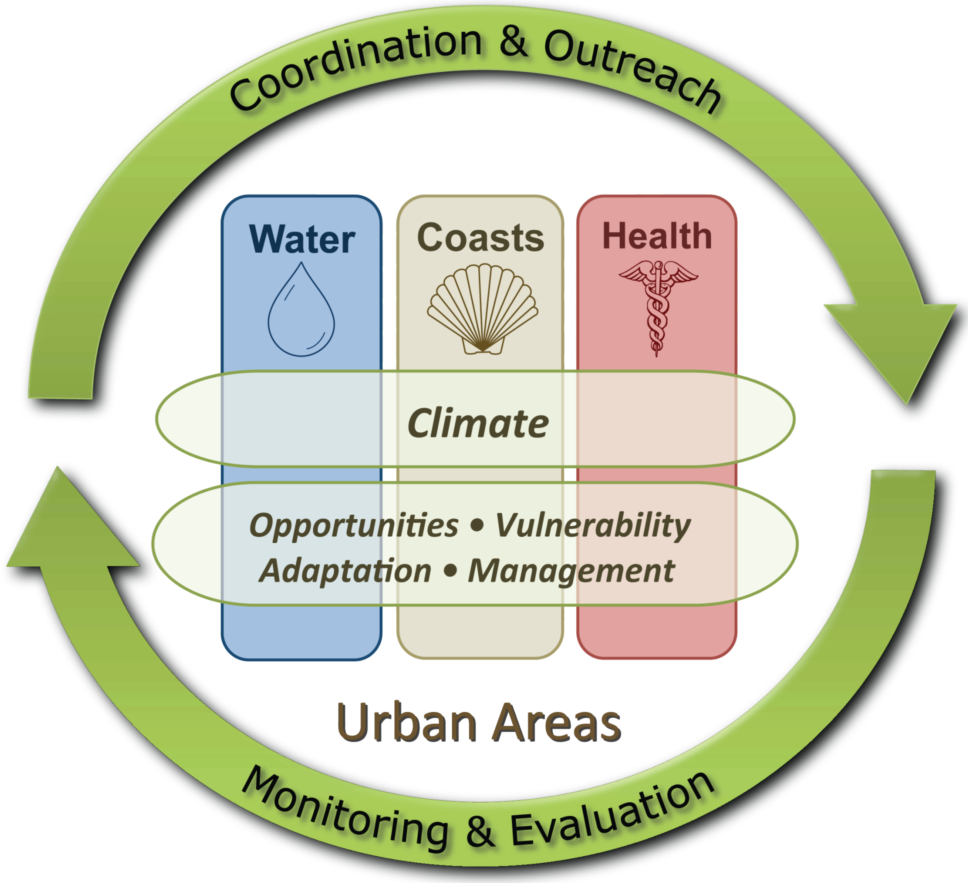
Consortium for Climate Risk in the Urban Northeast

Research Highlights, October 1 2014 - March 31, 2015

CCRUN



CCRUN's Mission

To conduct stakeholder-driven research that reduces climate-related vulnerability and advances opportunities for adaptation in the urban Northeast

Columbia University in the City of New York

University of Massachusetts Amherst

Stevens Institute of Technology
The Innovation University

Drexel University

The City College of New York

The CCRUN Team

The team is comprised of investigators, research & support staff, and graduate students from five institutions across the CCRUN project area: Columbia University (CU), the University of Massachusetts-Amherst (UMass), City College of the City University of New York (CCNY), Stevens Institute of Technology (Stevens), and Drexel University (Drexel).

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Stakeholders and Partners

A & D Hydro, Inc.
Alternatives for Community and Environment (ACE)
American Red Cross of Greater New York
American Water Company
American Water Works Association
Appalachian Mountain Club
Ashburnham (MA) Department of Public Works
Bear Swamp Power Company, LLC
Boston Office of Environmental and Energy Services
Boston Public Health Commission
Brattleboro (VT) Water Department
Bristol (CT) Water Department
Brookfield Renewable Power, Inc.
Bucks County (PA) Water & Sewer Authority
Burlington (MA) Water Department
Canaan (NH) Water Department
Chester (PA) Water Authority
Chicopee (MA) Water Department
Clean Air Council
Clean Air-Cool Planet
Connecticut Department of Environmental Protection/Inland Water Resources Division
Connecticut River Watershed Council
Connecticut Water
Dalton Hydro, LLC
Delaware River Basin Commission
Delaware Valley Green Building Council
Delaware Valley Regional Planning Commission/Office of Energy and Climate Change Initiatives
Dorchester (MA) Environmental Health Coalition
East Hampton (CT) Water and Sewer Commission
Environmental Protection Agency (Regions 2and 3)
Fairmount Park Commission
Farmington River Power Co.
Fitchburg (MA) Public Works Department/Water Division
Green Mountain Power
Harvard University Graduate School of Design
Holyoke (MA) Gas and Electric Department
Keene (NH) Public Works Department/Water Division
L.S. Starrett Co.
Massachusetts Department of Conservation and Recreation
Massachusetts Department of Environmental Protection/Water, Wastewater, and Wetlands
Massachusetts Department of Fish and Game
Massachusetts Executive Office of Energy and Environmental Affairs
Massachusetts Water Resources Authority
Metropolitan District of Connecticut
Metropolitan Waterfront Alliance
Monson (MA) Water & Sewer Department
Montgomery County (PA) Advisory Committee on Climate Change
National Association of Water Companies
National Grid
National Park Service, Partnership Wild and Scenic Rivers/Farmington River, CT
National Park Service, Partnership Wild and Scenic Rivers/Westfield River, MA
Natural Resources Defense Council
The Nature Conservancy New Britain (CT) Water Department
New England Interstate Water Pollution Control Commission
New Hampshire Department of Environmental Services
New Hampshire Rivers Council
New York City Department of Health and Mental Hygiene
New York City Department of Environmental Protection/Bureau of Water Supply
New York City Department of Environmental Protection/Environmental Planning and Analysis
New York City Department of Parks and Recreation
New York City Office of Long-Term Planning and Sustainability
North American Energy Alliance, LLC
North Brookfield (MA) Water Department
Palmer (MA) Water Department
Pennsylvania Department of Conservation and Natural Resources
Pennsylvania Department of Environmental Protection/Climate Change Advisory Committee
Pennsylvania Environmental Council
Pennsylvania Horticultural Society
Philadelphia City Planning Commission
Philadelphia Department of Public Health/Air Management Services Division
Philadelphia Department of Public Health/Environmental Health Services Division
Philadelphia Department of Streets
Philadelphia Energy Coordinating Agency
Philadelphia Industrial Development Corporation
Philadelphia Mayor's Office of Sustainability
Philadelphia Municipal Energy Office
Philadelphia Office of Emergency Management
Philadelphia Water Department
Philadelphia Parks & Recreation
Rivers Alliance of Connecticut
Springfield (MA) Water and Sewer Commission
Stratford (CT) Department of Public Works/Water Pollution Control
The Trust for Public Land
TransCanada
Turners Falls Hydro, LLC
US Army Corps of Engineers
US Forest Service
University of Connecticut
Vermont Agency of Natural Resources
Vermont Department of Environmental Conservation/River Management Section
Vermont Department of Environmental Conservation/Water Quality Division
Vermont Department of Fish and Wildlife
Vermont Natural Resources Board
Vermont Natural Resources Council
WE ACT for Environmental Justice
West Harlem Environmental Action Group
Westfield (MA) Water Resources Department
Williamsburg (MA) Water and Sewer Commission
Women's Health and Environmental Network

New Areas of Focus/Partnership

During the course of CCRUN's fifth year, the team has extended its research partner network considerably through a series of new endeavors. We envision these new partnerships to be part of the foundation for an expanded reach for CCRUN.

Coasts

A significant new endeavor soon to be underway is a collaboration between CCRUN's Philip Orton, Kate Orff (SCAPE / Landscape Architects), Parsons Brinkerhoff, Ocean & Coastal Consultants, SeArc Ecological Consulting, LOT-EK, MTWTF, The Harbor School and Paul Greenberg and on an adaptation project for Staten Island, NY called "Living Breakwaters" (http://www.rebuildbydesign.org/project/scape-landscape-architecture-final-proposal/). This prize-winning plan, submitted to the Rebuild by Design competition funded by The Rockefeller Foundation, seeks to reduce the risks of coastal flooding and improve ecological resiliency by the construction of stone breakwater barriers that are also designed to provide new habitat space for finfish, shellfish and lobsters (Figure 1). The project also envisions becoming an important educational resource for the local community. At the same time, the approach developed here can serve as a template for improving resiliency in other coastal areas.

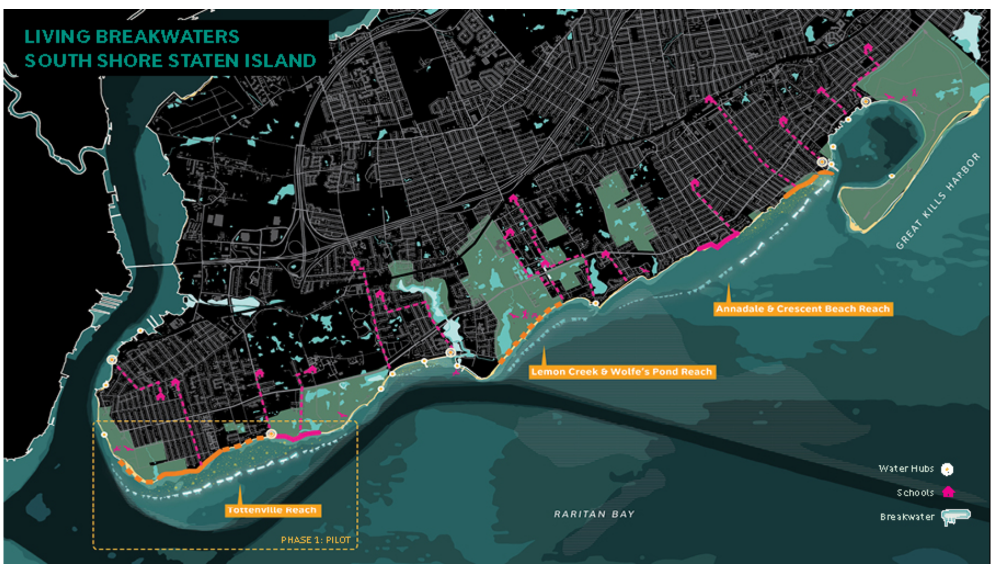


Fig. 1. The waterfront community of Tottenville, Staten Island (highlighted by the yellow dashed box at the lower left), hit hard by Hurricane Sandy, is the site of the Living Breakwaters pilot study area. Additional studay areas includes Lemon Beach (center yellow arrow) and Annandale Reach (right yellow arrow).

Coastal water quality is a new focal point, one being addressed by two projects including CCRUN team members and colleagues. For the first project, "Coastal Adaptation Impacts on Water Quality and Flooding," Stevens Institute team members Philip Orton, Nickitas Georgas, and Alan Blumberg are collaborating with water quality modeler James Fitzpatrick of HDR, Inc. to simulate how coastal adaptations of Jamaica Bay will affect parameters like oxygen. Water quality and storm damage avoidance are integrally linked research topics, as storm protection efforts can harm water quality and alter ecosystems.

For the second project, "Detecting Water Quality Regime Shifts in Jamaica Bay," Columbia team member Sandra Baptista is leading a group of colleagues working with Brett Branco of Brooklyn College and Patrick Sullivan of Cornell University on the development of an integrated Jamaica Bay water quality database, which will be used for the analysis of spatial and temporal patterns of water quality in the bay. Analytical tools for measuring resilience and detecting water quality regime shifts within Jamaica Bay in response to drivers and disturbances are also planned. Both projects are supported by the U.S. Department of the Interior/National Park Service.

Water

Two new projects are addressing water quality of rivers and watersheds in southern New York State. CCRUN team members from UMass have established a connection with the new water quality modeling group at the NYC Department of Environmental Protection. UMass personnel, led by Rick Palmer, plan to complete an existing project on the development of screening tool-based examination of the impacts of climate change, and begin examining methods of modeling extreme precipitation and streamflow in NYC Water Supply System watersheds.

With Dr. Andrew Peck of The Nature Conservancy, Malanding Jaiteh and other CCRUN team members from Columbia are developing a physical habitat model for a section of the Hudson River, as part of the Hudson River Restoration Project. The habitat model will be utilized in an ecological assessment aimed at identifying the distribution and condition of various habitats, and prioritizing those in need of restoration after years of pollution, urban development and other environmental impacts.

Public Health

CCRUN members from CCNY, led by Mark Arend and Prof. Jorge Gonzalez, have built collaborations with various partners to enhance fine-scale urban heat island observations with an urbanized numerical weather prediction modeling scheme: an **u**rban **W**eather **R**esearch and **F**orecasting model, or uWRF (http://air.ccny.cuny.edu/ws/wrfn/thindex.wrfmetnet.php). This model takes in to account the details of the interactions between building energy systems and the complex urban energy flux dynamics (see Figure 2). Work has begun on using our 100-meter scale observation-based statistical model to downscale the 1-km WRF surface temperature output. A proposal has been submitted to the New York State Energy Research and Development Authority (NYSERDA) to use the uWRF model to produce humidity fields for climate projections.

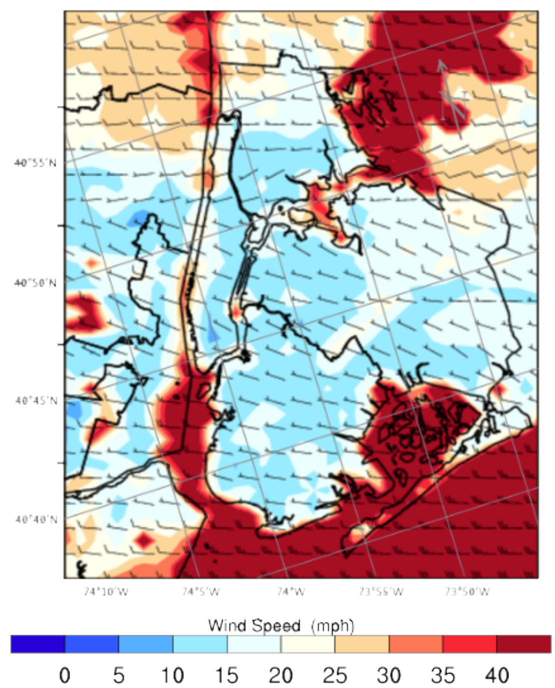


Fig. 2. An example of uWRF predictive analysis for hourly wind speeds and wind directions at the 1-km scale for January 5, 2015. Predictive analysis is performed daily by the uWRF model, yielding scenarios up to 72 hours in advance.

CCRUN's Patrick Kinney is working with several new post-doctoral researchers and students, covering a variety of projects:

- Post-doctoral researcher Victoria Lee will investigate the impacts of indoor temperature and humidity conditions on sleep.

- Visiting post-doctoral researcher Katrin Burkart is developing a new study to examine the health benefits of green infrastructure.
- Post-doctoral researcher Jenn Nguyen has initiated a study looking at the influence of climate on influenza outbreaks and subsequent cardiovascular deaths in NYC.
- Two undergraduate interns from Paris will do research on indoor environments in NYC through the Alliance Program between Columbia University and three French Institutions: Ecole Polytechnique, Sciences Po, and Partheon-Sorbonne University.

Green Infrastructure

With the help of a semester-long sabbatical in Venice, Italy, CCRUN member Franco Montalto has begun a survey of examples of efforts to enhance urban ecosystem services with multifunctional green infrastructure in several locations in the US and Europe:

- IUAV University (Venice, Italy)
- Technical University of Munich (Friesing, Germany)
- University of Copenhagen (Copenhagen, Germany)
- University of Padua (Padua, Italy)
- Urban Field Station (USDA Forest Service, Fort Totten, NY)

Montalto has also begun a new partnership with Matthew Palmer (Columbia) and Krista McGuire (Barnard College), who will co-locate biological investigations of plants and bacteria in some of the Drexel/CCRUN field green infrastructure facilities across the CCRUN project area.

Climate

CCRUN members Radley Horton and Dan Bader are advancing and expanding new methodologies for future climate projections to all cities throughout the Northeast, including gridded maps depicting our state-of-the-sea level rise projections. They are also developing downscaled climate change scenarios for multiple applications, including heat impacts on human health.

In addition, a new project has been launched with Con Edison, a major electrical utility in the NYC metro region, which is designed to explore the combined impacts of heat and humidity on electricity demand. The project will include both analysis of historical weather data for the New York Metropolitan Region, and projections focused on future demand.

Evaluation and Vulnerability

CCRUN member Malgosia Madajewciz has begun discussions about a new partnership with the US Forest Service and the New York City Department of Parks. The partnership would consist of three parts: 1) an investigation of resilience to coastal storms in large, public housing apartment complexes; 2) research into the role that institutions that act as environmental stewards play in building resilience to climate risks in urban areas; and 3) a larger initiative that addresses various dimensions of building resilience to coastal storms in urban neighborhoods.

Research Findings

Our most significant findings in CCRUN Year 5 include the following:

***Coasts*:** Philip Orton and colleagues performed a climate attribution study and presented it at the 2014 AGU conference. First, Hurricane Sandy's flooding was simulated and adjusted to correct any errors, based on available observations. Using that model simulation and spatial correction field, an experiment was conducted in which 20 cm of local sea level rise that has occurred since 1900 was removed, and flooding was simulated again. In this way, the effect of sea level rise on New York City region flooding was quantified (see Figure 3). In addition, collaborators quantified damages and impacts on population, showing that sea level rise added about $2 billion to Sandy's toll in New York City, and affected 11.4% more people and 11.6% more housing units than it would have without sea level rise.

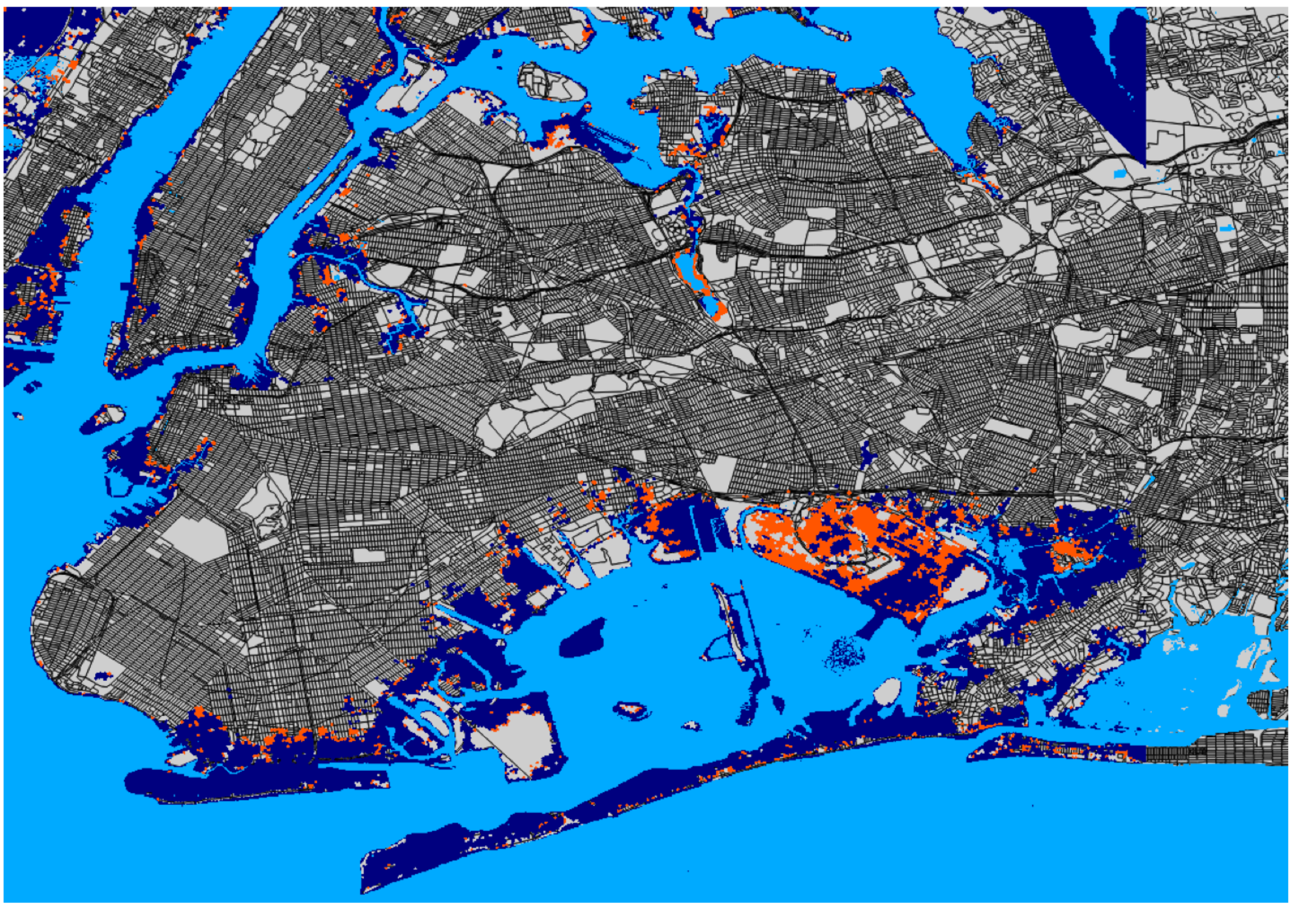


Fig. 3. Map showing the contrast between the extent of actual Sandy flooding (blue and orange areas), versus Sandy flooding as it would have happened without the added effects of sea level rise. See Kulp et al., 2014, http://bit.ly/1I75Yoa .

***Water*:** Using a reservoir operations model called the Screening Tool for the Assessment of Turbidity and Supply (STATS), we find that projected increases in precipitation and temperature result in earlier spring refill in Delaware River Basin reservoirs, and an increased number of days above an operationally significant turbidity threshold in the Ashokan Reservoir, in the

Catskill system in Ulster County, New York. For both of these metrics, the contribution to increases from climate change is greater than the increases from simple changes in screening model operations.

Public Health: Compared to other warm season days, deaths during heat waves were more likely to occur in black (non-Hispanic) individuals than other race/ethnicities, at home than in institutions and hospital settings, and among those living in census tracts that received greater public assistance (see Figure 4).

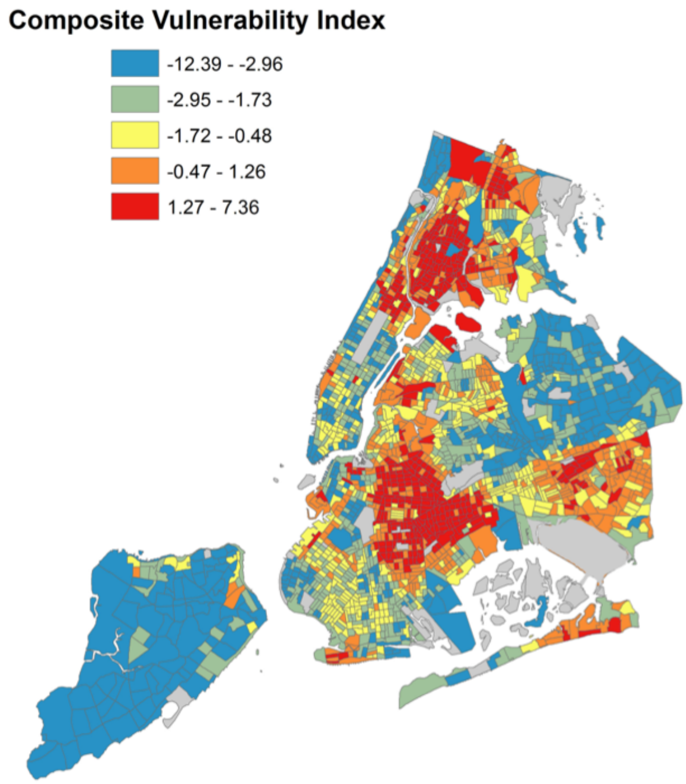


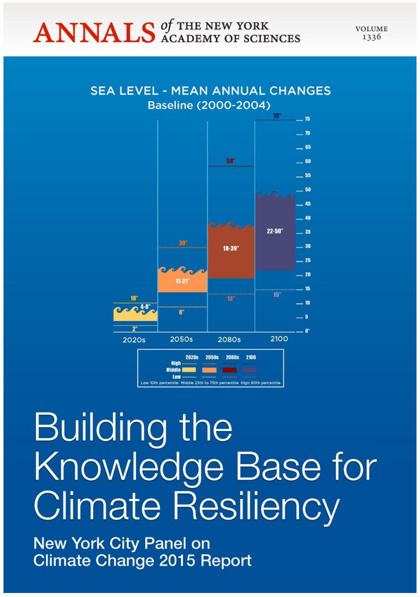
Fig. 4. NYC Census tracts according to Composite Heat Vulnerability Index, taking into account the proportion of homes receiving public assistance, proportion of non-Hispanic black residents, porportion of overall deaths occurrign in the home, relative surface temperature, and proportion of trees. A higher composite score (red and orange shaded areas) indicates a residential area with a higher risk of heat-related mortality. (Madrigano et al., 2015a).

Green Infrastructure: Green infrastructure programs are being implemented both in Europe and the US. European GI programs are typically more diverse and not as well funded as the US programs, since they target generation of a range of ecosystem services, in response to various EU guidelines. By contrast, in the US GI programs proposed as a means of reducing urban runoff are well-funded and more targeted since the performance of these systems for runoff capture is legally binding.

Climate: Using CMIP5 climate models, we project an approximately order of magnitude increase in coastal flood risk by the end of the 21st century in the Eastern U.S., due to combined effects of higher sea levels and increases in coastal storm strength and intensity (as estimated based on sea surface temperatures in the tropical North Atlantic relative to the tropical oceans as a whole).

Evaluation and Vulnerability: Preliminary findings from a survey of residents in the Rockaways neighborhood of New York City suggest that standard vulnerability analysis that posits that certain populations, such as the low-income, the elderly, women, etc. are more vulnerable to all climate risks is not a good guide to understanding vulnerability to coastal storms in urban neighborhoods.

Accomplishments



The New York City Panel on Climate Change, lead by CCRUN's Lead PI Cynthia Rosenzweig and with contributions from several CCRUN members, released their latest report in February 2015 as a special issue of the *Annals of the New York Academy of Sciences* (Figure 5). Climate projections developed by the CCRUN team provide the scientific foundation of the report. The report also offers a process for creating indicators and monitoring efforts that track data related to climate hazards, impacts and adaptation strategies, as well as recommendations for making the New York Metropolitan Area more resilient.

The next New York City Panel on Climate Change will convene in Spring 2015, and will again feature many CCRUN team members.

Public Health

CCRUN members, led by Brian vant-Hull of CCNY, have completed development of an automated temperature anomaly forecast model that is intended to assist the health community in understanding when mortality rates during heat waves may increase (http://glasslab.engr.ccny.cuny.edu/u/brianvh/UHI/modelpage.html). The empirically based approach to predicting daily spatial variations of the Urban Heat Island effect is based on high spatial resolution data, regressed against local characteristics (e.g., vegetation, building height) to produce a statistical model of relative temperature anomalies, which is then combined with weather model output such as wind speed, vertical temperture files and humidity. This model will provide a 24-hour advance prediction of the amplitude of the mid-afternoon temperature anomalies from the average for New York City (Figure 6).

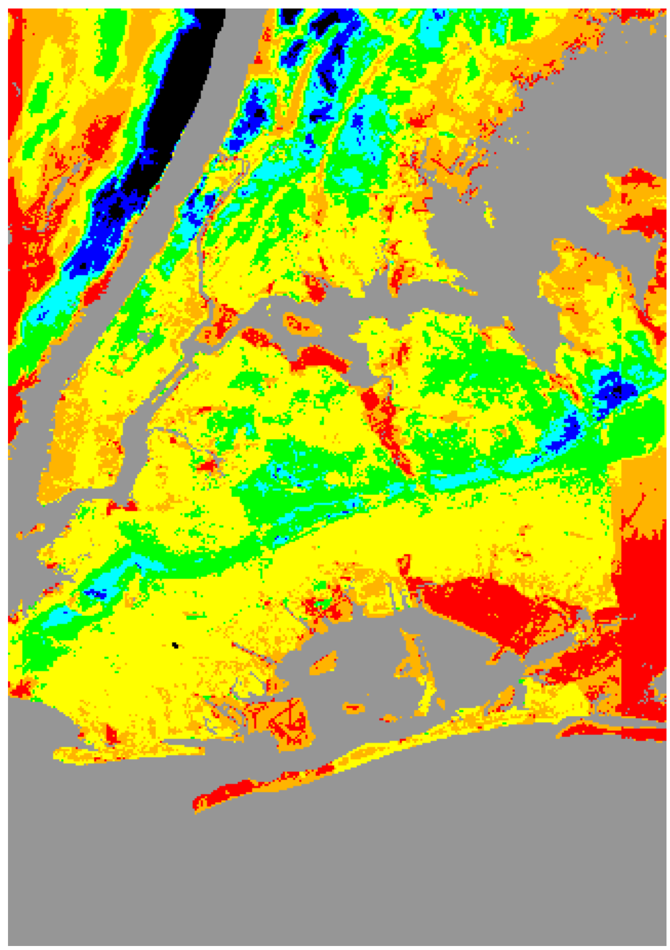


Fig. 6. Example of a predicted temperature anomaly map. The forecast average temperature is indicated by the yellow color on the map; weather inputs are used to adjust the map scale. See vant-Hull et al., 2015 (http://bit.ly/1IyymCC).

Green Infrastructure

The Alley Pond observatory, an old growth ecological reference site for the Drexel/CCRUN green infrastructure studies in New York City, has been retrofit and brought back online. Data collected at the site is now made available to the public through the USDA Forest Service Smart Forest Network (http://smartforests.org/alleypondsmarttech.shtml; see e.g., Figure 7). Next steps include comparing the microclimates of urban forests with rural forests around the region and nation.

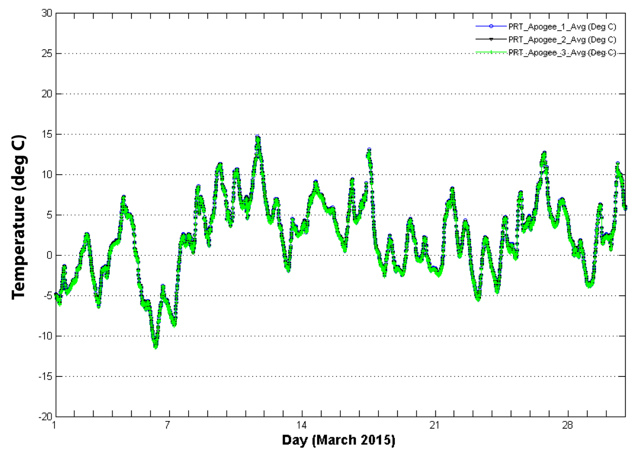


Fig. 7. At left, a webcam photo of the remnant old growth forest at the measurement site for Alley Pond, Queens, New York. At right, an example from March 2015 of the temperature plots available online for Alley Pond at the Smart Forest Network web site. Measurements in this plot are recorded every 15 minutes.

Climate

We have characterized the time and space properties of cold-season storms that cause high surges, by performing a hierarchical cluster analysis of the sea level pressure field (SLP) associated with high surge in the New York City Battery tide gauge station. Five types of surge-related situations have been identified. Not surprisingly, four of those are associated with relatively weak low-pressure perturbations that originate from the Southeast US and the Gulf coast. These perturbations move either over sea or land and amplify as they approach the Northeast. When they reach the Northeast, the storms develop a strong pressure gradient associated with high winds from the southeast to northeast sector. The clustering distinguishes between types by pattern of movement and the large-scale circulation surrounding the storm.

Publications and Reports

Catalano de Sousa, M.R. and **F.A. Montalto**, 2015, Green infrastructure as a climate change adaptation strategy for the urban northeast. In Musco, F. and E. Zanchini (eds). *Il clima cambia le citta': Strategia di adattamento e mitigazione nella pianificazione urbanistica*. Rome: Legambiente (League for the Environment), 414 pp.

Coffel, E., and **R. Horton**, 2015, Climate change and the impact of extreme temperatures on aviation. *Weather Clim. Soc.*, **7**, no. 1, 94-102, doi:10.1175/WCAS-D-14-00026.1.

Gornitz, V. and **A. Blumberg**; contributing authors: M. Brady, A. Cohn, E.K. Hartig, L. Patrick, L., and P. Rafferty, 2015, Chap. 3.7 Coastal Zones. In: *U.S. Cities and Climate Change: Urban, Infrastructure, and Vulnerability Issues, Technical Input to the National Climate Assessment Urban Zone*. W. Solecki and C. Rosenzweig, eds., 2015. Island Press. (In press).

Guitierrez, E., J.E. Gonzalez, A. Martilli, R. Bornstein,and **M. Arend**, 2015, Simulations of a Heat-Wave Event in New York City Using a Multilayer Urban Parameterization. *J. Appl. Met. Clim.* 54, 283-301.

Horton, R.M., and J.P. Liu, 2014, Beyond Hurricane Sandy: What might the future hold for tropical cyclones in the North Atlantic? *J. Extreme Events*, 1, no. 1, 1450007, doi:10.1142/ S2345737614500079.

Horton, R. and Co-authors. 2015. Climate Science for Decision-Making in the New York Metropolitan Area. *Climate in Context*. G. Garfin and A. Parris (eds.). Wiley. In press.

Horton, R., D. Bader, Y. Kushnir, C. Little, R. Blake, and **C. Rosenzweig**, 2015, New York City Panel on Climate Change 2015 Report: Climate observations and projections. *Ann. New York Acad. Sci.*, 1336, 18-35, doi:10.1111/nyas.12586.

Horton, R., C. Little, **V. Gornitz, D. Bader**, and M. Oppenheimer, 2015, New York City Panel on Climate Change 2015 Report: Sea level rise and coastal storms. *Ann. New York Acad. Sci.*, 1336, 36-44, doi:10.1111/nyas.12593.

Kinney, P. L., T. Matte, K. Knowlton, **J. Madrigano, E. Petkova, K. Weinberger, A. Quinn, M. Arend,** and **J. Pullen,** 2015, New York City Panel on Climate Change 2015 Report: Public Health Impacts and Resiliency. *Ann. New York Acad. Sci.*, 1336: 67–88. doi: 10.1111/nyas.12588.

Kopp, R.E., **R.M. Horton**, C.M. Little, J.X. Mitrovica, M. Oppenheimer, D.J. Rasmussen, B.H. Strauss, and C. Tebaldi, 2014, Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. *Earth's Future*, 2, no. 8, 383-406, doi:10.1002/2014EF000239.

Little, C.M., **R.M. Horton**, R.E. Kopp, M. Oppenheimer, and S. Yip, 2015, Uncertainty in twenty-first-century CMIP5 sea level projections. *J. Climate*, **28**, no. 2, 838-852, doi:10.1175/JCLI-D-14-00453.1.

Madrigano, J., K. Ito, S. Johnson, **P.L. Kinney,** and **T. Matte,** 2015a, A case-only study of vulnerability to heat wave–related mortality in New York City (2000–2011). *Environmental Health Perspectives*. doi: 10.1289/ehp.1408178.

Madrigano, J., D. Jack, G.B. Anderson, M.L. Bell, and **P.L. Kinney,** 2015b, Temperature, ozone, and mortality in urban and non-urban counties in the northeastern United States. *Environmental Health*, 14(1), 3.

Miller, S., G. Kidd, **F.A. Montalto,** P. Gurian, C. Worral, and R. Lewis, 2014, Contrasting perspectives regarding climate risks and adaptation strategies in the New York Metropolitan Area after Superstorm Sandy. *J. Extreme Events*, 1, no. 1. doi: 10.1142/S2345737614500055.

Nakamura, J., U. Lall, **Y. Kushnir**, and B. Rajagopalan, 2015, HITS: Hurricane Intensity and Track Simulator with Atlantic Ocean applications for risk assessment. *J. Appl. Meteorol. Climatol.,* doi: 10.1175/JAMC-D-14-0141.1.

Nguyen J.L., M.S. Link, H. Luttmann-Gibson, F. Laden, J. Schwartz , B.S. Wessler, M.A. Mittleman, D.R. Gold, and D.W. Dockery, 2015, Drier air, lower temperatures, and triggering of paroxysmal atrial fibrillation. *Epidemiology*, 26: 374-380. doi: 10.1097/EDE.0000000000000284.

Orff, K., G. Wirth, **P. Orton**, et al., 2014, Living Breakwaters: Volume II Staten Island and Raritan Bay, 118 pp, Housing and Urban Development, Rebuild By Design. Available at http://www.rebuildbydesign.org/project/scape-landscape-architecture-final-proposal/ .

Orton, P., F. Conticello, F. Cioffi, T. Hall, **N. Georgas, U. Lall,** and **A. Blumberg** (in press), Hazard assessment from storm tides and rainfall on a tidal river estuary. Paper presented at International Association for Hydro-Environment Engineering and Research, The Hague, the Netherlands, 10pp, 28 June - 3 July, 2015.

Orton, P., S. Vinogradov, N. Georgas, A. Blumberg, N. Lin, **V. Gornitz**, C. Little, K. Jacob, and **R. Horton**, 2015, New York City Panel on Climate Change 2015 Report: Dynamic Coastal Flood Modeling. *Ann. New York Acad. Sci*, 1336(1), 56-66.

Petkova, E.P., D.A. Bader, G.B. Anderson, **R.M. Horton**, K. Knowlton, and **P.L. Kinney**, 2014, Heat-related mortality in a warming climate: Projections for 12 U.S. cities. *Intl. J. Environ. Res. Public Health*, **11**, no. 11, 11371-11383, doi:10.3390/ijerph111111371.

Rosenthal J.K., **P.L. Kinney**, and K.B. Metzger, 2014, Intra-urban vulnerability to heat-related mortality in New York City, 1997-2006. *Health and Place* 30, 45-60.

Rosenzweig, C., R.M. Horton, D.A. Bader, M.E. Brown, R. DeYoung, O. Dominguez, M. Fellows, L. Friedl, W. Graham, C. Hall, S. Higuchi, L. Iraci, G. Jedlovec, J. Kaye, M. Loewenstein, T. Mace, C. Milesi, W. Patzert, P.W. Stackhouse, and K. Toufectis, 2014, Enhancing climate resilience at NASA centers: A collaboration between science and stewardship. *Bull. Amer. Meteorol. Soc.*, 95, no. 9, 1351-1363, doi:10.1175/BAMS-D-12-00169.1.

Rosenzweig, C., and W. Solecki, 2014, Hurricane Sandy and adaptation pathways in New York: Lessons from a first-responder city. *Global Environ. Change*, **28**, 395-408, doi:10.1016/j.gloenvcha. 2014.05.003.

Rossi, N., 2014, Potential Impacts of Changes in Climate on Water Quality in New York City's Ashokan Reservoir. *Environmental & Water Resources Engineering Masters Projects*. Paper 61. Available at http://scholarworks.umass.edu/cee_ewre/61

Rossi, N., L. DeCristofaro, S. Steinschneider, C. Brown, and **R.N. Palmer**, 2015, Potential Impacts of Changes in Climate on Turbidity in New York City's Ashokan Reservoir. *J. Water Resources Planning and Management,* in press.

Snyder, S., R.M. Hoffstadt, L.B. Allen, K. Crowley, **D.A. Bader, R.M. Horton**, G. Roehrig, and P. Hamilton, 2014, City-wide collaborations for urban climate education. In *Future Earth: Advancing Civic Understanding of the Anthropocene*, AGU Geophysical Monograph 203. D. Dalbotten, Ed. American Geophysical Union/John Wiley & Sons, 103-109, doi:10.1002/9781118854280.ch11.

Solecki, W., and **C. Rosenzweig**, 2014, Climate change, extreme events, and Hurricane Sandy: From non-stationary climate to non-stationary policy. *J. Extreme Events*, **1**, no. 1, 1450008, doi:10.1142/S2345737614500080.

Solecki, W., **C. Rosenzweig**, R. Blake, A. de Sherbinin, T. Matte, F. Moshary, B. Rosenweig, **M. Arend**, **S. Gaffin**, E. Bou-Zeif, K. Rule, G. Sweeny, and W. Dessy, 2015, New York City Panel on Climate Change 2015 Report: Indicators and monitoring. *Ann. New York Acad. Sci.*, **1336**, 89-106, doi:10.1111/nyas.12625.

Solecki, W., **C. Rosenzweig, V. Gornitz, R. Horton,** D.C. Major, L. Patrick, and R. Zimmerman, 2015, Climate change and infrastructure adaptation in coastal New York City. In: *Climate Change and the Coast: Building Resilient Communities*. B. Glacovic, R. Kaye, M. Kelly, and A. Travers, eds. Boca Raton, FL: CRC Press; Taylor and Francis.

Stevens, A., **R.M. Horton, D.A. Bader, C. Rosenzweig**, A.T. DeGaetano, and W. Solecki, 2014, *Climate Change in New York State: Updating the 2011 ClimAID Climate Risk Information Supplement to NYSERDA Report 11-18 (Responding to Climate Change in New York State)*. NYSERDA Report 14-25. New York State Energy Research and Development Authority. Available at http://www.nyserda.ny.gov/climaid

Travaline, K., **F.A. Montalto,** and C. Hunold, 2015, Deliberative Policy Analysis and Policy-Making in Urban Stormwater Management. *J. Environmental Planning and Policy*. doi: 10.1080/1523908X. 2015.1026593.

Vant-Hull, B., M. Karimi, A. Sossa, R. Khanbilvardi, 2015, A Simple Statistical Model for Predicting Fine Scale Spatial Temperature Variation in Urban Settings. *American Meteorological Society Annual Meeting, Sixth Symposium on Environment and Health,* Phoenix, AZ. Recorded oral presentation available at https://ams.confex.com/ams/95Annual/webprogram/Paper257722.html

Weinberger K.R., **P.L. Kinney,** and G.S. Lovasi, 2015, A review of spatial variation of allergenic tree pollen within cities. *Arboriculture & Urban Forestry* 41(2): 57-68.

Whateley, S., Steinschneider, S., and Brown, C., 2014, A climate change range-based method for estimating robustness for water resources supply. *Water Resources Research*, 50(11), 8944-8961, doi: 10.1002/2014WR015956

Yu, Ziwen, 2015, Assessment of the Physical, Socioeconomic and Climatic Constraints on Green Infrastructure. Ph.D. thesis, Drexel University, Philadelphia, PA, 317 pages; http://gradworks.umi.com/36/72/3672103.html

Zhao, H., H. Roberts, J. Ludy, A. Rella, J. Miller, **P. Orton,** G. Schuler, L. Allman, A. Peak, R. Shirer, K. Mathews, K. Orff, K. Wirth, L. Elachi, 2014, Coastal Green Infrastrucutre Research Plan for New York City. Northeast Interstate Water Pollution Control Commission, 157 p. Available at http://www.dec.ny.gov/docs/remediation_hudson_pdf/cginyc.pdf

Project Metrics

Graduate students and postdoctoral researchers supported by RISA funding (in whole or in part):

Current

- Maria Raquel Catalano de Sousa (PhD student, Drexel University)
- Leslie DeCristofaro (PhD student, University of Massachusetts-Amherst)
- Maryam Karimi (PhD student, City College of New York)
- Scott Steinschneider, (Post-Doctoral Research Scientist, Columbia Univesity)
- Kate Weinberger (PhD student, Columbia University)
- Sarah Whateley (PhD student, University of Massachusetts-Amherst)
- Walter Yerk (PhD student, Drexel University)

Past

- Naresh Devineni (Post-Doctoral Research Scientist, Columbia University)
- Jaime Madrigano (Post-Doctoral Research Scientist, Columbia University)
- Elisaveta Petkova (PhD, Columbia University)
- Nicholas Rossi (MA, University of Massachusetts-Amherst)
- Brian vant-Hull (Post-Doctoral Research Scientist, City College of New York)
- Ziwen Yu (PhD, Drexel University)

Tools, Datasets, and Resources Used by Stakeholders

VISTADATA is the data management system CCRUN Drexel team uses for making remote sensing data collected in our GI monitoring network sites available to the general public (with a password). Individual passwords have been provided to the NYC Dept of Parks and Recreation, the NYC Department of Environmental Protection, the Jacob K. Javits Convention Center Sustainability Director, http://vistadv.cae.drexel.edu/vdv/index.html).

LIDRA is a tool Drexel team developed for comparing the cost effectiveness of reducing runoff with different green infrastructure / low impact development technologies. Our stakeholders and users in general can run LIDRA simulations for free through this website (http://www.lidratool.net/). Over the past year, stakeholders used LIDRA in Bethlehem, PA and Newburgh, NY. LIDRA capabilities were presented at the LID workshop in Houston, Texas.

Citizen Scientist is a project of Drexel team that leverages teens and community members to measure the impact of urban green infrastructure projects in their neighborhoods (http://measurewith.us/). DU is expanding its citizen scientist program to more than 10 total paid participants.

Stakeholder Engagements/Outreach/Media Engagements

October

We hosted a "Sustainable Urban Coasts in the Urban Northeast" workshop in October 2014 to solicit input from a mix of sustainable shoreline practitioners and scientists that could be used to help inform this rapid movement toward use of natural and nature-based features to redesign urbanized coasts. The workshop was organized with instigation and organizational help from NOAA-CSI (Adrienne Antoine, Adam Parris) and CCRUN leadership.

We also organized a "NEIWPCC Coastal Green Infrastructure Research Plan: Review Meeting" in New York City in October, soliciting inputs for a scoping study. It was attended by stakeholders, natural resource managers, scientists, non-profits, from across New York State and New York City.

Montalto - SWRE research on adaptation to extreme precipitation on WNYC:
http://www.wnyc.org/story/nyc-2050-more-rain-harder-rains/

Montalto - SWRE research on the Jacob K. Javits Center featured in the NY Daily News:
http://www.nydailynews.com/life-style/big-town/raising-roof-article-1.1975080

Orton - Regarding Jersey City's flood adaptation plan to build a development like Battery Park City on NBC 4: http://www.nbcnewyork.com/video/#!/on-air/as-seen-on/Jersey-City-Mulls-Sea-Wall-Plan/281135972

Orton – On building barriers to help prevent coastal flooding, in the Jersey Journal:
http://www.nj.com/hudson/index.ssf/2014/10/jersey_city_studying_plan_to_buld_2_billion_sea_wall_to_protect_downtown_from_flooding.html

December

Montalto - SWRE research in Alley Pond Park and in the Smart Forest Network featured in New York Times: http://www.nytimes.com/2014/12/03/nyregion/high-tech-woods-in-queens-help-us-monitor-urban-ecology.html?ref=nyregion

January

Orton - Winter Storm Juno Threatens the Economy With Snowpocalypse:
https://www.mainstreet.com/article/winter-storm-juno-threatens-the-economy-with-snowpocalypse/page/3

February

On February 17, 2015, Cynthia Rosenzweig and Radley Horton spoke at City Hall for the release of the New York City Panel on Climate Change report.

On February 23, 2015 Radley Horton was a panelist at the launch event for Columbia's Initiative on Extreme Weather and Climate, part of Columbia's World Leaders Forum series:
https://www.youtube.com/watch?v=EYiYK5tlsrU&feature=youtu.be

March

Orton gave an invited online webinar as part of a seminar series for FEMA's Technical Mapping Advisory Committee, Future Conditions Sub-Committee, March 26, 2015. The title was "Hydrodynamic modeling of future coastal flood hazards for New York City".

Orton also gave a seminar for and helped provide advice to the team behind the American Museum of Natural History exhibit.

Bader was quoted in the Queens Tribune and Voices of America on the release of the New York City Panel on Climate Change Report:
http://queenstribune.com/more-sandys-ahead/
http://www.voanews.com/content/new-york-climate-panel-report-heat-flooding/2666920.html

Montalto - Lessons on Post-Resilience from Venice, 2015:
http://www.thenatureofcities.com/2015/03/22/lessons-on-post-resilience-from-venice-2015/

Orton - Sea Level Rise Added $2 Billion to Sandy's Toll in New York City:
https://eos.org/articles/sea-level-rise-added-2-billion-to-sandys-toll-in-new-york-city

Appendix A – Additional Research Findings

Coasts

Higher sea levels are virtually certain by late 21st-century. Sea levels in New York City by the 2080s are projected to rise 18-39 inches (mid-range estimates 25th-75th percentile), and 58 inches (high estimate; 90th percentile). By 2100, sea level could reach as high as 75 inches (90th percentile).

By the 2080s, increased sea level is very likely to increase the frequency, extent, and height of coastal flooding. The annual chance of today's 100-year flood (one with a 1 % probability of occurrence per year) could increase to 2.0-5.4 percent (25th-75th percentile), and as much as 12.7 percent (90th percentile). By the 2080s, flood heights of the 100-year storm could increase to 12.8-14.6 feet (25th-75th percentile), and as high as 16.1 feet (90th percentile), relative to the present baseline. By this time, the areas flooded by today's 100-yr storm plus sea level rise would cover significant portions of New York City: parts of southern Brooklyn, including Coney Island, Sheepshead Bay; Queens including the Rockaways, Jamaica Bay; and low-lying portions of lower Manhattan and Staten Island.

Our updated sea level rise projections have been incorporated into the Stevens dynamic hydrodynamic storm surge model and compared with results using the static "bathtub" model. The two methods yield similar results for most locations. Exceptions, where results differ by over 0.5 ft, are more widespread for hurricane flooding than for nor'easters.

We performed a validated tropical-extratropical flood hazard assessment for New York Harbor, and also did deeper analyses of historical New York City area storm tide estimates from estimated Category-3 hurricanes in 1788 and 1821. Results were new storm tide estimates (2.9 +/- 0.4 m and 3.0 +/- 0.3 m, respectively) that are lower than prior estimates, and we have also reduced uncertainties for these events (prior was +/- 0.5 m). Additional conclusions of our work are that Hurricane Sandy's storm tide of 3.39 m was a 290-year (180-450) storm tide, and it was the largest at NYH in at least 300 years.

We also did a validated tropical (TC) / extratropical (ETC) flood hazard assessment for the Hudson River, merging storm surge, rainfall and sea level rise. Results for the upper Hudson (Albany) suggest a dominance of inland ETC events, for the lower Hudson (at New York Harbor) a case where offshore ETCs are dominant for shorter return periods and TCs are more important for longer return periods (over 150 years), and for the middle-Hudson (Poughkeepsie) a mix of all three flood events types is important.

Public Health

Both spatial and temporal variability in surface air temperature can be captured by regression against weather variables, with a correlation coefficient of 0.5.

A building energy model can correct for an overprediction of night time cooling by an urbanized dynamical model. A multi-layer vertical building model captures diurnal variations better than a single layer system, attributed in large part to vertical distribution of turbulence.

A 10 ppb increase in ozone was associated with a 0.45% increase in mortality in urban counties, while this same increase in ozone was associated with a 0.73% increase in non-urban counties. An increase in temperature from 70°F to 90°F (21.2°C 32.2°C) was associated with a 8.88% increase in mortality in urban counties and a 8.08% increase (95% PI: 6.16, 10.05) in non-urban counties (Madrigano et al., 2015b).

Lower absolute humidity had the strongest and most consistent association: each 0.5 g/m decrease in the prior 24 hours increased the odds of atrial fibrillation by 4% and by 5% for exposure in the prior 2 hours (Nguyen et al., 2015).

Green Infrastructure

The Nashville Greenstreet (Cambria Heights, NY) captured 87% of runoff that presented itself at its inlet, computed considering approximately 41 different non-extreme rain events monitored over the past 4 years. The same site captured about 67% of the runoff presenting itself at its inlet during 51 extreme events, defined as precipitation events that either in terms of intensity or total amount are greater than the historical 95% percentile rain event for the CCRUN region. The average event performance efficiency of the site considering all events is approximately 76%.

For inflows of up to 21 cubic meters of runoff, the lined ABC carpet constructed wetland (Bronx, NY) was able to retain 100% of the runoff routed to it from an adjacent parking lot. Evapotranspiration of up to 30 cubic meters of water in one particular 10 day summer dry spell replenishes the storage capacity of the system, preparing it to receive runoff during the subsequent wet spell. Changes in the timing and/or amount of precipitation could significantly alter the site's performance.

Climate

We found that Regional Climate Model (RCM) projections for the Northeast project greater warming of extreme summer and winter temperatures than of average temperatures. We also found that regional climate models were able to capture the atmospheric dynamics associated with extreme temperature events (over the entire U.S.), but not the surface boundary conditions (soil moisture and snow water equivalent). This may suggest limits to the applicability of some RCMs for extreme event analysis.

Using the latest generation of climate models (CMIP5), we find that global thermal expansion remains a major source of uncertainty is sea level rise projections, despite (well-founded) growing emphasis on land based ice melt. We also confirm what was projected by the prior generation of CMIP3 models: a sea level rise maximum along the Northeast US coast. In addition, we have:

- Developed a nonparametric stochastic model for simulating movement and landfall probabilities of tropical storms.
- Calculated the spatial pattern of cold-season high surface wind events in the Northeast US, quantified their frequency of occurrence, and identified their link to winter storm events.
- Developing a statistical method for characterizing storm that cause high surge events in coastal regions in order to assess the future storm surge properties in the Northeast US.

All these findings are ultimately related to the exposure, vulnerability, and storm associated risk in the urban Northeast and are woven into work that examines these aspects.

Evaluation and Vulnerability

Preliminary findings from a survey of residents in the Rockaways neighborhood of New York City suggest that one of the most vulnerable groups in the aftermath of hurricane Sandy were middle income home owners, most of whose savings were tied up in their homes. Residents in this group have received little assistance for rebuilding, and have all but depleted their own resources to recover from the storm; a large percentage have gone into debt. This group would find it difficult to recover from another storm. The livelihoods of low-income populations in the Rockaways, on the other hand, were buffered by social programs that helped people to pay for food and lodging after the storm and helped pay moving costs for some. Since most low-income people rent, they could move fairly easily and did not lose a significant amount of their savings.

Appendix B – Additional Accomplishments

Climate

We developed a nonparametric stochastic model suitable for the simulation of tropical cyclone tracks based on past observations. The model is using archived tropical cyclone track data, which record information on location, time, and maximum wind speed throughout the life of a large collection of storms. These tracks fall into coherent track clusters, distinct from one another in space, a result most likely from distinct, underlying physical process (e.g., steering wind, wind shear, and underlying SST). Consequently, storm evolution is most likely non-Markovian. This property is addressed in our model through an algorithm that simulates tracks by randomly sampling track segments of varying length, selected from historical tracks while preferring tracks from the same cluster family. When running the model, storm birth location is chosen randomly. Total storm length is determined at birth by local distribution, and movement to other tropical cyclone segments by distance to neighbor tracks, comparative vector, and age of track. The model performance is evaluated by imposing a regular grid on the domain of interest (the North Atlantic). In each grid box, long-term tropical cyclone risk is assessed through the annual probability distributions of the number of storm hours, windspeed, and in relevant locations, landfalls statistics. Theses are compared to observations. The model is also applied to the conditional simulation of hurricane tracks from specific positions for hurricanes that were not included in model fitting (i.e., storms that occurred more recently than the smapled data coverage) to see whether the probabilistic coverage intervals properly overlays the actual track. The results show that the model provides an effective tool for probabilistic assessment of storm probabilities, particularly landfall probabilities along the Atlantic coast. A complete description of the model and its evaluation is given in Nakamura et al. (2015).

This study analyzes the association between wintertime high wind events (HWEs) in the northeast United States and extratropical cyclones. Sustained wind maxima in the Daily Summary Data from the National Climatic Data Center's Integrated Surface Database are analyzed for 1979-2012. For each station, a Generalized Pareto Distribution (GPD) is fit to the upper tail of the daily maximum wind speed data, and probabilistic return levels at intervals of 1, 3 and 5-years are derived from the GPD fit. At each interval, wind events meeting the return level criteria are termed HWEs. The HWEs occurring on the same day are grouped into multistation events allowing the association with extratropical cyclones, which are tracked in the European Center for Medium-Range Weather Forecast ERA-Interim reanalysis. This study finds that the HWEs are most often associated with cyclones travelling from southwest to northeast, usually originating west of the Appalachian Mountains. A series of sensitivity analyses confirms the robustness of this result. Furthermore, the relationship between the strength of the wind events and the corresponding storm minimum sea level pressure is analyzed. No robust relationship between these quantities is found for strong wind events. Nevertheless, subsequent analysis shows that a relationship between deeper storms and stronger winds emerges if the analysis is extended to the entire set of wintertime storms. The results of the study are in a paper under review by Both, Rider, Lee, and Kushnir. It is undergoing requested revisions and modifications to address the reviewers' comments.