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ORIGINAL ARTICLE

New York City Panel on Climate Change 2019 Report Chapter 1: Introduction

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While urban areas like New York City and its surrounding metropolitan region are key drivers of climate change through emissions of greenhouse gases, cities are also significantly impacted by climate shifts, both chronic changes and extreme events. These are already affecting the New York metropolitan region, including the five boroughs of New York City through higher temperatures, more intense precipitation, and higher sea levels, and will increasingly do so in the coming decades.

The City of New York has embarked on a flexible adaptation pathway (i.e., strategies that can evolve through time as climate risk assessment, evaluation of adaptation strategies, and monitoring continues) to respond to climate change challenges. This entails significant programs to develop resilience in communities and critical infrastructure to observed and projected changes in temperature, precipitation, and sea level.

The first NPCC Report laid out the risk management framing for the city and region via flexible adaptation pathways (Rosenzweig and Solecki, 2010). The second New York City Panel on Climate Change Report (NPCC2) developed the "climate projections of record" that are currently being used by the City of New York in its resilience programs (Rosenzweig and Solecki, 2015).

The NPCC3 2019 Report co-generates new tools and methods for the next generation of climate risk assessments and implementation of region-wide resilience. *Co-generation* is an interactive process by which stakeholders and scientists work together to produce climate change information that is targeted to decision-making needs. These tools and methods can be used to observe, project, and map climate extremes; monitor risks and responses; and engage with communities to develop effective programs (Fig. 1.1). They are especially important at "transformation points" in the adaptation process when large changes in the structure and function of physical, ecological, and social systems of the city and region are undertaken.

Stakeholder interactions and co-generation

Engagement with stakeholders and users of climate information has been emphasized throughout the NPCC process from the beginning in 2008. NPCC3 members interacted with a variety of stakeholders, including members of city government agencies, infrastructure managers, and communities to "co-generate" the information that is presented in this report. These interactions included communicating over email, phone calls, and in-person meetings or workshops, as well as discussing relevant science needs that decision makers have from the start, and reviewing draft report text, figures, and data. Throughout this process, NPCC3 scientists responded to and incorporated stakeholder feedback into the final NPCC3 Report.

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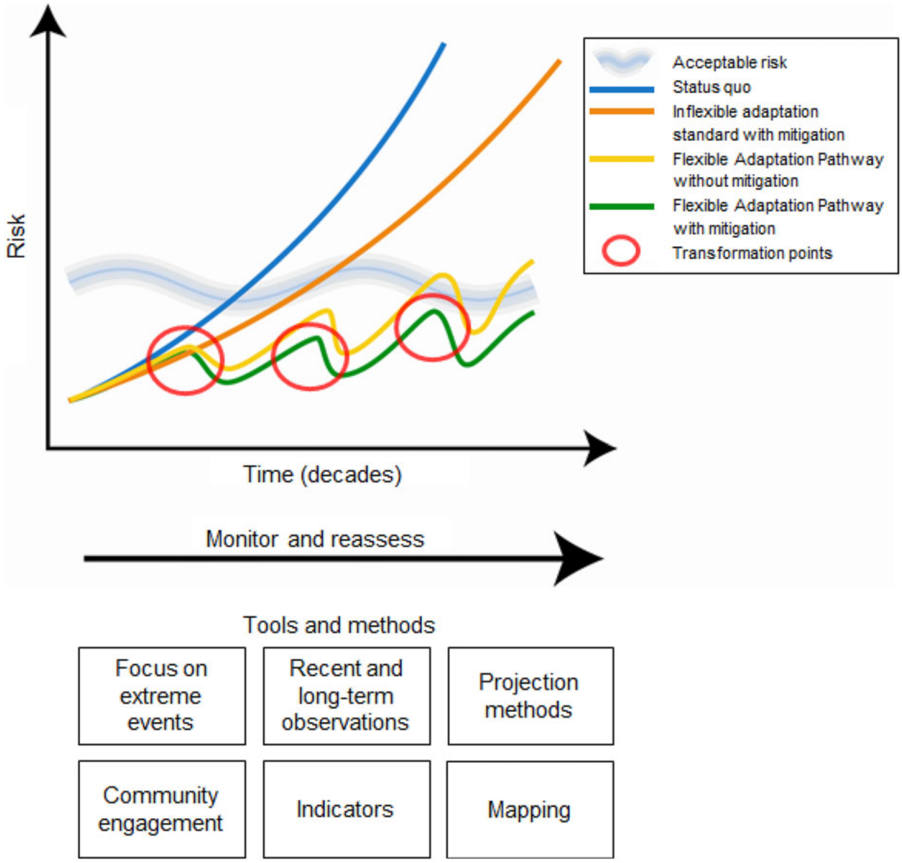

Figure 1.1. Tools and methods for implementing Flexible Adaptation Pathways and Transformation Points discussed in the NPCC 2019 Report.

To integrate feedback from community members, NPCC3 scientists interacted with community groups from three neighborhoods in the city: Sunset Park in Brooklyn, Harlem in northern Manhattan, and Hunts Point in the Bronx. In addition, the members of the work group engaged with city agencies to understand their interactions with community members in responding to the risks of climate change and environmental justice. The specific interactions that NPCC3 members had with community stakeholders are discussed in greater detail in Chapter 6, Community-Based Assessments of Adaptation and Equity.

In the development of the proposed New York City Climate Change Resilience Indicators and Monitoring System (NYCLIM) outlined in this report, NPCC3 engaged in a range of stakeholder interactions. This included meetings with individual infrastructure managers that took place over the phone, in-person, and over email, workshops with members of the New York City Climate Change Adaptation Task Force (CCATF), and reviews of NPCC3 proposed indicators by relevant New York City government agencies and infrastructure managers. The interactions that took place between the NPCC3, the city, and infrastructure stakeholders are discussed in detail in Chapter 7, Resilience Strategies for Critical Infrastructures and Their Interdependencies, and in Chapter 8, Indicators and Monitoring.

Key concepts

Several key concepts undergird the work of NPCC3, which focuses on the development of tools and methods for flexible adaptation pathways and integration of climate science and policy. These include1 adaptation, flexible adaptation pathways, impacts,

Box 1.1. Key definitions

Adaptation: The process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.
Flexible adaptation pathways: A sequence of adaptation strategies that policymakers, stakeholders, and experts develop and implement that evolve as knowledge of climate change progresses.
Impacts: Effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences or outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.
Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.
Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. In this report, the term risk is often used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services), and infrastructure.
Transformation: A change in the fundamental attributes of natural and human systems; the trajectory taken over time to meet different goals for greenhouse gas (GHG) emissions, atmospheric concentrations, or global mean surface temperature change that implies a set of economic, technological, and behavioral changes. This can encompass changes in the way energy and infrastructure are used and produced, natural resources are managed, and institutions are set up in the pace and direction of technological change.
Uncertainty: Uncertainty denotes a state of incomplete knowledge that results from lack of information, natural variability in the measured phenomenon, instrumental and modeling errors, and/or from disagreement about what is known or knowable (IPCC, 2013). See Box 1.2 for information on sources of uncertainty in climate projections.

Source: IPCC, 2014; Rosenzweig and Solecki, 2010; Rosenzweig and Solecki 2015.

resilience, risk, and transformation. For definitions of these concepts, see Box 1.1.

Organizational structure for responding to climate change

The structure of the New York City response to developing resilience to climate change is shown in Figure 1.2. Collaboration with communities is essential to the design and implementation of resilience programs and can help ensure that measures take local context into account. Recognizing this importance, New York City has made community engagement a central component of the OneNYC planning process and will continue to prioritize it through the use of fully collaborative adaptation planning approaches.

Spatial and temporal scales

The tools and methods developed for the NPCC3 2019 Report are for use by the metropolitan region over long-term, medium-term, and short-term timeframes. The spatial domain of the NPCC3 Report is the entire New York metropolitan region, consisting of 31 counties across New York State, New Jersey, and Connecticut (Fig. 1.3). This is important because many of the critical infrastructure systems extend far beyond the five boroughs. Further, regionally coordinated approaches to climate change resilience can help in scaling up adaptation and lessening widespread vulnerability.

Those responsible for developing resilience strategies for communities and critical infrastructure across the region need to understand how

Figure 1.2. Organizational structure of the New York City response to developing resilience to climate.

climate is projected to change in the short (2020s), medium (2050s), and long term (2080s, 2100, and beyond), because planning horizons often differ depending on type of activities and assets. The 2020s, 2050s, and 2080s timeframes are embedded in the NYC Climate Resilience Design Guidelines, which are based on NPCC2 projections (NYC ORR, 2018). These timeframes are also included in the NPCC adaptation framework steps to call out the explicit decision pathways relevant to these short-, medium-, and long-term periods (Fig. 1.4). Because climate change is a very long-term process, NPCC3 has begun to research potential changes in climate in the New York metropolitan region beyond 2100, especially regarding sea level rise.

Observations and projections

NPCC3 analyzes how recent temperature and precipitation trends (from 2010 to 2017) compare to the projections that NPCC made in 2015 for the New York metropolitan region. The goal is to understand how well what the New York metropolitan region is experiencing tracks the projections. The analysis finds that observed annual temperatures and precipitation increases are tracking the projections. These comparisons should be viewed with caution because of the role that natural variation plays in the short term.

Climate extremes

NPCC3 has a special focus on six climate extremes: extreme heat and humidity, heavy downpours, droughts, sea level rise and coastal flooding, extreme winds, and cold snaps. The city and region is already experiencing changes in some of these, and changes in some are predicted to occur in the future. These climate extremes are covered in various chapters throughout the NPCC3 Report (Table 1.1).

Uncertainty

Box 1.2. Sources of uncertainty in climate projections

Uncertainty regarding factors affecting the Earth radiative balance, such as future concentrations of GHGs and aerosols (particularly black carbon) and land use changes. Future concentrations will depend on population and economic growth, technology, and biogeochemical feedbacks (e.g., methane release from permafrost in a warming Arctic). Multiple representative concentration pathways are used to explore possible futures.

Sensitivity of the climate system to changes in GHGs and other "forcing" agents. Climate models are used to explore how much warming may occur for a given change in radiatively important agents. The direct temperature effects of increasing CO_2 are well understood, but models differ in their feedbacks (such as changes in clouds, water vapor, and ice with warming) that determine just how much warming ultimately will occur. A set of climate models is used to sample the range of such outcomes.

Regional and local changes that may differ from global and continental averages. Climate model results can be statistically or dynamically downscaled, but some processes may not be captured by existing techniques. Examples include changes in land–sea breezes and the urban heat island effect. In statistical downscaling approaches, results are sensitive to the method of adjusting the model output to represent the observed mean and variability of the weather in the target domain. Dynamical downscaling results depend on the high-resolution, regional model in use and global model used to provide boundary conditions.

Natural variability that is largely unpredictable over the long time ranges addressed in this report, especially in mid-latitude areas such as the New York metropolitan region. Even as increasing GHG concentrations gradually shift weather and climate, random elements will remain important, especially for extreme events and over short time periods. Chaos theory has demonstrated that natural variability can be driven by small initial variations that amplify thereafter. Other sources of natural variability include the El Niño Southern Oscillation (ENSO) and solar cycles.

Observations include uncertainties as well. These matter when comparing model projections to baseline conditions or when developing downscaling and model bias correction schemes. Sources of observational uncertainty include poor location of weather stations, instrument errors, and errors involved in data processing and maintenance.

Contents of the NPCC3 Report

The NPCC3 2019 Report consists of three sections: Urban Climate Science, Community Resilience and Critical Infrastructure, and Charting Adaptation Pathways.

The four chapters of the *Urban Climate Science* section focus on climate extremes (Chapter 2), sea level rise (Chapter 3), coastal flooding (Chapter 4), and mapping (Chapter 5). Chapter 2, entitled New Methods for Assessing Extreme Temperatures, Heavy Downpours, and Drought, develops and tests 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 provide quantitative analyses for heat and cold extremes, heavy downpours, and drought. They are available for developing the next full set of NPCC projections.

The heat section expands the number of weather stations from the one (Central Park) in NPCC2 to three (Central Park, LaGuardia, and JFK) in NPCC3 enabling a more spatially disaggregated analysis across the city. It develops new methods for projections of heat wave characteristics including heat wave frequency, heat wave duration, maximum temperature during a heat wave, and humidity, and analyzes observed trends in heavy downpours and long-term records of droughts in the region.

In Chapter 3, the NPCC3 reaffirms the NPCC2 2015 sea level rise projections as the basis of decision making in the region. For late in the century, new developments suggest the possibility of greater global mean sea level rise than previously anticipated, particularly under high greenhouse gas emission scenarios. To take these high-end risks into account, NPCC developed a new SLR scenario, Antarctic Rapid Ice Melt (ARIM) for the 2080s and 2100, which includes the possibility of Antarctic Ice Sheet destabilization. This scenario is associated with high uncertainty due to lack of knowledge about ice loss processes and atmosphere, ocean, and ice-sheets interactions. ARIM represents an upper-end, low-probability case for the late 21st century.

Since it may not be possible to find solutions to keep rising seas out of all neighborhoods, a shift of paradigm is needed to consider living with higher sea levels and more frequent and intense coastal flooding.

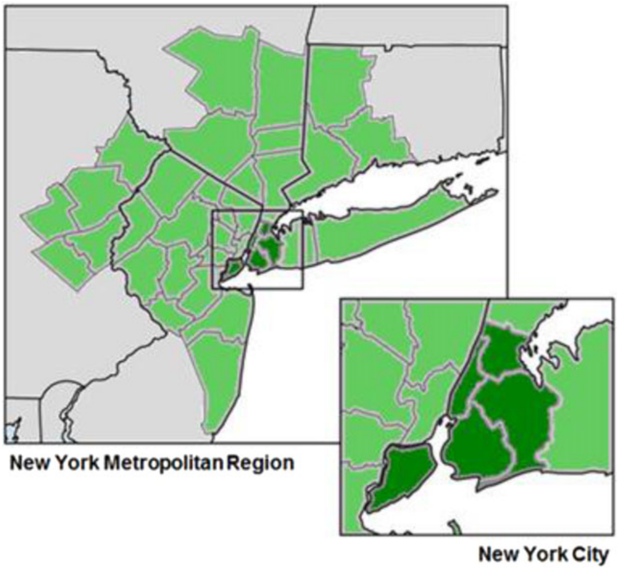

Figure 1.3. The New York metropolitan region is the spatial domain of NPCC3 (as in Rosenzweig and Solecki, 2001).

Coastal flooding is one of the most dangerous and damaging natural hazards that societies face. Extreme water levels are increasing globally, mainly driven by rises in mean sea level. In Chapter 4, Coastal Flooding, NPCC3 continues to use FEMA's 1% annual chance floodplain as a baseline extreme flood hazard. New to this chapter is a review of the latest science, a dynamic model-based analysis of monthly tidal flooding, a broadened set of sea level rise scenarios including the ARIM scenario,

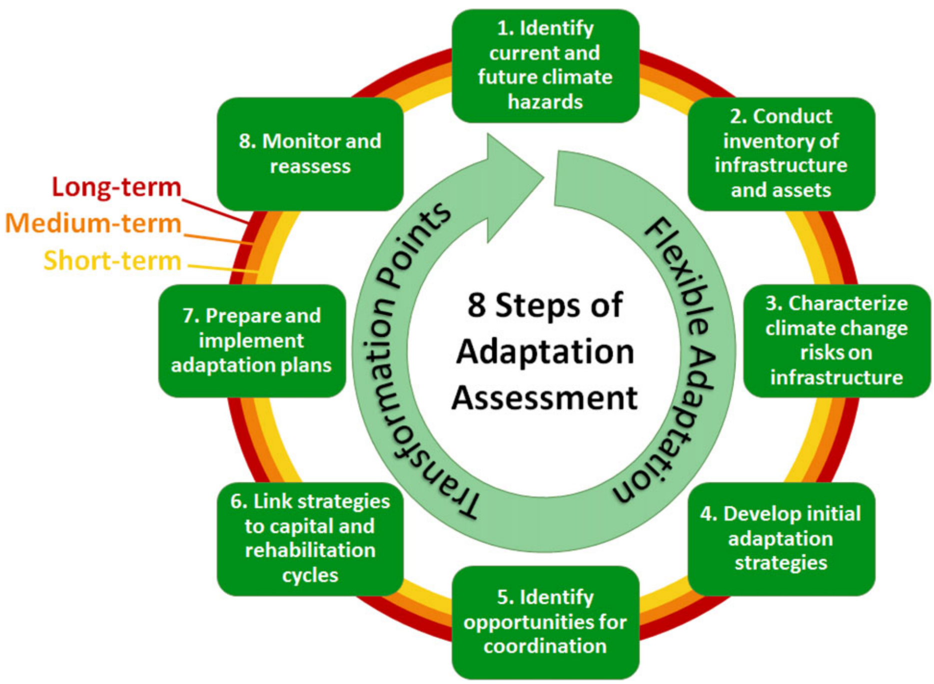

Figure 1.4. Adaptation steps across long-term (2080s, 2100, and beyond), medium-term (2050s), and short-term (2020s) time frames (modified from Adaptation Steps diagram in the NPCC 2010 Report, Rosenzweig & Solecki, 2010).

Table 1.1. Six climate extremes and the NPCC3 chapters in which these are considered

Climate extreme	Chapter 3: Extreme temperatures, heavy downpours, and drought	Chapter 4: Sea level rise	Chapter 5: Coastal flooding	Chapter 6: Community-based assessments of adaptation and equity	Chapter 7: Critical infrastructure systems	Chapter 8: Indicators and monitoring
Extreme heat and humidity	X			X	X	X
Heavy downpours	X				X	
Drought	X				X	
Sea level rise and coastal flooding		X	X	X	X	X
Extreme winds			X		X	
Cold snaps	X				X	X

and sensitivity analyses that show how differing methods affect results.

Since it may not be possible to find solutions to keep rising seas out of all neighborhoods, a shift of paradigm is needed to consider living with higher sea levels and more frequent and intense coastal flooding.

Chapter 5, Mapping Climate Risk, focuses on the analysis and presentation of spatial climate risk information. The chapter focuses primarily on flood risk and presents new coastal inundation and flooding maps associated with the ARIM scenario utilizing a new LiDAR dataset for New York City and an improved digital elevation model used to depict baseline topography. The new LiDAR data, collected in 2017, are an update from the 2010 dataset and capture recent areas of changed shoreline. The information includes empirical or observed data and model projections. However, all spatial data involve uncertainty and error.

The second section of the NPCC3 Report, *Community Resilience and Critical Infrastructure*, consists of two chapters, Community-based Assessments of Adaptation and Equity (Chapter 6) and Resilience Strategies for Critical Infrastructures and Their Interdependencies (Chapter 7). Chapter 6 analyzes vulnerability to climate change in the New York metropolitan region and how it varies across social groups, economic levels, and neighborhoods. It considers how spatial analysis can provide guidance on the location of socially vulnerable neighborhoods and can aid in the targeting of adaptation resources. The chapter presents variables or indicators to assess and track spatial patterns of vulnerability at the neighborhood level; case studies of community adaptation in three socially vulnerable neighborhoods: northern Manhattan, Sunset Park, and Hunts Point; and ways to incorporate equity into adaptation planning at the city level.

Climate change poses many challenges to infrastructure in New York City. Chapter 7, Resilience Strategies for Critical Infrastructures and Their Interdependencies, builds upon earlier NPCC work on climate change and critical infrastructure systems and provides new directions, updates, and considerations. Heat waves, heavy downpours, and droughts are added as additional variables posing a threat to infrastructure. NPCC3 analyzes dependencies and interdependencies among infrastructure systems to examine how climate change will exacerbate the risks associated with these connections. It also examines risks to infrastructure in the context of two communities that depend on them: hospitals and housing. Two case studies on hospitals in Manhattan and the NYC Housing Authority are presented, as well as the role of insurance and finance in preparing for the impacts of climate change on infrastructure systems. Given the importance of both mitigation and adaptation to responding to climate change, the chapter explores synergies and trade-offs between them.

The third section, *Charting Adaptation Pathways*, addresses the need for indicators and monitoring of climate changes and responses, and provides perspectives on the work of the NPCC since its inception in 2008. Chapter 8, Indicators and

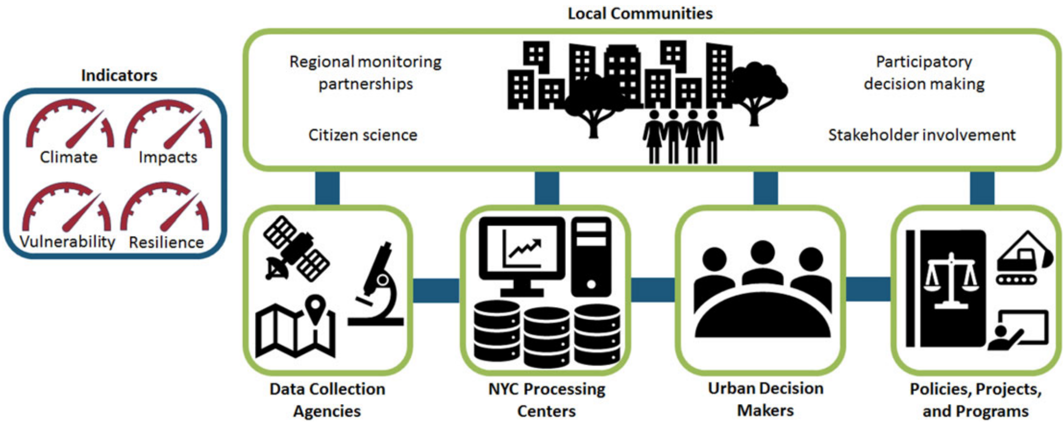

Figure 1.5. Prototype structure and functions of the proposed New York City Climate Change Resilience Indicators and Monitoring System (NYCLIM). The proposed system tracks four types of indicators from data collection agencies; processing centers; urban decision makers; and policies, projects, and programs. The proposed NYCLIM system is co-generated by scientists, practitioners, and local communities to determine which indicators should be tracked over time to provide the most useful information for planning and preparing for climate change in New York City.

Monitoring, has advanced this crucial area by proposing a New York City Climate Change Resilience Indicators and Monitoring System (NYCLIM) (Fig. 1.5). The chapter presents an initial set of indicators for variables to be tracked in the NYCLIM and explores how indicators may track interdependencies among infrastructure systems, with a particular focus on the energy and transportation sectors.

Chapter 9, Perspectives on a City in a Changing Climate, frames the third report of the New York City Panel on Climate Change (NPCC3) in the context of the role of cities in responding to climate change and the history of how New York City, in particular, has addressed climate change since the Metro East Coast Assessment that began in the 1990s and the founding of the NPCC in 2008 (Rosenzweig and Solecki, 2001; Rosenzweig and Solecki, 2010; Rosenzweig and Solecki, 2015). It explores ways that NPCC's role as a knowledge provider to the city and region can continue to assess vulnerability, impacts, and adaptation; monitor climate change; evaluate effectiveness of resilience measures; and serve as a convener for groups and stakeholders addressing climate change challenges in the New York metropolitan region.

Conclusions and recommendations from the entire NPCC3 Report are presented in Chapter 10.

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