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ORIGINAL ARTICLE

New York City Panel on Climate Change 2019 Report: Conclusions and Recommendations

Understanding climate change in cities is important because of the dramatic growth in urban populations, and thus vulnerability, as well as the emerging role of cities as first responders to climate change. Since 2008, the New York Panel on Climate Change (NPCC) has analyzed climate trends, developed projections, explored key impacts, and advised on response strategies. Charting a future course for the NPCC ensures that New York City (NYC) continues to develop resilience for the five boroughs and the surrounding metropolitan region, and play its role as a climate change leader for other cities, not only in the United States but also around the world.

As set forth by Local Law 42 of 2012, the New York City Panel on Climate Change 2019 Report provides tools and methods for implementing region-wide strategies. These tools and methods can be used to observe, project, and map climate means and extremes; monitor risks and responses; and engage with communities to develop effective programs.

The report finds that recent increasing trends in temperature and precipitation in Central Park are generally tracking the NPCC 2015 projections for the 2020s time period encompassing the years of 2010–2039.[a] NPCC2 confirms the use of the NPCC2 2015 projections for decision making by the city and region.

NPCC conducts and guides research that has high potential value for flexible adaptation planning. It supports the large body of evidence indicating that decision makers are better served by consideration of future climate risks, rather than by reliance on the climate of the past, in development of resiliency policies and programs.

[a]These comparisons should be viewed with caution because of the role that natural variation plays in the short term.

New methods for extreme temperatures, heavy downpours, and droughts

Projected increases in the frequencies and intensities of extreme events pose particular challenges to NYC. At the request of the NYC Mayor's Office of Recovery and Resiliency, the six climate extremes considered in NPCC3 are extreme heat and humidity, heavy downpours, droughts, sea level rise and coastal flooding, extreme winds, and cold snaps.

NPCC3 has begun to develop and test new methods for observations and projections to be used in resilience planning for the region. Using expanded observations, bias correction, and regional climate models, these methods can provide quantitative analyses for heat extremes, heavy downpours, and droughts. They are available for developing the next full set of NPCC projections.

Based on these and other methods, the next generation of global and regional climate model outputs will be used in upcoming NPCC assessments to create a new unified set of projections for decision making in the New York metropolitan region. The methods tested by NPCC3 using global and regional climate model ensembles and scenarios will enable the updated identification of climate change "hotspots" of vulnerability at finer spatial scales within the city and across the region.

Recommendations for research

- Analyze the declining impacts of heat over time (presumably due to increased prevalence of air conditioning), examine thresholds of heat and humidity effects on human health, and develop projections and interventions that will be most effective in NYC's hotter climate.
- Determine benchmarks for subhourly extreme precipitation and associated flooding events using satellite data and rain gauges. Use these benchmarks to develop subhourly extreme precipitation projections that take into account

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urban meteorological effects and identify neighborhoods likely to be flooded.
- Characterize large-scale conditions that may lead to drought based on further instrumental, tree-ring, and other paleoclimate indicators, and climate model analyses in the region.
- Study the association of polar air outbreaks extending into the New York metropolitan region and recent climate trends, and project how these might change over the coming century.

Recommendations for policy

- City agencies should work with the NPCC to improve quantitative heat wave projections. Such agencies could include, for example, the New York City Department of Health and Mental Hygiene, Emergency Management, and the National Weather Service. Together, such groups can investigate how best to prepare for future revisions of heat advisory criteria that consider changing combined effects of temperature and humidity (i.e., heat index).
- The NYC Department of Environmental Protection, NYC Emergency Management, and Mayor's Office of Recovery and Resiliency should commission a study to determine what levels of heavy rainfall (intensity, duration, and frequency) cause nuisance, moderate, or catastrophic flooding in NYC.
- Although there has not been a major, multiyear drought since the 1960s in the New York metropolitan region, the possibility of future droughts should be considered in planning based on long-term records.

Sea level rise

Recent increasing ice mass losses in Greenland and Antarctica, advances in modeling ice sheet–ocean–atmosphere interactions, as well as potential for marine ice-shelf instability in West Antarctica raise the prospects of higher sea levels than previously assumed. A growing awareness therefore exists for the need to consider high-impact, low-probability scenarios in coastal risk management, particularly when planning for long-lived infrastructure development. This new perspective also informs the need to supplement the NPCC (2015) sea level rise projections with an alternative, extreme scenario—the Antarctic Rapid Ice Melt (ARIM) scenario.

Because of the longevity of atmospheric CO_2, temperatures and sea level will continue to rise even after stabilization or reduction in greenhouse gas emissions. With total cessation of further anthropogenic CO_2 emissions by mid-century, CO_2 and atmospheric temperatures would slowly begin to decrease after several decades. But most of the CO_2 would still remain in the atmosphere and take centuries to millennia to slowly dissipate. This, and slow heat penetration into the deep ocean, would cause sea level to rise continuously well beyond 2100 due to thermal expansion alone.

Therefore, as a first step, further research into sea level change for the next several centuries, to 2200 and 2300, should be explored. In addition, the consequences of long-term sea level rise scenarios on coastal flooding, including those stemming from low-probability, high-end scenarios, should also be examined.

Recommendations for research

- Monitor trends in sea level rise and in the processes contributing to sea level rise in the New York metropolitan region.
- Research the processes leading to the destabilization of the Antarctic and Greenland ice sheets.
- Study trajectories of potential sea level rise that continue after 2100 in light of the sea level rise commitment on longer timescales.
- Examine the consequences of long-term sea level rise scenarios on coastal flooding, including those stemming from low-probability, high-end scenarios.

Recommendations for policy

- NYC Mayor's Office of Recovery and Resiliency should be aware of the increasing high-end risks, such as ARIM, affecting sea level rise in the New York metropolitan region as flexible adaption pathways for climate change evolve.
- Because of the long life span of some infrastructure, as well as the projected continuation of sea level rise beyond 2100, the city should be aware of sea level rise scenarios that extend into 2200 or 2300, when ice sheet destabilization effects will become even more pronounced. Sea level scenarios on such long time frames

are highly uncertain, but need to be taken into account with appropriate caveats.

Coastal flooding

In regard to coastal flooding, NPCC3 has reviewed key processes, summarized historical trends and present-day flood hazards, and assessed how sea level rise will affect storm-driven and tide-driven future flooding. An improved understanding of present and future flood risk should be helpful to NYC for effective long-term planning.

The combined dynamic/static NPCC3 analysis shows that monthly flooding will not be a widespread problem until the 2050s or later, but by late in the century, it could impact most of the neighborhoods immediately surrounding Jamaica Bay, as well as several other low-lying neighborhoods of the city. Areas particularly susceptible to monthly tidal flooding include Rockaway Peninsula, Howard Beach, and Coney Island and areas immediately to the north. Under the new ARIM scenarios, sea level rise by the end of this century could raise daily tidal flooding to levels even more severe than that which occurred during Hurricane Sandy.

A static assessment of storm-driven flooding shows how extreme events such as the 100-year and 500-year floods will rise with a variety of sea level rise projections, ranging from 10th to 90th percentiles for the 2020s, 2050s, 2080s, and 2100 and including the ARIM scenarios for the 2080s and 2100. Assumptions on future emissions pathways are shown to cause large differences in the sea level rise projections, and as a result, the flood projections. Moderate differences can also arise from differing methods for combining probabilities of storm tides and sea level rise.

Recommendations for research

- Continue to research flood hazards in the New York metropolitan region, including investigations of historical or sedimentary archives, flood modeling, storm modeling, and comparisons of how different hazard assessments compare.
- Conduct research into future changes to tropical, extratropical, and hybrid cyclones, given remaining substantial uncertainties.
- Analyze changing types of storms associated with extreme winds and climate change, particularly the association of changes in extratropical cyclones and their frequency and intensity in the New York metropolitan region, and the incorporation of convective storm events into climate model outputs.

Recommendations for policy

- Since it may not be possible to protect all shorelines from extreme coastal floods and sea level rise, NYC should continue to explore a wide range of structural and nonstructural risk reduction approaches, including paradigm-shifting concepts such as strategic relocation programs on floodplains and densification on high ground.

Mapping climate risk

Mapping of climate risk is a key activity of the NPCC. It is a major method for communicating how citizens in the New York metropolitan region may experience future changes. NPCC3 presents sea level rise and coastal flooding maps that are based on the latest LiDAR information for the city and region, specifically the 2017 NYC LiDAR capture.

Recommendations for research

- Use flood data that incorporate confidence intervals into modeled results. Error in the topographic elevation data, sea level rise projections, and FEMA model outputs all introduce uncertainty and limit accuracy. Estimates of population, facilities, and infrastructure within the future flood zones are associated with this uncertainty. For this reason, possible future work should consider using flood data that incorporate confidence intervals in their modeled results.
- Include mapping of concurrent events, for example, the cumulative effects of storm surge combined with intense rainfall that might impact the movement, timing, and drainage of floodwaters. Although coastal flooding dominates in NYC, fluvial and urban street flooding occurs during intense rainfall events resulting in overflows in residential and municipal drainage systems.
- In association with the proposed New York City Climate Change Resilience Indicators and Monitoring System (NYCLIM), map indicators that address climate risk, impact,

vulnerability, and adaptation concerns. Issues that need to be considered when developing climate risk indicator maps include spatial extent of the data, cost effectiveness, and ability to illustrate the concept/concern in question.

Recommendations for policy

- NPCC should continue to interact with FEMA in future years, particularly regarding their initiative to work with the city to map future flooding for adaptation planning.

Community-based assessments of adaptation and equity

NPCC3 explored equity in community-based adaptation planning in NYC using a framework that incorporated three key dimensions: *distributional*, *contextual*, and *procedural*. Distributional equity emphasizes disparities across social groups, neighborhoods, and communities in vulnerability, adaptive capacity, and the outcomes of adaptation actions. Contextual equity considers how social, economic, and political factors and processes contribute to vulnerability and shape adaptive capacity. Procedural equity emphasizes the extent and robustness of public and community participation in adaptation planning and decision making.

Recommendations for research

- Investigate the use of co-production processes that include community groups in planning for climate change resiliency and their adaptability to NYC.

Recommendations for policy

- In NYCLIM, there should be future tracking of social vulnerability and its relation to climate change using established indexes[b] and individual variables.
- All forms of equity should be reflected in climate adaptation efforts, particularly if resiliency planning is focused at the neighborhood level.
- City officials should work side by side with communities at the outset and throughout the process to co-design and co-implement neighborhood-based climate adaptation projects. This will help to incorporate local contexts and ensure procedural equity in adaptation planning.
- Climate adaptation projects should contain a stronger focus on community development to reduce the potential of displacing longtime residents and to promote the social sustainability of local communities.

Resilience strategies for critical infrastructure

Interconnections among different infrastructures in the form of dependencies and interdependencies are becoming recognized as important factors in the escalation of adverse consequences resulting from extreme events and climate change. Next steps will be to identify where the vital interconnection points are that produce cascading effects, the process by which those cascades occur, how to reduce their effects through management, and the role of decentralization of infrastructure services to reduce intersection points. Data collection and metrics development are crucial to understanding and enhancing resilience.

Insurance and finance policies continually evolve to provide opportunities to reduce the cost of the consequences of climate change that can further expand to support adaptation and mitigation. Potential modifications could include availability of funding to implement resilience improvements in conjunction with repairs, and mechanisms to encourage pre-disaster resilience improvements and insurance purchase. In this regard, public–private partnerships are essential for facilitating infrastructure resilience, particularly for publicly owned infrastructure systems that often lack resources for resilience improvements. Coordination of insurance and finance is an important future direction to achieve comprehensive resiliency in infrastructure that reduces negative climate change consequences.

Recommendations for research

- Advance knowledge of interactions among infrastructure types and climate risks to better understand evolving vulnerability conditions.
- Improve assessments of effectiveness of green infrastructure (e.g., tree planting and green roofs) in reducing the urban heat island and

[b]For example, University of South Carolina Hazards and Vulnerability Research Institute Social Vulnerability Index of the United State (SOVI); the Center for Disease Control Social Vulnerability Index (SVI).

excessive urban street and basement flooding, in light of anticipated increasing extreme rainfall events.

Recommendations for policy

- Since increased frequency of extreme heat will drive peak energy demand for air conditioning, the city should continue to work with the energy sector to develop improved resiliency to power outages.
- Identify where the vital interconnection points are among different infrastructures (i.e., dependencies and interdependencies) to reduce cascading effects resulting from extreme events and climate change through management and in some cases decentralization.
- Through management, and in some cases decentralization, the city should reduce cascading effects of dependencies and interdependencies resulting from extreme events and climate change.
- To increase resilience and ensure quality of life, the city should increase financial strength, invest in infrastructure maintenance and upgrades, and work with insurance companies to encourage incentives with attention to the risks that infrastructure systems and their users experience.
- Operators should provide access to infrastructure data and resources and work with scientists to explore infrastructure risks associated with climate change.

Indicators and monitoring

A centralized, coordinated, indicators and monitoring (I&M) system for NYC, where specific roles and responsibilities are identified, as described in the proposed NYCLIM, is essential for comprehensive, city-wide risk assessment and course correction toward climate change adaptation and resiliency goals. This is especially important for the design of short- to medium- to long-term investments targeted to adaptation. The proposed system should incorporate a consistent set of measures of climate, impacts, vulnerability, and resiliency to capture changes in climate conditions and progress toward implementation over time.

An effective I&M system must be sufficiently robust and comprehensive to track key climate variables and adaptation strategies. The system must identify vulnerabilities and adaptation measures related to observed conditions and their projected futures.

Spatial and temporal scale resolutions need to be consistent and comparable if the I&M system is to detect effectively trends and differences across sectors and enable effective comparison.

Recommendations for research

- Conduct research on how and to what extent indicators can be linked to current and future resilience under changing climate conditions, including increasing frequency of extreme events.
- Develop social vulnerability indicators, and infrastructure indicators (including dependencies and interdependencies), and mapping tools for NYCLIM.

Recommendations for policy

- The City should take on the responsibility to establish/pilot a climate indicator and monitoring system across multiple governance entities that provide periodic analytical reports on indicator trends to aid in policy, planning, and financial decisions. The goal is to protect citizens and assets under changing climate conditions. To accomplish this, the city should:

    - Designate one of its agencies and an academic partner to oversee the pilot indicator and monitoring system operations (community engagement, stakeholder interactions, data collection, storage and management, analysis, personnel and funding, etc.).
    - Facilitate a co-generation process for the development and dissemination of the NYCLIM system that involves community engagement and regional stakeholders through time.
    - Develop and implement a NYCLIM system that defines scope, explicitly provides information on relevant spatial and temporal scales, and facilitates integration across agencies, levels of governance, sectors, and spatial and temporal scales.

- Support evaluation and iterative research on climate change resilience.

Overall NPCC 2019 report recommendations for the City

The NPCC has provided an essential enabling condition for NYC to proactively and flexibly adapt to changing climate conditions. The challenge now is to sustain this function into the future. To meet this challenge, the city should consider the following set of broader recommendations:

- The City should establish a pilot system for NYCLIM that includes an initial set of indicators for variables to be tracked, including climate observations, social vulnerabilities, and economic metrics from the NPCC 2019 Report.
- As specified in Local Law 42 of 2012, the NPCC should be tasked with developing next-generation climate change projections for use by the city. These new projections of record, which need to be funded by the city, should include the potential for emerging high-end risks such as the ARIM.
- The City should task the NPCC to coordinate with other regional organizations, such as the Consortium for Climate Risk in the Urban Northeast (CCRUN), to conduct integrated climate assessments for the New York metropolitan region on a regular basis. These assessments should encourage the participation of a wide range of city and regional agencies and communities, and a full range of systems and sectors.
- As part of this on-going more integrated assessment process, the city should host a climate summit once during every mayoral term. The climate summits will bring together all of the key groups—both scientists and stakeholders—working on climate change in the New York metropolitan region to present key findings, share best practices, and develop coordinated approaches.