Projected Climate Change Impacts in New York City

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Outline

• New York City’s weather hazards landscape
  • Heat
  • Storm Hazards
    • Flooding Types
• Projected impacts of climate change
Heat

• Extreme heat is associated with increased mortality

• Heat wave:
  • 3 or more consecutive days with temperatures greater than 90° F (US National Weather Service)
Urban Heat Island

- Conventional road and building materials generally reflect less sunlight and absorb and reemit more heat energy than natural surfaces.
- Cooler surface temperatures with increased vegetation.
- Water bodies can moderate temperature.
Tropical cyclones

• ‘Powered’ by warm ocean waters

• Examples:
  • Hurricanes
  • Tropical Storms
  • Tropical Depressions

Track of Hurricane Irene (2011), which made landfall in Brooklyn as a Tropical Storm
Other storms

• ‘Powered’ by differences in air-temperature (baroclinic processes)

• Warmer land surfaces than air aloft

• Fronts where warm and cold air masses meet
Other Storms

• ‘Powered’ by differences in air-temperature (baroclinic processes)
  • Warmer land surfaces than air aloft
  • Fronts where warm and cold air masses meet

Examples associated with hazardous weather:
• Thunderstorms
• Clippers
• Squalls
• Nor’Easters
• Post-tropical ‘remnants’ of hurricanes
Storm Hazards
Any given storm event can be associated with one or more

- Rain
- Storm surge
- Lightning
- Wind
- Tornadoes
- Hail (except tropical cyclones)
- Snow/Ice (except tropical cyclones)
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- Snow/Ice (except tropical cyclones)

Associated with flooding
Tropical Storm Irene (2011)
Combined storm surge and rain

Post-tropical Storm Sandy (2012)
Storm surge, minimal rain

Cloudburst associated with Hurricane Ida remnants (2021)
Extreme rain, no storm surge
Flooding from rain

Pluvial flooding

- Most of New York City’s natural streams have been filled and replaced with storm sewers
- Pluvial flooding occurs when rainfall rates are greater than the rate of sewer drainage and soil infiltration
Flooding from rain

Pluvial flooding

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Flooding from below

Groundwater flooding

Downward percolation

Rainwater infiltrates into the ground

Water Table

Groundwater flow
Flooding from below
Groundwater flooding

During wet seasons, the water table can rise above the land surface of low-lying areas.
Flooding from below

Groundwater flooding

Modified from W.W. Norton Inc.
Flooding from the sea

Storm Surge

• Caused by wind and, to a lesser extent, the low pressure of coastal storms

• Coastal storms
  • Tropical cyclones (*Tropical Depressions, Tropical Storms, Hurricanes*)
  • Extratropical cyclones (*Nor’Easters*)
Flooding from the sea

Storm Surge

- Storm surge magnitude determined by coastal storm:
  - Size
  - Wind speed
  - Track (and the shape of the coast it affects)
  - Translational (travel) speed
Flooding from the sea

Storm Surge

Flooding is determined by the storm tide, which is storm surge + tide level.
Storm tide
Determines coastal flooding
Coastal Flood Stages

Harbor water levels that will result in flooding

Latest observed value: 1.81 ft at 1:48 PM EST 24-Jan-2023. Flood Stage is 7.5 ft

Major: 9.0'  Moderate: 8.2'  Minor: 7.5'  Low Stage: -1.8'
Latest observed value: 1.81 ft at 1:48 PM EST 24-Jan-2023. Flood Stage is 7.5 ft.

Major: 9.0'
Moderate: 8.2'
Minor: 7.5'
Low Stage: -1.8'
Mean Higher High Water (MHHW) - 5.9 ft
Mean Higher High Water (MHHW)

Minor Flooding 1.6 ft. Above MHHW

Latest observed value: 1.81 ft at 1:48 PM EST 24-Jan-2023. Flood Stage is 7.5 ft

Site Time (EST)

Graph Created (2:31PM Jan 24, 2023) - Observed

IWDN6(plotting HMIRG) "Gage 0" Datum: n/a

Observations courtesy of US Geological Survey
Mean Higher High Water (MHHW)

Moderate Flooding 2.34 ft. Above MHHW

Latest observed value: 1.81 ft at 1:48 PM EST 24-Jan-2023. Flood Stage is 7.5 ft
Mean Higher High Water (MHHW) is 5.9 ft.

Major Flooding: 3.1 ft. above MHHW
Mean Higher High Water (MHHW) - 9.81 ft above MLLW on December 23, 2022

Latest observed value: 1.81 ft at 1:48 PM EST on January 24, 2023. Flood Stage is 7.5 ft.
Mean Higher High Water (MHHW) 13.7 ft above MLLW on October 29, 2012 (Sandy)

Latest observed value: 1.81 ft at 1:48 PM EST 24-Jan-2023. Flood Stage is 7.5 ft

Major: 9.0'
Moderate: 8.2'
Minor: 7.5'

Low Stage: -1.8'
Climate change and weather hazards in New York City
Climate change pathways

Global emissions of heat-trapping gases

Data: SSP database (IIASA/GCP/Riahi et al 2017/Rogelj et al 2018

Scenario group
Forcing target and temperature range in 2100
Baseline (3.0–5.1°C)
6.0 W/m² (3.2–3.3°C)
4.5 W/m² (2.5–2.7°C)
3.4 W/m² (2.1–2.3°C)
2.6 W/m² (1.7–1.8°C)
1.9 W/m² (1.3–1.4°C)

More Global Warming

Net CO₂ emissions (GtCO₂)

-40
0
50
100
140

1980 2000 2020 2040 2060 2080 2100

net-negative global emissions

Global Carbon Project
Climate change pathways
Global emissions of heat-trapping gases

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2.6 W/m² (1.7–1.8°C)
1.9 W/m² (1.3–1.4°C)

Net CO₂ emissions (GtCO₂)

-40
-20
0
20
40
60
80
100
120
140

More Global Warming

1.5°C
2.0°C
5.0°C
Climate Change
Mitigation and Adaptation

• Climate Change Mitigation:
  • Preventing global warming and associated changes to climate, primarily through the global reduction of emissions of greenhouse (heat-trapping) gases

• Climate Change Adaptation:
  • Societal changes (including infrastructure and policy changes) to better manage the impacts of climate change
Climate Change and New York City
Warmer and wetter

Climate Change and Heat

More extremely hot days

- **Event frequency**: Number of heat waves each year
- **Mean event duration**: Average length of heat waves
- **Mean event intensity**: Average maximum temperatures during heat waves

Climate change and rain

More intense rain

• When conditions are favorable for rain, rainfall can potentially fall at higher rates

• Warmer temperatures can amplify the dynamics of thunderstorms

• Uncertainty about how much

• Challenge for planning

Rain during the Ida Remnants Cloudburst on 9.1.2021 (Photo: Anthony Behar)
Climate change and sea level rise

- Global sea levels will rise as the ocean expands and land ice melts
- New York City is part of the mid-Atlantic sea level rise hot spot
- Local relative sea level rise is much higher than the global average

Sunny day flooding on 1.4.2022 (Photo: Giles Ashford)
Sea Level Rise Projections

Sea Level Rise Projections


- 1.8 ft by the 2070s
- 1.8 ft by the late 2060s
Sea Level Rise Projections


2.34 ft major flood stage in Jamaica Bay with the highest high tide by the 2070s

1.8 ft by the 2070s

1.8 ft by the late 2060s
Mean Higher High Water (MHHW) is 8.37 ft above MLLW. Sea Level Rise is 5.9 ft.

Latest observed value: 1.81 ft at 1:48 PM EST on 24-Jan-2023. Flood Stage is 7.5 ft.
Groundwater flooding occurs when the water table rises above the land surface elevation.
Rising water tables can flood basements in urban settings. Historic Sea Level

Sump pumps are frequently utilized for local dewatering.
Coastal Flood Stages

Harbor water levels that will result in flooding… But are not set in stone. These can be changed through local adaptation measures.
Increased infiltration and reduced stormwater drainage with rising groundwater levels. Tide flaps can be deployed to prevent direct inflow of seawater into storm sewer outfalls, but do not prevent groundwater infiltration as sewers age.
Sea Level Rise Projections

Are dependent on global emissions of greenhouse gases. Climate change mitigation can reduce the likelihood of higher sea level rise scenarios.
Sea Level Rise Exceedance Probability

1.5°C end-century warming (SSP1-2.6 immediate, rapid energy transition)

- **92%**
  - NOAA 2022 Low
  - 2.34 ft major flood stage in Jamaica Bay with the highest high tide
  - 1.8 ft by the 2070s

- **37%**
  - NOAA 2022 Low-Intermediate
  - 2.34 ft by the 2070s
  - 1.8 ft by the late 2060s

- **<1%**
  - NOAA 2022 Intermediate
  - 1.8 ft by the 2070s
Sea Level Rise Exceedance Probability

2.0°C end-century warming (SSP1-2.6 to SSP2.6-4.5 - near-term energy transition)

98%

50%

2%

NOAA 2022 Low

2.34 ft major flood stage in Jamaica Bay with the highest high tide

1.8 ft by the 2070s

1.8 ft by the late 2060s

NOAA 2022 Low-Intermediate

NOAA 2022 Intermediate

2.34 ft by the 2070s

1.8 ft by the late 2060s
Sea Level Rise Exceedance Probability
5.0°C end-century warming (SSP8.5 high emissions + feedbacks)

>99%
NOAA 2022 Low

>99%
NOAA 2022 Low-Intermediate

23%
NOAA 2022 Intermediate

2.34 ft major flood stage in Jamaica Bay with the highest high tide
1.8 ft by the 2070s

2.34 ft by the 2070s
1.8 ft by the late 2060s

Relative Sea Level Rise (feet)

2020 2040 2060 2080 2100

2020 2040 2060 2080 2100

2020 2040 2060 2080 2100
Summary

• In New York City, climate change will result in:
  • More hot days
  • More intense precipitation
  • Sea level rise
• Adaptation will be necessarily to manage the impacts of these amplified hazards
• Global warming mitigation is critical for avoiding more severe climate change pathways

Long Island City, NY, August 2022