Claire Weisz, Alan F. Blumberg, and Jesse M. Keenan

Design Meets Science in a Changing Climate: A Case for Regional Thinking to Address Urban Coastal Resilience

HURRICANE SANDY, WHICH HIT THE EASTERN SEABOARD OF THE UNITED States in late October 2012, reminded the New York metropolitan area that coastal storms are among the world's costliest and deadliest disasters, capable of causing hundreds of billions of dollars in damage and threatening the livelihoods of entire neighborhoods. Storm-driven surge often represents the greatest threat to life and property associated with coastal storms as a result of additional water being pushed onto the shore.

These damages are likely to increase with a changing climate since rising sea levels, coupled with the potential for intensified storms, makes flooding and storm-driven surges even larger threats to the region (Walsh et al. 2014). Three of the nine highest recorded water levels in the New York Harbor region have occurred since 2010, and eight of the largest twenty (based on tide gauge data going back to 1844) have occurred since 1990 (Talke, Orton, and Jay 2014).

Storms of the future are going to be more intense and likely to occur more often (City of New York 2013). Sea-level rise is expected to accelerate over the twenty-first century, primarily due to increasing expansion of warming seawater and accelerated melting of land-based ice sheets. A conservative estimate of 30 to 60 centimeters for the New York City metropolitan region, including the New Jersey coast, by 2080 will change a 100-year flood event to a 30-year flood event. The latest localized projections show a 25 percent chance of sea level rising more than a meter over this period (Horton et al. submitted). Because of the increased risk of another major weather event, how we allocate resources to educate ourselves and prepare remains an important open question.

THE FORCES SHAPING OUR COASTLINES ARE DRIVEN BY ENERGY FROM THE atmosphere and the ocean. Coastal processes are controlled by surface winds and pressures, waves, ocean currents, and the tides that move water and sediment day in and day out. These processes are responsible for the constantly changing, shifting, and evolving landscape of the coast. Marine and climate scientists have developed theories and models, both conceptual and mathematical, to explain how ocean currents and waves create and deplete dunes and generate dynamic ecologies. Similar models have been developed by the financial industry to predict damages from a range of natural disasters. Social scientists have studied types of settlements and land planning that are best suited to be adapted to climate realities (Klinenberg 2002). Without the urgency of recovery or the foresight of when a coastal storm will occur, individuals, communities, and businesses equally are searching for ways to reduce their risk and lessen the pain of change. Those living and working within the urbanized North Atlantic region depend on increasingly interdependent systems and properties with varying degrees of vulnerability.

The US engineering and construction industries have developed and supplied walls, levees, and other physical barriers to prevent flooding and reduce storm impacts for decades, but the New

York City coastline alone is 573 miles long. Building comprehensive storm protections along all coastal edges is an inefficient and unreliable way to address storm surge. Taking sea-level rise into account, these walls would need to be between 15 and 16 feet high by 2050, severely impacting shoreline communities, public access to the waterfront, and transitional habitat zones (City of New York 2013).

THE REBUILD BY DESIGN COMPETITION

In June 2013, President Barack Obama announced an international competition, Rebuild by Design (RBD), to develop innovative concepts and proposals for rebuilding in the Sandy-affected region (http://www.rebuildbydesign.org/). Nearly 150 teams applied to the competition, from which 10 finalists were selected to participate.

One finalist was a multidisciplinary team led by the American and Dutch design firms WXY and West 8. They responded with a conceptual proposal for a regional-scale approach to coastal protection: the study of constructing new offshore barrier islands. The team worked for nearly a year in collaboration with scientists, engineers, and financial analysts to develop models that informed and verified the worthiness of the design concept.

At the beginning of the design process, the team asked: what contributions can engineering, science, and technology make to planning and managing the adaptive, evolving, and resilient coastal regions of New York and New Jersey? More specifically, if shorelines that are continually worked over by adding sand were planned and designed instead with coastal processes in mind, what could we have done in lieu of constructing walls and berms, or investing in gates to every harbor, to prevent Sandy's damage and upheaval?

Here, a more resilient strategy might involve finding a more "natural" investment that has greater benefits and "blunts the impact." The hypothesis is that a larger-scale approach might protect the region as a whole—and thus reduce the burden on localities and individual entities—to prepare for and respond effectively to each major storm, recover quickly from it, and allow for adaptation to changing conditions, while also reducing the risk of significant damage in a future storms. Coastal cities are extraordinarily resilient to the extent that they can leverage the consequences of natural or human-made disasters to create a new and better "normal."

THE BLUE DUNES CONCEPT

In response to the initial questions, the team hypothesized that there could be a way to deflect the storm-driven tides with a network of barrier islands nine to ten miles offshore in coastal waters. To test this hypothesis, a series of hydrodynamic simulations were run. These simulations used historical storm data to evaluate new barrier island landscapes without the use of closures or surge gates in a storm-surge flood. The analysis was based on two coastal ocean models, the three dimensional Stevens Institute Estuary and Coastal Ocean Model (sECOM) in its New York Harbor Observing and Prediction System (NYHOPS) application to the waters of New York and New Jersey (Blumberg and Mellor 1987; Georgas and Blumberg 2010; Blumberg, et al. 2015), and a vertically integrated, two dimensional, coupled Advanced Circulation modeling system, ADCIRC (FEMA 2013).Various configurations of barrier islands were investigated using atmospheric conditions from three significant storm events: Hurricane Donna (1960), Hurricane Sandy (2012), and the December 1992 nor'easter. The barrier configuration shown in figure 1 provided one of the most drastic reductions of storm surge in the study area. The peak flooding and the flood reductions for that barrier island configuration are also shown in figure 2.

The barriers themselves would be built from a combination of dredged sand and possibly rock outcroppings, stretching for miles along the New Jersey and Long Island shorelines and providing new habitats while dampening wave forces before they arrive onshore. The resulting concept to create an offshore barrier island chain centered on the New York Bight was called "The Blue Dunes": "blue" indicating the barrier islands' position in the open ocean and "dunes" for the natural landforms they mimicked. Subsequent financial and

Figure 1. The Blue Dunes plan. Source: WXY/West8

hydrodynamic modeling demonstrated that there was significant potential for a system of barrier islands to save hundreds of lives and billions of dollars across the region. Moreover, by decreasing the height of storm surge, this system would permit lower, softer, and less disruptive landside storm protections.

The Blue Dunes concept had the ability to reduce regional damage estimates by tens of billions from the hundreds of billions of dollars that future storms are projected to cost, making it a compelling proposition to manage catastrophic risk. In the context of the 10 RBD team concept proposals, Blue Dunes not only complemented the other teams' locally scaled coastal resiliency measures but also benefited areas that would remain vulnerable to surge because they lacked existing or planned localized projects.

The regional dimensions of Blue Dunes promoted economies of scale; allowed for complex and combined protection systems as well as physical coupling of onshore and offshore systems; and enhanced feasibility of financial risk mitigation efforts through more affordable pricing and more efficient supply of insurance, reinsurance, and catastrophic bond products. As one of the key beneficiaries, insurance providers and other risk management entities would be structured as funding partners for the project. The offshore islands would

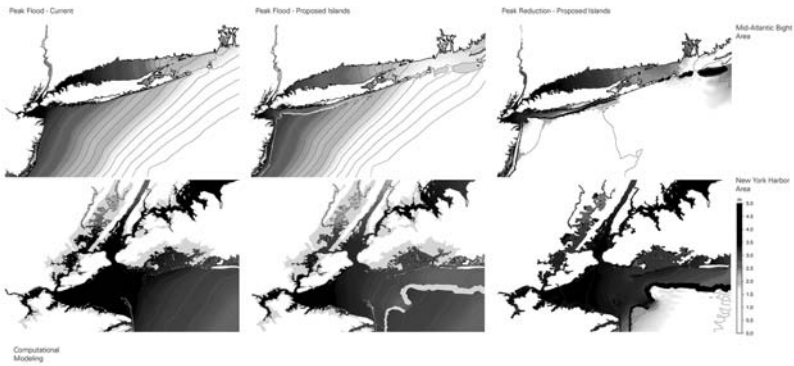

Figure 2. Computational modeling of peak flood and flood reduction based on existing and proposed scenarios. Source: Stevens Institute of Technology.

be physically transformative and would allow our risk framework to work more effectively and efficiently.

There is a long history in the United States of infrastructure investments driven by national interest. In the face of the complexity of coastline development, the construction of offshore dunes, potentially coupled with offshore wind renewable energy, may be required to prevent devastating economic losses. A wind farm on the barrier islands would turn the project from solely storm surge mitigation into a project also promoting climate change mitigation through the production of renewable energy. Additionally, the wind farm would be a major job generator: facilities for building and servicing the turbines could be sited on coastal brownfields that are often the underutilized sites of former ports. Further, this approach has the potential to be an effective line of defense for a wide variety of storm types. The annual savings for flood insurance associated with offshore dunes could prove substantial enough to attract both domestic and international investments.

EDUCATION AND ENGAGEMENT

One of the main challenges for political and social organizations is how to allocate resources for education and preparation for these climate challenges. Key to an effective participatory design process is the ability to engage the community, to inspire dialogue, and to garner input from them in order to design effectively, for the public good, and with confidence. The Rebuild by Design competition put great emphasis on developing the concept proposals with stakeholder input, and one of the primary challenges for the Blue Dunes project was to identify and engage with a regional coalition. Without an existing framework to approach issues that cross city, county, and state lines, it became of critical importance to engage the expertise of scientists and economists whose research and work transcends these geopolitical boundaries. Based on the premise that a regional strategy requires regional thinking, the team solicited feedback and reflections on its design concept through a series of organized colloquia, public lectures, and private meetings.

Reflecting this way of thinking, the first science community outreach meeting was entitled "Science Colloquia: Offshore Landscapes in the Mid-Atlantic." Organized as both an exchange of ideas and peer group discussion about the Blue Dunes proposal, science and engineering experts orchestrated a series of presentations on relevant research, bringing together a historical perspective with topics the science community has identified through decades of research as being critical to the systems and habitat of the North Atlantic coast. The research into major incidents including human changes to the water bodies demonstrated that water quality might be traced to engineering projects early in the twentieth century whose effects remain with us today. This research as well as research into which areas have greater probabilities over time of storm damage might inform an understanding of environmental change.

Presentations provoked an in-depth discussion on how various changes have affected the Hudson River plume (Chant et al. 2008a, 2008b; Jurisa and Chant 2013). The Hudson River plume is effectively flushed of its salt levels by river discharge and tidal ranges by stratification. Lowering the river discharge could result in deeper salt penetration north in the Hudson River. Other presentations discussed the role of the East River in dissolved oxygen and salinity distributions affecting New York Harbor water quality (Miller et al. 2011) and the tidal circulation and salinity stratification cycles in Long Island Sound (O'Donnell et al. 2014; O'Donnell and O'Donnell 2012).

Another key frame of reference was the New York Bight; the origin of waves; the typologies of regional sediments and sediment transport systems, which informed the discussions of the availability of large amounts of sand material offshore; and the dynamic systems at play in considering the use of this material (Herrington 2012; Miller, Mahon, and Herrington 2011). Reflecting on the potential of greater benefits to accrue from a regional approach to coastal thinking, the colloquium discussed the potential for large-scale wind turbine arrays to generate wind energy and dissipate storm energy (Archer, Mirzaeisefat, and Lee 2013; Jacobson, Archer, and Kempton 2014). Finally, the economy of the coastal ocean was characterized by the scale of both recreational and commercial fisheries and the tertiary negative effects of human activity on aquatic systems. When all these factors are considered, at the scale of the coastal area affected by Sandy, the sensitive ecosystems have massive economic impacts on the coasts of New York and New Jersey (Pinsky et al. 2011). The summation challenged all the RBD teams and by extension the federal, state and local entities charged with assisting people to adapt to a changing climate, to think about resiliency on a much larger scale and over a longer timeframe, and especially to consider sea level rise (Jacobs et al. 2011; Jacobs 2013).

The scientific community brought to the fore the importance of a wide range of regional issues, including hydrodynamics, salinity, coastal fishing economies, energy, wind dissipation, and basic wave physics. The conversation was able to transcend the bounds of political jurisdictions and speak to the regional issues that are at play in the mid-Atlantic coastal systems that affect the concept design. The colloquium format encouraged attendees to speak to their expertise, while small breakout groups for informal discussion further fostered participation in the design process. The scientific community challenged the preliminary conceptual design and helped direct subsequent Blue Dunes work on the proposed configuration of the barrier islands.

In addition to leveraging the expertise of the scientific community, the Blue Dunes team also sought feedback from the financial community. The second colloquium, Risk Economy, prompted participants to think about the alternative benefits and the potential financial feasibility of the concepts being advanced. Blue Dunes received feedback on regional strategies from a robust group of thinkers and industry leaders: insurance, reinsurance, and catastrophic bonding experts, risk modelers, real estate developers, economists, and academic researchers. The coalition of participants engaged on topics of governance, financing, and legal permitting. They suggested running financial models of the flood reduction to estimate cost savings from the barrier island configuration shown in figure 1; that loss reduction is shown in figure 3. Clearly, significant cost savings would be realized with Blue Dunes.

The research findings and concept design were also shared with state and federal officials who represented various jurisdictions in the mid-Atlantic coastal region. Blue Dunes gained the support of New York Senator Charles Schumer for its application for research funding to continue studying the feasibility of the ideas.

BEYOND BLUE DUNES: THE BLUE DUNES RESEARCH INITIATIVE

Drawing on the tremendous support and interest of federal, state, and local officials, private insurance and financial industry partners, engineers, and scientists, the team proposed the creation of the Blue

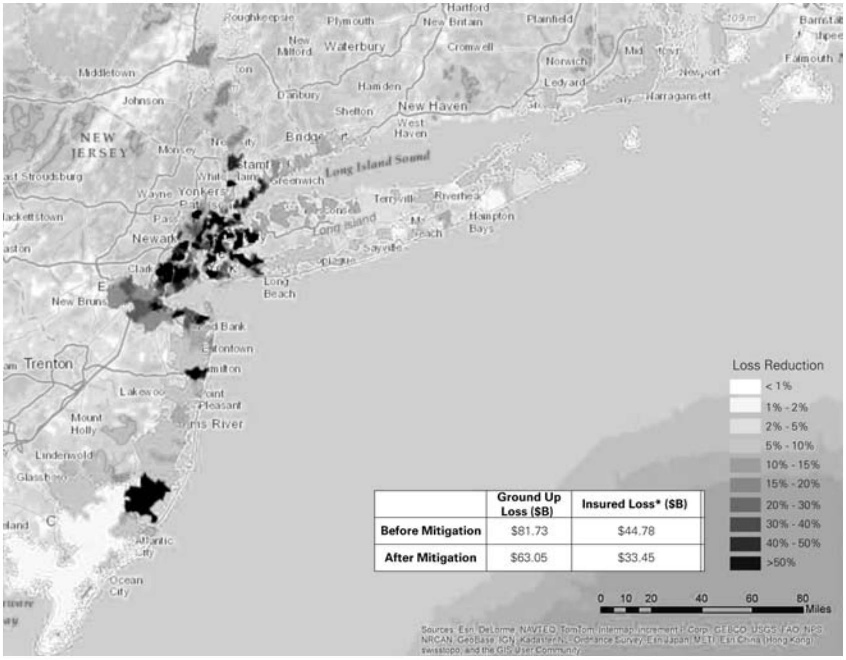

Figure 3. Regional estimated loss reduction. Source: AIR.

Dunes Research Initiative (BDRI) to examine further the feasibility of offshore islands. The components of the initiative are schematized in figure 4. There remains a critical need for deeper and more sophisticated modeling to explore how offshore dunes could provide protection from the next major storm. BDRI would continue the investigation, collaboration, and communication that began through the RBD process, as well as the collaboration and input from communities and organizations.

The proposed multidisciplinary initiative would span five years and become a planning and technology resource for the coastal communities of the mid-Atlantic. BDRI was proposed as an independent, not-for-profit research entity that would build on existing strengths of the Blue Dunes concepts and its partners, through basic and applied research in coastal ocean and environmental engineering, climate

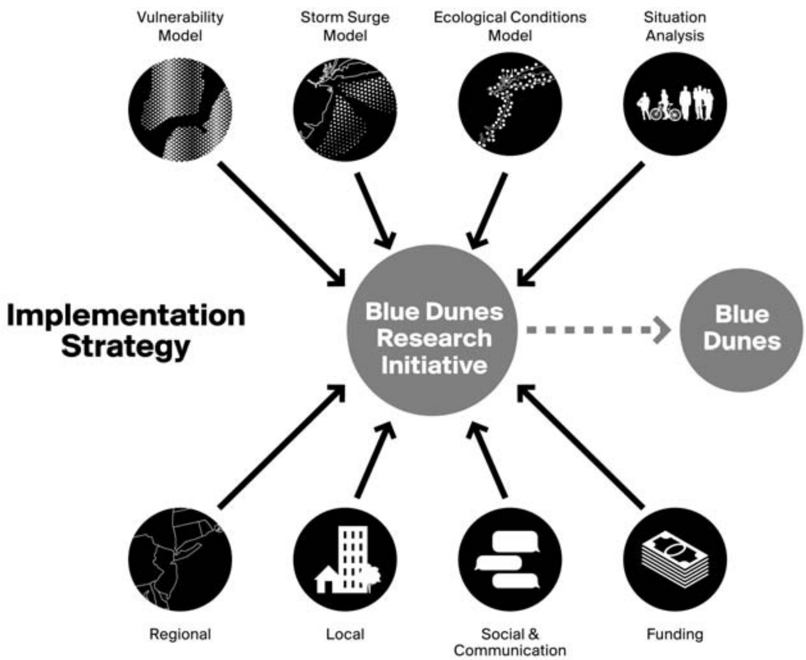

Figure 4. Blue Dunes Research Initiative. Source: WXY/West8

dynamics and atmospheric and ocean science, hydrology, transportation, resilience, sustainability, transportation, planning, maritime policy, and finance. In the process of developing the Blue Dunes concept, it would help launch the next generation of science, engineering, and technology that would enable this area and its inhabitants to adapt and respond to the certainty of an uncertain future. The total cost to create and maintain the initiative was anticipated to be about $50 million over the span of five years.

BDRI has the potential to set up an innovative coastal protection methodology that integrates the emerging key impacts and vulnerabilities of coastal urban regions with an improved understanding of the dynamics of coastal urban meteorology, oceanography, ecology, and economics. Understanding the interaction of coastal cities with the environment will make it possible to achieve unprecedented advances that contribute to securing the future for urban coastal regions. The scientists, economists, and maritime stakeholders who participated in the RBD process identified many of the key issues that need to be addressed: water quality, habitats, recreation, navigation, constructability, planning, and funding. Investment in developing an offshore line of defense can pave the way for new technologies.

The list of stakeholders that need to be engaged in the BDRI is lengthy and diverse. The implementation of barrier islands has a range of potential benefits, impacts, and viability challenges. On a basic level, differently sized barrier islands would have distinct implications for storm surge mitigation and affect what areas are protected, as well as what the insurance premiums might be in different geographies. The financial implications of the design would need to be tested against other potential impacts, such as how the islands might change currents and waves, which could affect coastal ecologies, boating and fishing patterns, and surfing beaches. BDRI would set up a transparent way for studying trade-offs and conducting negotiations.

STRATEGIC PRIORITIES

The Blue Dunes Research Initiative seeks to ensure the safety of the citizens who live in the coastal cities of New York and New Jersey and to guarantee to the extent possible their quality of life and harmony between society and the environment. The people most at risk tend to be those who are poorest and who have settled and built on the least expensive land, which is often prone to flooding, storms, and landslides. A natural event, such as a heavy rain, can become a full-blown crisis—especially when people lack the tools they need to cope in the aftermath. The initiative thus seeks to bring local, regional, and international knowledge to bear in order to:

1. learn to engage a wide range of stakeholders to develop a comprehensive understanding of the urban coastal region, its interdependencies, key players, and areas that warrant integrated design thinking and solutions;

المنارة للاستشارات

2. contribute to a better understanding the vulnerabilities, strengths, and interdependencies of the urban coastal region;
3. understand the temporal and spatial variability of key atmospheric and coastal ocean parameters;
4. address specific questions about how cities and the coastal ocean environment will interact in the face of climate change;
5. develop a set of best management practices for constructing the offshore dunes, including measures of uncertainty to guide decision making and action;
6. create multiscale visualization tools that integrate climate and hydro-meteorological information with geophysical, ecological, land use, and socioeconomic factors enhance the sustainability of the engineered dunes;
7. ignite creativity, innovation, and new avenues of scholarship and translate that perspective into educational achievement.

AFTERWORD

Today the proposal stands at a crossroads. Blue Dunes investigated a new form of designed coastal protection that would, on a large scale, mitigate risk for life, the economy, and property within coastal zones. The project represents a generalizable series of propositions grounded in art and science that have global implications for generations to come. It is the product of exploratory research, which was grounded with a measure of procedural clarity and serves as a model for future research and teaching. By expanding the scale of the problem, the project highlights many systematic and disciplinary tensions in the fields of design, development, ocean and marine sciences, public finance, civil engineering and risk and geospatial analytics.

The real innovation in Blue Dunes comes in three forms. First, it imagines a series of synthetic physical processes that mirror those of the natural world. By iteratively testing design scenarios with engineering performance criteria, the object of the solution balances aesthetics and function into a seamless hypothetical form and experience. Second, it lays the groundwork for coalitions of political, social, and economic interests by aligning the costs and benefits of action and inaction. By acknowledging existing public sector biases and jurisdictional fragmentation, the solution set engages the private sector in the language of return on capital, which is critical in order to leverage political will and enable economic risk-taking. Finally, the

Figure 5. Sandy flood line, Hoboken. Source: WXY/West8

process has the potential to educate. Real-time data collected during storms and measurements of sea level rise can be mapped onto buildings and signs to promote a deeper understanding of their implications for places where people live and work (figure 5).

Through a shared regional computational model, this tool could promote regional thinking and a way of planning to accommodate or minimize the possible effects various local and specific solutions might have on other communities and individuals that may not be protected. Together, these serve as the foundation for comprehensive strategic action.

In this sense, the processes that underscore the Blue Dunes concept themselves represent distinct innovations, irrespective of the product. A similar model could be applied to tackle urban flooding, energy distribution, ecological preservation, or any other climate-related challenge that defies the boundaries of existing political-economic organizations. To this end, Blues Dunes serves as a prototype for further research in decision science, participatory planning, organizational management and institutional change. More directly, the model provides an opportunity for analog simulation in architecture and landscape design studios.

AS COUNTRIES AND CITIES STRUGGLE WITH THE COMPLEXITIES OF SEA-level rise and climate change, and as the built environment professions struggle with field conditions that necessitate transdisciplinary management, the academic institutions have developed pedagogical approaches and are increasingly reengaging the idea that innovation can be facilitated within linear, rule-bound systems. Through a codification of criteria that defy optimization, the default programmatic and form biases of the designer are manipulated by a collective interpretation of sociopolitical relationships, market behaviors, and constitutional and scientific laws. The increased recognition of the limitations of professional acculturation of the objective public obligation is balanced by subjective realities of professional ethics and intra-organizational dynamics, which serve ostensibly the same outcome despite different and often frictional trajectories—in this case, the mitigation of systematic environmental risk to human and natural ecologies. One significant dimension of the application of this model is to question the notions of aesthetics in the face of efficiency-seeking production and replication whose applications on a regional scale defy any historical precedent beyond perhaps that of the Great Wall of China. While the challenges of the form and consequence of industrializing economies are certainly not a novel paradigm, this model represents a systemized process of analysis and scientific inquiry that not only informs but partially validates normative design propositions.

The implicit positivism of this model is certainly open to debate. However, there is little doubt that no one discipline in isolation can solve the challenges of climate change even when the simplest of solutions are themselves grounded in a domain conventionally attributable to a singular discipline. Blues Dunes provides professionals, academics, and students a platform for accelerating and testing a new process model for design and development. Each participant in the development of Blue Dunes must remember that the current team of collaborators and partners is merely a proxy for generations to come, each of whom must in turn bear the burden of a new environmental order defined by an ever-changing climate.

In the end, the method of creating a dialogue between scientists and designers might result in a very different answer than a barrier island. The resulting case might prove that individual raising of edges does not cause the detrimental effects in neighboring communities that do not raise their edges; it might prove that an investment in offshore wind power despite bird conflicts has the best overall benefits for both carbon reduction and lowering risks to human settlements. In other words, without integrating science with planning, the prospect of dealing with any substantial change in our approach to resource consumption and human settlement is not likely within our lifetimes.

ACKNOWLEDGEMENTS

The authors wish to thank the members of the Blue Dunes team: Claire Agre, Riette Bosch, Yeju Choi, Ela Chojecka, Jelmer Cleveringa, Gary Cornbrooks, Roni Dietz, Piete Dirke, Janneke Eggink, Giulia Frittoli, Adriaan Geuze, Maxine Griffith, Helen Han, William Hanson, Kei Hayashi, Daniel Hitchings, Kennedy Howe, Kate John-Alder, Andrew Kao, Olivia Lerner, Adam Lubinsky, Lauren Micir, Catherine Nguyen, Layng Pew, Paul Salama, Alice Shay, Maiko Shimizu, B. Tyler Silvestro, Thom Stead, Mathew Suen, Florentia van Gils, Daniel Vasini, Sergey Vinogradov, Edgar Westerhof, Moniek Widdershoven, and Mark Yoes; the colloquia presenters: Cristina L. Archer, Robert Chant, Thomas Herrington, Klaus Jacob, Olaf Jensen, Henry John-Alder, Sandra Knight, William Morrish, James O'Donnell, and David Paget; and not least Rebuild by Design, its staff, and its partners, MAS, RPA, Van Alen, and the Institute for Public Knowledge. The authors gratefully acknowledge Justine Shapiro-Kline for keen editorial skills and for offering insights that greatly improved the quality of the manuscript.

REFERENCES

Archer, C. L., S. Mirzaeisefat, and S. Lee. 2013. "Quantifying the Sensitivity of Wind Farm Performance to Array Layout Options Using Large-Eddy Simulation." *Geophysical Research Letters* 40 (18): 4963–4970.

Blumberg, A. F., and G. L. Mellor. 1987. "A Description of a Three-Dimensional Coastal Ocean Circulation Model." In *Three-Dimensional Coastal Ocean Models*, edited by N. S. Heaps. Washington, D.C.: American Geophysical Union.

Blumberg, A., N. Georgas, L. Yin, T. Herrington, and P. Orton. 2015. "Street Scale Modeling of Storm Surge Inundation along the New Jersey Hudson River Waterfront." *J. Atmos. Oceanic Tech.* 32 (8): 1486–1497.

Chant, R. J. et al. 2008a. "Bulge Formation of a Buoyant River Outflow." *Journal of Geophysical Research: Oceans (1978–2012)*, 113 (C1).

——— 2008b. "Dispersal of the Hudson River Plume on the New York Bight: Synthesis of Observational and Numerical Studies during LaTTE." *Oceanography* 21 (4): 148–161.

City of New York. 2013. “Chapter 2: Climate Analysis.” In *A Stronger, More Resilient New York*. New York, NY. http://www.nyc.gov/html/sirr/html/report/report.shtml.

Federal Emergency Management Agency. 2013. *Final Draft Report: Region II Storm Surge Project Mesh Development Report*. Prepared by Risk Assessment, Mapping, and Planning Partners (RAMPP), Washington, D. C.

Georgas, N., and A. F. Blumberg. 2010. “Establishing Confidence in Marine Forecast Systems: The Design and Skill Assessment of the New York Harbor Observation and Prediction System, Version 3 (NYHOPS v3).” Estuarine and Coastal Modeling (2009): 660–685. doi: 10.1061/41121(388)39.

Herrington, T. O. 2012. “New Jersey Inlet Erosion Hot Spot Assessment and Mitigation.” NJ Coastal Protection Technical Assistance Service, Davidson Laboratory Technical Report SIT-DL-12-9-2904, October 2012.

Horton, R. et al. 2015. “New York City Panel on Climate Change 2015 Report: Chapter 2: Sea Level Rise and Coastal Storms.” *Annals of the New York Academy of Sciences* 1336: 36–44.

Jacob, K. et al. 2011. “Chapter 9: Transportation.” In *Responding to Climate Change in New York State*, 299–362. New York State Energy Research and Development Authority. November. http://nyserda.ny.gov/climaid. Republished in *Annals of the New York Academy of Sciences* 1244 (December 2011).

Jacob, K. 2013. “A Primer on Risks from Climate Change-Induced Sea Level Rise and Pathways Towards Sustainable Resilience for Coastal Cities and Communities.” *Rebuild by Design*. Research Advisory Group Reports. http://www.rebuildbydesign.org/research/resources.

Jacobson, M. Z., C. L. Archer, and W. Kempton. 2014. “Taming Hurricanes with Arrays of Offshore Wind Turbines.” *Nature Climate Change* 4 (3): 195–200.

Jurisa, J. T. and R. J. Chant. 2013. “Impact of Offshore Winds on a Buoyant River Plume System.” *Journal of Physical Oceanography* 43 (12): 2571–2587.

المنارة للاستشارات

Miller, J. K., A. Mahon, and T. O. Herrington. 2011. “Long Branch Alternative Fill Placement: Assessment of Fill Evolution and Impact on Surfing Resources.” NJ Coastal Protection Technical Assistance Service, Davidson Laboratory Technical Report SIT-06-9-2889, June.

Miller, R. E. L. et al. 2011. “Fate and Transport Modeling of Sediment Contaminants in the New York/New Jersey Harbor Estuary.” *Urban Habitats* 6.

O’Donnell, J. et al. 2014. “The Physical Oceanography of Long Island Sound.” In *Long Island Sound*, edited by J. S. Latimer et al 79–158. New York: Springer Series on Environmental Management.

O’Donnell, J. and J. E. D. O’Donnell. 2012. “Coastal Vulnerability in Long Island Sound: The Spatial Structure of Extreme Sea Level Statistics.” *Oceans* (Oct 2012): 1–4, 14–19. doi: 10.1109/OCEANS.2012.6405099

Pinsky, M. L. et al. 2011. “Unexpected Patterns of Fisheries Collapse in the World’s Oceans.” *Proceedings of the National Academy of Sciences* 108 (20): 8317–8322.

Talke, S. A., P. Orton, and D. A. Jay. 2014. “Increasing Storm Tides in New York Harbor, 1844–2013.” *Geophysical Research Letters* 41 (9): 3149–3155. doi: 10.1002/2014GL059574.

Walsh, J., et al. 2014. “Chapter 2: Our Changing Climate.” In *Climate Change Impacts in the United States: The Third National Climate Assessment*, edited by J. M. Melillo, T. C. Richmond, and G. W. Yohe 19–67. U.S. Global Change Research Program. doi:10.7930/J0KW5CXT

Notes on Contributors

EDDIE BAUTISTA is Executive Director of the NYC Environmental Justice Alliance, which advocates for the empowerment and just treatment of environmentally overburdened neighborhoods. An award-winning community organizer and urban planner, he is also a visiting assistant professor at Pratt Institute.

FRANCES BEINECKE is the former president of the Natural Resources Defense Council. She is a member the Secretary of Energy's Advisory Board; she also serves on the advisory boards of the MIT Energy Initiative and National Academies of Science, and the board of World Resources Institute.

ALAN BLUMBERG is the George Meade Bond Professor and director of the Davidson Laboratory at Stevens Institute of Technology. A specialist in urban oceanography, predictive modeling, and ocean physics, he has advised the NYC Mayor's Office on the impacts of sea level rise and the NJ Governor's Office on state-wide storm surge reduction alternatives.

EMANUELE CASTANO, an associate professor at the New School for Social Research, is a social and political psychologist focusing on nationalism and international relations, intergroup conflict and reconciliation, and collective responsibility. His articles have appeared in numerous journals and edited collections.

STEVEN COHEN is executive director and chief operating officer of the Earth Institute and professor in the practice of public affairs at Columbia University. His publications include *Sustainability Policy: Hastening the Transition to a Cleaner Economy* (2015) and other books. He also writes a weekly blog for the *Huffington Post*.

NATASHA DWYER is currently finishing her Master's degree in city and regional planning at Pratt Institute. She previously worked as a policy organizer for the New York City Environmental Justice Alliance.

JEFFREY P. FITTS is a research scientist in the Civil and Environmental Engineering Department at Princeton University. His research combines numerical and experimental methods to advance the science and engineering needed to quantify the human health, environmental, and climatic costs of energy technologies.

RUSSELL HARDIN is Helen Gould Shepard Professor of Politics at New York University. His books include *Indeterminacy and Society* (2003), and *How Do You Know? The Economics of Ordinary Knowledge* (2009, 2014). His work combines rational choice and normative arguments as applied to major real world issues.

JENNIFER JACQUET is assistant professor in New York University's department of environmental studies. She is interested in large-scale cooperation dilemmas, such as overfishing and climate change. Part of her research uses lab experiments to test cooperative decision-making.

DALE JAMIESON is professor of environmental studies and philosophy, affiliated professor of law, and affiliated professor of bioethics at New York University. His recent books are *Reason in a Dark Time: Why the Struggle to Stop Climate Change Failed—And What It Means For Our Future* (2014), and *Love in the Anthropocene* (with Nadzam, 2015).

JOHN JOST is professor of psychology and politics, and co-director of the Center for Social and Political Behavior at New York University. His research addresses stereotyping, prejudice, ideology, social justice, and system justification. He is president of the International Society of Political Psychology.

CHARLOTTE KAISER leads product development for NatureVest, the Nature Conservancy's program developing opportunities to drive private capital to conservation. She managed the launch and sale of the $25M Conservation Note.

JEROLD S. KAYDEN, an urban planner and lawyer, is the Frank Backus Williams Professor of Urban Planning and Design at the Harvard Graduate School of Design. His books include *Privately Owned Public Space: The New York City Experience* (2000). He serves as principal constitutional counsel to the National Trust for Historic Preservation.

JESSE M. KEENAN, research director for the Center for Urban Estate Development at Columbia University, is an internationally-recognized expert on climate change planning and design with a focus on private sector adaptive capacity and technical design and development analytics. He is jointly affiliated with the TU Delft Graduate School of Architecture and the Built Environment.

CHRISTINA LEIJONHUFVUD is managing partner of Tideline Advisors, a boutique impact investment consulting firm. She advises clients on strategies to align their capital with their social and environmental goals. Her published work focuses on both failures in the capital markets and the potential of impact investments.

ROBERT MENDELSOHN is Edwin Weyerhaeuser Davis Professor of Forest Policy, professor of economics, and professor in the School of Management at Yale University. His recent work values the impacts of greenhouse gases, including the effects of climate change on agriculture, forests, water resources, energy, and coasts.

GUY NORDENSON is a partner at Guy Nordenson and Associates and professor of architecture and structural engineering at Princeton University. His practice includes an expertise in climate adaptation design and engineering. Nordenson is a member of the New York City Panel on Climate Change.

MICHAEL OPPENHEIMER is the Albert G. Milbank Professor of Geosciences and International Affairs at Princeton University and Director of Princeton's Program in Science, Technology and Environmental Policy (STEP). His research focuses on the science and policy aspects of climate change and its impacts.

JUAN CAMILO OSORIO is the NYC Environmental Justice Alliance's director of research and an adjunct assistant professor at Pratt Institute. He was formerly a senior geographic information systems analyst and planner at the Municipal Art Society and a research assistant at the Massachusetts Fair Housing Center.

KAITLIN T. RAIMI is a social psychologist and postdoctoral fellow at the Vanderbilt Institute for Energy and Environment. Her areas of interest include belief superiority, self-presentation, and the role of knowledge and ideology in the creation and maintenance of belief about climate science and related technology.

CATHERINE SEAVITT is an associate professor of landscape architecture at City College of New York and principal of Catherine Seavitt Studio. Her research focuses on design adaptation to sea level rise in urban coastal environments and explores novel landscape restoration practices given the dynamics of climate change.

PAUL C. STERN is a scholar with the Board on Environmental Change and Society, National Research Council. His research interests include determinants of environmentally significant household behavior, participatory processes for environmental decision making, and the governance of environmental resources and risks.

JOEL TOWERS is Executive Dean of Parsons The New School for Design. He also serves as an associate professor of architecture and sustainable design.

ELKE U. WEBER is the Jerome A. Chazen Professor of International Business at Columbia Business School, and professor of psychology and Earth Institute Professor at Columbia University. She is an expert on behavioral models of judgment and decisionmaking under risk and uncertainty.

CLAIRE WEISZ is a founding partner of WXY and visiting distinguished professor at City College of New York's Bernard & Anne Spitzer School of Architecture. As an architect and cofounder of the Design Trust for Public Space, her projects focus on infrastructure, neighborhoods, and urban ecology.

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

www.manaraa.com