AU/ACSC/8697/AY09

AIR COMMAND AND STAFF COLLEGE

AIR UNIVERSITY

TWO DEGREES OF SEPARATION

ABRUPT CLIMATE CHANGE AND THE ADVERSE IMPACT TO US NATIONAL SECURITY

By

Omar A. Velasco, Major, USAF

A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

Advisor: Dr. John T. Ackerman

Maxwell Air Force Base, Alabama

April 2009

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
APR 2009	**N/A**	**-**

4. TITLE AND SUBTITLE
Two Degrees of Separation: Abrupt Climate Change and the Adverse Impact to US National Security

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Command And Staff College Air University Maxwell Air Force Base, Alabama

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**54**	

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Preface

Climate change is an environmental phenomenon which is taking place every day yet we hardly even notice it. Climate change is only detected if you are looking for it and it is in this relative obscurity where potential danger lies. An introspective look at climate change reveals several disturbing trends which if unchanged could have serious social, economic, and political global impacts in both the near and distant future. It is the assessments of these impacts which make global climate change an issue for future natural security.

I would like to thank Dr. John Ackerman, my research advisor, for guiding me through this research paper. Additionally, his subject matter expertise on this topic was invaluable to gathering the necessary research and formulating my position. Many thanks also go to Ms. Diana Simpson, librarian at the Muir S. Fairchild Research Information Center, for compiling a research bibliography on climate change and national security. I would be remised if I did not mention my research seminar colleagues who provided highly constructive feedback to me throughout the writing of this research paper. Their names are as follows:

Major Ed Peters, USAF	Major Konrad Madej, Polish Air Forces
Major Dave Gale, USAF	Major João Vicente, Portuguese Air Force
Major Ken Johnson, USAF	Wing Commander, Mostafa Siddiq, Bangladesh Air Force

Lastly, I would like to express heartfelt gratitude to my family for their unwavering support throughout this school year. It is they who serve as my motivation to succeed.

Abstract

Scientific evidence indicates recent global climate trends which if remain unchanged or develop further could result in abrupt climate change. Abrupt climate change could result in serious environmental and social impacts. The most serious environmental impact would be the disruption of the natural processes which sustain, feed, and fuel people and nations. The disruption of these natural ecosystem processes could result in the scarcity and/or inaccessibility of vital natural resources like water, food, and energy supplies. Scarcity and/or inaccessibility of vital natural resources could create social and political turmoil and adversely impact regional stability and homeland security. As the US is the largest historical producer of carbon dioxide, the most prevalent of the greenhouse gases, it should reform and adopt policies to adapt to the effects and/or mitigate the onset of abrupt climate change. Failure to take action will leave the US vulnerable to the environmental, social, and political impacts of abrupt climate change and threaten national security and vital US interests.

1. INTRODUCTION

> Few challenges facing America and the world are more urgent than combating climate change. The science is beyond dispute and the facts are clear. Sea levels are rising. Coastlines are shrinking. We've seen record drought, spreading famine, and storms that are growing stronger with each passing hurricane season. Climate change and our dependence on foreign oil, if left unaddressed, will continue to weaken our economy and threaten our national security.
>
> Barack Obama, November 2008[1]

The new United States (US) administration of President Barack Obama has identified the need for the federal government to decisively address the environmental, social, and security issues associated with global climate change. To this end, President Obama appointed renowned atomic physicist Dr. Steven Chu as his Secretary of Energy.[2] Dr. Chu authored a 2007 report on the subject of global warming and energy supply which concluded: "What the world does in the coming decade will have enormous consequences that will last for centuries. It is imperative that we begin without further delay."[3] This appointment provides the necessary strategic vision for the US to effectively contend with the emerging issues President Obama references and provides insight into the level of urgency needed to bring about change. More importantly, this executive appointment is accompanied by a call for the US to decisively engage in existing international global climate actions. These measures are in direct response to the sobering reality created by relatively recent environmental phenomena observed around the world. US government agencies have already tasked national resources to monitor and ascertain the gravity of global climate change. What this national environmental surveillance effort has discovered has been alarming to say the least.

1.1 *Alarming Changes Attributed to Global Climate Change*

Since 2003, the National Aeronautics and Space Administration (NASA) used its GRACE satellite to take land ice concentration measurements.[4] This satellite data revealed that more than 2 trillion tons of land ice in Greenland, Antarctica, and Alaska has melted since 2003.[5] Appendix A contains actual satellite imagery of the Sermersuaq (or Humboldt) Glacier in Greenland comparing land ice concentrations in 2001 and 2008.[6] Visual observation of this satellite imagery reveals a significant and otherwise unexpected reduction in the total area of land ice. As this is just one example of environmental phenomena observed around the world, the US government and scientific community are not the only parties monitoring this precarious situation. Chile is a country of interest in the study of global climate change because of its large glaciers and as such its scientists are also on alert.

Glacier scientist Gino Casassa observed a unique phenomenon in November 2008 involving Chile's Colonia glacier.[7] Melting ice in southern Chile caused the Cachet glacial lake to swell and then empty suddenly, sending a "tsunami" rolling through the Baker River.[8] The result of the swell was increased pressure on the ice sheet which caused the excess water to bore a 5-mile (an 8-kilometer) tunnel through the glacier and finally empty into the Baker River.[9] According to Casassa, "the remarkable thing is that the mass of water moved against the current of the river" and that glacier melting can be attributed to the unusually high temperatures of the recent Southern Hemisphere summer.[10] For Chile, glaciers are more than just an object for environmental study; they are a primary source for one of the Earth's most valuable resources - water. It is in the realization of the potential impacts global climate change can have on natural resources where the preservation of vital social and national interests now comes into play. The inextricable link between global climate change and its observed environmental and potential social impacts would serve as the impetus for the formation of an international scientific body devoted to the study and assessment of global climate change, the Intergovernmental Panel on Climate Change (IPCC) which was founded in 1988.

1.2 *Background and Significance*

In 2001, the IPCC announced that although the climate system was so complex that scientists would never reach complete certainty, it was *much more likely than not* that our civilization faced severe global warming.[11](emphasis added) The subsequent IPCC 2007 *Climate Change Synthesis Report* identified the high probability that climate change was anthropogenic. The report stated the following:

> Global atmospheric concentrations of CO_2, CH_4 and N_2O have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years. The atmospheric concentrations of CO_2 and CH_4 in 2005 exceed by far the natural range over the last 650,000 years. Global increases in CO_2 concentrations are due primarily to fossil fuel use, with land-use change providing another significant but smaller contribution. It is very likely that the observed increase in CH_4 concentration is predominantly due to agriculture and fossil fuel use. The increase in N_2O concentration is primarily due to agriculture.[12]

This proclamation represented the global climate science community's official consensus on the issue of global warming and the culmination of many years of extensive research and study of global climate. More importantly, it directly attributed the increase in Greenhouse Gas (GHG) concentrations to predominantly human versus natural activities. This same report goes on to provide a plausible explanation for the global warming trend of the past 250 plus years. The report states "there is *very high confidence* that the global average net effect of human activities since 1750 has been one of warming."[13](emphasis added) Additionally, the report goes on to state that "most of the observed increase in average global temperature since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations."[14](emphasis added) The IPCC's assertions serve as the unequivocal scientific foundation for the continued study and assessment of global climate change. With this declaration the discovery of global warming was essentially completed and scientists knew the most important things about how the climate could change during the 21st century.[15] Although global climate science is extremely complex, understanding the causes of global warming is imperative to any effort investigating global climate change.

Global warming is a product of the 'Greenhouse Effect.' The Greenhouse Effect is caused by the concentrations of carbon dioxide and other greenhouse gases in the atmosphere. While some challenge the science concluding that humans are the primary contributor of the GHG which cause global warming, it is conclusive that GHG concentrations, specifically CO_2, have increased in the atmosphere. Charles David Keeling directed a program to measure the concentrations of CO_2 in the atmosphere that continued without interruption from the late 1950s until present day.[16] This program, operated out of Scripps Institution of Oceanography, is responsible for the Mauna Loa Record, which is almost certainly the best know icon illustrating the impact of humanity on the planet as a whole.[17] The most recent Mauna Loa Record is included in Appendix B.[18] While this trend of increasing CO_2 concentration in itself may not seem so alarming, global climate prediction models indicate another story. Increasing concentrations of GHG can accelerate global warming and result in abrupt climate change. Dr. Naomi H. Naik, research scientist at the Lamont-Doherty Earth Observatory of Colombia University's Earth Institute, prescribes two definitions for abrupt climate change; in term of physics and in term of impacts.[19] In terms of physics, an abrupt change is a transition of the climate system into a different mode on a time scale that is faster than the responsible forcing.[20] In terms of impacts, an abrupt change is one that takes place so rapidly that human or natural systems have difficulty adapting to it.[21] For the purpose of this research paper and the prediction contained within, abrupt climate change is also defined as a greater than two degree increase in average global temperature. Such an increase in temperature could result in significant environmental first-order effects like the melting of glaciers globally. Second-order effects include reduction in the availability of critical natural resources. Both effects can be seen in present-day Chile.

Chile's official water authority warned that the Echaurren Glacier near Santiago, which supplies the capital with seventy percent of its water needs, could disappear in the next half century.[22] In a new report on Chile's glaciers, the official water authority said the ice fields are receding up to 12 meters (39.37 feet) per year.[23] The implications for Santiago, Chile's capital city, losing its primary water supply are grim. The water shortage would force Chileans to seek new sources of water and cause large-scale population displacement in central Chile.[24] The Echaurren Glacier is one of the ten most studied ice fields in the world and is considered a landmark in the global studies on climate change.[25] While this is just one example of the potential impact of climate change, it illustrates the potential regional and global implications of this disturbing global climate trend.

The regional and global security implications of the environmental effects caused by global warming are grave. Inaccessibility to critical natural resources has the potential to create and fuel existing regional instability and also weaken failing and developing states. The potential impacts of global warming span the social, economic, and political spectrums within the international arena.[26] Due to the myriad of concerns which arise, the US should assess the impacts of abrupt climate change and take action to protect vital regional and global humanitarian, sustainable development and security interests. The challenge that remains today is determining what if anything can be done to decelerate this trend and how to mitigate and/or adapt to the changes caused by abrupt climate change. Abrupt climate change could quite possibly result in a planet plagued by intense regional conflicts. Indications are that this prediction could very well become reality unless action is taken now. How the climate could actually change now depends chiefly on what policies humanity chooses for its GHG emission levels.[27] The future security environment is characterized by emerging threats and the uncertainty created by these threats. Failure to account for global climate change will only make navigating through the security environment of the future all the more difficult.

1.3 *Argument*

Scientific evidence indicates recent global climate trends which if they remain unchanged or develop further could result in abrupt climate change. Abrupt climate change would have drastic international environmental and social effects according to the IPCC 2007 *Climate Change Synthesis Report*.[28] The most serious environmental impact would be the disruption of the natural ecosystem processes which sustain, feed, and fuel people and nations. The disruption of these natural ecosystem processes would result in the scarcity and/or inaccessibility of vital natural resources like water, food, and energy supplies. Scarcity and/or inaccessibility of vital natural resources would create social and political turmoil and adversely impact regional stability and homeland security. According to the IPCC, abrupt climate change is highly probable given global climate model forecasts and the current and projected greenhouse gas emission trends.[29] As the US is the largest historical producer of carbon dioxide, the most prevalent of the GHG, it should reform and adopt policies to adapt to the effects and/or mitigate the onset of abrupt climate change. Failure to take action will leave the US vulnerable to the environmental, social, and political impacts of abrupt climate change and threaten national security and vital US interests.

1.4 *Research Questions and Thesis*

This research paper will seek to answer three main questions concerning global climate change and national security. The questions are as follows:

1) What are the effects on environmental processes of a greater than two degree increase in average global temperature?

2) What is the impact of these effects on natural resource availability, regional stability and homeland security?

3) What changes in future national security policy could these impacts drive?

The research presented seeks to establish three main points concerning global climate change and national security. These points are as follows:

1) Establish that abrupt climate change is a potential eventuality given the current global warming trend.

2) Document the environmental processes currently and potentially affected by abrupt climate change and the prospective regional and security impacts these effects could have.

3) Illustrate the viability and success of possible future policy measures taken to mitigate and adapt to the effects of global warming.

These points support the following thesis concerning abrupt climate change and the impact to US national security. Current global climate trends, which if remain unchanged, will cause abrupt climate change and have an adverse impact to US national security.

2. GLOBAL CLIMATE CHANGE

It is important to understand the distinction between global warming and global climate change. This distinction is important because of the prevalence and popularity of the term global warming, inadvertent juxtaposing of the terms, and the incomplete environmental picture the term global warming paints. Global warming is the increase in Earth's average surface temperature due to rising levels of greenhouse gases.[30] Global climate change is a long-term change in the Earth's climate, or of a region on Earth.[31] The important distinction lies in the difference in scientific perspective and scope of each term. Global warming is limited to temperature change while global climate encompasses the entire spectrum of changes associated with natural and anthropogenic climate catalysts. Temperature change in itself is not the most severe but the resulting changes to precipitation patterns and sea level are likely to have much greater human impact than the higher temperatures alone.[32] For this reason, scientific research on climate change encompasses far more than surface temperature change making global climate change the more scientifically accurate term.[33] The study of global climate change is not a new field. Understanding global climate change is imperative to understanding global warming, assessing its effects, and prescribing actions for its mitigation and environmental adaptation.

2.1 *History of Global Climate Study*

The history of global climate study is rooted in the discovery that human activity in addition to natural ecological processes could affect and change climate. In 1896, Swedish scientist Svante Arrhenius published the notion that as humanity burned fossil fuels such as coal, which added carbon dioxide gas to the Earth's atmosphere, we would raise the planet's average temperature.[34] This scientific proclamation would serve as the impetus for the global climate research which followed. In the 1930s, scientists realized that the United States and North Atlantic region had warmed significantly during the previous half-century.[35] While the vast majority of scientists supposed this was just a phase of some mild natural cycle with unknown causes, one exception, G.S. Callendar, insisted that more greenhouse warming was on the way.[36] Unfortunately, scientific climate modeling was limited at the time so Callendar's prognosis remained speculation. In the 1950s, Callendar's claims provoked a few scientists to look into the question with improved techniques and calculations.[37] The new studies showed that, contrary to earlier crude estimates, carbon dioxide could indeed build up in the atmosphere and should bring warming.[38] In 1961, measurements showed that the level of atmospheric carbon dioxide was in fact rising, year by year.[39] The scientific community had finally begun to legitimize Arrhenius' and Callendar's earlier claims.

Over the next decade scientists devised simple mathematical models of the climate and in 1967 a calculation suggested that average temperatures might rise a few degrees within the next century.[40] In the early 1970s, study panels, first in the US and then elsewhere, began to warn that one or another kind of future climate change might pose a severe threat.[41] The next thirty or so years would bring about revolutionary discoveries and advances in the study of global climate. Ice cores arduously drilled into the Greenland and Antarctic ice sheets showed large and disconcertingly abrupt temperature jumps in the past.[42] Greatly improved computer models began to suggest how such jumps could happen and experts predicted droughts, storms, rising sea levels, and other disasters.[43] One unexpected discovery was that the level of certain other greenhouse gases was rising, which would not only add seriously to global warming but also degrade the atmosphere's protective ozone layer.[44] By the late 1970s global temperatures had begun to rise again and the summer of 1988 marked the hottest summer on record until then.[45] By this time it was evident that global climate change was a stark reality and that extensive research needed to be conducted in order to come to terms with this complex scientific phenomenon. The world's governments created the IPCC to give them the most reliable possible advice, as negotiated among thousands of climate experts and officials.[46]

The formation of the IPCC marked a turning point in the history of global climate research. Since its inception, the reports of the IPCC have played a foundational role in the continued study of global climate and the formation of associated policy. The findings of the first IPCC Assessment Report of 1990 played a decisive role in leading to the United Nations Framework Convention on Climate Change (UNFCCC), which was opened for signature in the Rio de Janeiro Summit in 1992 and entered into force in 1994.[47] The IPCC Second Assessment Report of 1995 provided key input for the negotiations of the Kyoto Protocol in 1997 and the Third Assessment Report of 2001 as well as Special and Methodology Reports provided further information relevant for the development of the UNFCCC and the Kyoto Protocol.[48] The IPCC continues to be a major source of information for the negotiations under the UNFCCC.[49]

This quick synopsis of the history of global climate study reveals that the major developments in this field are based on extensive scientific research. It is the science behind these major developments which establish the credibility upon which subsequent policy formulations and decisions have and can be made. The reports of the IPCC represent the scientific benchmark in the field of global climate study.

2.2 *Scientific Consensus of the IPCC*

The IPCC's *Climate Change 2001 Synthesis Report* contains a Summary for Policymakers which identifies policy-relevant, but not policy-prescriptive, synthesis and integration of information in response to the questions submitted by governments and approved by the IPCC in 1999.[50] The following are the consensus conclusions outlined in the report:

> 1) The Earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activities.

2) Carbon dioxide concentrations, globally averaged surface temperature, and sea level are projected to increase under all IPCC emissions scenarios during the 21st century.

3) An increase in climate variability and some extreme events is projected.

4) Greenhouse gas forcing in the 21st century could set in motion large scale, high-impact, non-linear, and potentially abrupt changes in physical and biological systems over the coming decades to millennia, with a wide range of associated likelihoods.

5) Inertia is a widespread inherent characteristic of the interacting climate, ecological, and socio-economic systems. Thus some impacts of anthropogenic climate change may be slow to become apparent, and some could be irreversible if climate change is not limited in both rate and magnitude before associated thresholds, whose positions may be poorly known, are crossed.

6) The projected rate and magnitude of warming and sea-level rise can be lessened by reducing greenhouse gas emissions.

7) Reducing emissions of greenhouse gases to stabilize their atmospheric concentrations would delay and reduce damages caused by climate change.

8) Adaptation is a necessary strategy at all scales to complement climate change mitigation efforts. Together they can contribute to sustainable development objectives.

9) There are many opportunities, including technological options, to reduce near-term emissions, but barriers to their deployment exist.

10) Technology development and diffusion are important components of cost-effective stabilization.

11) Local, regional, and global environmental issues are inextricably linked and affect sustainable development. Therefore, there are synergistic opportunities to develop more effective response options to these environmental issues that enhance benefits, reduce costs, and more sustainably meet human needs.[51]

The 2001 scientific consensus of the IPCC was revolutionary in that it served as the first scientific standard from which global climate strategy and policy could be developed and implemented. In essence, this report was the genesis for the present-day global climate change scientific, social, and political movements.

2.3 *Counter Arguments to Anthropogenic Climate Change*

The arguments against the scientific consensus of the IPCC regarding anthropogenic climate change focus on disputing evidence, the attribution of global climate change to natural cyclical processes, and questioning potential environmental impacts and proposed policy measures. David Deming, a geology professor at the University of Oklahoma, disagrees with the characterization that global warming is accelerating.[52] According to Deming, the data and trends supporting global warming have reversed:

> The mean global temperature, at least as measured by satellite, is now the same as it was in the year 1980. In the last couple of years sea level has stopped rising. Hurricane and cyclone activity in the northern hemisphere is at a 24-year low and sea ice globally is also the same as it was in 1980.[53]

Opponents of anthropogenic climate change sometimes limit the observation period of their supporting climate trends and disregard climate trends observed over a more representative period of time which indicate otherwise. Others agree that global warming is taking place but blame a different culprit.

Michael R. Fox, a retired nuclear scientist and chemistry professor from the University of Idaho, is another academic who disputes anthropogenic climate change.[54] According to Fox, "These kinds of temperatures cycle up and down and have been doing so for millions of years…it's silly to lay it all on man-made carbon dioxide."[55] Fox also contends that there is little evidence to believe that man-made carbon dioxide is causing temperature fluctuations.[56] As with most anthropogenic skeptics, natural cyclical processes are primarily to blame and the observed trend of increasing GHG emissions is marginally impacting or irrelevant altogether. "Other factors, including sun spots, solar winds, variations in the solar magnetic field and solar irradiation, could all be affecting temperature changes," according to Fox.[57] However, a study conducted by the NASA Goddard Institute for Space Studies concluded that solar activity increases do not have the ability to cause large global temperature increases.[58] If Fox's assertion of the relationship between solar activity and global temperature was true and given that we are currently approaching the minimum solar activity point of the sun's 11 year cycle, global warming would be decreasing instead of on the rise. Despite the preponderance of speculative naysayers, more credible and supported opposition does exist.

Patrick J. Michaels and Robert C. Balling Jr. are two of the most renowned scientists opposing anthropogenic climate change. Michaels is a research professor of environmental sciences at the University of Virginia and Balling is a professor in the climatology program in the School of Geographical Science at Arizona State University.[59] Michaels and Balling assert that climate science is hardly unbiased, even though the global climate community itself believes that any new finding has an equal probability of making our climatic future appear more or less dire.[60] They go on to challenge the accuracy of existing scientific climate data, present detailed evidence to the contrary, and discount projected environmental impacts as short on scientific fact and long on exaggeration.[61] Balling contends that the models and empirical data are often manipulated to rally support for misguided policies that would have little impact on GHG concentrations and whose climate impact would be undetectable for many years to come.[62] Michaels is also part of a group of over 100 scientists who have recently signed a statement addressed to President Obama in response to his climate change consensus of November 2008. Following is the critical excerpt from this statement:[63]

> Surface temperature changes over the past century have been episodic and modest and there has been no net global warming for over a decade now.[64][65] After controlling for population growth and property values, there has been no increase in damages from severe weather-related events.[66] The computer models forecasting rapid temperature change abjectly fail to explain recent climate behavior.[67]

While some of this skepticism and opposition may appear superficially plausible and potentially grounded in science, these particular declarations are not accompanied by years of extensive global climate research. It is in its scientific rigor that the IPCC maintains a superlative position of credibility in explaining climate change and its associated impacts. Through its mandate, the IPCC provides reports based on scientific evidence and reflects existing viewpoints within the scientific community.[68] The comprehensiveness of the scientific content is achieved through contributions from experts in all regions of the world and all relevant disciplines including, where appropriately documented, industry literature and traditional practices, and a two stage review process by experts and governments.[69] Until the declarations of the IPCC are refuted through extensive climate science research, skeptics and opponents of anthropogenic climate change will remain exactly that. For now, an interpretation of current scientific data reveals an irrefutable and disturbing trend.

2.4 *Science Behind Climate Change*

Changes in the atmospheric concentrations of GHGs alter the energy balance of the climate system and are drivers of climate change.[70] They affect the absorption, scattering, and emission of radiation within the atmosphere and at the Earth's surface.[71] The resulting positive or negative changes in energy balance due to these factors are measured and used to determine the warming or cooling influences on global climate.[72] Human activities result in emissions of four long-lived GHGs: CO_2, methane (CH_4), nitrous oxide (N_2O) and halocarbons (a group of gases containing fluorine, chlorine or bromine).[73] These gases are commonly known as anthropogenic GHGs.

The scientific data which underscores the current global warming trend is broken out into three main categories: anthropogenic GHG emissions, atmospheric GHG concentrations, and radiative forcing. The effect of anthropogenic GHG emissions is measured using radiative forcing.[74] Atmospheric GHG concentrations affect climate processes like the Greenhouse Effect.

Climate modeling allows these data points to be extrapolated into climate predictions based on existing and forecasted trends for both anthropogenic emissions and atmospheric GHG levels.

Radiative forcing is a measure of the influence a factor, GHG, has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism.[75] GHGs differ in their warming influence (radiative forcing) on the global climate system due to their different radiative properties and lifetimes in the atmosphere.[76] In the 2007 IPCC Synthesis Report, radiative forcing values are for changes relative to preindustrial conditions defined at 1750.[77] Pre-industrial conditions are the applicable standard for comparison given the anthropogenic argument that the marked increase in GHG emissions corresponds to a period of global industrialization. The radiative forcing of the climate system is dominated by GHGs and the anthropogenic emissions of these gases have spiked in the last forty years.[78] Global GHG emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.[79] The largest growth in GHG emissions from 1970 to 2004 has come from energy supply, transport, and industry, while residential and commercial buildings, forestry (including deforestation), and agriculture sectors have been growing at a lower rate.[80] Appendix C contains a chart which shows annual anthropogenic GHG emissions, percentage of each respective GHG in total emissions for 2004, and percentage of GHG emissions attributable by sector for 2004.[81] A quick analysis of this chart reveals the overwhelming influence and importance of CO_2.

The level of emissions for all GHGs, except CO_2 from fossil fuel, has remained relatively constant and it is the progressive increase in CO_2 fossil fuel emissions over time which has caused the overall increase in GHG emissions. Additionally, CO_2 from fossil fuels accounts for the largest percentage of total GHG emissions and the energy and industrial sectors account for the largest percentage of total GHG emissions. Annual CO_2 emissions have grown between 1970 and 2004 by about 80%, from 21 to 38 gigatonnes (Gt), and represented 77% of total anthropogenic GHG emissions in 2004.[82] The rate of growth of CO_2 emissions was much higher during the recent 10-year period of 1995-2004 (0.92 $GtCO_2$ per year) than during the previous period of 1970-1994 (0.43 $GtCO_2$ per year).[83] Data analysis also shows that a relationship exists between developed and developing countries and their respective GHG emissions. In 2004, UNFCC Annex I countries held a 20% share in world population, produced 75% of the world's Gross Domestic Product (GDP) and accounted for 46% of GHG emissions.[84] Annex I countries are the industrialized and developed countries of the world as well as those developing via transition to a market-based economy.[85] This data indicates not only that GHG emission levels are rapidly ascending but that as industrialized development continues so will the trend all things remaining equal. The result of this trend in emissions is an increase of anthropogenic GHG concentrations within the atmosphere.

Atmospheric concentrations of GHG increase when emissions are larger than removal processes.[86] These removal processes include but are not limited to natural processes like photosynthesis which utilize atmospheric CO_2. The critical role of these natural removal processes is why deforestation is a problem which contributes to rising GHG concentrations. The global atmospheric concentration of CO_2 increased from a pre-industrial value of about 280ppm to 379ppm in 2005.[87] The annual CO_2 concentration growth rate was larger during the last 10 years (1995-2005 average: 1.9ppm per year) than it has been since the beginning of continuous direct atmospheric measurements (1960-2005 average: 1.4ppm per year).[88] The global atmospheric concentration of CH_4 has increased from a pre-industrial value of about

715ppb to 1732ppb in the early 1990s, and was 1774ppb in 2005.[89] The global atmospheric N_2O concentration increased from a pre-industrial value of about 270ppb to 319ppb in 2005.[90] Many halocarbons (including hydro fluorocarbons) have increased from a near-zero pre-industrial background concentration, primarily due to human activities.[91] The increased concentrations of anthropogenic GHGs have affected global climate.

There is *very high confidence* that the 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.[92] (emphasis added) The combined radiative forcing due to increases in CO_2, CH_4 and N_2O is +2.3 [+2.1 to +2.5] W/m^2 and its rate of increase during the industrial era is *very likely* to have been unprecedented in more than 10,000 years.[93] (emphasis added) The CO_2 radiative forcing increased by 20% from 1995 to 2005, the largest change for any decade in at least the last 200 years.[94] Radiative forcing is just part of the equation when determining climate impact. The equilibrium climate sensitivity is a measure of the climate system response to sustained radiative forcing.[95] It is defined as the equilibrium global average surface warming following a doubling of CO_2 concentration.[96] An assessment of equilibrium climate sensitivity, given projected radiative forcing, indicates that climate sensitivity is *likely* to be in the range of 2 to 4.5°C with a best estimate of about 3°C, and is *very unlikely* to be less than 1.5°C.[97] (emphasis added) The scientific data and corresponding effect metrics support the global warming trend observed over the past 50 years. 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.[98] (emphasis added) Appendix D illustrates observed temperature changes on each continent and the globe as a whole.[99] The increase in average global temperature is not the only trend which has spawned as a result of global warming.

3. GLOBAL CLIMATE TRENDS

The increase in average global temperature has also been the catalyst for other environmental trends which have been observed on a global scale. These trends have been witnessed over a relatively compressed time scale contrary to what may be expected for the effects observed. It is this accelerated onset which not only draws attention to the observed trends but to their anthropogenic attribution. Working Group I of the IPCC's 2007 assessment identifies global climate trends in the report *The Physical Science Basis*. These trends include the following: surface and atmospheric climate change, changes in snow, ice and frozen ground, and oceanic climate change and sea level.[100] It is these trends which begin to show the potential for direct impact to social, economic, and political spheres. This potential cannot be taken lightly and is the reason why these trends must be continually observed and accounted for.

3.1 Surface and Atmospheric Climate Change

Global mean surface temperatures have risen by 0.74°C ± 0.18°C when estimated by a linear trend over the last 100 years (1906–2005) while the rate of warming over the last 50 years is almost double that over the last 100 years (0.13°C ± 0.03°C vs. 0.07°C ± 0.02°C per decade).[101] This trend indicates that rising surface temperatures are getting exponentially worse and represents a possible tipping point in anthropogenic drivers which has caused a diversion from the expected linear progression. Land regions have warmed at a faster rate than the oceans and changes in extreme temperatures are consistent with warming of the climate.[102] This trend supports anthropogenic attribution and serves as warning of the onset of more severe temperature extremes and their associated effects. Recent warming is strongly evident at all latitudes in surface sea temperature over all the oceans.[103] Given that 75% of the globe is covered by water and serves as a key driver in the global climate system, the implications of increased and intensified climate activity are significant. Average arctic temperatures increased at almost twice the average global rate in the past 100 years.[104] The subsequent reduction of the polar ice caps could invariably result in rising sea levels and severe ecological impacts to the polar regions.

Precipitation has generally increased over land north of 30°N over the period 1900 to 2005 but downward trends dominate the tropics since the 1970s while substantial increases are found in heavy precipitation events.[105] The tropical areas prone to drought are receiving less needed rain and the more temperate areas potentially face higher incidences of flooding. Droughts have become more common especially in the tropics and subtropics, since the 1970s.[106] This trend coupled with the decrease in tropical precipitation places further climate strain on an already strained region. Tropospheric water vapor is increasing and changes in large scale atmospheric circulation are apparent.[107] Water vapor fuels precipitation cycles and circulation determines weather patterns, both of which can increase and intensify climate events. Intense tropical cyclone activity has increased since about 1970.[108] Tropical cyclone activity, as seen recently with Hurricane Katrina in 2005, has the potential to cause unprecedented damage and reshape entire regions.

3.2 Changes in Snow, Ice, and Frozen Ground

In the climate system, the cryosphere (which consists of snow, river and lake ice, sea ice, glaciers and ice caps, ice shelves and ice sheets, and frozen ground) is intricately linked to the surface energy budget, the water cycle, sea level change and the surface gas exchange.[109] The cryosphere integrates climate variations over a wide range of time scales, making it a natural sensor of climate variability and providing a visible expression of climate change.[110] Recent decreases in ice mass are correlated with rising surface air temperatures.[111] Additionally, changes in the cryosphere could potentially result in the redefining of geographic boundaries and the disruption of established ecosystems. Following are the cryospheric trends identified within the IPCC's 2007 *The Physical Science Basis*:[112]

> Northern Hemisphere (NH) snow cover observed by satellite over the 1966 to 2005 period decreased in every month except November and December, with a stepwise drop of 5% in the annual mean in the late 1980s.
>
> Freeze-up and breakup dates for river and lake ice exhibit considerable spatial variability. Averaged over available data for the NH spanning the past 150 years, freeze-up date has occurred later at a rate of 5.8 ± 1.6 days per century, while the breakup date has occurred earlier at a rate of 6.5 ± 1.2 days per century.
>
> Satellite data indicate a continuation of the 2.7 ± 0.6% per decade decline in annual mean arctic sea ice extent since 1978. The decline for summer extent is larger than for winter, with the summer minimum declining at a rate of 7.4 ± 2.4% per decade since 1979.
>
> Submarine-derived data for the central Arctic indicate that the average sea ice thickness in the central Arctic has *very likely* decreased by up to 1 m from 1987 to 1997.
>
> Mass loss of glaciers and ice caps is estimated to be 0.50 ± 0.18 mm yr^{-1} in sea level equivalent (SLE) between 1961 and 2004, and 0.77 ± 0.22 mm yr^{-1} SLE between 1991 and 2004.
>
> Taken together, the ice sheets in Greenland and Antarctica have *very likely* been contributing to sea level rise over 1993 to 2003.
>
> Temperature at the top of the permafrost layer has increased by up to 3°C since the 1980s in the Arctic. The permafrost base has been thawing at a rate ranging up to 0.04 m yr^{-1} in Alaska since 1992 and 0.02 m yr^{-1} on the Tibetan Plateau since the 1960s.
>
> The maximum extent of seasonally frozen ground has decreased by about 7% in the NH from 1901 to 2002, with a decrease in spring of up to 15%.

3.3 Oceanic Climate Change and Sea Level

Over the period 1961 to 2003, global ocean temperature has risen by 0.10°C from the surface to a depth of 700 m.[113] This increase in temperature facilitates water evaporation and accelerates existing climate cycles. Large-scale, coherent trends of salinity are observed for 1955 to 1998, and are characterized by a global freshening in sub polar latitudes and a salinification of shallower parts of the tropical and subtropical oceans.[114] Changes in salinity have a direct impact to available freshwater supplies relied upon for potable consumption and affect organisms residing in each. The total inorganic carbon content of the oceans has increased by 118 ± 19 GtC between the end of the pre-industrial period (about 1750) and 1994 and continues to increase.[115] Increases in carbon content result in changes to the ocean's acidity/basicity or pH. Direct observations of pH at available time series stations for the last 20 years also show trends of decreasing pH at a rate of 0.02 pH units per decade.[116] Disruption of the pH balance can potentially destabilize oceanic ecosystems to include those which support human activities. From 1961 to 2003, the average rate of sea level rise was 1.8 ± 0.5 mm yr^{-1}. For the 20th century, the average rate was 1.7 ± 0.5 mm yr^{-1}.[117]

It is evident that the impact of climate change on the oceans can have catastrophic effects on marine ecosystems which not only help regulate GHG concentrations but serve as a major source of sustenance for many people. Sea level rise has the potential to redefine geographic boundaries and consequently affect state sovereignty. Sea level rise can permanently eliminate inhabited and industrialized coastal areas. The impact of sea level rise can invariably lead to refugee populations and migratory flows into unaffected regions.

While these global climate trends may appear alone in characteristic, they certainly do not act in isolation. These trends affect the entire spectrum of environmental processes.

4. ENIRONMENTAL PROCESS IMPACTS

Working Group II of the IPCC's 2007 assessment studied the effects of global warming upon key environmental processes. These findings are contained within the report *Impacts, Adaptation, and Vulnerability*. Physical and biological systems on all continents and in most oceans are already being affected by recent climate changes, particularly regional temperature increases.[118] This supports the notion that although climate change may transpire regionally its effects are truly global. Climatic effects on human systems, although more difficult to discern due to adaptation and non-climatic drivers, are emerging.[119] Through the advancement of climate science, the effects on human systems can be more accurately determined. Global-scale assessment of observed changes shows that it is likely that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems.[120] This statement serves as the environmental indictment of global warming. Changes in several aspects of the human health system have been related to recent warming.[121] The human health system is perhaps the most vulnerable and as such this trend should be reason for alarm. Adaptation to recent warming is beginning to be systematically documented.[122] Whether cognizant of global warming or not, humans have to account for the changes brought about in the environment.

4.1 Physical Systems

Changes in river discharge, as well as in drought intensity/duration and heavy rains in some regions indicate that hydrological conditions have become more intense.[123] Climate change signals related to increasing runoff and stream flow have been observed over the last century in many regions particularly in basins fed by glaciers, permafrost, and snow melt.[124] Freshwater lakes and rivers are experiencing increased water temperatures and changes in water chemistry.[125] Surface and deep lake waters are warming, with advances and lengthening of periods of thermal stability in some cases associated with physical and chemical changes such as increases in salinity and suspended solids, and a decrease in nutrient content.[126] Any impact to the hydrological system has the potential not only to disrupt critical water supply but to destabilize ecosystems relied upon for human activities.

In many coastal regions, particularly in subsiding regions, local sea-level rise exceeds the 20th century global trend of 1.7 to 1.8 mm/yr.[127] Sea-level rise, enhanced wave heights, and increased intensity of storms are affecting some coastal regions distant from human modification, e.g., polar areas and barrier beaches, mainly through coastal erosion.[128] Coastal erosion and losses of wetlands are widespread problems today, under current rates of sea-level rise, although these are largely caused by anthropogenic modification of the shoreline.[129] Rising sea level has the potential to redefine geographic areas and relocate population concentrations.

In marine and freshwater ecosystems, many observed changes in phenology and distribution have been associated with rising water temperatures, as well as changes in salinity, oxygen levels and circulation.[130] Globally, freshwater ecosystems are showing changes in organism abundance and productivity, range expansions, and phenological shifts (including earlier fish migrations) that are linked to rising temperatures.[131] Many of these climate-related impacts are now influencing the ways in which marine and freshwater ecosystems function.[132] Human reliance on these ecosystems as a source of food is threatened by global warming.

4.2 Biological Systems

Most plants and animals can reproduce, grow and survive only within specific ranges of climatic and environmental conditions.[133] If conditions change beyond the tolerances of species, then they may respond by: shifting the timing of life-cycle events, shifting range boundaries or the density of individuals within their ranges, changing morphology, reproduction or genetics, and extirpation or extinction.[134] Given these necessary conditions, it is easy to see the potential impact of global warming on biological systems.

The vast majority of studies of terrestrial biological systems reveal notable impacts of global warming over the last three to five decades, which are consistent across plant and animal taxa: earlier spring and summer phenology and longer growing seasons in mid- and higher latitudes, production range expansions at higher elevations and latitudes, some evidence for population declines at lower elevation or latitudinal limits to species ranges, and vulnerability of species with restricted ranges, leading to local extinctions.[135] Perhaps the most shocking of trends yet seen, if biological systems do not respond actively to global warming then extinction is an eventuality for some. For systems with less measures of adaptability, there is no option.

In terms of agriculture and forestry, trends in individual climate variables or their combination into agro-climatic indicators show that there is an advance in phenology in large parts of North America and Europe, which has been attributed to recent regional warming.[136] In temperate regions, there are clear signals of reduced risk of frost, longer growing season duration, increased biomass, higher quality (for climate-sensitive crops), insect expansion, and increased forest-fire occurrence that are in agreement with regional warming.[137] Although the present effects are of limited economic consequence and appear to lie within the ability of the sectors to adapt, both agriculture and forestry show vulnerability to recent extreme heat and drought events.[138] The susceptibility of agriculture and forestry to drought exposes a critical vulnerability to a vital natural resource and key factor in the processing of CO_2.

4.3 Human Systems

Episodes of extreme heat or cold have been associated with high mortality.[139] This holds particularly true for groups of people who do not have the resources to protect themselves from temperature extremes. Vector-borne diseases are known to be sensitive to changes in temperature and rainfall.[140] This sensitivity is very dangerous as an unexpected outbreak may occur as a result of drastic climate changes. Food and water-borne diseases are major adverse conditions associated with warming and extreme precipitation events.[141] Another negative side effect of warming and extreme precipitation is the creation of a safe haven for the harboring and spreading of disease. Observed climate change is affecting the timing of the onset of allergenic pollen production.[142] Modern medicine can prevent the side effects of allergenic pollen if applied preventatively. With no visibility to the onset of allergenic pollen production, medical effectiveness is hampered.

While these trends represent a fraction of the environmental process impacts resulting from global warming, their occurrence and intensity is related to the severity of global warming. For this reason, global warming needs to be controlled to avoid abrupt climate change. Crossing this climate threshold could create effects which the environment may be unable to handle.

5. ABRUPT CLIMATE CHANGE

As defined earlier, abrupt climate change represents the breaking point for anthropogenic global warming. As this point has not yet been reached but anthropogenic global warming has been observed, data modeling can project when this point will be reached given the current global warming trends of increasing anthropogenic GHG emissions and increasing average global temperature. As with any model, there are limitations with accuracy as is the case with global climate given the size and complexity of the system being replicated.

5.1 Global Climate Modeling

The IPCC published a 2007 Special Report on Emissions Scenarios (SRES) that utilized atmospheric modeling to project an increase of baseline global GHG emissions by a range of 9.7 to 36.7 $GtCO_2$-eq (25 to 90%) between 2000 and 2030.[143] This projection, given current global warming trends and the potential for abrupt climate change, clearly indicates the need for action to reduce future GHG emissions. In these models, fossil fuels are projected to maintain their dominant position in the global energy mix to 2030 and beyond.[144] Hence CO_2 emissions from energy use between 2000 and 2030 are projected to grow 40 to 110% over that period.[145] Given the attribution of GHG emissions to fossil fuel use, this projection supports exploration of alternative energy sources. Using these projections as parameters for its climate modeling, the SRES accounted for possible variances in influencing variables by creating different representative anthropogenic scenarios.[146] Appendix E illustrates potential GHG emissions given the modeling scenarios for the period 2000-2100.[147] Subsequent climate modeling for the SRES scenarios also projected climate changes (average global temperature change) and resulting effects (average sea level rise).[148] The value in data modeling lies in the ability to forecast current trends which allows scientists to ascertain the severity of potential impacts.

5.2 Greenhouse Emission Scenarios

The SRES scenarios are grouped into four scenario families (A1, A2, B1 and B2) that explore alternative development pathways, covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions.[149] The SRES scenarios do not include additional climate policies above current ones.[150] The emissions projections are widely used in the assessments of future climate change, and their underlying assumptions with respect to socio-economic, demographic and technological change serve as inputs to many recent climate change vulnerability and impact assessments.[151] The A1 storyline assumes a world of very rapid economic growth, a global population that peaks in mid-century and rapid introduction of new and more efficient technologies.[152] A1 is divided into three groups that describe alternative directions of technological change: fossil energy intensive (A1FI), non-fossil energy resources (A1T) and a balance across all sources (A1B).[153] B1 describes a convergent world, with the same global population as A1, but with more rapid changes in economic structures toward a service and information economy.[154] B2 describes a world with intermediate population and economic growth, emphasizing local solutions to economic, social, and environmental sustainability.[155] A2 describes a very heterogeneous world with high population growth, slow economic development and slow technological change.[156] No likelihood has been attached to any of the SRES scenarios.[157] While all or some of these scenarios may not represent all reality to some, they do represent viable possibilities given current scientific and social trends.

5.3 Global Climate Predictions

For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emissions scenarios.[158] Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.[159] Afterwards, temperature projections increasingly depend on specific emissions scenarios.[160] Continued GHG emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would *very likely* be larger than those observed during the 20th century.[161] These projections support the conclusion that the current global warming trend is moving towards possibly reaching abrupt climate change. The 2007 SRES included projected global average surface warming and sea level rise at the end of the 21st century for each of the anthropogenic scenarios.[162] The table below summarizes these predictions.

Scenario	**Global average surface warming (°C) (best estimate)**	**Global average surface Warming (°C) (likely range)**	**Sea level rise (m)(likely range)**
B1	1.8	1.1 - 2.9	0.18 - 0.38
A1T	2.4	1.4 - 3.8	0.20 - 0.45
B2	2.4	1.4 - 3.8	0.20 - 0.43
A1B	2.8	1.7 - 4.4	0.21 - 0.48
A2	3.4	2.0 - 5.4	0.23 - 0.51
A1FI	4.0	2.4 - 6.4	0.26 - 0.59

These alarming projections are not the only bad news within the IPCC's 2007 SRES. Anthropogenic warming and sea level rise would continue for centuries due to the time scales associated with climate processes and feedbacks, even if GHG concentrations were to be stabilized.[163] Despite the pessimistic forecast, action should be taken to address the disturbing present and future trends of global warming for the impacts transcend the environment.

6. IMPACTS OF CLIMATE CHANGE

Global warming is a scientifically established and proven trend which is not going away anytime soon. Indications are that global warming will continue to exist and evidence supports the likelihood of abrupt climate change occurring in the not so distant future. Given these eventualities, anthropogenic climate change results in impacts and vulnerabilities and the corresponding adaptation and mitigation needed for socio-economic development.[164] Appendix F illustrates a schematic framework representing anthropogenic drivers, impacts of and responses to climate change, and their linkages.[165] Coupling climate science, current socio-economic trends, and the anthropogenic framework, a prediction can be made as to the effects of a world experiencing abrupt climate change.

6.1 Severe Climate Change Over the Next Thirty Years

This projection of severe climate change is based on IPCC findings with an adjustment to account for possible "tipping point" events such as the abrupt release of massive quantities of methane from melting tundra or of carbon dioxide as the sea warms up.[166] The following predictions from *Climatic Cataclysm* by Kurt Campbell are startling to say the least.

> Average global surface temperature rises unexpectedly to 2.6°C above 1990 levels, with larger warming over land and at high altitudes. Dynamic changes in polar ice sheets accelerate rapidly resulting in about 52 centimeters of sea level rise. Climate scientists express high confidence that the Greenland and West Antarctic ice sheets have been destabilized and that 4 to 6 meters of sea level rise are inevitable.
>
> Water availability decreases strongly, affecting 1 to 2 billion people worldwide. The North Atlantic meridional circulation slows significantly with consequences for marine ecosystem production and fisheries.

> Crop yields decline significantly in the fertile river deltas because of sea level rise and damage from increased storm surges. Agriculture becomes nonviable in the dry sub tropics where irrigation is exceptionally difficult and soil salinization is exacerbated by rapid evaporation of water from irrigated fields. Arid regions have spread significantly by desertification, taking marginally productive crop lands out of production.
>
> Global fisheries are affected by widespread coral bleaching, ocean acidification, substantial loss of coastal nursery wetlands, and drying of tributaries that serve as breeding grounds for fish.
>
> The Arctic Ocean is now navigable for most of the year because of decreased Arctic sea ice, and the Arctic marine ecosystem is dramatically altered. Developing nations are impacted most severely because of climate sensitivity and high vulnerability. Industrialized nations experience net harm from warming and must expend greater proportions of GDP adapting to climate change.[167]

While the social, economic, and political consequences of severe climate change are ominous, the forecast for catastrophic climate change is almost apocalyptic.

6.2 Catastrophic Climate Change Over the Next Hundred Years

Everybody remembers the incredible damage caused by Hurricane Katrina. A world of catastrophic climate change would have Katrina strike New Orleans as a Category 5 with the very realistic possibility of another severe hurricane striking only months after during reconstruction rendering the city permanently uninhabitable.[168] In a catastrophic climate scenario, this fate would not be shared by New Orleans alone but by every major city in the world if not from a hurricane then from massive sea level rise or prolonged drought.[169] Hundreds of millions of thirsty and starving people will have to flee or perish and the sudden nature of these climate events will challenge the ability of all societies to adapt including the US's.[170] Persistent conflict – civil, communal, sectarian, regional, and between nations – will be the norm in this plausible scenario.[171] Over the course of the next century, however, if the catastrophic scenario described above comes to pass, hope will be eclipsed as all nations of the Earth struggle to meet the challenges of profound climate change.[172] In this scenario, by the end of the century, the world will have entered the 'Age of Survival.'[173] The catastrophic climate change scenario paints an almost unreal picture of the future however, the anthropogenic drivers needed and the possibility of occurrence are very real. It is this possibility which presents a threat to national security given the Armageddon scenario described above.

7. LINK TO NATIONAL SECURITY

The 2006 *Quadrennial Defense Review* (QDR) identifies four types of security challenges facing the US: irregular, disruptive, traditional, and catastrophic.[174] The QDR goes on to define operational imperatives for the DoD of which one is to "prepare for wider asymmetric challenges".[175] Although not explicitly stated as a challenge, the threat presented by emerging global climate change certainly meets the DoD standard for operational imperative. Dr. John Ackerman in *Climate Change, National Security and the QDR* aligns the threats of global climate change into the challenge categories outlined in the *QDRs* security challenge framework. Irregular challenges include ocean acidification, environmental refugees, and geo-engineering.[176] Traditional challenges include droughts, heat waves, and floods.[177] Disruptive challenges include famine, water stress, and pandemics.[178] Catastrophic challenges include mass extinctions, state failure, and melting ice caps.[179] By structuring the threat of climate change in this manner, it is easier for DoD planners to apply the guidance prescribed in the QDR and provides the appropriate context needed to address the threat of global climate change.

Climate change represents a valid and legitimate threat to national security. The emergence of harmful nonlinear, long-term, cumulative, anthropogenically generated changes to the Earth's climate and natural environment pose a "serious threat to America's national security."[180] The challenge to national security created by global climate change is based on threats, vulnerabilities, and risks across the spectrum of strategic, operational, and even tactical challenges.[181] One such operational challenge is resource availability.

7.1 Resource Availability

Energy security means protecting our way of life and our future from the security, economic, and environmental risks associated with fossil fuels.[182] Both oil and coal are contributing to global climate change, which could have terrible security consequences as nations around the world, including the US, struggle with droughts, food shortages, floods, heat waves, and unpredictable and severe weather.[183] Additionally, global climate change has the potential to disrupt oil drilling and refining operations. Abrupt climate change could also drastically reduce the number of competitive oil producers and subject fossil fuel dependent nations to an oppressive and exploitative energy monopoly. Fossil fuels are not the only vulnerable natural resource whose availability is jeopardized by climate change.

Adequate supplies of fresh water for drinking, irrigation, and sanitation are the most basic prerequisite for human habitation.[184] Changes in rainfall, snowfall, snowmelt, and glacial melt have significant effects on fresh water supplies, and climate change is likely to affect all of those things.[185] Forty percent of the world's population derives at least half of its drinking water from the summer melt of mountain glaciers, but these glaciers are shrinking and some could disappear within decades.[186] Most countries in the Middle East and northern Africa are already considered water scarce, and the International Water Resource Management Institute projects that by 2025, Pakistan, South Africa, and large parts of India and China will also be water scarce.[187] Due to its criticality, water availability could easily become a fracturing force within the global arena. The struggle for availability of potentially scarce natural resources like fossil fuels and water could invariably lead to national and regional social, economic, and political instability.

7.2 Regional Stability

Climate change alone is unlikely to trigger state failure in any state out to 2030, but the impacts will worsen existing problems - such as poverty, social tensions, environmental degradation, ineffectual leadership, and weak political institutions.[188] Climate change could threaten domestic stability in some states, potentially contributing to intra- or, less likely, interstate conflict, particularly over access to increasingly scarce water resources.[189] Economic migrants will perceive additional reasons to migrate because of harsh climates, both within nations and from disadvantaged to richer countries.[190] These impacts associated with climate change have the potential to weaken state sovereignty. Refugee and other migratory flows into climate adaptive states will more than likely be unwelcomed and place additional strain on already taxed social systems.

Many developing countries do not have the government and social infrastructures in place to cope with the types of stressors that could be brought on by global climate change.[191] When a government can no longer deliver services to its people, ensure domestic order, and protect the nation's borders from invasion, conditions are ripe for turmoil, extremism and terrorism to fill the vacuum.[192] The conditions needed for the inception of extremism and terrorism already exist in several weak and failing states. The effects of global climate change will only make these states more susceptible.

7.3 Homeland Security

Anticipated impacts to the Homeland, including possible increases in the severity of storms in the Gulf, increased demand for energy resources, disruptions in US and Arctic infrastructure, and increases in immigration from resource-scarce regions of the world, are expected to be costly.[193] Hurricane Katrina gave us a glimpse of the threat global climate change presents to homeland security.

In the immediate aftermath of Hurricane Katrina, oil production in the Gulf of Mexico was reduced by just under 92% and natural gas production by about 83%.[194] As bad as this was, the damage to oil refining capacity was even worse: about a month and a half after Katrina hit and a few weeks after Hurricane Rita, all but about 10% of US oil refining capacity was still offline, and 15 natural gas processing plants remained inactive.[195] President Bush and Energy Secretary Samuel Bodman announced quickly that the US would release crude oil from the Strategic Petroleum Reserve.[196] Hurricane Katrina illustrated the crippling effect of severe climate events and thus warns of the impending danger of global climate change.

8. POLICY RECOMMENDATIONS

Effective global climate policy has to be proactive and comprehensive. The US, as the world's industrial leader, should bear the international responsibility of addressing global climate change. In doing so, the US should be partner to international groups and policies which focus on combating global climate change. The US has not ascribed to the Kyoto Protocol which represents the international community's formal mechanism for prescribing mitigation actions in the battle against global warming. As this is a complex and dynamic scientific problem, international consensus and a multilateral approach is not only convenient but necessary.

8.1 Responses

The US needs an energy security strategy which cuts both our dependence on oil and our emissions of GHG.[197] A 70-40 strategy, cutting GHG emissions by 70% over 40 years will reduce US dependence on fossil fuels.[198] To change fuel supply and demand, investment in innovation for alternative energy is paramount.[199] The US should seek partners abroad to protect energy infrastructure and prevent a crisis.[200] Terrorists who attack oil fields or power outages from natural disasters cannot single-handedly derail out nation.[201] Since fossil fuels are the largest contributor of CO_2, they should be the primary target of global climate change policy.

In the immediate aftermath of a natural disaster in a world of abrupt climate change, the international community would look to the US, with its unique world role and response assets (to include the military), to assume a role in long-term resolution.[202] In all but the extreme scenario, in which most of the world is put in a fundamentally severe set of circumstances, the unique character of the American people, with their strong optimism and penchant for the practical, will be a major asset.[203] It is this same approach of optimism and practicality which should underscore the national commitment to mitigate and adapt to global warming.

Peter Schwartz and Doug Randall propose several additional steps which should be taken to better assess the impact of global climate on national security and to better content with the expected effects. Following is their seven step prescription:[204]

1. Improve predictive climate models to allow investigation of a wider range of scenarios and to anticipate how and where changes could occur.

2. Assemble comprehensive predictive models of the potential impacts of abrupt climate change to improve projections of how climate could influence food, water, and energy.

3. Create vulnerability metrics to anticipate which countries are most vulnerable to climate change and therefore, could contribute materially to an increasingly disorderly and potentially violent world.

4. Identify no-regrets strategies such as enhancing capabilities for water management.

5. Rehearse adaptive responses.

6. Explore local implications.

7. Explore geo-engineering options that control the climate.

Extrapolating Schwartz and Randall's prescription to the current global warming trend is constructive to the end of ascertaining the broad range of impacts and formulating viable adaptation and mitigation strategies. As there is much yet to be learned about global climate, continued scientific study and planning is also essential. Luckily, global climate change has garnered the requisite attention it deserves and there are already major efforts afoot to contend not only with its anthropogenic causes but its potentially destabilizing effects.

8.2 National and International Efforts Already Underway

The United Kingdom has taken a proactive approach to global climate change and its effects and as such has developed a model for relating climate change to the instability which sometimes results. The UK Prime Minister's Strategy Unit developed a framework that can be used to map the interaction of the various factors associated with instability and conflict in a country or region. Following are the contextual factors of this framework:[205]

> Country capacity and resilience lies at the center of country stability and determines the extent to which countries can successfully manage the risk factors and shocks which are present in all countries. Country capacity depends on both state and non-state institutions. Where country capacity and resilience are low, then destabilizing factors can give rise to instability.
>
> Risk factors for instability. These can arise from internal processes and factors within the country, or be consequences of the actions or inaction of other countries and the international community. Risk factors are generally 'structural' and must be addressed through long-term policy measures.
>
> Shocks comprise more proximate and unpredictable risk factors which can trigger unstable situations at any moment in time e.g. assassinations and natural disasters.
>
> External stabilizing factors are regional and global in nature and support and strengthen country capacity and resilience. External stabilizing factors can also set incentive frameworks which can foster stability in a country.

> The feedback of instability into the risk factors. Once crisis or conflict emerges, a feedback loop of weak country capacity and resilience can drive a vicious cycle of instability by increasing risk factors further.

This framework allows military planners to assess instability in areas affected by global climate change. Through this assessment, more vulnerable areas can be identified and consequently targeted form mitigation and/or adaptation. In essence, instability resulting from global climate change can be predicted with some degree of certainty using this framework.

In the US, in response to President Obama's consensus statement on global climate change, Democrats unveiled a climate bill. The Waxman-Markey Bill requires that emissions be reduced 20% from 2005 levels by 2020 and reduce GHG emissions 80% by 2050.[206] While this bill may not have much support right now as the country is focused on resurrecting the economy, this measure represents a step in the right direction for the federal government. Tackling the global warming problem has to begin at home.

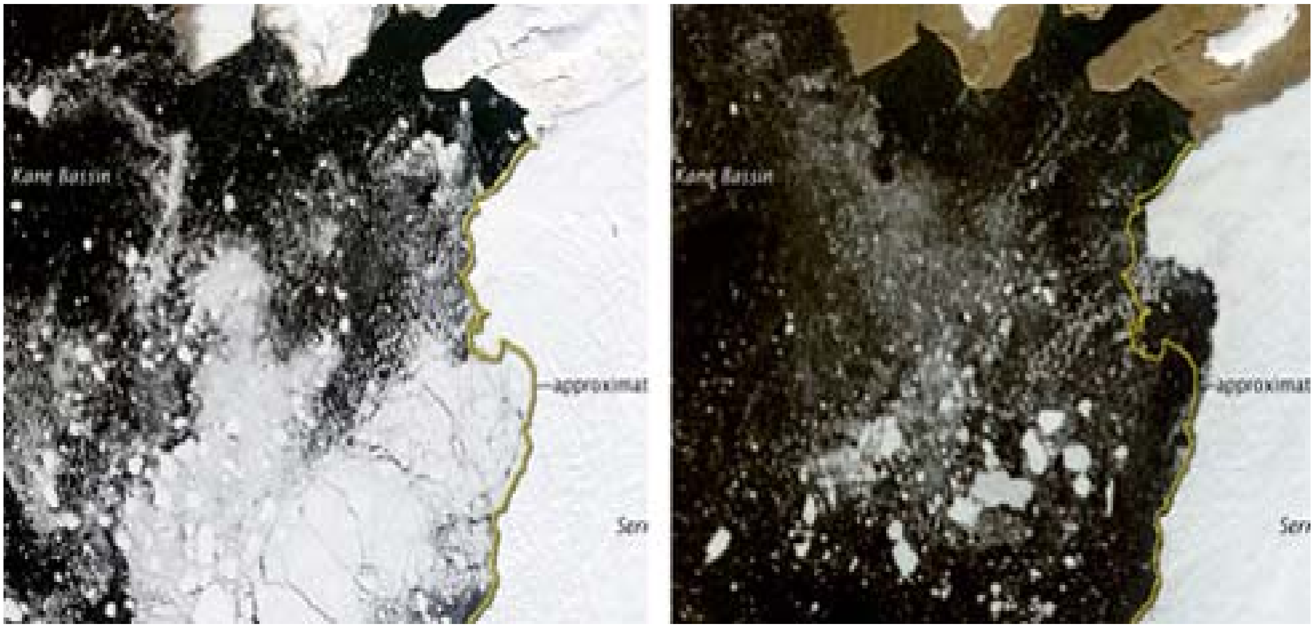
9. CONCLUSION

The science behind global climate change supports the observed GHG and global climate trends and the resulting environmental process effects. The social, economic, and political impacts are profound and could potentially be accelerated by the onset of abrupt climate change. An abrupt climate change scenario presents credible and valid national security threats and as such requires applicable policy to adapt to and/or mitigate global warming. Failure to do so will leave the US and its allies vulnerable to what in the worse cases may be an apocalyptic scenario. The time to act is now for waiting may result in an environmental indictment for all mankind.

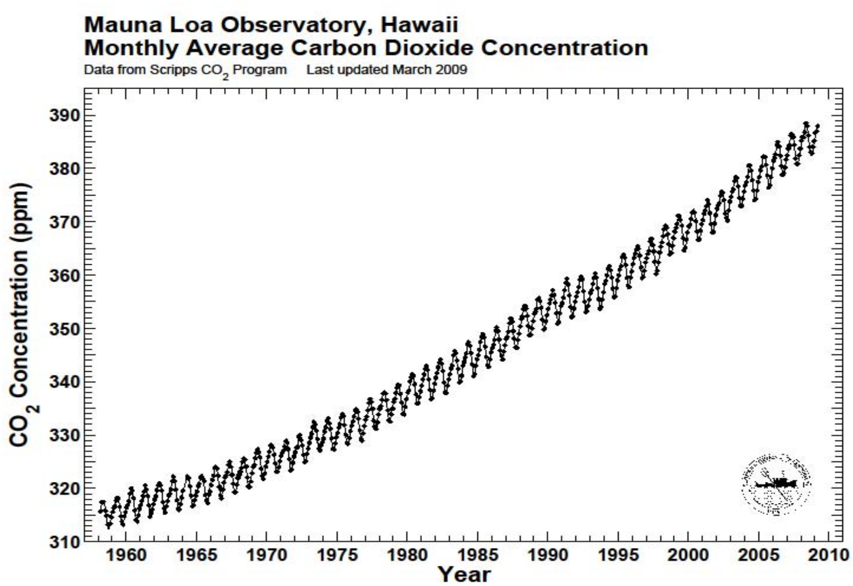
Luckily, the international community is unifying again to readdress the continuing and disturbing global climate trend. In the same spirit of international endeavor which resulted in the creation of the Kyoto Protocol, the United Nations will be convening the COP (Conference of the Parties) 15 for the UN Global Climate Convention in December 2009. Below as an excerpt by Connie Hedegaard, Minister for Climate and Energy, for the upcoming convention which best captures the essence of this research topic.

> The ice is melting faster than we thought it would. The extreme weather is upon us. Climate changes are now exceeding our worst fears. Therefore the world is now facing a giant task. Not only on a governmental level, but on all levels of society. Government officials, politicians, NGO's, scientists, business people, consumers – we all have a very important role to play. We need to find the answer to the global challenge. And we hope to do so by making an ambitious agreement that brings together all nations. The poorest and the most vulnerable countries are threatened the most, but we all have to take responsibility. To reach a global agreement is not only our task, it is our duty. The eyes of the world are watching and everybody expects us to act – and it would mean the world to our children and grandchildren. We cannot simply leave the bill for future generations to pay.[207]

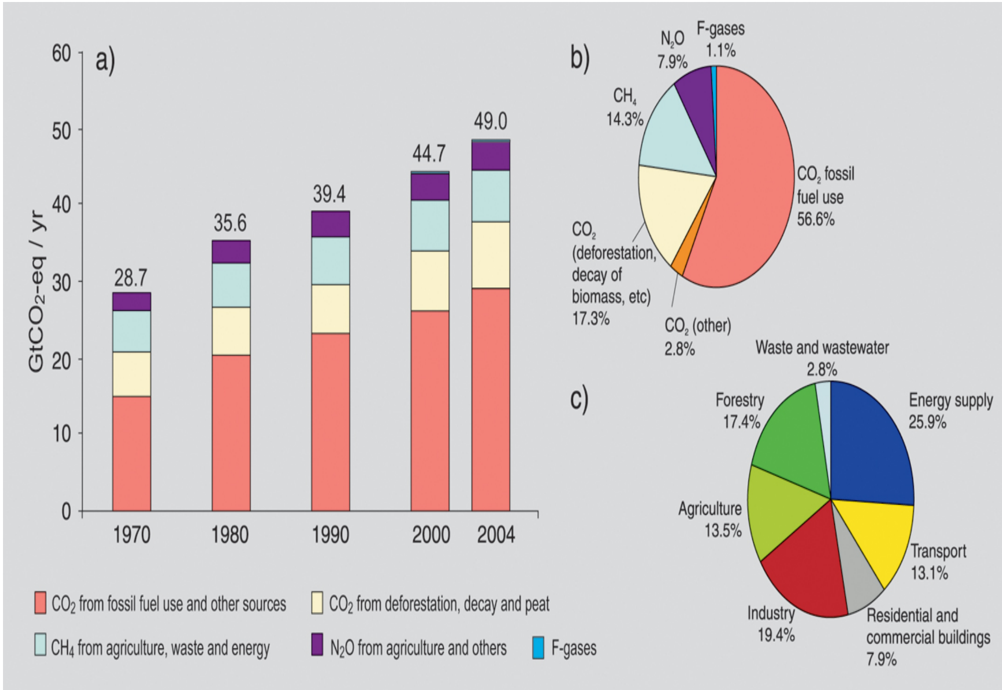
Appendix A - Satellite imagery of the Sermersuaq (or Humboldt) Glacier in Greenland comparing land ice concentrations in 2001 and 2008



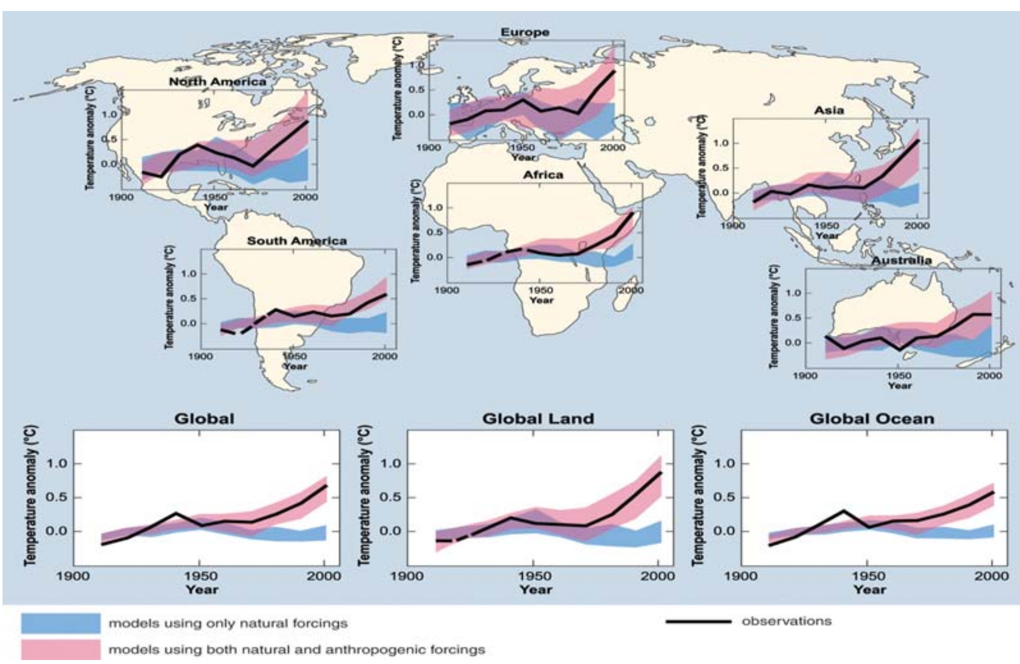
Appendix B - Most recent Mauna Loa Record



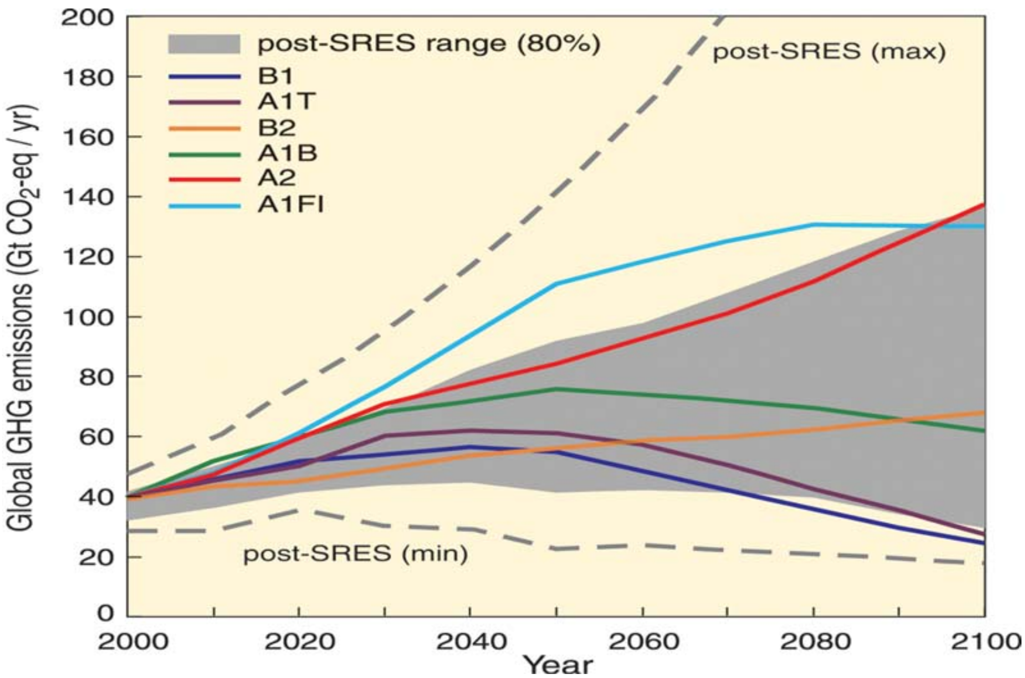
Appendix C - Annual anthropogenic GHG emissions, percentage of each respective GHG in total emissions for 2004, and percentage of GHG emissions attributable by sector for 2004



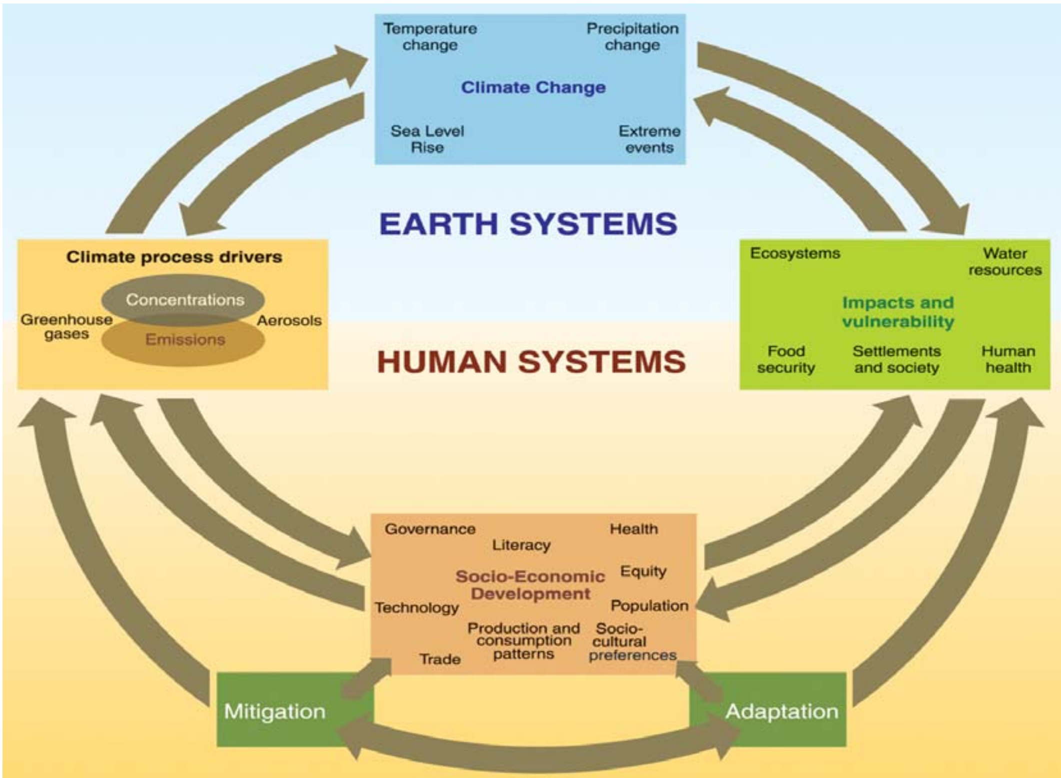
Appendix D - Observed temperature changes on each continent and the globe as a whole



Appendix E - Potential GHG emissions given SRES modeling scenarios for period 2000-2100



Appendix F – Schematic framework of anthropogenic climate change



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