“Climategate”:

An Evaluation of Recent

Controversy in Climate Science

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History of Global Warming Research and Climategate Controversy

In November 2009, authorities at East Anglia University confirmed reports that the school's server had been hacked, leading to the release and internet-circulation of over 1000 emails and 3000 documents of from the Climatic Research Unit database (Washington Post). The targets of the cyber attack were scientists from the United Nations' Intergovernmental Panel on Climate Change, a group of thousands of scientists from across the globe that have been collecting data on climate change since the late 1980s. The leaked emails, which contain statements suggesting some data were distorted or omitted, have caused a resurgence of skepticism in the science of climate change and how human activity relates to it.

"Climategate," as the controversy has been named, identifies the recent investigation of the East Anglia emails by the British Parliament. Climatologist and East Anglia Professor Phil Jones was at the center of the investigation, as many of his emails used vocabulary that sounded incriminating. In a 1999 email, for example, Jones wrote "I've just completed 'Mike's Nature trick' of adding in the real temps to each series for the last 20 years... to hide the decline" (CNN). The British House of Commons led an investigation of the emails clearing Jones in March 2010 of charges stating that he had manipulated data. However, Jones has since resigned as head of the Climatic Research Unit, or CRU, and despite the positive verdict in Parliament's investigation, he has been highly criticized due to his failure to release the organization's raw data. As a result, lawmakers are demanding that this data be shared with the public so that experiments may be replicated (CNN).

Although Phil Jones has been let off of the hook, the debate over global warming has taken a favorable turn for those skeptical of the message expressed by mainstream climate science. Before the release and investigation of the East Anglia documents, those skeptics were scattered and not unified; however, the 2009 CRU controversy is just a recent event in a struggle that has lasted over thirty years. Thus, a debate that has been waged for decades has finally earned a name which the underdogs—those who disagree with the conclusions of the Intergovernmental Panel on Climate Change—can stand behind. The term “Climategate” evokes a since of distrust in government power, being derived from the infamous Watergate scandal that sank the Nixon Administration in the 1970s. Now, thirty-five years later, it could be those on the left side of the political spectrum, or those who push the climate issue, who are in the wrong. At least, this is what climate change-skeptic Patrick J. Michaels might argue.

Michaels, former State Climatologist for the Commonwealth of Virginia, worries that the debate over climate change has taken a political shape rather than a scientific one. “In the world of global warming,” he writes in his book *Climate of Extremes: Global Warming Science They Don’t Want You to Know*, “fact-checking has become fantasy, and perceptions have become the opposite of reality" (9). Instead, he argues, we have adopted a worldview of extremes as a “result of ‘science as usual,’ hyped up on the steroids of massive public funding” (8). Michaels, a self-described “market-liberal,” now works in association with the CATO Institute, a libertarian think-tank in Washington, D.C. His book, co-written by Robert C. Balling, Jr., was published just months before the release of the East Anglia files and attempts to debunk myths about global climate change. The arguments the two authors set out to silence come primarily from the IPCC and Al Gore, winners of the 2007 Nobel Peace Prize for their dedication in spreading the message of the threat of global warming (The Nobel Foundation).

In order to best understand the concept of Climategate, one must understand the origins of climate change science. As global warming research has only occurred for about a halfcentury, the following series of paragraphs should help educate the reader well enough to be familiar with terms and concepts to be discussed throughout the paper.

In the late 1950s, Roger Revelle and C. D. Keeling began monitoring carbon dioxide levels in the atmosphere from a measuring station atop Mauna Loa, a volcano in Hawaii; this marked the first time that this relatively common gas had been regularly monitored in the atmosphere (Gore 4, 5). The purpose for their measurements was to gain an understanding of how CO_2 may affect the greenhouse effect. As energy from the sun enters the Earth's atmosphere, the light that has avoided deflection by clouds and other airborne substances reaches the surface. Much of that energy is absorbed by both biotic and abiotic objects of the environment, and the rest is reflected skyward; while much of this energy radiates back into space, clouds trap a substantial portion via the greenhouse effect, which keeps the planet at a temperature tolerable for the vast majority of organisms. Because carbon dioxide is a greenhouse gas, it helps trap the heat required for human life. Therefore, it follows that if a "standard" level of CO_2 traps and maintains a certain temperature, increasing that level will increase the temperature. Thus, Revelle concluded, monitoring CO_2 would aid in monitoring temperature. Between 1960 and 1990, the concentration of CO_2 in the atmosphere surrounding Mauna Loa steadily increased from around 315 parts per million to about 355 ppm (Gore 5).

As the statistical results of carbon dioxide monitoring began to permeate the scientific community, concerns of a possible shifting global climate began to increase. The cause for the increase of CO2, scientists began to agree, must be anthropogenic to at least some degree; the burning of fossil fuels releases carbon into the atmosphere, and deforestation decreases the amount of flora that absorb the greenhouse gas as the fuel for photosynthesis.

The global warming issue is difficult as it affects both science *and* politics. In investigating the history of Climategate, three published works stand out in importance. The first, chronologically, is Al Gore's book *Earth in the Balance: Ecology and the Human Spirit*. This book, first published in 1992, was among the first devices that brought the concept of global warming into the understanding of the general public, and helped pave the way for future thought and policy on the subject. The second is Patrick J. Michaels' and Robert C. Balling's *Climate of Extremes: Global Warming Science They Don't Want You to Know*. This 2009 book can be considered an argumentative response to Gore's book, challenging the validity of scientific findings concerning climate change and suggesting a political response very much in contrast with those called for by the former Senator and Vice President.

Gore's book and Michaels' and Balling's rebuttal represent the political nature of Climategate, applying scientific research into suggested policymaking. If these publications depict the political aspect of climate change, then the IPCC's series of publications depict the scientific aspects. The Intergovernmental Panel on Climate Change was founded in 1988 "to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences" (IPCC). This organization, an offshoot of the United Nations Environment Programme and the World Meteorological Organization, gives a definition of itself on its webpage:

> The IPCC is a scientific body. It reviews and assesses the most recent scientific, technical and socio-economic information produced worldwide relevant to the understanding of climate change. It does not conduct any research nor does it monitor climate related data or parameters. Thousands of scientists from all over the world contribute to the work of the IPCC on a voluntary basis. Review is an essential part of the IPCC process, to ensure an objective and complete assessment of current information. Differing viewpoints existing within the scientific community are reflected in the IPCC reports (IPCC).

The IPCC stresses its impartiality in the publications it supplies. However, the individual scientists whose research findings are represented in IPCC reports, Patrick J. Michaels might say, are not always without bias.

Michaels' role in the Climategate controversy is in the spectrum of politics. The major argument made in *Climate of Extremes* is that the science is close-minded and has a particular goal in mind. He quotes IPCC scientist Phil Jones to support this argument: "'We have 25 years or so invested in the work. Why should I make the data available to you, when your aim is to try and find something wrong with it?'" (Michaels and Balling vii). This statement, made in a 2005 letter to Australian climatologist Warrick Hughes, helps validate Michaels' point. In the opening words of the first chapter of *Climate of Extremes*, he writes

> Earth's mean surface temperature is doubtlessly warmer than it was 100 years ago. Get over it. What matters is (1) how much it has warmed, (2) how much of that warming is caused by human activity, and (3) how the relationship between that activity and present temperatures can be translated into a reliable estimate of future warming and its effects (11).

According to Michaels, the generally perceived "answers" to these questions have been guided by political agendas and the desire to get work published at the expense of sound science. In a "climate of extremes," he argues, "the best way to make headlines in the global warming game is to generate scary scenarios about how many people are going to die" (*Climate of Extremes* 180). Michaels and co-author Robert Balling, Jr. draw from examples of various natural phenomena that have only recently been attributed to global warming.

In short, *Climate of Extremes* offers "sensible explanations" for natural disasters. Hurricane Katrina, the most devastating hurricane in recent American history, flooded the streets of New Orleans in 2005. What is often overlooked, the book stresses, is that the city was built several feet below sea-level, waiting behind an antiquated levy system for its inevitable eventual destruction. Forest fires, drought, heat waves, and floods, the authors state, are part of the natural order of existence on Earth, and have been blamed on global warming for the sake of convenience. Described in the book also are doomsday scenarios that scientists speculate could occur, despite the fact that the evidence, according to Michaels, points to a different future. Chief among these concerns is a rise in sea levels due to increased melting of icecaps. Gore's *Earth in the Balance* describes such an event—the break-up of the West Antarctic ice sheet. He asserts that were this sheet to breakup, sea-levels would rise over twenty feet. "Since one third of humankind lives within sixty kilometers of the coastline," Gore writes, "the number of refugees likely to be created [due to flooding] will be unprecedented" (104). NASA scientist James E. Hansen, who has studied ice-sheets throughout the world, predicts a sea-level rise of 20 feet due to melting in Greenland by the year 2100. The problem with the above scenarios, Michaels argues, is that there is no solid prediction that these ice-sheets will melt at such a rate; in fact, the IPCC predicts Greenland to add as little as two inches to the world's sea-levels by 2100 (*Climate of Extremes* 100). This exemplifies Michaels' and Balling's point of emphasis that there is a publication bias that makes all the news we hear about global warming bad.

In 1992, then-Senator Al Gore, perhaps globally the most recognized name concerning the issue global warming, published *Earth in the Balance: Ecology and the Human Spirit*. This book was among the first devices to bring the concept of a global climate threat to the attention of the public on a widespread scale. Prior to its publishing, the global warming debate had existed primarily in the scientific community, and was a generally unknown concept to the majority of Americans. For over a decade, *Earth in the Balance* served as the major medium for bringing the global climate issue to the public eye. However, it was the 2006 release of the documentary *An Inconvenient Truth* that brought the issue to the forefront of political discussion.

The film, which follows Gore presenting a slideshow of IPCC data and predictions and climate conventions around the world, received heavy publicity, reaching millions of viewers and helping bring the issue toward the top of public concern. With Gore and the IPCC such success in influencing public opinion over global warming, naysayers of climate change would have to make a strong and convincing opposition; this opposition took the form of the East Anglia emails.

Investigation of East Anglia Documents

To start the investigation of Climategate it is important to understand the CRU. Founded in 1971, the Climatic Research Unit at the University of East Anglia analyzes climate change in many different ways. The CRU focuses on four areas of climate research:

> (1)To establish firmer knowledge of the history of climate in the recent and distant past. (2) To monitor and report on current climatic developments on a global scale. (3) To identify the processes (natural and man-made) at work in climatic fluctuations and the characteristic timescales of their evolution. (4) To investigate the possibilities of making advisory statements about future trends of weather and climate from a season to many years ahead, based on acceptable scientific methods and in a form likely to be useful for long-term planning purposes. (Sir Muir Russell to head the Independent Review into the allegations against the Climatic Research Unit)

With these goals in mind the CRU has been conducting research for thirty-nine years. Respected since its founding, the CRU has published many climate reports and produced endless data for studying climate science. The United States along with many European countries fund the CRU's efforts. In an effort to expand the scientific study of climate and in following the Freedom of Information Act, the CRU is expected to share any knowledge and data they have collected. Some of the controversy surrounding the CRU sprouts from their not sharing the data. Despite the negative attention, one of the CRU's most significant accomplishments is the global near-surface temperature record that was first compiled in the early 1980's. The record documented global temperature changes since the 1850's. Through tree ring and ice core sampling (along with a few other techniques), the CRU has collected data for the past 10,000 years. The CRU has proven itself credible in the past and it seems that the Climategate allegations surround only a few scientists.

There are three independent reviews tasked with getting to the bottom of Climategate scandal. One review was conducted by the House of Commons Science and Technology Committee, which published its report on 31 March 2010. This report showed no evidence of Jones or his colleagues manipulating data. According to this report, the e-mails sent back and forth between the scientists were nothing more than scientific lingo that the scientists used on a daily basis. Some internet sources claim that the House of Commons Science and Technology Committee is not a legitimate independent review committee for a number of reasons, most revolve around opinion.

Along with the House of Commons Science and Technology Committee's review, the University of East Anglia (UEA) has conducted two independent reviews of the controversy. The UEA appointed Sir Muir Russell to head the central investigation. As a former civil servant, former Principal and Vice-Chancellor of the University of Glasgow and Chairman of the Judicial Appointments Board for Scotland, Russell had experience in previous investigations of this type. The investigation of the e-mails and documents has been classified as an independent review to assure no outside influence. Russell's not having any ties with neither the institution nor climatic study helped to assure that no bias would be involved and the evidence would be clearly reviewed. Russell gladly took the position and commented on appointment:

> I agreed very willingly to Professor Acton's request to undertake this Independent Review. Given the nature of the allegations it is right that someone who has no links to either the University or the Climate Science community looks at the evidence and makes recommendations based on

> what they find. My first task is to scope the project, gather the information I need and source the additional expertise that will be required in order to investigate fully the allegations that have been made. Once this has happened I will be in a position to confirm timescales for publishing the review. (Sir Muir Russell to head the Independent Review into the allegations against the Climatic Research Unit)

Russell has yet to publish his review, and judging from his resume it seems that he will carry out an honest investigation. The independent review will investigate key allegations that arose from the uncovered e-mails. According to the CRU the review will cover:

> (1)Examine the hacked e-mail exchanges, other relevant e-mail exchanges and any other information held at CRU to determine whether there is any evidence of the manipulation or suppression of data which is at odds with acceptable scientific practice and may therefore call into question any of the research outcomes.
> (2) Review CRU's policies and practices for acquiring, assembling, subjecting to peer review and disseminating data and research findings, and their compliance or otherwise with best scientific practice.
> (3) Review CRU's compliance or otherwise with the University's policies and practices regarding requests under the Freedom of Information Act ('the FOIA') and the Environmental Information Regulations ('the EIR') for the release of data.
> (4) Review and make recommendations as to the appropriate management, governance and security structures for CRU and the security, integrity and release of the data it holds. (Sir Muir Russell to head the Independent Review into the allegations against the Climatic Research Unit)

Two different issues are being investigated by Russell. The first issue is whether or not the scientists under investigation were doing honest work. The second issue is whether or not the CRU follows the guidelines of the FOIA or appropriately manages the data it holds. If the CRU was not running smoothly in the first place it leaves room for error. If the scientist involved were manipulating and withholding data then that becomes an employee issue and takes pressure off of the CRU as a research facility. The media has had an opportunity to sift through some of the e-mails and has created a very negative outlook on the situation. Russell has to take the time to give both the scientist and the evidence an equal opportunity to see who is responsible.

The e-mails that were uncovered consisted of more than one thousand e-mails and over three thousand other documents between scientists working for the CRU. On 19 November an archive file containing the data was uploaded to a server in Tomsk, Russia. After the server received the files it was copied to many random places all over the internet. Global Warming skeptics jumped on these files and tried to use them as proof that the globe is not warming as a result of humans. Until the e-mails were reviewed as a whole the skeptics could only pretend to know what they're talking about. Most of these documents and e-mails do not pose any threat to the integrity of the climatic research being conducted at East Anglia, but many have. Some of the more familiar controversial e-mails between the scientists have become the focus of media attention. The manipulation of data is the most common of the accusations being pressed against the CRU, but others documents and data suggest other problems. Besides the manipulation of the data the scientist had personal conversations about their true feelings of warming that was not consistent with their opinions expressed to the public though published work. Also, the e-mails showed a possibility that the scientists were suppressing data or evidence that did not support there hypothesis in order to prove a theory.

Many e-mails appear to show obvious manipulation of data, but certain ones have become more prevalent than others especially in the eyes of the media. One e-mail between Phil Jones and Mike Mann can be found on almost any site or blog that relates to climate change:

> From: Phil Jones
> To: ray bradley ,mann@xxxxx.xxx, mhughes@xxxx.xxx
> Subject: Diagram for WMO Statement
> Date: Tue, 16 Nov 1999 13:31:15 +0000
> Cc: k.briffa@xxx.xx.xx,t.osborn@xxxx.xxx
> Dear Ray, Mike and Malcolm,
> Once Tim's got a diagram here we'll send that either later today or
> first thing tomorrow.
> I've just completed Mike's Nature trick of adding in the real temps to
> each series for the last 20 years (ie from 1981 onwards) and from 1961

> for Keith's to hide the decline. Mike's series got the annual land and
> marine values while the other two got April-Sept for NH land N of 20N.
> The latter two are real for 1999, while the estimate for 1999 for NH
> combined is +0.44C wrt 61-90. The Global estimate for 1999 with data
> through Oct is +0.35C cf. 0.57 for 1998.
> Thanks for the comments, Ray.
> Cheers
> Phil
> (Mikes Nature Trick)

This e-mail in particular shows that particular scientists might have been using a formula that changes the true outcome of the data's trend in order to skew the graft in the desired direction. It is difficult to understand exactly what the scientist were talking about in their conversations because they use their own slang, yet the words "to hide the decline" sends up a red flare to some. The decline being referred to was an apparent decline in temperatures shown in analysis of tree rings, which have historically correlated well with changes in temperature. Mann defended himself on these accusations in an interview with the Guardian, saying "this is a trick only in the sense of being a good way to deal with a vexing problem" (Climategate: the final nail in the coffin of 'Anthropogenic Global Warming?') Tree ring data being compared and used to analyze temperature is a statistical way of cross referencing data to make sure it is true. Even if the formula was more suspicious it is the right of these scientists to conduct their research in any way they like; including the freedom to speak to one another privately. Some people believe that scientist have a right to their personal ways of expressing themselves regardless of how it sounds to someone not involved in their research, but others feel that scientist must be more transparent to ensure no interior motives are at hand.

Manipulation of data is only one of the accusations being pressed upon the scientist. Beyond just manipulating the data to prove a designated point, the scientist also may have had private doubts about global warming between themselves. Scientists working for the CRU show their doubts in another e-mail:

> From: Kevin Trenberth <trenbert@xxx>
> To: Michael Mann <mann@xxx>
> Subject: Re: BBC U-turn on climate
> Date: Mon, 12 Oct 2009 08:57:37 -0600
> Cc: Stephen H Schneider <shs@xxx>, Myles Allen <allen@xxx>, peter stott <peter.stott@xxx>, "Philip D. Jones" <p.jones@xxx>, Benjamin Santer <santer1@xxx>, Tom Wigley <wigley@xxx>, Thomas R Karl <Thomas.R.Karl@xxx>, Gavin Schmidt <gschmidt@xxx>, James Hansen <jhansen@xxx>, Michael Oppenheimer <omichael@xxx>
> Hi all
> Well I have my own article on where the heck is global warming? We are asking that here in Boulder where we have broken records the past two days for the coldest days on record. We had 4 inches of snow. The high the last 2 days was below 30F and the normal is 69F, and it smashed the previous records for these days by 10F. The low was about 18F and also a record low, well below the previous record low. This is January weather (see the Rockies baseball playoff game was canceled on saturday and then played last night in below freezing weather).
> Trenberth, K. E., 2009: An imperative for climate change planning: tracking Earth's global energy. Current Opinion in Environmental Sustainability, 1, 19-27, doi:10.1016/j.cosust.2009.06.001. [1][PDF] (A PDF of the published version can be obtained from the author.)
> The fact is that we can't account for the lack of warming at the moment and it is a travesty that we can't. The CERES data published in the August BAMS 09 supplement on 2008 shows there should be even more warming: but the data are surely wrong. Our observing system is inadequate. (Lack of Warming: The CMU Climategate Scandal)

At the end of this particular e-mail the scientist mentions that the observing system is inadequate. The suspicion here is why the scientists would be publishing information on climate change if they knew there research would be flawed. While reading these e-mails and documents it is important to realize that it is not possible to see the entire conversation so many crucial comments may be left out. Any part of this e-mail and many others could be completely harmless, but looking over just one of them and isolating it makes it impossible to understand the real story.

The scientists under investigation come from extensive backgrounds in scientific research and development. The four scientists under investigation are Phil Jones, Michael E. Mann, Tim Osborn and Mike Hulme. Phil Jones was in partnership with Jean Palutikof until 2004 when Palutikof retired. Jones resigned from his position as climate gate started to unfold with a brief message:

> What is most important is that CRU continues its world leading research with as little interruption and diversion as possible. After a good deal of consideration I have decided that the best way to achieve this is by stepping aside from the Director's role during the course of the independent review and am grateful to the University for agreeing to this. The Review process will have my full support. (CRU update 3)

Jones understands the importance of climate research and looks at climate gate as a waste of time. To Jones the research that was being conducted does not need to be delayed any further and that is exactly what climate gate is doing. Outside of the manipulation of data Jones is being accused of withholding data. Once Palutikof retired Jones changed some of the ways the CRU conducted research and the public was disappointed before climate gate even began. Jones was asked to make the data they had at the CRU public, but to avoid scrutiny he opted to withhold the data for as long as could going against the FOIA's regulations. Regardless of Jones's involvement in the manipulation of data he still will be held accountable for withholding it. The other scientists involved were working under Jones, although they work as a unit with their own specialties it is still his job to prevent bad science.

Climate Modeling and the IPCC

The establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988 brought about a modern plan on confronting climate change and its impact. The World Meteorological Organization and the United Nations Environment Programme wanted the IPCC to make a full and complete assessment of the impact—scientific, technical, and socioeconomic—of anthropogenic global climate change. Their charge was rather large and ambitious:

> (a) Identification of uncertainties and gaps in our present knowledge with regard to climate changes and its potential impacts, and preparation of a plan of action over the short-term in filling these gaps; (b) Identification of information needed to evaluate policy implications of climate change and response strategies; (c) Review of current and planned national/international policies related to the greenhouse gas issue; (d) Scientific and environmental assessments of all aspects of the greenhouse gas issue and the transfer of these assessments and other relevant information to governments and intergovernmental organisations to be taken into account in their policies on social and economic development and environmental programs. (Le Treut et al, 2007, p.118)

To tackle this undertaking, the IPCC uses three Working Groups and a Task Force. The reports from this organization give direction to global policies governing climate change. They also provide an empirical and quantitative basis for such policies. There are currently four reports (FAR, SAR, TAR, AR4, respectively), each report suggesting a definite human influence on global climate change. The IPCC points out, though, that their definition of "climate change" differs from the United Nations Framework convention on Climate Change in that it refers to any change in climate over time, whether due to natural variability or as a result of human activity (Summary For Policy Makers, 2007, p. 2). The reports have become increasingly more in-depth and comprehensive with the third report even containing the impact of aviation on the global atmosphere. The latest IPCC assessment report, number four, has continued this trend and increased the confidence in climate science by using better models and more accurate data.

Two important issues addressed by the IPCC report are that of complexity and uncertainty. According to the report, "the complexity of the climate system and the multiple interactions that determine its behaviour impose limitations on our ability to understand fully the future course of Earth's global climate" (Solomon, et al., 2007, p. 21). In this light, AR4 uses data available in mid-2006. As noted, the increasing ability to gather data more accurately and in greater detail allows for more conclusive evidence and outcomes. The working groups split uncertainties into two categories: value uncertainties and structural uncertainties. Value uncertainties come from inaccurate data or data that does not fully explain something. These can be explained through statistics. Structural uncertainties come from a misunderstanding of a process and are usually explained through a scientific consensus of how accurate a model may be. In most cases, the report uses the 90% confidence interval when sufficient data allows.

[1]

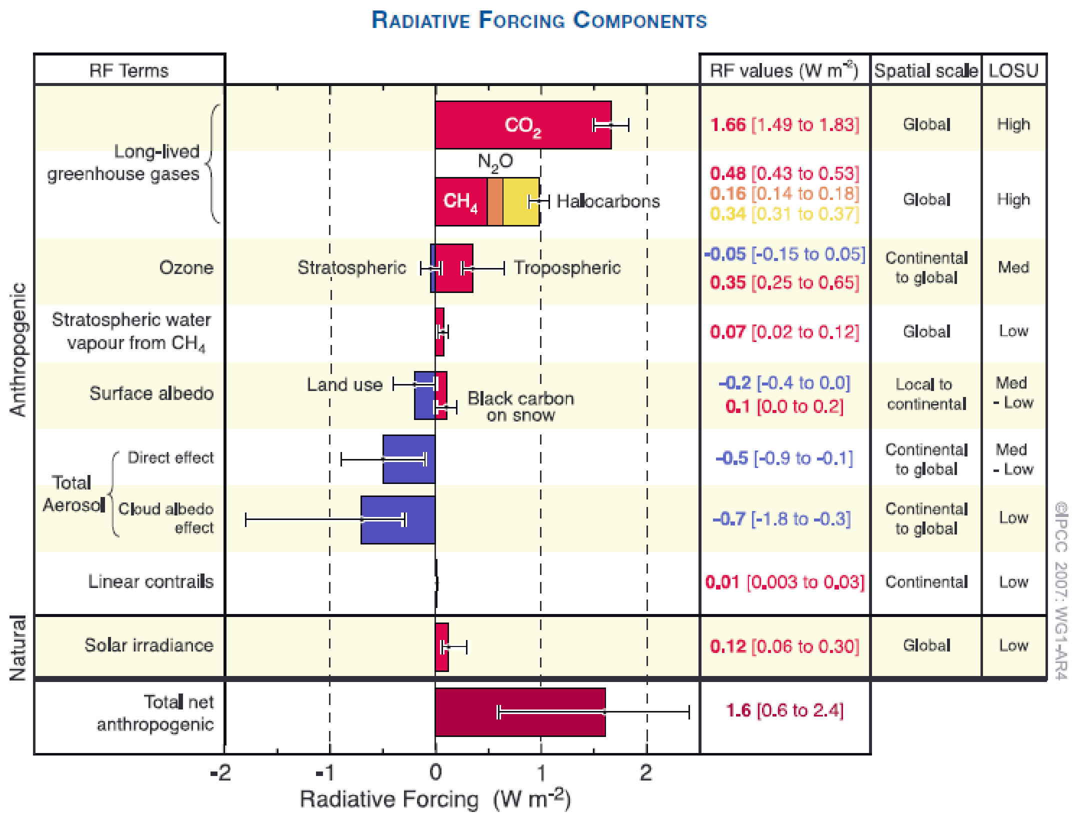
Likelihood Terminology	**Likelihood of the occurrence/ outcome**
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

As previously noted, AR4 builds upon past assessments to understand and explain both the human and natural drivers of climate change. These changes are understood through what is known as radiative forcing. This forcing measures the difference in the balance of energy transferred to Earth and its atmosphere and that leaving that arena. Specifically, radiative forcing

[1] The terms ‘extremely likely’, ‘extremely unlikely’ and ‘more likely than not’ as defi ned above have been added to thosegiven in the IPCC Uncertainty Guidance Note in order to provide a more specifi c assessment of aspects including attribution and radiative forcing. Unless noted otherwise, values given in this report are assessed best estimates and their uncertainty ranges are 90% confidence intervals (i.e., there is an estimated 5% likelihood of the value being below the lower end of the range or above the upper end of the range). Note that in some cases the nature of the constraints on a value, or other information available, may indicate an asymmetric distribution of the uncertainty range around a best estimate. In such cases, the uncertainty range is given in square brackets following the best estimate. (Solomon, et al., 2007, p. 22-3)

looks at the impact as a potential factor for climate change. A positive factor tends to warm the Earth while a negative factor cools it down. These changes come in the form of greenhouse gases and aerosols, solar radiation and land surface properties. It is observed as the change in the troposphere and expressed in watts per square meter ($W\ m^2$). In AR4, the radiative forcing is based on a base level from the year 1750 (as had been collected by 2005). This is the first report to express both the component radiative forcing and combined radiative forcing to give a broader picture of the impact of humans on global climate change. It is important to understand, though, that RF does not attempt to explain all of climate change. Instead, it is meant to look at the component parts in an effort to compare and rank them. AR4 gives a total anthropogenic RF of +1.6 [–1.0, +0.8][2] and says that it is *extremely likely* that humans have made a warming impact on the Earth. It also notes that the natural RF is *exceptionally unlikely* to have made an effect comparable to that of humans (Forster et al., 2007, p. 131).

[2] 90% confidence ranges are given in square brackets. Where the 90% confidence range is asymmetric about a best estimate, it is given in the form A [–X, +Y] where the lower limit of the range is (A – X) and the upper limit is (A + Y). (Forster et al, 2007, p. 131)



[3]

The most important of the RF factors include increased global concentrations of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halocarbons and sulphur hexafluoride (SF_6). These gases, combined, are known as long-lived greenhouse gasses (LLGHGs) because of their lasting influence on the atmosphere (Forster et al., 2007, p. 131). The carbon dioxide increase is mainly attributed to fossil fuel use and land use change while methane and nitrous oxide come mostly from agriculture. In 2005, the global atmospheric concentration of carbon dioxide was 379 ppm[3]; about 100 ppm higher than pre-industrial values. It is *likely* that fossil fuel emissions

[3] Global average radiative forcing (RF) estimates and ranges in 2005 for anthropogenic carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O) and other important agents and mechanisms, together with the typical geographical extent (spatial scale) of the forcing and the assessed level of scientific understanding (LOSU). The net anthropogenic radiative forcing and its range are also shown. These require summing asymmetric uncertainty estimates from the component terms, and cannot be obtained by simple addition. Additional forcing factors not included here are considered to have a very low LOSU. Volcanic aerosols contribute an additional natural forcing but are not included in this figure due to their episodic nature. The range for linear contrails does not include other possible effects of aviation on cloudiness.(IPCC, Summary For Policymakers, 2007, p. 4)

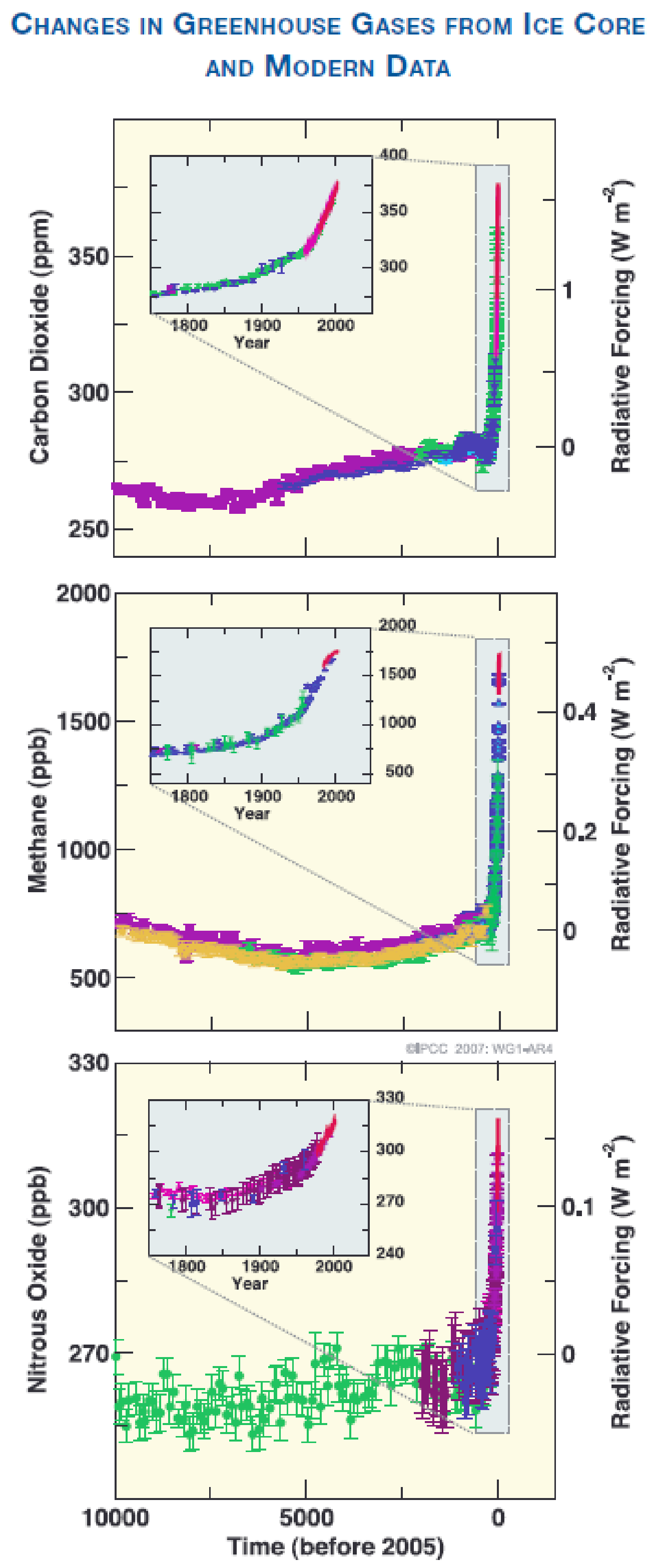
and cement productions account for about three-quarters of that increase. This value is well beyond the natural range for the last 650,000 years (180 to 300 ppm) and the past decade has been the largest growth since atmospheric measurements started in 1960 (Summary For Policymakers, 2007, p. 2).

Methane, CH_4, has also shown a dramatic increase in atmospheric concentration. After carbon dioxide, it is the most important LLGHG affecting climate change. The pre-industrial value was about 715 ppb and in 2005 it was measured at 1774 ppb. This value is far outside the natural range of about 320 to 790 ppb. Although the growth rates have declined since the early 1990s because of constant emissions, the IPCC considers it *very likely* that the increase in methane concentration is anthropogenic (Summary For Policymakers, 2007, p.3). As with other gasses, methane measurements can be taken from pre-industrial ice samples. Today, there are 40 measuring site which take 36 measurements a day, each. This automated system has given a much more accurate look at the increasing methane concentration. In 2005, the recorded average was 1,774.03 ± 1.68 ppb (Forster et al., 2007, p. 140). As previously noted, there has been a great decline in the increase of atmospheric methane. At some times, it is down to almost zero. The reason behind this decline, though, is still not well understood. The largest sink for methane is a reaction with the hydroxl free radical (OH) while the sources for methane are wetlands, agriculture, biomass burning, and the like (Forster et al., 2007, p. 142).

	Concentrations[b] and their changes[c]		Radiative Forcing[d]	
Species[a]	2005	Change since 1998	2005 (W m^{-2})	Change since 1998 (%)
CO_2	379 ± 0.65 ppm	+13 ppm	1.66	+13
CH_4	1,774 ± 1.8 ppb	+11 ppb	0.48	-
N_2O	319 ± 0.12 ppb	+5 ppb	0.16	+11
CFCs Total[k]			0.268	–1
HCFCs Total			0.039	+33
Montreal Gases			0.320	–1
Other Kyoto Gases ($HFCs + PFCs + SF_6$)			0.017	+69
Halocarbons			0.337	+1
Total LLGHGs			2.63	+9

[4]

[4] a: See Table 2.14 for common names of gases and the radiative efficiencies used to calculate RF.
b :Mixing ratio errors are 90% confidence ranges of combined 2005 data, including intra-annual standard deviation, measurement and global averaging uncertainty. Standard deviations were multiplied by 1.645 to obtain estimates of the 90% confi dence range; this assumes normal distributions. Data for CO2 are combined measurements from the NOAA Earth System Research Laboratory (ESRL) and SIO networks (see Section 2.3.1); CH4 measurements are combined data from the ESRL and Advanced Global Atmospheric Gases Experiment (AGAGE) networks (see Section 2.3.2); halocarbon measurements are the average of ESRL and AGAGE networks. University of East Anglia (UEA) and Pennsylvania State University (PSU) measurements were also used (see Section 2.3.3).
c: Pre-industrial values are zero except for CO2 (278 ppm), CH4 (715 ppb; 700 ppb was used in the TAR), N2O (270 ppb) and CF4 (40 ppt).
d: 90% confidence ranges for RF are not shown but are approximately 10%. This confi dence range is almost entirely due to radiative transfer assumptions, therefore trends remain valid when quoted to higher accuracies. Higher precision data are used for totals and affect rounding of the values. Percent changes are calculated relative to 1998. (Forster et al, 2007, p. 141)



[5]

[5] Atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the last 10,000 years (large panels)

Another important component of global climate change that the IPCC addresses is that from aerosols. These are primarily sulphate, organic carbon, black carbon, nitrate and dust. They actually produce a cooling effect on Earth and its atmosphere. They have a RF of -0.5 [-0.9 to -0.1] W m^2 and an indirect cloud albedo forcing of -0.7 [-1.8 to -0.3] W m^2. Because of satellite measurements and better modeling, scientists have been better able to understand the forces and consequences of these aerosols. But, they continue to be the most uncertain of the factors in radiative forcing (Summary For Policymakers, 2007, p. 4). They can be broken down into essentially two categories: direct and indirect. The direct effect is from the absorption and scattering of shortwave and longwave radiation. The specific albedo of these aerosols depends on wavelength and the relative humidity of the atmosphere and their distribution in space (Forster et al., 2007, p. 153). The scattering of aerosols provides a negative direct RF, but the absorbing aerosols can provide a negative effect over dark surfaces and a positive effect of light surfaces. Aerosols have an indirect effect through clouds. They can affect the size, amount, composition and therefore the radiative and reflective properties of clouds. Essentially, the effect that an aerosol particle has on cloud formation depends on its effectiveness as a cloud condensation nucleus (Forster et al., 2007, p. 153). The TAR was unable to assess with much certainty the full effect of cloud albedo. Changes in observational and data collection techniques have allowed for a better understanding of cloud albedo effects.

Looking at the most important impact aerosols make on our atmosphere, clouds, we notice that only a portion of aerosols actually contribute to cloud formation. It is now believed that an increase in the concentration of aerosols brings about an increase in cloud albedo and possibly cloud lifetime (Forster et al., 2007, p. 171). As previously mentioned, the

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and since 1750 (inset panels). Measurements are shown from ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). The corresponding radiative forcings are shown on the right hand axes of the large panels. (IPCC, Summary For Policymakers, 2007, p. 3) size and composition of particles partly determine cloud formation, but the cloud optical properties are determined by wavelength. Because of the increased understanding of the cloud albedo effect, the AR4 gives a median RF estimate of –0.7 W m^{-2} (Forster et al., 2007, p. 180).

The IPCC AR4 makes a strong argument for the anthropogenic effects of global warming. They are showing an increasing impact with greater certainty for assessment report. One of the greatest anthropogenic impacts is a result of land surface changes and the resulting change in RF and the movement and transfer of heat. The difference in albedo between agricultural land and natural land composition can be much different, which makes huge changes in RF across the surface. The albedo of a forest is generally much lower than that of cleared agricultural land. This is because a green forest canopy means higher absorption of incident radiation. To understand the impact, the IPCC looked at the change in surface composition since 1750. There are many uncertainties associated with this research such as: mapping and characterization of vegetation, parameterizations of the surface radiation process, and the snow cover effects. The estimated RF for surface change, relative to 1750, is –0.2 ± 0.2 W m^{-2}. The level of scientific understanding, though, is only medium-low (Forster et al., 2007, p. 184). There are other minor anthropogenic causes such as black carbon in snow and ice, tropospheric water vapor, heat release, and CO_2's effect on plant physiology (Forster et al., 2007, p. 185).

One of the most fascinating components of the anthropogenic mechanisms of global climate change is that of contrails and aircraft-induced cloudiness. Aviation induced cloudiness (AIC) is all of the changes in cloudiness due to aviation. The IPCC evaluated both subsonic and supersonic aviation and their contrails and the effect of their aerosols. The contrails produced by aircraft are basically thin cirrus clouds. They reflect solar radiation and absorb longwave radiation leaving the atmosphere. There are some contrails that persist in the upper troposphere and others that are only temporary. The absorption effect of the persistent contrails is believed to result in a positive net RF for contrails in general (Forster et al., 2007, p. 186). The IPCC notes, though, that this sector is still rife with uncertainty. In 2000, the AIC mean estimate was +0.030 W m^{-2}. Although this is not the best estimate because of the wide range, it is consistent with earlier models (Forster et al., 2007, p. 187). It has also been concluded that the contrails are not as influential as previously modeled due to the ineffectiveness of high clouds on surface temperatures. Another major issue came about when all of the planes were grounded in American skies during September 11, 2001. A study of the diurnal temperature range (DTR) showed that there was a significant increase in the DTR (mostly the maximum temperatures) when there was little-to-no AIC. There is a strong argument to suggest that this study is insufficient because of the small range of data and conclusions based on correlation rather than causation (Forster et al., 2007, p. 187). The presence of aerosols in aviation contrails also presents a mechanism of anthropogenic climate change. It is generally included with aviation contrails in general, though, because of the inability to measure that portion of the RF due to aerosols. The effects mainly come in the form of black carbon (soot) and the ability of aerosols to act as ice cloud nuclei.

The IPCC also recognizes two natural forcings that contribute to global climate change. One has to do with solar irradiance and other with volcanic activity. Solar irradiance has both direct and indirect RF. Since the TAR, the best estimate for direct RF has been reduced to +0.12 W m^{-2}. The scientific understanding of solar radiation with regard to RF is also considered low. The sulphate aerosols from volcanoes are thought to be part of the general aerosol calculations. Volcanoes also produce siliceous ash particulates that make a small but not-insignificant role of radiative perturbations. The effect of volcanoes can be measured by reflected solar radiation, but part of that effect if from natural feedbacks. Although we understand volcanoes and their effects, it is difficult to assign a definite RF value due to of lack of prior knowledge. The interesting aspect of volcanic activity is actually the climate response (Forster et al., 2007, p. 194).

An important question that scientists must keep in mind concerns why we are studying things like radiative forcing. The IPCC has concluded that, to some extent, radiative forcing gives a pretty good look at global climate change. By no means does it encompass every aspect, though; it does not really get in to feedback mechanisms and the role of emissions really requires its own study. Essentially, RF is the smoothest way to quantitatively understand global climate change, especially with respect to LLGHGs. The importance of RF really displays itself when modeling. RF gives a simple value with which scientists can enter into a multi-dimensional equation to understand all of the forces together (Forster et al., 2007, p. 195). The IPCC makes an important note, though, that RF is not the same thing as surface forcing. Surface forcing has its particular part in the climate change equation. It does a better job of explaining surface aerosol absorption, for example (Forster et al., 2007, p. 196). To evaluate the efficacy of a given RF component, scientists look at the ratio of the climate sensitivity of that component to the sensitivity of CO_2, $E_i = \lambda_i / \lambda CO_2$ (Forster et al., 2007, p. 197). The efficacy for LLGHGs is about 1.0 with a medium confidence interval—there are not enough studies to determine individual gasses). Solar irradiance has an efficacy between 0.7 and 1.0. The range—medium confidence— for ozone is 0.6 to 1.1 (Forster et al., 2007, p. 198). The scattering effect of aerosol is essentially too uncertain to make a strong enough guess and there is no real consensus on the efficacy of the absorbing effect of aerosol. One model suggests that land use has an RF efficacy of 1.0 and others see that stratospheric water vapor has an efficacy of about 1.0. The efficacies presented here are results of global climate models rather than actual climate efficacies (Forster et al., 2007, p. 199).

RFs are not considered to be part of the climate system. Rather, they are measurement of present-day concentrations that, ultimately, depend on historical concentrations of certain agents. Most RF is thought to be anthropogenic. Although RF is a necessary indicator of global climate change, it is not sufficient. It cannot completely account for emissions and climate feedback mechanisms. But, when used in conjunction with other models, RF provides a simple, yet thorough, understanding of climate change.

The Analytics of Climate Modeling

History and Development

For hundreds of years man has pursued a greater knowledge of climate, as it is so influential in so many aspects of life. Understanding climate, in its most elementary form, became increasingly important as man realized the advantage that knowledge of climate provided in terms of locating desirable living conditions and food. That desire to better understand climate is still thriving today, but for different reasons. We now use our understanding of climate to produce forecasts used in determining budgets for weather emergencies, start dates for construction projects, and more (Washington 1). In addition, as the realization that man is altering the earth's climate has become more prominent, so, too, has the importance of understanding climate.

Our understanding of climate modeling was very limited until the advent of the computer. Philosophical reasoning dominated a slowly developing discipline for decades. As Newtonian Mechanics arose in the late eighteenth century, the laws of physics were mathematically tied to the atmosphere, which was considered to be one of the greatest advancements in climate science

(Washington 1). Given the complex nature of climate science and lack of the appropriate data and tools, our ability to research and study climate was extremely limited, which made advancements in the discipline rare. With the advent of computers, however, climatologists have made tremendous improvements in the field. This development allowed climatologists to solve for thousands of equations relating to the physical laws that govern the earth's climate (Washington 1). As computer technology has advanced, so, too, has our ability to understand climate.

During World War I, Lewis Frye Richardson, an English scientist, applied basic equations of the movement of the atmosphere in an attempt to produce weather forecasts. The math was so highly complex that it could not be solved for; solutions could only be estimated. His work involved a set of continuous equations that was approximated with finding the solution to a corresponding set of discrete equations (Washington 3). In 1922, Lewis Fyre Richardson improved upon his work with the inclusion of better atmospheric physics. The issue, however, was that the forecasts were less realistic (Washington 3). Richardson's work, *Weather Prediction by Numerical Process*, has become the foundation for constructing any numerical model (Washington 3). The next major advancements were not made again until the 1940's, and were made by institutions and universities, not individuals. This can be attributed to the fact that the future of climate modeling was dependent upon extremely expensive electronic computer systems (Washington 4). Climate modeling then entered the era in which we know today, which entails more complex and specialized research and development in aspects of modeling such as atmospheric modeling, sea ice modeling, land modeling, and ocean modeling (Washington 5). Given this complex nature of climate modeling, the development of climate tools has played an important role in the discipline. Some of those tools are simple while some are so highly sophisticated that they challenge the even the world's most powerful super computers, and will continue to do so into the future (McGuiff 1).

Data Collection

Super computers are undoubtedly important when constructing climate models; however, those super computers would have nothing to process if it were not for the data. Data are critical input factors in climate modeling, and perhaps one of the most controversial aspects of modeling. For example, the collection of data is not always standardized, and if it is that doesn't necessarily mean the standardized method is enforced. One of the most well-known data collection investigators is meteorologist Anthony Watts of the Heartland Institute, a think-tank promoting free-market solutions to public policy issues (Watts 1). Watts discovered that only 11% of the temperature data collected in the United States met the National Oceanic and Atmospheric Administration's national standard technique of measurement, which significantly influences model estimates and potentially policy. He discovered thousands of thermometers located in paved parking lots, next to exhaust fans and sewage plants, below trees, and even next to burn barrels (Watts 29). These findings have led us to question the reliability of our data. Inaccurate data readings tend to occur more frequently when the data relates to political agenda; however, it is occurring in other less politically sensitive aspects of data collection as well, such as sea ice composition (Washington 7). Without question, the reliability of the data is in question. As society progresses, there will likely be great emphasis on standardization and enforcement in an effort to improve the reliability of the data. After all, having the world's most powerful super computer and the best climate models aren't worth much if the data they process is inaccurate.

Modeling Basics

In order to understand the basics of climate modeling, we must first examine the climate system by looking at the three major components that influence climate, which includes the atmosphere, the ocean, and sea ice, and the interaction between the three. The atmosphere consists of approximately 99% nitrogen and oxygen, followed by small amounts of argon, carbon dioxide, neon, helium, methane, and others. The atmosphere also contains 0% to 3% water vapor. Levels vary greatly depending on geographic location, evaporation rates, and temperature (Washington 7). While some gases such as water vapor and methane are only found in trace amounts, those gases tend to have the greatest influence on climate (Washington 8). Other important factors in modeling the atmosphere include pressure and density characteristics, temperature profiles, and incoming solar energy. With all of these characteristics of the atmosphere taken into consideration and the laws of physics applied accordingly, climatologists can produce models of the earth's atmosphere.

Oceans cover the vast majority of the earth's surface, so understanding the dynamics of the ocean are critical in understanding the earth's climate. Oceans not only transfer heat, salt, nutrients, and momentum; they interact with the atmosphere in a way that influences both the oceans, the atmosphere, and the earth's climate (Washington 20). When modeling the ocean, climatologists observe a wide range of characteristics such as seawater composition, ocean temperatures, depth, and circulation patterns. In addition, climatologists have also been exploring how abyssal waters influence climate (Washington 28). With all of these factors brought together, and the laws of physics applied to them, climatologist can model the oceans.

Sea ice covers only 7% of the earth; however, it has drastic effects on climate. This can be attributed to the way sea ice influences the interaction between the ocean and the atmosphere, and the absorption of solar energy (Washington 30). When modeling sea, climatologist look at sea ice and sea ice distribution, sea ice formation and growth, sea ice ablation, sea ice composition and properties, sea ice topography, and sea ice concentration and velocity. Similarly to the ocean and atmosphere, once all of these factors are taken into consideration and the laws of physics are applied accordingly, climatologists can produce models of sea ice.

Historically, sea ice, the atmosphere, and the ocean were analyzed separately when producing climate models. This is no longer the case, as studies have revealed the three are interrelated and interconnected in many ways (Washington 37). For example, oceans and the atmosphere are connected through the transfer of energy, mass, and momentum, and the relationship between oceans and the atmosphere can be greatly altered by the presence of sea ice (Washington 37). Some other basic interconnections include the atmosphere's influence on the upper layers of the ocean and sea ice, the ocean's influence on the presence of water vapor in the atmosphere, and sea ice's influence on the temperature and circulation patterns of both the ocean and the atmosphere (Washington 44). With all of the aforementioned details taken into consideration, and the laws of physics applied accordingly, climatologists can produce complete climate models.

Zero-Dimensional Models

A zero-dimensional model is the simplest approach to climate modeling. It is also useful in showing how models are constructed and relationships defined. The simplest zero-dimensional model is the radiative equilibrium of the earth.

$$(1 - a)S\pi r^2 = 4\pi r^2 \varepsilon\sigma T^4$$

The left hand side of the equation represents incoming energy from the sun while the left hand side represents outgoing energy from the earth. The point in which both incoming and outgoing energy are equal yields the average temperature of the earth. S is the solar constant, *a* is the earth's average albedo, *r* is the earth's radius, ε is the effective emissivity of the earth, σ is the Stefan-Boltzman constant, *T* is the constant radiative temperature.

We can then factor out πr^2:

$$(1 - a)S = 4\varepsilon\sigma T^4$$

Then solve for temperature:

$$T = \sqrt[4]{\frac{(1-a)S}{4\varepsilon o}}$$

This equations contains a great deal of information. Firstly, solving for temperature reveals that the earth is a livable 288 K, which can be attributed to effective emissivity and the albedo effect. While zero-dimensional models do not take into consideration the other complexities of the world, these models do produce useful and instructive information.

Higher-ordered Climate Models

Climate models using higher than zero-dimensional equations are based on the notion of either providing analytical solutions to specified differential equations, or (more likely) providing non-analytical, computational solutions using (forward and backward) difference equations. As models get more complex, computational solutions become increasingly prevalent.

Fundamental equations govern the motions of the atmosphere, oceans, and sea ice. Those fundamental equations are derived from the laws of physics, mainly the laws of conservation. After applying the laws for momentum, mass, and energy, climate modeling transitions into a focus on the particular aspects that influence climate and how those aspects influence each other. Because climate modeling addresses how the various aspects influence each other, an equation of state is required that relates the parameters of the other equations to each other (Washington 49).

The various categories and subcategories that make up a climate model are based on the following deferential equations. These equations relate to the movement of heat and energy, which is the most critical factor in study climate. The following is a simple example of the basic method of solving model equations using differential equations. Consider the following equation that governs the motion of a wave moving with constant speed c in x direction (Washington 150).

$$\frac{\partial u}{\partial t} + c\frac{\partial u}{\partial x} = 0$$

With c held constant, the solution can represented it its harmonic form:

$$u = Ae^{ik(x-ct)}$$

In this case, *A* and k are constants and I = $\sqrt{-1}$. Substitution of the second equation into the first verifies that the second equation is a partial differential equation. The equation describes a wave moving at speed *c*, wave number *k*, wavelength $2\pi/k$, and a wave amplitude of *A*. The equation can now be express in terms of trigonometric functions by the following identity through the Euler Formula (Washington 150):

$$e^{iP} = \cos P + i\sin P$$

This equation does have an analytical solution; however, as mentioned earlier, non-analytical solutions are encountered frequently in modeling, particularly as they models get more complex.

Simulation of the Ocean

To further illustrate how climate models work, a simulation of a category of climate modeling is necessary. Perhaps one of the best examples is the ocean with a look at what specifics must be accounted for in the model. The ocean plays a very important role in the earth's climate as it capable of storing and transferring large amounts of heat. As the atmosphere warms, the upper layers of the ocean are heated, which is transferred through major currents, upwellings, and poleward heat transfers (Washington 207). There are also irregular factors that must be taken into consideration, such as El Nino and the Southern Oscillation, the North Atlantic Oscillation, and other atmosphere-ocean interactions (Washington 207). The most successful oceanic simulations are beginning to account for turbulent mixing of the upper ocean by the wind, vertical mixing by shear and buoyancy forces, horizontal do to vertical mixing due to mesoscale eddies, large scale horizontal heat transport by the oceans currents, deep and intermediate level convection in the polar regions, mixing along isopyncal surfaces, and boundary changes with the atmosphere and sea ice (Washington 207). By this point, the complexity of these simulations is apparent. When the other categories are factored in and related to one another it is overwhelming. It also helps to illustrate why the processing power of our super computers is so critical to the field of climate modeling.

IPCC Fourth Assessment Report

IPCC Report for Work Group I

Work Group I's main duties in the IPCC Fourth Assessment Report were to "describe progress in the understanding of the human and natural drivers of climate change, observed climate change, climate processes and attribution, and estimates of projected future global climate change" (Solomon 2). The report is split up into numerous chapters and sections that help the public and policymakers to get a better grasp of what is going on up to date with global climate change and how new data might affect climate change in the future.

Information about greenhouse gasses and their effects on the atmosphere have changed since the IPCC Third Assessment Report. The atmospheric concentration of carbon dioxide, methane gas, and nitrous oxide has greatly increased in the last century or so by even greater amounts then we had previously estimated. The concentration of the three major greenhouse gasses in the atmosphere has drastically shot up since the pre-industrial era. Carbon dioxide, methane gas, and nitrous oxide increased in the atmosphere from "the pre-industrial amount of 280 ppm to 379 ppm in 2005…from a pre-industrial value of about 715 ppb to 1774 in 2005," and "from the pre-industrial amount of 270 ppb to 319 ppb in 2005," respectively (Solomon et al., 2, 3). The report also said that the main cause of this increase was the burning of fossil fuels and new global trends in land usage.

The report also goes into great detail about direct observations of climate change but admits that "data coverage remains limited in some regions" (Solomon et al., 5). There are a number of observations that have been made that the report says to be direct examples of the changing global climate and that there is no denying this change. Eleven of the past twelve years are some of the warmest we've recorded in history, extreme temperatures and the "linear warming trend over the last 50 years is nearly twice that for the last 100 years" (Solomon et al., 5). As a result of climate change and the oceans warming there has been a huge increase in the amount of water vapor in the atmosphere. Sea level rise is another example that is consistently measured and there definitely seems to be a rise in sea level over the past 50 years. More observations about global climate change have been made when observing Greenland ice sheets, Antarctic ice sheets, glaciers, permafrost, and snow cover because of their rapid decline over the last century. The freshening of waters in northern latitudes and the increased precipitation in certain parts of the world have been observed and have significantly increased. Due to shifts in the precipitation patterns around the globe there are now "more intense and longer droughts that have been observed over wider areas since the 1970s" (Solomon et al., 8). Even though there have been many parts of climate change data that have changed since the TAR (third assessment report), "some aspects of climate change have not been observed to change" (Solomon et al., 9).

One example is the DTR or diurnal temperature range. In the TAR the work group found a decrease in DTR but “updated observations reveal that DTR has not changed from 1979 to 2004 as both day- and night-time temperature have risen at about the same rate” (Solomon et al., 9). More issues arise in areas concerning Antarctic sea ice in which there are little or no statistically significant average long term trends and over the subject of different whether trends because of GCC because there simply is not enough evidence. Naturally important factors like volcanoes can also alter and skew the data and “it is very unlikely that climate changes of at least the seven centuries prior to 1950 were due to variability generated within the climate system alone” (Solomon et al., 12).

The projections of future changes in climate are an important part of the report because they estimate future climate change with the currently available data When it comes to greenhouse gases and aerosols, even if they “had been kept constant at year 2000 levels, a further warming of about 0.1 degree Celsius per decade would be expected” (Solomon et al., 12). Another interesting future projection revolves around current or increased greenhouse gas emissions. There is evidence that if we “continued greenhouse gas emissions at or above current rates it 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” (Solomon et al., 13). Experts and scientists who were involved in Work Group I also found that if current patterns continue there will be a definite increase of warming and other regional weather and climate changes and as a result global warming and sea level rise would continue for a long time even if we did everything we could to stabilize emissions.

IPCC Report for Work Group II

The beginning of the report relates to the current knowledge about observed impacts of climate change on the natural and human environment. Evidence shows that natural systems are affected by climate change and temperature increase. These increases affect natural systems. This can be seen through the growing of glacial lakes, a prominence of ground instability causing avalanches in mountain regions and changes in Arctic and Antarctic ecosystems. The report also states that hydrological systems are also being affected. There has been an increase in runoff and a noticeable warming of lakes. Also terrestrial biological systems have been thrown out of sorts. The spring season has been coming sooner, causing effects in leaf output and bird migration patterns. Marine and freshwater environments have not been spared by this over encompassing change. There has been a rising of water temperature coupled with other changes in water composition. Data since 1970 shows that anthropogenic warming influenced m**a**ny ecological systems. Over the past five year it has become more and more clear that show that the changes to the over many ecosystems are contributes to warming. However, there are still many holes that need to be filled in the data to complete the link. Other changes to the environments are appearing. Climate change is beginning to act as a catalyst on its affect on natural and human systems.

Scientists currently know much about the future impacts on the environments. There is now data more widely available, some of which was previously unavailable, and that shows the relevancy of future impact on the environment. Freshwater resources and the management will be affected. It is projected that there will be an increase in droughts and a decrease in water supplied in glaciers and snow. There is currently being programs and management techniques developed to combat these problems. A projected increase in environmental disturbances will put an added increase of stress on the environment. This will also cause a disturbance in the biodiversity and species interactions, possibly leading to species extinction. Additionally, this will also cause an influx of carbon dioxide, resulting in an acidification of the world's oceans.

In the future the report projects that there will be many affects on food, fiber and forest products. It is projected that crop productivity will increase in higher latitudes because of the temperature spike and do the opposite in lower latitudes. Because of the higher likelihood of floods and droughts will cause crop production to decrease. Another area that will be affected is timber production. An increase in temperature will be positive in the short to medium term but is projected to be very volatile in the long term.

Costal systems and low-lying area will also be affected. Coast are very threatened by climate change and are predicted to fall susceptible to erosion from a rising sea-level. A rising sea could also lay siege to coastal wetlands like salt marshes and mangroves. It is projected that a rising sea could produce many more coastal area floods in densely populated and low lying areas.

Effects will also be seen in industry, settlement and society. Like the previous sectors, an increase in temperature will have a negative effect on industry, settlement and society. It is predicted that the most vulnerable areas will be the area previously discussed like coastal and river flood plains as well as poor communities. Gerneral health, too, will be affected by upcoming climate change. The projected climate change will likely cause an increase of malnutrition, death, disease and other health risks. Information is more readily available across regions of the world regarding future impacts.

Africa: It is projected that there will be between 75 and 250 million people exposed to water shortages by 2020. Due to this water shortage, agricultural production is predicted to sharply decline.

Asia: The predicted melting of the Himalayian glaciers could cause flooding and avalanches, therefore affecting water resources. Climate change would also affect river basins in Asia by decreasing freshwater. Flooding would also be seen near the coast.

Australia and New Zealand: Like Africa, Australia and New Zealand could experience water security issues. By 2020, it is predicted that there will be a great loss in the biodiversity in place where it is currently rich places such the Great Barrier Reef. Australia and New Zealand may also experience sea-level changes much like much of the other areas previously discussed

Europe: It is predicted that the almost all of Europe will be negatively affected by upcoming climate change. Negative effects will be seen over all sectors including natural resources, floods, erosion, ecosystems.

Latin America: Looking into future implications of climate change it is possible that Latin America will too experience problems with water, be it in soil composition or in sea-levels. Like in most other areas the rising of the sea level will cause coastal area flooding. There could also be a lack of water that is available to people in this area effecting agriculture, energy and consumption.

North America: Mountainous areas will be affected in North America. This will be seen in levels of snow pack, winter flooding and summer flows. Increases in agriculture will also be seen towards the beginning of the century.

Polar Regions: The main effect that will be seen in the polar regions is a decrease in the size of glaciers.

The intensity of the affect of a temperature increase can now be estimated more methodically. Since the release of the Third IPCC assessment there has been an influx of additional studies. These additional will begin to clear up the future affects of climate change. Large climate events have a possibility to create very large affect. The effect of climate change will continue to negative effect the globe as temperature increases.

There is a vast understanding of the current knowledge about responding to climate change. There has been little adaptation of the predicted future climate change. Adaptations to these predictions need to be changed to account for previous emissions. There need to be more adaptation to counteract future vulnerability. To counteract this there needs to be a trend toward to Sustainable development. Many of these effects of climate change can also be sidestepped by mitigation.

IPCC Report for Work Group III

The third Working Group also contributed a ton of new data and evidence to the IPCC Fourth Assessment about “new literature on the scientific, technological, environmental, economic, and social aspects of mitigation of climate change” (Metz 3). In the third section of the IPCC Fourth Assessment Report there are six main sections that include: Greenhouse gas emission trends, mitigation in the short and medium term across different economic sectors, mitigation in the long term, policies and instruments to mitigate climate change, sustainable development and climate change mitigation, and gaps in knowledge.

Greenhouse gas emission trends have grown in recent years as a result of human activities mainly involving the burning of fossil fuels. Emission of GHG’s like carbon dioxide “have grown since pre-industrial times, with an increase of 70% between 1970 and 2004” (Metz 3). The energy supply sector has added the most to this figure because of all the fossil fuels that are used and burned to keep it running. Ozone depleting substances have greatly declined due to new protocol and are not nearly as big a threat to the earth's atmosphere and life on the planet as they were twenty years ago. Unfortunately, even though there has been some positive advancements in recent years, the results of current "climate change mitigation policies and the current level of sustainable development practices will continue to grow over the next few decades" (Metz 4). There has also been a serious growth in the baseline emissions scenarios for GHG's and climate change related data.

Mitigation in the short and medium term shows that "both bottom-up and top-down studies indicate that there is substantial economic potential for the mitigation of global GHG emissions over the coming decades" (Metz 9). By 2030 it is projected that if carbon dioxide emissions stay between 445 ppm and 710 ppm there is a chance that the macro-economic costs will be "between a 3% decrease of global decrease and a small increase, compared to the baseline" (Metz 11). This section of the report also talks about how lifestyle and behavioral changes made by humans can have a huge impact on global climate change and can help reduce GHG emissions. This is important because this change in lifestyle could produce near-term health benefits and increase the quality of life for humans and other living organisms around the globe. There are also many new investments, policies, and technologies in both developing and industrialized countries "that promote energy security and create opportunities to achieve GHG emission reductions compared to baseline scenarios" (Metz 12). The transport sector lacks a solid base for climate change mitigation as a result of different barriers like consumer preferences which makes everything more difficult. There are a number of new carbon dioxide reducing options that would greatly reduce the amount of carbon dioxide emissions in the short- and mid-term with substantial economic benefits. A huge short-term and mid-term issue is found in energy intensive industries because “full use of available mitigation options is not being made in either industrialized or developing nations” (Metz 14). The agricultural, forest-related, and waste sectors can help also help the reduction of GHG emissions in affordable and quick ways with new technologies and protocols.

There is a small amount of information on mitigation in the long-term but it is still relatively important. The report says that “in order to stabilize the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter,” meaning it would be absolutely imperative that there was a steady decline in GHG levels and output after the peak (Metz 15). The only way for this peak and decline to occur is if “the appropriate and effective incentives are in place for development, acquisition, deployment and diffusion of technologies, and for addressing related barriersin the future” (Metz 16). The effect that his change will have on global GDP is uncertain but it is possible for costs to vary in different countries and sectors. The last part of this section talks about the importance of GHG mitigation and how to go about acting in ways to change policy.

There are many policies and instruments used to mitigate climate change and there is “a wide variety of national policies and instruments available to governments to create the incentives for mitigation action” (Metz 19). Cap-and-trade regulations and other EPA monitored policies need to be closely monitored in the United States and similar organizations in other countries need to be monitored by their respective governments as well. Putting prices on the release of carbon and other potentially harmful GHGs should have a great effect on lowering the amount of GHG emissions each year. The report says that governments need to start making more environmentally based decisions because of the issues that could hurt our economies and species in the future. Sustainable development and climate change mitigation described how to "make development more sustainable by changing development paths" and can overcome many barriers that hurt mitigation of climate change in the future (Metz 21).

The end of the report begins to talk about gaps in knowledge and data concerning climate change but fails to go into great detail about these gaps. The authors of the report believe that "there are still relevant gaps in currently available knowledge regarding some aspects of mitigation of climate change, especially in developing countries" and that obtaining this information in the near future would greatly strengthen decision-making about mitigation of climate change (Metz 22). It is possible that some of these gaps could be related to "climategate" and that the majority of the data collected was only from a select number of locations and not all over the world.

Conclusion

In addition to the CRU investigations carried out by the British government, an investigation by a group of students from Hampden-Sydney College took place. After assessing the data provided, the methods used to acquire that data, and the prominent scientists researching climate science, the group concluded that the Climategate controversy is nothing more than a minor hurtle in the IPCC's long road to reassessing the way humans relate to the environment. Climategate, it seems, was nothing but an attempt to influence public opinion on climate science by consolidating attention to a small group of suspicious e-mails. However, despite the conclusion that the IPCC's assessment of climate change is indeed correct, the Climategate controversy has made positive changes in the way scientific study is carried out. The CRU and IPCC are now responsible for sharing their data and the methods used to obtain it; with available data and repeatable methods, the validity of scientific research can be ensured and objectivity secured.

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