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Hurricane Sandy and adaptation pathways in New York: Lessons from a first-responder city

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ABSTRACT

Two central issues of climate change have become increasingly evident: Climate change will significantly affect cities; and rapid global urbanization will increase dramatically the number of individuals, amount of critical infrastructure, and means of economic production that are exposed and vulnerable to dynamic climate risks. Simultaneously, cities in many settings have begun to emerge as early adopters of climate change action strategies including greenhouse gas mitigation and adaptation. The objective of this paper is to examine and analyze how officials of one city – the City of New York – have integrated a flexible adaptation pathways approach into the municipality's climate action strategy. This approach has been connected with the City's ongoing response to Hurricane Sandy, which struck in the October 2012 and resulted in damages worth more than US$19 billion. A case study narrative methodology utilizing the Wise et al. conceptual framework (see this volume) is used to evaluate the effectiveness of the flexible adaptation pathways approach in New York City. The paper finds that Hurricane Sandy serves as a "tipping point" leading to transformative adaptation due to the explicit inclusion of increasing climate change risks in the rebuilding effort. The potential for transferability of the approach to cities varying in size and development stage is discussed, with elements useful across cities including the overall concept of flexible adaptation pathways, the inclusion of the full metropolitan region in the planning process, and the co-generation of climate-risk information by stakeholders and scientists.

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1. Introduction

Hurricane Sandy struck the East Coast of the United States on October 29, 2012 and brought the issue of urban resilience to the forefront of public discussion not only in New York City, but in cities around the world. Globally, climate change is already increasing the frequency and intensity of some extreme events, such as heatwaves and heavy downpours, and these effects are projected to accelerate in the future (IPCC, 2013). Highly germane to coastal cities, flooding events from storms are expected to increase in frequency and extent due to sea level rise (IPCC, 2013). While Hurricane Sandy as an individual extreme climate event cannot be attributed to climate change, it serves as warning for cities regarding disaster risks, focuses attention on the importance of reducing climate vulnerability, and highlights the need to include increasing climate risks and resilience into rebuilding programs.

Hurricane Sandy motivates an examination of how New York City had been addressing climate risks before and after the storm, specifically through an analysis of the flexible adaptation/resilience approach developed by the City in the years prior to its occurrence. This paper is one of the first critical evaluations of how New York City has embraced adaptation pathways, with special attention to the major decision point propelled by Hurricane Sandy (see also Wagner et al., 2014). It then expands the analysis to the use of adaptation pathways in other cities, examining whether this concept is easily transferable to a variety of urban settings.

The work in New York City is situated at the nexus of climate change adaptation (CCA) and disaster risk reduction (DRR). Solecki et al. (2011) focus on the overlaps between CCA and DRR in cities in regard to event likelihoods related to hazards, risks and uncertainty; key impact parameters of exposure, vulnerability, and equity; and societal responses related to adaptive capacity and resilience. The linkages between DRR and CCA strategies in New

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York and other cities have started to change how researchers and practitioners conceive and approach the analysis and management of urban climate risks and associated impacts and response activities.

Further, this work is embedded in the context of current thinking on the potential for transformational adaptation when incremental adaptations to climate change prove insufficient (e.g., Folke et al., 2010; Kates et al., 2012). Folke et al. (2010) laid out definitions and issues relating to the integration of resilience, adaptability, and transformability across multiple scales. *Resilience* is the capacity of a social-ecological system (SES) to continually change and adapt yet remain within critical thresholds. *Adaptability* is part of resilience and represents the capacity to adjust responses to changing external drivers and internal processes and thereby allow for development along the current trajectory. *Transformability* is the capacity to cross thresholds into new development trajectories.

The key issue following Hurricane Sandy is whether it represents a tipping point that leads to new development trajectories, i.e., toward transformative adaptation (Kates et al., 2012). While challenges to transformative adaptation relate to the high costs of such actions, and the inertia that tends to maintain existing policies and systems, crises can provide windows of opportunity for innovation. Thus we explore whether Hurricane Sandy, as such a focusing event, has helped to initiate transformative adaptation in the New York Metropolitan Region.

2. Flexible adaptations pathways in New York City

In 2008, Mayor Bloomberg convened the First New York City Panel on Climate Change (NPCC, 2010). NPCC1, which was composed of leading climate and social scientists and risk management experts, developed climate change projections, advised on adaptation assessment, and examined how standards and regulations could be revised. The New York City Panel on Climate Change projects with high confidence that there will be increased heatwaves, heavy rainfall events, and extended coastal flooding in the New York metropolitan region in the coming decades (NPCC, 2010, 2013) (see Supplementary data Table 1 and Table 2).

To manage these increasing risks, the NPCC1 in conjunction with city stakeholders developed the 'flexible adaptation pathways' approach to guide the City in developing greater resilience (NPCC, 2010). The key elements of the approach are the explicit recognition that risk management strategies need to evolve through time in response to continuous climate risk assessment, evaluation of adaptation strategies, and monitoring. New York City climate resilience plans were included in the 2011 update of PlaNYC, the long-term sustainability plan for New York City, and set forth eleven initiatives that spanned continuing vulnerability and risk assessments, as well as updating building regulations, and improving responses to extreme events (NYC, 2011).

The concept of 'flexible adaptation pathways' as an approach to responding to climate change was laid out by the New York City Panel on Climate Change in 2010 (Yohe and Leichenko, 2010; NPCC, 2010; Major and O'Grady, 2010). The NPCC1 application of the concept as a planning tool is based on the study done by the City of London and the UK Environment Agency for the renovation of the Thames barriers (Lowe et al., 2008; Reeder and Ranger, 2011; Ranger et al., 2013). The New York City flexible adaptation framework encompasses both mitigation and adaptation and enables the consideration of long-range goals as well as their translation into short-term objectives.

The NPCC flexible adaptation pathways conceptual framework shown in Fig. 1a represents the societal 'acceptable level of risk' (wavy horizontal line), as fluctuating rather than static. For example, the acceptable risk level of New York inhabitants has without doubt been lowered by the experience of Hurricane Sandy. The schematic indicates that without climate change mitigation or adaptation, the acceptable level of risk could be crossed relatively soon. Inflexible adaptation standards, even with mitigation, improves the *status quo* but eventually results in crossing the acceptable risk level. Flexible adaptation consists of a successive set of strategies developed and implemented as knowledge and understanding of climate change proceeds. However, without greenhouse gas emission mitigation actions, adaptation by itself might not be enough to maintain (within socially defined cost limits) the urban system at an acceptable level of risk on the multi-decadal timeframe. Thus, the combination of flexible adaptation strategies with mitigation (with the caveat that mitigation must occur on both local and global scales to be effective) will enable New York City to remain below the acceptable level of risk as climate change proceeds.

The NPCC emphasized that flexible adaptation pathways are not fixed; adaptations are defined in terms of acceptable risk levels and are re-evaluated over time, rather than using an approach that sets inflexible standards for adaptation early in the process (NPCC, 2010). More permanent, inflexible approaches (e.g., sole reliance on large-scale storm surge barriers) are likely to be costlier and less effective in the long term than flexible adaptation pathways in implementing adaptations to dynamic and on going climate change conditions. In recognition of the City's need for climate risk information through time, the City Council of New York City codified the NPCC in August 2012 legislation, signed by Mayor Bloomberg in September, requiring the establishment of the NPCC as an body to provide regular climate science updates and localized projections. This was set in place 2 months before Hurricane Sandy and helped to formalize the flexible adaptation pathway approach within the City's response strategy.

Fig. 1b presents the specific timeline and trajectory of NYC's flexible adaptation pathways, key milestones and decision points, and adaptation actions. The blue line in Fig. 1b represents the socially acceptable level of risk that was rising gradually over time before Hurricane Sandy. The spike in the yellow line (the trajectory of NYC's flexible adaptation pathway) shows that the socially acceptable risk level was breached during Hurricane Sandy. Immediately following Sandy, multiple measures designed to bring the flexible adaptation pathway below the socially acceptable level of risk were rapidly adopted.

3. Hurricane Sandy

Hurricane Sandy hit New York City on the evening of October 29, 2012 (NPCC, 2013). Some weather prediction models provided accurate forecasts of the storm track and intensity of a Mid-Atlantic landfall more than one week in advance. As a measure of the storm's strength, Sandy had a central pressure of 945 mb, the lowest on record at landfall of any storm north of North Carolina. Sandy's wind field extended about 1610 km (1000 mil.). The peak storm surge of 2.9 m (9.4 ft) coincided closely with high tide in the areas facing the Atlantic Ocean, especially in Staten Island and Brooklyn. The storm tide at The Battery at southern Manhattan, just meters away from the Wall Street financial center, was 4.3 m (14.1 ft) above mean lower low water (MLLW), or 3.4 m (11.3 ft) above the North American Vertical Datum (NAVD88) (Blake et al., 2013).

Hurricane Sandy flooded the area roughly equivalent to that projected by NPCC1 for the 1-in-100 year storm 'rapid ice-melt' sea level rise scenario in the 2080s (Fig. 2). The NPCC1 'Rapid ice-melt scenario' was based on acceleration of recent rates of ice melt in the Greenland and West Antarctica ice sheets and paleoclimate studies (Horton et al., 2010). Two elements contribute to this surprising