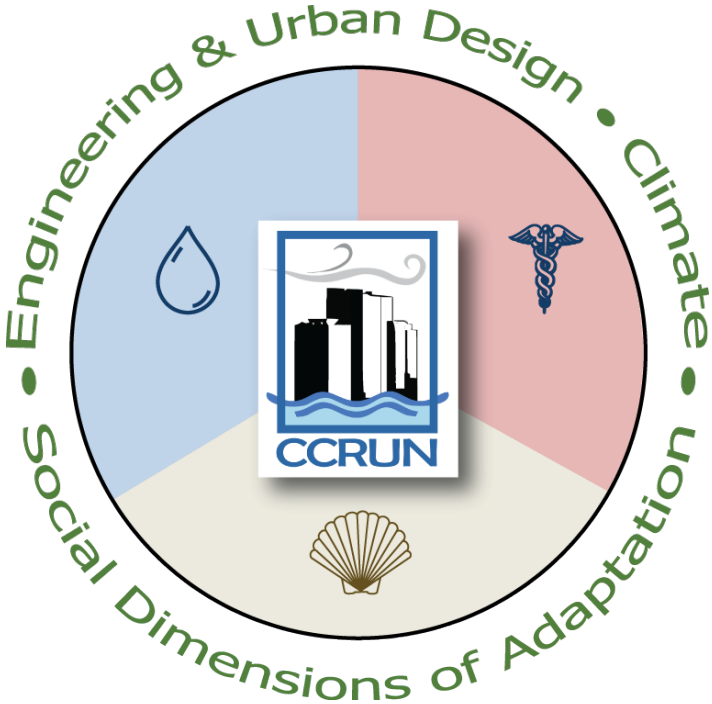
Supporting Regional Implementation of Integrated Climate Resilience Consortium for Climate Risk in the Urban Northeast (CCRUN) Phase II

Research Highlights, June 1, 2017 – May 31, 2018

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

University *of* Massachusetts Amherst

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Stakeholders and Partners

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

New Areas of Focus/Partnership

During the third year of Phase II, CCRUN further expanded its research partner network through a series of new endeavors, while expanding interactions amongst the research teams. These partnerships are critical to the success of the research and serve as the foundation for future work. Over the past year, CCRUN's engagement has increased throughout the urban Northeast and researchers continue to build their work within small to medium sized cities in the region.

Coasts: One new area of focus for the CCRUN coastal team is studying the potential for estuary impacts (positive or negative) of flood adaptation using harbor-wide storm surge barriers. As part of this work, CCRUN researchers were initial members of a Barrier Impacts Workgroup and leveraged initial work on this topic into a NOAA grant from the National Estuarine Research Reserve System Science Collaborative. This grant will fund us in deeper research on this topic and allows us to hold stakeholder workshops from September 1, 2018 to August 31, 2019.

Health: Over the past year, the CCRUN health team has begun to incorporate satellite remote sensing of aerosol optical depth as an input to models that can estimate fine scale spatial patterns of population exposure to health-damaging fine particles (PM2.5). Recent research and work has demonstrated the value of these data as a complement to ground-based monitoring, atmospheric models, and land use variables, in estimating exposures to and health effects of PM2.5. The new methods being used by the team are being applied to work in both New York City and Boston.

Figure 1. Air quality monitoring sensor near Boston, MA.

Water: The CCRUN water team has expanded their research to include the water systems in both Philadelphia and Washington D.C.. The addition of these two cities will create a complete assessment of the vulnerability of water resources to climate risk in the entire Northeast region. In the Washington, D.C. area, CCRUN has established a connection with the Interstate Commission on the Potomac River Basin, which studies the region's water supply. In addition to this research, CCRUN water researchers are working with the Northeast Climate Science Center to develop climate impacted streamflows.

Climate: The New York Panel on Climate Change (NPCC), on which CCRUN team members serve, continues to provide the City of New York with the latest information on climate change and its potential impacts, and to offer recommendations on climate change adaptation and resiliency. The findings of the Panel over the last two years will be summarized in the New York Panel on Climate Change Third Report (in prep.), to be published December, 2018, in the Annals of the New York Academy of Sciences. The report includes separate chapters on sea level rise (V. Gornitz, co-lead author), and coastal flooding (Philip Orton), in addition to sections on extreme heat, heat waves, droughts, extreme urban precipitation and street flooding in the climate chapter.

Consolidated Edison, Inc (Con Ed) is the utility that provides electricity, gas, and steam to New York City and some surrounding areas. High temperatures and humidity stress can impact workers and equipment, while coastal and inland flooding threaten critical infrastructure. Working with over 40 experts at the utility and a private consultant, CCRUN climate science experts are providing downscaled climate projections tailored to utility needs. An established set of climate variables will be provided and form the foundation of a summary project report. CCRUN team members are also serving on the project advisory committee, which is guiding the project through regular meetings. This project offers and excellent opportunity to advance both the climate science and the decision science, working with a highly motivated stakeholder that amenable to risk-based approaches to climate change.

Engineering and Urban Design: CCRUN's engineering and urban design team is investigating how changes in precipitation, which may be altered by climate change, generated with General Circulation Models (GCMs) are often biased and not appropriate for use in municipal hydrologic and hydraulic models. There exists a need to develop precipitation time series consistent with a future changed climate system at fine enough temporal resolution so as to be useful in urban runoff and flood studies. Development of such time series is of interest to the NYC Department of Environmental Protection and other regional stormwater utilities and floodplain managers.

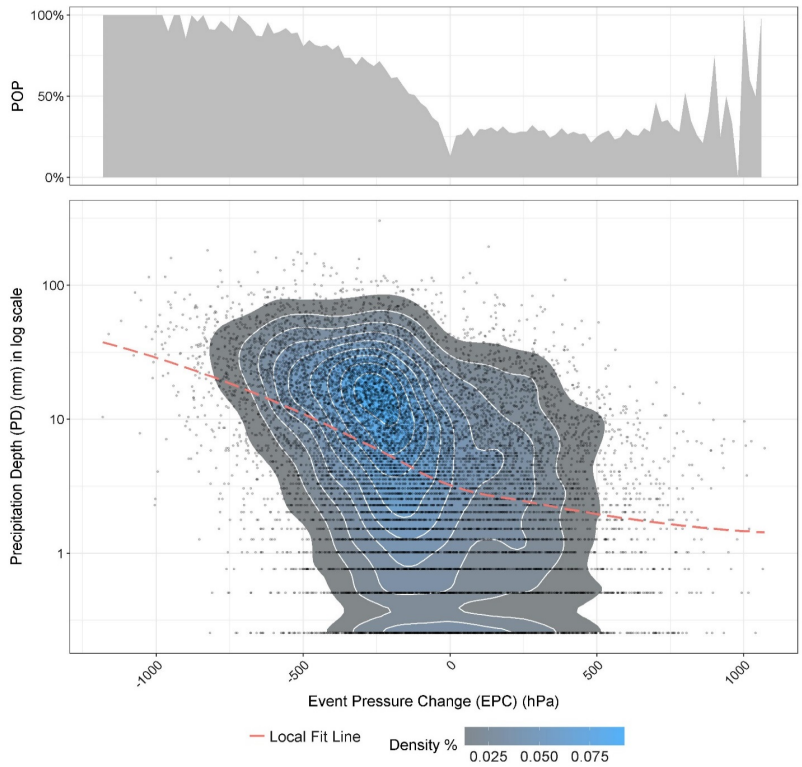

Figure 2. Dependence of probability of precipitation (POP) and precipitation depth (PD) on event pressure change (EPC). Source: Yu et al., 2018.

An additional areas of research for CCRUN's engineering and urban design team is focused on exploring the dependence of fine temporal precipitation characteristics on air pressure and air temperature using historic observations. The goal is to develop, based on the key causes of precipitation, a climatological basis for a stochastic precipitation generator for non-stationary precipitation under climate change conditions. The analysis focuses on precipitation in the urban Northeast United States and utilizes pooled observations from meteorological stations in New York City, Philadelphia, and Boston over 60 years.

Social Dimensions of Adaptation: CCRUN's social science team is working on a new partnership focused on determining the economic value of climate information, as well as the economic and

broader value to society of networks that provide climate information to decision makers, such as RISAs and other boundary organizations. The partnership includes NOAA Climate Program Office, National Institute of Standards and Technology (NIST), the Alaska Center for Climate Assessment and Policy (ACCAP), and the Great Lakes Integrated Sciences and Assessment Center (GLISA). Part of this group organized and participated in a panel at the American Meteorological Society (AMS) annual meeting, which discussed approaches to assessing the value of networks that provide climate services. Another part submitted a proposal for a workshop that will synthesize available approaches to assessing the socio-economic value of boundary organizations that generate climate knowledge.

In addition, CCRUN's social science team is testing their two community based toolkits, Post-Extreme Event Learning Toolkit (PELT) and Macro-Adaptation and Resilience Toolkit (MART). PELT is a boutique toolkit that allows a diverse range of users to take full advantage of the post extreme event "policy window" by provide a moment for reflexive or individual based assessment; collaborative or co-production of knowledge; and collaborative action to address future events. MART provides a template for multi-stakeholder groups to examine the discourse surrounding climate change and risk in order to transform short-term adaptation measures into long term, macro-adaptation processes. In order to make these toolkits successful and equitable in diverse stakeholder environments (e.g. community organizations, practitioners, researchers, and private interests), the team is looking into potential partnership with outside non-profits who already specialize in community-based environmental justice work.

A new initiative for the social science team is the development of a framework for municipal - environmental justice community based organization interaction. The framework provides an innovation approach to how city and municipal governments can positively interact with local EJ organizations to co-generate new knowledge, review and assessment community level risk and resiliency efforts. The work involved interviews with municipal representatives and community organizations in five major cities (Baltimore, Philadelphia, Newark, New York, and Boston) in the extended CCRUN region and application in New York City.

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's health team is working with the State of Massachusetts and the City of Boston to map health vulnerability to extreme heat. Contributions from the team were included in the Climate Ready Boston Final Report. New CCRUN public health team research focused on estimating potential health benefits associated with alternative pathways for Boston's 2050 zero carbon emission goal. The team is also field testing low cost particle pollution sensors in Boston and combining these with remote sensing to estimate fine scale patterns of health risk in the city.

Climate adaptation and resilience strategies in the City of Boston and surrounding metropolitan area are being informed by CCRUN's research. The CCRUN engineering and design team's work

on modeling the extent to which green infrastructure can reduce runoff under historical and future changed climate conditions in East Boston was delivered to the research team at the University of Massachusetts-Boston and then passed on to the city and local governments.

New Jersey: CCRUN's work with Camden County Municipal Utilities Authority (CCMUA), has helped to quantify the percent reduction in stormwater runoff that could be achieved in the Cramer Hill section of the City of Camden. This information was delivered directly to the CCMUA consultant team that is developing the County's Long Term Control Plan for Combined Sewer Overflows

In Ocean City, New Jersey, CCRUN's engineering and urban design team is investigating flood risk. The team has incorporated lot-level real-estate data from Zillow into projected future flood damage estimates. Preliminary results have quantified annual damages associated with different tidal events and there are plans to meet with local government officials.

CCRUN is also working with officials in Hoboken, Jersey, and Newark.

New York City: In Jamaica Bay, New York City, CCRUN developed climate risk information, including mapping of flooding arising from tides and storm surge, is helping build resilience. Neighborhoods around the bay include hundreds of thousands of residents within flood zones and affected recently by Hurricane Sandy. Within a public process led by the Science and Resilience Institute at Jamaica Bay (SRIJB), CCRUN contributed to a series of meetings and final report (submitted) providing information on how climate change will affect flood risk, water quality and wetland habitat, as well as the efficacy of adaptation through community-derived proposals. Jamaica Bay is also the site of the CCRUN co-hosted Climate Forum Series.

CCRUN's engineering and urban design team's applied research with the New York City Department of Environmental Protection, the New York City Department of Parks and Recreation, and the Jacob K. Javits Convention Center has helped to quantify the stormwater capture, heat island mitigation, and other resilience benefits of a wide range of New York City Green Infrastructure sites.

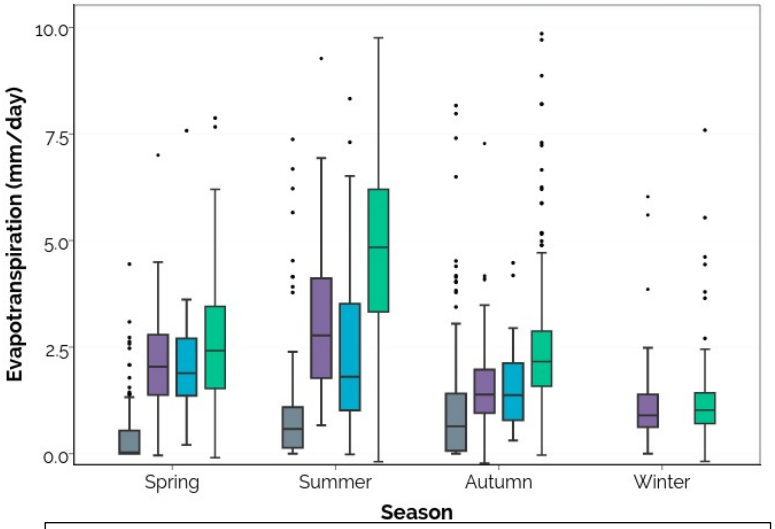

Figure 3. Differences in actual urban evapotranspiration at New York City monitoring sites; Urban park (grey), Greenstreet-no inlet (purple), Greenstreet-inlet (green), and Javits Center (blue). Source: Smalls Mantey, 2017.

Members of the CCRUN team participate in the ongoing work of the New York City Panel on Climate Change (NPCC), which provides climate risk information to the City of New York, including flood and sea level rise mapping. CCRUN coastal team members have drafted the NPCC chapter on Coastal Flooding and co-

authored a chapter on Sea Level Rise. The report is now nearly finished with the review process complete. A new tailored climate service is the mapping of monthly tidal flooding.

New York State: Continuing work with New York State, CCRUN researchers upgraded their Hudson River Flood Impact Decision Support System, an online flood mapper, to include tidal flooding and a broader geography (Westchester New York, on Long Island Sound). 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.

CCRUN's data science team is producing a complete set of building footprint and critical infrastructure data in riverine flood zones for all 45 counties in upstate and western New York. The building footprint and critical infrastructure data will be integrated with current property assets data and evaluated for potential flood impacts in accordance with flood risk data produced by FEMA. The data will be made available through web mapping tools and services.

Philadelphia: The CCRUN coastal team has provided climate risk information, including mapping of flooding arising from rainfall and storm surge, for Philadelphia and surrounding areas. Working with the engineering and urban design team, CCRUN provided the Eastwick neighborhood (in Philadelphia) with results of initial modeling of recent hurricanes, as well as the efficacy of adaptation through a proposed levee. Workshops and community feedback were an important part of this research.

The CCRUN climate science team has engaged with the Philadelphia Water department, helping advise on sea level rise scenarios that can be used for the agency's and city's planning efforts. CCRUN climate projections for sea level rise are available for use in the city.

Philadelphia is also home to CCRUN's Green Infrastructure, Climate, and Cities seminar series, held each month at Drexel University. Many stakeholders from through the regional have attended (in-person) the seminars. Participants who attend include those in the private sector, government, non-profits, and academics.

Program Impacts Evaluation

The three components of the CCRUN program evaluation include the program theory, monitoring, and evaluation. Broadly defined, the key goal of the CCRUN evaluation is to assess progress toward the project goal of improving adaptation to climate risks in the urban Northeast. The team has been conducting primarily monitoring and *process evaluation* in the years past, assessing whether CCRUN initiatives – and how the team undertakes those initiatives – are advancing toward the ultimate goal according to the program theory. In the coming year, the team will increasingly focus on *impact evaluation*.

The program theory describes what actions and inputs can bring about the improvement in adaptation that CCRUN intends to achieve and through what causal mechanisms. The inputs, actions, and causal mechanisms may differ across decision problems and contexts. 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
  - Outreach to communicate research results and experience with using the research results to 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

The team is expanding impact evaluation efforts. Impacts are specific to decision problems and contexts. Evaluation will focus on cases that are strategically selected in order to provide evidence that can be aggregated to measure broader impacts. Initially, we will focus on understanding how new knowledge and data that CCRUN has co-produced with decision-makers are used by those and other decision-makers in our RISA region and beyond. Data collected through monitoring will help to identify the case studies in which we will examine the use of information, which is a necessary intermediate outcome before improvements in adaptation can occur. The impact evaluation will begin to assess whether and how the use of new knowledge and data influences climate resilience and adaptation policy, management, or operations among the local stakeholders. Impact metrics will include changes in codes, standards, regulations, capital investments, allocation of administrative resources, and actions taken by residents.

Building Expertise for Local/Regional Decision Making

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.

For example, many stakeholders in the region now use the projections of record that CCRUN created for the cities of New York City and Philadelphia. However, some of these same stakeholders have more specific information needs associated with their agencies and sectors that

require different information. CCRUN is now performing calculations in a climate change context that stakeholders have previously had to complete on their own, focused only on historical events. For example, ConEd has their own decision-based metrics, including one called 'temperature variable' which is actually a complex and idiosyncratic rolling average to temperature and humidity which CCRUN projected for them. Through weekly calls and monthly meetings with this stakeholder we have deepened their science knowledge and our system knowledge in an iterative process.

Other science capacity building approaches have included contributions to Scenario and Sea Level Rise Tasks Forces, as well as National Assessments, including Lead-PI Horton's contributions to USGCRP's Climate Science Special Report, and Co-PI Solecki's Contributions to Part 2 of the 4th National Climate Assessment. The latter report included extensive outreach through webinars, and press, for example. Work with the National Climate Assessment has also served as a way to introduce CCRUN's process to other stakeholders in the Northeast outside of the urban corridor.

Most Significant Accomplishment for June 2017 – May 2018

CCRUN continues to seek to improve interactions between our multiple institutions and research teams and across the numerous groups working in the Northeast. Last year's report highlighted the CCRUN research template, designed to facilitate interactions amongst the project team. Building from that, over the past year, CCRUN has initiated a plan to hold four workshops in the urban Northeast as a mechanism for further advancing interactions while also expanding collaborations with other groups (NOAA and non-NOAA).

	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.

The CCRUN workshops are planned to take place from the Fall 2018 to the Spring 2019. The four topics selected are climate data tools, coastal communities, extreme precipitation, and public health. For each workshop, team leads from CCRUN have been identified, as well as a stakeholder partner to co-organize the event. From the CCRUN side, a sector lead (e.g., water, coasts, or health) is paired with a cross-cutting theme lead (e.g. climate, engineering/design, or social dimensions of adaptation), furthering the designed intent of the research template. The precipitation worked is to be co-led by CCRUN and the New York City Department of Environmental Protection. The workshops will provide an opportunity to expand CCRUN's reach into smaller communities in the Northeast. For example, the coastal workshop is planned for towns on the New Jersey shore, including Ocean City. Across all workshops, one goal is to hear directly from the stakeholders about their specific needs and how the CCRUN science and research agenda can meet their goals. CCRUN views the workshops as a collaborative opportunity to make sure we can continue delivering the most useful products, as our research is already the foundation of significant resilience activities across the Northeast.

CCRUN is also working with NOAA on the workshops, communicating with the Regional Climate Services Director for example to find those groups that may be interested in participating. As one of CCRUN's PIs is the lead author on the Northeast Chapter of the National Climate Assessment, the team has also been able to expanded connections throughout the Northeast through that relationship. The climate science team of CCRUN is now working with the National Weather Service on setting up meetings between the Weather Forecast Offices in the region and CCRUN team members. A set of webinars to introduce the work of CCRUN to the NWS are planned for Summer 2018, with initial topics of heat and health and heat and aviation impacts.

Research Findings

Our most significant findings in CCRUN Phase II Year 3 include the following:

Coasts: CCRUN's Coastal team has mapped how sea level rise will worsen daily and monthly tidal flooding across New York City (NYC) for the NYC Panel on Climate Change. Under a new Antarctic Rapid Ice Melt scenario, sea level rise this century could raise daily tidal flooding to levels even more severe than that which occurred during Hurricane Sandy, City-wide.

Hard defenses, such as levees or land berms, are often considered the most effective approach to reduce flood risk. Staten Island, New York City, suffered devastating damage from Hurricane Sandy, with 23 fatalities. Through hydrodynamic modeling of floodwater conditions and statistical analysis of fatalities, CCRUN research shows evidence that an elevated protective berm increased the water rise rate in one of the most affected neighborhoods by 62%, and as a result the probability of mortality by 350%.

Health: A recent paper authored by CCRUN researchers developed new models for incorporating adaptation into future projections of heat-related mortality, based on empirical observations over the 20th century in NYC. Using a unique dataset on daily death counts in NYC starting before 1900, CCRUN's Public Health team first quantified decade to decade changes in the exposure-response function linking high temperatures to increased death risk. This work revealed that heat-health responses decreased markedly over the 20th century, but that the pace of that decline showed signs of slowing in the last few decades. The team speculated that increasing air conditioning prevalence may have been responsible for the observed decline in risk, an observation that has been replicated in other locations in the recent literature. This paper also developed a model to project changes in risk into the future, in conjunction with both climate and population projections over the 21st century. This work found that increases in heat-health risks driven by climate change in the 21st century may be reduced, but not eliminated, by further reductions in the exposure-response function for heat and mortality.

Water: One key finding of the CCRUN water team's research is that future floods in the Northeast are anticipated to increase in the coming decades due to changes in the timing of runoff, more extreme precipitation, and warm rain on snow events in the fall and spring. Although average flows in the summer are expected to increase, models suggest that streamflows in later summer and early fall my decrease in periods when increasing temperatures are more impactful on streamflow (through evapotranspiration) than the increased precipitation. Increased extreme precipitation may

have impacts on some water supplies due to increases in turbidity. This is particularly relevant to the New York City water supply, New research with a focus on drought planning and proactive measures in the City of Baltimore illustrates the value of developing drought management plans for cities that have faced drought in the recent past.

Climate: In line with decision-maker requests, a large focus of the climate team's work was on extreme heat events. More specifically, stakeholders included Consolidated-Edison, the Port Authority of New York and New Jersey, and New York City's Office of Resilience have requested more nuanced information about extreme heat than what was available in the past. These requests led to three publications, as well as ongoing research to be published during the next year. All three publications covered the topic of combined impacts of high heat and high humidity, where CCRUN has emerged as a thought leader. This topic is important because heat and humidity are directly related to the human body's ability to cool itself, thus inducing health and economic impacts. In one paper, we used historical data to show that high temperature and high humidity tend to be positively correlated in the Northeast U.S., but not in some other regions; we also demonstrate some predictability of extreme heat-humidity events ten days in advance. A second paper showed by increasing greenhouse gas concentrations are projected to increase the frequency of extreme heat-humidity days by more than 30-fold over the Northeast within two generations, a more rapid frequency increase than is expected for temperature-only. A third paper used non-technical language to explain to diverse audiences how societies can adapt to extreme heat and humidity.

The climate team also continued its research focused on societal impacts of 'temperature-only' extremes. For example, the team published two highly influential papers on the impacts of a) extreme high temperature on permissible aircraft weight for takeoff, and b) extreme cold temperatures on an economically important forest pest species that has been expanding into the Northeast.

As part of the above research, the climate science team has advanced climate projection methods for stakeholders dramatically. For example, in working with Consolidated-Edison, we have for the first time provided projections that differ throughout the distribution; for example, we for the first time based projections on the idea that the hottest days might warm more than the average summer day. We also developed multivariate projections for the first time, considering the relationship between temperature and humidity.

CCRUN also advanced our sea level rise methods. Recent observations indicate growing ice mass losses in both Greenland and Antarctica within the last two decades, closely related to rising air and ocean temperatures. These findings have important implications for New York City, because a number of factors will contributed to a higher local sea level rise than the global mean value. Key New York City infrastructure and real estate assets lining the 520 miles shoreline or within the FEMA 100-year flood zone are at high risk to combined effects of sea level rise and coastal flooding. In the absence of adaptation measures, these assets would face increased flooding risks. In response to the new findings, the NPCC, with contributions from CCRUN climate science researchers, has developed a new high-end sea level rise scenario, the Antarctic Rapid Ice Melt (ARIM) scenario for inclusion into coastal risk assessments. Although ARIM represents a low

probability scenario that might occur only approaching or later than 2100, the impact of such an extreme high sea level rise could have immense impacts on long-lived city infrastructure.

Engineering and Urban Design: Investing the relationship between precipitation and temperature-pressure change events, the CCRUN Engineering and Urban Design team found that the probability of precipitation (POP) and precipitation depth (PD) are both negatively related to pressure increase events. They also found that the pressure change event frequency is statistically related to temperature. In a separate study, their research shows that there are statistically significant differences in micrometeorological conditions and estimated Reference Evapotranspiration rates (RET) rates observed between six monitoring sites within New York City. On a cumulative annual basis, estimated RET amounts could vary by up to 40 percent between the sites. Actual ET values will, however, be dependent on moisture availability, a factor heavily influenced by the degree to which urban green spaces are hydraulically connected to adjacent impervious areas in green infrastructure configurations.

Results from studies looking at maximizing green infrastructure, achieving a meaningful density of GI in the neighborhoods most in need of sustainable redevelopment may require new and creative strategies for GI implementation tailored for the types of land present in those particular communities. Standard implementation of right-of-way GI strategies will neither achieve the watershed management goals needed for CSO abatement, nor contribute significant co-benefits to urban neighborhoods.

Social Dimensions of Adaptation: CCRUN Social Science Team analysis of household survey data shows that homeowners in the NYC neighborhood of the Rockaways did not benefit from having flood insurance after Hurricane Sandy in the sense that insured homeowners spent no less out of their own pockets to rebuild their homes than did uninsured homeowners, holding the level of damage to the home constant. The same is not true in another NYC neighborhood, the south-eastern shore of Staten Island, where insured homeowners did have lower out-of-pocket expenses. Interviews with residents suggest that some reasons for the finding in the Rockaways may have been widespread cases of appraisers valuing damage below actual damage and increased mold damage to insured homes caused by residents waiting for insurance appraisers before beginning repairs.

Additional key findings from the CCRUN Social Science team are the perception and definition of extreme events in individual communities are multi-faceted and these differences play a significant role on the capacity and structure of the communities response. Macro-adaptation strategies that are associated with positive community goals including economic development are better received than 'risk-reduction-only' strategies. Effective municipal - community based organization interaction includes three forms of equity - distributional, contextual, and procedural equity. The team also found that the role of extreme events in driving policy change is quite variable.

Outreach and Communication Activities

Seminar series

CCRUN's Green Instructure, Climate and Cities seminar series continues, with an presentation held each month. For each event, invited speakers present on a new topic related to the general themes of climate impacts, adaptation, and mitigation, with a focus on green infrastructure. The seminars are held in-person at Drexel University and are also broadcast live online via webinar. Over the past year, nearly 200 have attended the seminars in person, with close to 400 participating online. Stakeholders from across the Northeast attend the seminars and also have had the opportunity to present. All archived seminar series videos are also available for viewing online, with over 900 views and 51 subscribers to our Youtube Channel.

Climate forums

Working with the Science and Resilience Institute at Jamaica Bay (SRIJB), CCRUN continues to co-host an ongoing climate forum series, which kicked off in November 2016 and held two additional events this past year. The forums are focused on providing information to residents in communities in the Jamaica Bay area (New York City) to learn more about weather and climate risk. This past year, the September 2017 event focused on hurricanes and hurricane preparedness and the May 2018 event focused on flood hazards. At these forums, CCRUN researchers have the opportunity to present the science information while local decision-makers (e.g. representatives from New York City's Office of Emergency Management) describe how they are responding, with a focus on the neighborhood level. The structure of the events dedicates time to presentation followed by a tools café, where attendees can interact with the speakers. For the climate forums, attendance averages around 40 people per event.

Figure 5. CCRUN's Daniel Bader presents at the climate forum in Bergen Beach, New York.

Special Nor'easter Webinar

On March 13, 2018, CCRUN co-lead a special edition webinar with the Science and Resilience Institute at Jamaica Bay and the National Weather Service - New York City Weather Forecast Office. This weather roundtable discussion focused on a series of coastal storms (nor'easters) impacting New York City and Long Island. Early March 2018 saw consecutive nor'easters bring rain, snow, wind, and coastal flooding to the New York metropolitan area, with one actually occurring on the day of this event. On the webinar, the forecaster from the weather service discussed the meteorology of the coastal storm events and the conditions that lead to significant coastal flooding along New York City's and Long Island's coastal line. CCRUN researcher Philip Orton placed these storms into the context of historical events and projections for future flooding.

Wrapping things up, CCRUN program manager Daniel Bader talked about adaptation and resilience efforts in the region working to protect against future coastal storm and flood events.

Workshops and Conference Presentations

The Waterfront Alliance holds an annual Waterfront Conference (May 8, 2018) including hundreds of stakeholders from government, business and regional neighborhoods. Sessions are crowdsourced via proposals, and were conceptualized and proposed (and presented in) a session titled "What Have Scientists Learned about Flood Risk and Climate Change?" The objective of this session was to share with practitioners and the general public our present understanding of flood risks, present and future. Building on the newest report from the New York City Panel on Climate Change, the session helped clarify the connection between rising sea levels and flood risk, shedding light onto the latest research. The session featured a journalist Facilitator, Janet Babin, WNYC and The New School, and two CCRUN researchers Philip Orton and Radley Horton as presenter/panelists. It was 40 minutes long, including brief introductory presentations, discussion, and audience questions.

CCRUN participated in a session with other RISA teams at the National Council for Science and the Environment in Washington, DC, in January 2018. The title of the session was Bringing climate and weather impacts knowledge to infrastructure problems: NOAA's RISA program. CCRUN's presentation focused on the interconnectivity of infrastructure systems in the Northeast and how the team's research is helping to build resilience across these sectors.

Additional workshop and conference presentations include:

The CCRUN coastal team lead was a panelist/presenter at the Mid-Atlantic Blue Ocean Economy 2030 forum October 12-13, 2017, at Monmouth University, speaking on sea level rise and coastal development. This two-day meeting of about 200 people assembled leading scientists, policymakers, conservationists, business and community leaders, and communicators to identify opportunities to promote, protect and prosper from the region's largest and most important natural asset, the ocean.

CCRUN's engineering and urban design team Co-led the Green Infrastructure and Flooding Workshop in Cramer Hill with the Camden County Municipal Utilities Authority in Camden, NJ (May, 2018). Additional presentations given by team members include a seminar on Enhancing Communities Through Applied, Multifunctional Green Infrastructure Research (CUNY - Queens College, Queens, NY in April 2018), panelist at the Green Infrastructure Workshop, University of Pennsylvania Environmental Humanities Symposium in Philadelphia, PA (May 2018).

The CCRUN Social Science team presented "Frameworks for assessing value of climate information services" in a panel titled Valuing Climate Information and Networks for Improved Planning and Preparedness, organized by NOAA CPO, at the American Meteorological Society meeting (January 2018)

CCRUN was also represented at the Science of the Living City event titled New York City's Coastal Future: What Can Jamaica Bay Be? at Kingsborough Community College. Science of the Living City is a program of the New York City Urban Field Station, New York City Parks, US

Forest Service, and the Natural Areas Conservancy. SRIJB and Jamaica Bay Rockaway Parks Conservancy were partners for this event, which discussed climate risks and ideas for the future for the neighborhoods in the Jamaica Bay watershed.

In November, 2017, the CCRUN social science team was able to conduct a beta test of the PELT toolkit with a diverse group of New York City-based practitioners, including officials from the NYC Department of City Planning, Office of Emergency Management, and the Mayor's office, as well as staff from SRIJB. For the beta test, participants reflected on the impact of Hurricane Sandy five years later using four modules that attempted to address the following questions: 1)What is the event and why is it important to learn about it? 2) What do we know and need to know about this event? What can we learn from each other? 3) How do we communicate our knowledge of these events to others? 4) What are next steps for continued learning?

Working groups

CCRUN social science team members have joined a Socio-Economic Impacts Technical Working Group for a two-year initiative, titled Measuring Success: Monitoring Natural and Nature-Based Features in New York State, led by the NYS Department of State (DOS) and NYS Energy Research and Development Authority (NYSERDA) in partnership with the Science and Resilience Institute at Jamaica Bay. The initiative is developing a framework for monitoring shoreline erosion and flood management projects.

CCRUN climate science and coastal team members are participating in the Port Authority of New York and New Jersey's Working Group on Climate Change Impacts, which has a focus on identifying the likely impacts on the region's critical infrastructure operations in the future. The goal of the working group is to enable the agency and its regional partners to more fully consider the current and future impacts of climate change and actively adapt their planning and operations to those impacts to assure continued operation of the agency's critical infrastructure and that of the wider region.

Social media

CCRUN continues to expand its social media presence, particularly during extreme weather events. Our posts focus on disseminating key forecast and impact information from NOAA and the National Weather Service. To help better document storm impacts, CCRUN asked followers to submit any photos from events, which were then shared across our platforms. Social media also enables CCRUN to as advertise for upcoming events, such as the climate forums and seminars. Our Twitter account has garnered about 120 followers and we've sent out nearly 175 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.

<u>Television</u>

Did climate change make recent extreme storms worse?
https://www.pbs.org/newshour/show/climate-change-make-recent-extreme-storms-worse
After Harvey and Irma, what's the future of flood insurance?

https://www.pbs.org/newshour/show/harvey-irma-whats-future-flood-insurance

Newspaper/Magazine
The Climate Risks We Face
https://www.nytimes.com/2017/11/06/opinion/climate-report-global-warming.html
How hot weather – and climate change – affect airline flights
https://theconversation.com/how-hot-weather-and-climate-change-affect-airline-flights-80795

Key Publications

Coffel, E. D., Thompson, T. R., & **Horton, R. M.** (2017). The impacts of rising temperatures on aircraft takeoff performance. *Climatic Change, 144*(2), 381-388. doi: 10.1007/s10584-017-2018-9

Steadily rising mean and extreme temperatures as a result of climate change will likely impact the air transportation system over the coming decades. As air temperatures rise at constant pressure, air density declines, resulting in less lift generation by an aircraft wing at a given airspeed and potentially imposing a weight restriction on departing aircraft. This study presents a general model to project future weight restrictions across a fleet of aircraft with different takeoff weights operating at a variety of airports. We construct performance models for five common commercial aircraft and 19 major airports around the world and use projections of daily temperatures from the CMIP5 model suite under the RCP 4.5 and RCP 8.5 emissions scenarios to calculate required hourly weight restriction. We find that on average, 10-30% of annual flights departing at the time of daily maximum temperature may require some weight restriction below their maximum takeoff weights, with mean restrictions ranging from 0.5 to 4% of total aircraft payload and fuel capacity by mid- to late century. Both mid-sized and large aircraft are affected, and airports with short runways and high temperatures, or those at high elevations, will see the largest impacts. Our results suggest that weight restriction may impose a non-trivial cost on airlines and impact aviation operations around the world and that adaptation may be required in aircraft design, airline schedules, and/or runway lengths.

DiGiovanni-White, K., **Montalto, F.,** & Gaffin, S. (2018). A comparative analysis of micrometeorological determinants of evapotranspiration rates within a heterogeneous urban environment. *Journal of Hydrology, 562*, 223-243. doi: https://doi.org/10.1016/j.jhydrol.2018.04.067

Variability in micrometeorological conditions and their influence on estimated reference evapotranspiration (RET) rates were evaluated across a heterogeneous urban environment. Micrometeorological data sets (incoming solar radiation, air temperature, relative humidity and wind speed) were collected over a one-year period at six weather stations in New York City, NY (USA). Weather stations are located at four new urban green space monitoring sites and two airports. Reference evapotranspiration (RET) rates were estimated from the micrometeorological data sets for a short reference surface at a daily time-step using the ASCE Standardized Reference Evapotranspiration Equation, a Penman-Monteith based combination equation. Non-parametric comparative statistical analyses (Kruskal-Wallis) revealed statistically significant differences (at significance level $\alpha = 0.05$) in micrometeorological conditions and estimated RET rates between

the six sites. On a cumulative annual basis, estimated RET varied by up to 40 percent between the sites. A new technique for adjusting weather data collected at one location (e.g. regional airports) for use at another location (e.g. interior engineered urban green spaces) was evaluated. The study highlights the importance, for accurate estimation of ET, of onsite micrometeorological data sets, but concludes that additional research is needed to more thoroughly characterize micrometeorological variability across heterogeneous urban environments, and also to evaluate the influence of non-meteorological determinants, e.g. vegetation type, soil/media type, media moisture conditions and anthropogenic heat fluxes, on urban ET.

Nayak, S. G., Shrestha, S., **Kinney, P. L.,** Ross, Z., Sheridan, S. C., Pantea, C. I., . . . Hwang, S. A. (2017). Development of a heat vulnerability index for New York State. *Public Health*. doi: https://doi.org/10.1016/j.puhe.2017.09.006

The frequency and intensity of extreme heat events are increasing in New York State (NYS) and have been linked with increased heat-related morbidity and mortality. But these effects are not uniform across the state and can vary across large regions due to regional sociodemographic and environmental factors which impact an individual's response or adaptive capacity to heat and in turn contribute to vulnerability among certain populations. We developed a heat vulnerability index (HVI) to identify heat-vulnerable populations and regions in NYS.

Thirteen variables were reduced to four meaningful components representing 1) social/language vulnerability; 2) socioeconomic vulnerability; 3) environmental/urban vulnerability; and 4) elderly/ social isolation. Vulnerability to heat varied spatially in NYS with the HVI showing that metropolitan areas were most vulnerable, with language barriers and socioeconomic disadvantage contributing to the most vulnerability. Reliability of the HVI was supported by preliminary results where higher rates of heat stress were collocated in the regions with the highest HVI.

The NYS HVI showed spatial variability in heat vulnerability across the state. Mapping the HVI allows quick identification of regions in NYS that could benefit from targeted interventions. The HVI will be used as a planning tool to help allocate appropriate adaptation measures like cooling centers and issue heat alerts to mitigate effects of heat in vulnerable areas.

Orton, P. M., Conticello, F. R., Cioffi, F., Hall, T. M., Georgas, N., Lall, U., . . . **MacManus, K.** (2018). Flood hazard assessment from storm tides, rain and sea level rise for a tidal river estuary. *Natural Hazards*. doi: 10.1007/s11069-018-3251-x

Cities and towns along the tidal Hudson River are highly vulnerable to flooding through the combination of storm tides and high streamflows, compounded by sea level rise. Here a three-dimensional hydrodynamic model, validated by comparing peak water levels for 76 historical storms, is applied in a probabilistic flood hazard assessment. In simulations, the model merges streamflows and storm tides from tropical cyclones (TCs), offshore extratropical cyclones (ETCs) and inland "wet extratropical" cyclones (WETCs). The climatology of possible ETC and WETC storm events is represented by historical events (1931-2013), and simulations include gauged streamflows and inferred ungauged streamflows (based on watershed area) for the Hudson River and its tributaries. The TC climatology is created using a stochastic statistical model to represent a wider range of storms than is contained in the historical record. TC streamflow hydrographs are

simulated for tributaries spaced along the Hudson, modeled as a function of TC attributes (storm track, sea surface temperature, maximum wind speed) using a statistical Bayesian approach. Results show WETCs are important to flood risk in the upper tidal river (e.g., Albany, New York), ETCs are important in the estuary (e.g., New York City) and lower tidal river, and TCs are important at all locations due to their potential for both high surge and extreme rainfall. The raising of floods by sea level rise is shown to be reduced by ~30-60% at Albany due to the dominance of streamflow for flood risk. This can be explained with simple channel flow dynamics, in which increased depth throughout the river reduces frictional resistance, thereby reducing the water level slope and the upriver water level.

Examples of Implemented CCRUN Work

The New York State Department of Environmental Conservation's Community Risk and Resiliency Act (CRRA) establishes a standardized set of sea level rise projections for the state of New York. These projections were developed by CCRUN Climate and Coastal team members. The CRRRA requires applicants for permits or funding in certain programs to demonstrate the sea level rise and coastal flood risk have been considered. The Act also requires DEC, working with the New York Department of State, to develop guidance on the use of natural systems to enhance community resilience.

Over the reporting period, implementation of the CRRA continued, part of the process which includes holding stakeholder workshops to introduce them to the policy. CCRUN, through the Sustained Assessment, supported and led one a workshop in Westchester County, New York. The goal was to provide stakeholders with additional information about the CCRA and present various flooding and sea level rise tools and applications, created by CCRUN, that can be used by stakeholders to comply with the legislation and/or better understand future scenarios. CCRUN's AdaptMap and Jamaica Bay Water Quality Data Visualization and Access Tool incorporate the sea level rise scenarios of record and identify infrastructure and natural systems at risk.

Issues identified at the meeting include the need for improved models & tools for both local governments and the general public and improved two-way communication with local citizens, groups, political leaders about climate risk and resilience. CCRUN can help lead this efforts and this meeting can also serve as an example workshop for future Sustained Assessment efforts and CCRUN outreach.

For another example, together with the Northeast Regional Climate Center, the CCRUN climate science team is building a web-based data portal that will provide access to weather and climate information. This data tool will enable stakeholders to have direct access to climate data and information on extreme events that at present are only available by directly asking the researchers. For example, the Port Authority of New York and New Jersey has indicated that they would like to have access to the full synthetic climate projection time series developed by CCRUN, so that rather than having to focus on the specific climate thresholds emphasized to date (e.g., number of days over 90 F) they could explore other thresholds of their own choosing in near real time (such as number of days above 97F). With the new portal, our stakeholders will have the ability to see this information in a graphic interface that will not only provide the current season but place it into historical context (e.g., running above or below average). Extreme event metrics will be updated

by season (e.g., hot days in the summer) and the portal will also have information on mean temperature and precipitation throughout the year. The data will be available for cities throughout the CCRUN region, including small and medium sized cities, which will help to expand the project's reach into those areas.

A CCRUN Public Health team lead heat vulnerability assessment of New York City was used by the Mayor's Office to target cooling interventions as part of the Cool Neighborhoods New York City Program, started in June 2017. CCRUN researchers created a composite heat vulnerability index that allowed for the identification of the most vulnerable (in terms of risk of heat-related mortality) areas in the city. The Cool Neighborhoods New York City Program is $106 million program designed to curb the effect of extreme heat. It will include both proactive and reactive measures in heat-sensitive neighborhoods to help mitigate the threat to public health from the urban heat island effect exacerbated during summer months. CCRUN climate science research is also included throughout the report, which references the work of the NPCC.

One strategy identified in the Plan to help reduce the impacts of warmer temperature is the New York City Cool Roofs program. By 2025, the program is expected to generate $1 million in annual energy cost savings (e.g. through reduced air conditioning use) and train 500 New Yorkers who will be prepared for jobs promoting energy efficiency in buildings. It's possible monetary incentives are provided for buildings that install a cool roof surfaces, as was done with green roofs, where a law allowed buildings to receive a tax relief of $4.50 per square foot (up to $100,000 or the building's tax liability, whichever is less).

Appendix A. CCRUN Publication List

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