yielding increased aridity in southern United States (Barnett et al., 2008; Levi, 2008), the Mediterranean region, and Australia. Increased aridity and temperatures have contributed to increased forest fires that burn hotter and are more destructive in all of these regions (Westerling et al., 2006).

Although there is large year-to-year variability of seasonal temperature, decadal averages reveal that isotherms (lines of a given average temperature) having been moving poleward at a rate of about 50 km per decade during the past three decades (Hansen et al., 2006). This rate of shifting of climatic zones exceeds natural rates of change. The direction of movement has been monotonic (poleward) since about 1975. As long as the planet is as far out of energy balance as at present, that trend necessarily will continue, a conclusion based on comparison of the observed trend with interdecadal variability in climate simulations (Hansen et al., 2007).

Humans may be better able to adapt to shifting of climate zones, compared with many other species. However, political borders can interfere with migration, and indigenous ways of life may be adversely affected. Impacts are apparent in the Arctic, with melting tundra, reduced sea ice, and increased shoreline erosion. Effects of shifting climate zones may also be important for native Americans who possess specific designated land areas, as well as other cultures with long-standing traditions in South America, Africa, Asia and Australia.

Loss of Species. Explosion of the human population and its presence on the landscape in the past few centuries is having a profound influence on the well being of all the other species. As recently as two decades ago biologists were more concerned with effects on biodiversity other than climate change, such as land use changes, nitrogen fertilization, and direct effects of increased atmospheric CO_2 on plant ecophysiology (Parmesan, 2006). However, easily discernible impacts on animals, plants, and insects of the nearly monotonic global warming during the past three decades (Figure 1) has sharply altered perceptions of the greatest threats.

A dramatic awakening was provided by sudden widespread decline of frogs, with extinction of entire mountain-restricted species attributed to global warming (Pounds et al., 1999, 2006). Pounds et al. (2006) attribute the amphibian declines principally to the fact that climate change encouraged outbreaks of deleterious fungi. Although there are somewhat different interpretations of detailed processes involved in the amphibian declines and extinctions (Alford et al., 2007; Fagotti and Pascolini, 2007), there is agreement that global warming is a main contributor to a global amphibian crisis: "The losses portent a planetary-scale mass extinction in the making. Unless humanity takes immediate action to stabilize the climate, while also fighting biodiversity's other threats, a multitude of species is likely to vanish" (Pounds et al., 2007).

Mountain-restricted species in general are particularly vulnerable to global warming. As warming causes isotherms to move up the mountainside so does the specific climate zone in which a given specific species can survive. If global warming continues unabated, i.e., if all fossil fuels are burned, many mountain-dwelling species will be driven to extinction.

The same is true for species living in polar regions. There is documented evidence of reductions in the population and health of Arctic species living in the southern parts of the Arctic and Antarctic species in the more northern parts of the Antarctic.

A critical factor for survival of some Arctic species will be retention of all-year sea ice. Continued BAU fossil fuel use will result in loss of all Arctic summer sea ice within the next several decades. In contrast, the scenario in Figure 5a, with global warming peaking just over 1°C and then declining slowly, should allow some summer sea ice to survive and then gradually increase to levels representative of recent decades.

The threat to species survival is not limited to mountain and polar species. Plant and animal distributions are a reflection of the regional climates to which they are adapted. Although species attempt to migrate in response to climate change, their paths may be blocked by human-constructed obstacles or natural barriers such as coast lines. As the shift of climate zones becomes comparable to the range of some species, the less mobile species will be driven to extinction. Because of extensive species interdependencies, this can lead to mass extinctions.

Mass extinctions have occurred in conjunction with rapid climate change during Earth's long history, and new species evolved over hundreds of thousands and millions of years. But such time scales are almost beyond human comprehension. If we drive many species to extinction we will leave a more desolate planet for our children, grandchildren, and as many generations as we can imagine.

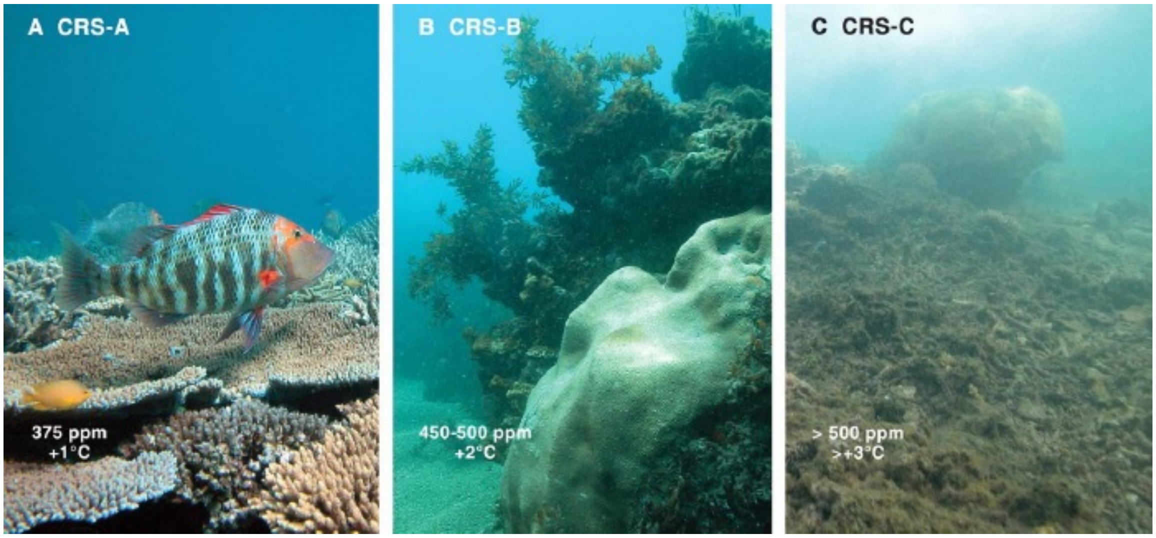

Figure 7. Extant reefs used as analogs (Hoegh-Guldberg et al., 2007) for ecological structures anticipated for scenarios A (375 ppm CO_2, +1°C), B (450-500 ppm CO_2, +2°C), C (>500 ppm CO_2, >+3°C)

Coral reef ecosystems. Coral reef ecosystems are the most biologically diverse marine ecosystem, often described as the rainforests of the ocean. An estimated 1-9 million species (most of which have not yet been described; Reaka-Kudla 1997) populate coral reef ecosystems generating ecosystem services that are crucial to the well-being of at least 500 million people that populate tropical coastal areas. These coral reef ecosystems are vulnerable to current and future warming and acidification of tropical oceans. Acidification arises due to the production of carbonic acid as increasing amounts of CO_2 enter the world's oceans. Comparison of current changes with those seen in the palaeontological record indicate that ocean pH is already outside where it has been for several million years (Raven et al. 2005; Pelejero et al. 2010).

Mass coral bleaching and a slowing of coral calcification are already disrupting coral reef ecosystem health (Hoegh-Guldberg et al 2007; De'Ath et al. 2009). The decreased viability of reef-building corals have led to mass mortalities, increasing coral disease, and slowing of reef carbonate accretion. Together with more local stressors, the impacts of global climate change and ocean acidification are driving a rapid contraction (1-2% per year, Bruno and Selig 2007) in the extent of coral reef ecosystems.

Figure 7 shows extant reefs that are analogs for ecological structures anticipated by Hoegh-Guldberg et al. (2007) to be representative of ocean warming and acidification expected to accompany CO_2 levels of 375 ppm with +1°C, 450-500 ppm with +2°C, and >500 ppm with > +3°C. Loss of the three-dimensional framework that typifies coral reefs today has consequences for the millions of species that depend on this coral reef framework for their existence. The loss of these three-dimensional frameworks also has consequences for other important roles coral reefs play in supporting fisheries and protecting coastlines from wave stress. The consequences of losing coral reefs are likely to be substantial and economically devastating for multiple nations across the planet when combined with other impacts such as sea level rise.

The situation with coral reefs is summarized by Schuttenberg and Hoegh-Guldberg (2007) thus: "Although the current greenhouse trajectory is disastrous for coral reefs and the millions of people who depend on them for survival, we should not be lulled into accepting a world without corals. Only by imagining a world with corals will we build the resolve to solve the challenges ahead. We must avoid the "game over" syndrome and marshal the financial, political, and technical resources to stabilize the climate and implement effective reef management with unprecedented urgency."

Hydrologic extremes and storms. The extremes of the hydrologic cycle are intensified as Earth becomes warmer. A warmer atmosphere holds more moisture, so heavy rains become more intense and increase flooding. Higher temperatures, on the other hand, cause an intensification of droughts, as does expansion of the subtropics with global warming. The most recent IPCC (2007) report confirms existence of expected trends, e.g., precipitation has generally increased over land north of 30°N and decreased in more tropical latitudes. Heavy precipitation events have increased substantially. Droughts are more common, especially in the tropics and subtropics. Tropospheric water vapor has increased.

Mountain glaciers. Mountain glaciers are in near-global retreat (IPCC, 2007). After a one-time added flush of fresh water, glacier demise will yield summers and autumns of frequently dry rivers originating in the Himalayas, Andes, and Rocky Mountains (Barnett et al., 2008) that now supply water to hundreds of millions of people. Present glacier retreat, and warming in the pipeline, indicate that 390 ppm of CO_2 is already a threat for future fresh water security.

Human health. Human health is affected by climate change in a large number of ways, principal ones summarized in Table 1 under the headings: (1) heat waves, (2) asthma and allergies, (3) infectious disease spread, (4) pests and disease spread across taxa: forests, crops and marine life, (5) winter weather anomalies, (6) drought, (7) food insecurity.

7. Societal Implications

The science is clear. Human-made climate forcing agents, principally CO_2 from burning of fossil fuels, have driven planet Earth out of energy balance – more energy coming in than going out. The human-made climate forcing agents are the principal cause of the global warming of 0.8°C in the past century, most of which occurred in the past few decades.

Earth's energy imbalance today is the fundamental quantity defining the state of the planet. With the completion of the near-global distribution of Argo floats and reduction of calibration problems, it is confirmed that the planet's energy imbalance averaged over several years, is at least 0.5 W/m^2. The imbalance averaged over the past solar cycle is probably closer to 0.75 W/m^2. An imbalance of this magnitude assures that continued global warming is in the pipeline, and thus so are increasing climate impacts.

Global climate effects are already apparent. Arctic warm season sea ice has decreased more than 30 percent over the past few decades. Mountain glaciers are receding rapidly all over the world. The Greenland and Antarctic ice sheets are shedding mass at an accelerating rate, already several hundred cubic kilometers per year. Climate zones are shifting poleward. The subtropics are expanding. Climate extremes are increasing. Summer heat of a degree that occurred only 2-3 percent of the time in the period 1950-1980, or, equivalently, in a typical summer covered 2-3 percent of the globe, now occurs over 20-40 percent of Earth's surface each summer (http://www.columbia.edu/~jeh1/mailings/2011/20110327_Perceptions.pdf). Within these expanded areas smaller regions of more extreme anomalies, such as the European heat wave of 2003 and the Moscow and Pakistan heat waves of 2010.

Global climate anomalies and climate impacts will continue to increase if fossil fuel use continues at current levels or increases. Earth's history provides our best measure of the ultimate climate response to a given level of climate forcing and global temperature change. Continuation of business-as-usual fossil fuel emissions for even a few decades would guarantee that global warming would pass well beyond the warmest interglacial periods in the past million

Table 1. Climate Change Impacts on Human Health

Heatwaves. Heatwaves are not only increasing in frequency, intensity and duration, but their nature is changing. Warmer nighttime temps [double the increase of average temperature since 1970 (Karl et al.)] and higher humidity (7% more for each 1ºC warming) that raises heat indices and make heat-waves all the more lethal.

Asthma and allergies. Asthma prevalence has more than doubled in the U.S. since 1980 and several exacerbating factors stem from burning fossil fuels.

Increased CO_2 and warming boost pollen production from fast growing trees in the spring and ragweed in the fall (the allergenic proteins also increase). Particulates help deliver pollen and mold spores deep into the lung sacs. Ground-level ozone primes the allergic response (and O_3 increases in heat-waves). And climate change has extended the allergy and asthma season two-four weeks in the Northern Hemisphere (depending on latitude) since 1970.

Increased CO_2 stimulates growth of poison ivy and a chemical within it (uruschiol) that causes contact dermatitis.

Infectious disease spread. The spread of infectious diseases is influenced by climate change in two ways: warming expands the geographic and temporal conditions conducive to transmission of vector-borne diseases (VBDs), while floods can leave "clusters" of mosquito-, water – and rodent-borne diseases (and spread toxins). With the ocean the repository for global warming and the atmosphere holding more water vapor, rain is increasing in intensity -- 7% overall in the US since 1970, 2"/day rains 14%, 4"/day rains 20%, and 6"/day rains 27% since 1970 (Groisman and Knight 2005), with multiple implications for health, crops and nutrition.

Tick-borne Lyme disease (LD) is the most important VBD in the US. LD case reports rose 8-fold in New Hampshire in the past decade and 10-fold (and now include all of its 16 counties). Warmer winters and disproportionate warming toward the poles mean that the changes in range are occurring faster than models based on changes in average temperatures project. Biological responses of vectors (and plants) to warming are, in general, underestimated and may be seen as leading indicators of warming due to the disproportionate winter (Tminimum or Tmin) and high latitude warming.

Pests and disease spread across taxa: forests, crops and marine life. Pests and diseases of forests, crops and marine life are favored in a warming world. Bark beetles are overwintering (absent sustained killing frosts) and expanding their range, and getting in more generations, while droughts in the West dry the resin that drowns the beetles as they try to drive through the bark. (Warming emboldens the pests while extremes weaken the hosts.) Forest health is also threatened in the Northeast U.S. (Asian Long-horned beetle and wooly adelgid of hemlock trees), setting the stage for increased wildfires with injury, death and air pollution, loss of carbon stores, and damage to oxygen and water supplies. In sum, forest pests threaten basic life support systems that underlie human health.

Crop pests and diseases are also encouraged by warming and extremes. Warming increases their potential range, while floods foster fungal growth and droughts favor whiteflies, aphid and locust. Higher CO_2 also stimulates growth of agricultural weeds. More pesticides, herbicides and fungicides (where available) pose other threats to human health. And crop pests take up to 40% of yield annually, amounting to some $300 billion in losses (Pimentel)

Marine diseases (e.g., coral, sea urchin die-offs, and others), harmful algal blooms (from excess nutrients, loss of filtering wetlands, warmer seas and extreme weather events that trigger HABs by flushing nutrients into estuaries and coastal waters), plus the over 350 "dead zones" globally affect fisheries, thus nutrition and health.

Winter weather anomalies. Increasing winter weather anomalies is a trend to be monitored. More winter precipitation is falling as rain rather than snow in the NH, increasing the chances for ice storms, while greater atmospheric moisture increases the chances of heavy snowfalls. Both affect ambulatory health (orthopedics), motor vehicle accidents, cardiac disease and power outages with accompanying health effects.

Drought. Droughts are increasing in frequency, intensity, duration, and geographic extent. Drought and water stress are major killers in developing nations, are associated with disease outbreaks (water-borne cholera, mosquito-borne dengue fever (mosquitoes breed in stored water containers)), and drought and higher CO2 increase the cyanide content of cassava, a staple food in Africa, leading to neurological disabilities and death.

Food insecurity. Food insecurity is suddenly a major problem worldwide. Demand for meat, fuel prices, displacement of food crops with those grown for biofuels all contribute. But extreme weather events today are the acute driver. Russia's extensive 2010 summer heat-wave (over six standard deviations from the norm, killing over 50,000) knocked what production some 40%; Pakistan and Australian floods in 2010 also affected wheat and other grains; and drought in China and the US Southwest are boosting grain prices and causing shortages in many nations. Food riots are occurring in Uganda and Burkino Faso, and the food and fuel hikes may be contributing to the uprisings in North Africa and the Middle East. Food shortages and price hikes contribute to malnutrition that underlies much of poor health and vulnerability to infectious diseases. Food insecurity can also lead to political instability, conflict and war.

years, implying transition to literally a different planet than the one that humanity has experienced. Today's young people and following generations would be faced with continuing climate change and climate impacts that would be out of their control.

Yet governments are taking no actions to substantially alter business-as-usual fossil fuel emissions. Rhetoric about a 'planet in peril' abounds. But actions speak louder than words. Continued investments in infrastructure to expand the scope and nature of fossil fuel extraction expose reality.

The matter is urgent. CO_2 injected into the atmosphere by burning fossil fuels remains in the surface climate system for millennia. The practicality of any scheme to extract CO_2 from the air is dubious. Potentially huge costs would be left to young people and future generations.

The apparent solution is to phase out fossil fuel emissions in favor of clean energies and energy efficiency. Governments have taken steps to promote renewable energies and encourage energy efficiency. But renewable energies total only a few percent of all energy sources, and improved efficiency only slows the growth of energy use. The transition to a post-fossil fuel world of clean energies is blocked by a fundamental fact, as certain as the law of gravity: as long as fossil fuels are the cheapest energy, they will be burned.

However, fossil fuels are cheapest only because they are subsidized directly and indirectly, and because they are not made to pay their costs to society – the costs of air and water pollution on human health and costs of present and future climate disruption and change.

Those people who prefer to continue business-as-usual assert that transition to fossil fuel alternatives would be economically harmful, and they implicitly assume that fossil fuel use can continue indefinitely. In reality, it will be necessary to move to clean energies eventually, and most economists believe that it would be economically beneficial to move in an orderly way to the post fossil fuel era via a steadily increasing price on carbon emissions.

A comprehensive assessment of the economics, the arguments for and against a rising carbon price, is provided in the book The Case for a Carbon Tax (Hsu, 2011). An across-the-board price on all fossil fuel CO_2 emissions emerges as the simplest, easiest, fastest and most effective way to phase down carbon emissions, and this approach presents fewer obstacles to international agreement.

The chief obstacles to a carbon price are often said to be the political difficulty, given the enormous resources that interest groups opposing it can bring to bear, and the difficulty of getting the public to understand arcane economic issues. On the other hand, a simple, transparent, gradually rising fee on carbon emissions collected, with the proceeds distributed to the public, can be described succinctly, as it has by Jim DiPeso, Policy Director of Republicans for Environmental Protection http://www.rep.org/opinions/weblog/weblog10-10-11.html

The basic matter, however, is not one of economics. It is a matter of morality – a matter of intergenerational justice. The blame, if we fail to stand up and demand a change of course, will fall on us, the current generation of adults. Our parents honestly did not know that their actions could harm future generations. We, the current generation, could only pretend that we did not know.

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