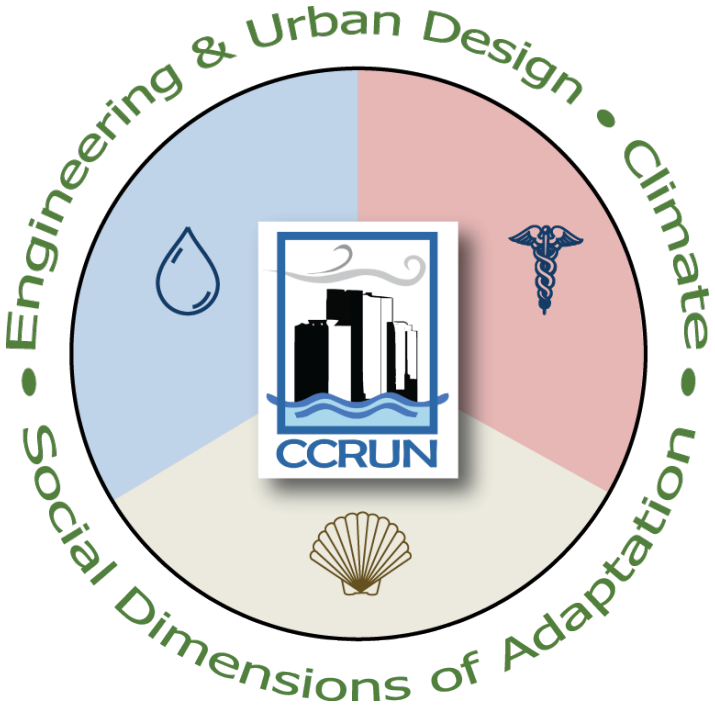
Supporting Regional Implementation of Integrated Climate Resilience Consortium for Climate Risk in the Urban Northeast (CCRUN) Phase II

Research Highlights, June 1, 2016 – May 31, 2017

Boston

New York City

Philadelphia



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

Drexel University

Hunter
The City University of New York

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Stakeholders and Partners

A & D Hydro, Inc.
All Hazards Consortium
Burlington (MA) Water Department
Camden County Municipal Utilities Administration
Canaan (NH) Water Department
Chicopee (MA) Water Department
City of Cambridge (MA) Public Health Department
Connecticut Department of Environmental Protection/Inland Water Resources Division
Connecticut River Watershed Council
Connecticut Water
Dalton Hydro, LLC
Delaware River Basin Commission
Delaware Valley Regional Planning Commission
Eastwick Friends and Neighbors Coalition
East Hampton (CT) Water and Sewer Commission
Environmental Protection Agency (Regions 2 and 3)
ESIP Federation
Farmington River Power Co.
Green Mountain Power
Holyoke (MA) Gas and Electric Department
Hudson River Foundation
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
Metropolitan District of Connecticut
Monson (MA) Water & Sewer Department
National Institute for Coastal & Harbor Infrastructure
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 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 Mayor's Office of Recovery and Resiliency
New York City Mayor's Office of Sustainability
New York City Office of Emergency Management
New York State Department of Environmental Conservation
New York State Energy Research and Development Authority
North Brookfield (MA) Water Department
Palmer (MA) Water Department
Pennsylvania Horticultural Society
Philadelphia Office of Sustainability
Philadelphia Parks & Recreation
Philadelphia Water
Riverkeepers
Rivers Alliance of Connecticut
Rockaways Waterfront Alliance
Science and Resilience Institute at Jamaica Bay
Springfield (MA) Water and Sewer Commission
Staten Island Long Term Recovery Organization
Stephen Sillers Tunnel to Towers Foundation
StormCenter Communications, Inc.
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
US National Park Service
University of Connecticut
University of Massachusetts Boston
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 Council
Waterfront Alliance
WEACT for Environmental Justice
Westchester County GIS
Westchester Municipal Planning Federation
Westfield (MA) Water Resources Department
Williamsburg (MA) Water and Sewer Commission

Italics indicates stakeholders CCRUN has engaged within the past year.

New Areas of Focus/Partnership

During the second year of Phase II, CCRUN continued to broadened its research partner network through a series of new endeavors, while expanding interactions amongst the research teams. These partnerships provide the foundation for future work. Our team is now working on integrated projects and the CCRUN network now includes non-funded partners. In addition, CCRUN's engagement has increased throughout the urban northeast and researchers are now working with small to medium sized cities in the region.

Coasts: The CCRUN coastal team has embarked on new flood modeling and green/gray adaptation assessment work for an area within Philadelphia, including both rainfall and storm tide effects, as well as community workshops and guidance. This work aims to provide quantitative information to help guide decisions and inform the community of Eastwick.

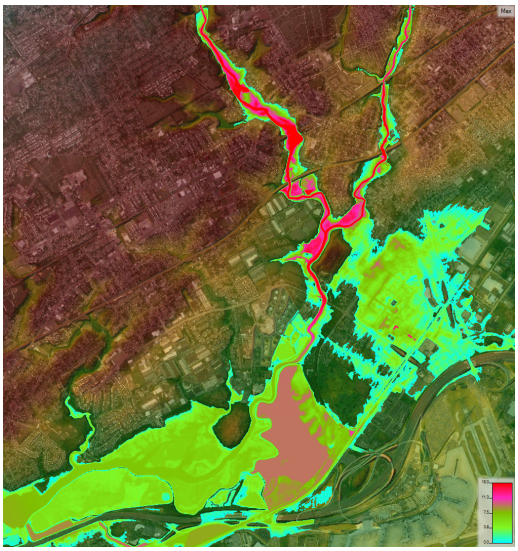

Figure 1. Flood modeling including both rainfall and storm tide in Philadelphia. Example of Hurricane Sandy storm surge combined with Hurricane Irene type streamflow.

In Boston, the CCRUN team is working on flood adaptation and design collaboration with collaboration with West-8 design and Harvard Design. A new concept was considered – constructing a set of offshore barrier dunes in the Boston Harbor offshore waters that would lower storm surges by blocking waves or storm surge. The team used their hydrodynamic model to simulate storm tides from the worst flood in the past century, the February 1978 "Blizzard of 78" event, quantifying the impact of the landscape changes. The goal of the work is to decrease the height of storm surge offshore, thus enabling lower, softer and less disruptive landside storm protections.

A final area of new research for the coastal team of CCRUN is alternative metrics of risk and resilience. The team is studying flooding during Hurricane Sandy, and whether water velocity or depth is a more useful metric of human mortality risk during a flood. A related focus area is idealized modeling of a levee-fronted neighborhood, to study the effect of various configurations on physical conditions during overtopping, such as water velocity and depth. This research links the CCRUN coastal and social science teams.

Health: The CCRUN health research team has expanded research into two new areas over the past year. First, the team is exploring the effects of weather and air pollution on bike share program usage in New York City and Boston. Seeking to investigate this relationship is an important question because there are health benefits that derive from active transportation, and it's important to understand how the environment affects physical activity. This research has implications for other cities in the urban northeast that may have or soon start bike share programs. CCRUN climate science team members have engaged with the health team and are providing data for this new work.

An additional area of new work is evaluating the value of low-cost air pollution sensors for characterizing fine scale patterns of air pollution in cities, in connection with other data sources such as remotely sensed aerosol optical depth. The goal is to provide new tools for assessing air pollution related health burdens and mitigation strategies in community settings.

Water: A new partnership, with a focus on hydrological modeling, has been formed between CCRUN researchers and stakeholders in the Philadelphia metropolitan area. The goal of this research is to build a model of the Philadelphia water supply system. To date, meetings have focused on defining the scope of work, discuss on-going modeling problems, and review climate downscaling methods. In addition, a modeling workshop was held where the CCRUN researchers had the opportunity to interact. Stakeholders involved in this new partnership include the Philadelphia Water and the Delaware Valley Regional Planning Commission.

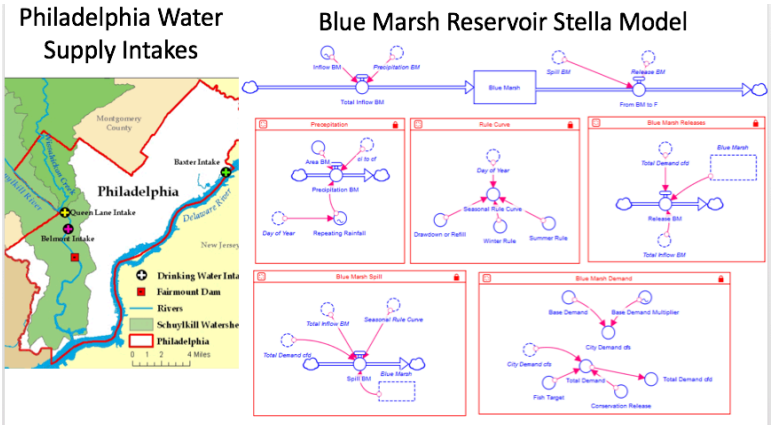

Figure 2. Streamflow model of the Schuylkill River and Delaware River.

This new effort for the CCRUN team is an extension of modeling work already completed in New York City. Through our conversation and presentation of this research with other team researchers and the stakeholders in Philadelphia, expanding to the new geographic fills a need while advancing the science simultaneously.

Climate: The CCRUN climate science team has increased its focus on extreme weather and climate events, advancing both core scientific understanding of the range of possible climate outcomes decision-makers could face, and helping decision-makers prepare for specific impacts of those climate extremes.

The team's work has focused on three types of extremes. First, researchers conducted a comprehensive review article on how heat waves could change in the future, including new analysis of societal vulnerability to high humidity. Second, they were involved in one of the most comprehensive analyses of extreme precipitation in the Northeast. Third, the team contributed to several advances in sea level rise and coastal flood research, including updated global sea level rise projections to reflect the latest findings about ice sheet melt, and analyses of how different types of coastal landforms (such as concrete structures or marshes) may respond to sea level rise (thereby influencing long term inundation amounts).

New partnerships have included the community groups the team has been discussing extreme events with through CCRUN's Climate Forums Series with the Jamaica Bay Science and Resilience Institute and the New York City Emergency Management. Another new partner is the

water managers for the cities of Groton and Stamford, CT, whom the team is working with on extreme precipitation and coastal flood events.

Engineering and Urban Design: The CCRUN engineering and urban design team has advanced and started new research related to the use of green infrastructure interventions to promote urban sustainability and resilience. This research is focused on several communities in the Northeast, including New York City and Camden, New Jersey. Another new area of research the team is investigating is the mitigation of the urban heat island through green infrastructure. Partners in this work include the U.S. Forest Service, New York City Department of Parks and Recreation, and Jacob K. Javits Convention center. The team also researching the impacts of intense precipitation on locations in the Northeast, including Boston, Massachusetts, and Perth Amboy, New Jersey.

Working with the coastal team, the engineering and urban design team has embarked on a new collaborative research project investigating flooding in the Eastwick neighborhood of Philadelphia. The primary stakeholder is the Eastwick Friends and Neighbors Coalitions.

Social Dimensions of Adaptation: A new area of focus for the CCRUN social science team comprises using community-level education to build adaptation to coastal flooding in urban neighborhoods. The focus is a result of prior CCRUN research on determinants of vulnerability to coastal flooding in urban neighborhoods based on evidence of the recovery after Hurricane Sandy. The research showed that one significant driver of vulnerability is lack of awareness among residents of risks of future flooding that are specific to their neighborhoods and of practical options for improving adaptation. Working together with stakeholders from the City of New York, the goal of this work is to test an innovative approach to community education and evaluate its impacts on progress toward adaptation to assess whether the approach should be scaled up.

In addition, the CCRUN social science team developed decision-maker toolkits focused on knowledge co-production and proactive planning. The team conceptualized and operationalized elements of two climate risk tools, the Post Extreme Event Learn Tool (PELT) and Macro Adaptation Resilience Tool (MART), which could be used by stakeholders and practitioners involved in climate risk management and decision-making processes. The tools are in their development stage, and are in the process of being *beta* tested in a co-production / co-design protocol. These tools are intended to be applied to a range of local and regional sectors in support of a) disaster risk reduction and resiliency plans and b) project level investment strategies.

The team also created and are in the process of implementing a new survey to be given to stakeholders and practitioners in the CCRUN region. The survey focused on policy shifts during the five years since Hurricane Sandy and conditions under which shifts did and did not occur. Examination of the spatial and temporal dislocation of Hurricane Sandy impacts is especially important to understand the narrative of local climate risk and how hazards are perceived and translated into new policy by stakeholders and practitioners in different locations.

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.

Boston: CCRUN researchers have developed a tool (web-based) that illustrates potential future flood risk in the City of Boston. The mapping tool allows the user to display flood scenarios for the 10-, 100-, and 500-year flood in the Boston, while overlaying maps of critical infrastructure, including transportation systems, landcover/land use, and hospitals. Changes in flood recurrence (due to sea level rise) can also be mapped with this tool. The sea level rise projections within the tool were developed by the CCRUN climate science team. Two flood scenarios can be displayed, both assuming that the tide gates of a new dam would be closed during the storm event. The more extreme case allows water to flood up to the offshore flood elevation, while the more optimistic case assumes that the cities of Boston and Cambridge are able to take response measures to reduce flooding in advance of the storm.

Camden, New Jersey: The CCRUN engineering and urban design team is engaging with communities in New Jersey, including Camden. The multidisciplinary research on green infrastructure helps stormwater managers plan, model, site, operate, maintain and monitor this distributed approach to urban water management. The team's research emphasizes how the decentralized management of urban runoff can reduce wet weather impacts, but also promote urban sustainability, resilience, and climate change mitigation and adaptation. In Camden, CCRUN's research demonstrated how green infrastructure facilities can be strategically planned, sited, and designed to fill "ecosystem service gaps" in this challenged urban community. Partners on this work include the Camden County Municipal Sewerage Authority and the Trust for Public Land, both of which have and continue to implement urban green infrastructure in this area.

Hudson River Valley, New York

CCRUN team members have developed a tool, the Hudson River Flood Hazard Decision Support System (HRFHDSS), that illustrates the scale of potential flooding in the Hudson River Valley under different sea level rise and storm scenarios. Stakeholders within the region, including municipal and regional planners, can access the tool to help prepare for future flood events. When using the tool, the user is able to view critical infrastructure, such as transportation and emergency services, along with the flood map, allowing them to identify those areas that may become vulnerable in the future. A unique feature of the tool is that it

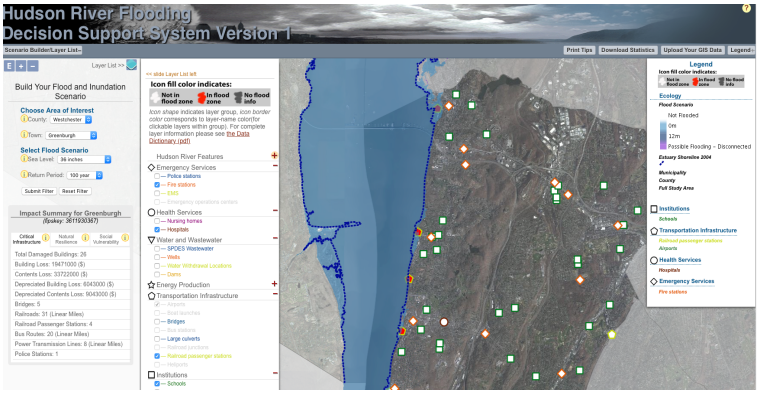

Figure 3. Screenshot of the Hudson River Valley Flooding Decision Support System.

includes freshwater flowing into the Hudson River, in addition to tides, storm surge, and sea level rise, therefore illustrating the combined impacts of heavy rainfall and coastal flooding.

New York City: The CCRUN coastal research team has had many interactions with stakeholders through their Jamaica Bay climate adaptation work, where they are part of a team of modelers conducting "integrated modeling" of the Bay's physical system (for a project initially called "Towards a Jamaica Bay Master Plan"). This work is led by the Science and Resilience Institute at Jamaica Bay, and includes public and governmental stakeholder workshops and guidance. Products include a final report with modeling results showing the effects of two stakeholder-guided adaptation scenarios intended to improve future flood and ecological resilience of the Bay.

CCRUN contributions to the New York City Panel on Climate Change (NPCC), currently convened for the third time, continue. CCRUN researchers contribute to the panel's leadership and work groups, focusing on climate science, community-based adaptation, indicators and monitoring, and mapping and risk. The work of the NPCC is fundamental to ongoing resiliency work in New York City and the surrounding metropolitan region.

Philadelphia: New research by the CCRUN coastal and engineering and urban design teams is investigating joint coastal and inland flood risk in the Eastwick neighborhood in south Philadelphia. In addition, interactions with Philadelphia Water have led to new research on hydrological modeling for the city's water system. CCRUN team members have also engaged with the Delaware Valley Regional Planning Commission (DVRPC) about extending some of CCRUN's core research capabilities into the Philadelphia metropolitan region.

Program Impacts Evaluation

The three components of the CCRUN project evaluation approach include three basic mechanisms. These include program theory, monitoring, and evaluation. Broadly defined, the key goal of the CCRUN evaluation approach is to assess progress toward the project goal of improving adaptation to climate risks in the urban Northeast. The team has been conducting primarily *process evaluation* in the years past. This approach assesses whether CCRUN initiatives – and how the team undertakes those initiatives – advance toward the ultimate goal, according to the program theory. In the coming year, the team will further refine its evaluation strategy by enhancing its focus on *impact evaluation*.

The program theory describes what actions (or inputs) can bring about the improvement in adaptation that CCRUN intends to achieve and through what causal mechanisms, and under what conditions the actions will actually result in the intended changes. CCRUN intends to achieve improvements in adaptation by directly engaging decision-makers in the co-production of climate science to support decision-making. 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 intended goal of improving adaptation. The process indicators fall into the following categories.

- Engagement with decision-makers
  - The decision-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 decision-makers
  - Publications in outlets read by decision-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

As mentioned above, the evaluation component consists of *process evaluation* and *impact evaluation*. The team is expanding impact evaluation efforts. The first of these will focus on an intermediate outcome - how new knowledge and data, that CCRUN co-produced with decision-makers, are used by those and other decision-makers in our RISA region and beyond. The monitoring on how this information was used provides a foundation for a process evaluation of the use of co-produced science and associated decision-support tools. The impact evaluation will begin to assess how the application of this new knowledge and data resulted in shifts in climate resiliency and adaptation policy, management, or operations among the local stakeholders. Impact metrics will include the presence of new codes, standards, and regulations and shifts in capital and administrative resources.

Building Expertise for Local/Regional Decision Making

The previously-reported successful strategy whereby CCRUN has built decision-maker capacity in NYC is now being applied, and modified based on stakeholder needs and feedback, for multiple new groups. These include 1) the big cities of Boston and Philadelphia as well as medium sized cities, 2) more specialized groups of decision-makers with unique climate needs, regulatory structures and decision-contexts, such as electrical utilities, and 3) evolving City of New York needs as the city's resilience efforts evolve.

One thing that has stayed constant is the iterative process that has allowed the CCRUN team to build the expertise and ability of decision-makers to prepare for climate variability and change in the Northeast. CCRUN's stakeholder engagement is facilitated by regular interactions between research team members and policy practitioners. At its root, the co-generative process, which starts by CCRUN inquiry about the specific decision contexts and climate information needs of the stakeholder, allows for the development of tailored information, presented to users in a manner that resonates for them.

As an example of '1' above, CCRUN is now working with small coastal cities in Connecticut on two issues that have been impacting them, based on '311' calls: inland rainfall flooding and stormwater management. The climate science team is also helping them understand the role of weather and climate in 311 calls and flooding, as well as how coastal flooding and sea level rise can make rainfall flooding worse in low elevation communities of Stamford and Groton.

As an example of '2' CCRUN researchers are assisting community groups and electrical utilities in their resilience efforts. Specifically, the team is a) informing community groups about flood risk and navigating flood zone designations, and b) providing electrical utilities with information about specific climate metrics of concern for their planning, such as combined effects of temperature and humidity on electrical demand, which can impact the risk of power failures.

As an example of '3', with time, the Mayor's Office in New York City has gained a greater level of understanding of the information and in many cases now drives a process that had previously been directed by the New York City Panel on Climate Change and its CCRUN scientists. While many conversations circa 2010 started with climate science team members describing projects, climate hazards, and other science information, the conversation now is in large part based on science questions that the city is asking. For example, the CCRUN science team has recently been asked to investigate and contextualize tail risks of extreme precipitation events and extreme sea level rise based on a peer-reviewed journal articles the Mayor's Office of Recovery and Resiliency found. CCRUN has helped elevate the decision-maker knowledge of the science, and formed a process and relationship that supports evolving needs of increasing sophistication and nuance.

Most Significant Accomplishment for June 2016 – May 2017

Over the reporting period, CCRUN's greatest accomplishment has been the increased interactions within the network and expansion of work to new stakeholder groups. At the team's annual meeting in October 2016, a significant emphasis was placed on finding ways for the CCRUN research teams to work amongst themselves more effectively, as well as reach new communities, including small to medium sized cities, in the urban Northeast. The core objectives of the CCRUN research template are 1) to help the team break out of sector based silos and develop cross-disciplinary work, 2) help team members become more aware of ongoing work and research interests of other team members, and 3) efficiently document and share work to date for annual reporting and other 'increasing-impact' type-purposes. Based on the work over the past year, it's evident that the template has been successful in meeting its intended goals, as CCRUN has started these new partnerships, internal and external to the core team, with evaluation and documenting ongoing.

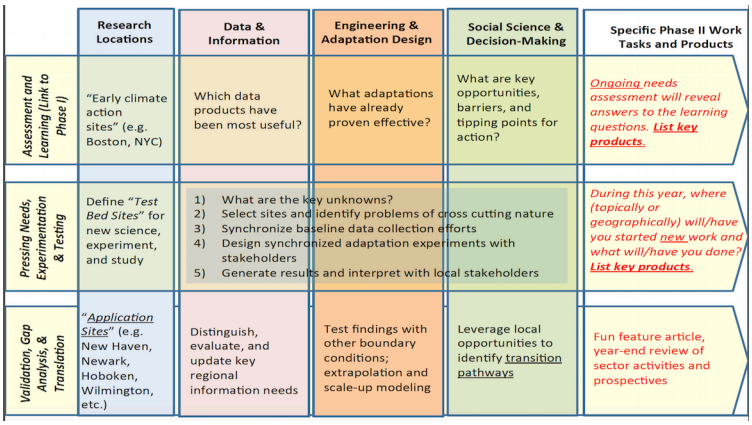

Figure 4. CCRUN Research Template.

Within the CCRUN team, members of the cross cutting theme teams are engaging with the core research sectors. Engineering and urban design researchers have partnered with the coastal team on the flood assessment for a neighborhood in south Philadelphia. Combined, the expertise of

both of these groups is now developing information on flood risk to community members and stakeholders. Two of CCRUN's cross cutting themes are also working together, with the climate science team's research on coastal storms in the Northeast now featuring a defined social science and evaluation component. As the scientists research the components of coastal storms, the impacts of these extreme weather events, specifically on the New York City area, are also being measured. Tools for evaluation have also been developed by the social science team, with potential application across different CCRUN sectors and also different cities throughout the Northeast.

Interactions with stakeholders in the cities and communities in the urban Northeast are a fundamental component of CCRUN's work. While there has been significant emphasis on the three major metropolis to date, over this past year, CCRUN is now engaging more frequently with small to medium sized cities in the region. For example, the developing partnership with the Delaware Valley Regional Planning Committee has the potential to bring CCRUN's research into a 9-county area surrounding Philadelphia. The proposed work with this group seeks to apply CCRUN's existing climate science, coastal, water, engineering, and social research. In the state of New Jersey, the team has engaged with Camden and Perth Amboy, two 'new' cities where CCRUN is now working on green infrastructure projects as a core tenet of adaptation planning.

This year represents a transformation in how the CCRUN team works and implementation of the plans set forth at the start of Phase II. As the need for accessible weather and climate information grows, CCRUN is well-positioned to provide this across the urban Northeast.

Research Findings

Our most significant findings in CCRUN Phase II Year 2 include the following:

Coasts: New York City flood assessment results show that today's 100-year flood of 2.7 m is 25 times more likely at the 2080s (17-50 times, at 90% confidence), in stark contrast to the most recent NPCC central assessment result of 3 times. This change arises due to a different baseline curve, different methods for incorporating sea level rise uncertainty, and the inclusion of tropical cyclone climatology changes. New York City ORR and Sustainability were engaged in this work done for NPCC3.

Jamaica Bay climate adaptation scenarios of sedimentary restoration – a shallowed bay with a narrower inlet, mimicking some of the characteristics of the historical system – can lead to substantial reductions in storm tides as well as a lessening of the impacts of future climate warming on hypoxia. This work was performed for the National Parks Service, who manages Gateway Recreation Area including some Jamaica Bay areas.

Health: The key finding from the CCRUN health team is that the per-unit exposure risk for heat-related mortality in New York City declined over the 20th century, and that this trend could be used to develop adaptation projections for future impact assessments. To reach this conclusion, researchers on the team applied a unique historical database on heat-related mortality in New York City to quantify and model the observed adaptation trend over that period, and then used

the adaptation model to project future health impacts, taking alternative climate and population futures into account.
For the research that monitored traffic-related particle (TRAP) exposures of recreational cyclists in NYC during a series of commutes while also measuring breathing rates, the key finding is that the bulk of one's daily inhaled dose of TRAP is encountered in the brief period of commuting, due to the interaction of high air concentrations and high breathing rates. Future real-time data on route-specific TRAP levels could be used by cyclists to choose routes that minimize exposures to this dangerous pollutant.

In a third study, the CCRUN health team found that the effects of ambient fine particles on hospitalizations for cardiac problems were higher in winter and at colder temperatures, suggesting that warming temperatures might lead to slightly reduced health effects of air pollution.

Water: One key finding from the CCRUN water team is that hydrologic forecast error and uncertainty increases with increasing lead time for 90-day forecasts. Looking at City-specific research, based on models of the City of Baltimore Water Supply System, indicated that improved ensemble hydrologic forecasting (modeled as a decrease in forecast ensemble spread) resulted in quantifiable improvements in system performance over the 2001 to 2010 historic period, including the 2001 drought.

Previous results indicated that the use of seasonal scale hydrologic forecasting was an effective method for drought management under projected climate change conditions for the northeast. In literature and based on conversations with stakeholders, quantifying the value of forecasts (and of forecast improvement) is cited as an impediment to adopting forecasts in practice. This experiment aimed to quantify the value of improved forecasts in a way that compliments existing National Weather Service forecast verification tools.

Climate: The CCRUN climate science team found that under a high greenhouse gas emissions scenario within 50 years, heat stress events that currently occur only once per year could occur on 30 or more days per year.

The climate science team was also involved in a study that found that much of the well-documented long-term upward trend in extreme precipitation, actually stems from merely the past two decades. Specifically, 1996-2014 precipitation exceeded 1901-1995 precipitation by 53% across a large number of stations.

The climate team was involved in another study that found that along our urban coasts, sea level rise will cause flood heights that currently occur only once every five years to occur 5 times per year, most likely sometime between 2050 and 2100. A sea level rise and coastal morphology study found that some natural landforms, such as beaches and marshes, may be able to temporarily 'keep up' with sea level rise, under certain conditions.

In addition, the CCRUN climate science team completed the primary task of designing an empirical stochastic model that generates and tacks winter extratropical cyclones (ETCs) over North America, which can potentially impact the Northeast. The ability to produce synthetic

distributions of cold-season North American cyclone tracks, including intensity information and conditional on the state of the El Niño/Southern Oscillation (ENSO) and North Atlantic Oscillation (NAO) phenomena, supports assessments of the seasonal ETC risk to the Northeast. The team also completed a study that examines and compares the magnitude, spatial footprint, and paths of hurricanes and tropical storms (TCs) and ETCs that caused the largest surge events along the east coast. The study finds while tropical storms cause larger surges, overall surge occurrences are more influenced by cold season ETCs

The climate science team has also engaged with the CCRUN social science research teams to look at the impacts of coastal storms. The team is using principal component analysis to build a social vulnerability index (SoVI) at the census block-group level using U.S. census data from 1990, 2000 and 2010. In addition, an analysis of the dollar-value of property losses related to past major ETCs that affected the study region was performed. The analysis indicated that flooding (from all from rain and/or coastal storms) resulted in the costliest damages and that storms falling into two or more categories (based on a classification system that used storm characteristics) were responsible for a greater proportion of the overall damage.

Engineering and Urban Design: For the CCRUN research on using green infrastructure to mitigate the urban heat island, findings from the Javits center (in New York City) green roof show that the exterior surface of the green roof is significantly cooler than the black roof exterior surface. Based on the monitoring station data at the site, the maximum difference in temperature is 17.5°C. Looking at seasonal variations, during the summer, the green roof appears to provide significant thermal buffering of the interior ceiling of the Javits center, even as the exterior surface of green roof undergoes diurnal temperature fluctuations. During the winter, the green roof appears to provide some insulation value to the building

For the research on sewer monitoring in Boston, forecasted changes in future precipitation will reduce the performance of green infrastructure facilities, but not wholly or even significantly enough to negate their potential positive watershed impact. Spatial patterns and densities of green infrastructure application are much more significant determinants of future GSI performance than forecasted changes in precipitation.

The engineering and urban design research work in Camden, NJ shows that by quantifying the "ecosystem service gaps" of an urban community, green infrastructure systems can be customized through selection of typology, siting, and operation and maintenance protocols to promote urban resilience and sustainability, in addition to managing stormwater.

Social Dimensions of Adaptation: Stakeholders and practitioners in the urban northeast require targeted decision support tools that are relevant for specific and action oriented information needs. This research finding was a result of the CCRUN social science team's general needs assessment survey where stakeholders and practitioners noted that had many general "big box" tool kits to choose from but also needed more targeted "boutique" resiliency tools.

Community based organizations can be apprehensive about municipal level efforts at enhanced resiliency because of concerns regarding "green gentrification" and resiliency efforts which enhance the market value of their communities and costs of living for local, long term residents.

This emerged from CBO engagement and interviews and resulted in the motivation for the development of a community-municipal engagement framework.

Outreach and Communication Activities

Seminar series

CCRUN launched our second Green Instructure, Climate and Cities seminar series in October 2016. Each month, invited speakers present on a new topic related to the general themes of climate impacts, adaptation, and mitigation, with a focus on green infrastructure. The seminars are held in-person at Drexel University and are also broadcast live online via webinar. To date, 500 people have attended the series. All archived seminar series videos are also available for viewing online, with over 400 views and 43 subscribers to our Youtube Channel.

Climate forums

CCRUN is partnering with the Science and Resilience Institute at Jamaica Bay (SRIJB) for an ongoing climate forum series, which kicked off in November 2016. The forums are focused on providing information to residents in communities in the Jamaica Bay area to learn more about weather and climate risks (e.g., costal storms, flooding, extreme heat) and how local decision-makers are responding. Speaker have represented organizations including CCRUN, New York City Department of Planning, and New York City Emergency Management. The structure of the events dedicates time to presentation followed by a tools café, where attendees can interact with the speakers. To date, there have been 3 forums held, with attendance averaging around 40 people per event.

Figure 5. CCRUN Lead PI Dr. Radley Horton presents at the climate forum in Far Rockaway, New York.

Social media

The new CCRUN website was launched in the Fall of 2016. In addition to a fully re-designed webpage, CCRUN has significantly expanded its social media presence over the reporting period. These tools allow us to broadcast information during extreme weather events, as well as advertise for upcoming events, such as the climate forums and seminars. Over the reporting period, our Twitter account has garnered about 80 followers and we've sent out nearly 100 messages.

Media

CCRUN team members have participated in a number of print and digital new stories over the reporting period. A select list is presented here, with the complete summary available on the CCRUN website.

Newspaper

Researchers and residents explore ways Eastwick floods and ideas for mitigation
http://planphilly.com/articles/2017/05/19/researchers-and-residents-explore-ways-eastwick-floods-and-ideas-for-mitigation
Scientists Glimpse New York's Perilous Path in an Ancient Patch of Marsh
https://www.nytimes.com/2017/01/19/nyregion/bronx-marsh-sea-level-rise.html?mcubz=0&_r=1
Hurricane Sandy was a 260-year storm — here's what that means
http://www.businessinsider.com/another-hurricane-sandy-flood-risk-hit-new-york-2016-10

Radio and Television

Examining Calls for Storm Surge Barrier Connecting Queens to Sandy Hook
http://www.ny1.com/nyc/all-boroughs/politics/2017/05/12/storm-surge-barrier-calls-breezy-point-connect-sandy-hook-new-jersey.html
FEMA to Incorporate Climate Change in New Flood Maps
http://www.wnyc.org/story/fema-incorporate-climate-change-new-flood-maps/

Magazine

Can New York Be Saved in the Era of Global Warming?
http://www.rollingstone.com/politics/news/can-new-york-be-saved-in-the-era-of-global-warming-20160705
How We'll Predict the Next Natural Disaster
http://discovermagazine.com/2016/sept/12-fair-warning

NOAA Roundtable

On May 1, 2017, CCRUN helped co-organize with NOAA and host a Pennsylvania Congressional Roundtable, held at Drexel University in Philadelphia. The event was attended by approximately 20 local decision makers, including staff members of the congressional delegation that represents the region surrounding Philadelphia. CCRUN gave a presentation on their work and highlighted the importance of NOAA data products across our research teams.

Stakeholder meetings and workshops

A community presentation, "Using Modeling to Evaluate Flood Mitigation Strategies in Eastwick, PA) was organized by CCRUN in May, 2017. The event, held in collaboration with the University of Pennsylvania and Neighbors of Eastwick Coalition, was attended by approximately 30 local stakeholders.

CCRUN researchers held meetings with stakeholders, including local government officials, in Westchester County, NY to discuss possible collaboration with CCRUN, specifically focused on the use of decision-making and mapping tools for sea level rise.

CCRUN co-organized and presented at *Promoting Resilience and Transformation in Cities: A Conference for a Public Policy of Urban Climate Governance,* held in May 2017 at Hunter College. The goal of this conference was to identify barriers and opportunities for developing new and innovative climate change public policy in cities. The objectives of these policies will

be to promote urban climate resiliency and transformative climate adaptation and mitigation. CCRUN social science team members also led a task force on the relationship between policy transitions, and extreme weather and climate events as part of the Urban Resilience to Extremes (URex) networks meeting.

CCRUN members helped to organize and participated in a FEMA/NPCC/City of New York workshop on FEMA's planned "future conditions" flooding meeting.

Conference Attendance and Presentations

CCRUN team members presented (in-person and web-based) the use of the Jamaica Bay Water Quality Data Visualization and Access Tool, a product developed with the New York State Department of Environmental Conservation and the New York City Department of Parks and Recreation. One event held at the Intrepid Sea, Air, & Space Museum drew more than 1,600 visitors. In addition, team members also gave a presentation of the Hudson River Flood Impacts Decision Support System (HRFIDSS) at the "Hudson River on the Rise: Waterfront Planning for Communities and Nature" event. Approximately 200 Hudson Estuary riverfront stakeholders, including municipal officials, community leaders, planners/resource managers, and private sector professionals, attended the event.

CCRUN researchers have attended and presented at the American Water Resources Association annual conference and ASCE World Environmental and Water Resources Congress. Additional presentations were given at AGU and American Public Health Associate Annual Meeting.

Participation and presentations by multiple CCRUN team members in events led by the Science and Resilience Institute at Jamaica Bay have also occurred over the past year. Audiences at these events include scientists, public agencies, and local community representatives.

Key Publications

Catalano de Sousa, M. R., **Montalto, F. A**., & **Gurian, P.** (2016). Evaluating Green Infrastructure Stormwater Capture Performance under Extreme Precipitation. *Journal of Extreme Events, 03*(02), 1650006. doi: 10.1142/S2345737616500068

The use of green infrastructure (GI) for urban stormwater management has become a big industry, with cities like New York and Philadelphia planning to invest more than a billion dollars over multiple decades into this distributed approach to runoff reduction. Throughout the northeast US, GI systems are typically sized to fully capture all runoff generated within their tributary areas during approximately 90 percent of all wet weather events occurring annually (e.g., ≤≤ 25–30mm of precipitation). Though many claim that retrofitting such GI systems into urban landscapes will also help cities adapt to climate change, few researchers have actually attempted to document GI facility performance during more extreme precipitation.

In this study, the stormwater capture performance of a bioretention facility located in Queens, New York City was evaluated under non-extreme and extreme precipitation conditions occurring between 2011 and 2014. Performance was found to be highly variable from event to event. The site rarely ponded, and overflowed only once for a short time, generating an insignificant volume

(0.085m3) of overflow, likely because of the high infiltration capacity of in-situ, sandy soils and the facility's low hydraulic loading ratio (3.8:1). Though the facility was able to infiltrate nearly all the runoff that it receives through its inlet, field monitoring suggests that site performance is often hindered by inlet bypass, not soil saturation or overflow. The site captures 70, 77, and 60 percent of all runoff generated within its tributary area during all events (n=92), just the non-extreme events (n=78), and just the extreme events (n=14). The facility also regularly receives and infiltrates runoff originating outside of its designed tributary area. A regression analysis suggests that storm duration, total amount of precipitation and peak-hourly intensity are significant predictors (p-value $<0.05<0.05$) of, and negatively correlated with, the facility's stormwater capture performance.

The analysis also anecdotally suggests that performance might improve as vegetation gets established and/or as the frequency of maintenance visits are increased. Though this study suggests that this facility does attenuate a significant amount of runoff extreme precipitation, future work will investigate factors other than the climate which could be triggering inlet bypass occurrence, in particular GI maintenance frequency.

Close, S. L., **Montalto, F., Orton, P.,** Antoine, A., Peters, D., Jones, H., . . . **Blumberg, A.** (2017). Achieving sustainability goals for urban coasts in the US Northeast: research needs and challenges. *Local Environment, 22*(4), 508-522. doi: 10.1080/13549839.2016.1233526

In the wake of Hurricane Sandy and other recent extreme events, urban coastal communities in the northeast region of the United States are beginning or stepping up efforts to integrate climate adaptation and resilience into long-term coastal planning. Natural and nature-based shoreline strategies have emerged as essential components of coastal resilience and are frequently cited by practitioners, scientists, and the public for the wide range of ecosystem services they can provide. However, there is limited quantitative information associating particular urban shoreline design strategies with specific levels of ecosystem service provision, and research on this issue is not always aligned with decision context and decision-maker needs. Engagement between the research community, local government officials and sustainability practitioners, and the non-profit and private sectors can help bridge these gaps. A workshop to bring together these groups discussed research gaps and challenges in integrating ecosystem services into urban sustainability planning in the urban northeast corridor. Many themes surfaced repeatedly throughout workshop deliberations, including the challenges associated with ecosystem service valuation, the transferability of research and case studies within and outside the region, and the opportunity for urban coastal areas to be a focal point for education and outreach efforts related to ecosystem services.

Horton, R. M., Mankin, J. S., Lesk, C., Coffel, E., & Raymond, C. (2016). A Review of Recent Advances in Research on Extreme Heat Events. *Current Climate Change Reports, 2*(4), 242-259. doi: 10.1007/s40641-016-0042-x

Reviewing recent literature, we report that changes in extreme heat event characteristics such as magnitude, frequency, and duration are highly sensitive to changes in mean global-scale warming. Numerous studies have detected significant changes in the observed occurrence of extreme heat events, irrespective of how such events are defined. Further, a number of these

studies have attributed present-day changes in the risk of individual heat events and the documented global-scale increase in such events to anthropogenic-driven warming. Advances in process-based studies of heat events have focused on the proximate land-atmosphere interactions through soil moisture anomalies, and changes in occurrence of the underlying atmospheric circulation associated with heat events in the midlatitudes. While evidence for a number of hypotheses remains limited, climate change nevertheless points to tail risks of possible changes in heat extremes that could exceed estimates generated from model outputs of mean temperature. We also explore risks associated with compound extreme events and nonlinear impacts associated with extreme heat.

Petkova, E. P., Vink, J. K., **Horton, R. M.,** Gasparrini, A., **Bader, D. A**., Francis, J. D., & **Kinney, P. L.** (2017). Towards More Comprehensive Projections of Urban Heat-Related Mortality: Estimates for New York City under Multiple Population, Adaptation, and Climate Scenarios. *Environmental Health Perspectives, 125*(1), 47-55. doi: 10.1289/EHP166

High temperatures have substantial impacts on mortality and, with growing concerns about climate change, numerous studies have developed projections of future heat-related deaths around the world. Projections of temperature-related mortality are often limited by insufficient information to formulate hypotheses about population sensitivity to high temperatures and future demographics. The present study derived projections of temperature-related mortality in New York City by taking into account future patterns of adaptation or demographic change, both of which can have profound influences on future health burdens.

We adopted a novel approach to modeling heat adaptation by incorporating an analysis of the observed population response to heat in New York City over the course of eight decades. This approach projected heat-related mortality until the end of the 21st century based on observed trends in adaptation over a substantial portion of the 20th century. In addition, we incorporated a range of new scenarios for population change until the end of the 21st century. We then estimated future heat-related deaths in New York City by combining the changing temperature–mortality relationship and population scenarios with downscaled temperature projections from the 33 global climate models (GCMs) and two Representative Concentration Pathways (RCPs).

The median number of projected annual heat-related deaths across the 33 GCMs varied greatly by RCP and adaptation and population change scenario, ranging from 167 to 3,331 in the 2080s compared with 638 heat-related deaths annually between 2000 and 2006. These findings provide a more complete picture of the range of potential future heat-related mortality risks across the 21st century in New York City, and they highlight the importance of both demographic change and adaptation responses in modifying future risks.

Shimkus, C., Ting, M., Booth, J. F., Adamo, S., **Madajewicz, M., Kushnir, Y.,** & Rieder, H. E. (2017). Winter Storm Intenstiy, Hazards, and Property Losses in the New York Tri-State Area. *Annals of the New York Academy of Sciences*.

Winter storms pose numerous hazards to the U.S. Northeast including rain, snow, strong wind, and flooding. These hazards cause millions in damages from one storm alone. This study

investigates meteorological intensity and impacts of winter storms from 2001–2014 on coastal counties in Connecticut, New Jersey, and New York, and underscores the consequences of winter storms.

The study selected seventy winter storms based on station observations of surface wind strength, heavy precipitation, high storm tide, and snow extremes. Storm rankings differed between measures, suggesting intensity is not easily defined with a single metric. Several storms fell into two or more categories ("multiple-category storms"). Following storm selection, property damages were examined to determine which types lead to high losses. The analysis of hazards (or events) and associated damages using the Storm Events Database of the National Centers for Environmental Information indicates that "multiple-category storms" were responsible for a greater portion of the damage. Flooding was responsible for the highest losses, but no discernible connection exists between the number of storms that afflict a county and the damage it faces. These results imply that losses may rely more on the incidence of specific hazards, infrastructure types and property values, which vary throughout the region.

Examples of Implemented CCRUN Work

New York City released a set of preliminary Climate Resiliency Design Guidelines in April 2017. The guidelines establish citywide guidance on incorporating projected impacts from climate change into the planning, engineering, and construction, and renovation of City facilities and capital projects. The Mayor's Office of Recovery and Resiliency, a key CCRUN stakeholder, was responsible for developing these guidelines, along with other City agencies that the CCRUN team interacts with.

New York City has a comprehensive set of climate projections informing City resiliency policy. These projections were developed by the NPCC, whose leadership and technical research team members are principals on CCRUN, and are the foundation of the design guidelines. With this plan, the use of CCRUN-driven science, already informing planning and decision-making in the city, will be taken one step further. Climate information from CCRUN will be used from the concept phase to final design, for all new construction and substantial improvements of City buildings and infrastructure. The incorporation of a coordinated and consistent set of projections, provided by CCRUN, will make the built environment in New York City more resilient to extreme weather and climate events, while enhancing the quality of life for city residents.

The climate projections developed by CCRUN are also being used by other agencies in New York City, including the Department of Design and Construction and Department of Parks and Recreation. For these two group, their intra-agency guidelines are being coordinated with the newly released city-wide guidelines, ensuring that the science is consistent throughout all projects.

Appendix A: Sustained Assessment Activities

CCRUN's initial work for the Sustained Assessment began during the reporting period. In support of the Assessment effort of the Northeast U.S. and CCRUN's goal to expand their network to smaller cities, the team has initiated a collaboration with members of the GIS team in Westchester County, New York. The purpose of this collaboration is to bring attention to sea-level rise mapping tools that support a wide range of geospatial applications for infrastructure management, emergency dispatching, health and human services, transportation systems, and environmental and land use planning in the area. Preliminary discussions and arrangements are being made to conduct a technical training workshop for a targeted audience who require such tools for regulatory compliance and infrastructure planning purposes.

Other activities in support of the sustained assessment have included Lead PI Horton's contributions as a member of the USGCRP Climate Scenarios Task Force and the Sea Level Rise Task Force. Both activities have had dual goals of supporting NCA4 and building sustained assessment capabilities, for example through the stakeholder contributions to the Sea Level Rise Task Force. Horton also was an author on the USGCRP-led Climate Sciences Special Report, which also serves the aforementioned dual goals. Co-Lead PI Solecki is also supporting the Sustained Assessment, through his authorship of the Northeast Chapter of NCA4.

For the next year, CCRUN plans to expand the project's activities in support of the Sustained Assessment, with a full-time specialist fully supporting this work. The primary responsibility of the specialist will be to canvass the Northeast National Climate Assessment (NCA) region to identify examples of successful integrations of science into decision with the capacity for sustained assessment. CCRUN plans to engage with stakeholders and partners involved in developing and implementing both sector-specific and integrated, multi-sector adaptation plans in communities throughout the Northeast. In addition, CCRUN will create a system to categorize the information collected through stakeholder interactions.

To support these activities, CCRUN plans to organize and convene multiple workshops to promote the exchange of knowledge. Part of this work with entail working with the NCA, the RISA program, and other climate assessment specialists to identify ongoing activities.

CCRUN plans to disseminate and share the research finds and outcomes of the sustained assessment through peer-review journal articles, research reports, and conference presentations.

Appendix B: CCRUN Publication List

Alvizuri, J., Cataldo, J., Smalls-Mantey, L. A., & **Montalto, F. A.** Green Roof Thermal Buffering: Insights derived from fixed and portable monitoring equipment. *Energy and Buildings*. doi: https://doi.org/10.1016/j.enbuild.2017.06.020

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