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NPCC2 Climate Risk Information 2013

Climate Methods Memorandum

December 17, 2013

1. Spatial Extent of Projections

The NPCC2 Climate Risk Information 2013 projections (http://ccrun.org/NPCC-2013) are generally applicable for the New York City metropolitan area, defined here as the 100-mile land radius that surrounds Central Park, New York, NY (Figure 1). The 100-mile land radius used here encompasses all, or in some cases a portion, of the 31 counties that were used to define the New York metropolitan area in the 2001 Metro East Coast Assessment (Rosenzweig and Solecki, 2001).

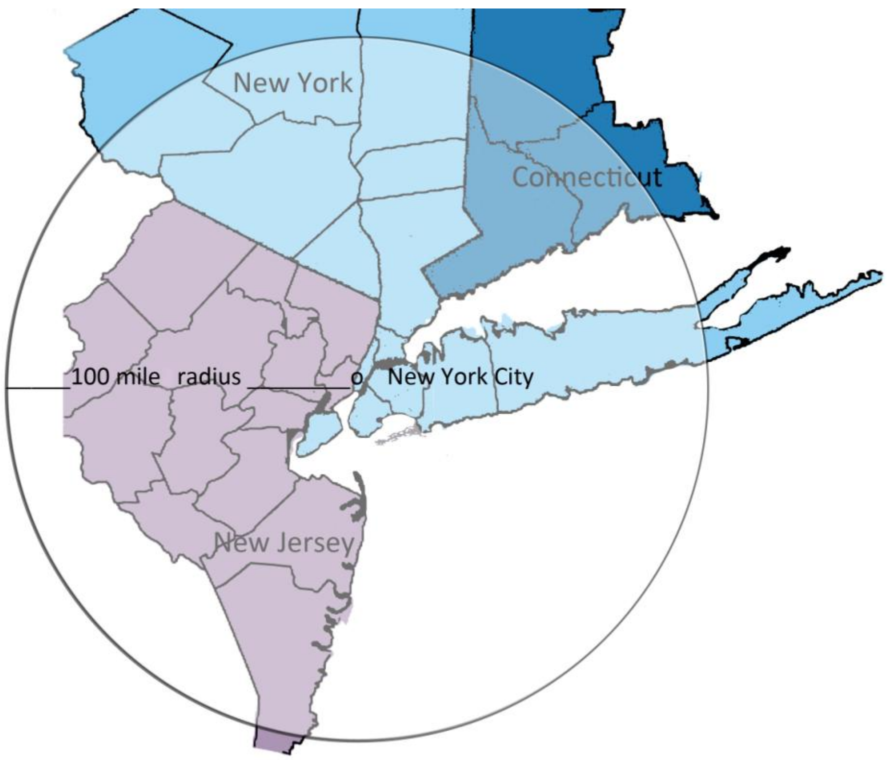

Figure 1. The 100-mile land radius centered on Central Park, New York, NY.

The projections are based on recent global climate model outputs (known as Coupled Model Intercomparison Project 5 or 'CMIP5'), observed data, and projection methodologies used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5). The NPCC2 projections are being used in long-term planning by New York City (NYC Panel on Climate Change, 2013; City of New York, 2013). The NPCC2 projections are generally consistent with the projections of other major assessments, such as the first NPCC report (Rosenzweig and Solecki, 2010), IPCC AR5 (IPCC 2013), the 2013-2014 National Climate Assessment (USGCRP 2014), the NOAA Sea Level Rise Report (Parris et al., 2012), and the National Research Council Report (NRC, 2012), and Horton et al. 2014.

The spatial area of applicability of the NPCC2 projections is larger for some variables than for others. The mean changes for temperature and precipitation are generally applicable across at least a 100-mile radius (Box 1) [1].

Box 1. Comparison of Projections in New York, Philadelphia, and New Haven

While the precise quantitative mean temperature and precipitation change projections for Philadelphia (approximately 78 miles direct from Manhattan) or New Haven (approximately 70 miles direct from Manhattan) differ slightly from NYC (i.e., +/- 4%)[2], these small differences are within the bounds of the climate uncertainty in any long-term projections.

Similarly, the qualitative projections for changes in extreme events (such as coastal storms and extreme winds) are expected to be generally applicable across an approximately ~100 mile radius. However, the quantitative projections of changes in the frequency of extreme event *thresholds* (e.g., days over 90°F) can be highly variable spatially, even within the confines of a city itself. For example, there is large spatial variation in the number of days over 90°F across the region as a result of factors such as the urban heat island and the distance to the Atlantic Ocean. The percentage change in the number of days over 90°F can thus be variable as well.

While the NPCC2 projections for total sea level change are applicable for the New York Metropolitan area, projected changes in flood extent will vary substantially within the 100-mile radius, as show in the NPCC2 Climate Risk Information Report coastal flood maps (NPCC, 2013; Page 25, Figure 8 and Figure 9). This is primarily due to the fact that coastal topography differs dramatically throughout the region.

It is scientifically appropriate to use the NPCC2 projections to inform planning across multiple governmental scales (e.g., city, county, state) in the New York metropolitan region. Such coordinated efforts can serve as test cases of successful local, state, and federal coordination at a critical time for integrated climate adaptation initiatives.

[1] There may be isolated, relatively small local exceptions for sea level rise, such as parts of New Jersey's coastal plain experiencing more rapid subsidence than NYC due to sediment compaction.

[2] Spatial variation in mean temperature and precipitation projections across these three cities is based on the comparison of the 35 global climate model ensemble for representative concentration pathway 8.5. Climate projections are changes for the 2050s relative to the 1980s base period.

References for Spatial Extent of Projections

City of New York, 2013: *New York City Special Initiative on Rebuilding and Resiliency. 'A Strong, More Resilient New York*.

Horton, B. P., S. Rahmstorf, S. E. Engelhart, and A. C. Kemp, 2014: Expert assessment of sea-level rise by AD 2100 and AD 2300. *Quaternary Science Reviews*, **84,** 1-6.

IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY.

National Research Council, 2012: *Sea-level rise for the coast of California, Oregon, and Washington: Past, present, and future.* The National Academy Press, Washington, D. C., 201 pp.

New York City Panel on Climate Change, 2013: *Climate Risk Information 2013: Observations, Climate Change Projections, and Maps.* C. Rosenzweig and W. Solecki (Eds.), NPCC2. Prepared for use by the City of New York Special Initiative on Rebuilding and Resiliency, New York, New York.

Parris, A., and Coauthors, 2012: *Global Sea level rise Scenarios for the US National Climate Assessment.* US Department of Commerce, National Oceanic and Atmospheric Administration, Oceanic and Atmospheric Research, Climate Program Office.

Rosenzweig, C., & Solecki, W. (Eds.), 2010: Climate Change Adaptation in New York City: Building a Risk Management Response: New York City Panel on Climate Change 2010 Report. *Annals of the New York Academy of Sciences* (Vol. 1196), 352 pp.

Rosenzweig, C., & Solecki, W. (Eds.), 2001: *Climate Change and a Global City: The Potential Consequences of Climate Variability and Change, Metro East Coast*. New York: Report for the U.S. Global Change Research Program, Columbia Earth Institute.

USGCRP, 2014: National Climate Assessment, Public Review Version, available online at: http://ncadac.globalchange.gov/.

2. Methods for 2100 Projections

Projections for 2100 require a different approach from the 30-year timeslices centered on the 2020s, 2050s, and 2080s (10-year for sea level rise) that the New York City Panel on Climate Change (NPCC) traditionally uses (NPCC 2013). The primary difference is that because the vast majority of climate model simulations end in 2100, it is not possible to make a projection for the 30-year timeslice (10-year for sea level rise) centered on the year 2100. Given this model availability constraint, the NPCC considered the following four alternate approaches to generate projections for 2100. All four approaches share one thing in common: they involve adding a linear trend to the final timeslice (2080s for temperature and precipitation, 2090s for sea level rise), and extrapolating that trend to 2100. The final period linear trend (FPLT) is for 2085 to 2099 for temperature and precipitation, and 2095 to 2099 for sea level rise. The NPCC considered quadratic trends as well, but determined that over the short time periods used for the trends, a linear approach produced comparable results. The two approaches are:

1. Add each representative concentration pathway (RCPs) ensemble mean FPLT to the final timeslice projections for the corresponding RCP, and calculate the four distribution points (i.e., 10th, 25th, 75th, and 90th percentiles).
2. Add the FPLT from each individual model and RCP to the final timeslice for the corresponding model and RCP, and then calculate the four distribution points (i.e., 10th, 25th, 75th, and 90th percentiles).

Approaches 1 and 2 were averaged to generate projections for 2100 (Table 1).

It is also important to note that uncertainties are inherently much greater for the end of the century than the mid-century. For example, the RCP runs do not sample all the possible carbon, and other biogeochemical cycle feedbacks associated with climate change. For example, even the few Earth System Models in CMIP5 used by the NPCC2 may underestimate the potential for increased methane and carbon release from the Arctic under extreme warming scenarios. More generally, the potential for surprises, such as technological innovations that could remove carbon from the atmosphere, increases the further into the future one considers.

2100 Projections for Temperature, Precipitation, and Sea Level Rise

Table 1a. Temperature projections for 2100

	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
Approach 1	+4.5 °F	+6.0 to 10.4 °F	+11.9 °F
Approach 2	+3.9 °F	+5.5 to 10.3 °F	+12.3 °F
2100 Projections (Average of Approaches 1 and 2)	**+4.2 °F**	**+5.8 to 10.4 °F**	**+12.1 °F**

Based on 35 GCMs and two Representative Concentration Pathways. Projections are relative to the 1971-2000 base period.

Table 1b. Precipitation projections for 2100

	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
Approach 1	-1%	+2 to +14%	+18%
Approach 2	-11%	-5 to +24%	+32%
2100 Projections (Average of Approaches 1 and 2)	**-6%**	**-1 to +19%**	**+25%**

Based on 35 GCMs and two Representative Concentration Pathways. Projections are relative to the 1971-2000 base period.

Table 1c. Sea level rise projections for 2100*

	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
Approach 1	7 inches	9 to 18 inches	24 inches
Approach 2	6 inches	9 to 19 inches	26 inches
Model-based component average	6 inches	9 to 18 inches	25 inches
2100 Total SLR Projections (Average of Approaches 1 and 2)	**15 inches**	**22 to 50 inches**	**75 inches**

Based on 24 GCMs and two Representative Concentration Pathways. Projections are relative to the 2000 - 2004 base period.

*Note rows 1, 2, and 3 are for model-based sea level rise components only; the final row shows row 3 plus all other sea level change components)

References for 2100 Projections Methods

New York City Panel on Climate Change, 2013: *Climate Risk Information 2013: Observations, Climate Change Projections, and Maps*. C. Rosenzweig and W. Solecki (Eds.), NPCC2. Prepared for use by the City of New York Special Initiative on Rebuilding and Resiliency, New York, New York.

3. Adjustments to 2020s and 2050s Sea Level Rise Projections

With the release of the IPCC AR5 in Fall 2013, the NPCC has had the opportunity to incorporate additional sources of information. This process led to modification of the methods for two sea level rise components: 1) dynamic ocean height and 2) land water storage. As in Yin et al. 2012, dynamic sea level is now defined as the grid point anomaly from the global mean field. We also adopted the IPCC 2013 approach in calculating the contribution of changes in land water storage to sea level rise. Specifically, the NPCC 10th, 25th, 75th, and 90th percentile distribution points were calculated by assuming that IPCC projections of sea level rise are based on a normal distribution. The land water storage rates were treated as linear over time; therefore, the 2020s, 2050s, and 2080s projections could be calculated directly from the IPCC timeslices.

These adjustments led to small changes in the NPCC2 sea level rise projections for the 2020s and 2050s and tended to narrow projection ranges slightly (Table 2a and Table 2b). Specifically, the 90th percentiles in the 2020s and 2050s timeslices each decreased by one inch, the 75th percentile in the 2050s decreased by 3 inches, and the 10th percentile in the 2050s increased by one inch.

Table 2a. November 2013 NPCC2 Sea Level Rise Projections – Updated

Sea Level Rise	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
2020s	+ 2 inches	+ 4 in to 8 in	+ 10 inches
2050s	+ 8 inches	+ 11 in to 21 in	+ 30 inches
2080s	+ 13 inches	+ 18 in to 39 in	+ 58 inches

Based on 24 GCMs and two Representative Concentration Pathways. Shown are the low-estimate (10th percentile), middle range (25th percentile to 75th percentile), and high-estimate (90th percentile).

Table 2b. June 2013 NPCC2 Sea Level Rise Projections

Sea Level Rise	Low-estimate (10th percentile)	Middle range (25th to 75th percentile)	High-estimate (90th percentile)
2020s	+ 2 inches	+ 4 in to 8 in	+ 11 inches
2050s	+ 7 inches	+ 11 in to 24 in	+ 31 inches
2080s	+ 13 inches	+ 18 in to 39 in	+ 58 inches

Based on 24 GCMs and two Representative Concentration Pathways. Shown are the low-estimate (10th percentile), middle range (25th percentile to 75th percentile), and high-estimate (90th percentile).

References for Adjustments to Sea Level Rise Projections

New York City Panel on Climate Change, 2013: *Climate Risk Information 2013: Observations, Climate Change Projections, and Maps.* C. Rosenzweig and W. Solecki (Eds.), NPCC2. Prepared for use by the City of New York Special Initiative on Rebuilding and Resiliency, New York, New York.

Yin, J., 2012: Century to multi-century sea level rise projections from CMIP5 models. *Geophysical Research Letters*, **39,** L17709.

4. Comparison of NPCC2 Projections to IPCC AR5 Projections

This document provides a comparison of the climate projections from the New York City Panel on Climate Change (NPCC2) 2013 Climate Risk Information Report (NPCC 2013) to those of the Intergovernmental Panel on Climate Change in their Fifth Assessment Report (IPCC 2013), NPCC developed climate projections in advance of IPCC AR5.

Temperature and Precipitation Projections

Projections for temperature and precipitation differed between the NPCC2 and IPCC in their spatial domain selection of representative concentration pathways (RCPs) and global climate models (GCMs), reported percentiles of model-based distributions, and timeslice definitions (Table 3 and Table 4).

Spatial Domain

NPCC2 projections are local and specific to the New York City metropolitan area, whereas IPCC AR5 projections do not extend to finer spatial scales than the Eastern North American region.

GCM and RCP Selection, Percentiles, and Timeslices

For the NPCC2 projections, 35 GCMs and 2 RCPs (RCP 4.5 and RCP 8.5) were used. Based on Table 14.1 from Chapter 14 of IPCC AR5 Working Group 1 Report (IPCC 2013), the IPCC uses 42 GCMs to provide projections for one RCP (RCP 4.5).

The NPCC2 uses a 30-year baseline (1971-2000) and three 30-year future timeslices (2020s, 2050s, and 2080s), whereas the IPCC used a 20-year baseline from 1986-2005, and 20-year time slices centered around the 2020s, 2050s, and 2090.[3]

NPCC2 projections are provided for the 10th, 25th, 75th, and 90th percentiles of the model-based outcomes for the New York City metropolitan area. Table 14.1 in Chapter 14 of IPCC AR5 WG1, in contrast, shows the minimum value, the 25th, 50th, and 75th percentiles, and the maximum value for Eastern North America.

In Annex 1 of the Working Group 1 AR5 report, the IPCC provides additional projections for Eastern North America from a broader set of RCPs (4 in total), with the number of GCMs ranging from 25 to 42 depending on the RCP, and more points provided from the distribution of projected values of climate variables (such as the 5th and 95th percentiles).

Extreme Events Projections

The NPCC2 also included local quantitative and qualitative extreme event projections based on specific stakeholder impacts and decision-making needs (e.g., number of days per year above

[3] The choice of model baseline period has only a minor impact on the results, since greenhouse gas concentrations were similar for the two time periods.

90F). The IPCC AR5 does not include tabular information about extreme events at regional (or local) scales.

Table 3. Comparison of NPCC2 and IPCC AR5 Temperature and Precipitation Projections

	NPCC2	IPCC AR5
Spatial Domain	Local and specific to the New York City metropolitan area	Do not extend to finer spatial scales than the Eastern North American region
GCM Selection	35	42*
RCP Selection	2 (RCP 4.5 and RCP 8.5)	1 (RCP 4.5)*
Percentiles	10th, 25th, 75th, and 90th	Minimum, 25th, 50th, 75th percentiles, and the maximum
Timeslices	Baseline - 1971 to 2000 Future - three 30-year (2020s, 2050s, 2080s)	Baseline - 1986 to 2005 Future - three 20-year (2020s, 2050s, 2090)
Extreme Events Projections	Local quantitative and qualitative extreme event projections	Does not include tabular information about extreme events at regional (or local) scales.

* The values in the table are based on Table 14.1 in the IPCC AR5 WG1 report. The IPCC provides projections using a broader set of GCMs and RPCs and additional distribution points in Annex 1 IPCC AR5 WG1.

Sea Level Rise Projections

Projections for sea level rise differed between the NPCC2 and IPCC in their spatial domain selection of RCPs and GCMs, reported percentiles of model-based distributions, timeslice definitions, and calculation methods for different sea level rise components (Table 4).

Developing projections of sea level rise on a local basis requires component-by-component analysis of changes in local land height, the local fingerprint of ice mass changes, and changes in relative ocean height. NPCC2 sea level rise projections are therefore specific to the New York City metropolitan area. Although the IPCC AR5 performs calculations to project sea level rise for New York City (Figure 13.23 in Chapter 13 of IPCC AR5 WG1), they do not provide details of these calculations or the local allocation between components. Thus, only a partial reconciliation – resulting from reported global thermosteric expansion and additions of freshwater – is possible.

Model-Based Sea Level Rise Components

Projections of thermal expansion and dynamic sea level differ between NPCC2 and IPCC AR5 in a manner similar to those of temperature and precipitation, including selection of RCPs and GCMs, reported percentiles of model-based distributions, and timeslice definitions.

Differences among other Sea Level Change Components

The sea level contribution of glaciers and ice caps in the NPCC2 and IPCC AR5 analysis are based on the same peer-reviewed studies. The projections differ in the set of RCPs used to force the simulations, and in the confidence interval associated with the projections. Changes in land-water storage in the NPCC2 projections are derived using the IPCC AR5 methodology.

The largest differences between the two analyses among the non-model-based sea level change components lie in the projections of ice sheet mass loss. Because both the IPCC AR5 and the NPCC2 use linear extrapolations to estimate the rate of mass loss in 2100, these differences become more pronounced in the latter half of the 21st century.

The IPCC AR5 and NPCC2 methodologies differ for projecting future ice sheet behavior. IPCC AR5 makes likelihood judgments based on model-based projections, and examines the contribution of changes in surface mass balance and ice dynamics separately. In contrast, NPCC2 uses the expert elicitation of Bamber and Aspinall (2013) in which projections are associated with likelihoods, and in which the contribution to sea level change from each ice sheet includes both surface mass balance and dynamic contributions.

The IPCC AR5 also qualitatively describes the possibility of collapse of the marine-based sectors of Antarctica, which might result in several tenths of a meter of additional sea level rise. This possibility is represented in the NPCC2 probability distribution, although not explicitly.

The NPCC2 projections include relative ocean height, local fingerprint (associated with the ocean's responses to ice mass loss) and land height change terms. While the IPCC AR5 includes these two terms in the analysis, the report does not provide specific values for the NYC region as the NPCC2 does.

Table 4a. Comparison of NPCC2 and IPCC AR5 Temperature Projections

	NPCC2	IPCC AR5 ENA	IPCC AR5 Global
Early Century	+ 1.5 (2.0 to 2.8) 3.2 °F	+ 0.7 (1.4 to 2.3) 3.4 °F	N/A
Mid Century	+ 3.1 (4.1 to 5.7) 6.6 °F	+ 1.8 (3.1 to 4.3) 6.3 °F	+ 1.6 to 3.6 °F
Late Century	+ 3.8 (5.3 to 8.8) 10.3 °F	+ 1.8 (3.8 to 5.6) 7.6 °F	+ 2.0 to 4.7 °F

NPCC2 climate projections (Column 2) are specific to the New York City area. They are based on 35 GCMs and 2 RCPs (RCP4.5 and RCP8.5) with a 30-year baseline (1971 - 2000) and three 30-year future timeslices centered around the 2020s (early), 2050s (mid), and 2080s (late). Projections are provided for the 10th, 25th, 75th, and 90th percentiles of the model-based outcomes.

IPCC AR5 regional projections (Column 3) are for the Eastern North American region. They are based on 42 GCMs and 1 RCP (RCP4.5) with a 20-year baseline (1986 - 2005) and three 20-year future timeslices centered around the 2020s (early), 2050s (mid), and 2090 (late). Projections are provided for the minimum, 25th percentile, 75th percentile, and maximum values.

IPCC AR5 global projections (Column 4) are based on the CMIP5 ensemble, RCP 4.5, relative to the 1986 – 2005 base period. Provided is the 5-95% model range.

Table 4b. Comparison of NPCC2 and IPCC AR5 Precipitation Projections

	NPCC2	IPCC AR5 ENA	IPCC AR5 Global
Early Century	-1% (+ 1% to 8%) 10%	-4% (+1% to 5%) + 9%	N/A
Mid Century	+ 1% (4% to 11%) 13%	-1% (+3% to 7%) + 14%	N/A
Late Century	+ 2% (5% to 13%) 19%	-2% (+ 4% to 9%) + 14%	N/A

NPCC2 climate projections (Column 2) are specific to the New York City area. They are based on 35 GCMs and 2 RCPs (RCP4.5 and RCP8.5) with a 30-year baseline (1971 - 2000) and three 30-year future timeslices centered around the 2020s (early), 2050s (mid), and 2080s (late). Projections are provided for the 10th, 25th, 75th, and 90th percentiles of the model-based outcomes.

IPCC AR5 regional projections (Column 3) are for the Eastern North American region. They are based on 42 GCMs and 1 RCP (RCP4.5) with a 20-year baseline (1986 - 2005) and three 20-year future timeslices centered around the 2020s (early), 2050s (mid), and 2090 (late). Projections are provided for the minimum, 25th percentile, 75th percentile, and maximum values.

Table 4c. Comparison of NPCC2 and IPCC AR5 Sea Level Change Projections

	NPCC2	IPCC AR5 NYC	IPCC AR5 Global
Early Century	+ 2 in (4 in to 8 in) 10 in	+ 2 to 9 inches	N/A
Mid Century	+ 8 in (11 in to 21 in) 30 in	+ 8 to 23 inches	+7 to 13 inches
Late Century	+ 13 in (18 in to 39 in) 58 in	+ 13 to 41 inches	+ 13 to 25 inches

NPCC2 sea level rise projections (Column 2) are specific to the New York City area. They are based on both global and local components. For the model-based terms, the NPCC uses 24 GCMs and 2 RCPs (RCP4.5 and RCP8.5) with a 2000 - 2004 baseline and three 10-year future timeslices centered around the 2020s (early), 2050s (mid), and 2080s (late). Projections are provided for the 10th, 25th, 75th, and 90th percentiles.

IPCC AR5 regional projections (Column 3) are centered on the New York City tide gauge station. They are based on 21 GCMs for the RCP 4.5 emissions scenario (Figure 13.23). Provided is the 5-95% model range, estimated from Figure 13.23.

IPCC AR5 global projections (Column 4) are based on 21 CMIP5 models for RCP 4.5, relative to the 1986 – 2005 base period. Provided is the 5-95% model range. .

References for Comparison of NPCC2 Projections to IPCC AR5 Projections

Bamber, J.L. and Aspinall, W.P., 2013: An expert judgment assessment of future sea level rise from the ice sheets. *Nature Climate Change* doi:10.1038/nclimate1778.

IPCC, 2013: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* Cambridge University Press, Cambridge, United Kingdom and New York, NY.

New York City Panel on Climate Change, 2013: *Climate Risk Information 2013: Observations, Climate Change Projections, and Maps.* C. Rosenzweig and W. Solecki (Eds.), NPCC2. Prepared for use by the City of New York Special Initiative on Rebuilding and Resiliency, New York, New York.