Urban Climate Resilience and the Case of New York City

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CIESIN and the Earth Institute

• The Earth Institute’s overall mission is to harness science for environmental sustainability and poverty alleviation
• CIESIN is a unit of the Earth Institute focused on research and data related to human interactions in the environment
• CIESIN projects include:
  • NASA Socioeconomic Data and Applications Center (SEDAC)
  • USAID Africa Resilience to Climate Change (ARCC)
  • USAID West Africa Biodiversity and Climate Change (WABiCC)
  • NYSERDA Hudson River Flood Hazard Decision Support System
  • Support for IPCC Data Distribution Center
Overview

1. Definitions: vulnerability, risk and resilience
2. Urban climate risk
3. Past and future climate impacts in New York City (NYC)
   - Heat stress
   - Flooding
   - Sea level rise
4. NYC resilience and adaptation strategies
5. Conclusions

Definitions of Vulnerability, Risk and Resilience
Definition of Vulnerability

“Vulnerability is the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.”

- IPCC Working Group 2

Population’s Vulnerability = f (E, S, A)

Where

• E = exposure — size of the area and/or population affected (does the event occur there?)
• S = sensitivity — the intrinsic (age, sex, SES, ethnicity, livelihood strategies, etc.) and extrinsic (institutions, entitlements, etc.) characteristics of a population
• A = adaptive capacity — capacities of the population, place or system to resist impacts, cope with losses, and/or regain functions

Definition of Risk

Risk = \( \frac{\text{Exposure to Hazard} \times \text{Vulnerability}}{\text{Adaptation}} \)

- Risk = Probability of Event \( \times \) Magnitude
  - Characteristics of the hazard (intensity, magnitude, timing, speed)
  - New (sea level rise, EID) and changing hazards (increasing drought or flood frequency, re-emergence of diseases)
- IPCC prescribes a risk management approach to reduce risk of disruptions
  - Economic loss and disruption of livelihoods
  - Health and mortality impacts
  - Political instability, conflicts and refugee flows
  - Biodiversity loss
  - Etc.

Source: Dow et al, 2013. “Limits to Adaptation”
Definition of Resilience

1. Ability to bounce back after change or adversity
2. Capacity to prepare for, respond to, and recover from difficult conditions

Urban Climate Risk
Cities

- Concentrate population
- Concentrate economic activities and trade
- Concentrate investments in the built environment (buildings, supporting infrastructure)
- Represent the entire economic spectrum of a society
- Depend on a predictable relationship between the natural and built environment

*Climate Change will bring both predictable and unpredictable impacts … the stability will be perturbed*

What are the risk management challenges?

- Warmer and more frequent hot days and nights over most land areas (likelihood: virtually certain)
- Increases in heat wave frequency over most land areas (very likely)
- Increases in heavy precipitation events over most areas (very likely)
- Increases in areas affected by drought (likely)
- Increasingly intense tropical cyclone activity (likely)
- Rising sea level (likely)

Source: IPCC AR4 Working Group 2 Report

*…and cities are vulnerable to all of these!*
More Frequent Hot Days and Nights

Warming will cause an increase in the diseases associated with heat stress:
• heat edema
• heat rash
• heat cramps
• heat exhaustion
• heat stroke

It will also increase demand during peak load periods on the electrical grid, potentially contributing to power outages

Source: Battisti and Naylor (2009)

Heat Waves & the Urban Heat Island Effect

Combined with population ageing, mortality risk increases greatly

Source: Ganguly et al. 2010
• The number of flood events is increasing and likely will increase further under climate change.
• Also will have important impacts on electrical grids.


Increases in Heavy Precipitation

Blue areas will see increases in river runoff of >20%, orange areas declines of >-20%.

Source: Adikari and Yoshitani, 2009
Source: Adikari and Yoshitani, 2009.
Drought and Water Scarcity
Spatial distribution of large cities and their water shortage status, in 2000 and 2050

Source: McDonald et al. 2011 PNAS

Sao Paulo Drought

The actual values for 2014 and 2015 are respectively -2.28 and -1.63 standard deviations. By definition, SPI < -1 is moderate drought.

Degrees C/decade

1.75°C increase since 1950

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Drought Frequency Today and Projected Runoff in 2080

Legend

<table>
<thead>
<tr>
<th>Standardized Precip Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 5</td>
</tr>
<tr>
<td>5.51 - 7</td>
</tr>
<tr>
<td>7.51 - 9</td>
</tr>
<tr>
<td>9.01 - 10</td>
</tr>
</tbody>
</table>

Black = Runoff projected to decline by >-20%

Sources: de Sherbinin and Chen 2010, based on Nohara et al. 2006 (for IPCC AR4) UNISDR Global Risk Update and Lehner et al. (2010) Global Reservoir and Dam Database (GRaND)
Drought Frequency Today and Projected Runoff in 2080

Sources: de Sherbinin and Chen 2010, based on UNISDR Global Risk Update and Lehner et al. (2010) Global Reservoir and Dam Database (GRaND)

Exposure to Cyclones

Typhoon Haiyan


Mekong Delta Sea Level Rise
(1-2 meter)

Nile Delta Sea Level Rise
(1-2 meter)


Past and Future Climate Impacts in New York City
Past and Future Climate Impacts in New York City

- Heat stress
- Flooding
- Sea level rise

Exposure to Heat Stress

- Heat wave defined as:
- Exceeding the 85th percentile of daily average temperature based on July and August temperatures for 1961-1990
- Continuing for three or more consecutive days.

Daily average temp of 82°F for NYC

NYC: Urban Heat Wave Indicator

Number of Heat Waves


NYC: Urban Heat Wave Indicator

Cumulative Duration (days per year) of Heat Waves

Trends in Land Surface Temperatures

LST

Social Sensitivity Index

Poverty

% of HH Built before 1960

% of HH 65+
Living Alone

% of Pop. Without High School Graduation
Heat Stress Sensitivity Index

Intersection of areas of high exposure and high sensitivity

Heat Vulnerability Outcome Measures

- Deaths during heat waves more likely to occur:
  - In black individuals than other races
  - At home than in the hospital
  - In census tracts receiving greater public assistance
  - In areas with higher relative daytime surface temperatures
  - In areas with less green space


Future Heat Stress in NYC

- **Mean annual temperatures** are projected to increase by 2.2 to 3.2°C* by the 2050s and by 3 to 4.9°C* by the 2080s.
- **Frequency of heat waves** is projected to triple by the 2080s from 2 to 6 heat waves per year.

* Temperature projections for New York City

Impacts of Heat Waves on Energy Demand

During heat waves (tmax, tmin, specific humidity), even a small increase in temperature can mean a large increase in energy load.…

…Leading to an increased risk of power outages and deteriorating air quality

Indirect effects
=More stress on systems

Daily Electric Energy Load (gigawatt-hours) in NY State, vs. Daily-Average Temperature.
Solid Points=1966;
Open Points=1997 => Peak Load Issues

Source: Climate Change Research for the Urban Northeast (CCRUN)

Hurricane Sandy

US Landfall: 30 October 2012
Strength: Extratropical Storm
Storm Characteristics: moderate winds (130 km/h), significant storm surge. Record gale diameter
Impact: 44 fatalities (NYC), estimated $60bn economic loss

Source: Bevington, ImageCAT, (2013)
Are socially vulnerable people more likely to be in flooded areas?

<table>
<thead>
<tr>
<th>Category</th>
<th>Weighted SoVI</th>
<th>Averaged SoVI</th>
<th>% Population Aged &lt;5 and &gt;65</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (no exposure)</td>
<td>0.13</td>
<td>0.13</td>
<td>18.4</td>
</tr>
<tr>
<td>B (low exposure)</td>
<td>-0.05</td>
<td>0.08</td>
<td>19.4</td>
</tr>
<tr>
<td>C (moderate exp.)</td>
<td>-0.02</td>
<td>0.05</td>
<td>19.0</td>
</tr>
<tr>
<td>D (high exposure)</td>
<td>0.20</td>
<td>0.32</td>
<td>21.5</td>
</tr>
</tbody>
</table>

But who was most heavily impacted?

- In the longer run, a preliminary answer is middle income home owners
- Social programs and renter status were significant sources of resilience for lower-income households
- Different parts of the population had different vulnerabilities at different times in the recovery process
- **Sea level** is expected to rise 27 to 53 cm* by the 2050s, 46 to 99 cm* by the 2080s, and, for the high estimate, 1.8m feet by 2100.

- Projected sea level changes alone would increase the frequency and intensity of coastal flooding (absent any change in storms themselves).

- **Queens** is the borough with the most land area at risk of future coastal flooding due to sea level rise, followed by Brooklyn, Staten Island, the Bronx, and Manhattan.

* Middle range (25th to 75th percentile) of model-based projections.

NYC Resilience and Adaptation Strategies

Approaches to Resilience Action

Source: Bader (2015)
Examples

- **Policy**
  - Flood insurance and zoning regulations to guide development
  - Cooling centers for heat waves
- **Engineering**
  - Sea walls, sea gates
  - Levees
- **Ecosystem-based adaptation**
  - Dune replenishment
  - Wetland restoration
- **Social**
  - Empowering community groups and neighborhood self-help
  - Training neighbors to help elderly or handicapped during emergencies

Insurance

Proceedings Before New York Public Service Commission

- Petition by Columbia and other NGOs
- Consolidated Edison rate increase request
- NGO interventions
- Presentations by climate scientists
- Adjudication
- Negotiation
- Settlement


“The obligation to address these considerations should be broadened to include all utilities. The State’s utilities should familiarize themselves with scientists’ projections for local climate change impacts … We expect the utilities to consult the most current data available to evaluate the climate impacts anticipated in their regions over the next years and decades, and to integrate these considerations into their system planning and construction forecasts and budgets.”
Implementation

- Development of further scientific information
  - Geographically-specific projections
  - Humidity as well as heat and storms
- Modifications to technical standards
- Formulation of adaptation strategies based on projections

Engineering Approaches

- Three Barriers a preferred option

- Single harbor wide barrier
  - Cost $25b to build
  - Environmental impacts
  - Massive levees north and south
  - Insider/outsider dynamic
Wetlands and Beaches as Surge Defenses

Heat Stress

Cooling Centers

Green roofs and tree planting
Conclusions

Closing Remarks

• Temperature increases of up to 4° C (global mean) this century are a strong possibility
• Absent adaptation, urban impacts are likely to be particularly severe owing to the concentration of population and resources
• Researchers need to target decision support for adaptation and risk management through a co-production of knowledge
• Risk assessment, planning, and management need to be integrated
• Recognize that adaptation measures that can be justified for other reasons (current hazard risk, pop growth) are likely to be received more favorably
• New York City is in the vanguard of efforts to increase resilience
• Significant challenges remain
Merci!

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