Supporting Regional Implementation of Integrated Climate Resilience Consortium for Climate Risk in the Urban Northeast (CCRUN) Phase II

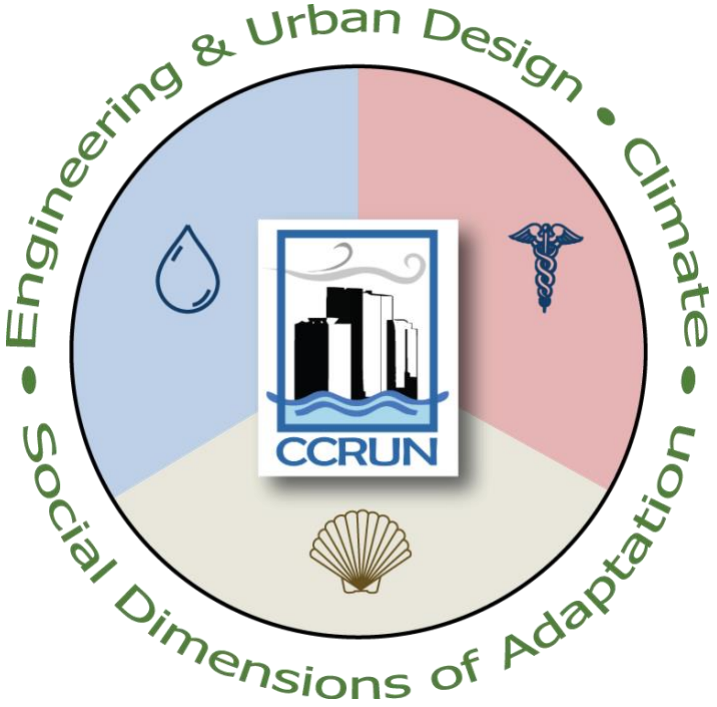
Research Highlights, June 1, 2018 – May 31, 2019

Boston

New York City

Philadelphia

CCRUN



CCRUN's Mission

CCRUN conducts 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

Stevens
Institute of Technology
The Innovation University

University of Massachusetts Amherst

Boston University

Drexel University

Hunter
The City University of New York

The CCRUN Team

Lead Investigators, Sectors, and Cross-Cutting Themes: Radley Horton (CU), Patrick Kinney (Boston University)**,** Franco Montalto (Drexel)**,** Richard Palmer (UMass), Philip Orton (Stevens)**,** William Solecki (CUNY)

Program Manager: Daniel Bader (CU)

Investigators: Robert Chen (CU), Alex de Sherbinin (CU), Patrick Gurian (Drexel), Yochanan Kushnir (CU), Kytt MacManus (CU), Malgosia Madajewicz (CU), Gregory Yetman (CU)

Research & Support Staff: Jim Carcone (CU), Maria Castillo (Boston University)*, Annie Gerard (CU), Merlie Hansen (CU), Cuihua Li (CU)*, Dara Mendeloff (CU)*, Jane Mills (CU), Frank Pascuzzi (CU), Al Pinto (CU), John Scialdone (CU), Jessica Spaccio (Cornell)*, David Strom (CU), Sri Vinay (CU), Ziwen Yu (Drexel)

Graduate Students and Post-docs:
Rebekah Breitzer (CUNY), Paige Brochu (Boston University)*, Kristoper Cadieux (Hunter College)*, Ziyu Chen (Stevens), Hannah Densten (UMass), Erin Friedman (CUNY), Lelia Heidari (Boston University)*, Marcia Pescador Jimenez (Harvard)*, Katelyn Johnson (Drexel)*, Annesia Lamb (Brooklyn College), Ian Lempitsky (Drexel)*, Khai Hoan Nguyen (Rutgers), Colin Raymond (CU), Parisa Setayesh (Hunter College)*, Leena Shevade (Drexel)*, Karly Soldner (Drexel)*, Walter Yerk (Drexel)*, Lun (Larry) Yin (Stevens)*, Fanglin Zhang (Stevens)

Research Affiliates:
Bita Alizadehtazi (Drexel)*, Susana Adamo (CU), James Booth (CCNY), Arthur Degaetano (Cornell), Kevin Lane (Boston University), Peter James (Harvard)*, Alison Kenner (Drexel)*, Upmanu Lall (CU), Dong-Eun (Donna) Lee (CU), Stephanie Miller (Drexel)*, Jennifer Nakamura (CU)*, Babak Roodsari (Drexel)*, Raymond Sambrotto (CU), Mingfang Ting (CU)

Other Collaborators:
Achira Amur (Drexel), Reginald Blake (New York City College of Technology), Craig Bond (RAND), James Booth (CCNY), Brett Branco (Brooklyn College), Maya Buchanan (Princeton), Matt Campo (Rutgers University)*, Brian Colle (SUNY Stony Brook), Ellen Douglas (UMass Boston), Donovan Finn (Stony Brook University)*, Jorge González (City College)*, Vivien Gornitz (CU). Thomas Herrington (Monmouth University)*, Marjorie Kaplan (Rutgers University)*, Paul Kirshen (UMass Boston), Debra Knopman (RAND), Robert Kopp (Rutgers University), Robin Leichenko (Rutgers University)*, Ning Lin (Princeton), Reza Marsooli (Princeton), Anthony MacDonald (Monmouth University)*, Jon Miller (Stevens Institute), Mira Olson (Drexel), Michael Oppenheimer (Princeton), Adam Parris (SRIJB; Brooklyn College), Lesley Patrick (SRIJB), Eric Sanderson (Wildlife Conservation Society), Cari Shimkus (CU), Stefan Talke (Portland State University), Thomas Wahl (Univ. Central Florida), Jon Woodruff (UMass)

*Indicates new team member over the past year

Stakeholders and Partners

100 Resilient Cities
AKRF Environmental Services Group
All Hazards Consortium
American Littoral Society
Baltimore City Department of Public Works
Beacon Institute for Rivers & Estuaries
Boston Environmental Department
Boston Public Health Commission
Camden County Municipal Utilities Administration
City of Cambridge (MA) Public Health Department
City of New Rochelle NY
City of Stamford CT
City of Yonkers NY
Connecticut Water
Consolidated Edison, Inc.
Delaware River Basin Commission
Delaware Valley Regional Planning Commission
Eastwick Friends and Neighbors Coalition
Environmental Protection Agency
ESIP Federation
F.P. Clark Associates
Groundwork Hudson Valley
Hudson River Foundation
Hudson River Watershed Alliance
Hudson Valley Initiative
Interstate Commission on the Potomac River Basin
Jamaica Bay-Rockaway Parks Conservancy
Javits Center in Manhattan
Jersey City Division of Planning
Jersey City Office of Sustainability
Massachusetts Department of Conservation and Recreation
Massachusetts Department of Environmental Protection
Massachusetts Department of Fish and Game
Massachusetts Executive Office of Energy and Environmental Affairs
Massachusetts Water Resources Authority
National Institute for Coastal & Harbor Infrastructure
National Oceanic and Atmospheric Administration, National Ocean Service
National Oceanic and Atmospheric Administration, National Weather Service
National Oceanic and Atmospheric Administration, Office of Coastal Management
Natural Resources Defense Council
The Nature Conservancy
Neptune Township, New Jersey
Newark Office of Sustainability
New England Climate and Health Network
New Jersey Department of Environmental Protection
New Jersey Sea Grant Consortium
New York City Department of City Planning
New York City Department of Environmental Protection
New York City Department of Health and Mental Hygiene
New York City Department of Parks and Recreation
New York City Geographic Information System and Mapping Organization
New York City Mayor's Office of Recovery and Resiliency
New York City Mayor's Office of Sustainability
New York City Office of Emergency Management
New York City Urban Field Station
New York-New Jersey Harbor Estuary Program
New York State Department of Environmental Conservation
New York State Department of Health
New York State Department of State
New York State Energy Research and Development Authority
New York State GIS Association
Philadelphia Office of Sustainability
Philadelphia Parks & Recreation
Philadelphia Water Department
Port Authority of New York and New Jersey
Providence Water
Regional Plan Association
Riverkeepers
Rockaways Waterfront Alliance
Rockland County NY Dept. of Planning
Sage Services LLC
Scenic Hudson
Science and Resilience Institute at Jamaica Bay
StormCenter Communications, Inc.
The Trust for Public Land
Town of Cortland NY
Town of Groton CT
US Army Corps of Engineers
Urban Climate Change Research Network
US Forest Service
US National Park Service
University of Connecticut
University of Massachusetts Boston
University of Pennsylvania
Village of Mamaroneck NY
Village of Nyack NY
Village of Tarrytown NY
Waterfront Alliance
Westchester County NY GIS and Department of Planning

CCRUN's Engagement with Local Communities

CCRUN's research has ramped up at the community and neighborhood scale within the three major cities in the urban corridor of the Northeast, while also expanding into medium and smaller sized municipalities in the region.

Over the past year, CCRUN has engaged in multiple efforts with communities throughout the Northeast U.S.. Working with each community has enabled CCRUN to build adaptive capacity at a finer geographical scale, while simultaneously harnessing the power of neighborhoods in the adaptation and resilience process. This accomplishment, greater engagement at the community-scale, is highlighted here and is a theme throughout this report.

Community-based adaptation is one of the chapters in the 2019 New York City Panel on Climate Change Report (NPCC), released in March, with extensive contributions from CCRUN team members. As part of the chapter's discussion of how vulnerability to weather and climate risks vary, it focuses on 3 communities within New York City as well as other cities in the Northeast. One neighborhood and Community Based Organization (largely environmental justice focused) in Brooklyn, the Bronx, and Manhattan was featured, and the chapter analyzes the different factors, such as environmental pollution, health stressors, and gentrification pressures, that may cause vulnerability to differ across the city (see Figure 1). A comparison of how environmental equity is brought into the adaptation plans of multiple cities across the Northeast--specifically, New York, Boston, Baltimore, Newark, and Philadelphia--is also included in the chapter.

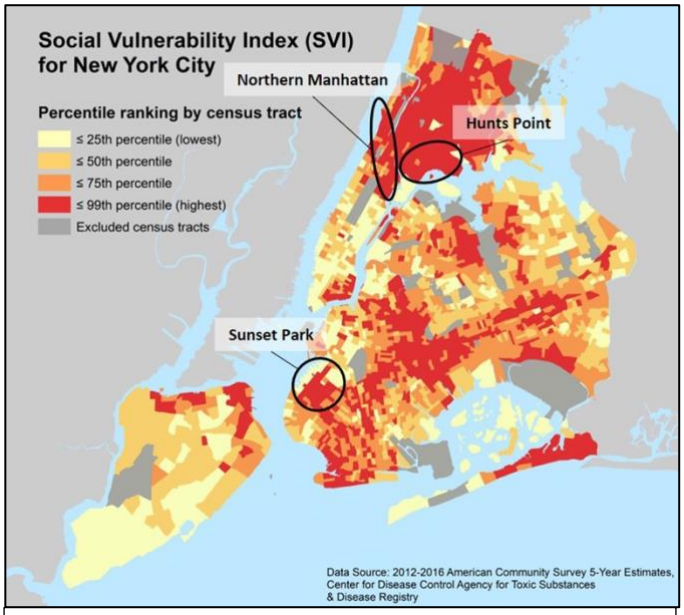


Figure 1. Social Vulnerability Index for New York City. Source: NPCC, 2019

Key findings were that communities are involved in many forms of adaptation planning but express a desire for deeper engagement with the city via use of fully collaborative, co-production planning approaches. Community engagement will continue to be a focal point in the City of New York's comprehensive sustainability plan, *OneNYC* (Early results of CCRUN work was incorporated into the April 2019 updated city sustainability and resiliency plan). The cross-city comparison found that New York and other cities in the Northeast are bringing equity into their resilience planning but limited to only distributional equity.

In addition to this specific report chapter, there are further examples of CCRUN partnering with communities in the urban Northeast. One of the Community Based Organizations highlighted in

the NPCC 2019 Report, The Point CDC, worked with CCRUN researchers and New York City stakeholders to address heat and health vulnerabilities at the neighborhood scale in Hunts Point, Bronx. This collaboration is described in greater detail later in this report and was featured in a NOAA video segment.

CCRUN's coastal and social science research has concentrated on communities in the Rockaways and Staten Island in New York City. With the support of a key stakeholder, the Rockaway Waterfront Alliance, CCRUN team members are working on research looking at the value of climate information. In particular, valuation could inform local adaptation decisions.

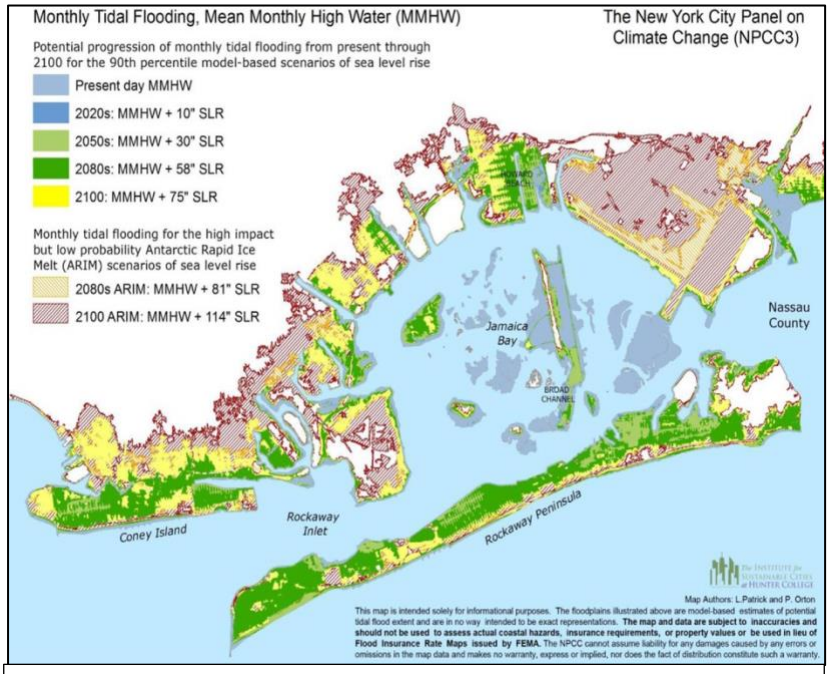


Figure 2. Expansion of area affected by monthly tidal flooding for Jamaica Bay and Coney Island areas of New York City for NPCC (2015) 90th percentile sea level rise and ARIM scenarios. Source: NPCC, 2019.

In addition, researchers from CCRUN developed a new approach for mapping monthly tidal flooding in coastal New York City neighborhoods through mean monthly high water (MMHW) (see Figure 2). This approach provides a broadened perspective and serves as a useful indicator of when areas may begin to be affected by recurring "sunny-day" flood events due to sea level rise. This work is supplemented with citizen science and through the Jamaica Bay Community Flood Watch Project, CCRUN is interacting with communities that see frequent flooding. Residents in these neighborhoods are providing detailed reporting that helps to validate the maps.

CCRUN investigators also worked with residents of Canarsie neighborhood in the Jamaica Bay region of New York City to review and assess the interaction between local metrics of community well-being, resiliency, and climate risk. The work co-partnered with the Science and Resilience Institute at Jamaica Bay through additional funds available from the Spitzer Foundation. Elements of this project are to be extended to workshops with local practitioners and policy-makers in coastal Long Island and New Jersey. These workshops will focus on the co-generation of an assessment of current coastal resiliency effort and definition of a set of social science-focused data and information gaps.

Outside of New York, in the Cramer Hill neighborhood of Camden, New Jersey, CCRUN engineering and urban design team members are working on the local Master Plan, specifically

focusing on ways to integrate green infrastructure. The outcomes of this work may lead to a green jobs training program with local stakeholders.

Building off of the progress made engaging with communities over the past year, CCRUN is already planning further efforts in the forthcoming project year which will include community-level workshops at locations throughout the urban Northeast. Transferring the knowledge and process of working with stakeholders in the big cities of the region has led to successful partnerships at the local level and presents an exciting opportunity for continued growth in the future.

New Areas of Focus and Partnerships

A number of new partnerships and areas of focus started during the fourth year of Phase II of CCRUN. Our research partner and stakeholder network expanded while simultaneously increasing interactions amongst our research teams. CCRUN also continues to broaden its reach outside of the major metropolitan areas in the urban Northeast.

Health benefits of urban greenspace
CCRUN's public health team started a new interdisciplinary research collaboration on the health benefits of urban greenspace, with Boston University's expertise in health and Harvard University expertise in GIS mapping. Using Google Earth Engine, the team is mapping urban NDVI for the 33 cities in the United States with populations of 500 thousand or greater and assessing potential health benefits of increased greenspace coverage. The results of the research could have significant value to stakeholders throughout the Northeast in assessing the potential impacts of greenspace on climate-related heat-health risks.

Improved coastal flood mapping and awareness
New monthly tidal flood mapping led by CCRUN's coastal team that began with the New York City Panel on Climate Change (NPCC) 2019 Report has evolved into a pilot study collaboration with USGS. This novel approach to nuisance flood mapping will be piloted for Boston and an area along the coast of Chesapeake Bay, with proposed expansion of mapping all of New Jersey as well. These areas include a significant portion of the CCRUN study corridor.

The Jamaica Bay Community Flood Watch Project is another collaboration with communities, scientists and public agencies to address flooding in New York City coastal areas. Through this citizen science program, "Flood Watch" trains individuals to document and report flooding in their communities. Documentation helps raise awareness and improve resilience in this critically affected area of New York City. The project is a collaboration between Stevens, the Science and Resilience Institute at Jamaica Bay, and New York City Emergency Management.

Soil moisture and thermal regulation
The CCRUN engineering and urban design team is investigating the relationship between soil moisture, precipitation, runoff, and temperature. This work seeks to a) determine whether low cost, cloud-enabled soil moisture sensors can be used to develop data-driven irrigation schedules for urban rain garden networks, b) establish whether by directing runoff from adjacent impervious surfaces onto urban green spaces, infiltration and evapotranspiration processes can be accelerated,

promoting local thermal regulation, and enhanced groundwater recharge and c) whether irrigation of urban green roofs can be used to reduce heat penetration into the buildings during heat waves.

Updated climate science information
CCRUN's climate science team contributed to the NPCC 2019 Report. The climate science team of the NPCC, led by CCRUN researchers, focused on six types of climate hazards: extreme heat and humidity, heavy downpours, droughts, sea level rise and coastal flooding, extreme winds, and cold snaps. The city and region are already experiencing changes in some of these events, and changes are projected to continue and worsen in the future. Some new and experimental downscaling methods were explored and compared with the previous NPCC assessments.

CCRUN coastal and climate science researchers also developed, as part of the NPCC, a new upper-end sea level rise (SLR) scenario, the ARIM (Antarctic Rapid Ice Melt) scenario, which has been introduced to raise long-term high-end risk awareness for planning purposes. This scenario includes the latest progress in modeling ice-shelf-ice sheet-ocean interactions and the possibility of initiating West Antarctic ice sheet destabilization by late century, under continued warming at high greenhouse gas emission rates.

Through continued work with Consolidated Edison (ConEd), the CCRUN climate science team advanced new methods for projections, both quantitative and qualitative, of a set of hazards the utility is concerned with for their future preparedness and planning. Specific methods were developed for projections of combined heat and humidity, precipitation, and extreme storm events, including hurricanes and nor'easters and winter storms.

Valuation of climate information and evaluation
Part of CCRUN's social science team's efforts over the past year has been focused on understanding the value of climate information to society. A number of stakeholders have expressed interest in this work, including the National Weather Service. The team has developed a framework that explains existing research that assesses the value of climate information, identifies gaps in knowledge, and presents an approach to filling the gaps.

Working with the RISA Network
In a new partnership that started this past year, CCRUN's engineering and urban design team is working together with MARISA, NOAA, and other local water utilities (e.g., New York City Department of Environmental Protection, Philadelphia Water), on the planning of two workshops to help local water utilities develop strategies for reducing flooding during extreme precipitation.

The CCRUN team is also working on developing a new cross-RISA partnership that would investigate approaches to building resilience to coastal flood risk in coastal communities in different contexts. This initiative has been discussed with CISA and individuals in NOAA's Climate Program Office.

Where are CCRUN Products in Use?

The geographic focus of CCRUN is the urban corridor in the Northeast United States stretching from Philadelphia to Boston. Across this region, and for the region as a whole, there are numerous

examples of products developed through interactions between CCRUN researchers and stakeholders.

Atlantic Coastline

- CCRUN researcher's Atlantic Ocean tropical storm track simulator can model cyclones in the basin based on a set of initial conditions, including sea surface temperatures and state of ENSO. The stakeholder, Jupiter Intelligence, is testing the use of the simulator for assessing the risk of flooding at various coastal locations.

- The Stevens Flood Advisory System (SFAS) features ensemble and probabilistic flood forecasting for locations along the east coast (stretching from North Carolina to Maine and including the coastline of CCRUN's geographic region). The National Weather Service utilizes outputs and data from the advisory system and collaborates with CCRUN at times when forecasting coastal flood events. The information and forecasts can also be accessed directly by stakeholders.

Connecticut

- CCRUN researchers are working with the Department of Stormwater Management in Stamford, Connecticut, to understand the impacts of combined precipitation and coastal flood events. A GIS map product pairing 311 reports of flooding to climate data is being developed, with the potential to allow the city to identify vulnerable locations in particular types of storm events. For example, one question being addressed as part of this work is, do nor'easters cause flooding in different parts of the city than intense thunderstorms?

- For Stamford and Groton, both coastal communities in Connecticut, CCRUN researchers are preparing Coastal Communities Resource Guides, which will describe a key data tool/product relevant to precipitation and/or coastal flooding and provide step-by-step instructions on how the stakeholders can use the information. The three products featured in the guides will be tide and sea level data from NOAA Tides and Currents, precipitation data from NOAA and USGS, and precipitation intensity-duration-frequency curves.

Massachusetts

- Climate Ready Boston, the climate adaptation planning effort of the Boston Environment Department, uses results from CCRUN-supported research on current and future mortality impacts of high temperatures in Boston. In this research, CCRUN team members provided projections of future temperatures which were then used in health-impact modeling.

New York

- AdaptMap uses a dynamic flood model to demonstrate how sea level rise may worsen storm-driven flooding in Jamaica Bay, and enables users to select flood adaptation scenarios to see how they reduce flooding. In addition to visualizing flood impacts, map layers and animations are also available for stakeholders to download. A user could, for example, view an animation of the Bay for a 100-year storm tide, under a medium sea level rise scenario, and compare three different adaptation options to better understand current and future risk to Jamaica Bay

- CCRUN researchers are contributing to Con Ed's climate change vulnerability study. As the utility assess its risk to current and future weather and climate extremes, CCRUN has provided both quantitative and qualitative climate projections for a variety of variables including temperature, precipitation, and extreme storm events. The data provided as part of the study is based on the utility's needs and specific metrics used in its operations.

- The Hudson River Flood Impacts Decision Support System (Figure 3) is a flood assessment mapping tool for the lower Hudson Valley region. Communities along the river, many of which CCRUN has engaged with, can analyze the impacts of flooding by selecting different sea level rise scenarios and identify critical infrastructure (e.g., hospitals, transportation routes) that may be at risk.

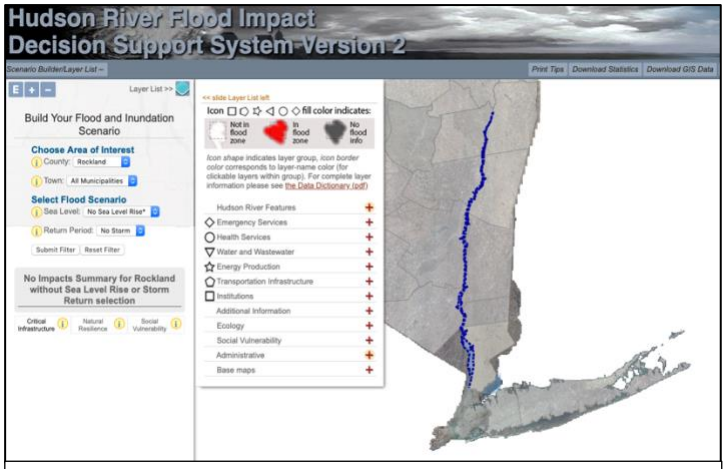


Figure 3. The Hudson River Flood Impacts Decision Support System

- The third New York City Panel on Climate Change Report (NPCC 2019) presents the NPCC's latest findings and recommendations to the City of New York, for which the NPCC serves as an advisory body. CCRUN team members contributed to several chapters in the report including climate science, sea level rise, coastal flooding, risk mapping, and community-based adaptation.

- New York City's Mayor's Office of Resiliency's Climate Resiliency Design Guidelines provide step-by-step instructions for City agencies on how to supplement historic climate data with specific, regional, forward-looking climate change data in the design of City facilities. The climate science the guidelines are based upon is a result of the work of CCRUN researchers participating in the New York City Panel on Climate Change (NPCC).

- New York City's Department of City Planning's New York City Flood Hazard Mapper provides a comprehensive overview of the coastal flood hazards (present and future) and is intended to enable more informed decision-making by residents, property and business owners, architects and engineers, and policy-makers. The tool incorporates NPCC sea level rise projections, developed by CCRUN researchers. The Department also uses NPCC data in coastal zone management.

- CCRUN researchers are working on co-generated projections of extreme precipitation to help inform the New York City Department of Environmental Protection's (NYCDEP) stormwater management plans. For a specific example, the Southeast Queens Flood Mitigation Plan, which focuses on protecting one particularly vulnerable area of the city, uses CCRUN projections developed as part of the NPCC.

- CCRUN team members are participating in the Westchester County Climate Task Force, including the subcommittee on Community Resilience. Results from CCRUN research on vulnerability and resilience to coastal flooding and community-based adaptation work (from NPCC) are being shared with the Task Force.

New Jersey

- Working with the Camden County Municipal Utilities Authority (CCMUA) and the Camden Power Corps in Camden, New Jersey, CCRUN researchers are working to develop a Green Infrastructure (GI) Master Plan for the flood-prone Cramer Hill neighborhood. The plan seeks to reduce flooding, manage stormwater, reduce combined sewer overflows (CSOs), and promote sustainable redevelopment and green jobs in the neighborhood.

Pennsylvania

- CCRUN team members are working with Philadelphia Water on research focusing on analysis and management of soil moisture to maximize thermal regulation. The results of this project could lead to improved strategies for storm water management in Philadelphia.

- Philadelphia is home to the CCRUN Green Infrastructure, Climate, and Cities seminar series, held each month at Drexel University. The series is co-sponsored by a number of stakeholders, including The Franklin Institute and the Climate and Urban Systems Partnership. Additional CCRUN stakeholders attend (either in-person or remotely) and participants include those in the private sector, government, non-profits, and academics.

Outreach Activities

Correlated Extremes Workshop

The last few years have seen emerging recognition of the societal impacts associated with climate extremes that occur close together in space or time. There is also growing evidence that we may be approaching critical "tipping points" in the climate system. The close interconnectivity of systems and networks makes certain combinations of events especially hazardous from an impacts standpoint. This is particularly true in urban environments like the CCRUN project region, where complex social, economic, infrastructure and transportation systems are exposed to climate hazards.

As awareness of these events increases, the body of research on correlated climate extremes and their impacts is rapidly growing and encompasses a wide variety of event types. Advances in atmospheric and climate science, statistics, policy, and social sciences all contribute to the knowledge base on correlated extremes.

In response to these concerns, CCRUN co-hosted the Workshop on Correlated Extremes, which took place at Columbia University on May 29-31, 2019, preceded by an evening panel on May 28. It was comprised of a blend of invited talks and abstract submissions (both talks and posters), with a significant amount of time devoted to discussions. Total in-person attendance was around 175 people, which included CCRUN team members and stakeholders.

The goal of the workshop was to aid in coalescing the community of interested researchers and practitioners around shared definitions, themes, best practices, and future research priorities. The organizers are optimistic that the cross-disciplinary interactions the workshop will foster will contribute to inspiring future research and supporting actionable science and risk calculations.

Lectures in Climate Change

CCRUN hosted presentations in a monthly series that were drawn from the recent book, Our Warming Planet: Topics in Climate Dynamics, published by World Scientific. The series encompasses topics such as natural and anthropogenic climate forcing, climate modeling, radiation, clouds, atmospheric dynamics and storms, hydrology, cryosphere, paleoclimate, sea level rise, agriculture, atmospheric chemistry, and climate change education. The lecture series is for students, teachers, and interested researchers and colleagues around the world to better understand various aspects of climate change. CCRUN researchers have contributed to the chapters of the book and have presented and participated in the series.

The lecture series features presentations on various topics on climate change by their authors and allows for a dialogue between experts in the field and people interested in gaining deeper knowledge in a broad array of topics in climate dynamics. All of the webinars are posted on the CCRUN website and Youtube page for viewing. Our stakeholders can access these as they are a terrific resource for general information on key topics related to weather and climate. Attendance has averaged approximately 30 persons for each of the webinars.

NPCC 10th Anniversary Event

On March 15, 2019, an event entitled "Science for Decision-Making in a Warmer World: 10 Years of the NPCC" was held at the New York Academy of Sciences in New York City. CCRUN researchers have played an integral role in the work of the NPCC, which was celebrated at this event. The summit also corresponded with the release of the 3rd NPCC report, NPCC 2019: Advancing Tools and Methods for Flexible Adaptation Pathways and Science Policy Integration (Figure 4).

Figure 4. NPCC 2019 Report

The event brought together climate scientists and those who use the outcomes of their research. Attendees included city planners and policy makers, many of whom are CCRUN stakeholders (e.g., Mayor's Office of Recovery and Resiliency, Department of Environmental Protection, NYSDERA). Featured topics covered at the event were the latest findings of the New York City Panel on Climate Change (NPCC), and their implications for New York City and other cities seeking to identify and mitigate the impacts of a changing climate.

This event marked 10 years of the NPCC. Established in 2008, the NPCC, in-part through the support of CCRUN, has pushed new boundaries of urban climate science, enabling New York City

to set an example for other cities of how science-stakeholder partnerships can achieve science-based responses to climate change challenges. The recommendations of the NPCC have been incorporated into tangible resilience policies that are helping the City to rebuild after Hurricane Sandy, and to withstand the impact of a changing climate in the decades to come.

While addressing climate impacts must be localized and context-specific, the outcomes from the work of the NPCC may be applicable to other cities and smaller communities through the urban Northeast corridor where CCRUN works.

Seminar Series

CCRUN's Green Infrastructure, Climate and Cities seminar series continues, with a presentation held each month. For each event, invited speakers present on a new topic related to the general themes of climate impacts, adaptation, and mitigation, with a focus on green infrastructure. A full list of topics from this past year, as well as the entire series dating back to 2015 can be found on the CCRUN website.

The seminars are held in-person at Drexel University and are also broadcast live online via webinar to allow access to a wider range of stakeholders. Over the past year, nearly 100 have attended the seminars in person, with close to 300 participating online. Stakeholders from across the Northeast attend the seminars and also have had the opportunity to present. All archived seminar series videos are also available for viewing online, with over 1,100 views and 57 subscribers to our Youtube Channel.

Additional workshop and conference presentations

Presentations of CCRUN's coastal research team's work on sea level rise and coastal flooding were giving at the American Geophysical Union Fall Meeting (December 2018) and the 10th International Conference on Urban Climate (August 2018). Members of the team also participated in Climate Signals: Ask a Scientist Day (October 2018) event, where experts interacted with community members in New York City to discuss possible climate impacts.

CCRUN's public health and social science teams assisted with the planning of, and participated in, a heat-health workshop (October 2018) in Massachusetts as part of NOAA's National Integrated Heat Health Information System (NIHHIS) program. NIHHIS works to understand how decision-makers in many disciplines are working to manage heat-health risks, and to improve and integrate the information available for this purpose. The goal of the workshop was to understand and document what information is needed by decision-makers and give employees a tool known as a "decision calendar" to do so. For this workshop, the tool was applied in the Northeast to understand heat health decision-making. A report back on the workshop was later presented as part of the CCRUN seminar series.

CCRUN's data science team presented their decision supports tools (the Hudson River Flood Impacts Decision Support System and AdaptMap) at a variety of events during the year. Presentations included speaking with the Board of Directors of the Hudson River Valley Greenway (June 2018), New York State Energy Research and Development Authority (December 2018), American Museum of Natural History (April 2018), and New York State Floodplain and Stormwater Managers Association (April 2018).

Planned Activities

Managed Retreat Workshop

CCRUN and partners are in the process of organizing a conference on managed retreat, entitled "*At What Point Managed Retreat? Resilience Building in the Coastal Zone*", hosted by the Climate Adaptation Initiative at Columbia University's Earth Institute, which will take place from June 19-21, 2019. As one of the first major academia-led conferences on the subject, the event will convene diverse stakeholders including researchers, community-based organizations, tribal and indigenous leadership, planners, practitioners, local government, industry representatives and more to discuss the issues surrounding retreat as an adaptation option. Major themes to be discussed include environmental justice, community resilience, policy and decision-making, and climate modeling of various aspects of retreat from sea level rise to migration.

Current registration suggests the event will bring together over 300 individuals, including researchers of multiple CCRUN universities, CISA, and other NOAA affiliates. The event will provide a platform for CCRUN to assess knowledge gaps and opportunities for future research agendas relevant to coastal communities in the Northeast and across RISA regions. Out of this conference, the organizers plan to build new partnerships for co-generating knowledge on adaptation and develop a policy-oriented article for a leading journal, op-eds for broader audiences, and a distillation of best practices in a white paper for local planners.

CCRUN Project Team Workshops

CCRUN is planning a series of workshops to be held in the forthcoming project year. These workshops are designed to serve as a mechanism for further advancing stakeholder interactions in the Northeast while also expanding collaborations with other groups (NOAA and non-NOAA). CCRUN views the workshops as an opportunity to make sure the project team can continue delivering the most useful products, as the research is already the foundation of significant resilience activities across the Northeast. Highlighted in this report are two of the workshops, coastal communities and extreme precipitation, with two additional events (one focusing on data tools and the other on public health) also being planned.

Coastal Communities

CCRUN, under the direction of Co-PI Solecki, is planning a series of workshops entitled *Promoting Successful Local Coastal Resiliency Policies and Programs: Addressing Key Knowledge Gaps*. One will be held at Stony Brook University in Suffolk County, New York, and another at Monmouth University in New Jersey (June 2019). The objective of the workshops is to bring together local practitioners and policy makers in the New York-New Jersey Metropolitan Region to evaluate emerging knowledge and data needs regarding how coastal residents and business owners are responding to, or might respond to, flood risk resiliency efforts associated with extreme storms, storm surge, sunny day/nuisance flooding, and sea level rise. As an output from the workshops, household surveys will be developed to address the gaps identified by policy-makers to improve effectiveness and communication of resiliency planning efforts. The surveys will be administered by Stony Brook and Monmouth students in conjunction with CCRUN researchers.

Extreme Precipitation
Under the direction of Co-PI Montalto, CCRUN is working with MARISA, NOAA, and local water utility partners on the planning of two workshops to help them develop strategies for reducing flooding during extreme precipitation events. The first workshop, organized by MARISA, will take place during July 2019. The second workshop, organized by CCRUN, will take place during the fall of 2019, with pre-workshop webinars beginning during the summer of 2019. The series of workshops is going to receive additional support from NOAA/NOS as part of their joint efforts to work on engagements to showcase the National Water Model, the Water Utilities Dashboard, and also to discuss precipitation extremes and flooding risk.

Program Impacts Evaluation

Broadly defined, the CCRUN program evaluation is assessing progress toward the program goal of improving adaptation to climate risks in the urban Northeast. The three components of the evaluation are the program theory, monitoring, and evaluation. The team has been conducting primarily monitoring and *process evaluation* in the years past, assessing whether CCRUN initiatives – and how the team undertakes those initiatives – are advancing toward the ultimate goal according to the program theory. During the past year, the evaluation work has included ex ante evaluation that shows potential, future socio-economic benefits. Much of the existing research on the socio-economic benefits of climate information falls into the ex-ante category. In the coming year, the team will increasingly focus on *impact evaluation*.

The program theory describes what actions and inputs can bring about the improvement in adaptation that CCRUN intends to achieve and through what causal mechanisms. The program theory has three broad components that articulate how CCRUN may achieve interim objectives on the path to achieving the goal of improved adaptation: (1) producing science that is useful for decision-making, (2) supporting the process of putting that science to use, and (3) designing and implementing uses that advance adaptation. CCRUN work has been focusing on the first two components.

CCRUN intends to achieve improvements in producing usable science and supporting decisions based on that science by directly engaging policy-makers in the co-production of climate science. The specific inputs, actions, and causal mechanisms may differ across decision problems and contexts. This report features numerous examples where this type of engagement proved successful.

The monitoring system currently tracks mainly process indicators, which inform the team whether the CCRUN process is advancing toward the objectives of useful science and support for decisions based on that science. The process indicators fall into the following categories.

- Engagement with policy-makers
    - The policy-makers with whom CCRUN researchers are working, including the length of the relationship and decision problems addressed
    - Climate information/decision support tools co-developed with the policy-makers
    - Publications in outlets read by policy-makers

    - Outreach to communicate research results and experience with using the research results to policy makers.
- Engagement with scientists
    - Presentations of results in various research venues;
    - Peer-reviewed publications/citations of peer-reviewed publications
- Broad communications
    - Contacts with the media
    - Number of views of various parts of the CCRUN website
    - Number of social media posts

The ex-ante evaluation that the team has begun over the past year has investigated the potential socio-economic value of coastal flood risk predictions produced by CCRUN to coastal residents. The research uses household survey data collected by a previous CCRUN study to quantify the present value of future expenditures on flood damages that coastal residents can avoid by taking adaptation actions.

The team is expanding impact evaluation efforts, which will rely on one of a number of methods, depending on the particular evaluation problem, including theory-based evaluation, contribution analysis, analyzing change in outcomes over time, non-experimental econometric methods, and field experiments when appropriate. Impacts are specific to decision problems and contexts. Evaluation will focus on cases that are strategically selected in order to provide evidence that can be aggregated to measure broader impacts.

In the first stage, data collected through monitoring will help to identify case studies in which the team will investigate how science that CCRUN has co-produced with policy-makers is being used by practitioners in the urban northeast region and beyond, what outcomes are emerging from that use, and what are the likely impacts. Coastal flood predictions co-developed with policy-makers in New York City will be the first case study.

In the longer term, impact evaluation will begin to assess whether and how the use of new knowledge and data influences adaptation. The team will begin a study in 2019 that will assess the impacts of co-producing information about local flood risks and costs and benefits of adaptation options on adaptation behavior among coastal residents in NYC.

In future work, outcome indicators will include changes in policies, codes, standards, regulations, management decisions, capital investments, and allocation of administrative resources. Impact indicators are more difficult to measure but will include losses due to extreme events as well as gradual changes over time, considering economic outcomes such as value of infrastructure, economic output, incomes, and other measures of livelihoods and their distribution in the population.

Building Expertise for Local/Regional Decision Making

Figure 5. CCRUN Program Manager Daniel Bader presents at the NPCC 10th Anniversary event. Source. Somayya Ali Ibrahim.

The NPCC celebrated its 10th anniversary during the reporting period (Figure 5). Since CCRUN began eight years ago, team members and researchers have contributed to the Panel, whether it be preparing the climate projections of record for New York City, working as lead chapter authors, or serving as panel Co-Chair. The release of the 3rd report and continued participation of CCRUN in the NPCC exemplifies how strong the science-stakeholder relationship can become over time. Looking at the audience that attended the summit celebrating this event and anniversary, one may have thought it was a large CCRUN meeting, with many of our team members along with key stakeholders from throughout the Northeast in the room.

CCRUN's technical assistance has been central to the NPCC process and thereby, the City of New York's climate adaptation and resiliency planning. At the root of this work has been the engagement with stakeholders and development of climate risk information through a process of co-generation. We've reached the point where stakeholders are bringing science to us and seeking further information, whereas at the start, the conversation was the other way around. Watching the evolution of these interactions is a testimonial to the success of this partnership. The near- and long-term planning decisions being made to protect New York City and the broader metropolitan region are deeply grounded in CCRUN's research.

The integration of the NPCCs work into the City's resilience planning was further solidified this past year, with the release of updated Climate Resiliency Design Guidelines by the Mayor's Office of Recovery and Resilience, coinciding with the release of the NPCC 2019 report. Climate projections developed by CCRUN are the backbone of the guidelines, which provide step-by-step instructions for City agencies (e.g., Department of City Planning, Department of Environmental Protection) on how to supplement historic climate data with specific, regional, forward-looking climate change data in the design of City facilities. CCRUN also works with and helps inform the City's Climate Adaptation Task Force, which brings in entities from the broader metropolitan region, including the private sector.

One of the key recommendations for policy in the report is:

"The City should task the NPCC to coordinate with other regional organizations, such as the Consortium for Climate Risk in the Urban Northeast (CCRUN), to conduct integrated climate assessments for the New York metropolitan region on a regular basis. These assessments should

encourage the participation of a wide range of city and regional agencies and communities, and a full range of systems and sectors."

Conversations with City officials emphasize that there exists a role for CCRUN to continue providing the climate science information needed for future planning. New topics that have come up, such as compound extreme events, directly fit into CCRUN's research agenda. As researchers on the team work with stakeholders outside of the City, CCRUN can be the vehicle that brings together information that would be best shared across groups.

With well established relationships in place and a strong scientific team, CCRUN stands ready to fill this need of being the science in place, in time, as it has been in years past (Sandy). This is also a model other cities and states throughout the broader Northeast can follow as well.

Examples of Implemented CCRUN Work

Camden, New Jersey

CCRUN's engineering and urban design team continues its ongoing collaboration with the Camden County Municipal Utilities Authority (CCMUA) and the Camden Power Corps. The overall goal of this collaboration has been to develop a Green Infrastructure (GI) Master Plan for the flood-prone Cramer Hill neighborhood of Camden, NJ. This plan seeks to reduce flooding, manage stormwater, reduce CSOs, and promote sustainable redevelopment and green jobs in the neighborhood. It was developed through a stakeholder-driven process that engaged the local stormwater utility (CCMUA), key community stakeholders (Camden Power Corps), as well as students and our CCRUN research team. The plan was developed through problem-based learning activities that CCRUN Co-PI Franco Montalto integrated into his teaching, research, and international collaborations.

As part of a course (started in the winter of 2018), CCRUN sought to develop a high resolution hydrologic and hydraulic model of the Cramer Hill neighborhood as a class project. CCMUA agreed to be the "class client" and gave researchers access to drainage, flow, land use, and other data needed to develop and calibrate the model, which would then be used to compare the effectiveness of different GI scenarios at reducing flooding and CSOs.

After the class finished, the work continued as one student sought to further improve the model by integrating it into a larger county-wide collection system model used by CCMUA for regulatory compliance purposes, and by establishing tidal boundary conditions for the outfalls that could eventually be adjusted to consider the effects of sea level rise. At this time, CCRUN researchers also began to develop an engagement plan with the local community. This plan involved establishing a relationship with the Camden Power Corps.

The next phase of this work, continuing into the Spring of 2019, involved conducting semi-structured interviews of the Power Corps members, developing guidelines for how GI systems could be best integrated into the local social, economic, and ecological context, while learning an important method for fostering meaningful public participation. The key message relayed to the research team by the community was that the siting, designing, building, and maintaining of GI

systems represented an opportunity not just to help CCMUA comply with clean water regulations, but also to create new "green" employment opportunities in the community for an expanded Power Corps.

This feedback was also incorporated into the Master Planning process. GI scenarios featured in the final plan were modeled by CCRUN, and the research also produced construction cost estimates and before and after estimates of flood frequency and CSO volumes. The final plan, with all associated sub-studies, was presented to CCMUA and Camden Power Corps in a presentation on May 24, 2019. CCMUA has indicated that they wish to fund both the construction of the GI systems featured in the Master Plan, and the Drexel team, which will be tasked with training the Power Corps members to perform the vast majority of the implementation.

Community-based adaptation

As illustrated by CCRUN's climate science and public health teams' research, urban areas face significant heat-health risks, especially during the summer time. In New York City, residents of the Hunts Point neighborhood in the Bronx are disproportionately susceptible to these hazards as a result of legacies of environmental injustice--one example of which is the high concentration of major roadways that exacerbates the effects of the urban heat island. This places young children, elderly, lower-income residents, and those with pre-existing medical conditions at greatest risk.

With the impacts of extreme heat already being felt in New York, the City's Department of Health and Mental Hygiene Heat wanted to better understand how heat risk varies across New York City. Partnering with the Health Department, CCRUN researchers worked to analyze the spatial differences in heat mortality and morbidity. A social vulnerability index (for extreme heat) was developed by the CCRUN team and the index identified the South Bronx as an area with high heat sensitivity.

The results from the research were then integrated into City policy, as the Mayor's Office of Resiliency used the vulnerability index as the foundation of their Cool Neighborhood's strategy. To execute this program and make it most effective, the City recognized the need to engage at the neighborhood scale through partnerships with community groups. The Point CDC, a Community Based Organization in Hunts Point, was an important partner and collaborator in implementing the program at the community scale.

The Be A Buddy program was developed to reach vulnerable residents in their homes, and was designed to prepare the community for future climate events through climate health education and community preparedness. The Program is aimed at increasing community resilience, reducing vulnerabilities to heat emergencies and extreme weather and promoting connections between local residents.

With the appropriate tools provided through the Be A Buddy, The Point is helping prepare residents in Hunts Point for extreme heat events. It encourages citizen science and lets residents be their own first responders. CCRUN research is supporting the important work Community Based Organizations are doing to help New Yorkers stay safe now and plan for the future.

Economic valuation of coastal flooding (AdaptMap)

As described earlier in this report, the AdaptMap tool allows stakeholders to explore how coastal flooding around Jamaica Bay, New York, will change with sea level rise and coastal adaptation using a dynamic flood model (see Figure 6). One feature of the tool is the ability to view a cost-benefit analysis of different adaptation options for Jamaica Bay. The three adaptation scenarios included emerged from a flood mitigation workshop that was held with government agency representatives, urban planners, designers, scientists, and the general public, to take input on an initial set of concepts and allow for new ideas to be contributed.

Figure 6. AdaptMap mapping application interface. The tool allows users to visualize different adaptation scenarios for Jamaica Bay, New York.

Through the analysis stakeholders have access to detailed breakdowns of the implementation costs and estimated economic damages avoided for the following adaptation scenarios: inlet narrowing; narrowing and sand replenishment; and narrowing and shallows restoration. This data allows stakeholders to assess the monetary losses, number of damaged buildings, hospitals impacted, land area flooded, and many other impacts associated with different storm return periods from 5 to 1,000 years.

A cost-benefit ratio is provided for each option. Results of the analysis show that all three nature-based adaptation options are cost effective over the time period of 2016 to 2055 and can reduce large amounts of flooding and damage. This is true even under high discount rates of 7%, where the most expensive option--inlet narrowing with shallows restoration--estimates a net saving of more than $675 million by 2055. For a relatively cheaper adaptation option like inlet narrowing alone, the analysis shows net benefits of $793 million (discount rate: 3%). The range of adaptation options, discount rates, and damage data available through AdaptMap's benefit cost analysis supports stakeholders in decision-making processes in Jamaica Bay, and builds capacity for long-term adaptation planning.

Appendix A. CCRUN Publication List

Select Publications

Miller, S. M., & Montalto, F. A. (2019). Stakeholder perceptions of the ecosystem services provided by Green Infrastructure in New York City. *Ecosystem Services, 37,* 100928. https://doi.org/10.1016/j.ecoser.2019.100928

US cities are investing heavily in green infrastructure (GI) to manage stormwater and improve local water quality. However, many other ecosystem services (ES) are attributed to these same GI systems. This paper presents a snapshot valuation of the urban ES provided by GI in New York City. Results indicate that, while stormwater management is the primary driver of GI investment in New York City, residents view other ES more favorably. Municipal programs that create multifunctional GI systems may be more widely supported than those focused exclusively on stormwater management. The results also suggest latent public support for GI initiatives that include new and enhanced parks, natural areas and community gardens.

Kinney, P. L. (2018b). Temporal Trends in Heat-Related Mortality: Implications for Future Projections. *Atmosphere, 9*(10), 409. https://doi.org/10.3390/atmos9100409

High temperatures have large impacts on premature mortality risks across the world, and there is concern that warming temperatures associated with climate change--and in particular larger-than-expected increases in the proportion of days with extremely high temperatures--may lead to increasing mortality risks. Evidence has also emerged in recent years of trends over time in heat-related mortality, suggesting that in many locations, the risk per unit increase in temperature has been declining. This study concludes that climate change projection studies will need to take into account trends over time (and possibly space) in the exposure response function for heat-related mortality.

Rosenzweig, C., & Solecki, W. (2019). Special Issue: Advancing Tools and Methods for Flexible Adaptation Pathways and Science Policy Integration: New York City Panel on Climate Change 2019 Report. *The New York Academy of Sciences, 1439,* 1–311.

The third New York City Panel on Climate Change Report presents the NPCC's latest findings and recommendations to the City of New York. The Report features chapters on climate science (temperature and precipitation change), sea level rise, coastal flooding, risk mapping, community-based adaptation, along with critical infrastructure systems and indicators and monitoring.

Additional Publications

Abualfaraj, N., Cataldo, J., Elborolosy, Y., Fagan, D., Woerdeman, S., Carson, T., & Montalto, F. A. (2018). Monitoring and Modeling the Long-Term Rainfall-Runoff Response of the Jacob K. Javits Center Green Roof. *Water*, *10*(11), 1494. https://doi.org/10.3390/w10111494

Coffel, E. D., de Sherbinin, A., Horton, R. M., Lane, K., Kienberger, S., & Wilhelmi, O. (2018). Chapter 7 - The Science of Adaptation to Extreme Heat. In Z. Zommers & K. Alverson (Eds.), *Resilience* (pp. 89–103). https://doi.org/10.1016/B978-0-12-811891-7.00007-4

Feldman, A., Foti,R. , & Montalto, F.. (2019). Green Infrastructure Implementation in Urban Parks for Stormwater Management. *Journal of Sustainable Water in the Built Environment*, *5*(3), 05019003. https://doi.org/10.1061/JSWBAY.0000880

Foster, S., Leichenko, R., Nguyen, K. H., Blake, R., Kunreuther, H., Madajewicz, M., … Ravenborg, D. (2019). New York City Panel on Climate Change 2019 Report Chapter 6: Community-Based Assessments of Adaptation and Equity. *Annals of the New York Academy of Sciences*, *1439*(1), 126–173. https://doi.org/10.1111/nyas.14009

Friedman, E., Breitzer, R., & Solecki, W. (2019). Communicating extreme event policy windows: Discourses on Hurricane Sandy and policy change in Boston and New York City. *Environmental Science & Policy*, *100*, 55–65. https://doi.org/10.1016/j.envsci.2019.06.006

García Sánchez, F., Solecki, W. D., & Ribalaygua Batalla, C. (2018). Climate change adaptation in Europe and the United States: A comparative approach to urban green spaces in Bilbao and New York City. *Land Use Policy*, *79*, 164–173. https://doi.org/10.1016/j.landusepol.2018.08.010

González, J. E., Ortiz, L., Smith, B. K., Devineni, N., Colle, B., Booth, J. F., … Rosenzweig, C. (2019). New York City Panel on Climate Change 2019 Report Chapter 2: New Methods for Assessing Extreme Temperatures, Heavy Downpours, and Drought. *Annals of the New York Academy of Sciences*, *1439*(1), 30–70. https://doi.org/10.1111/nyas.14007

Gornitz, V. (2016). Impacts of Sea Level Rise on Coastal Urban Areas. In *Lectures in Climate Change*: *Vol. Volume 1. Our Warming Planet* (pp. 351–371). https://doi.org/10.1142/9789813148796_0017

Gornitz, V., Oppenheimer, M., Kopp, R., Orton, P., Buchanan, M., Lin, N., … Bader, D. (2019). New York City Panel on Climate Change 2019 Report Chapter 3: Sea Level Rise. *Annals of the New York Academy of Sciences*, *1439*(1), 71–94. https://doi.org/10.1111/nyas.14006

Gurumurthy, P., Orton, P. M., Talke, S. A., Georgas, N., & Booth, J. F. (2019). Mechanics and Historical Evolution of Sea Level Blowouts in New York Harbor. *Journal of Marine Science and Engineering*, *7*(5), 160. https://doi.org/10.3390/jmse7050160

Hall, J. A., Weaver, C. P., Obeysekera, J., Crowell, M., Horton, R. M., Kopp, R. E., … White, K. D. (2019). Rising Sea Levels: Helping Decision-Makers Confront the Inevitable. *Coastal Management*, *47*(2), 127–150. https://doi.org/10.1080/08920753.2019.1551012

Jones, H. M., Mecray, E., Birkel, S. D., Conlon, K., Kinney, P., Silva, V. b. s, … Surgeon Rogers, Tm. (2019). Understanding Decision Context to Improve Heat Health Information. *Bulletin of the American Meteorological Society*. https://doi.org/10.1175/BAMS-D-19-0042.1

Kinney, P. L. (2018a). Interactions of Climate Change, Air Pollution, and Human Health. *Current Environmental Health Reports*, *5*(1), 179–186. https://doi.org/10.1007/s40572-018-0188-x

Lay, C. R., Mills, D., Belova, A., Sarofim, M. C., Kinney, P. L., Vaidyanathan, A., … Saha, S. (2018). Emergency Department Visits and Ambient Temperature: Evaluating the Connection and Projecting Future Outcomes. *GeoHealth*, *2*(6), 182–194. https://doi.org/10.1002/2018GH000129

Liu, J., & Horton, R. M. (2018). Arctic Sea Ice and Its Role in Global Change. In *Lectures in Climate Change*: *Vol. Volume 1. Our Warming Planet* (pp. 295–307). https://doi.org/10.1142/9789813148796_0014

Orton, P., Lin, N., Gornitz, V., Colle, B., Booth, J., Feng, K., … Patrick, L. (2019). New York City Panel on Climate Change 2019 Report Chapter 4: Coastal Flooding. *Annals of the New York Academy of Sciences*, *1439*(1), 95–114. https://doi.org/10.1111/nyas.14011

Patrick, L., Solecki, W., Gornitz, V., Orton, P., & Blumberg, A. (2019). New York City Panel on Climate Change 2019 Report Chapter 5: Mapping Climate Risk. *Annals of the New York Academy of Sciences*, *1439*(1), 115–125. https://doi.org/10.1111/nyas.14015

Reynolds, K., & Madajewicz, M. (2018). *Global, local, coastal: Preparing the next generation for a changing planet* (pp. 1–98) [Final evaluation report]. Retrieved from Groundwork Hudson Valley website: http://www.groundworkhv.org/wp-content/uploads/2019/04/Distance-Learning-Module-Teachers-Guide-NOAA-Full-Curriculum.pdf

Rosenzweig, Cynthia, & Solecki, W. (2019). New York City Panel on Climate Change 2019 Report Chapter 1: Introduction. *Annals of the New York Academy of Sciences*, *1439*(1), 22–29. https://doi.org/10.1111/nyas.14004

Saleem Khan, A., MacManus, K., Mills, J., Madajewicz, M., & Ramasubramanian, L. (2018). Building Resilience of Urban Ecosystems and Communities to Sea-Level Rise: Jamaica Bay, New York City. In W. Leal Filho (Ed.), *Handbook of Climate Change Resilience* (pp. 1–21). https://doi.org/10.1007/978-3-319-71025-9_29-1

Shultz, J. M., Kossin, J. P., Ettman, C., Kinney, P. L., & Galea, S. (2018). The 2017 perfect storm season, climate change, and environmental injustice. *The Lancet. Planetary Health*, *2*(9), e370–e371. https://doi.org/10.1016/S2542-5196(18)30168-2

Solecki, W., & et. al. (2018). *Jamaica Bay Watershed Protection Plan Update 2018, Community and Social Resilience Chapter*. New York Department of Environmental Protection (NY DEP).

Solecki, W., & et al. (2019). Extreme Events and Climate Adaptation-Mitigation Linkages: Understanding Low-Carbon Transitions in the Era of Global Urbanization. *WIRES Climate Change, Accepted*.

Solecki, W., & Rosenzweig, C. (2019). Indicators and Monitoring Systems for Urban Climate Resiliency. *Climatic Change*, *Accepted*.

Somos-Valenzuela, M. A., & Palmer, R. N. (2018). Use of WRF-Hydro over the Northeast of the US to Estimate Water Budget Tendencies in Small Watersheds. *Water*, *10*(12), 1709. https://doi.org/10.3390/w10121709

Weinberger, K. R., Kinney, P. L., Robinson, G. S., Sheehan, D., Kheirbek, I., Matte, T. D., & Lovasi, G. S. (2018). Levels and determinants of tree pollen in New York City. *Journal of Exposure Science & Environmental Epidemiology*, *28*(2), 119–124. https://doi.org/10.1038/jes.2016.72

Yu, Z., Miller, S., Montalto, F., & Lall, U. (2018). The bridge between precipitation and temperature - Pressure Change Events: Modeling future non-stationary precipitation. *Journal of Hydrology*, *562*, 346–357. https://doi.org/10.1016/j.jhydrol.2018.05.014

Yu, Z., Montalto, F., & Behr, C. (2018). Probabilistic green infrastructure cost calculations using a phased life cycle algorithm integrated with uncertainties. *Journal of Hydroinformatics*, *20*(5), 1201–1214. https://doi.org/10.2166/hydro.2018.107