Global Climate Projections: The 2007 IPCC Assessment

Statement of

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Introduction

I thank the chairman and other Members of the Committee for the opportunity to communicate to you today some of the recent findings from the IPCC Fourth Assessment Report (AR4). My name is Gerald Meehl, Senior Scientist at the National Center for Atmospheric Research (NCAR) in Boulder, Colorado. My research interests include tropical climate involving the monsoons and El Niño Southern Oscillation, climate variability and climate change. I have authored or co-authored more than 145 peer-reviewed scientific journal articles and book chapters. I have been involved with the Intergovernmental Panel on Climate Change (IPCC) assessments since the first one that was published in 1990. I was a Contributing Author on that first assessment and its update in 1992, a Lead Author for the 1995 Assessment, and a Coordinating Lead Author for the 2001 and the present 2007 assessments. I have been involved with committees of the World Climate Research Program (WCRP) on Climate Variability and Predictability (CLIVAR), and am currently co-chair of the WCRP/CLIVAR Working Group on Coupled Models (WGCM). This committee organized and coordinated the international modeling groups in performing climate model experiments for assessment in the AR4, and in the collection and analysis of data from those model experiments. Through the efforts of that committee, this extensive multi-model dataset on climate change has been made openly available for analysis, and over 950 scientists from around the world have been able to access and analyze these data. The resulting papers have contributed extensively to the IPCC AR4. I have served on several National Research Council (NRC) panels, and am currently a member of the NRC Climate Research Committee. I was a lead author on the U.S. Climate Change Science Program (CCSP) Report 1.1 on temperature trends in the atmosphere, and am currently co-coordinator for the CCSP report on weather and climate extremes in a changing climate.

In my capacity as a Coordinating Lead Author for the chapter on climate change projections for the IPCC AR4, I was in Paris last week attending the Plenary of the IPCC where the IPCC Fourth Assessment Report was accepted and approved by the roughly 180 governments that make up the IPCC. Thus, the IPCC is a group of governments, not a group of scientists, which is a common misconception. The IPCC commissions assessments to be performed roughly every 5 or 6 years, and they are prepared through the efforts of hundreds of scientists from around the world who are actively involved in state-of-the-art research in climate science. The IPCC assessments provide a comprehensive view of the current state of human understanding of climate science and climate change. My testimony today will summarize some of the main findings of the IPCC AR4 with regards to projections of future climate change.

A much larger group of climate models have contributed to the IPCC AR4

A major international effort to perform a set of coordinated climate change experiments was organized by the WCRP/CLIVAR WGCM. A total of 16 modeling groups from 11 countries (three groups from the U.S.) used 23 global coupled climate models to perform these coordinated climate change experiments that involved simulations of the 20th century climate, three possible outcomes for the 21st century (based on low, medium and high emission scenarios), and three idealized stabilization experiments. In addition there were idealized carbon dioxide increase experiments, and associated stabilization experiments with doubled and quadrupled CO_2 amounts. These data were then collected, and over 31 Terabytes of model data were archived at the DOE-sponsored Program for Climate Model Diagnosis and Intercomparison (PCMDI) at Lawrence Livermore National Lab (LLNL) in Livermore, CA. WGCM then coordinated the analysis of this multi-model dataset. This unprecedented effort has involved over 950 scientists who accessed these model data and wrote many papers that were assessed in the AR4. This massive effort was the first time the international climate modeling community has performed such an extensive set of climate change experiments, with the output from those experiments openly available for analysis. The amount of detail in climate models has increased in recent years, partly because of our increased understanding of the processes in the climate system, and also in part because of the calculation power provided by newer supercomputers. The higher resolution modeling that led up to the 2007 IPCC Working Group I report not only provides a more true-to-life depiction of atmospheric processes, but also allows for more realistic topography, which makes regional climate projections more accurate. We are now able to provide detailed information on possible future changes of weather and climate extremes.

Research assessed as part of the 2007 IPCC Working Group 1 Fourth Assessment Report relied on the output from major models at research centers around the world. While these models are far from perfect, scientists are confident that they capture the key processes that drive climate. For example, models now replicate the ups and downs of 20th-century global temperature quite accurately, and we can use the models to understand these changes of climate we have already observed.

Climate change commitment and near term warming

Several of the experiments run with the most recent global climate models explored the concept of climate change commitment. That is, if concentrations of greenhouse gases are stabilized at various levels, how much more warming would occur due to the emissions already in the system. Such committed climate change is due to the time lag introduced by the oceans because it takes longer for water to warm. Hypothetically, if concentrations of greenhouse gases could have been stabilized in the year 2000, a committed warming of about 0.1C per decade averaged over the period 2000 to 2020 would occur, with smaller warming continuing after that. Of course there are ongoing increases of greenhouse gases, so the models project that no matter what emissions scenario is followed (not taking into account possible large volcanic eruptions that we are not able to forecast but would produce temporary cooling a year or two after the eruption), the combination of climate change commitment and additional warming from increasing greenhouse gases would result in a warming of about 0.2C per decade over the next two decades. This is about the rate of warming we have observed in the past couple of decades.

The sea level rise commitment is much longer term. This is due to the effects of thermal expansion on sea level. That is, since water has the physical property of expanding as it heats up, as the warming penetrates deeper into the ocean, an ever increasing volume of water expands and contributes to ongoing sea level rise. Since it would take centuries for the entire volume of the ocean to warm in response to the effects of the greenhouse gases we have already put into the air, we are committed right now to further sea level rise that would continue for centuries.

Previous IPCC assessments starting in 1990 used global climate models to project global warming of between about 0.15C and 0.3C per decade for 1990 to 2005. The actual observed values of global warming for that time period are about 0.2C per decade. This increases our confidence in the climate model projections for future climate change, since previous generations of models were able to project warming rates similar to those subsequently observed.

Climate change later in the 21st century

As we approach the middle part of the 21st century and beyond, it makes a difference regarding what emissions scenario we choose to follow now. By 2100 there is a spread of globally averaged surface air temperature increase among the six scenarios considered, with best estimates ranging from nearly 2C for a lowest scenario (B1) and about 4C for the highest scenario (A1FI). These scenarios are constructed based on various assumptions of future population growth, economic activity, and energy usage. Likely ranges for warming at the end of the 21st century are also now provided. For example, for a low scenario (B1), the warming averaged for 2090-99 relative to 1980-99 has a best estimate of 1.8C with a likely range of 1.1C to 2.9C. For a medium scenario (A1B), the best estimate is 3.4C with a likely range of 2.0C to 5.4C, and for the highest scenario (A1FI), the best estimate is 4.0C with a likely range from 2.4C to 6.4C. There are greater values at the higher end of the ranges due to relatively new understanding regarding the nature of the feedbacks from the carbon cycle (i.e. how the oceans and land absorb and emit carbon dioxide). Though only relatively few global coupled climate models include the complex processes involved with modeling the carbon cycle, this feedback is positive (i.e. adding to more warming) in all models so far considered. Therefore, the addition of carbon cycle feedbacks provides higher values on the warm end of the uncertainty ranges. Though these globally averaged warming numbers seem small, the last ice age was only about 5C colder than present, and there were clearly many dramatic changes in global climate with just that difference of 5C. Additionally, a relatively small change in average temperature can result in much greater changes of extreme weather event. It is those extreme events that produce many of the significant impacts that affect human society. For example, it is very likely that heat waves will increase in intensity, frequency and duration, with heavy precipitation events also increasing. These projected changes in extremes continue trends we have already observed.

Rising global temperatures are very likely to raise sea level by expanding ocean water and melting mountain ice caps and glaciers. Recently observed ice sheet dynamical processes that could produce potentially larger contributions to sea level rise than accounted for in the present estimates are not fully included in existing models of the Greenland and Antarctic ice sheets assessed for the AR4. Therefore larger increases in sea level rise than the present projections cannot be excluded. Consequently, the AR4 cannot quantify a full uncertainty range of sea level rise at the end of the 21st century. Based on the existing models available for assessment, the central values for projections of sea level rise by 2100 are similar to previous estimates, ranging from about 30 to 40 cm. About 60% to 70% of this increase is due to thermal expansion of sea water (i.e. as water warms, it expands) and is thus connected to the more certain estimates of warming of surface air temperatures. There is less certainty with regards to the other components of sea level rise (contributions from melting land glaciers and small ice caps, the net balance between snow accumulation and melting ice for Greenland and Antarctica, and the dynamic ice flow contributions from Greenland and Antarctica). This is reflected in the ranges of sea level rise that differ from previous estimates, due in part to the way the uncertainty of these contributions is taken into account. This is an area of great concern and active ongoing research, given the potential consequences.

The projected globally averaged temperature increase is also reflected by patterns of regional climate changes. As noted in previous assessments, this pattern for temperature change is characterized by greater warming over land compared to oceans, and more warming at the high northern latitudes. Associated with these temperature changes, there are projected decreases of snow cover, and increases in thaw depth over most permafrost regions. Reductions in sea ice go along with the increased temperatures, with a sea-ice free Arctic by the end of the 21st century in the high forcing scenario in some models. The pattern of future precipitation change indicates likely increases at higher latitudes, such as the northern tier of states, and decreases over subtropical land areas such as the southwest U.S.

Though present-day global climate models used for the climate change projections discussed above have inherent limitations in simulating hurricanes, new types of specialized models have been formulated to study such possible future changes. From a range of models, it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense with larger peak wind speeds and more intense precipitation. This is physically consistent with ongoing increases of sea surface temperature since there is a well-established link between warmer water and hurricane intensity. There is less confidence in projections of a global decrease in numbers of hurricanes since the model results are not as consistent.

There has been some interest in the media and in Hollywood regarding the possibility of an abrupt shutdown of the Atlantic Ocean meridional overturning circulation (MOC). This large-scale ocean circulation system, sometimes called the "ocean conveyor belt," transports heat northwards, in part via the Gulf Stream, to the North Atlantic. A warming of the North Atlantic from increasing greenhouse gases could produce more precipitation and warmer water that would stabilize this overturning circulation and consequently reduce the amount of northward heat transport. Using this line of reasoning, if the MOC suddenly shut down, there could be a sudden decrease in northward heat transport and possibly a large cooling of the North Atlantic region. Research assessed in the IPCC AR4 indicates that it is very likely that the MOC will indeed slow down during the 21st century. With the weakening of this circulation, there is somewhat less heat transported northward. But there is still a future net increase of surface air temperatures over the North Atlantic since the warming from the increased greenhouse gases overwhelms any cooling from the MOC slowdown. Additionally, it is very unlikely that the MOC will undergo a large abrupt shut-down during the 21st century, with an associated cooling from such a sudden shut-down also very unlikely. No global coupled climate model simulation assessed in the AR4 produces such an abrupt change, even if Greenland ice melt is taken into account. However, changes in the MOC in the 22nd century and beyond cannot be assessed with confidence at this time.

Summary

The IPCC AR4 represents the current state of human understanding of climate science and climate change. Projected changes of future climate have relied on an unprecedented set of coordinated climate change experiments undertaken by the international climate modeling community, and the U.S. modeling groups have played a prominent role in this process. The projections of future climate are consistent with earlier IPCC assessments in terms of the magnitude of global changes. This is reassuring since successive generations of climate models are now producing comparable results from assessment to assessment. But there are now many more details as well as increased certainty regarding quantifications of regional climate change, extremes, hurricanes, climate change commitment, ocean circulation changes, and better information regarding both near term and longer term climate change.