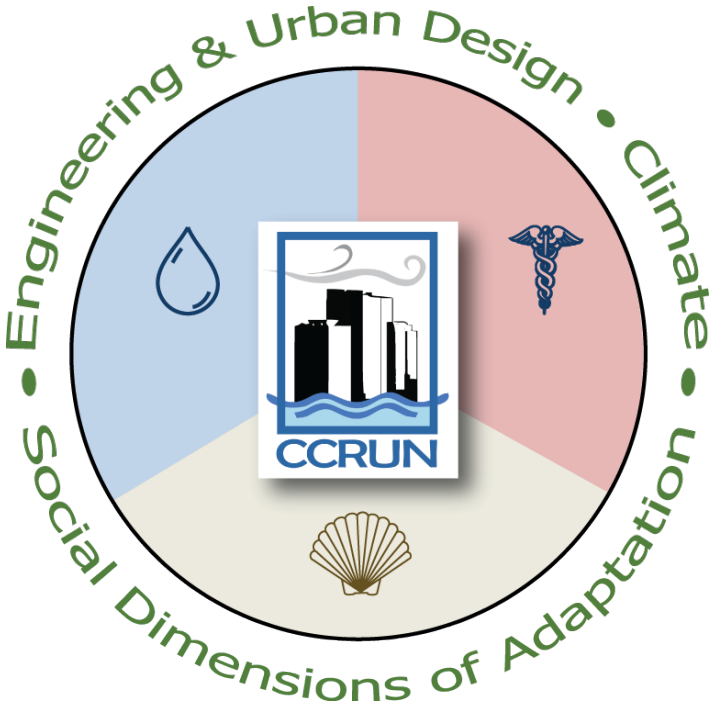
Supporting Regional Implementation of Integrated Climate Resilience Consortium for Climate Risk in the Urban Northeast (CCRUN) Phase II

Research Highlights, September 1, 2015 – May 31, 2016

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

The CCRUN Team

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Program Manager: Daniel Bader (CU)

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Other Collaborators: Kirk Bosma (UMass Boston), Brett Branco (Brooklyn College), Francisco Cioffi (University of Rome), Federico Conticello (University of Rome), Ellen Douglas (UMass Boston), Raluca Ellis (Franklin Institute), James Fitzpatrick (HDR, Inc.), Danielle Hagans (Brooklyn College), Timothy Hall (NASA), Kaz Ito (NYC DOHMH), Paul Kirshen (UMass Boston), Robert Kopp (Rutgers University) Annesia Lamb (Brooklyn College), Christopher Little (AER), Thomas Matte (NYC DOHMH), Adam Parris (SRIJB), Lesley Patrick (SRIJB), Beau Ranheim (NYCDEP), Harald Reider (University of Graz, Austria), Mark Ringenary (National Park Service), Hugh Roberts (Arcadis, Inc.), Eric Sanderson (Wildlife Conservation Society), Patrick Sullivan (Cornell), Stefan Talke (Portland State University)

Stakeholders and Partners

A & D Hydro, Inc.
Burlington (MA) Water Department
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
East Hampton (CT) Water and Sewer Commission
Environmental Protection Agency (Regions 2and 3)
Farmington River Power Co.
Fitchburg (MA) Public Works Department/Water Division
Green Mountain Power
Holyoke (MA) Gas and Electric Department
Keene (NH) Public Works Department/Water Division
L.S. Starrett Co.
Massachusetts Department of Conservation and Recreation
Massachusetts Department of Environmental Protection/Water, Wastewater, and Wetlands
Massachusetts Department of Fish and Game
Massachusetts Executive Office of Energy and Environmental Affairs
Metropolitan District of Connecticut
Metropolitan Waterfront Alliance
Monson (MA) Water & Sewer Department
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
North Brookfield (MA) Water Department
Palmer (MA) Water Department
Pennsylvania Horticultural Society
Philadelphia Office of Sustainability
Philadelphia Parks & Recreation
Rivers Alliance of Connecticut
Rockaways Waterfront Alliance
Springfield (MA) Water and Sewer Commission
Staten Island Long Term Recovery Organization
Stephen Sillers Tunnel to Towers Foundation
Stratford (CT) Department of Public Works/Water Pollution Control
The Trust for Public Land
TransCanada
Turners Falls Hydro, LLC
US Army Corps of Engineers
US Forest Service
University of Connecticut
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
WEACT for Environmental Justice
Westfield (MA) Water Resources Department
Williamsburg (MA) Water and Sewer Commission

New Areas of Focus/Partnership

During the first year of Phase II, CCRUN expanded its research partner network through a series of new endeavors, while continuing to support work started in Phase I. These partnerships provide the foundation for future work. These new partnerships have focused on: expanding the CCRUN network of researchers to include 1) non-funded partners, 2) expanded engagement in both Boston on the one hand, and medium to small cities on the other, and 3) sophisticated data provision through partnership with the Northeast Regional Climate Center.

Coasts

The CCRUN coastal sector team, led by Philip Orton at Stevens, has started collaborating with the University of Massachusetts Boston on climate risk work in the Boston metropolitan area. Orton's team plans to start work on new coastal flood modeling and risk assessment for Boston and the surrounding metropolitan region. This will include the completion and validation of a new hydrodynamic model grid. To facilitate this effort, there will be greater interaction with the UMass Boston team and Kirk Bosma at the Woods Hole Group. Another area of new research will be ensemble forecasting of flood heights for Boston.

Water

A new area of research for CCURN's water sector team is examining the skill in current short and medium term hydrologic forecasts, with an analysis of their potential operational use under climate change. Rick Palmer is leading this work at UMass and working with the New York City Department of Environmental Protection (NYCDEP). The proposed outcomes of the research are statistical measures of skill and the usefulness of weather and hydrological forecasts across different seasons, watershed, and antecedent conditions. In the current climate, operational decisions are made based on forecasts regardless of uncertainty. This project will improve decision-making based on an increased accuracy of forecasts.

An additional area of research includes a project focused on modeling and evaluating adaptations to climate change in the form of infrastructure projections and operational changes for the New York City water supply system. This work is collaborative between CCRUN team members and NYCDEP. Led by Rick Palmer at UMass, the project will demonstrate the robustness of several adaptations, including proactive management, demand reduction, seasonal forecasting, and aqueduct renovations, to mitigate drought and manage water quality under climate change.

Health

CCRUN's health team, led by Pat Kinney at Columbia, is focusing on three new areas of research. First, the team is analyzing storm-related health impacts in cities in the Northeastern United States. Next, the team has worked with the City of Cambridge, Massachusetts, on a health vulnerability assessment for the city. The assessment focused on three primary issues, heat and temperature, urban air quality, and vector-borne disease. New research examining humidity as a risk modifier for extreme heat events is also now underway.

Climate

The climate science team has partnered with stakeholders including the Consolidated Edison electrical company on an analysis of extreme heat events. Temperature metrics/thresholds have been co-generated based on decision-maker needs. The work includes historical analysis and projections. A new research area is consideration of the combined impacts of high heat and high humidity.

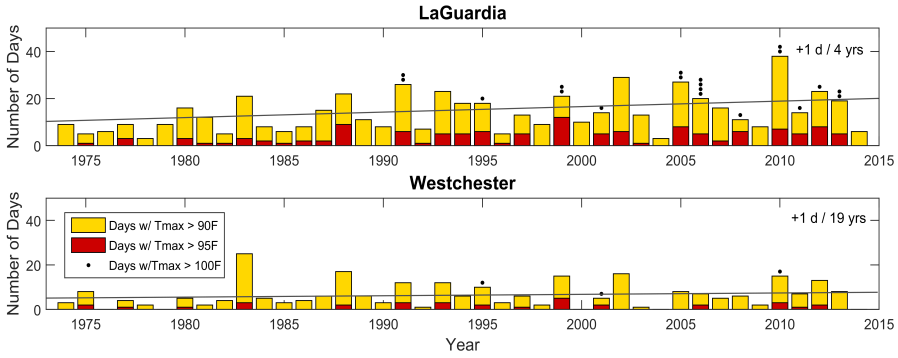

Figure 1. Number of days per year, 1974-2014, with maximum temperature greater than 90 °F (yellow), greater than 95 °F (red), and greater than 100 °F (black dots). Line displays trend in the days above 90 °F per year from 1974-2014.

Other climate science work, led by Yochanan Kushnir, continues previous research on the characteristics of and societal vulnerability to cold-season storm hazards along the Atlantic Coastline of the Northeast United States. The project broad objective of the work is to understand and quantify the risk posed by cold season extreme weather to the coupled human-natural systems in the region and aid in generating related probabilistic information for adaptation and preparedness for such extreme events in the future.

Radley Horton will be developing extreme precipitation and flooding risk information through a new partnership with investigators from the University of Connecticut. The work focuses on the needs of water managers and other urban planners in the medium-size cities of Stamford and Groton, Connecticut.

The Third New York City Panel on Climate Change (NPCC3) got underway, with CCRUN climate team members serving on the Panel (Vivien Gornitz) and leading the technical research in the climate sciences working group (Daniel Bader, Radley Horton, and Philip Orton). Research focuses on climate change and climate extremes, such as coastal flooding with sea level rise, urban flooding, increased heat waves and heat stress, and precipitation extremes (e.g., droughts). For coastal flooding, work in progress includes regional climate modeling of storm surge, re-assessment of NYC flood risk based on a synthesis of multi-study storm surge and sea level rise projections, including associated uncertainties, characterization of extra-tropical cyclones by hazard (maximum wind speeds, surge levels, precipitation (rainfall/snow), storm tracks) and their impacts on infrastructure.

Engineering and Urban Design

New research from the CCRUN team at Drexel, led by Franco Montalto, is focused on exploring the ability of coastal natural areas to reduce vulnerability to storms, surges, and sea level rise. This work, conducted with the Trust for Public Land, developed a GIS system and model to define the relationship between coastal houses' vulnerability to Hurricane Sandy and their

geographical features. The research will be able to identify if green infrastructure could be a strategy to reduce the damage risk. Additional new work uses urban parks to analyze urban resilience to achieve multi functionality through water management.

In addition to the Trust for Public Land, the CCRUN team is also partnered with the IUAV University in Venice, Italy on a project concerning coastal urban climate preparedness in an international coastal context, and with Cooper Union on analyzing the energy benefits of the Jacob K. Javits green roof at the building and neighborhood scales.

Social Dimensions of Adaptation

Based on previous research, study results indicate the one potential strategy to improve resilience to coastal storms in urban area is to educate communities about the future flood risk that they face, as well as actions that can reduce flood risk to their homes and neighborhoods. CCRUN researcher Malgosia Madajewicz seeks to further explore this work, partnering with the New York City Mayor's Office of Recovery and Resiliency, the New York City Department of City Planning, the Center for New York City Neighborhoods, the Waterfront Alliance, and the National Center for Disaster Preparedness to conduct research on flood risk and options for building resilience for residents of coastal neighborhoods and undertake an impact evaluation that would assess the effects of such education on resilience.

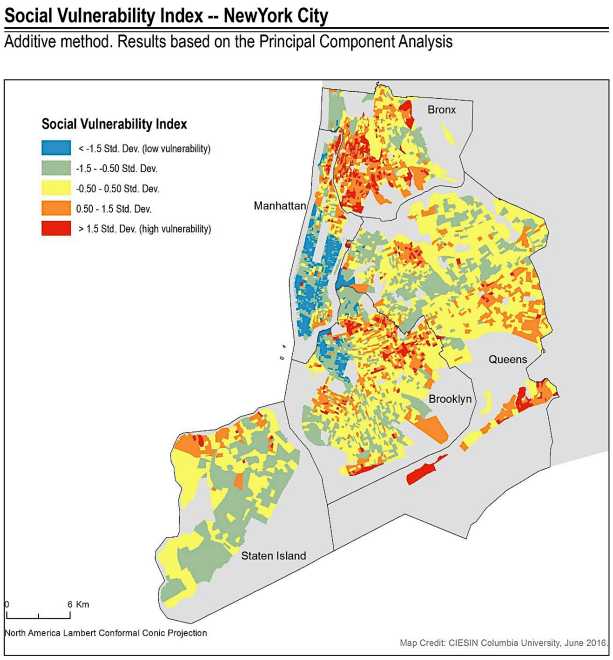

Figure 2. Social Vulnerability Index for New York City based on the Additive Method.

Madajewicz has also started to work with a team led by Groundwork Hudson Valley on a project that is educating middle school and high school children as well as members of the public in Yonkers, NY and the surrounding areas about climate change, climate risks in the children's neighborhoods, and actions that the residents can take to help mitigate and adapt to climate change.

The social science research lead by William Solecki at Hunter College has developed a survey addressing stakeholder needs regarding climate impact information, and adaptation strategies. Currently, the team is in the process of tailoring the survey by sector to attain results that identify specific opportunities for CCRUN tools and skill sets to be used within the wider CCRUN region.

The CCRUN social science team led by Solecki is using the collaborations gained through Urban Resilience to Extremes Sustainability Research Network (UREx SRN) to connect to the CCRUN work done concerning lessons learned from Hurricane Sandy, and how this can be

translated to other cities. In particular, one of the research interests of this collaboration is the role of extreme events, decision-making contexts and management practices that support the development of policy transitions.

Coordinating with Madajewicz, the social science team is discussing the next steps for expanding the their work beyond the New York metro region that would involve engaging with other community sites in the wider CCRUN area. The next steps include plans to work in a complementary way where both teams can address separate sets of issues. In addition, the CCRUN social science group is in the initial stages of developing a monthly webinar series that will focus on social science advancements within the Regional Integrated Sciences (RISA) programs and associated federal programs

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.

Northeast United States

On the Atlantic Coast, CCRUN climate science researcher Yochanan Kushnir worked with other CCRUN investigators, the New York City Panel on Climate Change, and the New York City Office of Emergency Management to understand and quantify the risk posed by cold season extreme weather to the Northeast Coast and to aid in generating related probabilistic information for adaptation and preparedness for such extreme events in the future.

CCRUN researchers Alan Blumberg and Nickitas Georgas worked with Port Authority of New York and New Jersey, the New York City Office of Emergency Management, and the New York City Mayor's Office of Recovery and Resiliency to improve preparedness and resiliency at critical Port Authority infrastructure sites through an innovative observation and forecast system that provides information on the potential risk and magnitude of overland flooding prior to and during significant storm events. The project delivers dynamic, web-based informational materials with unprecedented levels of accuracy and uncertainty quantification that relate real-time and forecasted flood levels to local flood benchmarks in order to aid in emergency preparation and decision-making.

CCRUN lead PI Radley Horton has contributed downscaled regionalized sea level rise projections to a GIS-based database covering 38,000 square miles of coastlines that tracks the ability of different coastal ecosystems to keep up with sea level rise. Horton is also a member of the sea level rise and climate scenario task forces contributing projections and analysis of associated uncertainties to the Fourth U.S. National Climate Assessment. He is also participating in a special report on climate scenarios as an input to the National Assessment.

New York City

CCRUN researcher Pat Kinney worked with the New York City Department of Health and Mental Hygiene to measure the spatial distribution of tree pollen across New York City and identify land use variables that predict local tree pollen levels. With the knowledge that intra-urban variation in tree canopy is an important driver of tree pollen exposure, this project delivers essential input and communication to the health departments and health providers to assess the effects of spatial variation in tree pollen exposure on allergic disease outcomes.

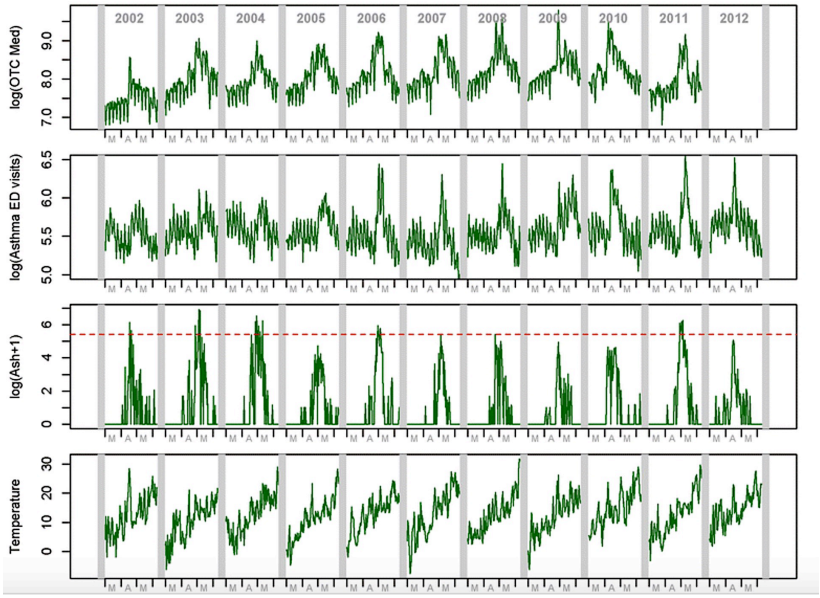

Figure 3. Time-series plots of OTC allergy medication sales, asthma syndrome ED visits, pollen (ash is shown), and weather during March 1 and June 10th, 2002-2012. The red horizontal dotted line for ash plot indicates 98th percentile level

CCRUN researcher Rick Palmer worked with the NYC Department of Environmental Protection to demonstrate the robustness of several adaptations available to the New York City Water Supply System to mitigate drought and manage water quality under climate change projections through the end of the century. The project delivers decision support tools that address overall trends (average reliability, etc.) and individual scenarios (weather, hydrologic, and system metric time series) representing the effectiveness of adaptations under projected climate change through the end of the century.

CCRUN researcher Franco Montalto worked with the Trust for Public Land to compile detailed information of coastal houses and the surrounding geographical information in a GIS system in addition to building a model to define the relationship between coastal houses' vulnerability to Hurricane Sandy and their geographical features. The project provides an analysis that will help stakeholders determine the key factor of the coastal houses' vulnerability to extreme weather like Hurricane Sandy and if green infrastructure could be a strategy to reduce the damage risk.

CCRUN researchers Radley Horton and Daniel Bader worked with Consolidated Edison to develop co-generated historical and projected climate risk information tailored to temperature thresholds used by the agency for planning.

Jamaica Bay, New York City

CCRUN researchers including Sandra Baptista have worked with national, state, and local government agencies, the scientific research community, nongovernmental and community

organizations concerned about Jamaica Bay land and water resources to develop decision support tools in an integrated Jamaica Bay water quality database. There is also a web application that will inform stakeholder efforts to reduce pollution loading and improve Jamaica Bay water quality.

Philip Orton of CCRUN's coastal team has worked with the New York State Department of Environmental Conservation and the New York City Mayor's Office of Recovery and Resiliency to enhance adoption of rapid and easy-to-use tools that allow policymakers and the public to see and value ecosystem services in the monetary terms that drive American land use and management decisions. The project delivers results and methodologies to decision-makers, scientists and the general public through workshops, peer-reviewed articles, and the free, public provision of Visionmaker.nyc.

Philadelphia, Pennsylvania

CCRUN researcher Franco Montalto worked with the City of Philadelphia and the Mayor's office of sustainability to evaluate the potential for reduced carbon emissions across energy usage in buildings, transportation emissions, and the regional electricity grid. This analysis could potentially help the city of Philadelphia achieve its goal of 80% reduction in GHG emission by 2050.

Cambridge, Massachusetts

CCRUN researcher Kinney worked with the City of Cambridge, MA to project future excess mortality attributable to extreme temperature. The study produced peer-reviewed publications and technical reports, which evaluated heat and temperature vulnerabilities, air quality, and vector-borne diseases such as West Nile virus. These reports provided the City of Cambridge with comprehensive health-risk information to aid in climate adaptation efforts.

Program Impacts Evaluation

We have developed multiple mechanisms to measure the overall program-level impact of the CCRUN team efforts and activities. These mechanisms and measures include participation in CCRUN team sponsored webinars and online seminars, completion of a CCRUN online needs assessment survey, the visitation to the project website, and informal stakeholder feedback. Each of these products and procedures has been (or are in the process of being) updated extensively with the start-up of CCRUN Phase II. For each product and procedure, the CCRUN team will catalog the number of person-contacts as well as the quality/character of that contact (e.g., was there follow-up discussion, multiple engagements, content analysis of feedback, etc.).

The CCRUN team is structured to incorporate several program-level impacts resulting from the evaluation process. For each evaluation product and procedure, we attempt to define quantitative and qualitative statements that are used to refine and adjust CCRUN engagement and research protocols. We continually evaluate our efforts to execute gap analyses (i.e., define where there are critical data and research needs), promote collaboration knowledge generation exercises

(between CCRUN team members and regional climate practitioners and stakeholders), and develop prototype decision-support tools.

Building Expertise for Local/Regional Decision Making

Throughout the Northeast United States, specifically focusing on the geographic scope of CCRUN, which spans the urban corridor from Philadelphia to Boston, there are numerous examples of how work produced by our team is building the expertise and ability of local/decision-makers to prepare and adapt to climate variability and change. This is a product of all three CCRUN sector teams and three crosscutting theme teams working with multiple local governments to best prepare for the future. Decision-maker expertise and capacity has been built by CCRUN run members through activities such as formal presentations, meetings and workshops, webinars, and product development such as reports.

Focusing on the three hub cities of CCRUN, Boston, New York, and Philadelphia, CCRUN team members have engaged with the local sustainability and planning offices in each city since the start of Phase II. The information and guidance provided by CCRUN are informing resiliency and adaptation efforts in each of the three cities.

In Boston, members of the CCRUN team have met with the Commissioner of the Environment Department for the City of Boston and Office of Environment, Energy, and Open Space to discuss ways to best integrate our research into the city's ongoing climate resiliency work. Through discussion, and with university partners in the Boston area, we now have a complete plan to bring CCRUN into ongoing activities, while taking on new endeavors to provide the city with the best available local climate information.

In New York City, the Mayor's Office of Recovery and Resiliency is directly engaged with CCRUN team members, primarily through the New York City Panel on Climate Change. City plans and reports, including the post-Sandy Special Initiative for Rebuilding and Resiliency and more recently released OneNYC, were developed in part through interactions with CCRUN team members. Adaptation and resiliency activities across the City, ranging from natural ecosystem restoration, hardening infrastructure, to building code changes, are grounded in the climate science information from CCRUN.

In Philadelphia, CCRUN researchers prepared a report for the Office of Sustainability analyzing the City's newly released 80 by 50 greenhouse gas emissions reduction plan. Strategies to reduce citywide emissions not only mitigate the potential impacts of climate change, they also are opportunities to build resilience in the future. Improvements in buildings, energy efficiency, and transportation will lower emissions while at the same time making these critical city infrastructure systems stronger and better able to withstand future climate extremes. The green infrastructure techniques that are a focal point of CCRUN green research are an example of a strategy with benefits for both mitigation and adaptation.

Most Significant Accomplishment for September 2015 – May 2016

During the first year of Phase II, CCRUN has focused on developing an integrated framework and vision for activities over the 1-5 year time frame. The initial framework, presented at CCRUN's kickoff meeting in November, has evolved based on discussions amongst the three lead PIs, who represent the cross cutting themes of climate, engineering and urban design, and social dimensions of adaptation, followed by engagement with the three sector leads. The primary goals of the framework are to 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 purposes.

	Research Locations	Data & Information	Engineering & Adaptation Design	Social Science & Decision-Making	Specific Phase II Work Tasks and Products
Assessment and Learning (Link to Phase I)	"Early climate action sites" (e.g. Boston, NYC)	Which data products have been most useful?	What adaptations have already proven effective?	What are key opportunities, barriers, and tipping points for action?	*Ongoing needs assessment will reveal answers to the learning questions.* ***List key products.***
Pressing Needs, Experimentation & Testing	Define "*Test Bed Sites*" for new science, experiment, and study	1) What are the key unknowns? 2) Select sites and identify problems of cross cutting nature 3) Synchronize baseline data collection efforts 4) Design synchronized adaptation experiments with stakeholders 5) Generate results and interpret with local stakeholders			*During this year, where (topically or geographically) will/have you started new work and what will/have you done?* ***List key products.***
Validation, Gap Analysis, & Translation	"*Application Sites*" (e.g. New Haven, Newark, Hoboken, Wilmington, etc.)	Distinguish, evaluate, and update key regional information needs	Test findings with other boundary conditions; extrapolation and scale-up modeling	Leverage local opportunities to identify transition pathways	Fun feature article, year-end review of sector activities and prospectives

Figure 4. CCRUN Research Template

Research Findings

Our most significant findings in CCRUN Phase II Year 1 including the following:

Coasts: Hydrodynamic modeling of flooding during Tropical Storm Irene indicates that Jamaica Bay salt marshes played only a minimal role in mitigating the peak water elevations induced by Irene. On the other hand, the presence of the marshes causes higher velocities in non-vegetated areas such as deep channels, and lower velocities in vegetated areas, and thus redistributes energy around the bay, with likely feedbacks on water quality, marsh stability, and the response to sea level rise (Marsooli et al. 2016).

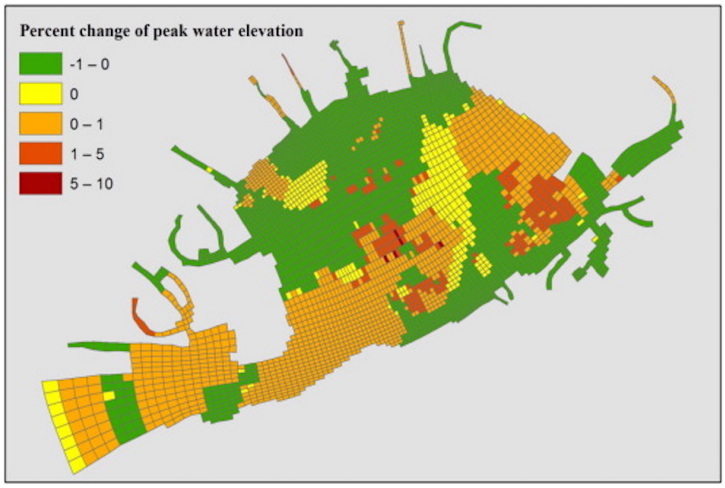

Figure 5. Impact of Jamaica Bay's present-day salt marshes on the peak water elevation induced by Hurricane Irene. Negative value means reduction.

Water: Adaptation to climate change through infrastructure and operational projects are effective in 1) minimizing low reservoir storages during hydrologic drought and 2) mitigating the consequences of storm event

turbidity for the New York City Water Supply System in climate change projections through the end of the century.

Health: For CCRUN's health team research, a key finding is that airborne abundance of tree pollen in New York City varies spatially in ways that correlated both with tree density and with population allergic sensitization. Additional work found that indoor temperatures often exceed those measured outdoors, especially on upper floor apartments. Also, research indicates that flu epidemics are driven in part by weather factors, and lead in turn to subsequent spikes in cardiovascular deaths.

Climate: A new paper on the spatial pattern of cold-season, multi-station high surface wind events in the Northeast US, quantified their frequency of occurrence, and identified their link to winter storm events. The paper classifies high wind events by their return periods and plots the tracks of storms that cause these events. Using the frequency of the tracks in each of the pathways, the study shows that storms associated with multi-station wind events are most likely to approach the northeastern United States from the southwest (Booth et al., 2015).

Engineering and Urban Design: As related to the ability of green spaces in urban areas to provide ecosystem services associated with protection from Hurricane Sandy, the research found that natural features played a key role in determining building damages during the storm in New York City. Trees appear to have provided protection from wind and flying debris and dunes reduced building flood damages where present. However, prediction of the protective services provided by specific types of green infrastructure is, in general, difficult given the spatial heterogeneity of NYC's coastline and the fact that damages are likely storm-specific.

Social Dimensions of Adaptation: The literature generally treats social vulnerability as being determined by the same factors for all climate risks. However, social vulnerability to climate risks depends on specific risks. No single population is vulnerable to all climate risks in the same way. We need to understand the loss itself, those it affects, strategies to reduce vulnerability according to each risk. Factors that influence vulnerability to coastal flood risk include assets owned (especially if the person owns a house), disability, understanding storm warnings, access to information about recovery process and available assistance, social networks, and local organizations in the neighborhood.

Outreach and Communication Activities

Coasts

Key outreach activities for the CCRUN coastal team include serving on the New York City Panel on Climate Change (NPCC), where the team interacted monthly with the New York City Mayor's Office of Recovery and Resiliency (NYC-ORR) to produce science-based assessments of flood risk for future decades.

Additional interactions with ORR include assisting with their appeal of FEMA flood zones, which had nearly a doubling of zone area, and are felt to be inaccurate. In CCRUN Phase I, for

the NYC Panel on Climate Change, we repeated FEMA's study with added sea level rise, and found a large problem with model validation that formed the basis of the appeal.

The team is participating as an integrated system modeling team member for the study "Towards a Master Plan for Jamaica Bay", which will help define flood nature-based mitigation options.

Philip Orton is also a member of the NJ Climate Adaptation Alliance's Science and Technical Advisory Panel (STAP) for coastal flooding

Select presentations and meetings attended include a presentation by Orton at the NOAA Annual Climate Predication Applications Science Workshop (March 2016), by Orton at the Pint of Science event on sea level rise and coastal flood risk (April, 2016), a seminar lead by Orton, titled "Mimicking Jamaica Bay's Historical Landscape for Urban Coastal Flood Resilience"at Brooklyn College (May 2016), and lecture by Alan Blumberg on Boston Harbor oceanography at the Harvard Graduate School of Design (May 2016)

Water

Leslie DeCristofaro, a graduate student working for Rick Palmer at UMass, gave two presentations highlighting CCRUN's water sector teamwork. Her presentation focused on the comparative effects of climate change and operational changes for the New York City Water supply system. Talks were given at the New England Graduate Student Water Symposium (September 2015) and at the ASCE's World Environmental and Water Resources Congress (May 2016). Palmer also participated in a panel discussion at the ASCE event, titled "Evaluating the Environmental Implications of Relicensing Five Major Hydropower Projects in the Connecticut River Basin."

Health

Members of the CCRUN health team have spoken at community group gatherings centered on climate vulnerability, include meetings of West Harlem Environmental Action (WE-ACT). Pat Kinney has also lectured at Boston University on climate, air quality, and health. The team has held meetings with the New York City Department of Health and Mental Hygiene, along with the City of Cambridge to advise them on health related climate vulnerabilities.

Climate

Members of CCRUN's climate science team are participating in the Third New York City Panel on Climate Change.

Radley Horton has made numerous national/international television and radio appearances to discuss vulnerabilities to climate change in the Northeast U.S. Radley has also given presentations this year on the same topic to numerous stakeholder groups, including, the Cape Coastal Conference in December, the Port Authority of New York and New Jersey, and City of New York.

The research team lead by Yochanan Kushnir has communicated with the New York City Office of Emergency Management, giving presentations that have described their work on extratropical storms.

Vivien Gornitz has presented CCRUN's work on facing higher sea levels and increased coastal flooding in New York City at several meetings, including the Geological Society of American Annual Meeting (November, 2015) and a New York State Assembly Roundtable on Climate Change (December, 2015). Vivien also represented CCRUN at the Mid Atlantic Council for the Oceans (MARCO) meeting in February 2016.

Engineering and Urban Design

CCRUN green infrastructure research has been presented at the 1st Climate Change Symposium: Adaptation and Mitigation (May 2015) and the American Geophysical Union Annual Meeting (December 2015).

Franco Montalto has participated in panel discussions and given presentations at a series of invites, highly the CCRUN green infrastructure team research. Events attended include the Roads and Water Quality Symposium at Manhattan College (April 2016), the Institute of Electrical and Electronics Engineers (April 2016), and the Science of the Living City Seminar Series, run by the New York City Department of Parks and Recreation and United States Department of Agriculture Forest Service (May 2016).

Patrick Gurian led, and Franco Montalto also participated in, the development of two City of Philadelphia plans associated with efforts to reduce greenhouse gas emissions by 80% by 2050.

Social Dimensions of Adaptation

CCRUN researcher Malgosia Madajewicz attended the NOAA RISA workshop on evoluating co-produced climate information in February 2015. Madajewicz has also presented her results to the Trust for Public Land (April 2016) attended the NOAA Annual Climate Predication Applications Science Workshop (March 2016). In addition, she has presented her research to the New York City Office of Emergency Management (May 2016) and attended meetings organized by Groundwork on the Hudson (October 2015 - January 2016), an education-focused group.

William Solecki and other CCRUN team researchers attended the 2016 State of the Bay Symposium, hosted by the Science and Resilience Institute at Jamaica Bay (SRI@JB), was a two-day symposium (June 15-16) which brought together community groups, scientists, and decision makers for presentations, discussions and breakout working groups concerning the management and decision context within Jamaica Bay.

CCRUN co-sponsored the Transforming Infrastructure in NYC for Sustainability: Critical needs and Opportunities Workshop. This workshop took place on April 25, 2016, at the Roosevelt House, Hunter College. This workshop allowed for CCRUN to expand its engagement with the New York metro and New York State practitioners, experts, researchers and decision-makers.

Media

Montalto - Why Philly Should Use Rainwater to Flush Toilets (March 8, 2016)
http://www.phillymag.com/news/2016/03/08/drexel-study-flush-rainwater/
Montalto - Researchers call for urban toilets to be flushed with rainwater (March 7, 2016)
http://www.upi.com/Science_News/2016/03/07/Researchers-call-for-urban-toilets-to-be-flushed-with-rainwater/6081457370167/
Orton - New York City Hit by Worst Flooding Since Sandy (February 9, 2016)
http://www.wnyc.org/story/flooding-continues-rockaways/

Figure 6. An example of CCRUN flood modeling for Hoboken, New Jersey. Featured. in the New York Times on February 7, 2016. http://www.nytimes.com/interactive/2016/02/08/nyregion/hoboken-flood-wall-maps.html

Key Publications

Blumberg, A. F., Georgas, N., Yin, L., Herrington, T. O., & **Orton, P. M.** (2015). Street-Scale Modeling of Storm Surge Inundation along the New Jersey Hudson River Waterfront. *Journal of Atmospheric and Oceanic Technology, 32*(8), 1486-1497. doi: doi:10.1175/JTECH-D-14-00213.1

A new, high-resolution, hydrodynamic model that encompasses the urban coastal waters of New Jersey along the Hudson River Waterfront opposite New York City, New York, has been developed and validated for simulating inundation during Hurricane Sandy. A 3.1-m-resolution square model grid combined with a high-resolution lidar elevation dataset permits a street-by-street focus to inundation modeling. Robust flooding and drying of land in the model physics provides for the dynamic prediction of flood elevations and velocities across land features during inundation events. The inundation model was forced by water levels from the extensively validated New York Harbor Observing and Prediction System (NYHOPS) hindcast of that hurricane.

Validation against 56 watermarks and 16 edgemarks provided via the USGS and through an extensive crowdsourcing effort consisting of photographs, videos, and personal stories shows that the model is capable of computing overland water elevations quite accurately throughout the entire surge event. The correlation coefficient (R2) between the watermark observations and the

model results is 0.92. The standard deviation of the residual error is 0.07 m. Comparisons to the 16 flood edgemarks suggest that the model was able to reproduce flood extent to within 20 m. Because the model was able to capture the spatial and temporal variation of water levels in the region observed during Hurricane Sandy, it was used to identify the flood pathways and suggest where flood-preventing interventions could be built.

Booth, J. F., Rieder, H. E., Lee, D. E., & **Kushnir, Y.** (2015). The Paths of Extratropical Cyclones Associated with Wintertime High-Wind Events in the Northeastern United States. *Journal of Applied Meteorology and Climatology, 54*(9), 1871-1885. doi: doi:10.1175/JAMC-D-14-0320.1

This study analyzes the association between wintertime high-wind events (HWEs) in the northeastern United States and extratropical cyclones. Sustained wind maxima in the daily summary data from the National Climatic Data Center's integrated surface database are analyzed for 1979–2012. Wind events meeting the return-level criteria are termed HWEs. The HWEs occurring on the same day are grouped into simultaneous wind exceedance dates, termed multistation events. In a separate analysis, extratropical cyclones are tracked using ERA-Interim. The multistation events are associated with the extratropical cyclone tracks on the basis of cyclone proximity on the day of the event. The multistation wind events are found to be most often associated with cyclones traveling from southwest to northeast, originating west of the Appalachian Mountains. To quantify the relative frequency of the strong-wind-associated cyclones, the full set of northeastern cyclone tracks is separated on the basis of path, using a crosshairs algorithm designed for this region. The tracks separate into an evenly distributed set of four pathways approaching the northeastern United States: from due west, from the southwest, and from the southeast and storms starting off the coast north of the Carolinas. Using the frequency of the tracks in each of the pathways, it is shown that the storms associated with multistation wind events are most likely to approach the northeastern United States from the southwest.

Little, C. M., **Horton, R. M.,** Kopp, R. E., Oppenheimer, M., Vecchi, G. A., & Villarini, G. (2015). Joint projections of US East Coast sea level and storm surge. *Nature Clim. Change, 5*(12), 1114-1120. doi: 10.1038/nclimate2801

Future coastal flood risk will be strongly influenced by sea-level rise (SLR) and changes in the frequency and intensity of tropical cyclones. These two factors are generally considered independently. Here, we assess twenty-first century changes in the coastal hazard for the US East Coast using a flood index (FI) that accounts for changes in flood duration and magnitude driven by SLR and changes in power dissipation index (PDI, an integrated measure of tropical cyclone intensity, frequency and duration). Sea-level rise and PDI are derived from representative concentration pathway (RCP) simulations of 15 atmosphere–ocean general circulation models (AOGCMs). By 2080–2099, projected changes in the FI relative to 1986–2005 are substantial and positively skewed: a 10th–90th percentile range 4–75 times higher for RCP 2.6 and 35–350 times higher for RCP 8.5. High-end FI projections are driven by three AOGCMs that project the largest increases in SLR, PDI and upper ocean temperatures. Changes in PDI are particularly influential if their intra-model correlation with SLR is included, increasing the RCP 8.5 90th percentile FI by a further 25%. Sea-level rise from other, possibly correlated, climate processes

(for example, ice sheet and glacier mass changes) will further increase coastal flood risk and should be accounted for in comprehensive assessments.

Rossi, N., **DeCristofaro, L.,** Steinschneider, S., Brown, C., & **Palmer, R.** (2016). Potential Impacts of Changes in Climate on Turbidity in New York City's Ashokan Reservoir. *Journal of Water Resources Planning and Management, 142*(3), 04015066. doi: doi:10.1061/(ASCE)WR.1943-5452.0000614

This paper applies an approach for determining water resources vulnerability caused by climate change to the New York City water supply system (NYCWSS). The results provide potential responses of the system to changes in climate and guidance that can inform short-term and long-term planning decisions. This research includes models of the hydrology and operations of the NYCWSS and includes a statistical model of turbidity loading and a zero-dimentional model of turbidity concentration in the Ashokan Reservoir. Using a stochastic weather generator, incremental changes are made to precipitation and temperature and these are used to drive a coupled hydrology-simulation model. The results illustrate the sensitivity of the system, and in particular Ashokan Reservoir turbidity, to changes in climate.

Rostad, N., Foti, R., & **Montalto, F. A.** (2016). Harvesting rooftop runoff to flush toilets: Drawing conclusions from four major U.S. cities. *Resources, Conservation and Recycling, 108*, 97-106.

As it provides the simultaneous benefits of reducing the demand for potable water and the generation of water runoff, rainwater harvesting (RWH) has received increasing attention from urban water managers in the past decades. This study employs a mass balance based method to estimate RWH performance for four large metropolitan areas of the United States, namely New York City, Philadelphia, Chicago, and Seattle. Geospatial analysis is used in concert with climatic records to characterize the cityscape and climatic patterns of each city and evaluate the RWH systems performance both in terms of potable water savings and roof runoff reductions. The analysis indicates that typical urban rainwater harvesting setups, consisting of a 100 m2 roof connected to a 5 m3 storage volume, would be able to reduce potable water demand by over 65% in all cities while contextually reduce roof runoff generation by over 75%. Small differences in performance are observed among cities due to differences in precipitation patterns, typical roof area, and population density. Furthermore, an evaluation of the total water savings and runoff reduction for the application of RWH practices at maximum build out for all four study cities is provided, and the sensitivity of our estimates of performance to precipitation patterns and to the systems' operating algorithm is also analyzed and discussed.

Schwartz, J. D., Lee, M., **Kinney, P. L.,** Yang, S., Mills, D., Sarofim, M. C., . . . **Horton, R. M.** (2015). Projections of temperature-attributable premature deaths in 209 U.S. cities using a cluster-based Poisson approach. *Environmental Health, 14*(1), 1-15. doi: 10.1186/s12940-015-0071-2

A warming climate will affect future temperature-attributable premature deaths. This analysis is the first to project these deaths at a near national scale for the United States using city and month-specific temperature-mortality relationships.

We found temperature-mortality relationships that vary by location and time of year. In general, the largest mortality response during hotter months (April – September) was in July in cities with cooler average conditions. The largest mortality response during colder months (October–March) was at the beginning (October) and end (March) of the period. Using data from two global climate models, we projected a net increase in premature deaths, aggregated across all 209 cities, in all future periods compared to 1990. However, the magnitude and sign of the change varied by cluster and city.

We found increasing future premature deaths across the 209 modeled U.S. cities using two climate model projections, based on constant temperature-mortality relationships from 1997 to 2006 without any future adaptation. However, results varied by location, with some locations showing net reductions in premature temperature-attributable deaths with climate change.

Examples of Implemented CCRUN Work

Radley Horton has contributed climate science information via presentation to the Public Services Commission (PSC) that regulates New York Utilities. This information about changing risks led to the formation of a collective within utilities, whereby the utilities are authorized and mandated to integrate climate planning into their long term decision making, something they were otherwise not allowed to do without PSC approval. The collective has thus far analyzed extreme temperatures at thresholds that are relevant for their systems. Future work may cover other types of extreme events, including extreme precipitation, coastal flooding, and combined effects of heat and humidity.

Climate science projections developed by CCRUN researchers Horton and Bader are now integrated into the New York State Climate Change Clearinghouse (https://www.nyclimatescience.org). The Clearinghouse is a web portal where users have access to information related to a variety of climate change topics with a specific focus on New York State. The CCRUN projections are featured in mapping tools and other data products on the website. In addition, several reports that CCRUN researchers have worked on, such as the New York City Panel Change and New York State Climate Adaptation Assessment Report (ClimAID) are also promoted through the Clearinghouse.

CCRUN researchers, including Sandra Baptista, are developing an in integrated water quality and web-based application for Jamaica Bay, New York City. The database is being designed to allow for the analysis of spatial and temporal patterns of water quality in the Bay and the analytical tool will aide with measuring resilience and detecting regime shifts in response to different drivers and disturbances. These applications will help inform stakeholder efforts to reduce pollution and improve the overall water quality in Jamaica Bay.

Appendix: CCRUN Publication List

Alizadehtazi, B., DiGiovanni, K., Foti, R., Morin, T., Shetty, N. H., Montalto, F. A., & Gurian, P. L. (2016). Comparison of Observed Infiltration Rates of Different Permeable Urban Surfaces Using a Cornell Sprinkle Infiltrometer. *Journal of Hydrologic Engineering, 21*(7), 06016003. doi: doi:10.1061/(ASCE)HE.1943-5584.0001374

Blumberg, A. F., Georgas, N., Yin, L., Herrington, T. O., & Orton, P. M. (2015). Street-Scale Modeling of Storm Surge Inundation along the New Jersey Hudson River Waterfront. *Journal of Atmospheric and Oceanic Technology, 32*(8), 1486-1497. doi: doi:10.1175/JTECH-D-14-00213.1

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Brandon, C. M., Woodruff, J. D., Orton, P. M., & Donnelly, J. P. (2016). Evidence for elevated coastal vulnerability following large-scale historical oyster bed harvesting. *Earth Surface Processes and Landforms, 41*(8), 1136-1143. doi: 10.1002/esp.3931

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Horton, R. M., Coffel, E. D., Winter, J. M., & Bader, D. A. (2015). Projected changes in extreme temperature events based on the NARCCAP model suite. *Geophysical Research Letters, 42*(18), 7722-7731. doi: 10.1002/2015GL064914

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Kinney, P. L., Schwartz, J., Pascal, M., Petkova, E., Tertre, A. L., Medina, S., & Vautard, R. (2015). Winter season mortality: will climate warming bring benefits? *Environmental Research Letters, 10*(6), 064016.

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