Re-Examining Projected Climate Changes for Maryland

MCCC Scientific and Technical Working Group

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In July 2008 the Scientific and Technical Working Group (STWG) produced a *Comprehensive Assessment of Climate Change Impacts in Maryland*[1] as part of the Commission on Climate Change's *Plan of Action*. That impact assessment reviewed past climate trends and projections of future climatic conditions and evaluated the likely impacts on water resources and aquatic ecosystems, farms and forests, coastal vulnerability, the Chesapeake Bay and coastal ecosystems, and human health. The assessment presented a vision of what the future might hold for Maryland with and without mitigation of global warming. This set the scene for the 2009 legislative commitments to reduce Maryland's greenhouse gas emissions. The climate impacts assessment also has served as the context for planning the state's climate adaptation and response strategies.

Much more scientific information has been gathered and published since 2008. In addition to hundreds of relevant articles reporting new research findings, the Intergovernmental Panel on Climate Change completed its Fifth Assessment Report (AR5) in 2015.[2] The U.S. Global Change Research Program completed two National Climate Assessments (NCAs), the Second in 2009 and the Third in 2014.[3] Here, the STWG provides a brief update on its 2008 climate change impacts assessment taking into account findings of the IPCC-AR5 and the Third NCA, the former on a global scale and the latter on the national scale. In particular, should the projections of future climatic conditions in included in the 2008 impact assessment for Maryland be modified based on these more recent assessments? On certain issues, the STWG also considers some more recent scientific literature, particularly regarding the important issue of sea-level rise.

Climate models. All of these climate impact assessments, from the scale of Maryland to the globe, rely on historic and recent climate observations and general circulation models (GCMs) that project how climactic conditions are likely to change in the future as a result of changing forces, particularly the concentrations of greenhouse gases in the atmosphere. Through an IPCC-managed process numerous GCMs are compared using the same assumptions. Ensembles of model results are then applied to develop projections of the central tendency and degree of confidence around it, much like the weather forecasts with which we are very familiar. These are global models. To provide finer resolution on the scale of the state of Maryland, for example, downscaling procedures are often applied.

Like the Maryland 2008 assessment, the Third NCA used downscaled projections from model ensembles that were produced for the IPCC Fourth Assessment Report (AR4) in 2007. Unsurprisingly, then, the projections of temperature and

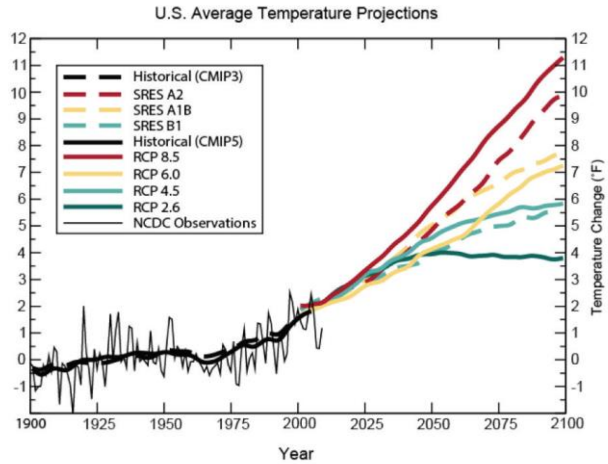

Figure 1. Comparison of projections of U.S. average temperature based on the IPCC AR4 models and SRES scenarios and on the IPCC AR5 models and RCP scenarios).[3]

precipitation for Maryland in the Third NCA (2014) are very similar to those presented in the Maryland impact assessment in 2008. However, the IPCC-AR5 introduced a new set of model assumptions and employed more than twice as many models that included significant model improvements. The scenarios used in the AR4 models were based on socioeconomic factors that affect greenhouse gas emissions and land use changes, while the AR5 models take into account geopolitical agreements that achieve mitigation of these emissions.

Both the 2008 Maryland assessment and NCA compared projections based on two AR4 scenarios, A2 for *high emissions* and B1 for *low emissions*. IPCC's AR5 scenarios are referred to as Representative Concentration Pathways (RCPs) and represent a larger set of mitigation scenarios that have different targets in terms of radiative forcing in 2100 (about 2.6, 4.5, 6.0 and 8.5 watts per square meter). In particular, the RCP 2.6 scenario assumes that steps will be taken to reduce greenhouse gas emissions sufficiently to avoid increasing global mean temperature by 2°C over preindustrial conditions—the pathway serving as the basis of the 2015 Paris Agreement. The RCP 2.6 scenario includes far more aggressive mitigation efforts than any of the AR4 scenarios and consequently results in less warming. As a general approximation, the RCP 4.5 scenario yields projections similar to the B1 (*low emissions*) scenario and the RCP 8.5 scenario similar to the A2 (*high emissions*) scenario) used in the 2008 Maryland assessment (Figure 1). For the present purpose, the RCP 8.5 scenario represents *unrestrained growth in emissions* and the RCP 2.6 scenario represents *rapid emissions reductions*.

Recent climate trends. Because the Third NCA was well underway before the IPCC AR5 was released, it largely used the earlier AR4 scenarios and model projections. However, the Third NCA did present notable new analyses of recent climate trends based on direct observations rather than models. For the Northeast U.S., including Maryland, the a detailed analysis[4] prepared for the NGA found that:

- Temperatures generally remained above the 1901-1960 average over the last 30 years, with warming more pronounced during the winter and spring seasons and statistically significant warming trends for each season.

- Annual precipitation showed a clear shift towards greater variability and higher totals since 1970, with precipitation trends statistically significant for fall and for the year as a whole.
- The frequency of extreme cold events has been 30% less than the long-term average.
- Since the late 1980s the frequency of heat waves increased to a level similar to that during the first half of the 20th century.
- While variable from decade to decade, the number of extreme precipitation events has been high since the 1990s.
- The length of the freeze-free season generally increased by about 10 days since the mid-1980s.
- The spring center-of-volume dates for river flow have come one to two weeks earlier on average.

As recently as 2014, the IPCC assessment authors addressed the potential causes for an apparent “hiatus” in global warming evidenced in global mean temperature records since the record high El Niño year of 1998. Viewed now with the successive record-breaking years of 2014, 2015 and, almost certainly, 2016, the hiatus seems little more than the typical interannual variability that has always been evident in the longer-term temperature record (Figure 2). If there were a slow down or pause in global warming it is surely over. Through September of 2016 global mean temperatures have broken or tied the observational records for every month of this year.

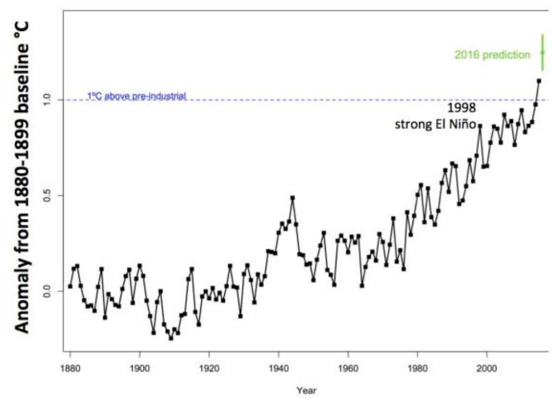

Figure 2. Global mean temperature since 1880, with the estimated range for 2016 once the year is completed (NASA Goddard Institute for Space Studies Surface Temperature Analysis).

Temperature projections. As the 2014 NSA relied on the same AR4 model ensemble for projections of 21st century surface temperatures, the warming projected was the same as that projected for Maryland by the STWG in 2008 for *high emissions* (A2) and *low emissions* (B1) scenarios. Using the newer models, the projections included in the IPCC AR5 for the *unrestrained growth in emissions* (RCP 8.5) scenario are very similar to those made by the STWF for the *high emissions* (A2) scenario, i.e. a likely increase in temperature in the 7 to 11°F range by the end of the century. Assuming the *rapid emissions reduction* scenario (RCP 2.6), i.e. a trajectory of emissions reductions to which Maryland committed in the 2016 Greenhouse Gas Emissions Reduction Act, 21st century warming in Maryland would more likely than not be held below 3°F. The projections made in the 2008 STWG regarding the increases in days exceeding 90°F and 100°F and more frequent and sustained heat waves also remain robust in light of the more recent IPCC projections. Extreme heat conditions would still become more frequent, but much less so under the *rapid emissions reduction scenario* (RCP 2.6) than in the previous *lower emissions* (B1) scenario. The confidence levels for temperature and precipitation projections based on the ensemble of AR5 climate models have recently been computed for every county in the United States in a way that facilitates climate risk analysis in Maryland.[5]

Precipitation projections. Once again, the NCA projections are essentially the same as those made in the 2008 Maryland climate impact assessment. The IPCC AR5 projected modest increases (10% or less) in annual precipitation for the region, with less change under the *rapid emissions reduction* scenario (RCP 2.6), and larger increases (~20%) during winter and spring and little change or even decreases in summer. GCM models differ quite a bit in their projections of precipitation and they also do not capture the regional scale weather dynamics that affect precipitation. Consequently, there remains quite a bit of uncertainty regarding changes in precipitation in the future in Maryland. It remains the case that winter and early spring will likely be wetter and that the frequency and intensity of extreme precipitation events will likely increase.

Sea-level rise projections. Sea-level rise projections made in the IPCC AR5 in 2014 are higher than those made in the AR4 in 2007, but are still widely criticized as being too conservative. Actually, this conservatism is a result of the caution within the IPCC rules that limit projections to those that can be reliably modeled quantitatively. The challenges in modeling abrupt losses of polar ice sheets presents a problem in that regard and create a wild card in projecting sea level later this century. The Third NCA, on the other hand, made no projections of sea level rise. Rather, it advanced the notion of scenario planning based on four "plausible" scenarios for 21st century sea-level rise developed by NOAA.[6] Using a similar approach the Department of Defense has generated five planning scenarios for sea-level rise for use in military facilities around the world.[7] The problem with this approach is that the range of projections is so broad—from one foot to over six feet over this century—as to be of limited utility. Furthermore, the selection of one scenario or another could be subject to the preferences or biases of the planner.

In 2013 the STWG updated the sea-level rise projections used in its 2008 climate impacts assessment, basing the update on projections for global sea-level rise then recently published by the National Research Council, adjusted for local factors.[8] Even more helpful planning within a specific region such as Maryland are the probabilistic estimates of sea-level rise, adjusted for regional factors, developed by Dr. Robert Kopp and his colleagues for tide gauge sites around the world.[9]

These probabilistic projections of relative sea-level rise are provided for both the *unrestrained growth in emissions* (RCP 8.5) and the *rapid emissions reduction* (RCP

2.6) scenarios. They provide a probability distribution around the mean projection. One could, for example, use a 17th to 83rd percentile range ("likely" in the parlance of the IPCC) for modest risk or longevity building or infrastructure decisions, but a 0.5th to 95.5th percentile range for highly risk-averse decisions. The advantages of this approach compared to the multiple scenarios approach used in the Third NCA or the DOD planning guidance are obvious in the comparison in Figure 3.

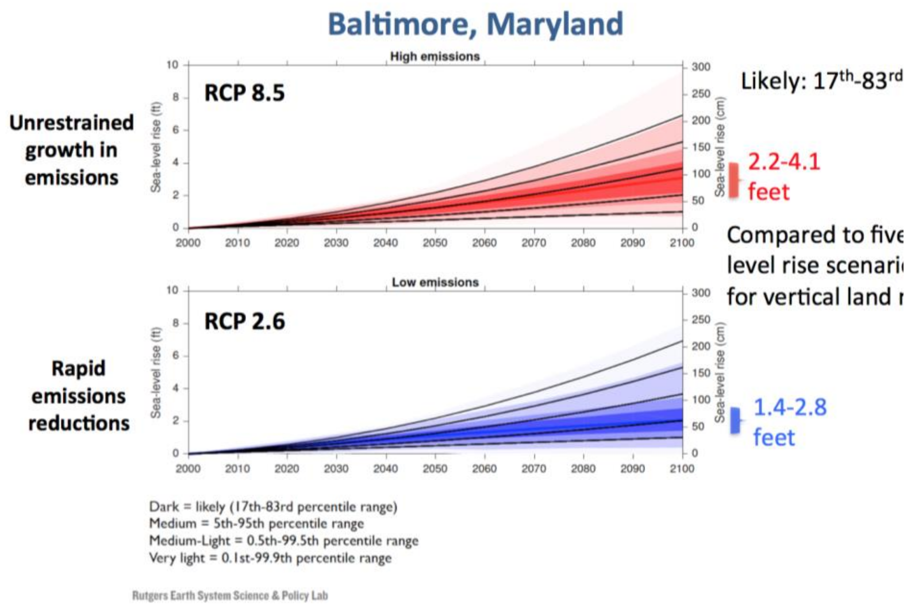

Figure 3. Probablistic projections of relative sea-level rise for Baltimore for the *unrestrained growth in emissions* (RCP 8.5) and *rapid emissions reductions* (RCP 2.6) scenarios. After Kopp et al. (2014).[9]

The STWG recommends that these updated probabilistic projections be used in Maryland Coast Smart and other coastal vulnerability planning. They are based on more recent scientific understanding, provide a differentiation based on the degree of mitigation, and present a more useful framework for evaluating risks than the projections provided in the STWG 2013 update or in the scenario planning approach. Even under the *unrestrained growth in emissions* scenario, the new probabilistic projections indicate somewhat less sea-level rise through the 21st century than the STWG 2013 update, with the 50% probability at 3.1 feet and 90% confidence that sea-level rise will fall between 1.6 and 4.9 feet at Baltimore.

Conclusions. For the most part, the projections of changes in temperature and precipitation for Maryland in the National Climate Assessment and IPCC Fifth Assessment are comparable with those used in the STWG 2008 impact assessment. Probabilistic projections of not only temperature and precipitation, but also of sea-level rise based on recent scientific advances allows for more effective risk analyses that can inform adaptation and response. The inclusion of the more aggressive *rapid emissions reduction* scenario that assumes the reduction of greenhouse gas emissions needed to achieve the Paris Agreement now coming into force provides an improved understanding of the climate change that Maryland would have to confront even if this mitigation were successful. In other words, how we can manage the unavoidable while avoiding the unmanageable.

Endnotes

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