Extreme Climate Events

December 10, 2015

Radley Horton

Lead Principle Investigator, Consortium for Climate Risk in the Urban Northeast (CCRUN)

3rd Annual Cape Coastal Resilience Conference

Managing Coastal Risk: Enhancing Community Resilience in a Changing Climate

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RISA
Regional Integrated Sciences and Assessments

Climate Hazards

- Sea level rise leading to more frequent and intense coastal flooding
- More extreme heat events
- More intense precipitation
- Possibly more drought, changes in coastal storms

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Climate Impacts

- Damage to infrastructure
- Human health and safety
- Ecosystem impacts
- Freshwater and agriculture
- Don’t underestimate indirect impacts

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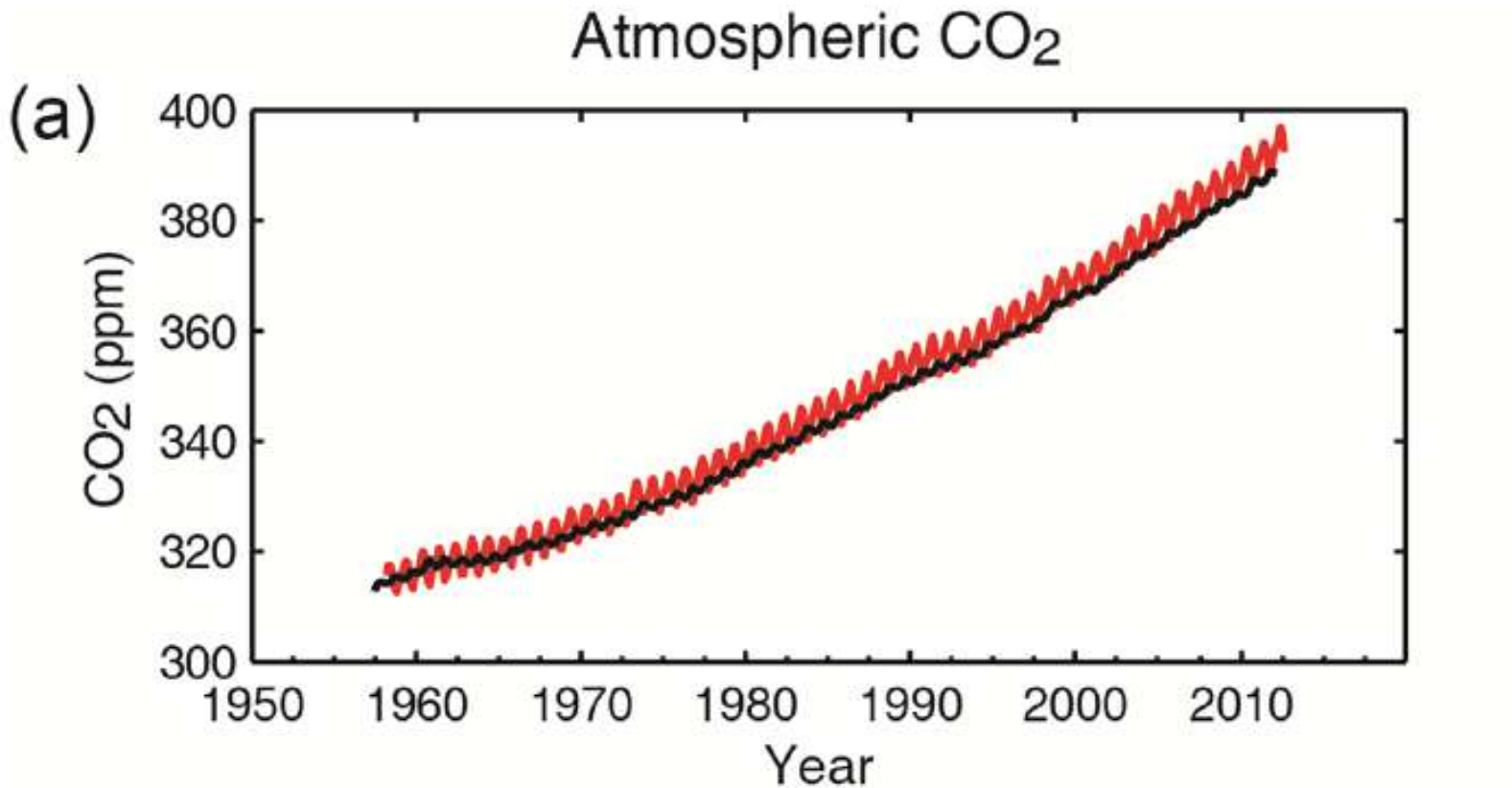
Carbon Dioxide Concentrations



"The atmospheric concentrations of carbon dioxide (CO_2), methane, and nitrous oxide have increased to levels unprecedented in at least the last 800,000 years. ***CO_2 concentrations have increased by 40% since pre-industrial times****, primarily from fossil fuel emissions and secondarily from net land use change emissions."*

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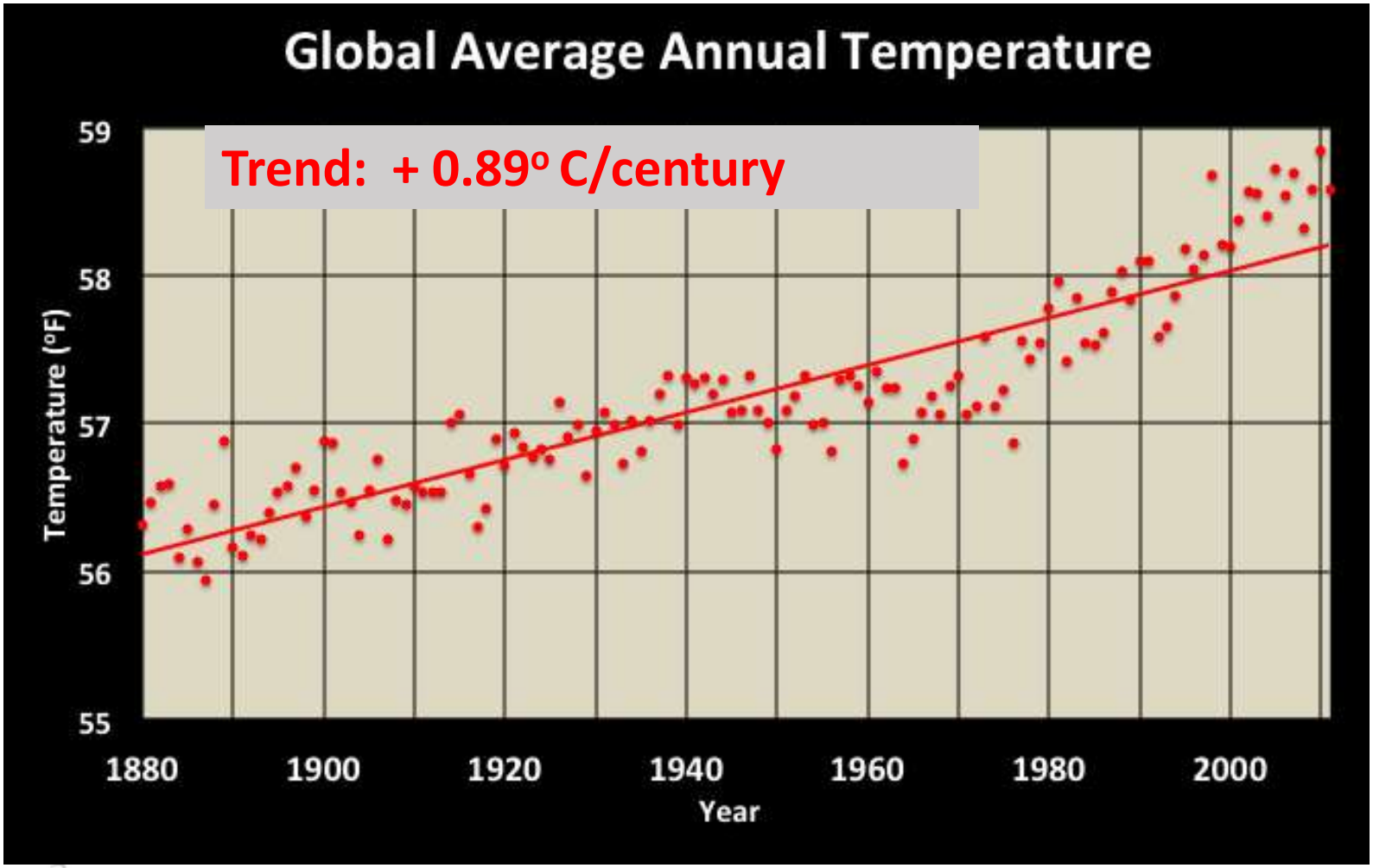
IPCC AR5 WG1 SPM, 2013

Changes in Climate – Global Trends



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Climate Change – Brief History

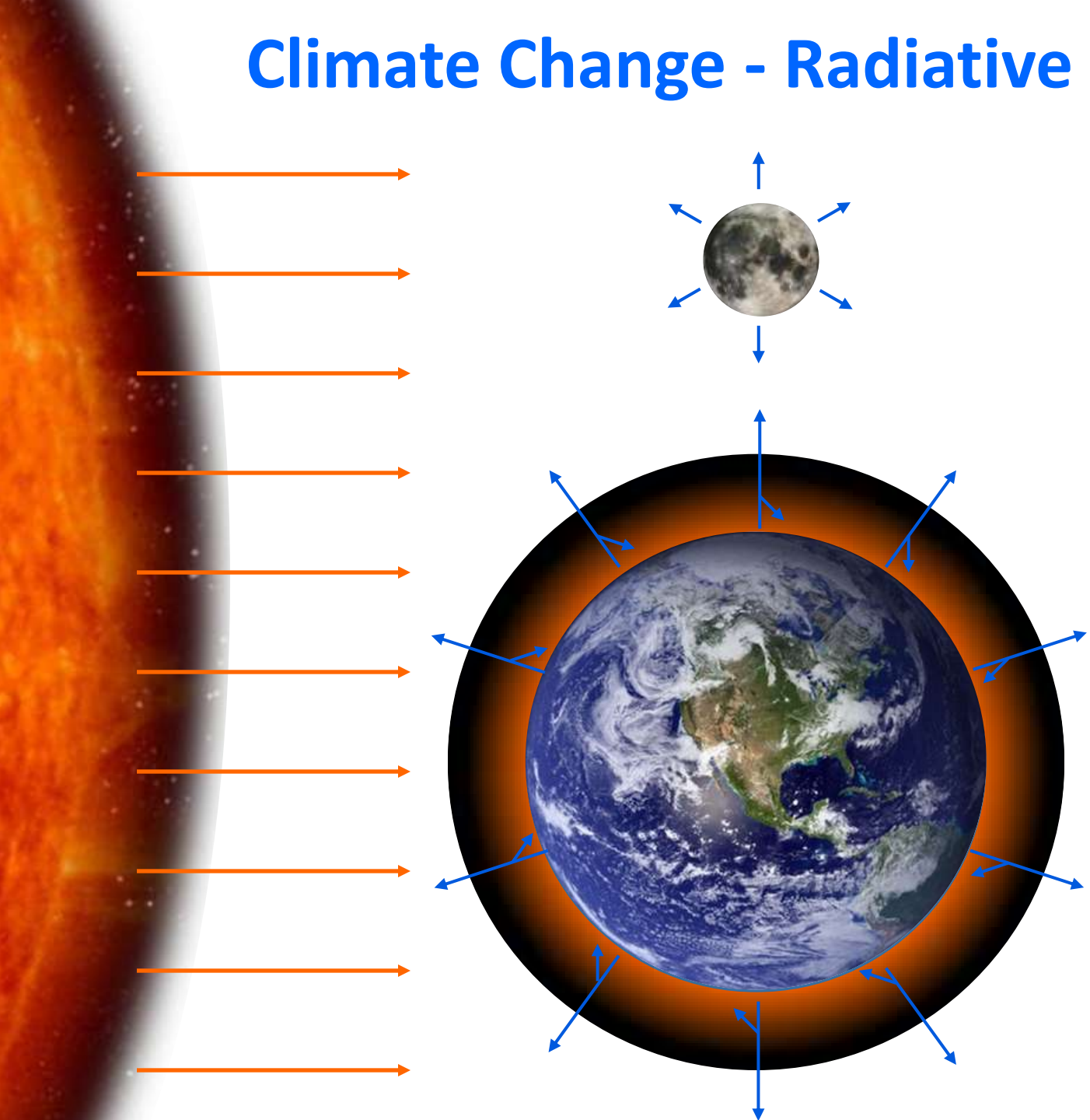
- **Joseph Fourier (1824)**
  - Atmosphere behaves like a "hothouse", with gases raising surface temperature

- **Samuel Langley (1884)**
  - Mapped out solar and infrared radiative absorption of the atmosphere by climbing Mount Whitney with his instruments

- **Svante Arrhenius (1896)**
  - Doubling of carbon dioxide would cause 5 ºC rise in surface temperature

- **Guy Stewart Callendar (1938)**
  - Published 'The artificial production of carbon dioxide and its influence on temperature'

Climate Change - Radiative Basis



Moon (no atmosphere)

Energy in = Energy Out

Earth

No Atmosphere

Energy in = Energy Out

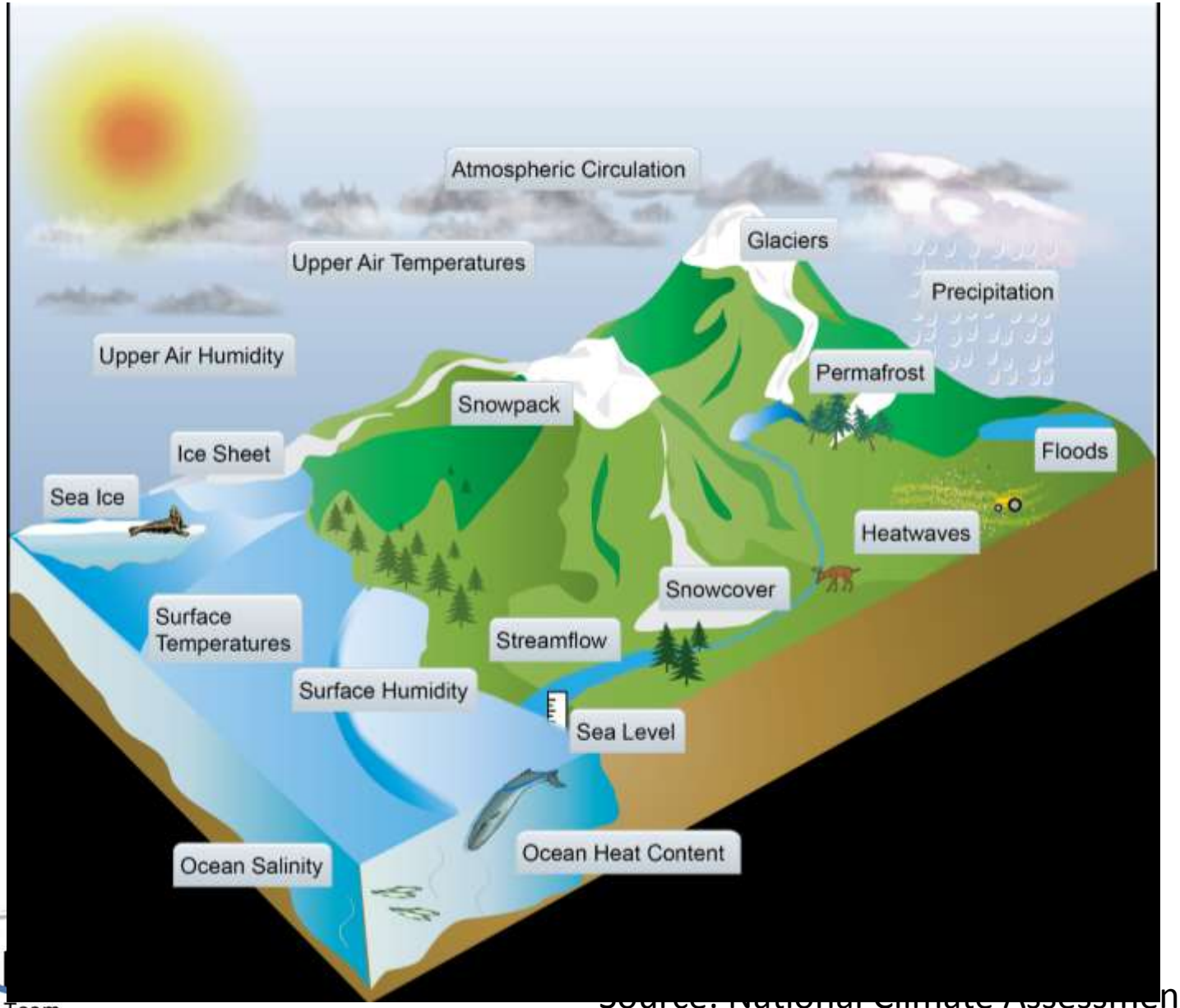
Add Atmosphere

- Same amount of sunlight in
- Some of outgoing energy trapped (imbalance)

Warmer World

- Surface must warm to get back in balance

How Humans Affect Climate

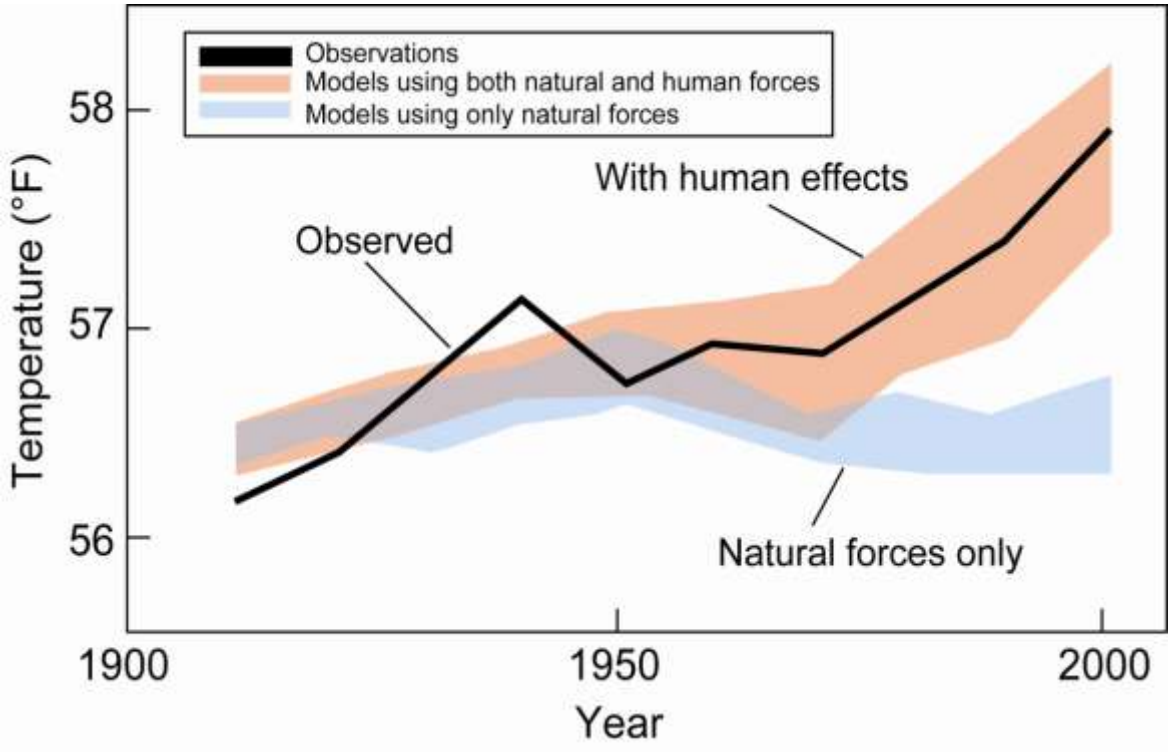


Source: National Climate Assessment, 2014

Human and Natural Factors

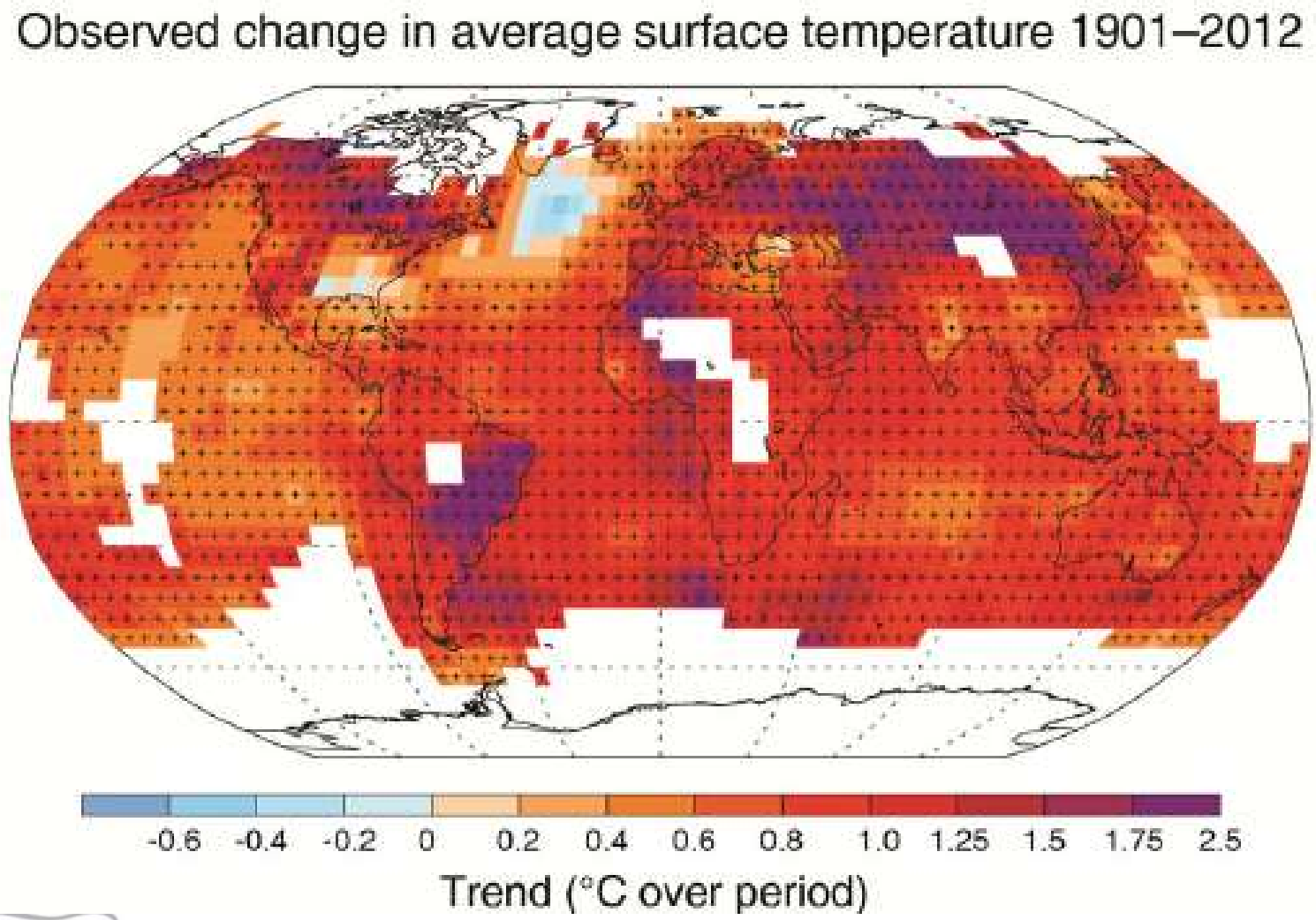
Need both natural and man-made influences (as well as feedbacks) to accurately represent historical climate

- **Natural:**
  - **Volcanoes**
  - **Sun spot cycles**
- **Man-made:**
  - **Greenhouse gas emissions**
  - **Aerosol emissions**
  - **Land-use changes**



IPCC, 2007

Changes in Surface Temperatures



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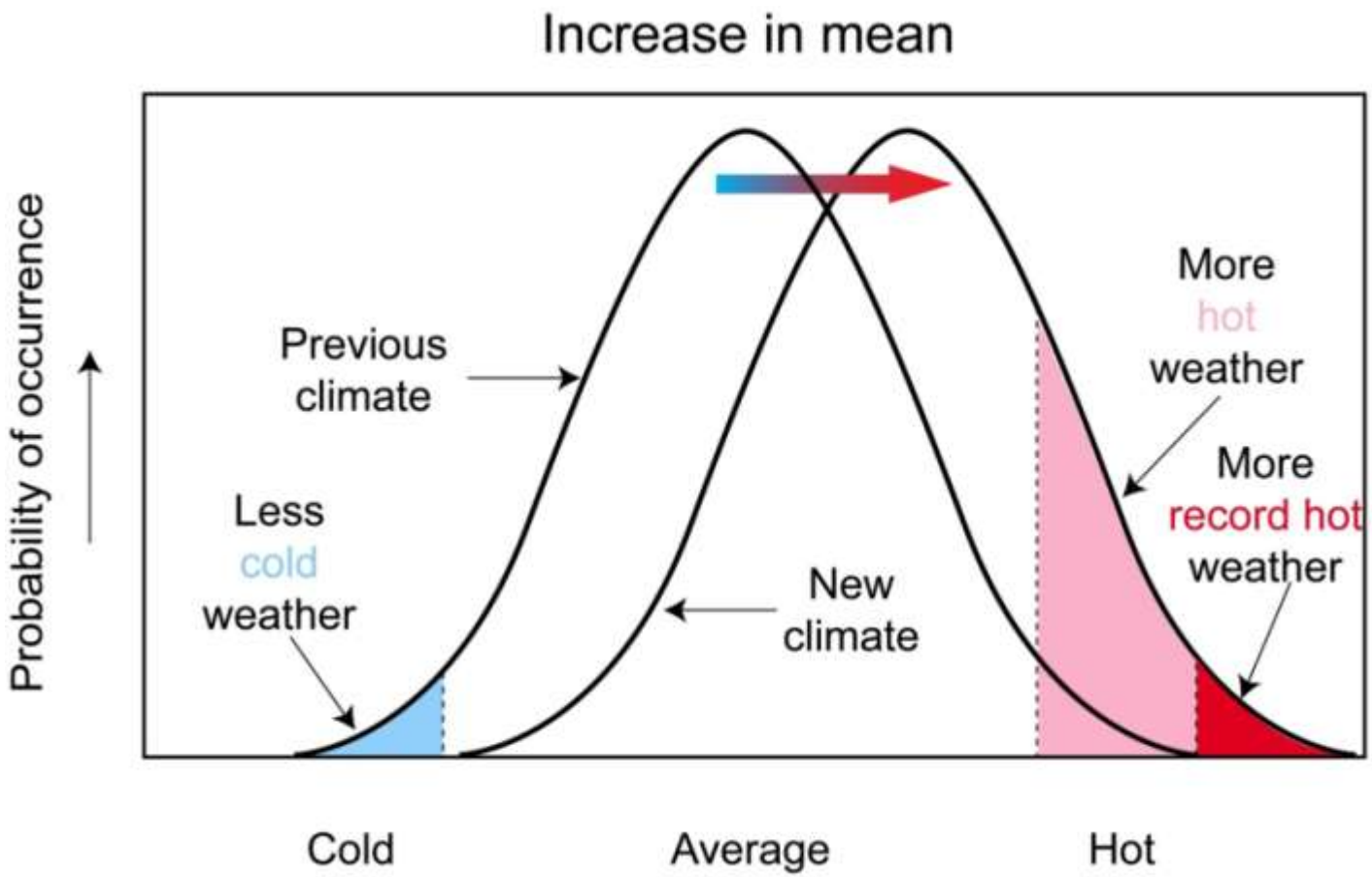
IPCC AR5 Draft SPM

Shifting Climate Extremes



- ***Natural variability will continue to occur***
- ***Small shifts in mean values can lead to large changes in the frequency of extremes***

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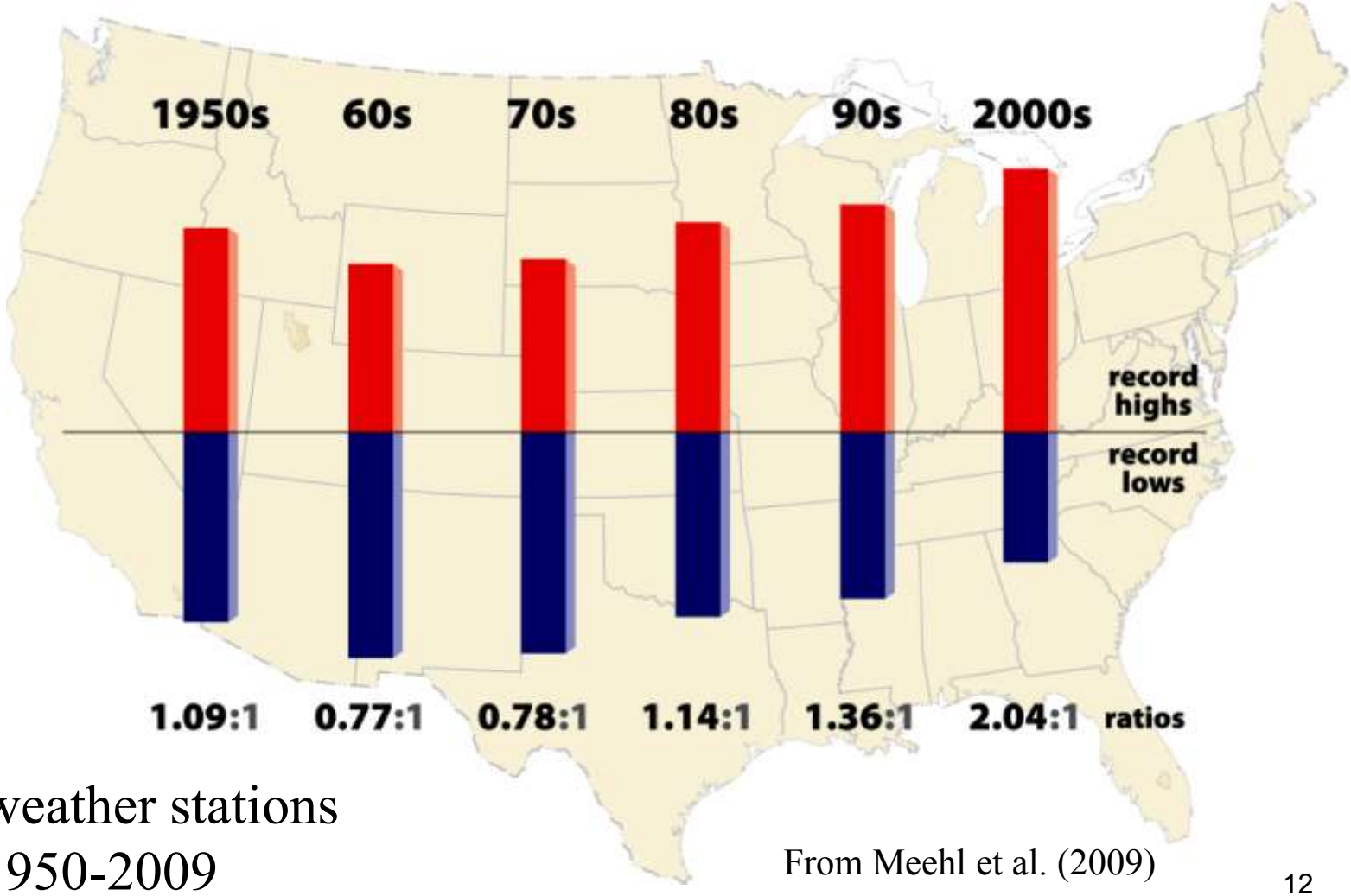
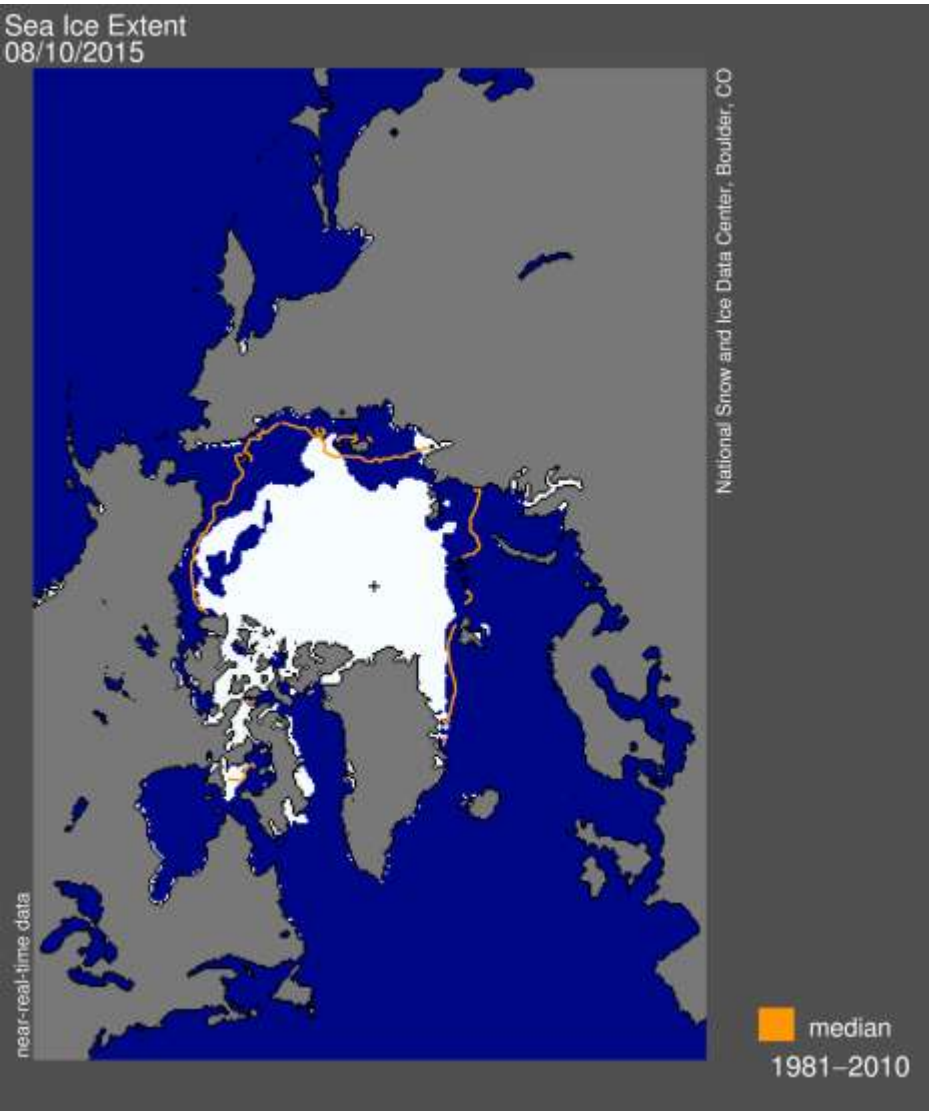
Increasing trend: U.S. breaking many more heat records than cold records

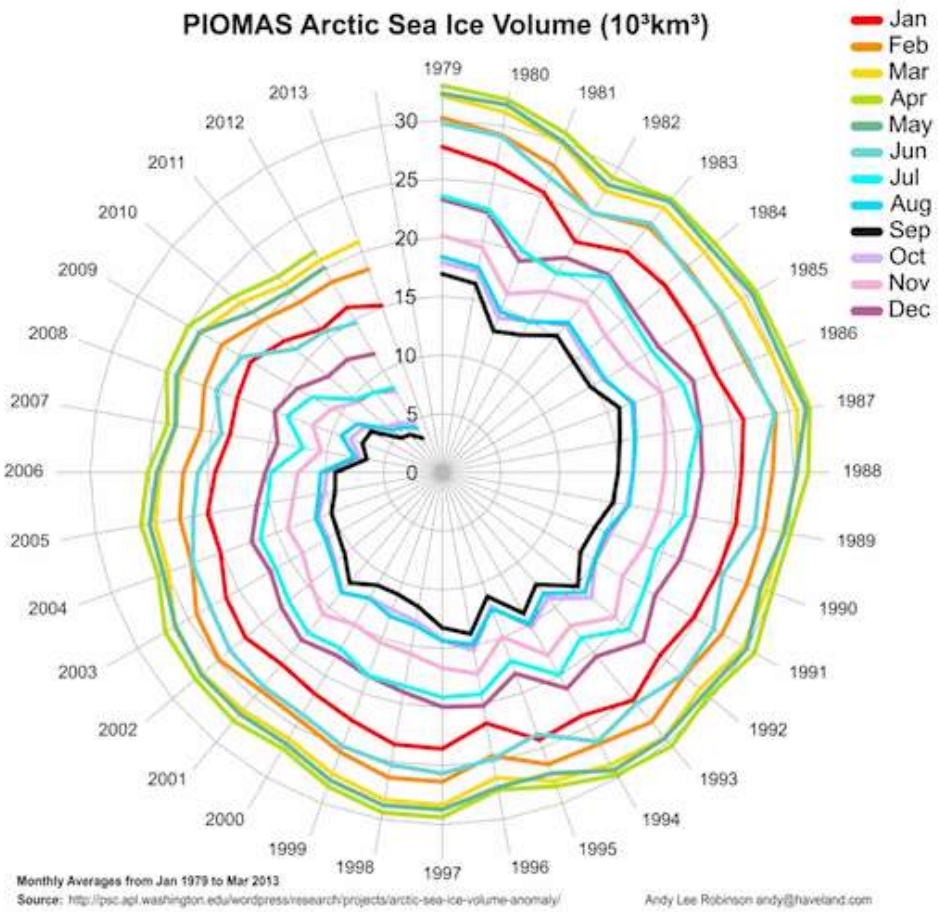


1800 weather stations from 1950-2009

From Meehl et al. (2009)

Arctic Sea Ice





Looking Forward--Momentum

- Even if temperatures stopped rising, sea level would continue to rise
- And temperatures will keep rising due to greenhouse gas emissions to date
- And greenhouse gas emissions will keep rising due (at minimum) to societal decisions to date

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Historical Climate Trends in the Northeast

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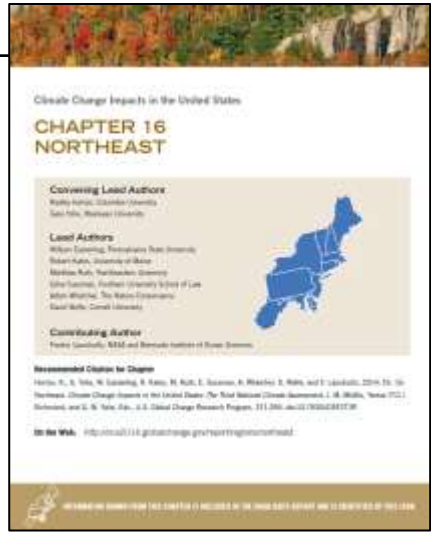
Climate Change in the Northeast



1. **Heat waves, coastal flooding, and river flooding will pose a growing challenge** to the region's environmental, social, and economic systems. This will increase the vulnerability of the region's residents, especially its most disadvantaged populations.

2. **Infrastructure will be increasingly compromised** over the next century by climate-related hazards, including sea level rise, coastal flooding, and intense precipitation events.

3. **Agriculture, fisheries, and ecosystems will be increasingly compromised** over the next century by climate change impacts. Farmers can explore new crop options, but these adaptations are not cost- or risk-free. Moreover, **adaptive capacity, which varies throughout the region, could be overwhelmed by a changing climate.**

4. While a majority of states and a **rapidly growing number of municipalities have begun to incorporate the risk** of climate change into their planning activities, **implementation of adaptation measures is still at early stages.**

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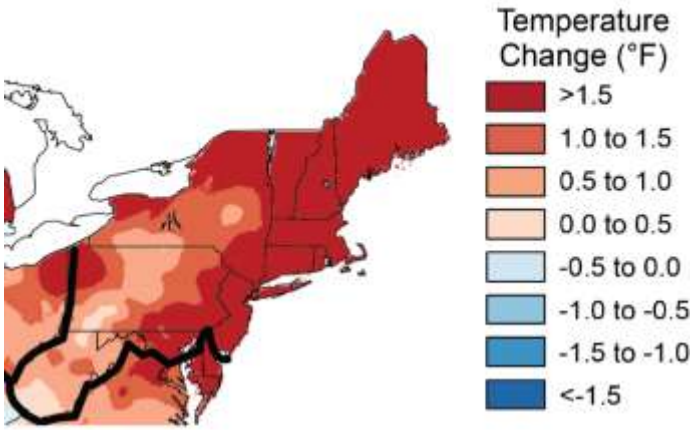
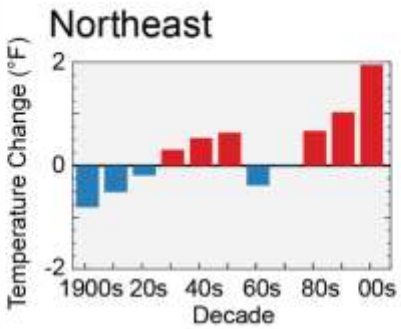
Source: National Climate Assessment, 2014

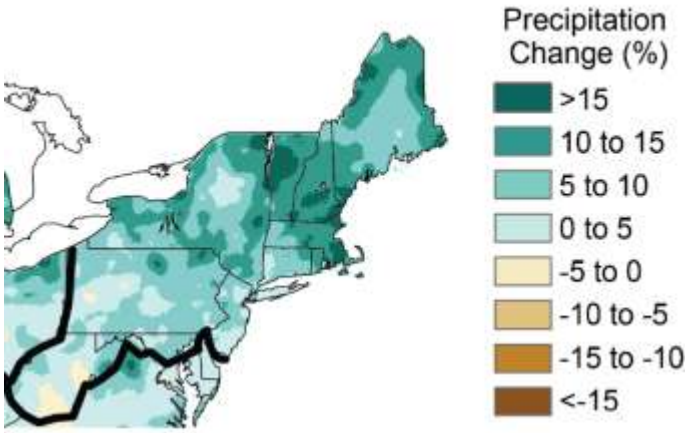
Observed Climate Changes

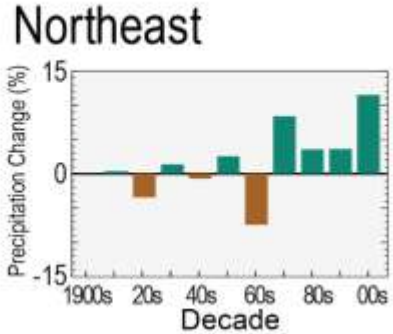
Temperatures have increased 1.9°F since 1900





Rainfall has increased 5 inches (10%) since 1900





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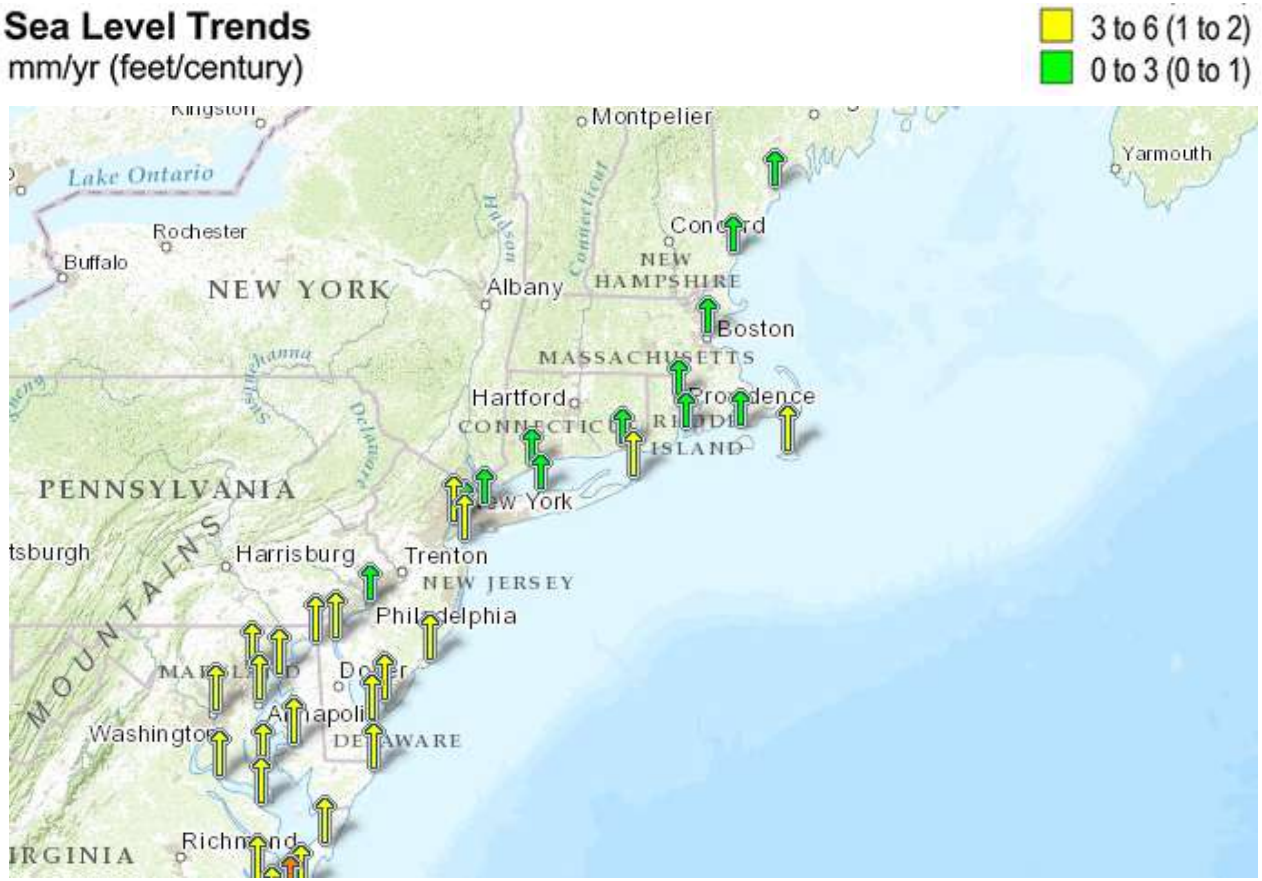
Source: National Climate Assessment, 2014

Observed Sea Level Rise



Sea levels have risen 1 foot since 1900 in the Northeast.

This rate of sea level rise in the Northeast exceeds the global average of 8 inches.

Source: National Climate Assessment, 2014

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Projected Climate Change in the Northeast

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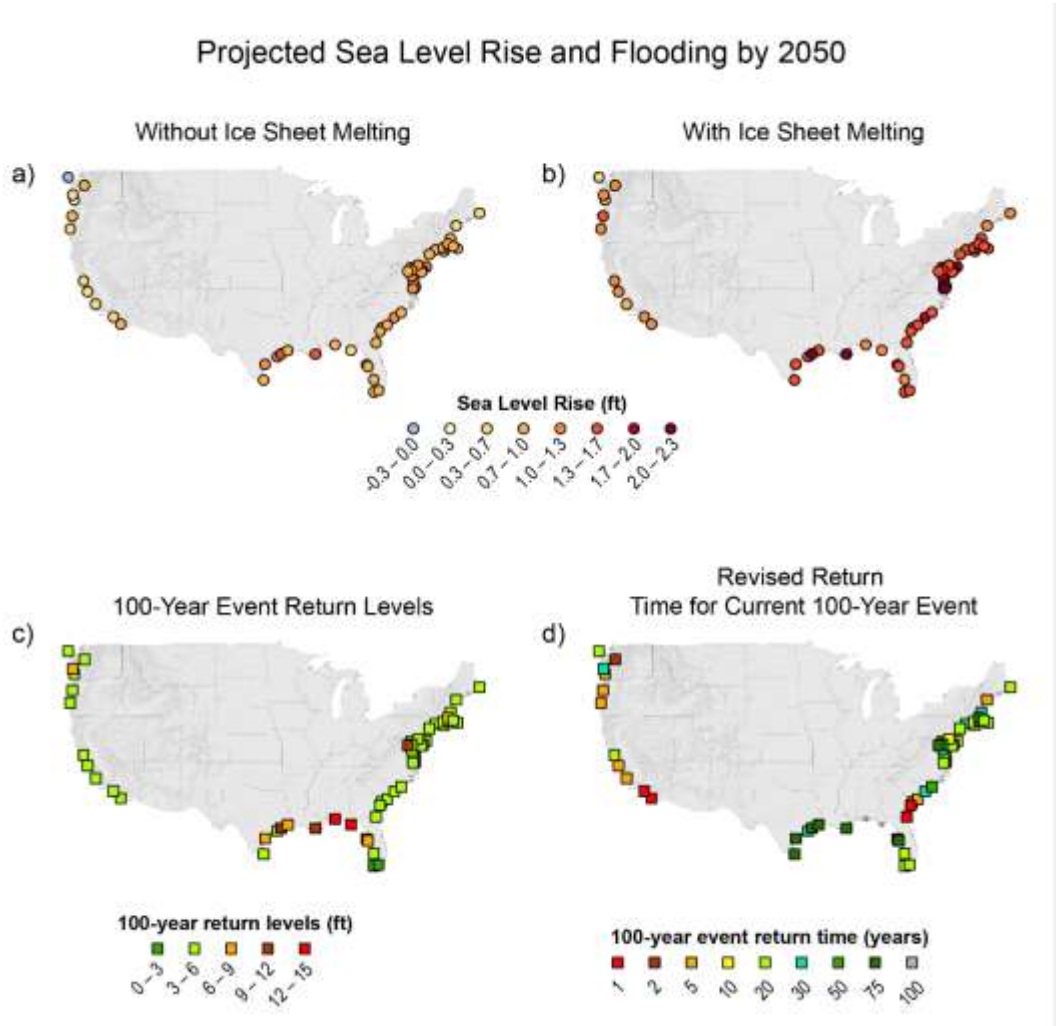
Sea Level Rise



Source: National Climate Assessment, 2014

Sea level rise in the **Northeast is expected to exceed the global average**

Sea level rise of 2 feet, without any changes in storms, **would more than triple the frequency of dangerous coastal flooding** throughout most of the Northeast.

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Coastal Flood Heights and Recurrence

			2020s			2050s		
		Baseline	Low-estimate	Middle range	High-estimate	Low-estimate	Middle range	High-estimate
Coastal Floods at the Battery	Annual chance of today's 100-year-flood	**1.0 %**	**1.1 %**	**1.2 to 1.5 %**	**1.7 %**	**1.4 %**	**1.7 to 3.2 %**	**5.0 %**
	Flood heights associated with 100-year flood (stillwater + wave heights)	15.0 feet	15.2 feet	15.3 to 15.7 feet	15.8 feet	15.6 feet	15.9 to 17 feet	17.6 feet
	Stillwater flood heights associated with 100-year flood	10.8 feet	11.0 feet	11.1 to 11.5 feet	11.7 feet	11.4 feet	11.7 to 12.8 feet	13.4 feet

Estimates in the top row refer to the values for projected sea level rise. Low-estimate indicates 10th percentile, middle range indicates 25th to 75th percentile, and high-estimate indicates 90th percentile. Flood heights for the 2020s and 2050s are derived by adding the sea level rise projections for the corresponding percentiles to the baseline values. Baseline flood heights associated with the 100-year flood are based on the stillwater elevation levels (SWELs). For 100-year flood, height is also given for stillwater plus wave heights. Flood heights are referenced to the NAVD88 datum.

Coastal flooding is very likely to increase in frequency, extent, and height as a result of increased sea levels

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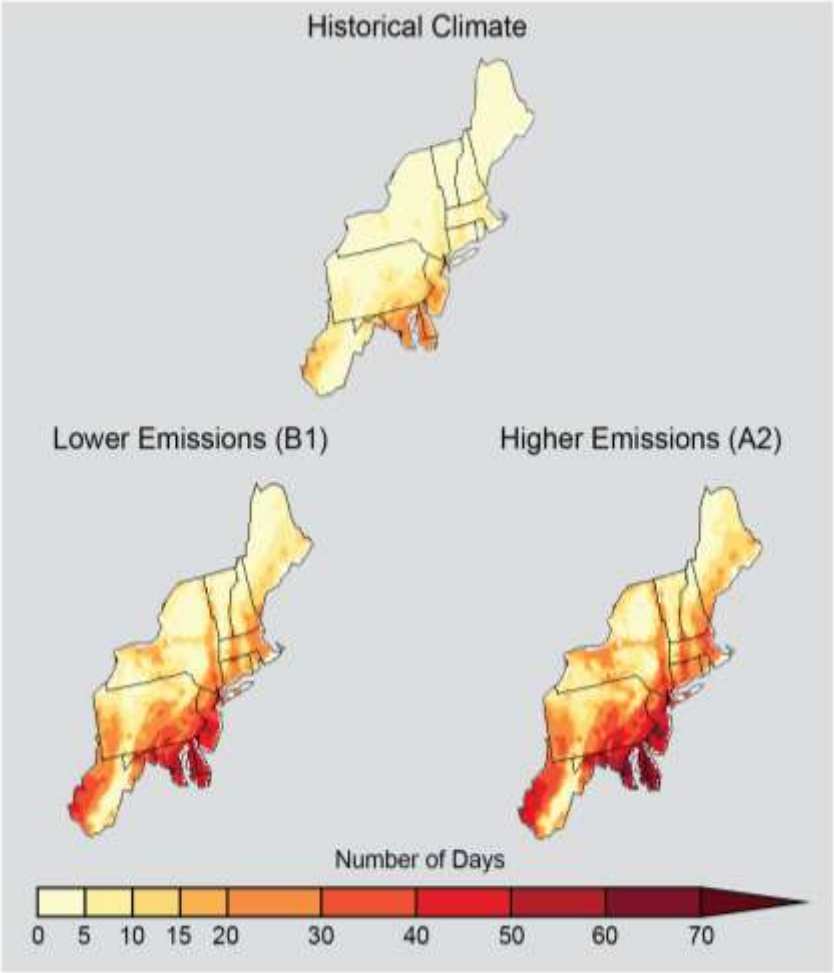
Future Heat in the Northeast

Projected increase in the number of days over 90°F in the 2080s.



Under a **high (A2) emissions scenario, average temperatures are projected to increase 4.5°F to 10°F** by the 2080s.

Under a **low (B1) emissions scenario, average temperatures are projected to increase 3°F to 6°F** by the 2080s.

The number of **extreme heat days over 90°F is projected to increase across the Northeast** in both the low and high emissions scenarios.

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Source: National Climate Assessment, 2014

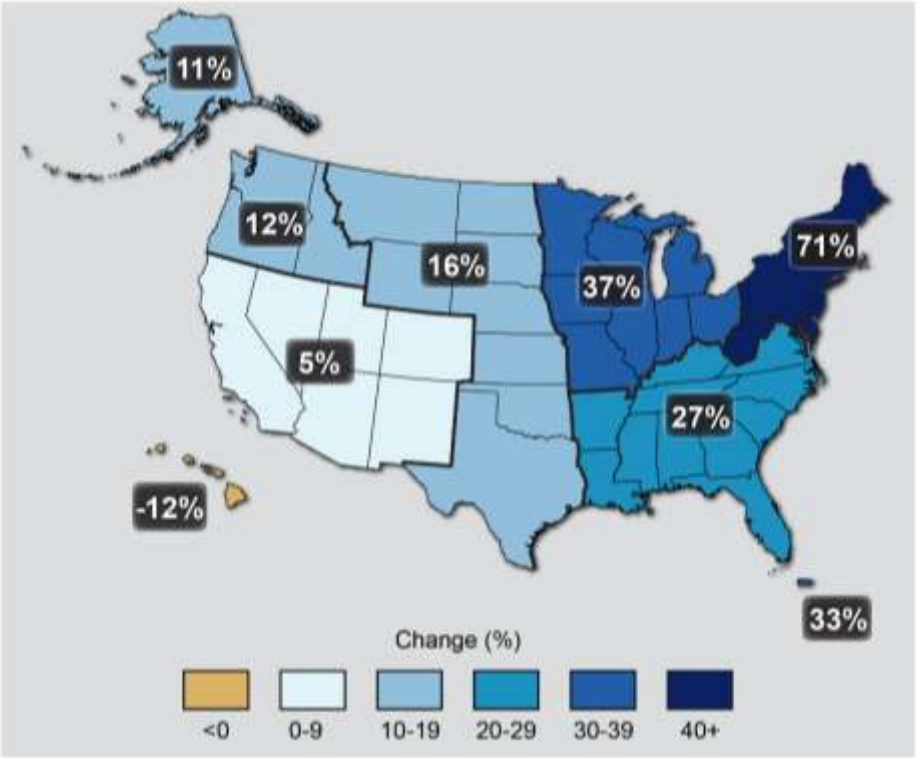
Changing Rainfall Patterns

The number of **extreme downpours are expected to increase** in the Northeast

Under a **high (A2) emissions scenario, winter and spring precipitation are expected to increase on average 5% to 20%** by the end of the century

Projections for **precipitation changes are less certain** than projections for temperature increases

The Northeast has already seen the greatest increase in heavy precipitation events (1958-2012).



Source: National Climate Assessment, 2014

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Risks to Coastal Northeast

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Why are Coasts Vulnerable?

Coastal zones are increasingly vulnerable to **higher sea levels and storm surges, inland flooding, and other climate-related changes**.

Climate change **increases exposure of important assets**, such as **ports**, **tourism and fishing sites**, threatening to disrupt economic activity beyond the coast and incurring significant costs for protecting or moving them.

Socioeconomic disparities create uneven exposure and sensitivity to coastal risks and limit adaptation options for some, **resulting in the displacement of the most vulnerable from coastal areas**.

Challenges of **multi jurisdictions**

ClimAID, 2011

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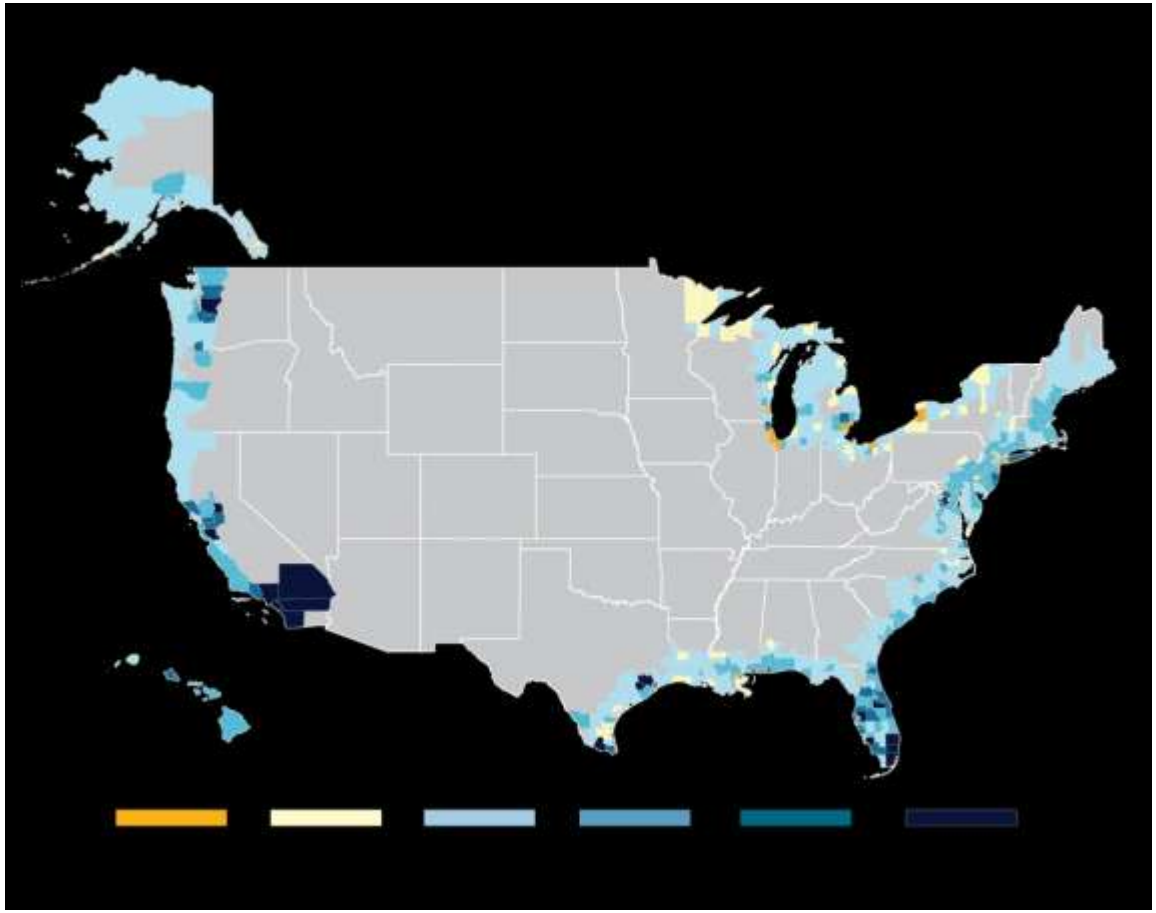
Source: National Climate Assessment, 2014

Northeast Coastlines are Vulnerable



Source: National Climate Assessment, 2014

The Northeast has seen a large influx to its population over the last 30 years, making the region even more vulnerable to coastal storms and sea level rise

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Challenges in the Northeast

Highly built-up coastal corridor concentrates population and supporting infrastructure

Storm surges from **nor'easters and hurricanes** can cause significant damage

The historical **rate of relative sea level rise varies** across the region

Wetlands and estuaries are vulnerable to **inundation from sea level rise**; buildings and infrastructure are most vulnerable to higher storm surges as the sea levels rise

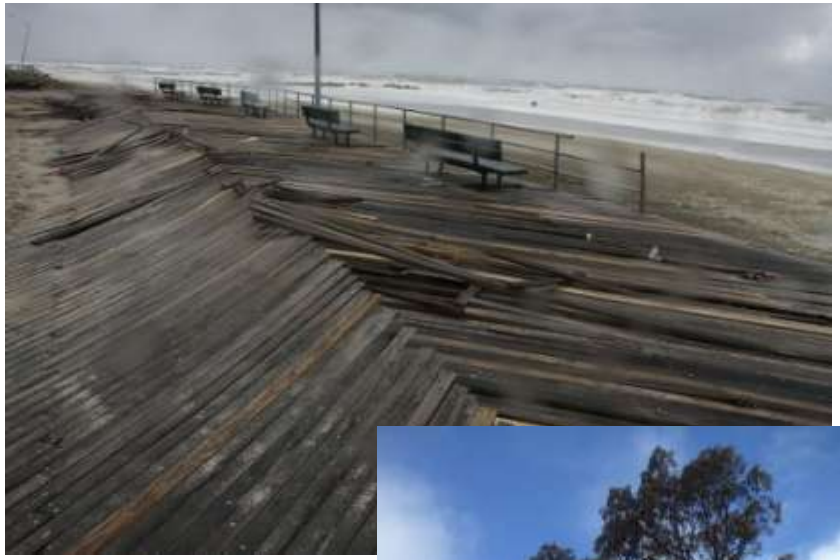

Image source: MTA, 2012

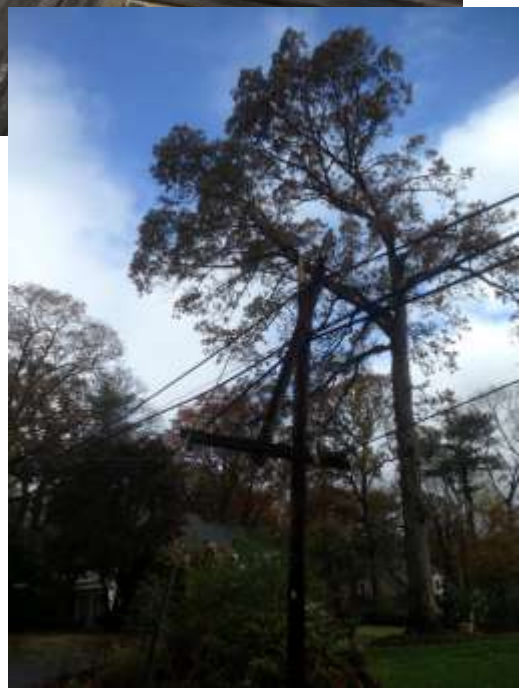

Image source: CCSR, 2013

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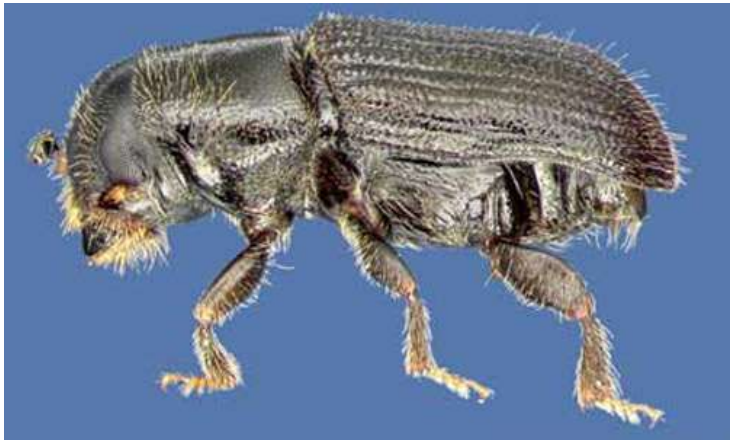
Southern Pine Beetle Northward Expansion

- **Major forest pest in the South**



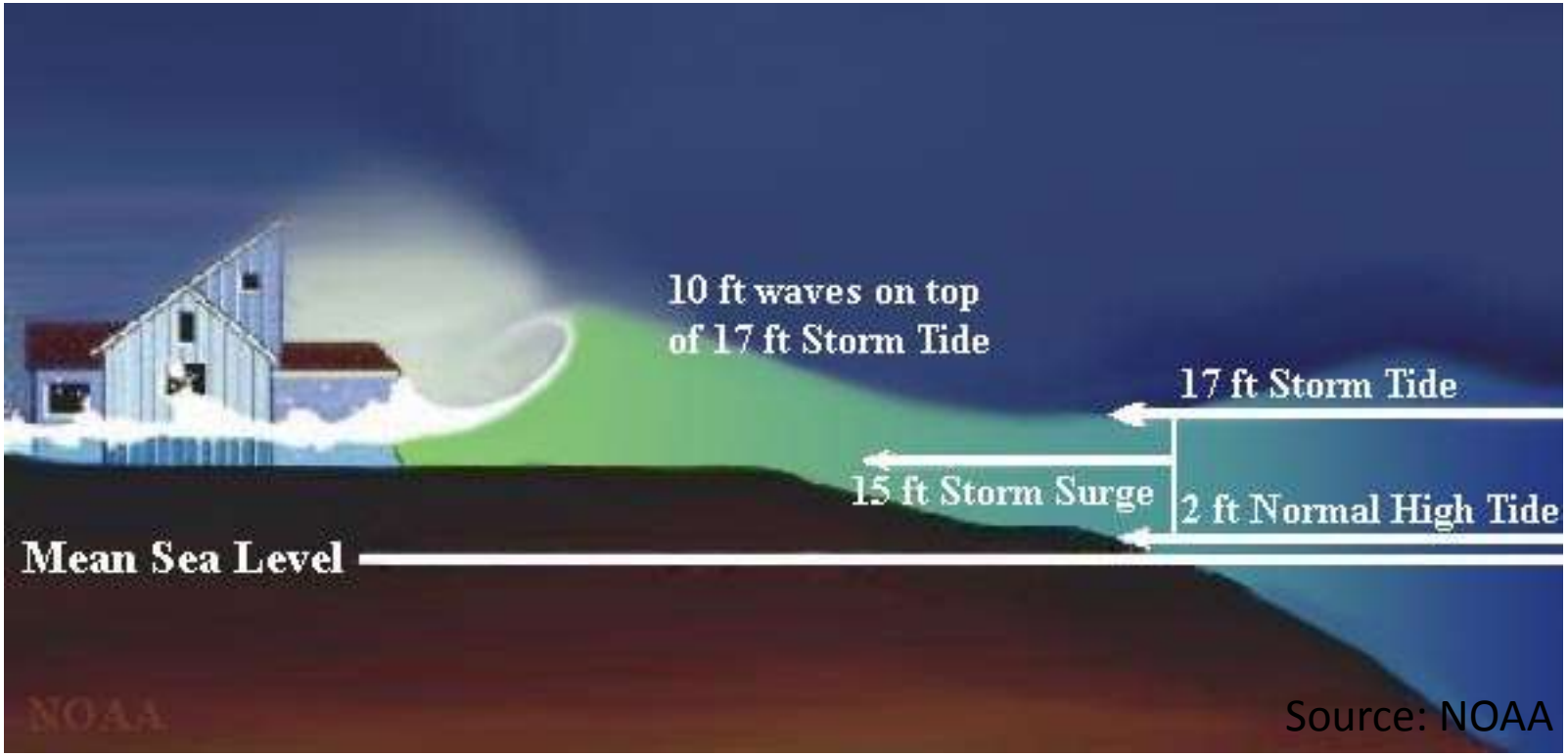
- **Can cause >$200 million per year in tree damage**

- **Spreading north into NJ since 2001, Long Island since 2014**

- **Will it continue into northern forests?**

Joint Hazards: Storm Surge and Storm Tide

Joint hazards like storm surge and storm tide consider multiple variables together, and address interaction and correlation between two events.



Source: NOAA

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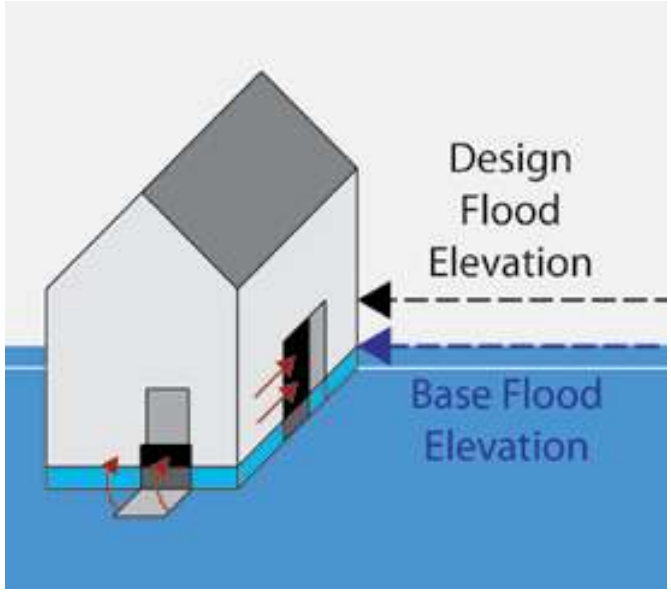
Adaptation Initiatives Underway

- Portland, Maine is assessing costs for retrofitting its wastewater infrastructure
- New Hampshire's Coastal Adaptation Workgroup is providing education, guidance, and networking for local planners
- City of Boston considers adaptation and mitigation equal priorities, and sea level rise is a top concern
- Connecticut State Assembly amended the state's Coastal Management Act to promote adaptation to sea level rise



Flood proofing industrial buildings. Diagram shows how a building that has water tight doors and cover plates create a water tight exterior in case of floods. The doors and covers can be deployed in anticipation of a severe storm. Source: Building Resilience in Boston, 2013

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Source: National Climate Assessment, 2014

Case Study: How has New York City responded to climate change?

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New York City Panel on Climate Change

Mayor Bloomberg convened the First New York City Panel on Climate Change (NPCC1) in 2008. The NPCC – leading climate and social scientists and risk management experts – worked to identify future climate risks facing New York City.

- Full report published by New York Academy of Sciences in 2010
- New York City Codified NPCC in August 2012 legislation with **Local Law 42**, requiring regular climate science updates
- After Hurricane Sandy, Mayor Bloomberg **re-convened the Panel (NPCC2)** in January to provide updated climate risk information for the **Special Initiative for Rebuilding and Resiliency (SIRR)**.

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NPCC 2015 Report

re•sil•ient [ri-zil-yuhnt] adj.

1. Able to bounce back after change or adversity.
2. Capable of preparing for, responding to, and recovering from difficult conditions.

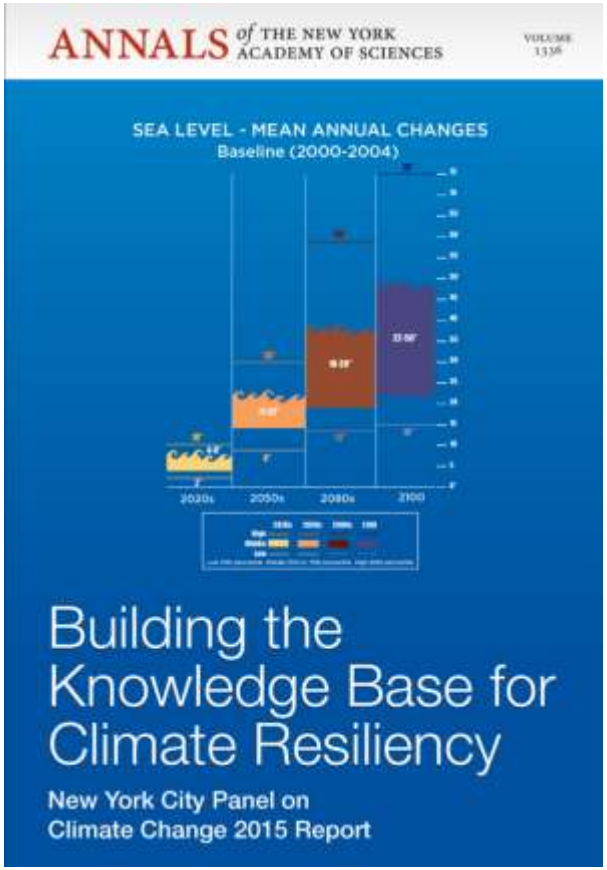
Syn.: TOUGH
See also: New York City

- NPCC 2015 projections are broadly consistent with NPCC 2010 projections. For the first time, they are **extended through the year 2100**.

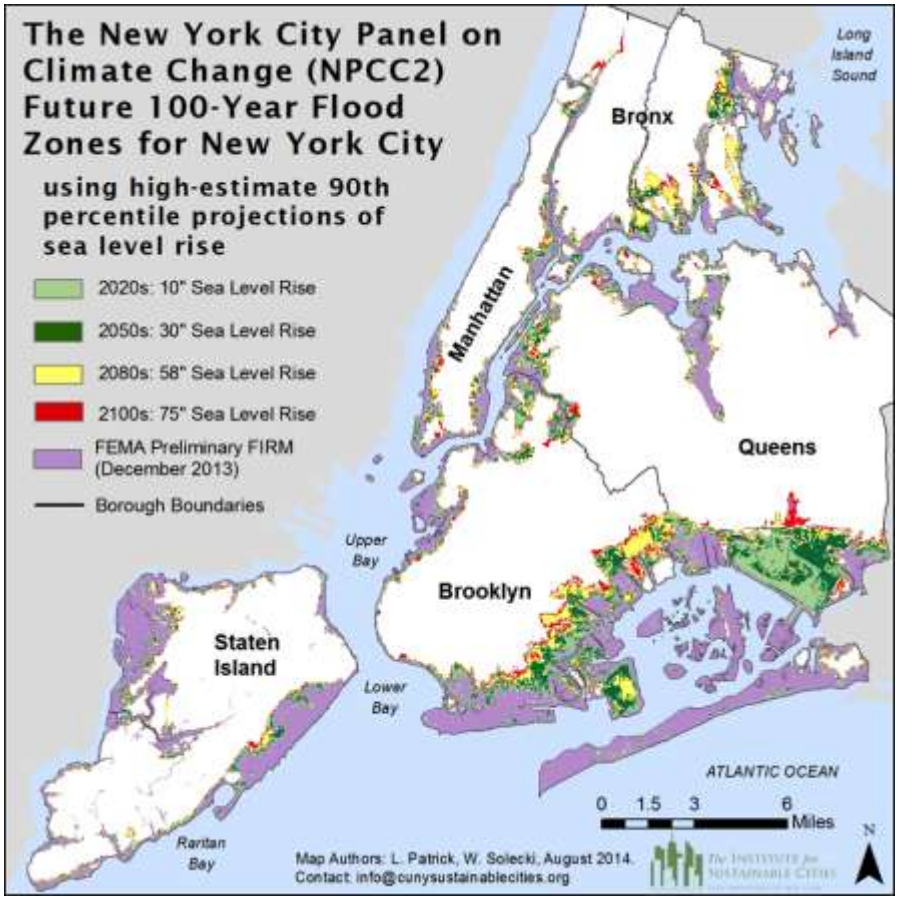
- The **science base has been broadened** to include an increased number of global climate models, new sea level rise methodologies, and dynamic coastal flood modeling.

- A new topic covered in the report is public health. New York City faces potential health risks related to two principal climate hazards: **increasing temperatures/heat waves and coastal storms with flooding.**

- NPCC 2015 provides the **'best available data' for use in the New York metropolitan region**, as recommended by President Obama's recent (1/30/2015) Executive Order.



Coastal Flood Mapping



100-year flood map developed using the static approach

- **For the 100-year flood**, the high-estimate sea level rise by 2100 roughly **doubles the affected area** compared to the December 2013 FEMA Preliminary Flood Insurance Rate Maps (FIRMs)
- **For the 500-year flood**, the high-estimate sea level rise by 2100 **increases the affected area by 50%** compared to the December 2013 FEMA FIRMs 500-year flood area.
- **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.

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Source: NPCC, 2015

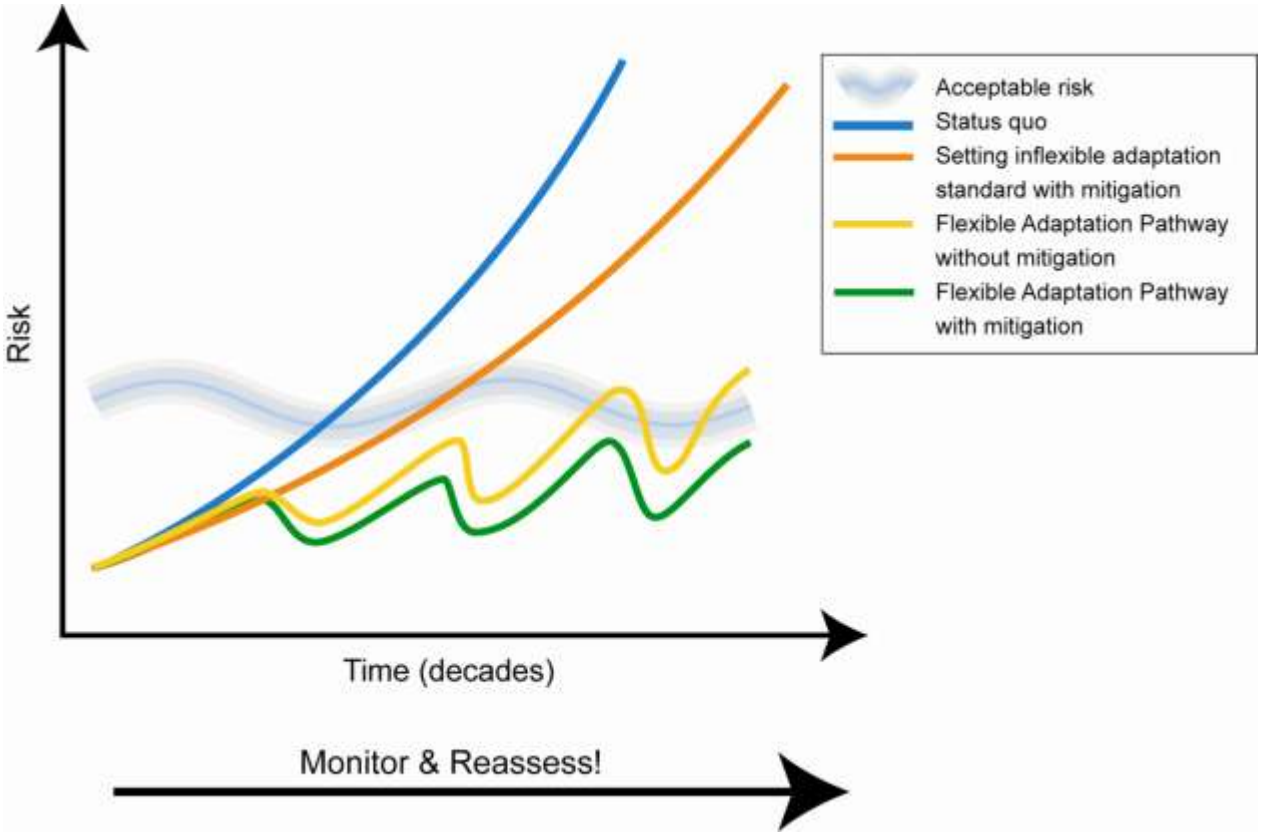
Flexible Adaptation Pathways

Climate change adaptation as a risk management issue

Flexible Adaptation Pathways as the response

Flexible pathways allow room for adaptation plans to shift according to new climate information.

Source: NPCC, 2010



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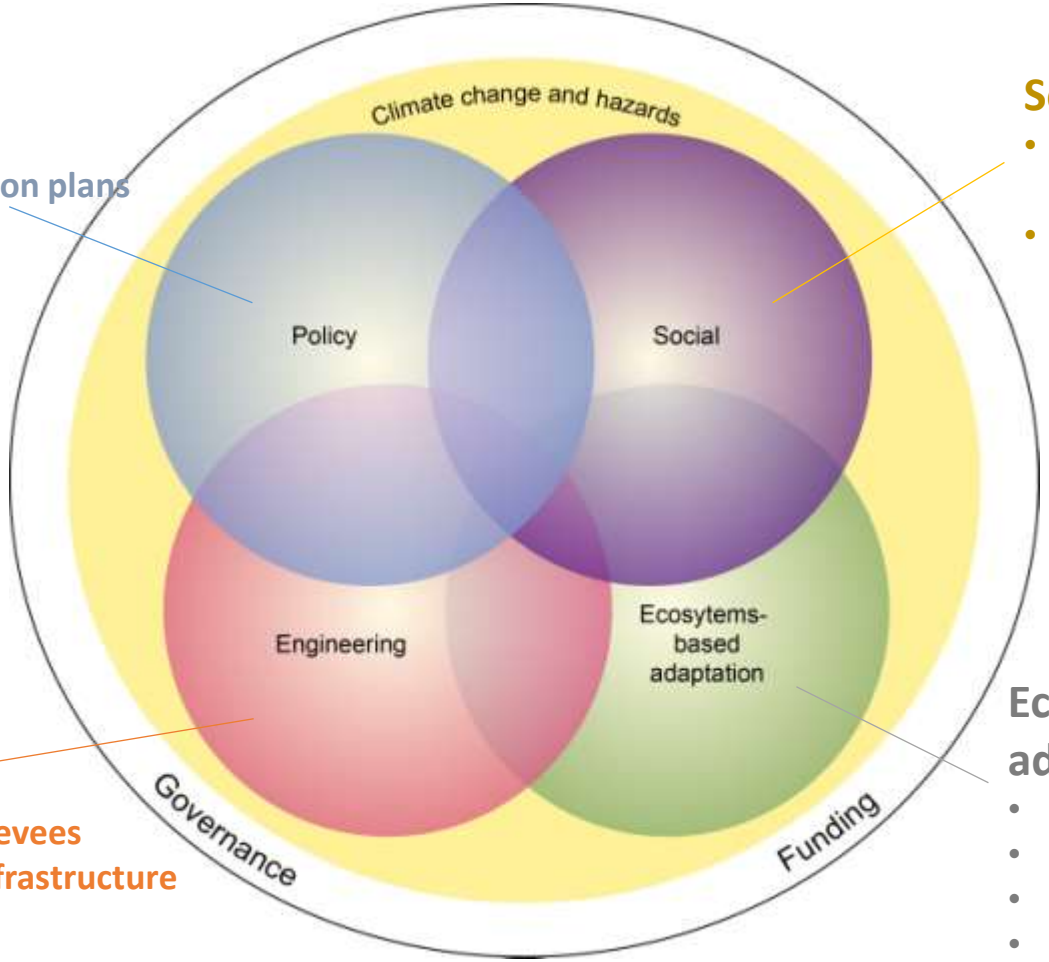
Approaches to Resilience Action

Policy
- Emergency evacuation plans
- Land use zoning
- Facility relocation



Social
- Neighborhood watch programs
- Early warning systems

Engineering
- Flood protection
- Sea walls, dikes, and levees
- Elevation of critical infrastructure
- Porous pavement

Ecosystems-based adaptation
- Green roofs
- Bio-swales
- Oyster beds
- Wetland restoration programs

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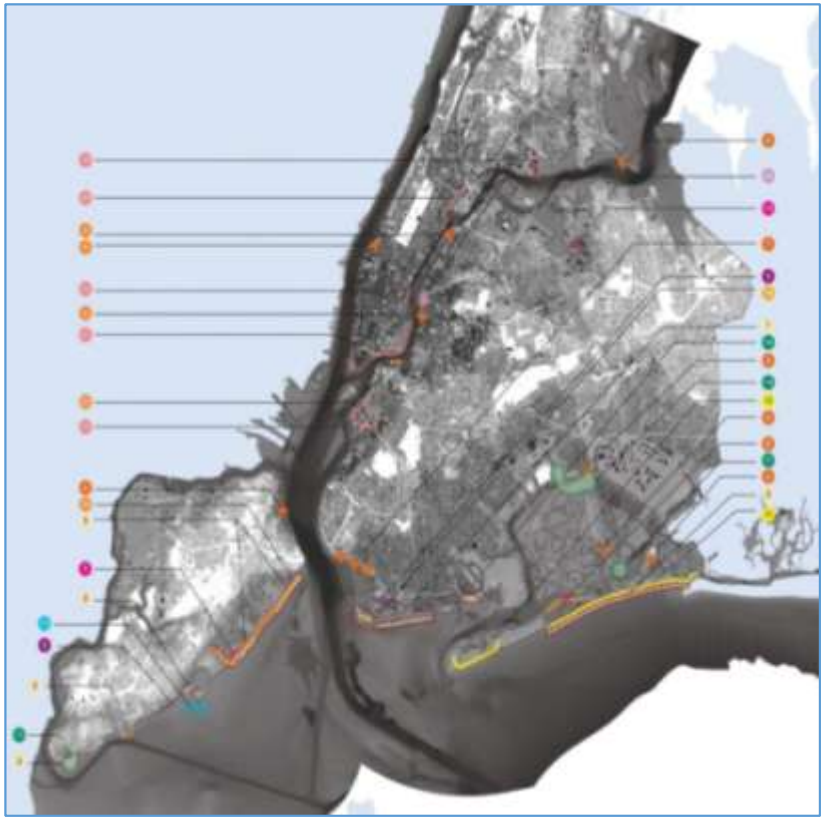
Strengthen Coastal Defenses

New York City's Comprehensive Coastal Protection Plan – Phase I



Source: *City of New York, 2015*

Progress

- **Secured funding** for over half of the City's $3.7 billion **first phase coastal protection** program
- In the final design and environmental review phase for **$335 million Lower East Side coastal resiliency** project
- Investing **$100 million vulnerable shoreline improvement** program targeted at lowest-lying neighborhoods
- Placed over **4.2 million cubic yards of sand** on city beaches, and created **10 new miles of protective dunes**
- **Advanced vital USACE projects** in the Rockaways, Jamaica Bay, Sea Gate, and Staten Island
- Created a new **Science and Resilience Institute at Jamaica Bay**

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Key Points

- Don't expect scientific uncertainty to be reduced in time to settle critical mitigation and adaptation decisions
- Even 'lower end' projections of mean sea level rise and temperature suggest large changes in the frequency, intensity, and duration of extreme events
- And we do not appear to be on track for 'lower end' projections
  - Pledges are presumed insufficient to even approach meeting the 2C target
- Some of the biggest local risks may be only weakly linked to local climate; some of these risks may be difficult to identify in advance

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About CCRUN

Consortium for Climate Risk in the Urban Northeast (CCRUN)

A NOAA Regional Integrated Sciences and Assessments (RISA) Project

Mission: CCRUN conducts stakeholder driven research that reduces climate-related vulnerability and advances opportunities for adaptation in the urban Northeast

Hurricane Sandy storm damage in Staten Island, NY, Oct 30, 2012.
Source: Somayya Ali / Columbia University

Green infrastructure for improved water quality and stormwater control.
Source: Franco Montalto / Drexel University

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For more information

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