# Urban Climate Resilience and the Case of New York City

Alex de Sherbinin, PhD
Center for International Earth Science Information Network (CIESIN), The Earth Institute at Columbia University
Population-Environment Research Network
NASA Socioeconomic Data and Applications Center (SEDAC)

Électricité de France Delegation
Columbia University
22 May 2015

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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

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## 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

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## Definitions of Vulnerability, Risk and Resilience

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## 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

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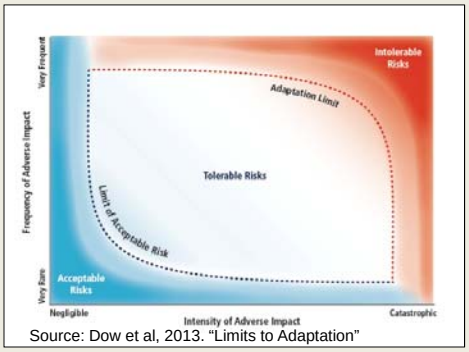
## Definition of Risk

$$\text{Risk} = \frac{\text{Exposure to Hazard x Vulnerability}}{\text{Adaptation}}$$

– Risk = Probability of Event x 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)

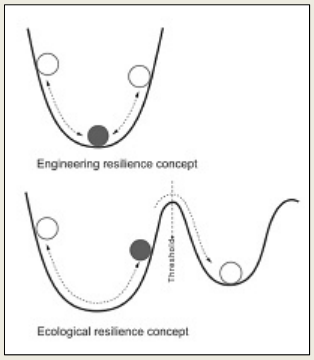
– IPCC prescribes a risk management approach to reduce risk of disruptions
  - Economic loss and disruption of livelihoods
  - Health and mortality impacts
  - Political instability, conflicts and refugee flows
  - Biodiversity loss
  - Etc.




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




How far a structure can be pushed and still return to its stable state

Multiple stable states and thresholds

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## Urban Climate Risk

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## 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

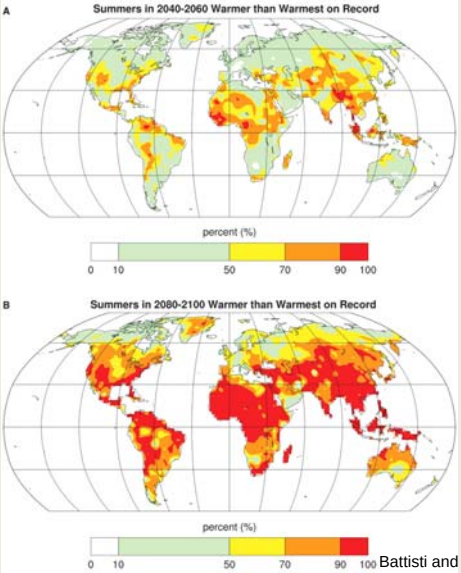
*…and cities are vulnerable to all of these!*

# More Frequent Hot Days and Nights

Warming will cause an increase in the diseases associated with heat stress:

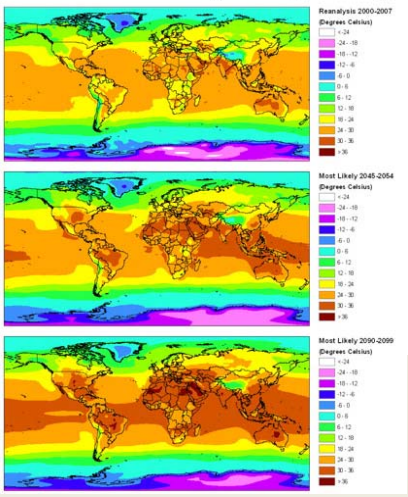
- heat edema
- heat rash
- heat cramps
- heat exhaustion
- heat stroke

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

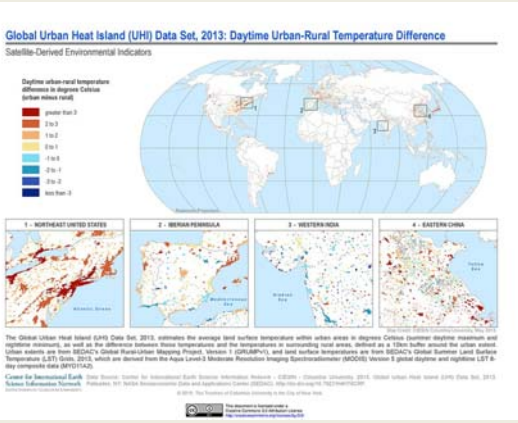



Battisti and Naylor (2009)

# Heat Waves & the Urban Heat Island Effect



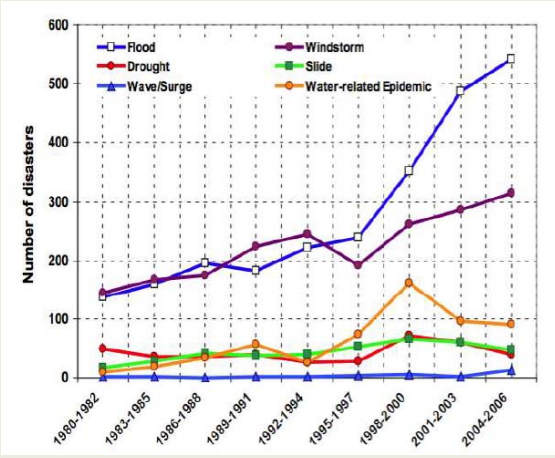

*Source:* Ganguly et al. 2010




Combined with population ageing, mortality risk increases greatly

# Increases in Heavy Precipitation

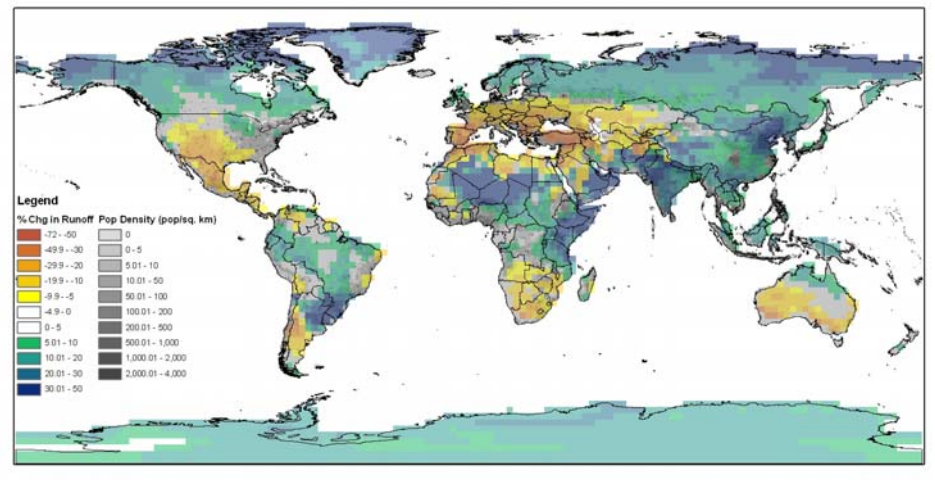
- The number of flood events is increasing and likely will increas further under climate change
- Also will have important impacts on electrical grids




Source: Adikari and Yoshitani, 2009

Source: Jha, A. 2011. Urban Flood Risk Management for the 21st Century. Expert Workshop on Urban Flood Risk Management, World Bank, Washington DC, March 27, 2011

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




*Source:* Adamo and de Sherbinin (2009). The impact of climate change on the spatial distribution of populations and migration. Proceedings of the Expert Group Meeting on Migration. New York: UN Population Division. Runoff data from Nohara et al. (2006). Population data from CIEISN (2005)

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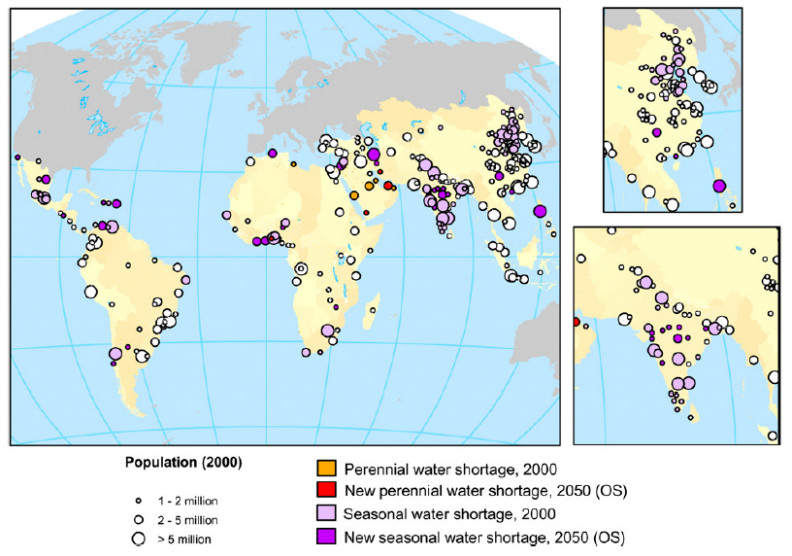
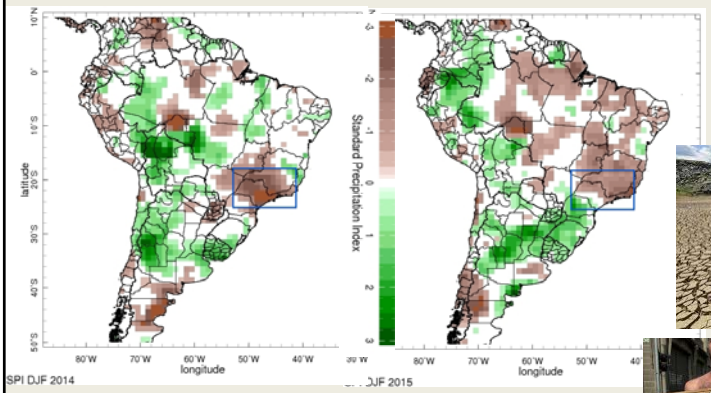
# Drought and Water Scarcity

Spatial distribution of large cities and their water shortage status, in 2000 and 2050

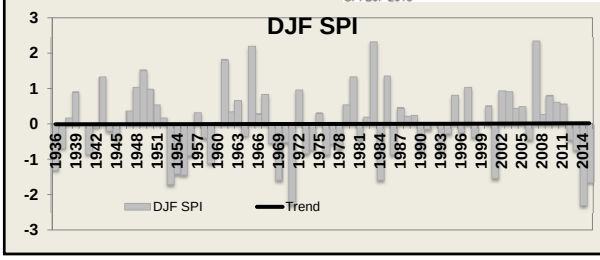



Source: McDonald et al. 2011 *PNAS*

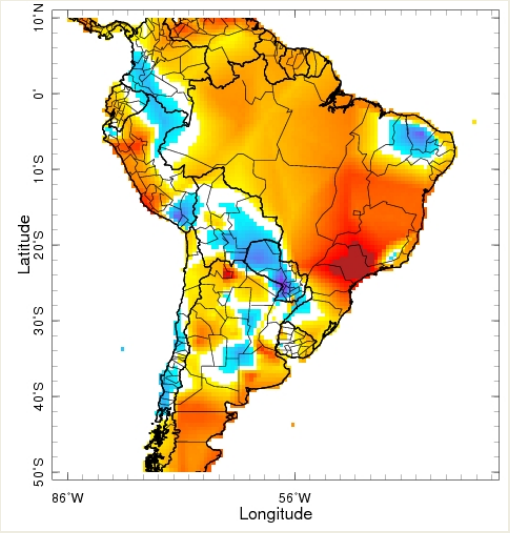
# Sao Paulo Drought







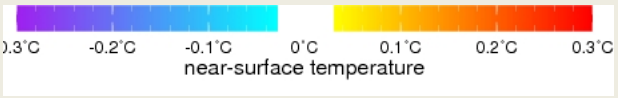

The actual values for 2014 and 2015 are respectively -2.28 and -1.63 standard deviations. By definition, SPI <-1 is moderate drought



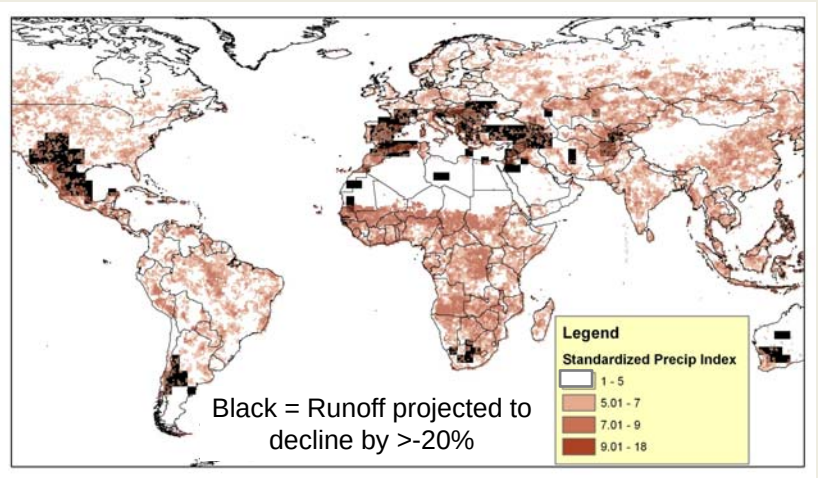

DJF temperature trends. 1950-2015.

Degrees C/decade

1.75ºC increase since 1950

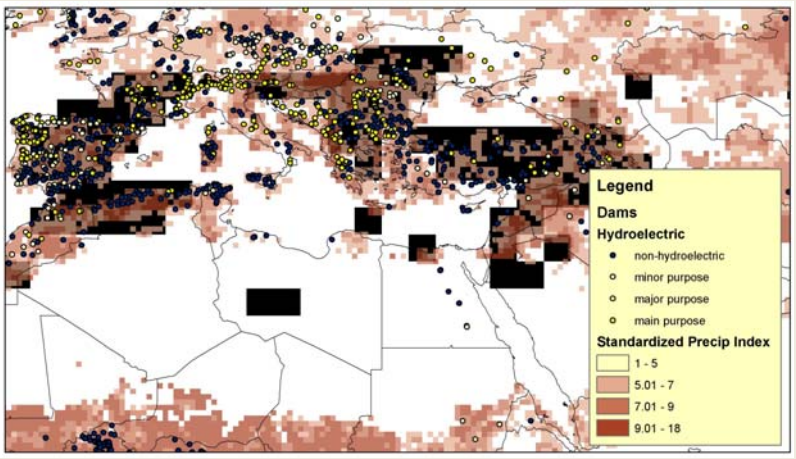



# Drought Frequency Today and Projected Runoff in 2080




*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)

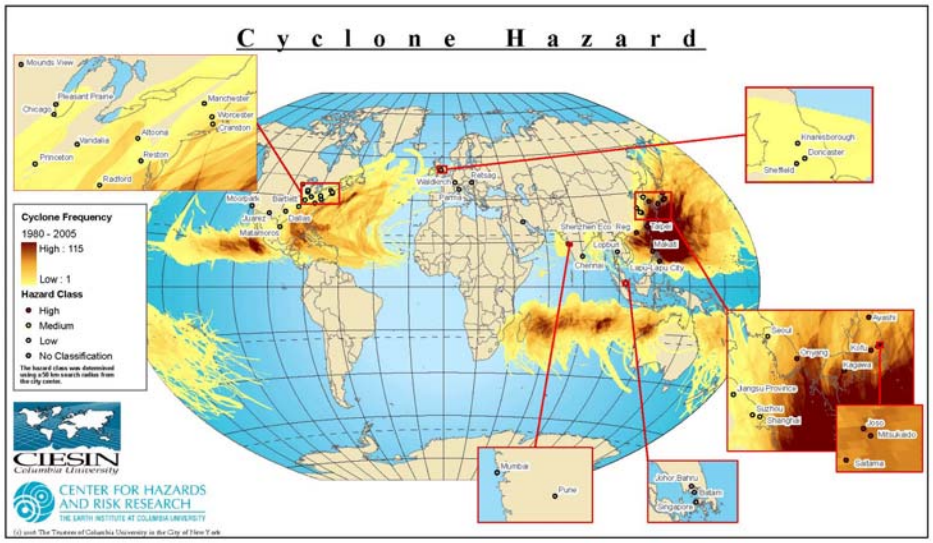
# Drought Frequency Today and Projected Runoff in 2080




Hydroelectric facilities in the Mediterranean Basin may experience seasonal shortages in hydropower

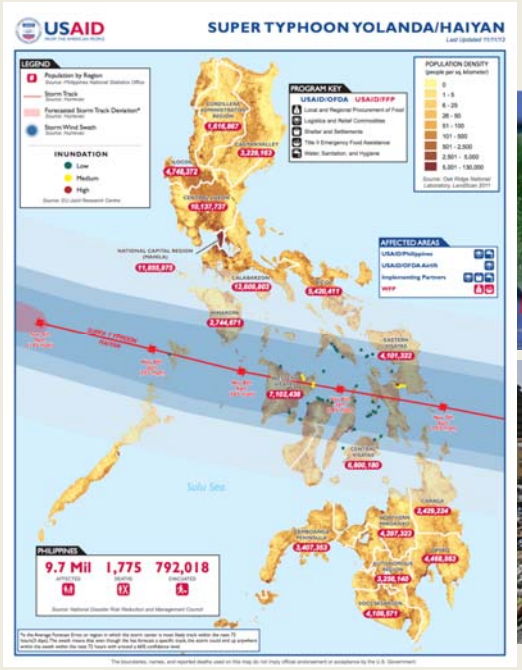
*Sources:* de Sherbinin and Chen 2010, based on UNISDR Global Risk Update and Lehner *et al.* (2010) Global Reservoir and Dam Database (GRaND)

# Exposure to Cyclones

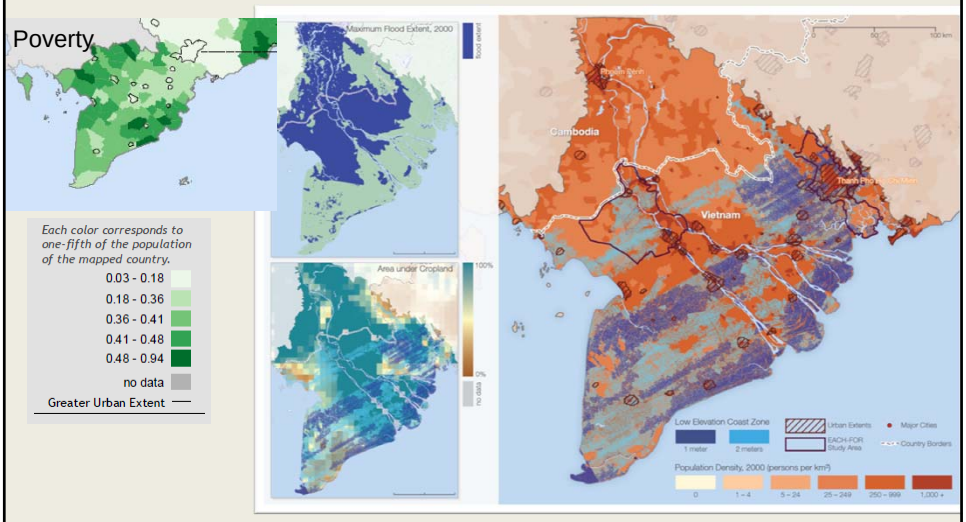



*Source*: Dilley, M., R.S Chen, U. Deichmann, A. Lerner-Lam and M. Arnold (2005), *Natural Disaster Hotspots: A Global Risk Analysis*, World Bank, Washington DC.

# Typhoon Haiyan

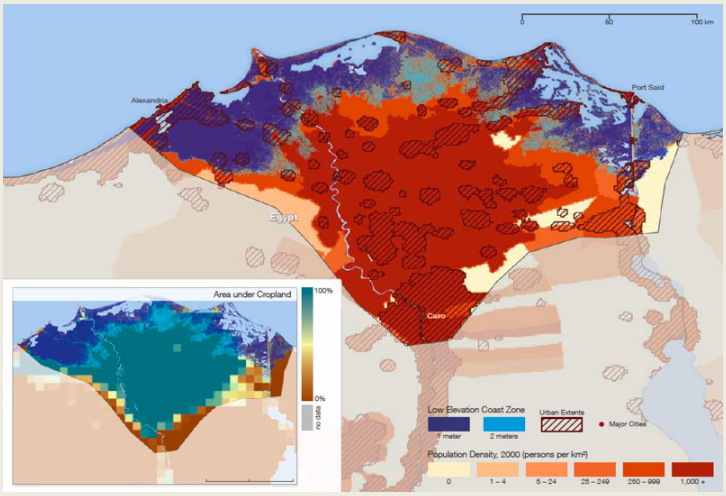



# Mekong Delta Sea Level Rise
## (1-2 meter)




*Source:* Warner et al. 2009 *In Search of Shelter.* Bonn, Germany: UNU-EHS, CARE, and CIESIN.

# Nile Delta Sea Level Rise
## (1-2 meter)




*Source:* Warner et al. 2009 *In Search of Shelter.* Bonn, Germany: UNU-EHS, CARE, and CIESIN.

# Past and Future Climate Impacts in New York City

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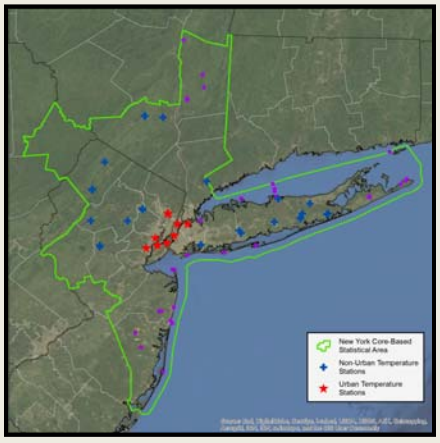
## Past and Future Climate Impacts in New York City

- 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
- Continuring for **three or more** consecutive days.

Daily average temp of **82 F** for NYC

*Source:* Weber, de Sherbinin et al., 2015. "Heat Stress and Urban Heat Island Indicators Associated with Climate Change"

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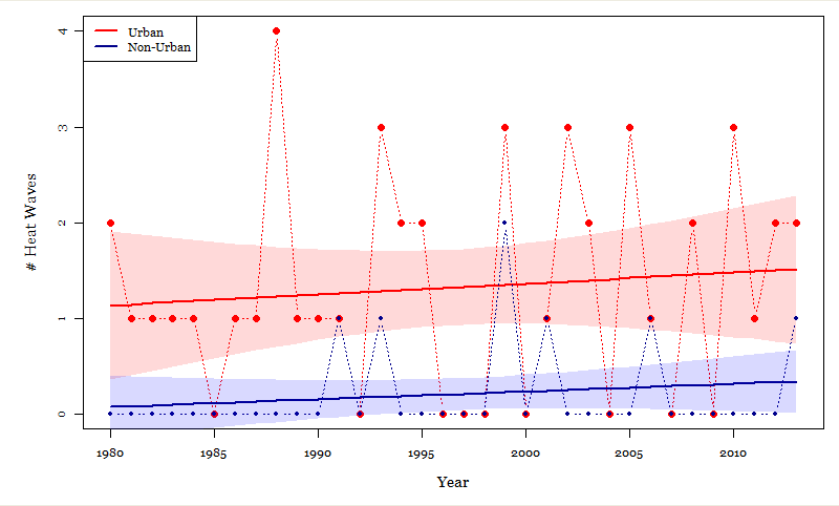
# NYC: Urban Heat Wave Indicator

## Number of Heat Waves




*Source:* Weber, de Sherbinin et al., 2015. "Heat Stress and Urban Heat Island Indicators Associated with Climate Change"

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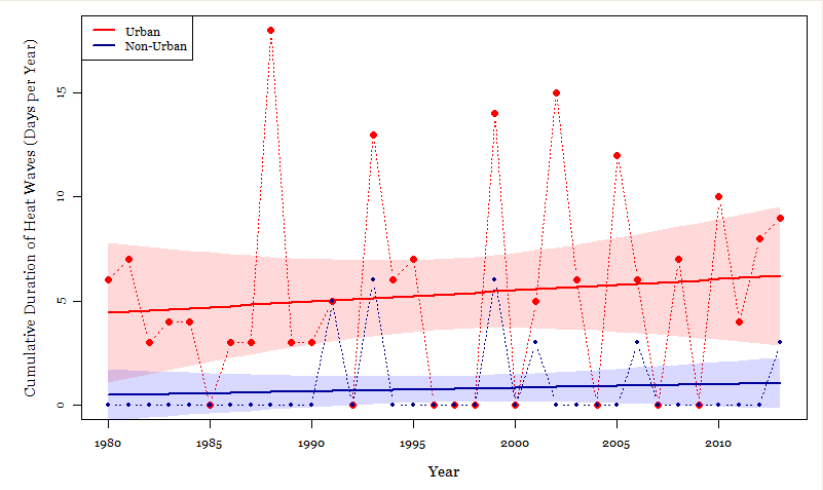
# NYC: Urban Heat Wave Indicator

## Cumulative Duration (days per year) of Heat Waves




*Source:* Weber, de Sherbinin et al., 2015. "Heat Stress and Urban Heat Island Indicators Associated with Climate Change"

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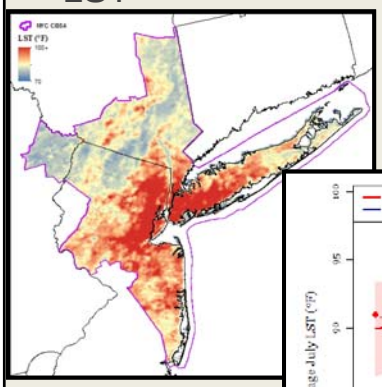
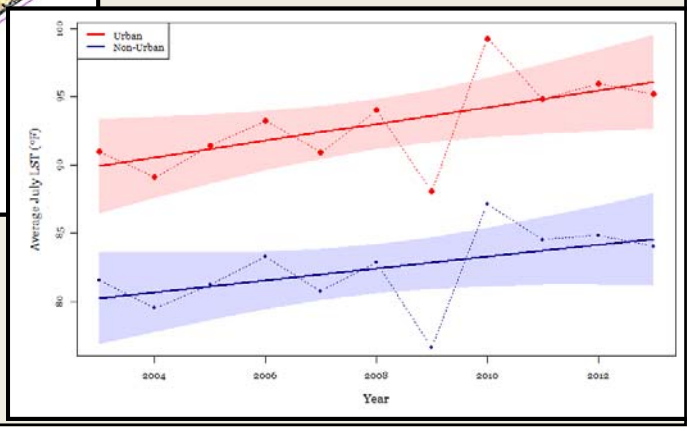
# Trends in Land Surface Temperatures

LST

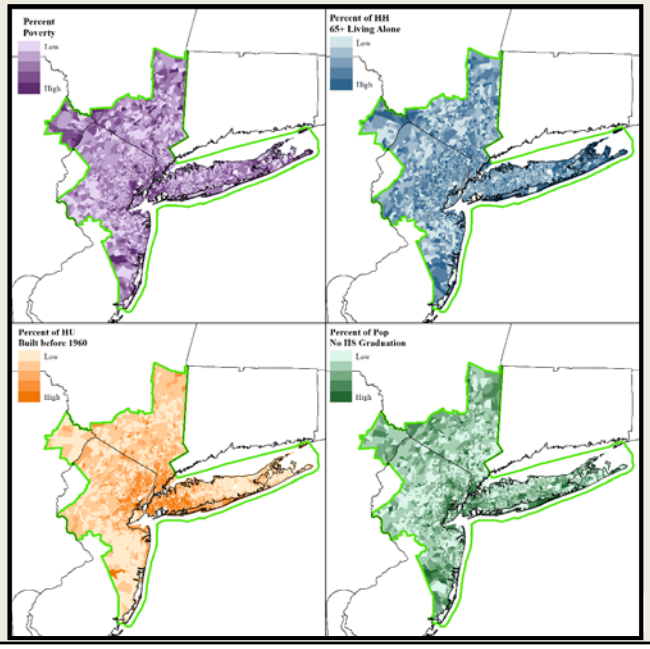


July 2012




# Social Sensitivity Index

Poverty



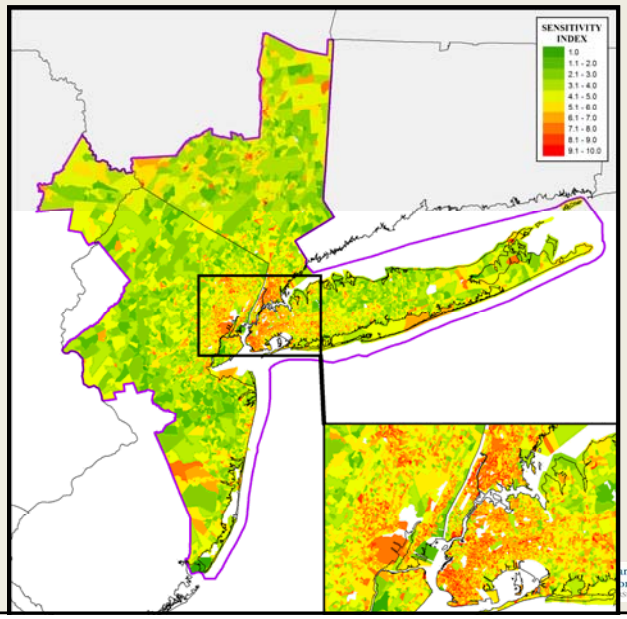

% of HH 65+ Living Alone

% of HH Built before 1960

% of Pop. Without High School Graduation

30

# Heat Stress Sensitivity Index

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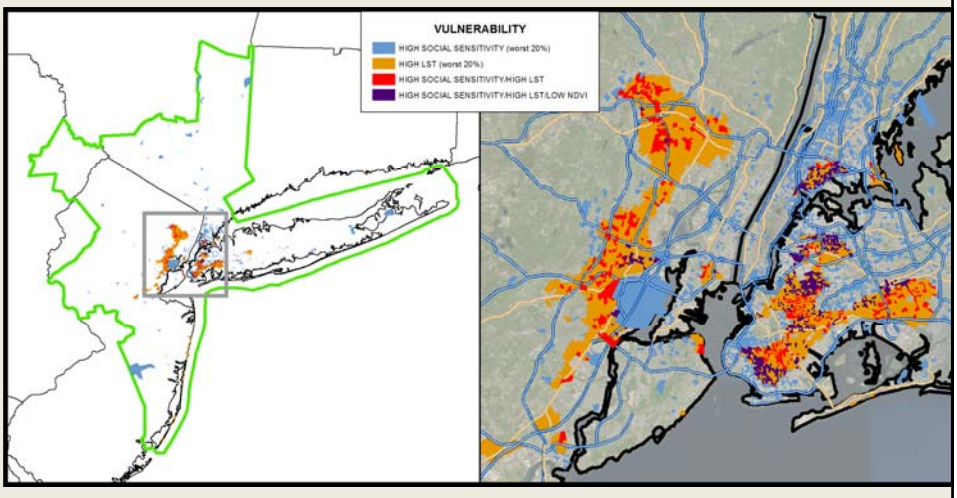
# Vulnerability

Intersection of areas of high exposure and high sensitivity




*Source:* Weber, de Sherbinin et al., 2015. "Heat Stress and Urban Heat Island Indicators Associated with Climate Change"

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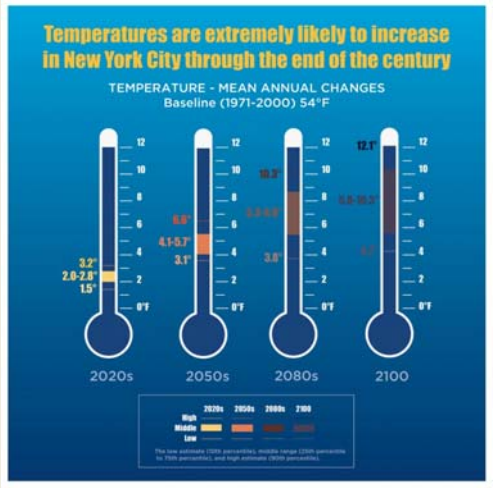
# Heat Vulnerability Outcome Measures

- 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

*Source:* Madrigano et al,, 2015. "A Case-Only Study of Vulnerability to Heat Wave–Related Mortality in New York City (2000–2011)", *EHP*

# Future Heat Stress in NYC




***Temperature projections for New York City***

- **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.

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

*Source:* New York Panel on Climate Change Second Assessment Report (NPCC2), 2015

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# Impacts of Heat Waves on Energy Demand

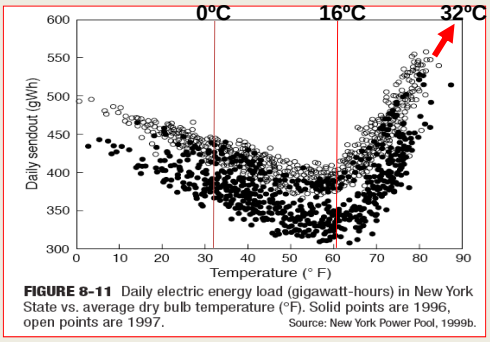



**FIGURE 8–11** Daily electric energy load (gigawatt-hours) in New York State vs. average dry bulb temperature (°F). Solid points are 1996, open points are 1997. Source: New York Power Pool, 1999b.

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

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

*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

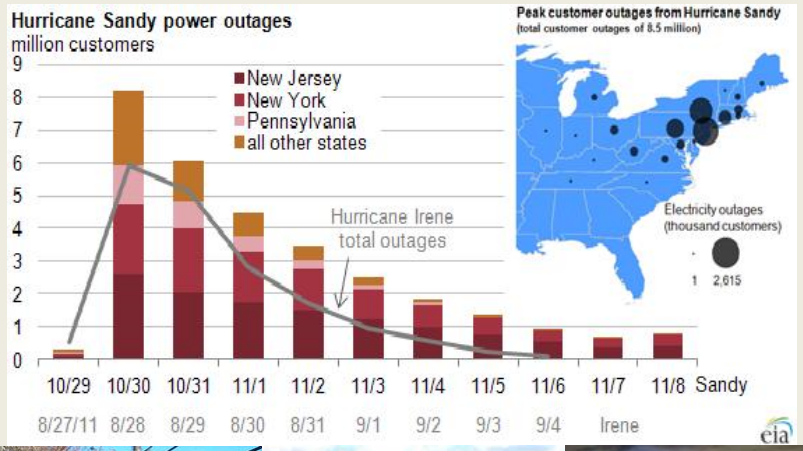
*Source:* Bevington, ImageCAT, (2013)

# Hurricane Sandy



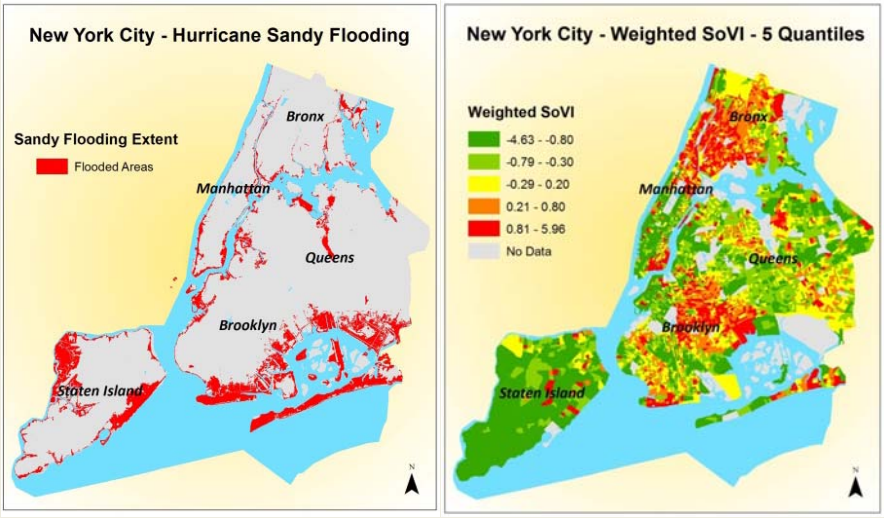


# Hurricane Sandy Power Outages






# Flood Vulnerability




*Source:* de Sherbinin and Bardy, 2015 (forthcoming)

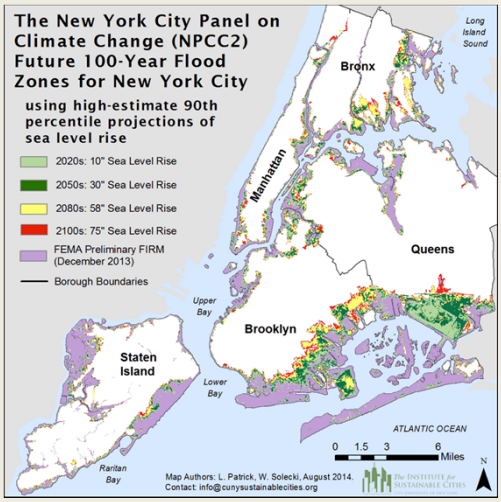
# Are socially vulnerable people more likely to be in flooded areas?

| *Category* | *Weighted SoVI* | *Averaged SoVI* | *% Population Aged <5 and >65* |
|---|---|---|---|
| A (no exposure) | 0.13 | 0.13 | 18.4 |
| B (low exposure) | -0.05 | 0.08 | 19.4 |
| C (moderate exp.) | -0.02 | 0.05 | 19.0 |
| D (high exposure) | 0.20 | 0.32 | 21.5 |

## 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 Rise




***100-year flood map***

- **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.

*Source:* New York Panel on Climate Change Second Assessment Report (NPCC2), 2015

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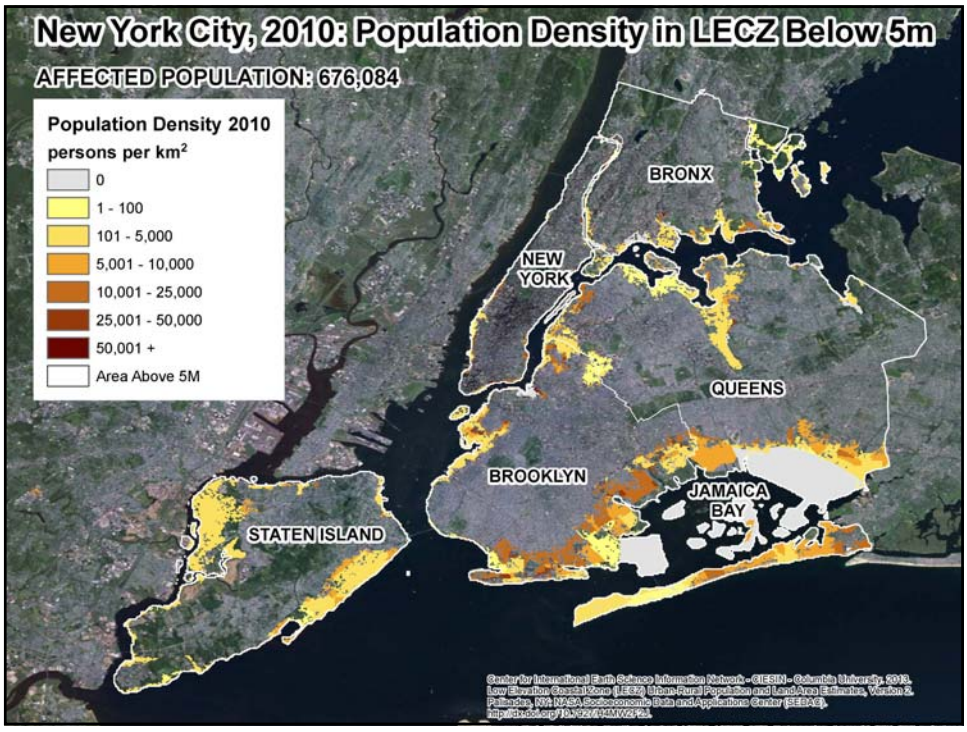

# NYC Resilience and Adaptation Strategies

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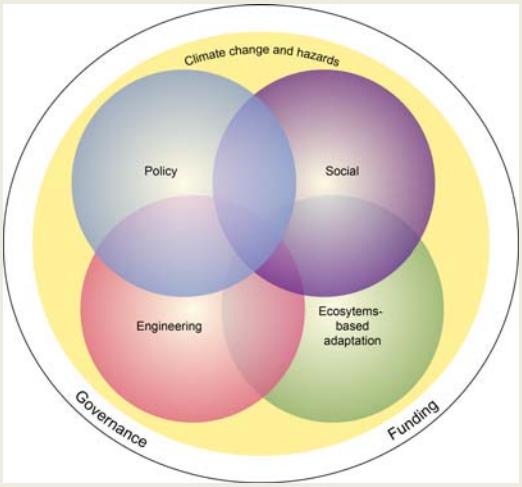
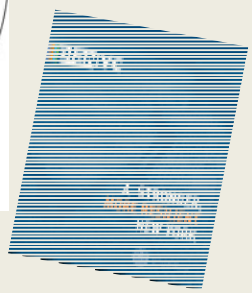
# Approaches to Resilience Action



*Source:* Bader (2015)

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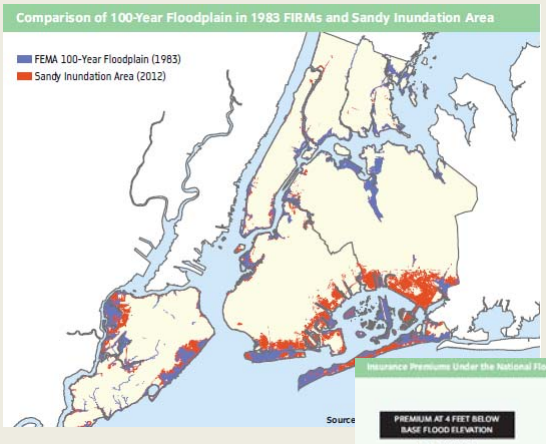
# Examples

- 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





*Source:* PlaNYC: A Stronger More Resilient New York (2013)

## Proceedings Before New York Public Service Commission

Policy

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

Slides Courtesy Michael Gerrard, Sabin Center for Climate Change Law

## New York Public Service Commission Decision – 20 February 2014

Policy

"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."

Slides Courtesy Michael Gerrard, Sabin Center for Climate Change Law

Policy

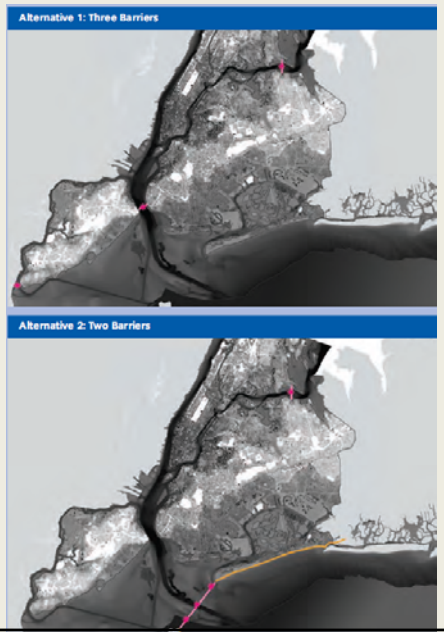
# Implementation

- 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

Slides Courtesy Michael Gerrard, Sabin Center for Climate Change Law

Engineering

# 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

Ecosystem

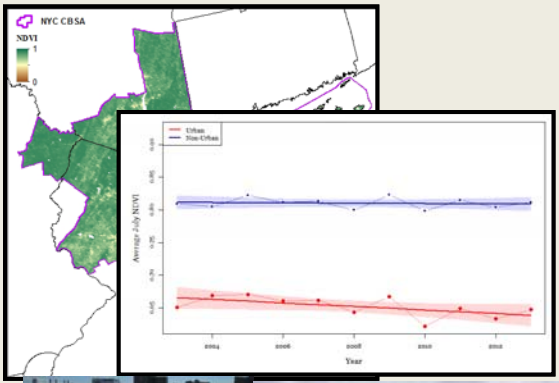
## Wetlands and Beaches as Surge Defenses


Social/Ecosystem

## Heat Stress

Cooling Centers


Green roofs and tree planting




## Conclusions

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## Closing Remarks

- Temperature increases of up to 4$^{o}$ 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

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Merci!

amd155@columbia.edu

www.ciesin.columbia.edu

www.populationenvironmentresearch.org