New Jersey Shore's Future: Coping with Climate Change and Storm Risk**

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Summary
Some observed climate changes and events are easier to link to human causes and make projections for the 21st century than others. Storm risk and sea level rise are linked and thus part of a larger issue of vulnerability. Communicating to the public about the practical implications of climate science and the risk of extreme events, such as hurricanes, is a challenge. The public, policymakers, and scientists all have roles to play in coping with storm risk, sea level rise, and climate change.

Current realities
Global climate change is a reality and will require future generations of New Jersey shore residents to cope with the changes to some degree. The 2013 U.S. National Climate Assessment (NCA) notes: "Heat waves, heavy downpours, and sea level rise pose growing challenges to many aspects of life in the Northeast." Climate change science can provide a picture of these emerging trends, but this picture is not clear and reliable in all climate features. However, sea level rise trends are already clear at the New Jersey shore; these trends are apparently the result of both climate change (anthropogenic and natural) and land subsidence. Some future acceleration of trends is anticipated, but their magnitudes are uncertain. Both warming and extreme precipitation trends are evident in the Northeast region. These trends are expected to continue and — at least for temperature — most likely accelerate. There is more confidence in projections for temperature than, for example, precipitation or wind extremes.

Intense coastal storms, such as hurricanes and Nor'easters, are significant hazards to New Jersey, and interest in their future behavior is great. However, forthcoming changes in risk from hurricanes due to global warming are very difficult to predict. There have been no significant long-term (i.e., century-scale) trends in U.S. landfalling hurricanes since the late 1800s. Climate models suggest that the frequency of Atlantic hurricanes may actually decrease with global warming, although the average intensity and rainfall rates from hurricanes may increase by up to about 10% and 20%, respectively, over the coming century. However, since significant century-scale trends in these metrics have not yet been observed, we cannot be as confident about future projections of U.S. landfalling hurricanes as we are about certain other regional climate changes (e.g., temperature, sea level rise). Nonetheless, even if we assume no future change in storm climate, sea level rise is expected to increase storm surge risk, all else equal.

Because society's future responses to limit emissions are still unknown, climate modelers currently perform climate change experiments for a wide range of future emission scenarios. Along with analysis of past changes, these models provide our best available information about what to expect over the coming decades. Since some predicted climate changes have already been observed and are projected to intensify, some adaptation to climate change along the coast will be inevitable. However, the degree of future adaptation required will presumably depend upon how much warmer the planet becomes as well as attendant related climate changes. Adapting to storm/surge risk involves accurately assessing the risk and how it might change in the future. Society at large, including the New Jersey shore, faces important future decisions about actions to limit emissions and adapt to climate change and storm risk.

Scientific opportunities and challenges
Climate change poses many scientific and societal challenges. Strictly as a physical earth science problem, the challenges are daunting. The earth's climate system is complicated, and some phenomena (e.g., temperature) have more readily detectable responses to increasing

greenhouse gases than others (e.g., hurricanes). Basic benchmarks, such as the global temperature response to a doubling of atmospheric carbon dioxide, continue to have wide error bars (i.e., 1.5 ^{o}C to 4.5 ^{o}C in the latest Intergovernmental Panel on Climate Change [IPCC] report, for equilibrium climate sensitivity). Society typically wants to know even more specific regional details, such as how hurricane activity will change over the next century at the New Jersey shore. The uncertainties associated with such projections are typically even larger than those for global mean temperature. In some cases scientists cannot even be confident about the direction of future change (e.g., whether hurricane frequency will increase or decrease).

Climate scientists face an additional challenge of communicating with the public on the issue of climate change. This is further complicated by the fact that while scientists mainly agree on the general trajectory of the expected climate changes, they often disagree with each other over details of the science. The public could misinterpret this disagreement, seeing it as evidence that scientists do not understand the causes of climate change. The IPCC Fifth Assessment Report provides a clear benchmark for the current consensus that climate scientists have reached. This report serves as a communication channel from scientists to policymakers and the public, by which the science is distilled down to consensus points across the science expert community with indications of the degree of confidence in each substantive statement about climate change. IPCC statements differ a lot for highly detectable climate change features, such as the global mean temperature, as compared to other phenomena such as hurricanes. In an assessment report, scientists might term a future projected change as "likely," meaning there is greater than 67% chance that the statement will turn out to be correct, or "very likely" for a greater than 90% chance. These likelihood levels are the scientists' way of saying, "we think things will evolve this way, but we could be wrong, since our scientific understanding is imperfect." This is a statement of consensus on the uncertainty as well as the change and, as such, is not a point of scientific disagreement.

Another challenge is communicating to the public about both the current and future risk of extreme events such as Hurricane Sandy's resulting storm surge. For example, a scientist might estimate that a given level of flooding at some location currently has a 1 in 250 chance to occur in a given year, and under a certain future emission scenario (e.g., "business as usual") will have a projected range of 1 in 50 to 1 in 200 by the year 2050. The public is not always able to quickly grasp this level of complexity, yet further distilling this estimation could cause a loss of important information. While scientists recognize the difficulty of predicting future climate change, in some cases we want to provide at least some indication of future climate trajectories and storm risks with appropriate levels of uncertainty in an effort to communicate science to the public.

Policy issues

What should New Jersey shore communities, New Jersey policymakers, the nation, and scientists do about climate change? Various groups can address local, global, short-term, and long-term perspectives in order to pursue future action. Some suggested actions include:

The "local" problem at the New Jersey shore

- *General public:* Be aware of risk of living at certain sites (e.g., within floodplain, within reach of storm surge) and take appropriate actions (e.g., flood insurance, avoid living in a floodplain) to mitigate risk. Have an emergency plan and know how to evacuate when necessary; follow instructions of local emergency officials. Be aware that while climate change itself might be subtle (e.g., a 2-foot rise over 50 years) the vulnerability to surge events could be severe (e.g., a 4-foot rise becomes a 6-foot rise).
- *State and federal government:* Provide to the public updated assessments of flood and wind damage risk from storms to reflect ongoing and future climate change, including the latest scientific information on storm risk. Identify where stationarity cannot be assumed (i.e., when anecdotal evidence such as "my grandparents' experience" should not be

relied upon). Communicate these risks in a clear manner to the public (e.g., via a pamphlet to each property owner or prospective home buyer/renter). Have community-scale plans (e.g., emergency shelters) for dealing with heat wave extremes. Consider whether changes that have occurred or are projected have implications for zoning or flood insurance programs. Provide funding for scientific research to produce relevant information about anticipated climate change impacts in the region (e.g., sea level rise, warming rates, storm/surge risk).

- *Climate scientists:* Participate in projects to produce tailored, regional-scale information on climate variability, climate change and its causes, and storm and surge risk, all with estimates of uncertainties. Strive to communicate scientific results, along with their uncertainties, to other scientists, policymakers, and the local public in New Jersey through public outreach, websites, and individual papers and assessments such as the IPCC and National Climate Assessment (NCA), which can be used to derive some regional-scale information.

The global problem, future generations, and ecosystems: Many climate change impacts will be global scale problems that are expected to grow with time (i.e., increasing decade after decade for a century or more) and affect both humans and a variety of ecosystems.

- *General public*: Become educated about the basics of climate change. Read the National Climate Assessment highlights to become generally informed about the issue. Participate in the democratic process (e.g., voting) to express your views on what should be done. Take steps to reduce carbon footprint at home, while traveling, and in the workplace.
- *Government (primarily federal, but also state government):* Use products developed by the science community for policymakers (e.g., the IPCC Summary for Policymakers, NCA, U.S. Climate Resilience Toolkit) to develop rational policies based on scientific information and its attendant uncertainties. The policy actions should take into consideration impacts on the global scale and in developing nations (i.e., not just in the U.S.) and for future generations (i.e., not just immediate impacts). Policy actions should also consider climate change impacts beyond traditional economic damages to infrastructure and society (e.g., ecosystem impacts). Provide funding for climate science aimed at improved scientific understanding of climate variability, change, and impacts. Provide information and options (e.g., improved mass transit) to the public for reducing carbon footprints.
- *Climate scientists:* Continue to execute a broad research program on climate science, including observations and monitoring; improved scientific understanding and modeling of climate variability and change; and analysis of past, ongoing, and potential future climate changes, their causes, and impacts. Strive to communicate scientific results, along with their uncertainties, to other scientists, policymakers, and the general public through individual papers, peer-reviewed assessments such as the IPCC, and outreach.

[The views in this position paper represent those of the author and should not be construed as representing the views of NOAA or the U.S. Government.]

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