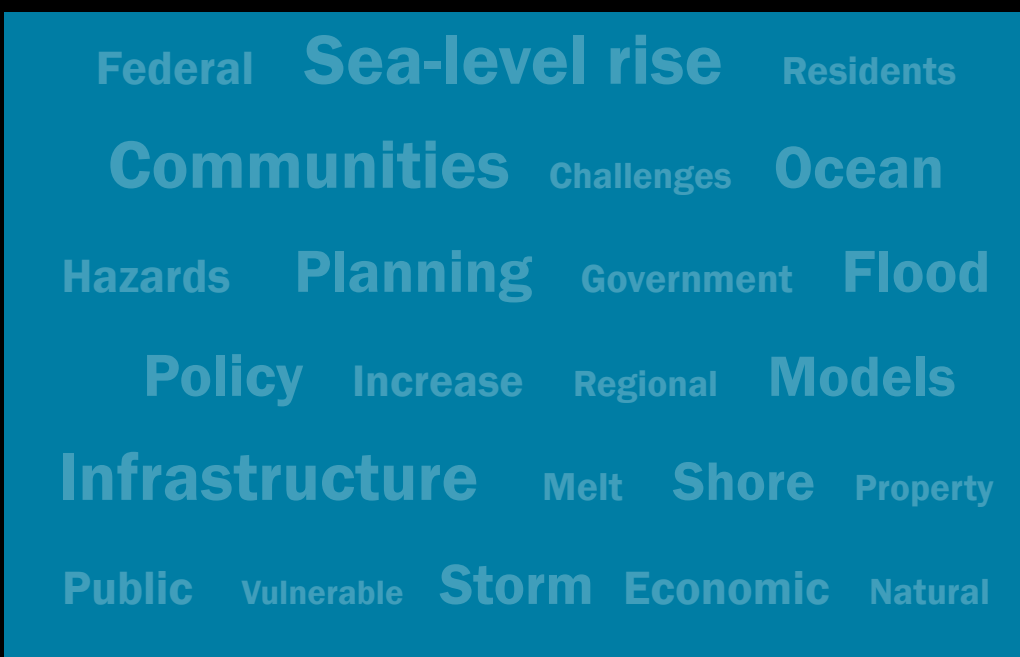
Institute on Science for Global Policy (ISGP)

The Shore's Future: Living with Storms and Sea Level Rise

Conference organized and convened by the ISGP in Toms River, New Jersey, in partnership with the Barnegat Bay Partnership, the Barnegat Bay Foundation, the Jay and Linda Grunin Foundation, Ocean County College and local government
Nov. 20–21, 2015



ISGP Climate Change Program (ICCP) Toms River, N.J.

Institute on Science for Global Policy (ISGP)

ISGP Climate Change Program (ICCP):

The Shore's Future: Living with Storms and Sea Level Rise

Conference organized and convened by the ISGP
in Toms River, New Jersey, in partnership with
the Barnegat Bay Partnership, the Barnegat Bay Foundation,
the Jay and Linda Grunin Foundation, Ocean County College
and local government
Nov. 20–21, 2015

An ongoing series of dialogues and critical debates
examining the role of science and technology
in advancing effective domestic and international policy decisions

Institute on Science for Global Policy (ISGP)

Tucson, AZ Office
3320 N. Campbell Ave.
Suite 200
Tucson, AZ 85719

Washington, DC Office
818 Connecticut Ave. NW
Suite 800
Washington, DC 20006

www.scienceforglobalpolicy.org

ISBN: 9780986100741

Table of contents

Introduction

Dr. George H. Atkinson
Founder and Executive Director, Institute on Science for Global Policy
and
Professor Emeritus, Department of Chemistry and Biochemistry and College of Optical Sciences, University of Arizona

Preface

The contents of this book were taken from material presented at a conference entitled *The Shore's Future: Living with Storms and Sea Level Rise* and held in Toms River, New Jersey, on November 20–21, 2015. This conference was organized and convened by the Institute on Science for Global Policy (ISGP) in partnership with several local partners, including the Barnegat Bay Partnership and the Barnegat Bay Foundation, with financial support provided by the Jay and Linda Grunin Foundation. The conference was the fourth of a series of ISGP Climate Change conferences being held around the United States.

These Climate Change conferences focus on communities that are concerned with how to mitigate and/or adapt to the anticipated impact of changing climates (e.g., drought, sea level rise, severe storms, warming seas and oceans). Special attention is given to how changes in climate may alter personal lifestyle choices and the collective decisions made throughout a community. Climate Change conferences, utilizing the ISGP's unusual, if not unique, debate/caucus format, attempt to significantly improve the communication of credible scientific and technological (S&T) understanding to both policy makers and to the public *writ large*. Sustained, broad-based support from all groups is often required to formulate and implement progressive policies that meet the needs of individual citizens and those of their respective communities.

ISGP conferences offer rarely encountered environments in which critical debates and extended caucuses can occur among internationally distinguished scientists, influential policy makers, societal stakeholders, students, and interested citizens.

Based on extensive interviews conducted by the ISGP staff with a national and international group of subject-matter experts, the ISGP invited three highly distinguished individuals with expertise in climate change, sea level rise, and

storm severity to prepare three-page, policy position papers (designed for the nonspecialist). On the first day of the conference, the author of each paper answered questions and commented in a moderated, 90-minute debate involving academics, public officials, and representatives from the private sector and nongovernmental public advocacy organizations. Each author was provided with a 5-minute period at the outset of each debate to summarize his/her views.

One the second day of the conference, groups of about 12 participants (debaters and audience) caucused with moderators to identify areas of consensus and actionable next steps relevant to the significance of sea level rise for individual lifestyle choices and the community-wide decisions under consideration. The results from all the caucuses were presented to a plenary session involving all participants for discussion.

The three policy position papers, together with the not-for-attribution summaries of the debates of each paper (as prepared by the ISGP staff from recordings of the debates), and the areas of consensus and actionable next steps (as developed by all conference participants) are presented in this book.

ISGP Climate Change Program (ICCP)

Of the seemingly innumerable societal challenges associated with science and technology (S&T) being debated worldwide, those connected to climate change are among the most challenging and at times, apparently the most intractable. The often contentious discourse and public uncertainty about climate change characterizes the complexity of the S&T issues and degree of uncertainly found among nonspecialist citizens concerning what can be done to mitigate and/or adapt to the consequences of climate change. While in some quarters the public and political disagreements rage over the existence of climate change and its relationship(s) to human activities, there are increasing clear physical indications that changes in climates (local, regional, and global) are occurring with a rapidity and severity not anticipated by many credible scientists and societal leaders.

Under these circumstances, it is increasingly important to more effectively engage citizens in discussions concerning the reality of climate change and its potential significance in their lives and the decisions being made in their respective communities. It is also evident that new models for engaging subject-matter experts with nonspecialist citizens are required to reconcile opposing views and to obtain practical policies that can be implemented and publicly supported.

To ensure that the societal debates of climate change issues lead to effective governmental and private-sector policies, two types of engagements are needed:

1. It is critical that well-informed, credible scientists and technologists candidly communicate the advantages and risks of practical options for addressing climate changes in the lives of citizens and their communities.
2. Citizens must be able to evaluate recommendations based on the predictions from climate change models against often expensive and difficult alterations in their personal lifestyles.

Since citizens legitimately have concerns regarding the credibility of information provided to them from multiple sources, they deserve the opportunity to question specific recommendations based on their own perspectives and to help formulate and implement those policies that garner broad, sustained public endorsements. These are the egalitarian environments created by the ISGP in its conferences.

Concluding remarks

The ISGP, a not-for-profit organization, has no opinions nor does it lobby for any issue except rational thinking. Members of the ISGP do not express any independent views on any topic. Rather, ISGP programs focus on fostering environments that can significantly improve the communication of ideas and recommendations derived from credible scientific and technological understanding to decisions makers in both the public and private sectors. It is hoped that all those responsible for formulating and implementing polices will benefit from the information in this report in their efforts to effectively serving their constituents.

Conference Conclusions

Area of Consensus

Although the pace of sea level rise cannot be precisely predicted, there is sufficient certainty about the reality of current and future sea level rise and its impact on individual and community decisions to justify the formulation and implementation of a range of adaptive policies coordinated across local, regional, state, and federal levels.

Actionable Next Steps

1. Collaboratively expand existing sea level rise policy initiatives, together with their commitments of resources, to support local municipalities and nonprofit organizations (e.g., Jacque Cousteau National Estuarine Research Reserve, the New Jersey Climate Adaptation Alliance, Barnegat Bay Partnership) to develop critical documentation characterizing (i) elevation mapping, (ii) vulnerability assessments, (iii) economic mitigation options, (iv) coastal erosion, (v) community flooding, and (vi) saltwater intrusion. These data are critical for accurate evaluations of the impact of sea level rise on vulnerable communities, ecosystem health, current and potential land use choices (including increased population density caused by developments away from the shore), and the economic consequences of different policy strategies
2. Utilize sound scientific research to develop coordinated, consistent local, state, and federal policies regarding land use and development, infrastructure maintenance, and interconnected areas (e.g., common watersheds). Both incentives and disincentives need to be provided by governmental agencies to encourage communitywide implementation of long-range adaptive plans (e.g., requiring communities to adopt practical, proactive plans for disaster recovery to qualify for disaster assistance).
3. Create metrics-driven benchmarks that identify "trigger points" for the implementation of different levels of adaptive responses based on projecting the functional viability of infrastructure (i.e., utilities, roads) at different sea elevations. These benchmarks need to be used to determine

the economic feasibility of maintaining communities in affected areas over long periods of time.

4. Require policy makers at all levels to incorporate sea level-rise projections into all relevant governmental planning decisions related to policies and programs (e.g., flood insurance maps). Regulating agencies (e.g., Public Utility Commission) need to require regulated entities (e.g., electric companies, utilities) to demonstrate that climate change projections are incorporated into their plans for building and maintaining infrastructure.

Area of Consensus

Given the recognition based on credible scientific evidence that the anticipated rise in sea levels will be accompanied by greater storm surges and increased community damage, it is evident that currently mandated adaptation policies need to be fully implemented and that multifaceted, coordinated policies for pre- and post-storm responses need to be developed immediately for coastal communities. Managed relocation, with appropriate compensation, is an option to be considered if policies are to be effective for a wide range of circumstances.

Actionable Next Steps

1. Create "redevelopment" policies for post-disaster recovery that implement sustainable and adaptive strategies, rather than simply rebuilding in place. These policies need to (i) reform zoning laws for new development at risk from sea level rise, (ii) introduce flexible economic options to encourage development of low-risk areas, (iii) affix greater financial responsibility for disaster recovery to property owners electing to build in high-risk areas, (iv) eliminate economically unsustainable national flood insurance subsidies, (v) revise building codes for vulnerable areas (i.e., below 10 feet) to require the removable of abandoned structures and cleaning of property, (vi) regulate the removal of hazardous materials and pollutants prior to inundation, (vii) establish policies to reduce services and utilities in correlation with decreased taxes in extreme high risk areas.
2. Develop relocation assistance programs and strengthen buy-out options (e.g., Blue Acres program) for designated vulnerable, waterfront properties (e.g., areas identified in the New Jersey State Plan), especially within the same municipality to aid individuals to relocate without depleting the tax base.

3. Implement precautionary, pre-storm precautionary measures to (i) educate the public about storm preparation (e.g., flood-proofing, elevation), (ii) improve advanced storm warnings by emphasizing evacuation timeframes, (iii) plan to recover from damages (e.g., identification of dump sites), (iv) identify areas to be considered for relocation, (v) organize amortized compensation polices for affected property owners who relocate, (vi) identify critical infrastructure requiring renovation, and (vii) establish emergency evacuation and management measures (e.g., analogous to those for nuclear emergencies).
4. Organize with specific corporate partners realistic opportunities to attract immediate and long-term private sector investments involving innovative technologies based on credible science and engineering designed to address the impact of rising sea levels and severe storms on coastal communities.
5. Strengthen the ecological health of the area by promoting ecosystem services, improving flood control, protecting natural shorelines, aligning building codes to reflect coastal natural hazard risks, and minimizing impervious ground-covering surfaces (e.g., best practices identified in the Pinelands Preservation Act).

Area of Consensus

The resilience, sustainability, and economic prosperity of a community exposed to the impact of climate change associated with rising sea levels and severe storms depends on individual citizens obtaining (i) a practical, comprehensive understanding of the risks to their specific coastal areas and (ii) an anticipatory governmental program assisting them to undertake risk-reduction actions using a regulatory system that clearly establishes the enforceable responsibilities for all stakeholders. Effective educational campaigns are needed to focus on closing the gap between the realistic impact on property and lifestyles imposed by sea level rise, together with the appearance of severe storms and the natural desire of many stakeholders to maintain the *status quo*.

Actionable Next Steps

1. Expand existing financial incentives and disincentives to discourage living in flood plain areas and those susceptible to future sea rise including (i) insurance rate pricing, (ii) higher taxes and impact fees to

encourage vacating at-risk property, (iii) deed restriction programs (e.g., conservation easement), and (vi) transfer of development rights to lessen financial losses on property located at higher elevations.

2. Use public and private funds to develop comprehensive, compelling educational and media campaigns to increase public understanding of the current and future risks (economic, environmental, safety, health, and national security) of sea level rise and the severity of the accompanying storms. Such campaigns need to produce elevation and sea level maps illustrating local impact of sea rise and storms and to ensure that K-12 students join seniors, business and neighborhood leaders in playing a primary role in the public discussions (e.g., in laboratory projects focused on designing "smart communities"). These educational efforts also need to engage homeowners, real estate professionals, as well as stakeholders from throughout the community to look beyond individual flood plains to recognize impacts affecting the entire region. The designation of "community liaisons" who are well versed in climate change issues and local viewpoints are excellent investments to ensure the effectiveness of the educational program.
3. Inform current policy decisions with respect to sea rise by showcasing the area's history of extreme storms by providing public access to digital and physical records describing the impact of natural disasters on the community (e.g., park exhibits, textbooks, websites, and demarcation lines on buildings indicating past flood levels).
4. Ensure that the political process for reclaiming flood zone properties is protected from corruption by centers of influence/government by identifying and eliminating policy loopholes and holding officials responsible for enacting approved policies.

ISGP conference program

Friday, Nov. 20th

08:00 – 09:00 **Registration**

09:00 – 09:15 ***Welcoming Remarks***
Dr. Stan Hales, Director, Barnegat Bay Partnership,
Mayor Tom Kelaher, Toms River Township,
and
Dr. George Atkinson, Institute on Science for Global Policy (ISGP), Founder and Executive Director

Presentations and Debates

09:15 – 10:45 **Dr. Harold R. Wanless, Department of Geological Sciences, University of Miami, United States**
The Coming Reality of Sea Level Rise Along the New Jersey Coast: Too Fast Too Soon

Moderated by Dr. Sweta Chakraborty, Associate Director, ISGP

10:45 – 11:00 *Break*

11:00 – 12:30 **Mr. Thomas R. Knutson, Geophysical Fluid Dynamics Lab/ National Oceanic and Atmospheric Administration, United States**
New Jersey Shore's Future: Coping with Climate Change and Storm Risk

Moderated by Ms. Aubrey Paris, Senior Fellow, ISGP

12:30 – 13:30 *Lunch*

13:30 – 15:00 **Dr. Karen M. O'Neill, School of Environmental and Biological Sciences, Rutgers University, United States**
Adapting to Climate Change on the Coast: Changing Values, Behavior, and Policies

Moderated by Dr. George Atkinson, Founder and Executive Director, ISGP

15:45 – 15:30 **Wrap-up, caucus information**

Saturday, Nov. 21st

08:00 – 09:00	**Registration**
09:00 – 12:15	**Focused group sessions**
12:15 – 13:15	*Lunch*
13:15 – 16:00	**Plenary Caucus Session** Moderated by Dr. George Atkinson, Founder and Executive Director, ISGP; and Dr. Sweta Chakraborty, Associate Director, ISGP
16:00 – 16:15	**Closing Remarks** Dr. George Atkinson, ISGP, Founder and Executive Director

The Coming Reality of Sea Level Rise Along the New Jersey Coast: Too Fast Too Soon**

Harold R. Wanless, Ph.D.
Professor and Chair, Department of Geological Sciences
University of Miami, Coral Gables, Florida, U.S.

Summary

The reality of accelerating rates of sea level rise as the result of human-induced global warming is becoming increasingly dire and urgently needs to be addressed. In 2012, the National Oceanic and Atmospheric Administration (NOAA) published the most recent United States Government sea level rise projections as a part of the National Climate Assessment. Those projections that include acceleration in ice sheet melt from Greenland and Antarctica are for 4.1 to 6.6 feet of global sea level rise by 2100. That could mean 2 feet by as early as 2048 and 3 feet by 2063. The projected global sea level rise will create challenges for low-lying coastal zones, including maintaining community infrastructure and welfare, continuing viable agriculture, and assuring protection of life and property during hurricanes and other extreme events. For the New York/New Jersey region, significant regional influences must be added to the global rate. Thorough, transparent community planning for the coming reality is urgently needed now.

Current realities

In the New York-New Jersey-Delaware-Maryland region, additional regional influences on sea level must be added to the 4.1 to 6.6 feet rise global projection for 2100. These include the following: (i) vertical land motion as the uplifted bulge south of the former North American Ice Sheet continues to collapse (+5 to +7 inches per century); (ii) dynamic ocean rise because of anticipated slowing of the Gulf Stream flow (+5 to +8 inches per century); and (iii) redistribution of self-gravitation pull on ocean water as the vast polar ice sheets melt and weaken their pull (+25% to +37% of ice-melt sea level rise) (Lemonick, 2010).

Most of the models projecting future sea level assume a gradual acceleration of rise through this century and beyond as Greenland and Antarctic ice melt gradually accelerates. Our knowledge of how sea level rose in the past ice age paints a very different picture of how sea level responds to climate change. At the depth of the

last ice age, about 18,000 years ago, sea level was some 420 feet below the present level as ice was taken up by large continental ice sheets. Subsequent ice melt and sea level rise was not a gradual acceleration and then deceleration; rather, it was a series of very rapid pulses of sea level rise followed by pauses. These rapid pulses of rise, ranging from 3 to 30 feet probably within a century, were fast enough to drown reefs, sandy barrier islands, tidal inlet deltas, and other coastal deposits and leave them abandoned across the continental shelves. As the climate warms, it destabilizes some ice sheet sector, which rapidly disintegrates, resulting in a rapid pulse of global sea level rise.

Our significantly warmed atmospheric climate is resulting in an accelerated melt of the surface of the Greenland Ice Sheet. Much of the surface of the Ice Sheet is darkening as the dust and black carbon in the ice concentrate on the melting surface. This accelerates heat adsorption, further accelerating surface ice melt — one of many feedbacks not in current models. More importantly, warmed ocean water is accelerating ice melt in both Polar Regions. The warming North Atlantic and Arctic Oceans have been accelerating ice melt all around Greenland since about 1995 as this dense, "warm" ocean water enters the deep outlet glacial fjords and penetrates far into and under the Ice Sheet. Warm ocean water is now also penetrating deeply into fjords under outlet glaciers and adjacent Ice Sheets of both West Antarctica and East Antarctica. Each of these warm waters is only 2 to 4 degrees Celsius, but they are causing a profound amount of melting. We are essentially providing an unlimited supply of warmth to the oceans for this melting to continue for centuries.

The beginning of this polar Ice Sheet melt is showing numerous reinforcing feedbacks, which are rapidly accelerating the rate of melt far beyond anything projected in current models. For example, because water on the ice surface absorbs more heat, surface melt is accelerated; this melted water percolates down through the ice and lubricates the base permitting faster motion, and culminating in more extensive fracturing. In addition to this, water percolating through the fractured ice accelerates ice melt and warms the ice, which results in the softening of the ice and even further acceleration of the melting process. With the rapid melting of pack ice and the warming of water in the Arctic Ocean, release of additional carbon dioxide and methane from decaying organics in the melted permafrost, and melting of methane hydrates on the Arctic continental shelf, the accelerating melt of the adjacent Greenland Ice Sheet seems irreversible. We are most certainly witnessing the onset of a rapid pulse of sea level rise.

In 2014, documentation came out showing that ice melt of the West Antarctic Ice Sheet is much less constrained by underlying bathymetry (underwater depth of the ocean floor) than previously considered (i.e., bottom substrate deepens

inward below the ice). The documentation also demonstrates that the numerous fjords penetrating in from the Greenland coast are deeper and extend much further under the Ice Sheet than previously thought. In 2015, it was demonstrated that similar ice melt acceleration is occurring under the East Antarctic Ice Sheet. Each of these findings means that warmed ocean water is now more easily penetrating under these ice sheets and that accelerating ice melt will happen much faster than previously thought.

In light of our improving understanding of ice melt, we should anticipate at least 7 to 30 feet of global sea level rise by the end of the century, regardless of any actions taken. This is because even if we stopped burning fossil fuels tomorrow, the greenhouse gases in the atmosphere will keep warming the atmosphere for at least another 30 years. Additionally, more than 90% of this global warming heat ends up in the oceans, which have the capacity to capture, store, and use the heat for centuries. Consequently, ice melt and sea level rise will continue for centuries. Most projections recognize sea level rise will accelerate through this century and the next. This level will continue to increase from ongoing acceleration of sea level rise stemming from the continuous acceleration of ice melt. Even if we encounter a minimal 5-foot increase in sea level at the end of the century, the rate of sea level rise will be a foot per decade!

There is currently a very aggressive building boom underway in many low-lying coastal areas of the nation. Most of this building is occurring without consideration for the viability of construction or the challenge of maintaining a functional infrastructure with the projected rates of sea level rise. There are areas that will be unlivable and properties that will be unsellable within a 30-year mortgage cycle all along the Atlantic coast, as hinted at by the recent repeated "king tide" floods (maximum tides when moon is closest and in full- or new-moon phase).

Scientific opportunities and challenges

Several recent papers, including one from the National Research Council, have suggested that current greenhouse gas levels are sufficient to cause a 70-foot rise in sea level. Our recorded history does not have direct observations as to how quickly destabilized ice sheet sectors can disintegrate. The past record and present trends indicate that pulses of sea level rise happen very fast (e.g., 3 to 30 feet per century).

Even with the current NOAA projection of 6.6 feet in sea level rise by the end of the century, it is beyond sobering to consider the risk in present infrastructure investments. With the distinct possibility of a 2-to-3 foot rise in sea level by 2065, most of the barrier islands of the world will become largely uninhabitable, displacing residing populations. At the same time, low mainland coastal communities, such as

those along Barnegat Bay, will become flooded more frequently and therefore become increasingly difficult locations in which to live. Citizens in affected areas will (i) lose local freshwater resources; (ii) live in communities with a failing and disconnected infrastructure; and (iii) be at an increased risk from catastrophic storm surges, flooding from hurricane and rainfall events, and failing sewage treatment plants.

While many renowned scientists have concluded that global sea level may rise 15 to 30 feet by the end of the century, communities must, at a minimum, begin to plan for sea level rise using the 2012 NOAA projections (i.e., 4.1 to 6.6 feet by 2100) in conjunction with any regional influences (+1 to +2 feet for New Jersey). By doing so, communities will quickly realize that very serious problems will arise very soon. With accelerated sea level rise projected through this century and beyond, there is a need to focus on realistic plans for both the maintenance of community stability during relocation and environmental quality during inundation. Most of New Jersey's barrier islands and sandy coastal mainland, for example, cannot consider the option of living below sea level with levees and dikes because the sand substrate is much too porous and permeable. By planning with the NOAA projections, it will be easy to adapt preparation plans to higher and faster rates of sea level rise — or enjoy a few extra years of being prepared if actual rates are slower.

Policy issues

- Counties must aggressively and transparently plan for their future by integrating high-resolution maps of elevation, storm surge, flood risk, and infrastructure elevation to determine the timing, costs, and economic feasibility for maintaining functional infrastructure, viable insurance, and human safety. States normally provide calibrated LiDAR (airborne laser) maps (see figures), but some counties and cities fly their own.
- Produce maps for each 6 inches of further local relative sea level rise (global plus regional) up to a valid planning projection through this century. By doing so, intelligent planning can be done to determine what areas and infrastructures are currently at unacceptable risk, and at what thresholds and costs infrastructure will have to be modified to maintain functionality and acceptable risk. These maps can determine where and when infrastructure services will have to be discontinued because of unacceptable risk or cost.
- We must act within the framework of the reality before us. As there is little possibility that these sea level rise projections will diminish, it is imperative to:

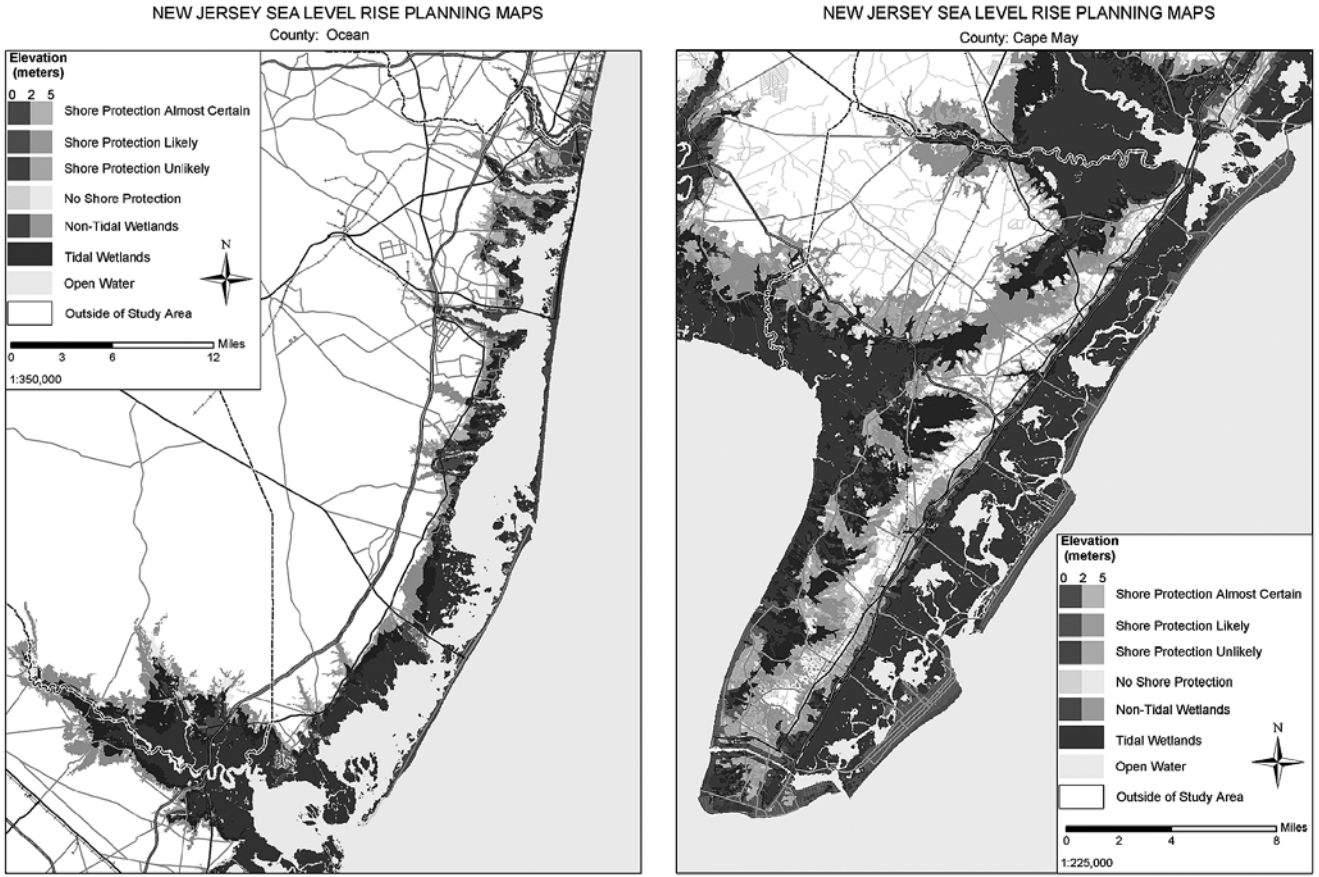
- Terminate long-term, infrastructure-intensive development of barrier islands and low-lying coastal zones.
- Divert public money from future hard or soft shore protection measures (e.g., sea walls, sand renourishment, levees) into funds used for relocation assistance, cleaning low-lying polluted lands, and removing storm-damaged development and infrastructure.
- Establish firm sea level rise thresholds for termination of infrastructure services, for permission to rebuild following storm destruction, for staging insurance withdrawals through cooperative public-private agreements.
- Implement Local and Regional Climate Change recommendations, which have action items to help insure the stability of affected individuals and communities (e. g., Township of Toms River "Getting to Resilience" Recommendations Report, by the Jacques Cousteau National Estuarine Research Reserve, June 2015).
- Initiate intensive education for the affected public to achieve an informed electorate.

Without planning, there will come a point where society and civilization as we know it will collapse into chaos. We can only prevent this scenario with serious planning and effort. Our children and future civilization deserve much better than what we are presently doing.

References

Lemonick, M.D., 2010. The secret of sea level rise: It will vary greatly by region. http://e360.yale.edu/feature/the_secret_of_sea_level_rise_it_will_vary_greatly_by_region/2255/

This paper is adapted from a policy position paper prepared for presentation at the conference on Sea Level Rise: What's Our Next Move?, convened by the ISGP, October 2–3, 2015, in St. Petersburg, Florida



Examples of sea level planning maps easily available for the New Jersey shore. Planning maps for Ocean County (left) and Cape May County (right) show areas less than 2 meters (6.6 feet) above sea level in and areas of likely protection efforts (e.g. sea walls, elevation of land, beach fill) (from: http://plan.risingsea.net/NJ/).

Debate Summary

The following summary is based on transcriptions of a recording made during the debate of the policy position paper prepared by Dr. Harold Wanless (see above). Dr. Wanless initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. Wanless. Although this summary has been written without attribution, the conference itself was open to the public and media and as such, did not restrict participants from attributing remarks to specific individuals. The views comprising this summary do not necessarily represent the views of Dr. Wanless, as evidenced by his policy position paper, or those of the ISGP, which does not lobby on any issue except rational thinking. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- Given that different climate models all project significant sea level rise ranging from 3 to 13 feet by the end of this century, policy makers and coastal residents need to accept the reality of this phenomenon, regardless of the cause, and begin long-term planning to adapt to impacts on structures (e.g., residences, businesses) and infrastructures (e.g., bridges, utilities). At a minimum, mitigation and adaptation planning must be based upon the U.S. governmental projection of 6.6 feet of sea level rise by 2100, a prediction reflecting an accelerated rate of ice melt from Greenland and Antarctica.
- Since public skepticism remains a barrier to initiating programs for both mitigation and adaptation, it is critical that the credible scientific and technological understanding supporting the certainly of sea level rise be clearly communicated while simultaneously acknowledging that there is uncertainty regarding the rate of sea level rise given its dependence on the degree of ice sheet melt. Distinguishing this relationship is essential to avoid creating further confusion and perpetuating distrust. Communication that links the scientifically credible data to the financial

and social consequences of sea level rise for both the individual and the community is critical in overcoming any lingering skepticism.

- Communities need to assess their unique values, preferences, and needs as they prioritize the mitigation, adaptation, and protective actions and policies. Related to sea level rise. Framing the impact of sea level rise in financial terms (e.g., property investments that will be imperiled within the lifetime of a mortgage) and expanding existing financial incentives and disincentives to discourage living in flood plain areas and areas susceptible to future sea level rise will engender community support and action. Community leaders need to be transparent and inclusive in their planning processes, and innovative in developing disaster preparation strategies.
- By developing accurate elevation maps, communities can appropriately assess the vulnerability of residences, businesses, and infrastructure with every incremental (e.g., 6 inches) rise in the sea level. Policy makers need to enforce setback lines designated by elevation maps, avoiding exceptions for developments that may offer short-term financial benefits, but carry long-term costs. Federal agencies (e.g., the Federal Emergency Management Agency) also need to consider the reallocation of resources from post-disaster recovery and rebuilding to pre-crisis protection and adaptation efforts (e.g., the relocation of at-risk residents and businesses).

Current realities

Warming seas and global temperature rise is causing widespread melting of the Earth's ice sheets, leading to rising sea levels around the world. The natural feedback mechanisms that accelerate ice melt, coupled with continued warming driven by human activities (e.g., fossil fuel burning), ultimately can result in a complete collapse of these ice sheets.

Although sea level rise is just one component of climate change, it is a challenge for which populations can actively plan. Wide agreement exists among scientists regarding the conservative projection of 3 feet of sea level rise by the end of the century (as reported by the Intergovernmental Panel on Climate Change [IPCC]). When accelerating ice melt from Greenland and Antarctica is incorporated into sea level models, projections (e.g., by the U.S. government in 2012) increase between 4.1 to 6.6 feet by 2100. Some predict sea level rise may be even higher, reaching 10 feet to 13 feet by the end of the century, due to natural accelerating mechanisms (e.g., warm water flowing in underneath outlet glaciers) that cause ice to melt ever

faster once the process has started. What is not in dispute, however, is that sea level rise will continue well beyond the end of the century, and that low-lying coastal communities are becoming increasingly vulnerable. This is a global phenomenon that cannot be reversed.

Historically, the climate has fluctuated over time, due primarily to natural processes (e.g., Milankovitch cycles, which are the collective effects of changes in the Earth's movements upon its climate). The geologic record shows that sea levels did not rise in a slow and steady progression, but rather in quick spikes as an ice sheet sector disintegrated, followed by a period of stability, followed by another quick rise. This historical pattern must be considered as climate modelers seek to predict future rise.

The vast majority (98%) of atmospheric scientists concur that the current warming trend is anthropogenic. Carbon dioxide levels have been rising since the Industrial Revolution, contributing significantly to the warming of the Earth's temperature. Because more than 90% of the heat trapped by carbon dioxide and other greenhouse gases has been transferred to the oceans, scientists are reporting increasing acidification of the oceans, diminishing the health of corals and other organisms that make up the base of the food chain. This trapped heat also induces thermal expansion, which increases the ocean's volume and causes sea level to rise.

Despite wide scientific agreement about sea level rise and climate change in general, there are many individuals who remain skeptical that it is occurring, or that it is caused by human factors. Convoluted science communication only adds to public misperceptions (e.g., in 2014, the increased floating ice surrounding Antarctica seemed to show an increase in ice pack, but it was later determined that it was caused by increased ice melt, as the melted fresh water floated atop the salt water).

Although current sea level rise models cannot make firm projections regarding timing and lack the complexity to incorporate all factors contributing to sea level rise (i.e., dark soot accumulating on ice surfaces and hastening melting), it was emphasized that current models clearly show the need for immediate community action regarding sea level rise.

Framing sea level rise in financial terms (e.g., property investments that will be imperiled within the lifetime of a mortgage) seems to have the most impact in convincing policy makers and business owners to begin adapting to rising seas. However, it was emphasized that attempts to respond to sea level rise by staving off its effects (e.g., beach renourishment, sea walls, levees) are considered (i) ineffective in the long term due to increasing sea level rise; (ii) counterproductive in the short term (e.g., by encouraging coastal development), and (iii) a poor use of valuable funds needed for adaptation projects and possible relocation of coastal residents. A

2-foot rise in sea level, which could occur as early as 2048 based on 2012 government projections, will trigger mass migrations away from coastlines that will result in significant societal challenges. Given such projections, it would be unethical not to inform property owners and buyers about their vulnerability.

As evidenced by the hundreds of new developments along U.S. coastlines, many vulnerable communities are not making long-term plans to adapt to sea level rise. Often, landowners and policy makers are uninterested in addressing the issue because of risks to coastal property values. Contributing to the problem is the perception that communities that sacrifice immediate economic prosperity to plan for future losses are highlighting a weakness that will discourage community investors. Those who deny the science behind sea level rise likely will be a hindrance to adaptation planning.

However, progress is occurring. Toms River, N.J., is working with the Jacques Cousteau National Estuarine Research Reserve to develop a proactive plan for responding to sea level rise. Miami-Dade County, Fla., which had been resistant to elevation mapping, now has created maps that examine the county's infrastructure at every 6 inches of sea level rise. Miami Beach has set aside $300 million in bond money for drainage systems and the raising of roads. The mayor of Coral Gables, Fla., has made the decision to not build levees, and to give residents a transparent view of the future, (e.g., that a 2-foot sea level rise will result in the loss of freshwater resources and sewage treatment plants serving 5 million people, roads that are unusable due to inundation, rising insurance rates, and devaluation of communities' bond ratings if they do not have plans for dealing with sea level rise). Unfortunately, communities that are attempting to plan (e.g., Pine Crest, Fla.) also are discovering that infrastructure changes are enormously costly (e.g., $40 billion to improve water drainage after a storm).

Scientific opportunities and challenges

Effective science communication is needed to counter public skepticism about sea level rise and help communities move forward with long-term planning. The crux of the challenge is that the public doesn't always believe scientists, in part because of scientific difficulties in pinpointing the rate of climate change. When short-term predictions have not proven accurate, distrust of both scientists and climate models has increased.

While the IPCC report and similar projections offer a good starting point for community planning, they may not be adequate to societal needs, in part because they do not account for natural processes that accelerate ice melt. However, an ongoing challenge to scientists is the danger of appearing "alarmist" when

communicating about the possibility of accelerated sea level rise. While it's hoped that more comprehensive, and therefore exact, sea rise models will be developed within the next 15 years, scientists also must develop better means of communicating uncertainty, while still maintaining focus on adaptation.

Although both policy makers and community members have a need for scientifically credible information regarding sea level rise, scientists should note that the most convincing avenue of public communication has been through identifying the financial risks incurred by coastal changes. In addition, examples are needed of communities and organizations that are correctly implementing adaptation measures.

Despite public skepticism and the pitfalls of scientific uncertainty, the most critical action communities can take may to use available models to begin planning now, and that scientists have a responsibility to continuously revise these models with updated data.

To plan appropriately for imminent sea level rise, it also is critical for communities to have accurate elevation maps, such as those that have been developed using LiDAR, a laser-mapping tool that yields a more accurate result than older topographical maps.

Policy issues

Although predicting the exact rate of sea level rise is difficult, coastal communities need to immediately begin long-term planning for changes to the coastlines. Current regulations are designed to maintain community life as it is now, not as it will be at higher sea levels. Planning must be based on the predicted 6.6-foot rise by the end of the century, which calculates to 2 feet as early as 2048. By planning for this 2-foot benchmark, communities will be prepared regardless of whether sea level rise progresses slower or faster than the predictions. If communities do not act, they risk losing the entirety of their infrastructure because of the overwhelming cost of maintaining it in the face of rising seas.

Before relegating planning to engineers, policy makers need to decide upon the specific actions that are most in line with the needs of their citizens, budgets, and infrastructure. Additionally, it must be recognized that there will be sectors where maintaining infrastructure will be impossible, and so planning for coastal retreat is necessary.

By developing accurate elevation maps, communities can appropriately assess the vulnerability of residences, businesses, and infrastructure with every 6 inches of sea level rise. Equally important, policy makers need to uphold construction setback lines designated by elevation maps, rather than routinely making exceptions for

financially appealing developments that exact long-term costs. It was argued that many elected officials are reluctant to focus on long-term issues due to their short (two- to four-year) terms. When local residents also are resistant to the idea of climate change, it is rare for elected officials to support policy changes for adapting to sea level rise that could be 30 or 40 years away. While some elected officials believe that sea level rise is a problem of such magnitude that policy is not the proper approach to address it, others (e.g., the mayors of Miami Beach, Pine Crest, and Coral Gables, Fla.) already have begun considering long-term planning for sea level rise. Given its controversial nature, sea level rise planning must be handled by political representatives with honesty and transparency.

Along with community planning, regulations for governmental institutions such as the Federal Emergency Management Agency (FEMA) need to be reconsidered. Although strong restrictions currently are in place for areas that sustain more than 50% storm damage, the regulations for rebuilding after storms also must be strengthened. Ideally, these restrictions not only would discourage rebuilding in high-risk areas but also would serve as incentives to strengthen local regulations against rebuilding after damage. FEMA also needs to revise its policies regarding relocation of coastal residents; currently the agency resists using funds to relocate residents who have experienced multiple storm damages as it is simpler to rebuild than to relocate.

In the face of coming sea level rise changes, communities need to implement a process for inclusively assessing their values, preferences, and needs, and then decide how to allocate funds between protective actions (e.g., beach renourishment) and adaptive measures (e.g., maintaining infrastructure at different sea levels). Legal changes also may be required (e.g., property rights, responsibility of governments to maintain infrastructures). This planning will ensure that local residents and businesses will not be blindsided by future sea level rise events.

The perception that planning for future losses projects an image of economic weakness must be challenged and changed by educated citizens and policy makers. Innovative thinking is needed to ensure that the economic strength of a community increases, rather than decreases, due to its preparedness in addressing climate issues. Serious adaptation planning for sea level rise will need this shift in ideology to the economic benefits of preparedness.

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

Thomas R. Knutson, M.S.
Head, Climate Impacts and Extremes Group, Geophysical Fluid Dynamics Lab/NOAA, Princeton, New Jersey, U.S.

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 °C to 4.5 °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.]

References

U.S. Global Change Research Program. (2014). *U.S. 2014 National Climate Assessment. Retrieved* from http://nca2014.globalchange.gov/highlights/regions/northeast#intro-section-2.

IPCC. (2013). *Climate Change 2013: The Physical Science Basis.* Contribution of Working Group 1 to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Stocker, T.F., et al., (Eds.). Cambridge University Press, Cambridge, UK.

A policy position paper prepared for presentation at the conference on "The Shore's Future: Living with Storms and Sea Level Rise," convened by the Institute on Science for Global Policy (ISGP), Nov. 20–21, 2015 in Toms River, New Jersey

Debate Summary

The following summary is based on transcriptions of a recording made during the debate of the policy position paper prepared by Mr. Thomas Knutson (see above). Mr. Knutson initiated the debate with a 5-minute statement of his views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Mr. Knutson. Although this summary has been written without attribution, the conference itself was open to the public and media and as such, did not restrict participants from attributing remarks to specific individuals. The views comprising this summary do not necessarily represent the views of Mr. Knutson, as evidenced by his policy position paper, or those of the ISGP, which does not lobby on any issue except rational thinking. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- Since a significant challenge facing policy makers stems from citizens' complacency about how climate changes might affect them personally, leaders need to demonstrate the urgency of climate change in the lives of area residents through updated information about (i) current effects of sea level rise and increased storm surge, (ii) flood- and wind-damage risk (e.g., via a Hazard Mitigation Plan), and (iii) the specific mitigation and adaptation actions the public *writ large* can take.
- Although the scientific community has a responsibility to communicate accurate, nonbiased, understandable climate science to both the public/private sectors and the public *writ large*, such communication needs to have direct relevance to individual and community-wide concerns to result in timely, effective proactive decisions. While remaining transparent about the inevitable uncertainties of climate-model results, such communication needs to emphasize the degree of confidence scientists have in their models, and, most importantly, the appropriate policies and activities required to be implemented despite these uncertainties.
- Given that the market forces underpinning insurance rates provide a tangible financial estimate of real-world risk, it is critical that its availability

and cost accurately reflect a realistic understanding of the potential impact of climate change, thereby raising consumer awareness in both the public and private sectors. The acceptance of such financial responsibilities based on risk burdens might significantly influence public and private sector policies and decision-making processes in regards to climate change (e.g., coastal homeowners would have an increased stake in climate change risk burden if their property was not subject to publicly-funded bailout and/or infrastructure rebuilding).

- To effectively plan for realistic scenarios associated with sea level rise and storm severity, the National Flood Insurance Program, private flood insurance, and public- and private-sector risk-management programs need to include climate change considerations in their flood maps. To better represent the real-world risks inherent in areas affected by rising sea levels and the increased severity of storms, the subsidies for public and private flood insurance need to be reduced.
- While the government has a responsibility to provide up-to-date risk assessments, the public has a responsibility to self-educate on the basics of the scientifically credible understanding of climate change. Educational programs and curricula need to be established, or improved, to increase science literacy among the U.S. population, especially for school children who are the community's future decision-makers.

Current realities

Unlike short-term weather forecasting, climate-change science is based on long-term statistics regarding how and why climate is changing, and so provides an actionable basis for immediate individual and public decision-making. While human activity (e.g., carbon emissions) is widely believed to be influencing global climate change, because these changes occur relatively slowly and everyone does not experience the effects at once, climate predictions can difficult for society *writ large* to accept and act upon.

Nonetheless, planning for mitigating and adapting to the effects of climate change is occurring in many parts of the private and public sectors. Because rising temperatures have created new possibilities for shipping routes through the Arctic, U.S. agencies (e.g., Coast Guard, Navy, Department of Commerce) are currently planning for the development and administration of these new environments. Similarly, the offshore oil industry has sought input from federal climate modelers in planning the construction of offshore oil platforms that must last 50 years in the face of increased storm intensity.

Despite general international concern regarding the effects of global climate change, the impacts of the changing climate continue to be experienced regionally, and ongoing scientific uncertainty exists as to the precise location and intensity of such effects (e.g., ocean acidification). In response, a new scientific subspecialty has emerged devoted solely to the research of climate change uncertainty.

Although scientists cannot predict with certainty the rate at which melting ice will raise sea levels, sea level rise is already occurring along the New Jersey shoreline and is expected to increase over the coming decades. While the IPCC Report projects sea levels to rise about a half-meter to 1 meter by 2100, several natural processes were excluded from IPCC calculations and levels may rise more quickly (e.g., up to 9 meters by 2100).

While rising sea levels and temperatures will continue cause higher storm surges in coastal communities, nationally, the trend of land-falling hurricanes is flat or even slightly decreased. Climate models are simultaneously projecting a decrease in hurricanes in the Atlantic in the coming century, but an increase in the average intensity of those hurricanes. Models indicate that recent high-intensity hurricanes are the result of warming in the tropical Atlantic and North Atlantic; because the oceans don't warm equally, however, some regions will experience more intense hurricanes than others. Hurricane-force winds are relatively rare in New Jersey, with only four events in the last 150 years: The Gale (1878), the Vagabond Hurricane (1903), Hurricane Irene (2011), and Hurricane Sandy (2012).

Climate change also elevates health risks such as heat stress, which occurs when temperature and humidity approach human body temperature, making it difficult to regulate excess body temperature and therefore making it untenable to work outdoors. Current climate models suggest if temperatures continue to rise, warm subtropical regions, including parts of New Jersey, will begin to approach this unlivable limit.

Scientific opportunities and challenges

The inevitable uncertainties and complex interactions of climate science pose an enormous challenge to effective science communication. While scientists need to improve public messaging regarding climate change risks and uncertainties, attempting to quantify uncertainty can further confuse, rather than educate, the public. Scientists need to recognize that the public and policy makers need clear and actionable information.

Because the debate about climate change often is driven by values and beliefs, providing more facts is not necessarily effective in engaging public attention. This presents a challenge to science communicators: While popular media personalities

can deny climate change by appealing to their audience's values and emotions, scientists need to base their messages on credible science, be unbiased, and are constrained by credible scientific understanding.

Although the uncertainty inherent in climate modeling impedes public action, climate models themselves may represent opportunities to increase confidence in climate science projections. Historical experiments are one way of testing the accuracy of a climate model; by entering factors or "forcings" that influence climate (e.g., solar and volcanic activity, aerosol distributions, land usage) into models that reflect atmospheric CO_2 data from 1850 to the present, scientists can see if the temperature change predicted by the model matches present day reality, enabling high confidence in the ability of the model to estimate human impact on temperature rise beyond the forcings' influence. A second type of model that provides opportunities for the scientific community is "future scenarios" modeling that compares the outcomes of three action categories: 1) status quo, 2) slight mitigation, and 3) strong mitigation. By experimenting with different iterations of the three categories, climate modelers can provide policy makers and the public with useful data. This predictive modeling approach was used to inform the drafting and passage of policies such as the phasing-out of chlorofluorocarbon products and the 1990 Clean Air Act.

Opportunities also arise from the Army Corps of Engineers Northeast Coastal Study, which assesses coastal risks along the Northeast shoreline by combining sea-level-rise scenarios with synthetic storm techniques (climate prediction approaches for estimating rain fall retention and attenuation). Such models are valuable for filling in knowledge gaps and developing accurate flood-risk maps.

Policy issues

Policy makers need to acknowledge the human role in climate change, and to use scientific information to inform mitigation and adaptation policies at all levels that increase communities' resilience and reduce CO_2 emissions. While the policy recommendations made in the position paper for this debate are valuable, they also represent "first steps" that should have been taken a long time ago.

Although the Federal Emergency Management Agency (FEMA) is now asking planners to consider risks posed by climate change (which may result in helpful dialogues about climate risks), the federal government needs to go further, requiring the National Flood Insurance Program to include projected sea level rise in its flood maps. Turning dialogue into action will require de-politicizing the issue of climate change on multiple levels — local, regional, state and federal governments. The scientific community's role in this endeavor is to provide credible scientific

and technological understanding to inform decisions in an unbiased, nonpolitical manner. Policy makers then must take this information and transform it into legislation.

The most significant challenge facing policy makers is that many citizens are hesitant to make personal choices and take actions that mitigate or adapt to the impacts of climate change because the perceived consequences of climate change occur in the distant future. Since effective decision-making in an open society depends on public engagement, public opinion is an important part of the political process. To increase public engagement and knowledge, and provide the next generation with a livable environment, governments, especially at the municipal level, need to provide (i) updated assessments of flood and wind-damage risk (e.g., through use of a FEMA-approved Hazard Mitigation Plan), (ii) simple and direct messages that help individuals understand their options for mitigating and adapting to the effects of climate change (e.g., reducing use of fossil fuels), and (iii) programs and curricula that improve science literacy in school children across all disciplines, not only climate change science.

Although the IPCC reports include a summary section intended for policy makers and concerned citizens, the summary language has grown increasingly more technical and difficult for nonscientists to understand. To effectively inform decision-making on individual, governmental and private levels, IPCC writers need to ensure that the report summaries communicate scientifically credible understanding in a comprehensible manner that engages and informs policy makers and the public *writ large*.

Groups with financial stakes at risk (e.g., insurance, offshore oil industry) are the most receptive to accepting climate change science. The insurance industry, which has heeded climate change communication and is now hiring climatologists to assess climate change risks, provides a tangible reflection of the reality of climate change, as its rates are an indication of perceived risks. The establishment of analogous financial stakes and risk burden throughout the private and public sectors might significantly influence policies and decision-making processes regarding the effects of climate change (e.g., coastal homeowners would have an increased stake in climate change risk burden if their property was not subject to publicly-funded bailout or rebuilding). Since premiums paid by consumers need to realistically reflect the risks from the effects of climate change, flood insurance offered by both the private and public sectors needs to be unsubsidized.

To help concerned citizens understand credible science regarding the effects of climate change, governments need to share information about historical successes of governmental intervention as well as future risks. Since the 1970s, environmental

regulations have improved air and water quality (e.g., the 1990 Clean Air Act, which led to the successful reduction of pollution emissions). Because the scientific and policy communities acted together in the 1980s to respond to the discovery that chlorofluorocarbons were destroying the stratosphere ozone layer, developing substitute chemicals that could be used in place of ozone-damaging chemicals and implementing policy to phase out the most damaging chemicals, today stratosphere chlorine levels are dropping and are expected to continue to improve. While policy makers need to understand the urgency for concrete climate mitigation policy, the public may be motivated to support such actions by reviewing positive past legislative actions and using them as references for future policy.

Adapting to Climate Change on the Coast: Changing Values, Behavior, and Policies**

Karen M. O'Neill, Ph.D.
Associate Professor, School of Environmental and Biological Sciences
Rutgers University, New Brunswick, New Jersey, U.S.

Summary

Coasts are experiencing the effects of climate change at the same time that coastal populations are growing. Even if we reduce carbon emissions, we will have to make some adaptations to the effects of climate change. Climate models, geological studies, and measures of sea levels show that waters are rising faster along coastlines in the northeastern United States than along other coastlines. The northeast can become a global leader in coastal adaptation by reducing harms from storm surge, wind, and flooding, while protecting vulnerable people and affirming local values for coastal living. Industry, government agencies, nongovernmental organizations, and social groups all need to act. Priorities should be to reduce development along hazardous shorelines and to use adaptive building practices throughout coastal watersheds.

Current realities

People are drawn to the water. Although few of us currently fish, sail cargo ships, or unload goods at the docks, 10% of the world's population live in low-lying shore areas. About half of the world's people live within 100 miles of a coastline and depend on its infrastructure and services. Coasts are dynamic by nature, but climate change is forcing unprecedented and dangerous changes, including sea level rise and increased likelihoods for severe storms, at the same time that even more people are moving to the shore.

Many of the human and financial costs of our over-exposure to climate risk are hidden, making it difficult for property owners and officials to appreciate the benefits of reducing hazards. Some costs are hidden because they are borne by people who attract little attention. For example, individuals who are uninsured or underinsured may be financially devastated by storm losses. Other costs are hidden because they are diffused and are borne by ecosystems, insurance and utility ratepayers, and national taxpayers. And most costs are hidden because they will happen in the future and are difficult for most of us to consider when making decisions today.

Scientific opportunities and challenges

Recognizing that intensive settlement along the shore is very recent and is increasing around the world can help us imagine a different future under climate change. This requires us to identify the causes of vulnerability (e.g., poverty, physical disabilities), the costs of inaction, what we love about the coast, and what we are willing to change. For instance, is it essential to have housing right on the sand to enjoy the beach?

The key causes of increased coastal hazards are climate change, skewed incentives for development, and building practices. Reducing carbon emissions (i.e., climate change mitigation) is necessary for reducing the rate of climate change. However, the amount of carbon already in the climate system means that we will have to adapt, no matter how much we reduce emissions. Adaptation should focus on the two other key causes for increased coastal hazards: skewed development incentives and building practices. Adaptation does include a range of other human behaviors (e.g., household disaster preparation, evacuation planning), but nearly all of these changes are needed because of coastal over-development.

The skewed nature of the incentives for developing coastal land can be understood using the demographer's perspective that people migrate in response to conditions that push and pull, such as the availability of housing. The pull of the shore is the problem. If a government is not strict in regulating coastal settlements or if it actively subsidizes development, it signals that coastal development is safe. Research also finds that disasters can become an opportunity for increased development, especially where property values were already rising. Property rights make it difficult for governments to restrict redevelopment. Yet research finds that municipalities greatly underestimate the costs of servicing sites that are repeatedly damaged.

Building practices make coastal hazards worse. Pavements and compacted grass turn rain and snow into runoff, causing inland flooding. In places where building is poorly regulated, such as poor areas in less-affluent countries, storms may easily damage flimsy buildings. Even in places with strong building codes, standards may not be suited to changing risks (e.g., by requiring houses to be elevated to reduce surge damage). And investment in high-value, nonadapted property continues in places where sea level rise is obvious. This is the case in Miami Beach, where seasonal high tides flood the streets, even in the absence of a storm.

Policy issues

Reducing hazards is not just a task for lawyers and engineers. The following recommendations concern public involvement, institutional arrangements, and social values.

- Understand that the shore is much broader than a narrow strip of sand. Ecological connections from the ocean to bays and estuaries support landscapes that are resilient. Connections can be restored where they have been broken. Removing bulkheads and other barriers allows protective coastal wetlands to migrate inland. A policy in the Netherlands called "room for the river" reduces flooding harms by prohibiting building in floodplains. This watershed-level approach requires action by the U.S. Federal Emergency Management Agency (FEMA), including the National Flood Insurance Program, the U.S. Environmental Protection Agency, the U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, state environmental agencies, municipalities, and landowners.
- Identify what people value about coastal life and how those values will be affected by climate change. This requires considering the most vulnerable people and valued sites, recognizing that climate change is creating new vulnerabilities. Processes for clarifying values have been promoted by several groups (e.g., 100 Resilient Cities, C40, Rebuild by Design, Changing Course), and social science research can assist, but bottom-up initiatives will be essential if communities are to identify and retain what they value.
- Change policies that damage ecosystems or increase social vulnerability. Municipal codes and state laws allow building in floodplains and on barrier islands or permit wetlands to be filled and replaced by inferior artificial wetlands. Gaps in regulations allow over-pumping of groundwater. State and federal environmental regulators, water supply agencies, the Army Corps of Engineers, and municipal planning boards may make some changes, but legislatures must set broader reforms.
- Recognize and reduce hazards and promote resilience. Major projects such as bridges can be designed to improve adaptation to climate change, rather than making hazards worse. Insurers, emergency responders, and utilities review their performance after disasters, a practice that others should emulate. Corporate boards must demand that firms estimate the costs and potential benefits of reducing their exposure to hazards. Federal and state regulators should request similar estimates from transportation agencies, water and electric utilities, and hospitals. FEMA and the U.S. Department of Housing and Urban Development can extend experiments allowing emergency response funds to be used for buyouts or more resilient designs, rather than rebuilding as before. State regulators and electric utilities must remove barriers to communities that wish to build

solar power microgrids for backup power. Local governments should reduce hazards in the most vulnerable sites.

- Engage with the public to identify local risks and to build support for longer-term planning. Because of homeowner protests against raising premiums for the National Flood Insurance Program, Congress will have to continue to bail out the program after catastrophic storms. By recognizing the shared benefits of harm reduction, regulators at all levels of government, nongovernmental groups, and community leaders can find some points of agreement with protest groups like Stop FEMA Now. For the near future, climate models will not be able to provide predictions down to the lot level. States, counties, and municipalities must enlist residents, emergency responders, and citizen science networks (e.g., Jersey Shore Hurricane News) as important sources of local information about changing hazards that models cannot predict. The National Science Foundation and the National Oceanic and Atmospheric Administration are beginning to encourage social science research about communication and citizen involvement in adaptive strategies, but can do much more.
- Select the right approach for the right site and communicate the limitations of each approach. Beach replenishment and artificial dunes can protect beaches for only a short while and do not protect against back-bay flooding. Engineered barriers will become more expensive and are suited only for critical infrastructure or intensively developed communities. Inland green infrastructure, such as low-lying rainwater collection sites, are helpful but filter only some of a large storm's water into the ground. The U.S. Army Corps of Engineers, consulting engineers, and municipal officials should take the lead.
- Plan to move people from dangerous shorelines and floodplains. Programs of managed retreat would be most humane and fiscally wise, despite being potentially politically unpopular. People are already retreating from the shore, household by household, with little public aid or attention. Many of them are poor or are members of ethnic minority groups, as in the Mekong Delta, Bangladesh, and rural areas of Alaska and Louisiana. Governments, engineers, landscape architects, environmental groups, and landowners can experiment with small projects. Much broader support is needed for fuller plans for managed retreat.
- Connect municipal planning to higher levels of government and coordinate actions among agencies. Cities, such as Charleston, New York,

San Francisco, and Boston have begun to plan for the future climate. Smaller cities lack this planning capacity and rely on state government help. Agency missions may also conflict, as when road-building proceeds without adequately considering its possible effect on flooding. Resilience officers at the executive level of large cities and state governments could coordinate among agencies, but must be given authority to be effective.

- Link climate adaptation to climate change mitigation. Government or private efforts to plant trees, build microgrids, or restore ecosystems can serve both mitigation and adaptation.
- Sponsor people-to-people exchanges across regions. States and nongovernmental organizations can sponsor exchanges that could share information about physical changes, new practices and institutions for adaptation, and aid from governments and funders. The Lowlander Center in Louisiana, groups from Alaska native villages, and representatives of small Pacific Island nations have begun such exchanges.

References

O'Neill, K. M., and Van Abs, D. J. (Eds.). (Forthcoming, June 2016). *Taking Chances: The Coast after Hurricane Sandy*. New Brunswick, NJ: Rutgers University Press.

Sasaki Associates, Rutgers University [Burger, J., Handel, S. N., and O'Neill, K. M.], and ARUP. (2015). Resilience + The Beach. In J. Bisker, A. Chester, and T. Eisenberg (Eds.), *Rebuild By Design* (pp. 162-177). New York, NY: Rebuild By Design, http://www.rebuildbydesign.org/book/.

Baird Team. (2015). A Delta for All. Changing Course Competition, http://deltaforall.com/.

A policy position paper prepared for presentation at the conference on "The Shore's Future: Living with Storms and Sea Level Rise," convened by the Institute on Science for Global Policy (ISGP), Nov. 20–21, 2015 in Toms River, New Jersey

Debate Summary

The following summary is based on transcriptions of a recording made during the debate of the policy position paper prepared by Dr. Karen O'Neill (see above). Dr. O'Neill initiated the debate with a 5-minute statement of her views and then actively engaged the conference participants, including other authors, throughout the remainder of the 90-minute period. This Debate Summary represents the ISGP's best effort to accurately capture the comments offered and questions posed by all participants, as well as those responses made by Dr. O'Neill. Although this summary has been written without attribution, the conference itself was open to the public and media and as such, did not restrict participants from attributing remarks to specific individuals. The views comprising this summary do not necessarily represent the views of Dr. O'Neill, as evidenced by her policy position paper, or those of the ISGP, which does not lobby on any issue except rational thinking. Rather, it is, and should be read as, an overview of the areas of agreement and disagreement that emerged from all those participating in the critical debate.

Debate conclusions

- Given that long-term coastal and floodplain resiliency is critical for the future economic sustainability and safety of coastal communities, local stakeholders, including citizens, homeowners, and the public and private sector, need to be aware of and understand the risks associated with the effects of climate change. At the municipal level, planning, design, and engineering ideas can identify development opportunities outside of floodplains and prioritize and support policies and programs targeted toward both adaptation and mitigation.
- To create consistent mitigation and adaptation polices and programs that appropriately address the effects of rising sea levels and storm severity, as well as their economic and social/cultural consequences, federal and state policies need to be coordinated with those of local municipalities. "Bottom-up" communication from local communities can help shape state and federal policies to better align and support individuals and communities most economically afflicted by the effects of climate change. Such alignment also can effectively ameliorate the socioeconomic challenges created by natural events (e.g., displacement of residents) and the mitigation and adaptation measures (e.g., relocation) enacted .

- The long-term risks associated with climate change need to be factored into cost assessments (e.g., flood insurance) related to mitigation and adaptation to provide accurate estimates and budgets. The outcomes of these assessments must inform which programs at local, state, and federal levels are most cost effective and practically useful in deploying available resources.
- While forced retreat from vulnerable coastal areas because of costly storm damage often has negative social and economic consequences for residents, managed retreat via existing land-purchase programs (e.g., Blue Acres) and innovative transition programs can enhance benefits for citizens, communities, and ecosystems. Additional innovations in technology and economics (e.g., reorienting tourism away from coastlines) can also provide opportunities that must be considered prior to, during, and immediately following natural events and political, governmental, and administration shifts.

Current realities

Given the continuing impact of hurricanes and flooding along the New Jersey shorelines, there is concern that current rebuilding policies and mitigation activities encourage residents to continue living in dangerous coastal areas rather than relocating away from the floodplain. The long-term costs associated with coastal developments, and the resulting possibility of property tax rate increases to pay for these costs, are not fully communicated to taxpayers. Because homeowners often believe they will be able to sell their homes before climate change worsens, short-term investors perpetuate the dangers of rebuilding in areas already experiencing sea level rise effects (e.g., saltwater in streets).

Despite the perception that new developments along the shore will lead to financial growth for municipalities, economic research in selected areas of New Jersey has demonstrated a hidden effect: a rising cost in services (e.g., through the rebuilding and maintenance of infrastructure) as climate change proceeds. Similarly, low tax revenues from those areas were found to lead to a rise in the municipality's overall tax rate. The construction of preventative infrastructure (e.g., dikes, levees, sea walls) near new developments has had the effect of raising property values in high-risk areas, further encouraging shore development.

In the past, catastrophic events (e.g., Hurricane Sandy) have resulted in problematic, top-down decision-making by federal and state government that promotes rebuilding in areas prone to hazardous flooding. Local interest in increasing property values by encouraging new development in such areas is

furthered by the presence of many elected municipal officials who also are builders. Because of the large number of municipalities in New Jersey (565), there is also significant difficulty in establishing consistent regulations across municipalities on development and adaptation measures.

Second-home owners in coastal communities also play a significant role in the development of high-risk areas. Their lack of community engagement and frequent lack of insurance coverage are factors likely to increase the costs borne by local residents.

Flood damage, including river flooding, is the leading cause and expense in disaster damages in the United States. Although flood insurance by private firms could insure homeowners against damages from sea level rise effects, the policies' year-to-year coverage is considered a limitation to ensuring proper protection of residents' homes.

Despite continued development and protection, at-risk coastal areas are experiencing a forced retreat by many long-term residents because of the high costs associated with rebuilding (e.g., expense of meeting new building codes) and associated social factors (e.g., New Jersey shoreline gentrification, affordability of housing). As people retreat from hazardous areas with the most valuable tax rates (e.g., 10% to 15% of Toms River's property tax base), there is additional concern that costs will be passed on to vulnerable residents left in those areas.

With a potential reduction in federal support as demand for post-disaster assistance increases, the state government's role in addressing the effects of sea level rise is paramount. State alternatives such as New York Governor Andrew Cuomo's buyout of residents in the Oakwood Beach area of Staten Island illustrate a rare, but effective approach. Other examples of managed retreat or transitioning include implementing a "two homes" program (e.g., Louisiana) whereby people alternate between living inland and along the coast, eventually leading to their permanent transition from the coast.

Scientific opportunities and challenges

There is a need to create a "risk-aware" culture on climate change through the communication of scientifically credible risks. Educating citizens within communities on the difference between mitigation (e.g., reducing carbon emissions) and adaptation (e.g., dealing with unavoidable effects of climate change) is an important step in enhancing understanding the affects of climate change, as well as influencing individuals' receptivity to relevant policies and programs.

Applying specific cases (e.g., the aftermath of Hurricane Sandy) can provide a foundation for explaining some of the future risks presented by coastal living,

especially for individuals unaffected by the disaster. However, because each storm presents unique circumstances and dangers, such examples need to be presented in context and not in isolation.

Due to this variation of risks related to locations and populations, a scientific opportunity exists at the municipal level to address these different tolerances (i.e., tipping points in risk culture) based on the value of local knowledge of a particular area. Highlighting routine events (e.g., basement and street flooding), and gathering data from long-term monitoring systems (e.g., river gauges that observe flooding frequency) provide evidence of the current local effects of climate change, and can be used to support local policies (e.g., watershed management and adaptive planning). The dissemination of this information through the involvement of scientists and municipal officials is necessary for helping people understand difficult sea level rise issues (e.g., how Barnegat Bay can affect flooding conditions at residents' homes).

Ecosystem-based services along the New Jersey shoreline present both scientific and economic opportunities for individuals and communities to mitigate and adapt to climate change. In areas such as the Barrier Islands, enhancing coastal wetlands can increase resilience to flooding while contributing to the mitigation of carbon emissions (e.g., through carbon capture). However, as demonstrated by local mapping (e.g., by Jamaica Bay consortium science organizations and universities), man-made structures such as bridges and roads often have hampered the ability of wetlands to expand or migrate. Declining marsh quality (e.g., near Jacques Cousteau Research Center and Cape May Wetlands) is a pressing ecological challenge that needs to be addressed due to the importance of marshes in adaptation projects.

Policy issues

Although the current disaster-recovery structure emphasizes short-term approaches, all levels of government need to develop plans that focus on long-term responses to recurring flooding events. This shift to a longer-term policy perspective could overcome the inherent problems caused by two-year and four-year election cycles, which deter many policy makers from proposing policy solutions that deliver future benefits but at immediate costs. At the municipal level, planning, design, and engineering ideas can support towns by promoting a "risk aware" culture of adaptation (e.g., proposals for a city's redesign, engagement of public input) and development opportunities exist in areas that are not located in floodplains.

A bottom-up approach to coastal adaptation and improved incorporation of municipal planners in state and federal decision-making are crucial for effectively mitigating and adapting to the effects on communities of long-term climate change. While adoption of stricter building codes by municipalities in New Jersey will help

create greater resiliency for people who rebuild in coastal communities, without efforts to align state and local building codes, these local codes could be undermined. An approach that encourages communication between municipal and state officials is especially important in managing areas of high risk to address areas considered risk-prone by local officials (e.g., the introduction of state coastal management rules that permit rebuilding in areas deemed unwise by local officials). Since rebuilding damaged structures and infrastructure and new developments raise increasing concerns about population growth in vulnerable areas, consistency across various levels of government can address modern planning issues within older systems, some dating to the 19th century. Joint regional planning between municipalities (e.g., Atlantic and Cape May County), also can assist in creating better uniformity of goals.

New Jersey land-acquisition programs (e.g., Green Acres, Blue Acres) to buy lands prone to flooding need to be promoted and potentially expanded to increase usage by community residents living in areas prone to damage from severe storms and sea level rise. The Green Acres program converts acquired land into recreational spaces (e.g., baseball fields) and the Blue Acres program converts publicly acquired land into accessible open spaces that also serve as natural buffers against future storms. Because the Blue Acres Program is a way to simultaneously relocate people from hazardous areas while creating conservation spaces that play a protective role (e.g., wetlands), it may be a more effective program.

Federal compensation to coastal communities after natural disasters (e.g. Hurricane Sandy, Katrina) has led to conflicting results regarding those communities' adaptation and mitigation efforts regarding the effects of climate change. The future availability of funding through the federal government's National Flood Insurance Program (NFIP) is uncertain, as demonstrated by the need for Congress to financially supplement the program in recent years. In the future, state laws such as New Jersey's right-to-rebuild provisions (e.g., Coastal Areas Facilities Review Act), will need to be aligned with federal programs (e.g., NFIP). Despite past financial policies regulating new development (e.g., federally insured bank loans that require flood insurance), additional insurance measures are needed to ensure that residents and second-home owners who choose to rebuild in high-risk areas are adequately covered in the event of a disaster. Insurance programs that provide more realistic coverage (e.g., eliminating the too-low $250,000 compensation cap for damage to homes) may be necessary to ensure people are not forced to make pivotal decisions under duress.

Although tourism-related activities traditionally have centered on coastal beach areas, encouraging an inland shift in tourist activity (e.g., Toms River, Barnegat Bay areas) could possibly relieve development pressure on vulnerable

areas prone to natural disasters. Through the promotion of ecotourism activities (e.g., bird watching, swimming in lakes), related ecosystem values (e.g., economic and environmental benefits) could be enhanced over time. However, the costs of applying an ecosystem approach to economic development and growth are not necessarily borne by the same group of people that benefit from the services (i.e., people who have to relocate versus tourists).

Stronger state regulation of coastal areas or complete state ownership of beaches (e.g., California) rather than portions under private ownership and control can assist in better coastal management. Current legislation in New Jersey (e.g., the National Shore Coastal Carrier Island Resources Act) that restricts development in uninhabited areas is consistent with proposals to reorient tourist activities towards an ecosystem-based model, while limiting the vulnerability of people inhabiting certain areas.

Policy makers and community leaders need to take advantage of all opportunities to advance adaptation and mitigation plans, including flooding and storm events, new technology, and new political administrations (e.g., following the impacts of severe storms along the Mississippi River and Sacramento River, existing plans for the building of levees were proposed before Congress, and Governor Cuomo in New York took the opportunity after Hurricane Sandy to discuss the effects of climate change).

Acknowledgments

Numerous individuals and organizations have made important contributions to the Institute on Science for Global Policy (ISGP) on Climate Change Program (ICCP) in general and to the conference entitled *The Shore's Future: Living with Storms and Sea Level Rise*. This conference was organized and convened on November 20-21, 2015 in Toms River, New Jersey, in partnership with several groups including the Barnegat Bay Partnership, the Barnegat Bay Foundation, the Jay and Linda Grunin Foundation, and local government. Other contributions aided the ISGP in preparing the material presented in this report, including the three policy position papers prepared by invited presenters, and the not-for-attribution summaries of the views presented in the discussions, critical debates, and caucuses that ensued.

Of special significance were the efforts of the three distinguished subject-matter experts invited by the ISGP to present their views in each of the three concise policy position papers that were debated. The biographies of these three authors are provided here. The ISGP also greatly appreciates the willingness of those in the scientific and policy communities who agreed to be interviewed by the ISGP staff as they organized the ICCP conference presenters and debaters.

The success of every ISGP conference critically depends on the active engagement of all invited participants in the often-intense debates and caucuses. The exchange of strongly held views, innovative proposals, and critiques generated from questions and debates fosters an unusual, and even unique, environment focused on clarifying understanding for the nonspecialist. These debates and caucuses address specific questions related to both formulating and implementing effective public and private sector policies. The ISGP is greatly indebted to the wide range of policy makers, scientists, students, and community members who engaged in the vigorous debates and caucuses that comprise all ISGP conferences.

The members of the ISGP Board of Directors also deserve recognition for their time and efforts in helping to create a vital, increasingly relevant not-for-profit organization focused on addressing many of the most important societal questions of our time. Their brief biographical backgrounds are presented at the end of this book.

The staff of the Barnegat Bay Partnership, as well as staff members from the Toms River Township and local volunteers, also merit special acknowledgment for their efforts to help organize and convene this ISGP conference. The contributions of the staff members of the Barnegat Bay Partnership in planning the ICCP conference

and assembling the diverse and knowledgeable debaters seated around the table are greatly appreciated. Brief biographical backgrounds of the conference volunteers and the ISGP Academic Partnership (IAP) interns from Western Connecticut State University who contributed to the organization and functioning of the conference are provided in this report.

The energetic, highly professional interviewing, organizing, and writing skills of the ISGP staff were essential to not only structuring the conference itself, but also to recording the often-diverse views and perspectives expressed in the critical debates, accurately capturing the areas of consensus and actionable next steps from the caucuses, and persevering through the extensive editing process needed to assure the accuracy of the material published here. Their biographies are provided in this report.

ISGP programs are financially supported by government agencies and departments and through gifts from private-sector entities and philanthropic organizations and individuals. Specifically, the ICCP conference *The Shore's Future: Living with Storms and Sea Level Rise* received funding for the general activities of the ISGP as generous gifts provided by The Sloan Foundation, the MARS Corp., Edward and Jill Bessey, the Barnegat Bay Foundation, and the Jay and Linda Grunin Foundation. The Toms River Township and Ocean County College generously provided the conference venues.

Dr. George H. Atkinson
Founder and Executive Director
Institute on Science for Global Policy
December 20, 2015

ISGP books from ISGP conferences listed below are available to the public and can be downloaded from the ISGP Web site: www.scienceforglobalpolicy.org. Hardcopies of these books are available by contacting info@scienceforglobalpolicy.org.

ISGP conferences on, or related to, Emerging and Persistent Infectious Diseases (EPID):

- *EPID: Focus on Antimicrobial Resistance,* convened March 19–22, 2013, in Houston, Texas, U.S., in partnership with the Baylor College of Medicine.
- *21st Century Borders/Synthetic Biology: Focus on Responsibility and Governance*, convened December 4–7, 2012, in Tucson, Arizona, U.S., in partnership with the University of Arizona.
- *EPID: Focus on Societal and Economic Context*, convened July 8–11, 2012, in Fairfax, Virginia, U.S., in partnership with George Mason University.
- *EPID: Focus on Mitigation*, convened October 23–26, 2011, in Edinburgh, Scotland, U.K., in partnership with the University of Edinburgh.
- *EPID: Focus on Prevention*, convened June 5–8, 2011, in San Diego, California, U.S.
- *EPID: Focus on Surveillance*, convened October 17–20, 2010, in Warrenton, Virginia, U.S.
- *EPID: Global Perspectives*, convened December 6–9, 2009, in Tucson, Arizona, U.S., in partnership with the University of Arizona.

ISGP conferences on Food Safety, Security, and Defense (FSSD):

- *FSSD: Equitable, Sustainable, and Healthy Food Environments*, to be convened May 1–4, 2016, in Vancouver, Canada, in partnership with Simon Fraser University.
- *FSSD: Food Security and Diet-linked Public Health Challenges*, convened September 20–23, 2015 in Fargo, North Dakota, in partnership with North Dakota State University.
- *FSSD: Focus on Food and the Environment*, convened October 5–8, 2014, in Ithaca, New York, in partnership with Cornell University.
- *FSSD: Focus on Food and Water,* convened October 14–18, 2013, in Lincoln, Nebraska, U.S., in partnership with the University of Nebraska–Lincoln.

- *FSSD: Focus on Innovations and Technologies,* convened April 14–17, 2013, in Verona, Italy.
- *FSSD: Global Perspectives,* convened October 24, 2012, in Arlington, Virginia, U.S., in partnership with George Mason University.

ISGP Academic Partnership (IAP) conferences

- *The Socioeconomic Context of Sustainable Agriculture*, to be convened mid-October 2016, in Danbury, Connecticut, U.S., in partnership with Western Connecticut State University.
- *Water and Fire: Impacts of Climate Change*, to be convened April 10–11, 2016, in Sacramento, California, U.S., in partnership with California State University, Sacramento
- *Communicating Science for Policy, convened August 10–11, 2015, in Durham, North Carolina, in partnership with Sigma Xi, The Scientific Research Society.*
- *Food Security: Production and Sustainability*, convened April 24–25, 2015, in St. Petersburg, Florida, in partnership with Sigma Xi, The Scientific Research Society, and Eckerd College.
- *FSSD: Safeguarding the American Food* Supply, convened April 10–11, 2015, in Collegeville, Pennsylvania, in partnership with Sigma Xi, The Scientific Research Society, and Ursinus College.
- *EPID: Focus on Pandemic Preparedness,* convened April 11–12, 2014, in Collegeville, Pennsylvania, U.S., in partnership with Ursinus College.

ISGP conferences on Science and Governance (SG):

- *The Genomic Revolution,* convened September 6, 2013, in cooperation with the Parliamentary Office on Science and Technology of the British Parliament within the House of Lords. London, United Kingdom.

ISGP reports from ISGP conferences on Global Challenges are available to the public and can be downloaded from the ISGP Web site: www.scienceforglobalpolicy.org:

- ISGP Climate Change Program (ICCP): *The Shore's Future: Living with Storms and Sea Level Rise*, November 20–21, 2015, in cooperation with several local partners, including the Barnegat Bay Partnership and the

Barnegat Bay Foundation with financial support provided by the Jay and Linda Grunin Foundation.

- ICCP: *Sea Level Rise: What's Our Next Move*, convened Oct. 2–3, 2015, in St. Petersburg, Florida, in cooperation with the St. Petersburg/Pinellas County Working Group and the Institute for Strategic Policy Solutions at St. Petersburg College.
- ISGP Climate Change Arctic Program (ICCAP): *Sustainability Challenges: Coping with Less Water and Energy,* convened June 5, 2015, in Whittier, California, in cooperation with the Whittier Working Group.
- ICCAP: *Living with Less Water*, convened February 20–21, 2015, in Tucson Arizona, in cooperation with the Tucson Working Group.

Biographical information of Scientific Presenters

Thomas R. Knutson, M.S.

Mr. Knutson is a research meteorologist and climate modeler at the Geophysical Fluid Dynamics Lab (GFDL), a research laboratory of the National Oceanic and Atmospheric Administration (NOAA) that is located in Princeton, New Jersey. He currently is head of GFDL's Climate Impacts and Extremes Group. He is a co-chair of the World Meteorological Organization's Expert Team on Climate Change Impacts on Tropical Cyclones. He served on the author team of the U.S. National Assessment and as a contributing author on the IPCC Fourth Assessment Report. He is a Fellow of the American Meteorological Society, and currently serves as an Associate Editor for the *Journal of Climate*. He received an M.S. in Meteorology from University of Wisconsin-Madison. Mr. Knutson's research interests include tropical cyclones and climate change, the impacts of climate change, and climate change detection and attribution.

Karen M. O'Neill, Ph.D.

Dr. O'Neill is a sociologist in the Human Ecology Department at Rutgers University. She studies how policies about land and water affect government power, the status of experts, and the well-being of various social groups. Topics include biodiversity protections in the urban plans of large cities around the world, local slow growth and pro-growth movements and policies in small towns, river flood control, and coastal storm vulnerability and municipal hazard reduction. She has written or co-edited books on landowners, the rise of the U.S. program for river flood control, and growth of government power (Duke University Press), on race and Hurricane Katrina (Rutgers University Press), and on changes in institutions in response to Hurricane Sandy (forthcoming from Rutgers University Press). She is a member of teams in two international competitions for coastal resilience designs, one for the New Jersey shore after Hurricane Sandy, under the "Rebuild by Design" competition (finalist team), and the second to use the Mississippi River to replenish coastal land in Louisiana, under the "Changing Course" competition (one of three winning teams).

Harold R. Wanless, Ph.D.

Dr. Wanless is Professor and Chair of the Department of Geological Sciences at the University of Miami. He received his bachelor's degree in Geology at Princeton

University, his M.S. in Marine Geology at the School of Marine and Atmospheric Science at the University of Miami, and his Ph.D. in Earth and Planetary Sciences at Johns Hopkins University. In 2010, he was named a Cooper Fellow in the College of Arts and Sciences at the University of Miami. Dr. Wanless actively interacts with policy and legislative groups at the local to federal levels to guide necessary decisions, including speaking at Everglades Coalition annual meetings, various Florida Legislative committees, environmental and industry executive and steering committees, and the Council on Environmental Quality in the White House. He was co-chair of the Science Committee of the Miami-Dade County Climate Change Advisory Task Force from 2006 to 2011 and works with the South Florida Regional Planning Council to provide the science background for and projections of sea level rise for the coming century. He currently has an active research program documenting hurricane effects on coastal environments, the geological and historical evolution of coastal and shallow marine environments, and the influences of sea level rise and anthropogenic stresses.

Conference Debaters

Mary Ann Bageac
Physician and Executive Director
Barnegat Bay Foundation

Cynthia Bianco
Community Resilience Planner
Tetra Tech Inc.

Matthew Csik
Assistant Public Health Coordinator
Ocean County Health Department

Catherine Duckett
Interim Dean
Monmouth University

Stewart Farrell
Director
Richard Stockton Coastal Research Center

Heather Fenyk
President, Lower Raritan
Watershed Partnership

Jenna Gatto
Community Resilience Specialist
Jacques Cousteau National Estuarine Research Reserve

Kathryn Goddard
Biology Professor
Ursinus College

Jeremy Grunin
Investor /Developer /Philanthropist
Jay and Linda Grunin Foundation

Stan Hales
Program Director
Barnegat Bay Partnership

Cyd Hamilton
Ecologist
Oak Ridge Institute for Science and Education

Joseph Hartnett
Consultant
Normandy Shores Beach Club

Chris Huch
Community Resiliency Specialist
Jacques Cousteau National Estuarine Research Reserve

Matt Kennedy
Vice President
Ocean County College

Bill Koch
Chemist
WFK Consulting LLC

Pankaj Lal
Assistant Professor
Montclair State University

Lance Landgraf, Jr.
Director of Planning, NJ Casino
Reinvestment Development Authority

Noelle Lotano
Executive Director, Greater Toms River Chamber of Commerce

David McKeon
Planning Director
Ocean County Department of Planning

John Miller
Water Resources Engineer,
Legislative Committee Chair, NJ Association for Floodplain Management

Theodora Pinou
Biology Professor
Western Connecticut University

Michael Schwebel
Community Resilience and Climate
Adaptation Specialist / Professor
New Jersey Sea Grant & Urban Coast Institute, Monmouth University

Peter Straub
Dean
Stockton University

Lenore Tedesco
Executive Director
The Wetlands Institute

Patricia Thompson
8th Grade Science Teacher
Toms River Schools

Daniel Van Abs
Department of Human Ecology
Rutgers University

Sarah Watson
Graduate Student, Bloustein School for Planning and Public Policy
Rutgers University

Britta Wenzel
Executive Director
Save Barnegat Bay

Biographical information of ISGP Board of Directors

Dr. George Atkinson, Chairman

Dr. Atkinson founded the Institute on Science for Global Policy (ISGP) and is an Emeritus Professor of Chemistry, Biochemistry, and Optical Science at the University of Arizona. He is former head of the Department of Chemistry at the University of Arizona, the founder of a laser sensor company serving the semiconductor industry, and Science and Technology Adviser (STAS) to U.S. Secretaries of State Colin Powell and Condoleezza Rice. He launched the ISGP in 2008 as a new type of international forum in which credible experts provide governmental and societal leaders with understanding of the science and technology that can be reasonably anticipated to help shape the increasingly global societies of the 21st century. Dr. Atkinson has received National Science Foundation and National Institutes of Health graduate fellowships, a National Academy of Sciences Post Doctoral Fellowship, a Senior Fulbright Award, the SERC Award (U.K.), the Senior Alexander von Humboldt Award (Germany), a Lady Davis Professorship (Israel), the first American Institute of Physics' Scientist Diplomat Award, a Titular Director of the International Union of Pure and Applied Chemistry, the Distinguished Service Award (Indiana University), an Honorary Doctorate (Eckerd College), the Distinguished Achievement Award (University of California, Irvine), and was selected by students as the Outstanding Teacher at the University of Arizona. He received his B.S. (high honors, Phi Beta Kappa) from Eckerd College and his Ph.D. in physical chemistry from Indiana University.

Dr. Ben Tuchi, Secretary/Treasurer

Dr. Tuchi is chairman of the board of directors of the Arizona Research Park Authority. He received his B.S. and M.S. degrees in Business Administration from the Pennsylvania State University and his PhD in Finance from St Louis University. His full-time teaching career began in 1961 at St. Francis College and continued until 1976 at West Virginia University. From 1976 through 1996 he served in cabinet levels at West Virginia University, The University of Arizona, The University of North Carolina at Chapel Hill, and finally as Sr. Vice Chancellor for Business and Finance of the University of Pittsburgh. During those assignments he was simultaneously a tenured professor of finance. He retired from the last executive post in 1996 and returned to a full-time teaching position as Professor of Finance at the University of Pittsburgh, until his retirement in 1999. For the two years prior to his retirement he

was the Director of Graduate Programs in Business in Central Europe, at Comenius University, making his home in Bratislava, The Slovak Republic.

Dr. Janet Bingham, Member

Dr. Bingham is President of the George Mason University (GMU) Foundation and GMU's Vice President for Advancement and Alumni Relations. GMU is the largest university in Virginia. Previously, she was President and CEO of the Huntsman Cancer Foundation (HCF) in Salt Lake City, Utah. The foundation is a charitable organization that provides financial support to the Huntsman Cancer Institute, the only cancer specialty research center and hospital in the Intermountain West. Dr. Bingham also managed Huntsman Cancer Biotechnology Inc. In addition, she served as Executive Vice President and Chief Operating Officer with the Huntsman Foundation, the private charitable foundation established by Jon M. Huntsman Sr. to support education, cancer interests, programs for abused women and children, and programs for the homeless. Before joining the Huntsman philanthropic organizations, Dr. Bingham was the Vice President for External Relations and Advancement at the University of Arizona. Prior to her seven years in that capacity, she served as Assistant Vice President for Health Sciences at the University of Arizona Health Sciences Center. Dr. Bingham was recognized as one of the Ten Most Powerful Women in Arizona.

Dr. Henry Koffler, Member

Dr. Koffler is President Emeritus of the University of Arizona (UA). He served as President of the UA from 1982-1991. From 1982 he also held professorships in the Departments of Biochemistry, Molecular and Cellular Biology, and Microbiology and Immunology, positions from which he retired in 1997 as Professor Emeritus of Biochemistry. His personal research during these years concentrated on the physiology and molecular biology of microorganisms. He was Vice President for Academic Affairs, University of Minnesota, and Chancellor, University of Massachusetts/Amherst, before coming to the UA. He taught at Purdue University, where he was a Hovde Distinguished Professor, and the School of Medicine at Western Reserve University (now Case Western Reserve University). Dr. Koffler served as a founding Governor and founding Vice-Chairman of the American Academy of Microbiology, and as a member of the governing boards of Fermi National Accelerator Laboratory, the Argonne National Laboratory, and the Superconducting Super Collider Laboratory. He was also a board member of the Association of American Colleges and Universities, a member and Chairman of the Council of Presidents and a member of the executive committee of the National Association of Land Grant Colleges and Universities. He was also Founder, President and board

member of the Arizona Senior Academy, the driving force in the development of the Academy Village, an innovative living and learning community. Among the honors that Dr. Koffler has received are a Guggenheim Fellowship and the Eli Lilly Award in Bacteriology and Immunology.

Mr. Jim Kolbe, Member

For 22 years, Mr. Kolbe served in the United States House of Representatives, elected in Arizona for 11 consecutive terms, from 1985 to 2007. Mr. Kolbe is currently serving as a Senior Transatlantic Fellow at the German Marshall Fund of the United States, and as a Senior Adviser to McLarty Associates, a strategic consulting firm. He advises on trade matters as well as issues of effectiveness of U.S. assistance to foreign countries, on U.S.-European Union relationships, and on migration and its relationship to development. He is also Co-Chair of the Transatlantic Taskforce on Development with Gunilla Carlsson, the Swedish Minister for International Development Cooperation. He also is an adjunct Professor in the College of Business at the University of Arizona. While in Congress, he served for 20 years on the Appropriations Committee of the House of Representatives, was chairman of the Treasury, Post Office and Related Agencies subcommittee for four years, and for his final six years in Congress, he chaired the Foreign Operations, Export Financing and Related Agencies subcommittee. He graduated from Northwestern University with a B.A. degree in Political Science and then from Stanford University with an M.B.A. and a concentration in economics.

Dr. Charles Parmenter, Member

Dr. Parmenter is a Distinguished Professor Emeritus of Chemistry at Indiana University. He also served as Professor and Assistant and Associate Professor at Indiana University in a career there that spanned nearly half a century (1964-2010). He earned his bachelor's degree from the University of Pennsylvania and served as a Lieutenant in the U.S. Air Force from 1955-57. He worked at DuPont after serving in the military and received his Ph.D. from the University of Rochester and was a Postdoctoral Fellow at Harvard University. He has been elected a Member of the National Academy of Sciences and the American Academy of Arts and Sciences, and a Fellow of the American Physical Society and the American Association for the Advancement of Science. He was a Guggenheim Fellow, a Fulbright Senior Scholar, and received the Senior Alexander von Humboldt Award in 1984. He has received the Earle K. Plyler Prize, was a Spiers Medalist and Lecturer at the Faraday Society, and served as Chair of the Division of Physical Chemistry of the American Chemical Society, Co-Chair of the First Gordon Conference on Molecular Energy Transfer, Co-organizer of the Telluride Workshop on Large Amplitude Motion and

Molecular Dynamics, and Councilor of Division of Chemical Physics, American Physical Society.

Mr. Thomas Pickering, Member

Mr. Pickering is Vice Chairman of Hills & Co, international consultants, and Strategic Adviser to NGP Energy Capital Management. He co-chaired a State-Department-sponsored panel investigating the September 2012 attack on the U.S. diplomatic mission in Benghazi. He served as U.S. ambassador to the United Nations in New York, the Russian Federation, India, Israel, El Salvador, Nigeria, and the Hashemite Kingdom of Jordan. Mr. Pickering also served on assignments in Zanzibar and Dar es Salaam, Tanzania. He was U.S. Under Secretary of State for Political Affairs, president of the Eurasia Foundation, Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs, and Boeing Senior Vice President for International Relations. He also co-chaired an international task force on Afghanistan, organized by the Century Foundation. He received the Distinguished Presidential Award in 1983 and again in 1986 and was awarded the Department of State's highest award, the Distinguished Service Award in 1996. He holds the personal rank of Career Ambassador, the highest in the U.S. Foreign Service. He graduated from Bowdoin College and received a master's degree from the Fletcher School of Law and Diplomacy at Tufts University.

Dr. Eugene Sander, Member

Dr. Sander served as the 20th president of the University of Arizona (UA), stepping down in 2012. He formerly was vice provost and dean of the UA's College of Agriculture and Life Sciences, overseeing 11 academic departments and two schools, with research stations and offices throughout Arizona. He also served as UA Executive Vice President and Provost, Vice President for University Outreach and Director of the Agricultural Experiment Station and Acting Director of Cooperative Extension Service. Prior to his move to Arizona, Dr. Sander served as the Deputy Chancellor for biotechnology development, Director of the Institute of Biosciences and Technology, and head of the Department of Biochemistry and Biophysics for the Texas A&M University system. He was Chairman of the Department of Biochemistry at West Virginia University Medical Center and Associate Chairman of the Department of Biochemistry and Molecular Biology at the College of Medicine, University of Florida. As an officer in the United States Air Force, he was the assistant chief of the biospecialties section at the Aerospace Medical Research Laboratory. He graduated with a bachelor's degree from the University of Minnesota, received his master's degree and Ph.D. from Cornell University and completed postdoctoral study at

Brandeis University. As a biochemist, Dr. Sander worked in the field of mechanisms by which enzymes catalyze reactions.

Mr. Richard Armitage, Special Adviser

Mr. L. Armitage is the President at Armitage International, where he assists companies in developing strategic business opportunities. He served as Deputy Secretary of State from March 2001 to February 2005. Mr. Armitage, with the personal rank of Ambassador, directed U.S. assistance to the new independent states (NIS) of the former Soviet Union. He filled key diplomatic positions as Presidential Special Negotiator for the Philippines Military Bases Agreement and Special Mediator for Water in the Middle East. President Bush sent him as a Special Emissary to Jordan's King Hussein during the 1991 Gulf War. Mr. Armitage also was Deputy Assistant Secretary of Defense for East Asia and Pacific Affairs in the Office of the Secretary of Defense. He graduated from the U.S. Naval Academy. He has received numerous U.S. military decorations as well as decorations from the governments of Thailand, Republic of Korea, Bahrain, and Pakistan. Most recently, he was appointed an Honorary Companion of The New Zealand Order of Merit. He serves on the Board of Directors of ConocoPhillips, ManTech International Corporation, and Transcu Ltd., is a member of The American Academy of Diplomacy as well as a member of the Board of Trustees of the Center for Strategic and International Studies.

Biographical information of ISGP staff

George Atkinson, Ph.D. Dr. Atkinson is the ISGP Founder and Executive Director and an Emeritus Professor of Chemistry, Biochemistry and Optical Science at the University of Arizona. His professional career includes academic teaching, research, administration, roles as a corporate founder and executive, and public service at the federal level. He is former Science and Technology Advisor (STAS) to U.S. Secretaries of State Colin Powell and Condoleeza Rice. Dr. Atkinson is the former president of Sigma Xi, The Scientific Research Society.

Jennifer Boice, M.B.A, ISGP Program Coordinator, worked for 25 years in the newspaper industry at the Tucson Citizen and USA Today, and was the Editor of the Tucson Citizen when it was closed in 2009. Ms. Boice received her M.B.A. from the University of Arizona and graduated from Pomona College in California with a degree in economics.

Sweta Chakraborty, Ph.D., ISGP Associate Director, received her doctorate in Risk Management from King's College London, and has more than 20 published articles, has contributed to three books, and is author of the forthcoming book "Pharmaceutical Safety: A Study in Public and Private Regulation." She is currently an adjunct assistant professor at Columbia University and a program associate at Oxford University's Centre for Socio-Legal Studies.

Casey L. Bannon, B.S., received her undergraduate degree in Environmental Science from Davis and Elkins College, Elkins West Virginia. She currently is pursuing a Private Pilots License at Hagerstown Flight School in Maryland.

Barbara Del Castello, B.A., ISGP Senior Fellow, is a graduate of Eckerd College, St. Petersburg, Florida, with a degree in Biology and a minor in Anthropology and currently is conducting post baccalaureate research on the genetic origins of the thymus at the University of Georgia, Athens.

Torsten Fiebig, Ph.D, an ISGP Fellow, Founder and Chief Executive of Advanced Optix Research, LLC. He holds two doctorate degrees in science, has been a professor and conducted research at various academic institutions, including the California

Institute of Technology, Northwestern University and the Max Planck Institute for Biophysical Chemistry (Germany). His research interests include energy sciences, medical optics and biological physics.

Christina Medvescek, B.A., ISGP Program Administrator, is an internationally published journalist and editor specializing in health, human development and cooperative conflict resolution. The former Vice President of Publications for the Muscular Dystrophy Association, she is an EEO mediator for the U.S. Postal Service, and a mediator, facilitator and instructor for the Center for Community Dialogue, Tucson, AZ.

Aubrey Paris, B.S., ISGP Senior Fellow, received undergraduate degrees in Chemistry and Biology from Ursinus College and is currently pursuing a Ph.D. in Inorganic Chemistry at Princeton University. A co-founder of Globalized Ethics for Medical Science (GEMS), LLC, a prototype infectious-disease reporting database, she has served as a Fellow of the Ursinus College Center for Science and the Common Good since its inception in 2012.

Joseph Roberts, Ph.D, ISGP Senior Fellow, earned his doctorate in social psychology from The Ohio State University in 2011. His research has examined the influence of mindsets on self-control, planning, and decision-making in health and public policy domains. In addition to his work for ISGP, he teaches courses in psychology, statistics, and research methods at The Ohio State University in Columbus, Ohio.

Andrea Vazquez, ISGP Fellow, is a senior at Arizona State University pursuing her bachelor's degree in social work. She is also a College Prep-Assistant at a high school in Tucson, Arizona. Her goal as a social worker is to challenge social injustice and advocate for people who are vulnerable and oppressed, especially youth.

Cleo Warner, B.A., ISGP Fellow, is a 2015 Eckerd College graduate with a degree in Literature and Environmental Studies. Her love for studying food systems is leading her through farming adventures all over the globe before eventually pursuing her graduate degree.

Biographical information of ISGP Academic Partnership (IAP) interns from Western Connecticut State University

Waverly Rose Brim is a junior at Western Connecticut State University majoring in Biology with a Pre-Medical track in the university's honors program. She has participated in research at Georgetown and Yale University and plans on pursing an M.D. and later, specializing in surgery. She is a Clinical Research Associate in St. Vincent Medical Center's Emergency Room.

Michelle Bissett is a junior at Western Connecticut State University, pursuing a degree in biology that focuses on ecological sciences. She hopes to have a career that allows her to make a positive impact in the world.

Alex Potocki is a BA/MA Mathematics candidate at Western Connecticut State University, focusing on an actuarial science path. He has passed two actuarial exams, and preparing for his third. He has completed two research assignments in the area of Applied Mathematics. One used applied wavelet theory to embed a message into an image, and the other applied financial mathematics to calculate the optimal wholesale price of a brand name product in the presence of a generic and competitive product.

Jasmine Jacobs, a Connecticut resident, is studying biology at Western Connecticut State University. Her interest in the sciences inspires and feeds her enthusiasm for her artwork and love of the natural world. She looks to the future with the hopes of getting published and being a teacher.

David Rothbart is a biology major at Western Connecticut State University with a strong interest in population genetics and mathematics. He is involved in several research projects and is aiming to be published for the first time by the end of the year. After graduation, David plans to pursue further education in the field of bioinformatics.

Conference volunteers

Ceilie Pestalozzi, Field Technician, Barnegat Bay Partnership

Tina Barreiro, Field Technician, Barnegat Bay Partnership

Bonnie Blume, Department of Human Resources, Toms River Township

Heather Fenyk, Executive Director, Lower Raritan Watershed Partnership

Kathryn Goddard, Associate Professor of Biology, Ursinus College

L. Stanton Hales, Program Director, Barnegat Bay Partnership

Mary Judge, Program Assistant, Barnegat Bay Partnership

Bill Koch, Consultant, WFK Consulting LLC

Pankaj Lal, Assistant Professor, Montclair State University

Lovepreet Multani, Self employed

Lauren O'Neil, Student, Stockton University

Nicole Petersen, Field Technician, Barnegat Bay Partnership

Dora Pinou, Associate Professor, Western Connecticut State University

Erin Reilly, Field and Lab Coordinator, Barnegat Bay Partnership

Talia Stillman, Field and Lab Technician, Barnegat Bay Partnership

Lynda Valeri, Executive Assistant to Mayor Thomas Kelaher, Township of Toms River

Jim Vasslides, Program Scientist, Barnegat Bay Partnership

Karen Walzer, Public Outreach Coordinator, Barnegat Bay Partnership

Britta Wenzel, Executive Director, Save Barnegat Bay

John Zingis, President, Air, Land & Sea Environmental Management Services