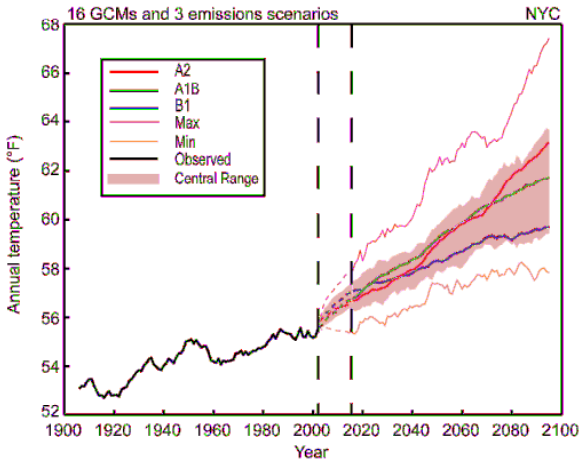
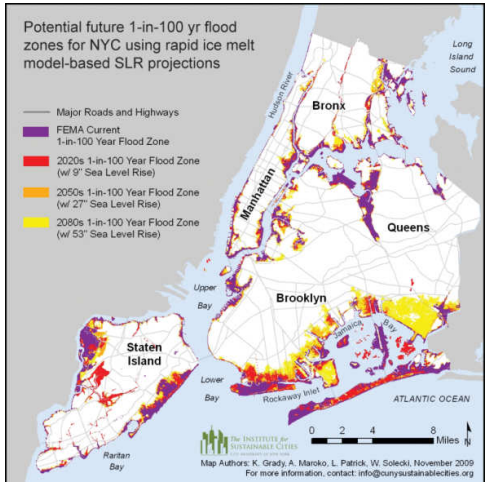


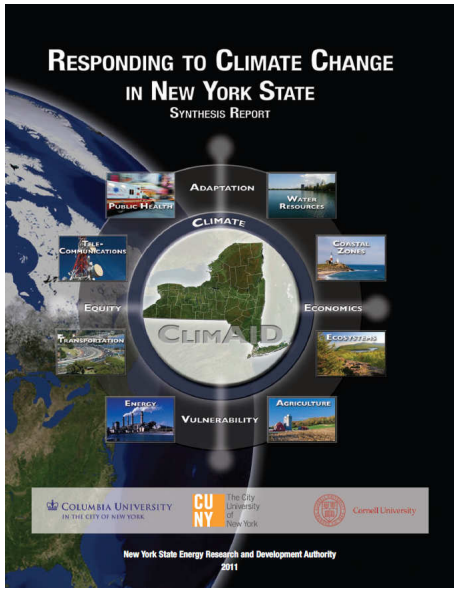
NPCC, 2010



NPCC, 2010

Climate Impacts and Adaptation

EPA Region 2

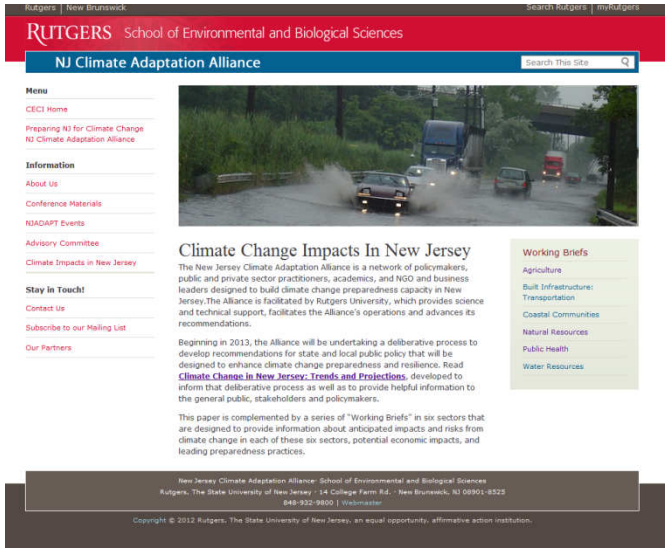


ClimAID, 2011

Dr. Cynthia Rosenzweig

NASA GISS / Columbia University

January 30, 2013



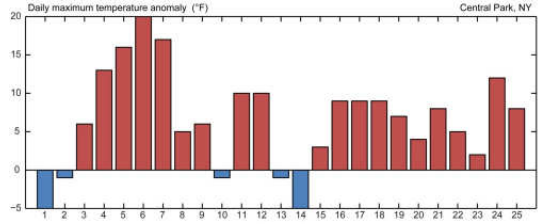
NJCAA, 2012

Outline

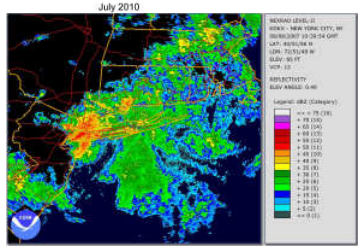
- Current Climate Stresses
- Future Climate Projections
- Climate Impacts
- Climate Adaptation – New York City and NASA
- Hurricane Sandy

Current Climate Stresses

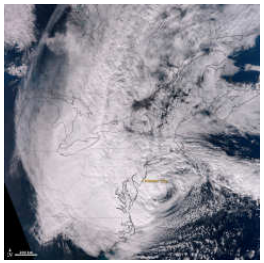
- Extreme heat and heat waves



- Intense precipitation and flooding



- Mid-latitude cyclones (nor'easters)
  - Peak November to April



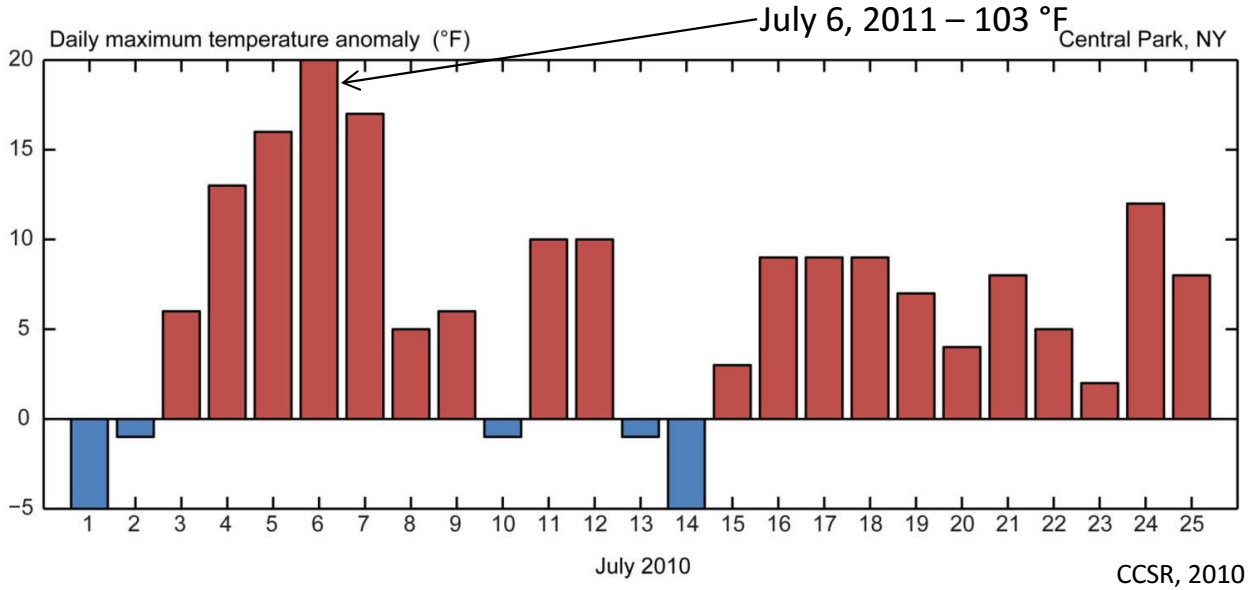
- Tropical cyclones/hurricanes
  - Peak August to September

- Droughts

CCSR, NOAA, NASA

Current Extreme Heat Events

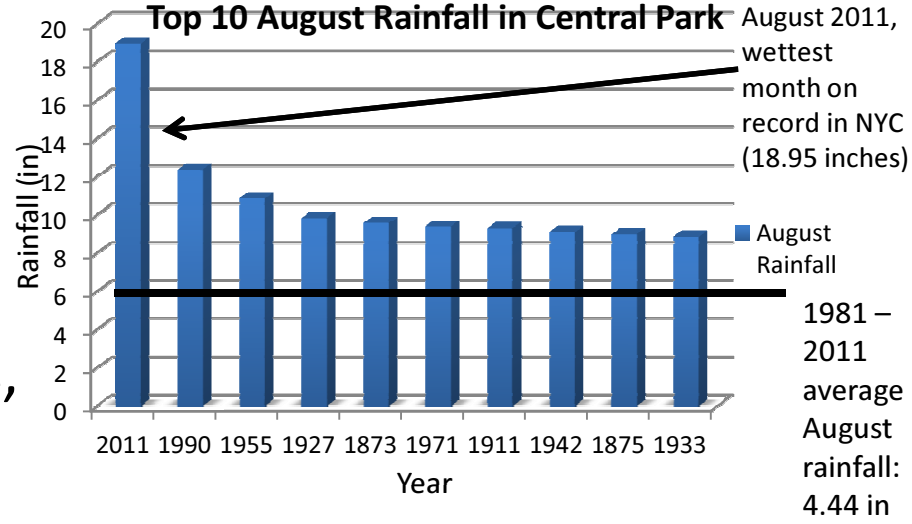
- ***Climate Hazard***
  - Number of days with maximum temperature above 90 °F or 100 °F
  - Heat waves defined as 3 or more consecutive days with maximum temperatures above 90 °F
- ***Recent examples***
  - Extreme heat in July, 2011
  - The past three summers ('10,'11,'12) have had a day with maximum temperatures above **100°F** in Central Park. Only one other time on record (early 1950s) has had this occur

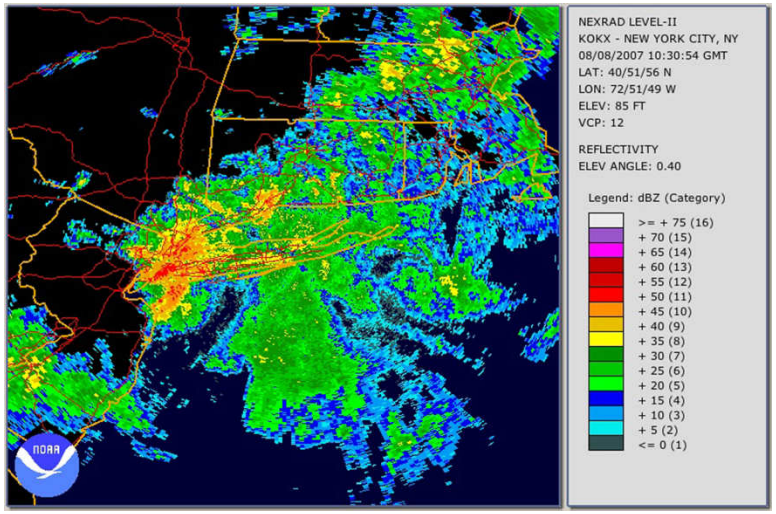


July 2011 experienced ~2.5 times more days above 90 °F (16) than the July 1870 – 2009 average (6.1)

Current Intense Precipitation Events

- ***Hazard***
  - Short duration, heavy rainfall events
  - Can be caused by thunderstorms, weather fronts, and coastal storms
- ***Recent examples***
  - August 14, 2011 (~ 8 inches of rain at JFK)
  - August 8, 2007 (1 inch per hour rainfall rates)





Radar image on August 8, 2007

CCSR, 2011 and NOAA

Current Nor'easters

- ***Hazard***
  - Non-tropical coastal storms that bring rain/snow, high winds, and coastal flooding
  - Named based on the wind direction from the northeast
- ***Recent examples***
  - Back – to back – to back storms in February/March 2011
  - Early season snowfall October 2011

February 25 – 26, 2011 Snowstorm

March 12 – 15, 2011 Rain and Wind Storm

March 29 – 31, 2011 Rainstorm

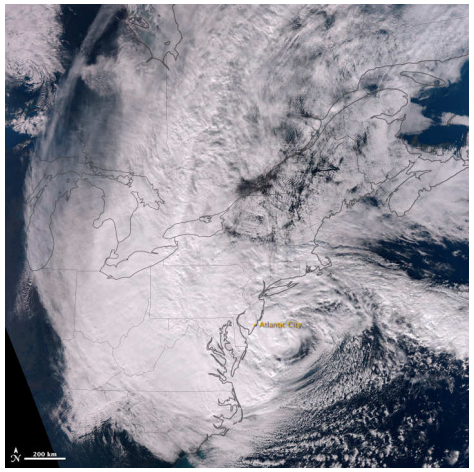
Newsday

Current Tropical Cyclones/Hurricanes

- ***Hazard***
  - Tropical cyclones bring coastal flooding, storm surge, high winds, and heavy rain

Hurricane Irene approaches the Northeast on August 28, 2011. Source: NASA

- ***Recent examples***
  - Hurricane Sandy, October 2012
  - Hurricane Irene, August 2011



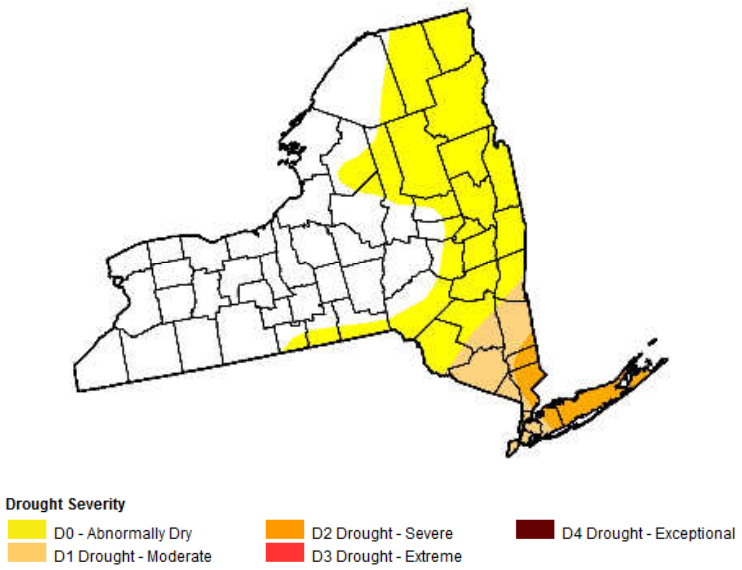
Hurricane Sandy approaches the on October 29, 2012. Source: NASA

Droughts

- ***Droughts reflect a complex blend of climate and non-climate factors that operate at a number of timescales***
  - Climate factors include precipitation, temperature, evaporation, wind, sky cover and humidity
  - Droughts can last from a few months to multiple years

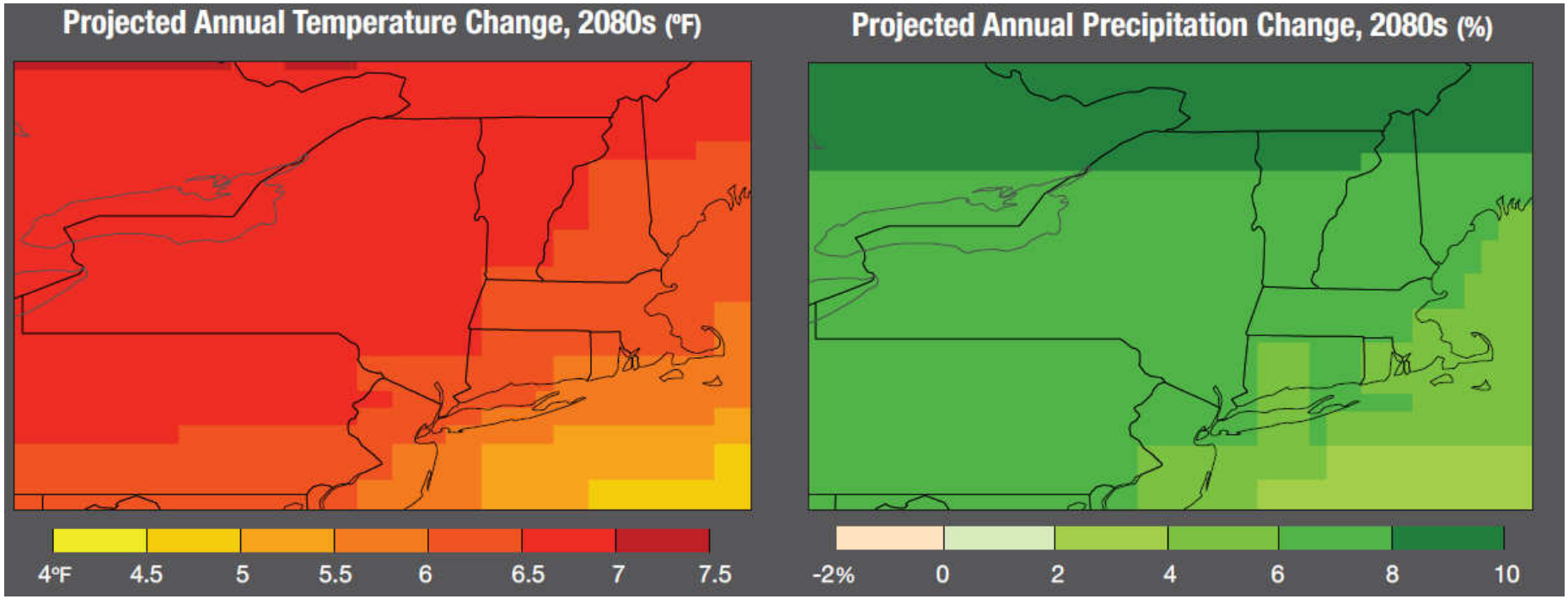
- ***Examples***
  - The Northeast region experienced an extended period of drought during the 1960s
  - Short duration drought in 1999
  - Spring 2012 (wildfires)

Drought Monitor April 10,2012



ClimAID, 2011 and Northeast Regional Climate Center

Climate Projections



Warmer temperatures are projected

Small increases in annual precipitation are projected

ClimAID, 2011 and NJCAA, 2012

Sea Level Rise Projections

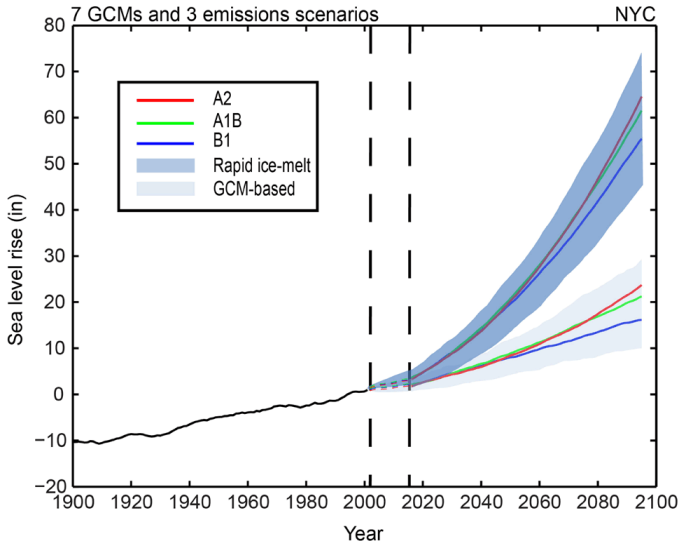
EPA Region 2

*Projected Sea Level Rise for New York State (inches)**

	2020s	2050s	2080s
GCM-based	+1 to +5	+5 to +12	+8 to +23
Rapid Ice Melt Scenario	+4 to +10	+17 to +29	+37 to +55

*Projected Sea Level Rise for New Jersey (inches)***

	2050	2100
Total SLR projections	+ 13 to 22	+34 to 56



Combined observed (black line) and projected sea level rise for two future sea level rise scenarios. Projected global climate model (GCM) changes through time are joined to the observed historical data. A ten-year filter has been applied to the observed data and modeled output.

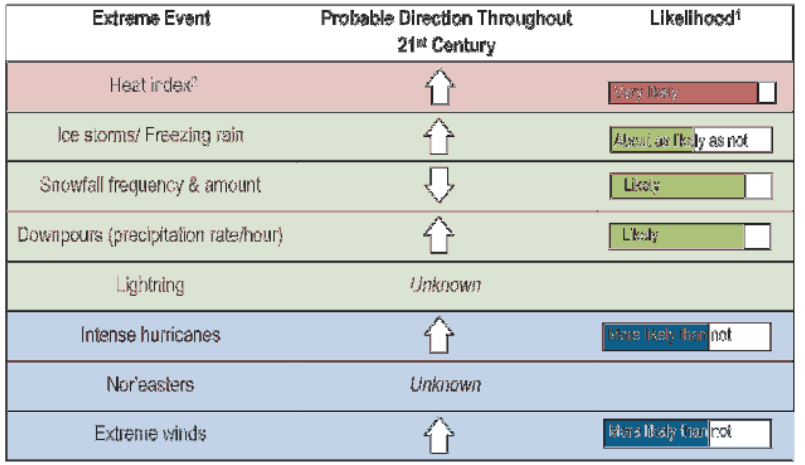
*NYS SLR projections from ClimAID, 2011

**NJ SLR projections from NJCAA, 2012

Qualitative Projections

EPA Region 2

- **Extreme heat events** are projected to increase, and **heat waves** are expected to increase in frequency and duration
- Precipitation is more likely to fall as **heavy precipitation events** and the intensity of the heaviest rainfalls is projected to increase
- **Short-duration warm season droughts** are projected to become more common
- **Coastal flooding** associated with sea level rise is likely to increase



Extreme Event	Probable Direction Throughout 21st Century	Likelihood[1]
Heat index[2]	⇧	Very likely
Ice storms/ Freezing rain	⇧	About as likely as not
Snowfall frequency & amount	⇩	Likely
Downpours (precipitation rate/hour)	⇧	Likely
Lightning	*Unknown*	
Intense hurricanes	⇧	More likely than not
Nor'easters	*Unknown*	
Extreme winds	⇧	More likely than not

Source: Columbia University Center for Climate Systems Research

[1] Likelihood definitions found in the first section, "Definitions and Terms."

[2] The National Weather Service uses a heat index related to temperature and humidity to define the likelihood of harm after "prolonged exposure or strenuous activity" (http://www.weather.gov/om/heat/index.shtml).

Likelihood definitions based on IPCC.
>90% Very likely
>66% Likely
>50% More likely than not
33 to 66% About as likely as not

NPCC, 2011, ClimAID, 2011and NJCAA, 2012

Water Resources

Climate Impacts

Enhanced water cycle due to warmer temperatures leads to increased evaporation and precipitation. More precipitation falling in heavy events with longer dry periods in between, which can have a variety of impacts on water resources.

- Increased flooding from heavy rains will increase pollutants in the water supply, inundating wastewater treatment plants and other vulnerable developments in floodplains
- Less frequent summer rainfall will stress water supply systems
- Increasing water temperatures in rivers and streams impact aquatic health

ClimAID, 2011 and NJCAA, 2012

Coastal Zones

Climate Impacts

High water levels, strong winds, and heavy precipitation from coastal storms already impact coastal areas. Warming ocean waters raise sea level through thermal expansion which will result in more frequent and extensive coastal flooding and stronger coastal storms.

- Barrier islands are being significantly altered due to erosion, overwash and new inlets created by strong coastal storms
- Sea level rise will increase the risks to populations in low-lying coastal areas and will lead to permanent inundation of low-lying areas, more frequent storm surge flooding and increased beach erosion
- Loss of coastal wetlands and salt marshes will reduce species diversity

ClimAID, 2011and NJCAA , 2012

Ecosystems

Climate Impacts

Within the next few decades, there will likely be widespread shifts in species composition in forests and other natural landscapes.

- Loss of spruce-fir forests, alpine tundra and boreal plant communities
- Longer growing season and fertilization effect of increasing carbon dioxide could increase the productivity of certain hardwood tree species, provided growth is not limited by other factors
- Carbon dioxide fertilization will increase the growth rate of fast-growing species, which are often invasive
- Lakes, streams, inland wetlands and associated aquatic species will be highly vulnerable to changes in timing, supply and intensity of rainfall and snowmelt, groundwater recharge and the duration of snow cover
- Increasing water temperatures will negatively impact coldwater fish

ClimAID, 2011 and NJCAA, 2012

Agriculture

Climate Impacts

Increased summer heat stress will negatively affect cool-season crops and livestock unless farmers take adaptive measures such as shifting to more heat-tolerant crop varieties and improving the cooling capacity of livestock facilities

- Longer growing seasons and warmer winters will result in Increased weed and pest pressure
- Water management will become more challenging due to the increased frequency of heavy rainfall events and summer water deficits by mid-to-late century
- Higher temperatures and a longer growing season will allow for opportunities to explore new crops, new varieties and new markets

ClimAID, 2011 and NJCAA, 2012

Energy Systems

Climate Impacts

Climate change will adversely affect energy system operations, increase the difficulty of ensuring adequate supply during peak demand periods, and worsen problematic conditions, such as the urban heat island effect.

- More frequent heat waves will cause an increase in the use of air conditioning, stressing power supplies, and increasing peak demand loads.
- Increased air and water temperatures will decrease the efficiency of power plants due to decreased cooling capacity.
- Energy infrastructure near the coast is vulnerable with increasing frequency and severity of coastal flooding due to sea level rise.
- Transformers and distribution lines for both electric and gas supply are vulnerable to extreme weather events.

Climaid, 2011

Transportation

Climate Impacts

Over the next several decades, heat waves and heavy precipitation events are likely to result in moderate, more frequent transportation problems such as flooded streets and delays in public transportation.

- Transportation infrastructure materials, such as asphalt, train rails and bridge expansion joints are vulnerable to increased temperatures and frequency of extreme heat events
- Low-lying transportation systems such as subways and tunnels, especially in coastal and near-coastal areas, are at particular risk of flooding as a result of sea-level rise, storm surge and heavy precipitation
- Freeze-thaw cycles that disturb roadbeds may increase in some areas as winter temperatures rise
- Less ice cover on the Great Lakes may increase the length of the shipping season, but may also increase the frequency of lake-effect snow events

ClimAID, 2011 ; NJCAA 2012

Telecommunications

Climate Impacts

Communication service delivery is vulnerable to tropical storms, ice, snow, lightning, high winds, and other extreme weather events, some of which are projected to change in frequency and/or intensity.

- The delivery of telecommunications services is sensitive to power outages, such as those resulting from increased demand associated with heat waves, which are expected to increase with climate change.
- Communication lines are vulnerable to heavy precipitation events, flooding, and freezing rain.
- Sea level rise in combination with coastal storm surge is causing increasing risks of widespread outages.

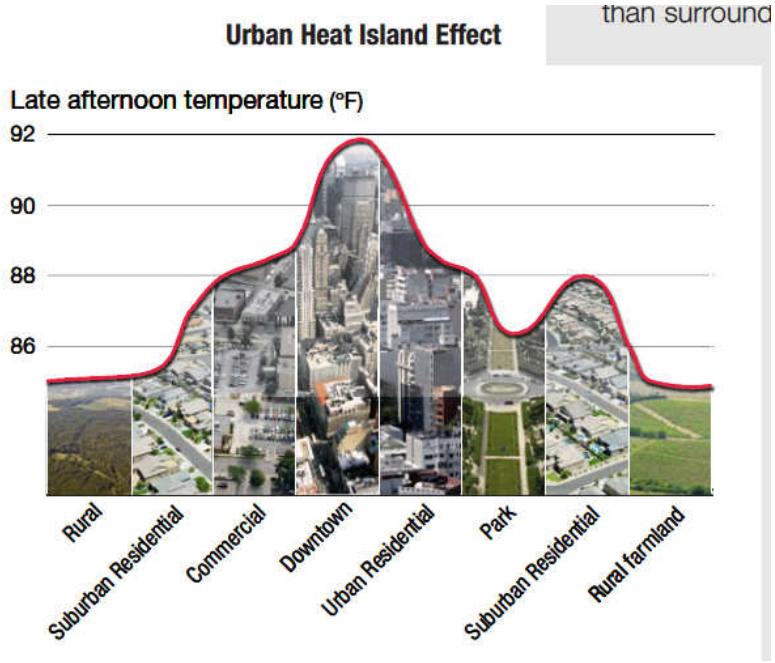
ClimAID, 2011

Public Health

Climate Impacts

Climate change impacts to be considered when enhancing resiliency of public health systems include:

- More intense precipitation and flooding along the coasts and rivers could lead to increased stress and mental health impacts, impaired ability to deliver public health and medical services, increased respiratory diseases such as asthma, and increased outbreaks of gastrointestinal diseases.
- Increases in heat-related mortality and morbidity are expected with more frequent and intense heat waves
- Changes in water supply and water quality could impact human health.
- Water- and food-borne diseases are likely to increase without interventions.



ClimAID, 2011 and NJCAA 2012

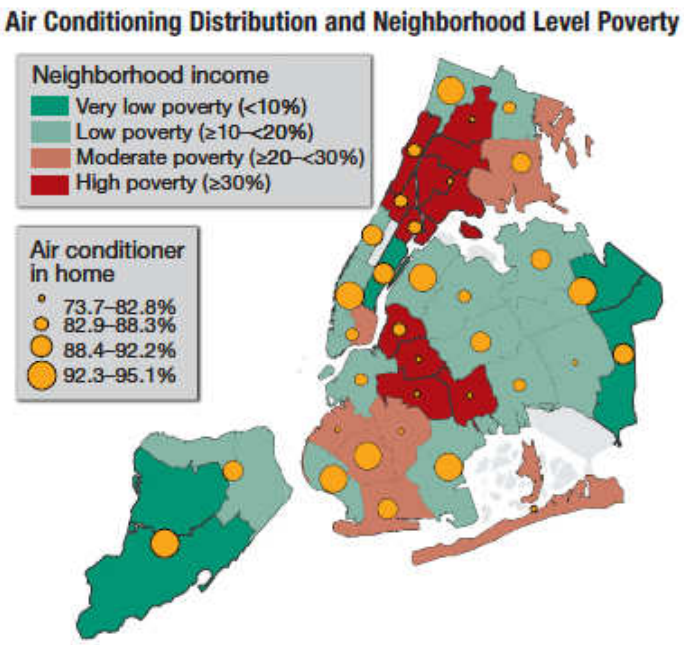
Vulnerable Groups

Climate Impacts

Climate change risks, vulnerabilities, and capacities to adapt are uneven across regions, sectors, households, individuals, and social groups. Equity concerns emerge because climate change impacts and adaptation policies can worsen existing inequalities and can also create new patterns of inequities.

In particular, certain groups will be disproportionately affected by the impacts of climate change. Elderly, disabled, and health-compromised individuals are especially vulnerable to climate hazards. Residents of coastal areas are vulnerable to increasing risks of,

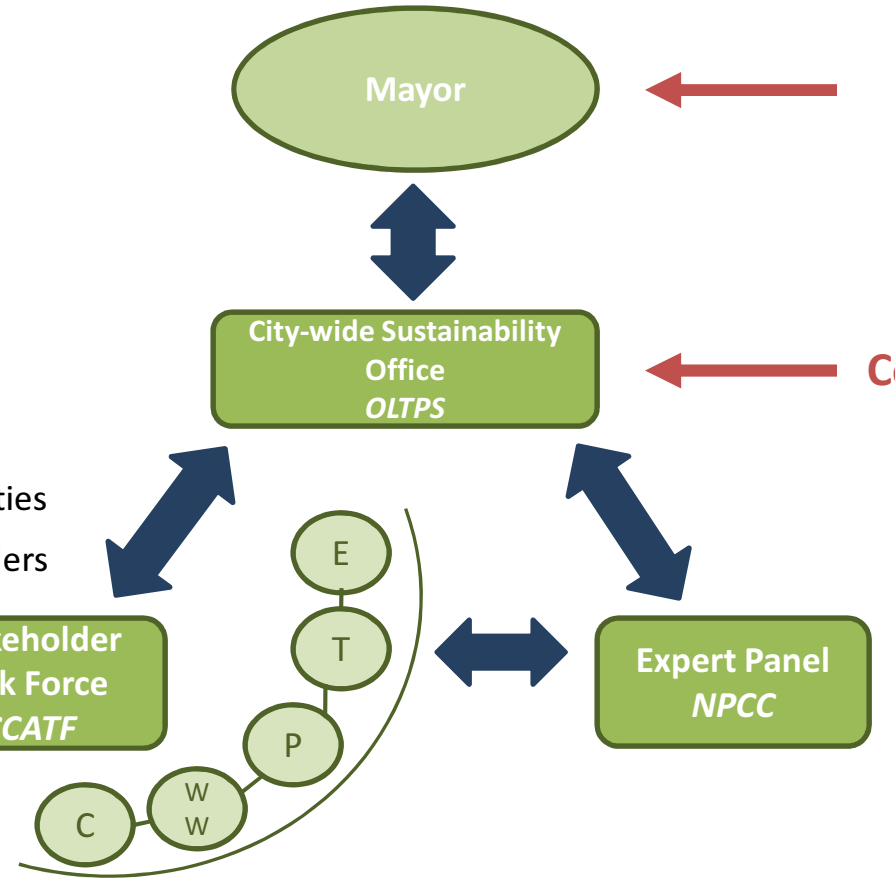
- Direct impacts of storm surge flooding
- Mental health stressors related to evacuation, and
- Mold and toxic exposures when they return home.



Neighborhoods with higher poverty rates, including Central Harlem, Washington Heights, Fordham, the South Bronx, Greenpoint, Williamsburg, Bedford-Stuyvesant, and others, have lower rates of in-home air conditioning than more affluent parts of the city.

ClimAID, 2011

New York City Process
2008 - 2011



Stakeholders

- City Agencies
- Regional Authorities
- Private Stakeholders

Expert Knowledge Providers

- University scholars and private sector experts
- Social, biological, and physical scientists
- Legal and insurance experts
- Risk management professionals

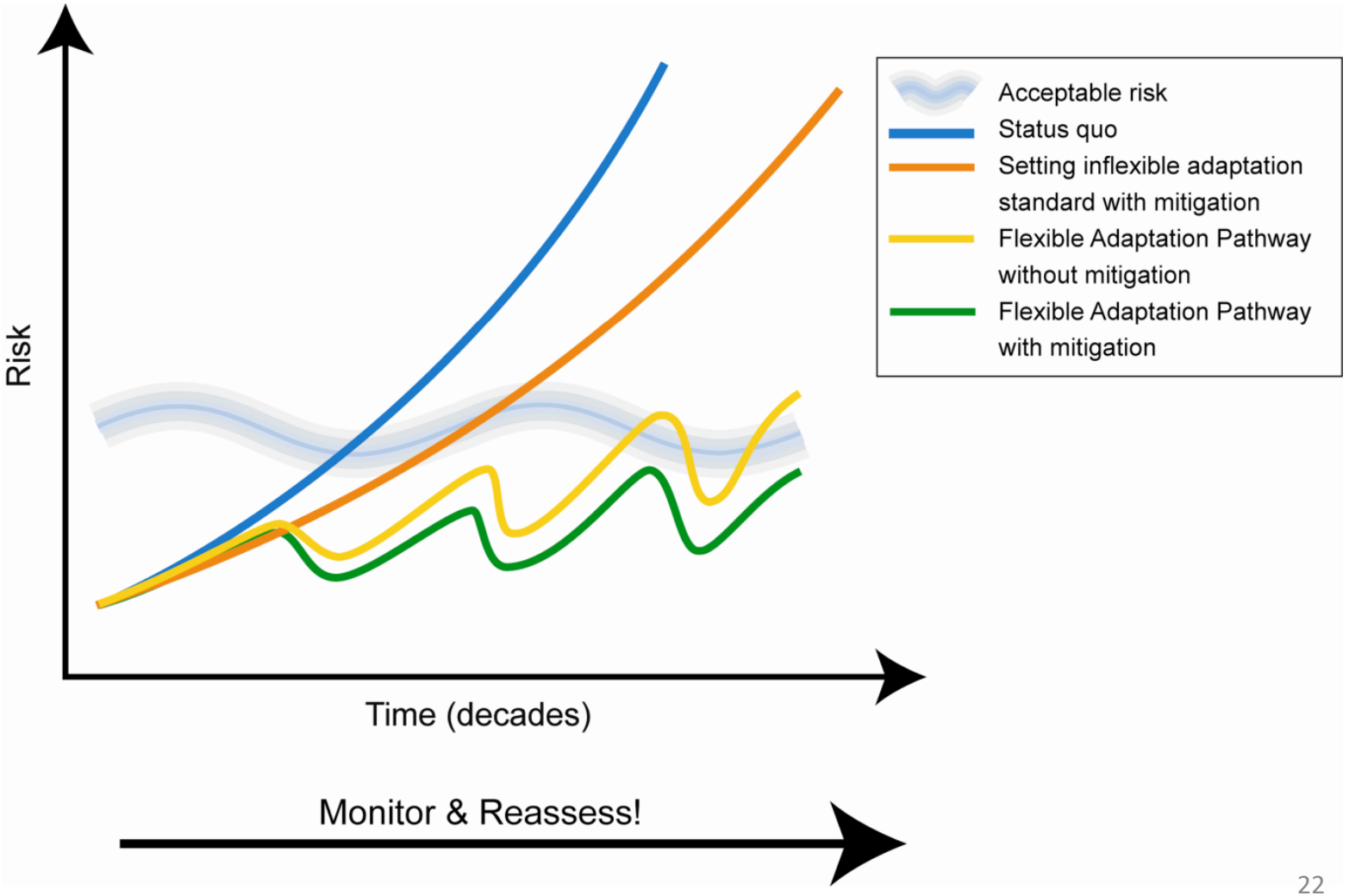
Integration across Sector-specific Working Groups

- Energy (E)
- Transportation (T)
- Policy (P)
- Water & Waste (WW)
- Communications (C)

Source: NPCC, 2011

NPCC Approach

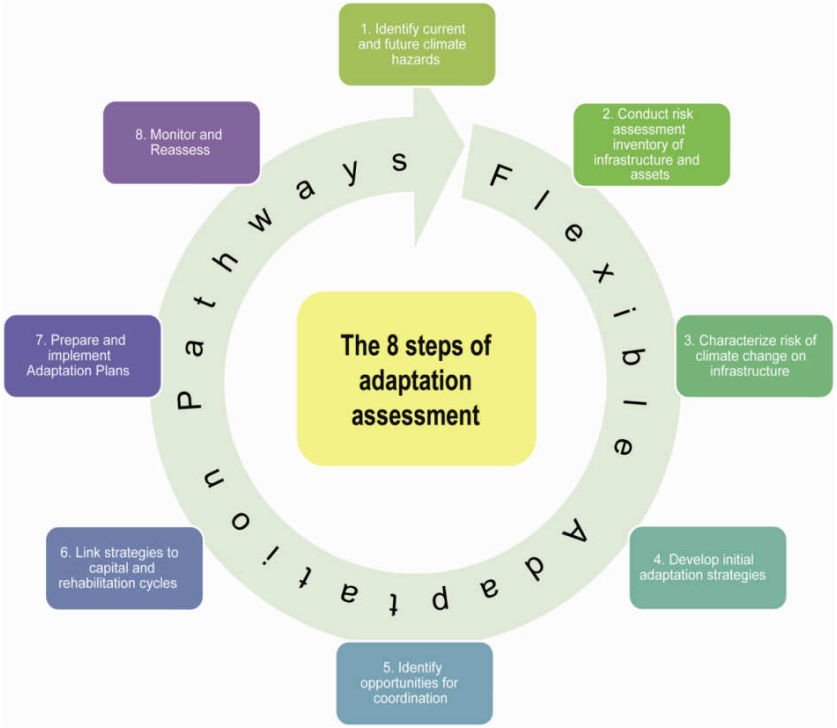
A risk management issue → **Flexible Adaptation Pathways as the response**



Source: NPCC, 2011

Design Adaptation Process

1. Identify current and future climate hazards
2. Conduct inventory of infrastructure and assets and begin to identify vulnerabilities
3. Characterize risk
4. Develop initial list of strategies
5. Identify opportunities for coordination
6. Prioritize strategies
7. Prepare and implement Resilience Plans
8. Monitor and reassess



Source: NPCC, 2011

Framing Adaptation

- *Reduce the level of physical, social, and economic impacts of climate*
- *Take advantage of new opportunities*

Types

- Management/operations
- Infrastructure – physical components of each sector
- Policy

Administrative Groups

- Private vs. public organizations
- Local/municipal, county, state, national

Level of Efforts

- Incremental action
- Large-scale shifts

Timing

- Short term <5 yrs; medium term 5-15 yrs; long term >15 years
- Abrupt Changes - tipping points/policy triggers

NASA Experience

- NASA has modified the 8-step process from NYC city to help guide the Agency's adaptation process
- Resilience and Adaptation Workshops have been held at NASA centers/facilities
- Climate adaptation handouts have been developed for all NASA centers/facilities

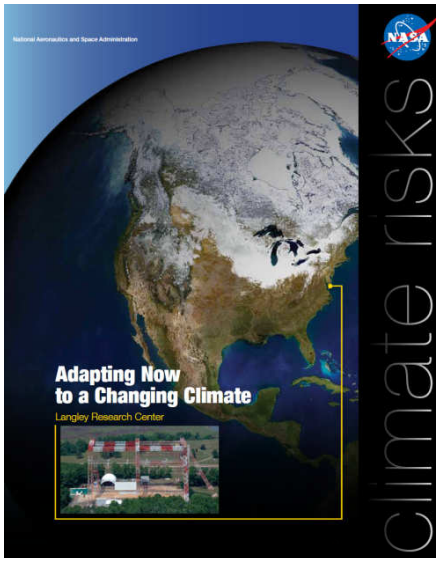


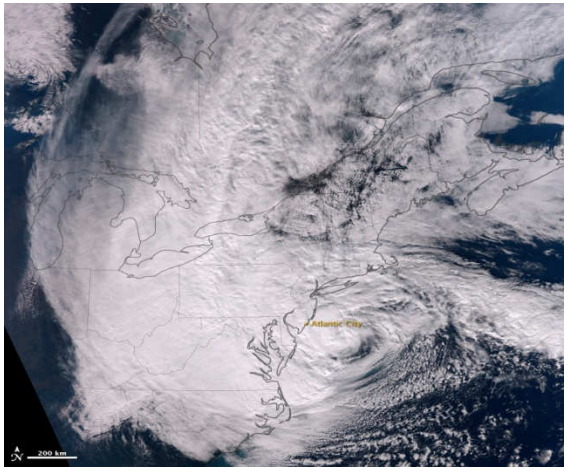
Figure 3. NASA's Climate Risk Workshop Progress

Protecting people, natural, and built systems at NASA sites: **NASA's Climate Risk Workshop Progress**				
		Share of NASA's assets		
Installation	*Workshop*	*Onsite Staff*	*Land Managed*	*Const. Assets*
Agency-wide	7/2009	58,000	330 mi²	$32 B
Kennedy Space Center, FL	5/2010	12.1%	66.4%	18.5%
Ames Research Center, CA	2/2011	7.8%	1.0%	15.1%
Dryden Flight Research Center, CA	8/2011	2.4%	0.4%	1.2%
Langley Research Center, VA	9/2011	6.4%	0.4%	11.3%
Johnson Space Center, TX	3/2012	12.7%	0.8%	7.0%
Progress as of June 2012		*41.4%*	*69.0%*	*54.1%*
Stennis Space Center, MS	10/2012	7.1%	9.9%	9.4%
Wallops Flight Facility, VA	11/2012	1.7%	2.9%	2.8%
Planned by June 2013		*50.2%*	*81.8%*	*66.3%*

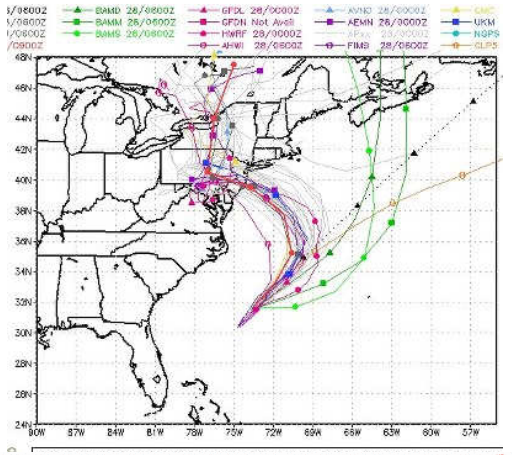
Hurricane Sandy

- Coastal flood elevations in New York Harbor were the highest in all ~300 years of New York City (and New Amsterdam) history
- The storm tide (total water elevation) at The Battery was 13.9 ft, with a peak storm surge of 9.2 ft coming close to high tide
- This is about 5 ft above many of the area's lower sea walls.

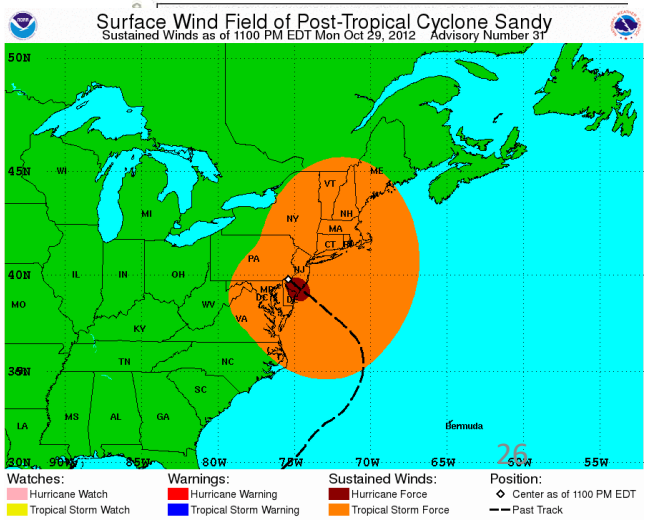
Lowest recorded central pressure north of Cape Hatteras, NC at 943 mb



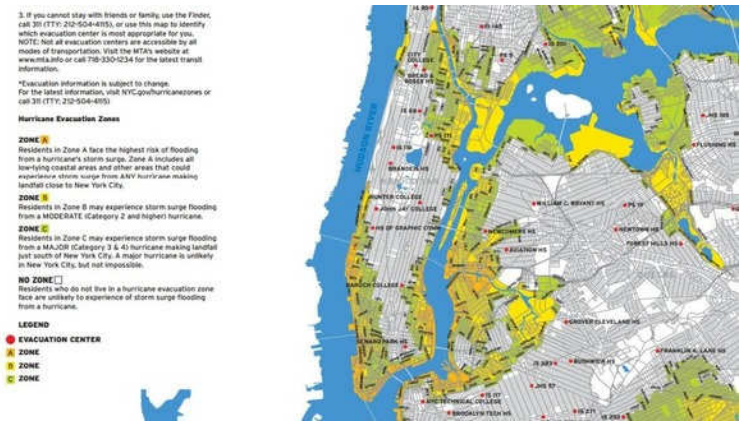
Storm track forecasts



Exceptionally large wind field tropical storm force winds over ~500 miles from the center



Hurricane Sandy
Immediate Preparations



New York City issued mandatory evacuation of Zone A on October 28, 2012

Out-of-state utility crews brought in before the storm

Evacuation – Not complete
43 people died in NYC
80% from drowning

Utilities – Not prepared
4 million without power in the region

MTA/DOT – Major flooding
7 subway lines under East River,
3 tunnels closed

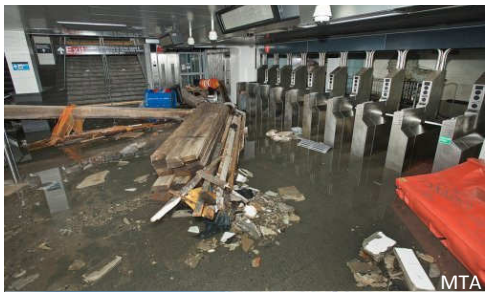
MTA closed down operations and boarded and placed sandbags at subway entrances to protect against flooding

CCRUN

Hurricane Sandy
Forecasting the Impacts

Interdependent Critical Infrastructure Systems and Vulnerable Communities

South Ferry Subway Station



Beach erosion and boardwalk damage in the Rockaways

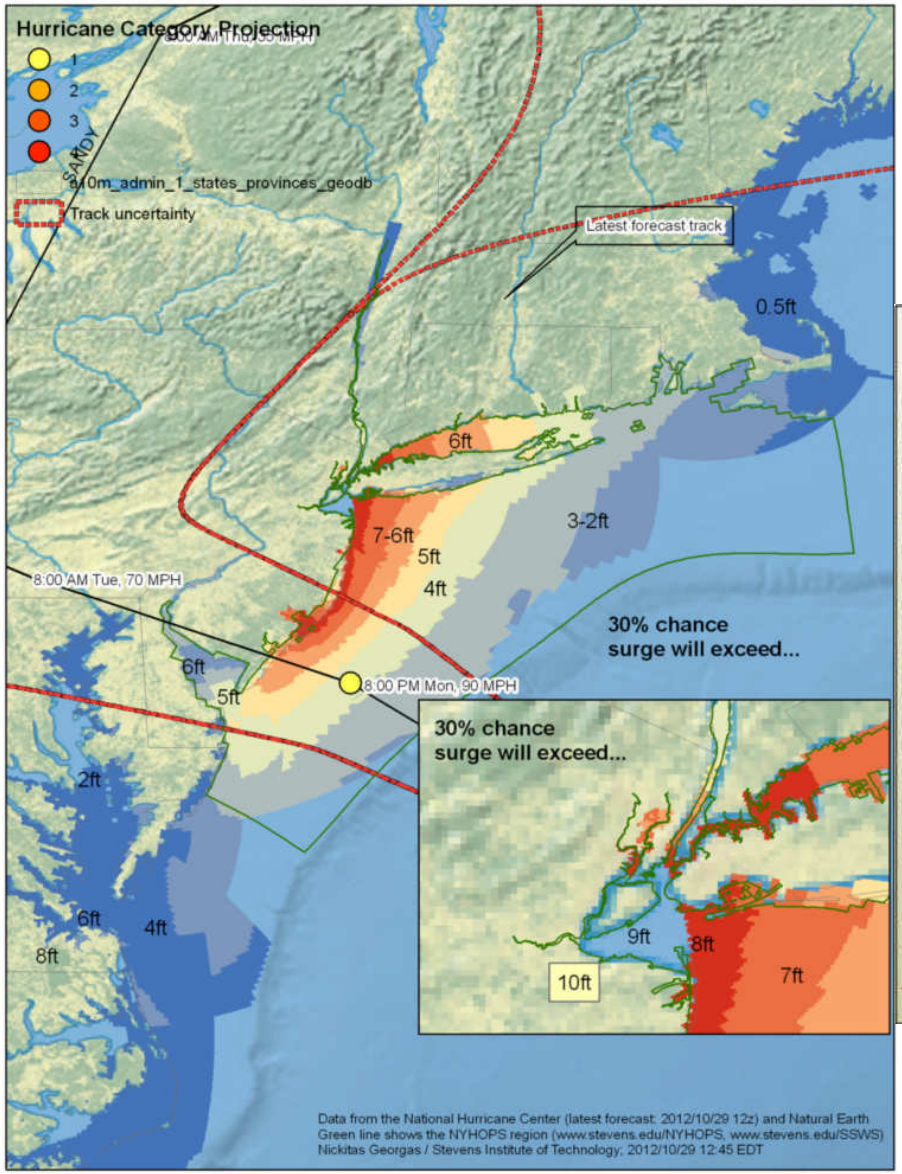
Extensive *power outages*

Hardest hit areas

Many impacts forecast well in advance

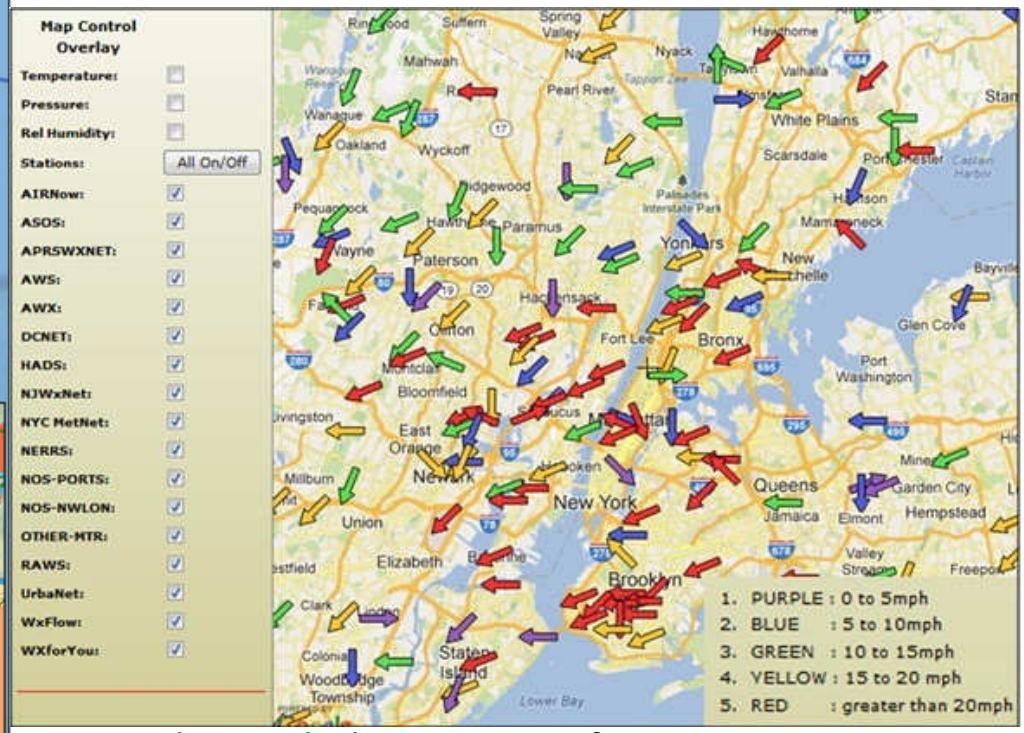
CCRUN

CCRUN Tracked the Storm



New York Harbor Observing and Prediction System (NYHOPS Model), Stevens Institute of Technology

Storm surge forecast



Wind speed observations from NYCMetNet
CUNY/ NOAA Cooperative Remote Sensing Science and Technology Center (CREST)

Documenting and Studying the Impacts

High Water Mark at South Street Seaport

Phil Orton, Stevens Institute of Technology

Damaged Home in Staten Island

Somayya Ali, Columbia University

Boardwalk and Beach Damage in Rockaway Park, Queens, NY

Gary Monitz, Columbia University

South Ferry Subway Station in Manhattan

Daniel Bader, Columbia University

Hurricane Sandy
Links to Climate Change Science

- ~1 ft of sea level rise in past 100 years in New York metropolitan region, due to local land subsidence, global thermal expansion of ocean water, melting of land-based ice, and local surface elevation

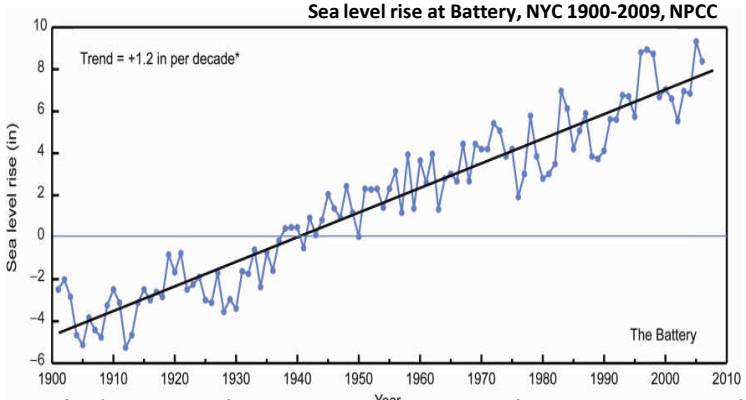
- Hurricane Sandy is defined as a 1 in multi-century event in current climate –
Coastal flooding projected to occur more frequently and to greater extent in future due to sea-level rise alone

- Intensity of severe hurricanes appears to be on rise and may increase in future***

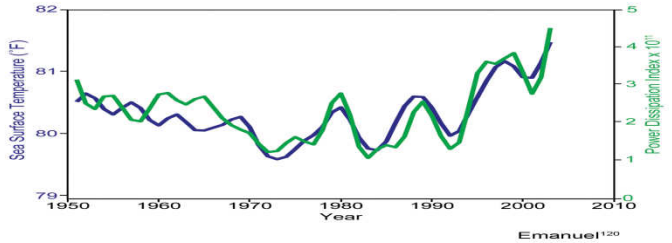
- Melting sea-ice may be changing pattern of jet stream, making westward-turning storm tracks more likely***

***Areas of active research

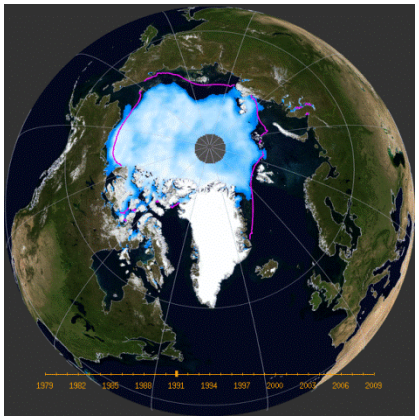
Sea level rise at Battery, NYC 1900-2009, NPCC



North Atlantic SSTs and Hurricane Power Dissipation Index 1950-2005, Emmanuel



Observed sea surface temperature (blue) and the Power Dissipation Index (green), which combines frequency, intensity and duration for North Atlantic hurricanes.120 Hurricane rainfall and wind speeds are likely to increase in response to human-caused warming. Analyses of model simulations suggest that for each 1.8°F increase in tropical sea surface temperatures, rainfall rates will increase by 6 to 18 percent.[68]



Median Minimum Sea Ice Extent 1979-2009

Conclusions

- Changes in climate have already been observed and are projected for the future in EPA Region 2
- The climate adaptation process developed in New York City can be modified for use by other agencies
- Hurricane Sandy can be used as a tipping point in responding to climate change

References and Links

- Consortium for Climate Risk in the Urban Northeast (www.ccrun.org)
- NYSERDA ClimAID (www.nyserda.ny.gov/climaid)
- New Jersey Climate Adaptation Alliance (NJCAA) (climatechange.rutgers.edu/njadapt.html)
- New York City Panel on Climate Change report available online at (www.nyas.org)

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