APPENDIX 5 SCENARIOS AND MODELS

Scenarios

Scenarios provide ways to help understand what future conditions might be. Each scenario provides an example of what might happen under particular assumptions, and is neither a prediction nor a forecast. Instead, scenarios provide scientifically rigorous and consistent starting points for examining questions about an uncertain future and help us to visualize alternative futures in human terms. The military and businesses frequently use these powerful tools for future planning in high-stakes situations. Scenarios are used to help identify future vulnerabilities as well as to support decision-makers who are focused on limiting risk and maximizing opportunities. Three types of scenarios are used within this assessment to help frame the impact analyses in a consistent way: emissions scenarios (including population and land-use components); climate scenarios; and sea level rise scenarios. Each is briefly described below.

Emissions Scenarios

Emissions scenarios quantitatively illustrate how the release of different amounts of climate-altering gases and particles into the atmosphere will produce different future climate conditions. Such emissions result from human activities including fossil fuel energy production and use, agriculture, and other activities that change land use. These scenarios are developed using a wide range of assumptions about population growth, economic and technological development, and other factors. A wide range of assumptions is used because future trends depend on unpredictable human choices.

Perspectives on "plausible" emissions scenarios evolve over time. The Intergovernmental Panel on Climate Change (IPCC) has released three different sets of scenarios since 1990. In 2000, the IPCC released a Special Report on Emission Scenarios[1] that provided a set of scenarios, known as the SRES, which described a wide range of socioeconomic futures and resulting emissions. Near the higher end of the range, the SRES A2 scenario represents a world with high population growth, low economic growth, relatively slow technology improvements and diffusion, and other factors that contribute to high emissions and lower adaptive capacity (for example, low per capita wealth). At the lower end of the range, the SRES B1 scenario represents a world with lower population growth, higher economic development, a shift to low-emitting efficient energy technologies that are diffused rapidly around the world through free trade, and other conditions that reduce the rate and magnitude of climate change as well as increase capacity for adaptation. The SRES A2 and B1 scenarios are the foundation scenarios used in this assessment to evaluate future impacts.

Recently, a new set of scenarios (Representative Concentration Pathways – RCPs) has been prepared and released by scientists who study emissions, climate, and potential impacts.[2] This new set incorporates recent observations and research and includes a wider range of future conditions and emissions. Because climate model results are just now being released using the new scenarios, and there are few impact studies that employ them, the RCP climate scenarios are used sparingly in this assessment.

Scientists cannot predict which, if any, of the scenarios in either the SRES set or the RCP set is most likely because the future emissions pathway is a function of human choices. A wide range of societal decisions and policy choices will ultimately influence how the world's emissions evolve, and ultimately, the composition of the atmosphere and the state of the climate system.

Climate Scenarios and Climate Models

Global models that simulate the Earth's climate system are used, among other things, to evaluate the effects of human activities on climate. This assessment incorporates a new set of model simulations that have higher resolution and enhanced representation of Earth system physics, chemistry, and biology. These models use the new set of RCP emissions scenarios described above to project expected climate change given various assumptions about how human activities and associated emissions levels might change.

The range of potential increases in global average temperature in the newest climate model simulations is wider than earlier simulations because a broader range of options for human behavior is considered. For example, the lowest of the new RCP scenarios assumes rapid emissions reductions that would limit the global temperature increase to about 3.7°F, a much lower level than in previous scenarios. The emissions trajectory in RCP 8.5 is similar to SRES A2 and RCP 4.5 is roughly comparable to SRES B1 (see Figure 1). These similarities between specific RCP and SRES scenarios make it possible to compare the results from different modeling efforts over time.

Emissions Levels Determine Temperature Rises

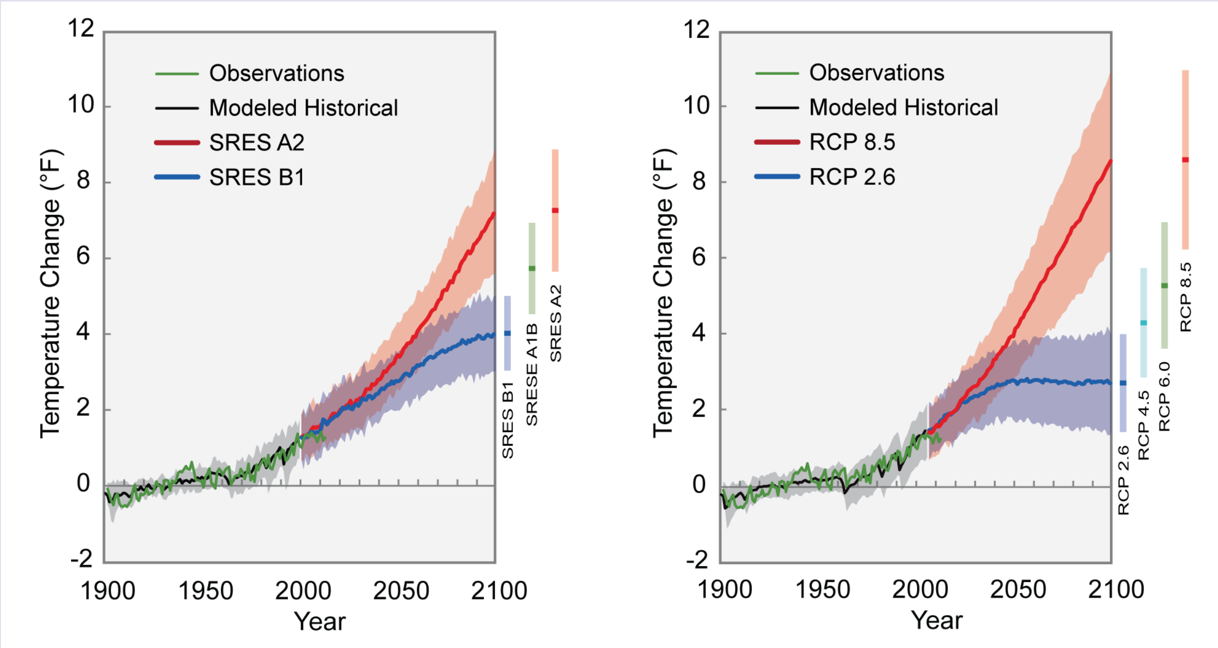

Figure 1. Different amounts of heat-trapping gases released into the atmosphere by human activities produce different projected increases in Earth's temperature. In the figure, each line represents a central estimate of global average temperature rise for a specific emissions pathway (relative to the 1901-1960 average). Shading indicates the range (5^{th} to 95^{th} percentile) of results from a suite of climate models. Projections in 2099 for additional emissions pathways are indicated by the bars to the right of each panel. In all cases, temperatures are expected to rise, although the difference between lower and higher emissions pathways is substantial. **(Left)** The panel shows the two main scenarios (SRES – Special Report on Emissions Scenarios) used in this report: A2 assumes continued increases in emissions throughout this century, and B1 assumes much slower increases in emissions beginning now and significant emissions reductions beginning around 2050, though not due explicitly to climate change policies. **(Right)** The panel shows newer analyses, which are results from the most recent generation of climate models (CMIP5) using the most recent emissions pathways (RCPs – Representative Concentration Pathways). Some of these new projections explicitly consider climate policies that would result in emissions reductions, which the SRES set did not.[8] The newest set includes both lower and higher pathways than did the previous set. The lowest emissions pathway shown here, RCP 2.6, assumes immediate and rapid reductions in emissions and would result in about 2.5°F of warming in this century. The highest pathway, RCP 8.5, roughly similar to a continuation of the current path of global emissions increases, is projected to lead to more than 8°F warming by 2100, with a high-end possibility of more than 11°F. (Data from CMIP3, CMIP5, and NOAA NCDC).

Emissions scenarios

Two SRES global emissions scenarios were recommended for use by the authors of this report for impact studies. One is a higher emissions scenario (the A2 scenario from SRES) and the other is a lower emissions scenario (the B1 scenario from SRES). These two scenarios do not encompass the full range of possible futures: emissions could change less than those scenarios imply, or they could change even more. Recent carbon dioxide emissions have, in fact, been higher than in the A2 scenario. Whether this trend will continue is not possible to predict because it depends on societal choices.

Sea Level Rise Scenarios

After at least two thousand years of little change, global sea level rose by roughly 8 inches over the last century, and satellite data provide evidence that the rate of rise over the past 20 years has roughly doubled. In the United States, millions of people and many of the nation's assets related to military readiness, energy, transportation, commerce, and ecosystems are located in areas at risk of increased coastal flooding because of sea level rise and associated storm surge.

Global sea level is rising and will continue to do so beyond the year 2100 as a result of increasing global temperatures. This occurs for two main reasons. First, when temperatures rise, ocean water heats up, causing it to expand. Second, when glaciers and ice sheets melt in response to hotter conditions, additional water flows into the oceans. Sea level is projected to rise an additional 1 to 4 feet in this century. Scientists are unable to narrow this range at present because the processes affecting the loss of ice mass from the large ice sheets are dynamic and still the subject of intense study.

Some impact assessments in this report use a set of sea level rise scenarios within this range, while others consider a wider range. Four scenarios (8 inches, 1 foot, 4 feet, and 6.6 feet of rise by 2100), along with explanations regarding how to use this information, are included in a guidance document on sea level rise that was provided to the National Climate Assessment (NCA) authors to use as the basis of impact assessments in coastal areas.[3]

Past and Projected Changes in Global Sea Level

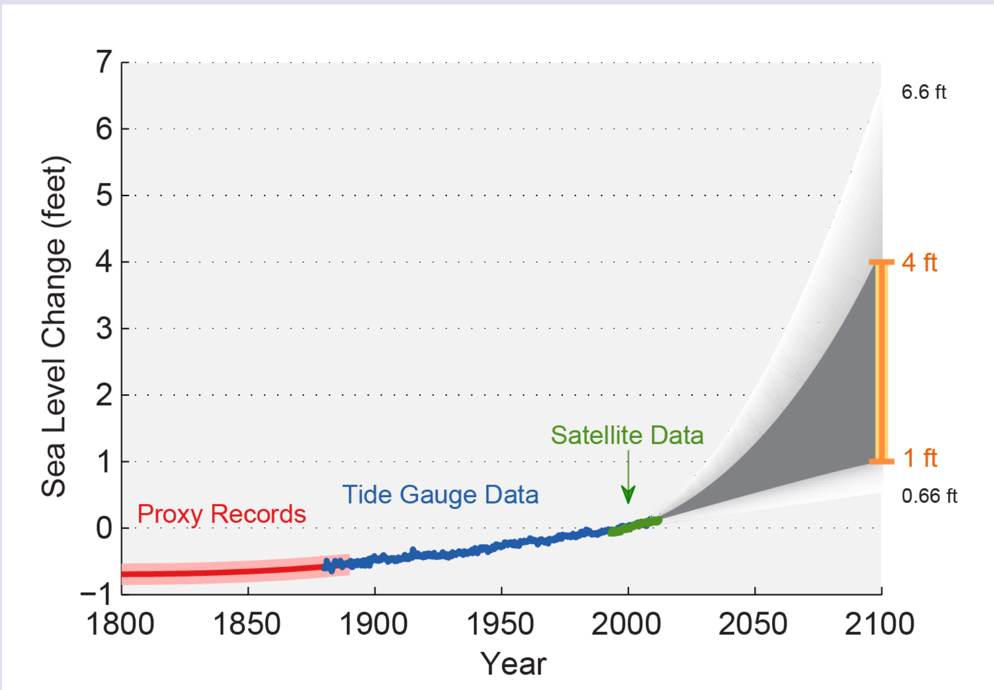

Figure 2. Historical, observed, and possible future amounts of global sea level rise from 1800 to 2100. Historical estimates[4] (based on sediment records and other proxies) are shown in red (pink band shows uncertainty range), tide gauge measurements in blue,[5] and satellite observations in green.[6] The future scenarios displayed here range from 8 inches to 6.6 feet in 2100.3 Sea level rise lower than 8 inches or higher than 6.6 feet is considered implausible by 2100. The orange line at right shows the currently projected range of sea level rise of 1 to 4 feet by 2100. The large range primarily reflects uncertainty about how ice sheets will respond to the warming ocean and atmosphere, and to changing winds and currents. (Figure source: Adapted from Parris et al. 2012,[3] with contributions from NASA Jet Propulsion Laboratory).

Models and Sources of Uncertainty

There are multiple well-documented sources of uncertainty in climate model simulations. Some of these uncertainties can be reduced with improved models. Some may never be completely eliminated. The climate system is complex, including natural variability on a range of time scales, and this is one source of uncertainty in projecting future conditions. In addition, there are challenges with building models that accurately represent the physics of multiple interacting processes, with the scale and time frame of the available historical data, and with the ability of computer models to handle very large quantities of data. Thus, climate models are necessarily simplified representations of the real climate system.

One of the largest sources of uncertainty in projecting future conditions involves what decisions society will make about managing the emissions of greenhouse gases. By later this century, very different conditions would result from higher emissions scenarios (such as A2) than from lower ones (like B1).

Over the last decade, concerted efforts in climate modeling have focused on understanding and better quantifying the uncertainties inherent in model simulations of climate change and on improving model resolution and representations of physical and biological processes important to the climate system. It is very clear that progress is being made in the accuracy of models in representing the physics of the climate system at smaller scales. This is demonstrated, for example, by the ability of these models to replicate observed climate.

To understand and better quantify uncertainty, multiple models generated by different modeling groups around the world are being used to identify common features in projections of climate change. The Third Coupled Model Intercomparison Project (CMIP3), and more recently CMIP5, established formalized structures that enable model evaluations against the climate record of the recent past. New elements of the CMIP5 effort include a major focus on near-term, decade-length projections designed for regional climate change and on predictions from the new class of Earth system models that include coupled physical, chemical, and biogeochemical climate processes. CMIP3 findings are the foundation for most of the impact analyses included in this assessment. Newer information from CMIP5 was largely unavailable in time to serve as the foundation for this report and is primarily provided for comparison purposes.

The breadth and depth of these analyses indicate that the modeling results in this report are robust. There is an important distinction to be made, however, between a "prediction" of what "will" happen and a "projection" of what future conditions are likely given a particular set of assumptions. All of the model results presented in this report are the latter: projections based on specified assumptions about emissions. The new regional projections provided in this report represent the state of the science in climate change modeling.[7]

APPENDIX 5: SCENARIOS AND MODELS

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