ClimAID Annex II

Climate Adaptation Guidebook for New York State

Authors: Cynthia Rosenzweig, Arthur DeGaetano, William Solecki,Radley Horton, Megan O'Grady, Daniel Bader

New York State Energy Research and Development Authority

Climate Adaptation Guidebook for New York State

NYSERDA
November 2011

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Climate Adaptation Guidebook for New York State

Annex II to the ClimAID Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State

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NYSERDA
November 2011

Responding to Climate Change in New York State

Climate change is already beginning to affect the people and resources of New York State, and these impacts are projected to grow. At the same time, the state has the potential capacity to address many climate-related risks, thereby reducing negative impacts and taking advantage of possible opportunities.

ClimAID: The Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State was undertaken to provide decision-makers with cutting-edge information on the state's vulnerability to climate change and to facilitate the development of adaptation strategies informed by both local experience and scientific knowledge.

This state-level assessment of climate change impacts is specifically geared to assist in the development of adaptation strategies. It acknowledges the need to plan for and adapt to climate change impacts in a range of sectors: Water Resources, Coastal Zones, Ecosystems, Agriculture, Energy, Transportation, Telecommunications, and Public Health.

The author team for the report is composed of university and research scientists who are specialists in climate change science, impacts, and adaptation. To ensure that the information provided would be relevant to decisions made by public and private sector practitioners, stakeholders from state and local agencies, non-profit organizations, and the business community participated in the process as well.

This Guidebook will help develop climate change adaptation strategies using a risk management approach. The larger technical report provides useful information to decision-makers, such as state officials, city planners, water and energy managers, farmers, business owners, and others as they begin responding to climate change in New York State.

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I. Climate Change and New York State

Over the last century, global mean temperatures and sea levels have been increasing and the Earth's climate has been changing. As these trends continue, climate change is increasingly being recognized as a major global concern. In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) formed an international panel of leading climate scientists, coined the Intergovernmental Panel on Climate Change (IPCC), to provide objective and up-to-date information regarding the changing climate. In its 2007 Fourth Assessment Report (AR4), the IPCC states that there is a greater than 90 percent chance that rising global temperatures, as observed since 1750, are primarily the result of human activities.

As predicted in the 19th century, the principal driver of climate change over the past century has been the increase in levels of atmospheric greenhouse gases (GHGs) associated with fossil-fuel combustion, changing land-use practices, and other human activities. The atmospheric concentrations of the major GHG carbon dioxide (CO_2) are now more than one-third higher than in pre-industrial times. The concentrations of other important GHGs, including methane (CH_4), ozone (O_3), and nitrous oxide (N_2O), have increased as well. Largely resulting from work performed by the IPCC and the United Nations Framework Convention on Climate Change (UNFCCC), global efforts to mitigate the severity of climate change by limiting levels of GHG emissions are now underway.

Because some of the added GHGs will remain in the atmosphere for centuries, and some parts of the climate system respond in a gradual manner, awareness is growing that some climate changes are inevitable. Responses to climate change have evolved from focusing on *mitigating* or reducing the amount of GHGs released into the atmosphere to including *adaptation* measures in an effort to both minimize the impacts and prepare for unavoidable future changes. In some cases, climate change may bring opportunities. (For more information, see the full ClimAID Technical Report.)

New York State possesses a wide range of vulnerabilities to a changing climate and, at the same time, has great potential to adapt to its impacts. From the Great Lakes to Long Island Sound, from the Adirondacks to the Susquehanna Valley, climate change will affect the people and resources of New York State. Risks associated with climate change include higher temperatures leading to greater incidence of heat stress caused by more frequent and intense heat waves; increased summer droughts and extreme rainfall affecting food production, natural ecosystems, and water resources; and sea level rise causing exacerbated flooding in coastal areas.

Climate change—and associated uncertainties in future climate projections, as well as complex linkages among climate change, physical systems, biological systems, and socioeconomic factors—poses special challenges for New York State decision-makers. However, there is a knowledge base that decision-makers can use to make progress in reducing vulnerability to climate change and building adaptive capacity needed to respond to extremes in the current climate, as well as increased climate risks in the future.

This *Climate Adaptation Guidebook for New York State* describes a risk management approach to developing climate change adaptation strategies. The climate change adaptation process involves understanding climate trends and projections, identifying vulnerabilities, assessing the risk levels, and developing and prioritizing strategies. The guidebook discusses these key aspects in the context of New York State. By developing climate change adaptation strategies following a risk management approach, New York State can effectively respond to future climate impacts.

Key Definitions for Responding to Climate Change

Adaptation – Actions that take place in response to a changing climate. Actions can create opportunities or challenges.

Adaptive capacity – Ability of a system to adjust to actual or expected climate stresses, or to cope with the consequences.

Adaptation strategies – Operational, managerial, budgetary, or infrastructure changes that will result in reducing risk and/or taking advantage of potential opportunities associated with climate change. A strategy is usually developed for a key vulnerability. Adaptation strategies do not directly include actions that reduce the likelihood of climate change occurring.

Climate resilience – A state in which climate risk information, vulnerability, and adaptation knowledge are taken into account in order to reduce the level of physical, social, or economic impact of climate variability and change.

Climate risks – Generally, risk is a product of the likelihood of an event occurring (typically expressed as a probability) and the magnitude of consequences should that event occur. For climate change impacts, risk can be thought to have three dimensions: the probability of a climate hazard occurring; the likelihood of impacts associated with that hazard; and the magnitude of consequence, should that impact occur. These risk estimates can be adapted and improved as additional information becomes available.

Impacts – The natural or potential effects a change in climate has or could have on natural or human systems.

Mitigation – Direct actions that reduce the concentrations of greenhouse gases in the atmosphere and other factors that are currently altering, or have the potential to alter, the earth's climate system.

Prioritization – Methods to assess and evaluate a set of adaptation strategies to determine those that are more pressing or suitable to undertake. Various prioritization criteria can be used.

Vulnerability – The degree to which geophysical, biological, and socio-economic systems are susceptible to, and unable to cope with, adverse impacts of climate change.

Sources: IPCC (2007) and New York City Panel on Climate Change (NPCC) (2010)

II. Framing Adaptation

Developing climate change adaptation involves understanding how the *climate* in New York State might change; identifying potential *vulnerabilities* a change in climate might create; assessing *risk* levels of those vulnerabilities; developing *adaptation strategies* that will help to minimize those risks; and prioritizing those strategies. This process helps to distill the complexities involved in considering climate change, its impacts, and how to adapt. The outcome of the process involves enhancing the overall *adaptive capacity* of a particular region, jurisdiction, or organization. *Adaptive capacity* is defined as the ability of a system to adjust to actual or expected climate stresses, or to cope with the consequences (see Figure 1).

Risk Management

Climate adaptation strategies and actions have a direct connection to risk and hazards management. Individuals and organizations reduce their vulnerability and exposure to threats through risk management as they develop protocols to avert and manage hazards and promote disaster risk reduction, especially around areas of uncertainty. Stakeholders can modify risk management tools, such as a risk matrix, for climate change adaptation, especially as a way to deal with the uncertainties surrounding climate hazards and associated impacts. Other uncertainties that may affect climate change adaptation include changes in technologies and social dynamics. The exact need and context in which stakeholders develop adaptation strategies reflect both the history and emerging understanding of the amount and significance of ongoing climate change.

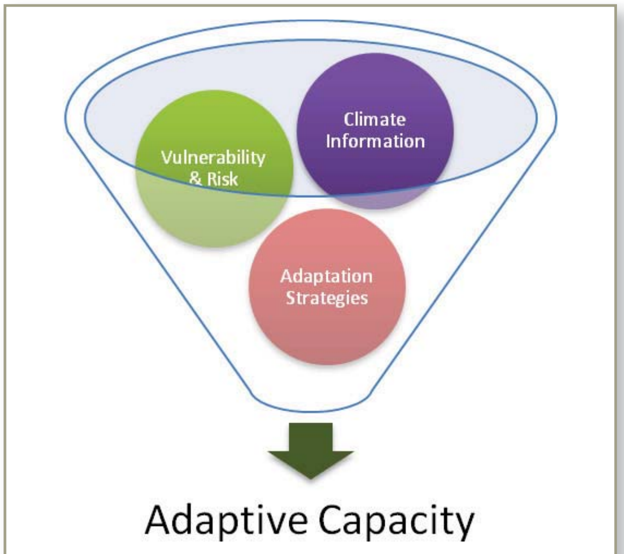


Figure 1. Climate Change Adaptive Capacity

Climate Resilience and Flexible Adaptation Pathways

To build climate resilience, climate change adaptation should allow for flexible responses to changing climate conditions. Flexible adaptation consists of implementing actions or infrastructure that stakeholders can adjust or shift over time in response to new climate science and evidence from ongoing monitoring, as well as implementing shifts in policies and strategies to better respond to emerging climate threats and opportunities (see Figure 2).

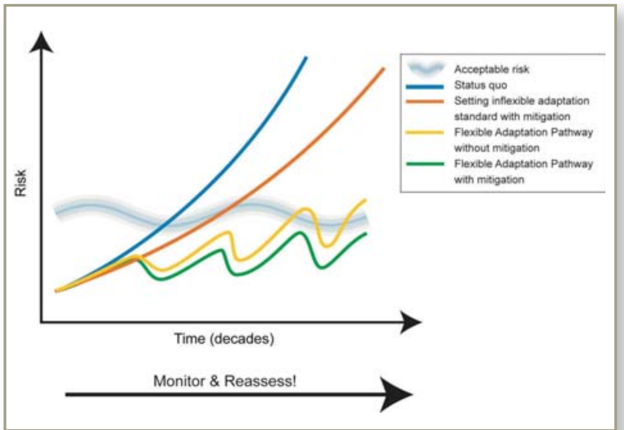


Figure 2. Flexible Adaptation and Mitigation Pathways

Graphic adapted from Lowe (2009)

An acceptable level of risk, as determined by society, is likely to change over time; for instance, the acceptable level of risk is likely to be lower after an extreme event, such as a hurricane. A one-time static or inflexible adaptation is better than maintaining the status quo, but such actions would still eventually result in crossing into an unacceptable level of risk, when climate conditions change beyond what the action was designed to withstand. *Flexible adaptation pathways* that include both adaptation and mitigation allow policymakers, stakeholders, and experts to develop and implement strategies that evolve as climate change progresses. The process of adaptation assessment can be summarized in an eight-step process (see Section IV) and adjusted as needed, depending on varying circumstances.

III. Current Climate and Climate Change Projections

This section provides an overview of the current climate in New York State and summarizes the climate change projections for New York. Understanding the climate is the first step in developing adaptation strategies for New York State (see Section IV).

New York State's Climate

The following components are key features of New York State's climate:

- Average annual temperature varies from 40°F in the Adirondacks to near 55°F in the New York City metropolitan region.
- Average annual precipitation ranges from approximately 30 inches in Western New York to close to 50 inches in the New York City region, Tug Hill Plateau, and Adirondacks.
- The state experiences a variety of extreme events:
  - **Heat waves** are common in urban areas, especially in the southern parts of the state.
  - **Short-duration flooding,** which can result from heavy rainfall and/or runoff from snowmelt, affects the entire state.
  - **Lake-effect snow** is a major climate hazard in western and central New York State.
  - **Coastal storms** along the Atlantic coast and Hudson River Valley bring heavy precipitation, high winds, and flooding.

Because New York State's climate is varied, climate impacts and effective adaptation strategies will be varied as well.

New York State Climate Regions

The climate of New York State varies from the Great Lakes to Long Island Sound. To help in developing adaptation strategies, the ClimAID assessment divided New York State into seven regions, as shown in Figure 3.

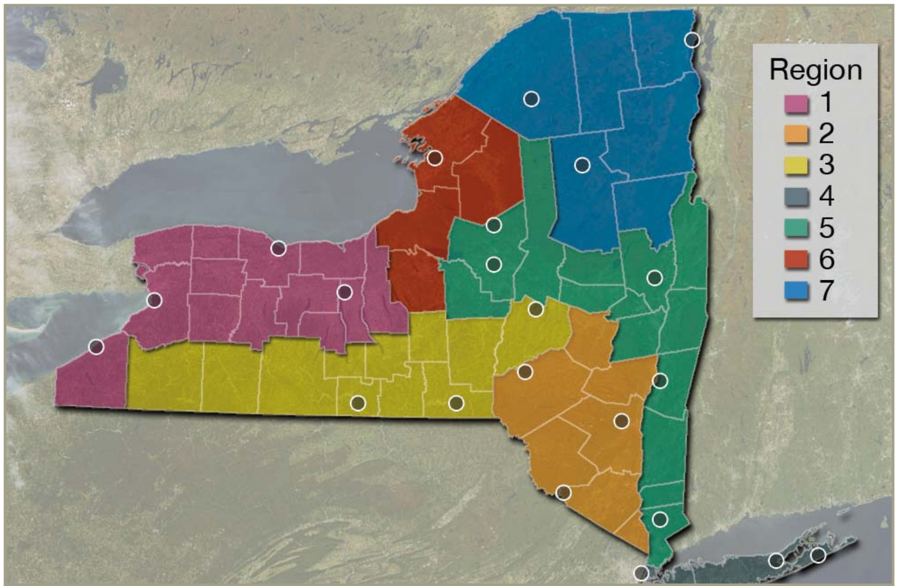


Figure 3. ClimAID Regions

Observed Climate Trends

Temperatures in New York State have risen over the course of the 20th century, with the greatest warming occurring in recent decades. New York State has experienced an increase in extreme hot days (days at or above 90°F) and a decrease in cold days (days at or below 32°F). In addition, the sea level has steadily risen in the coastal areas of the state. Figure 4 shows observed 20th century trends in temperature, precipitation, and sea level rise for New York City (ClimAID Region 4); these trends serve as an example of how the climate has already begun to change in different parts of the state.

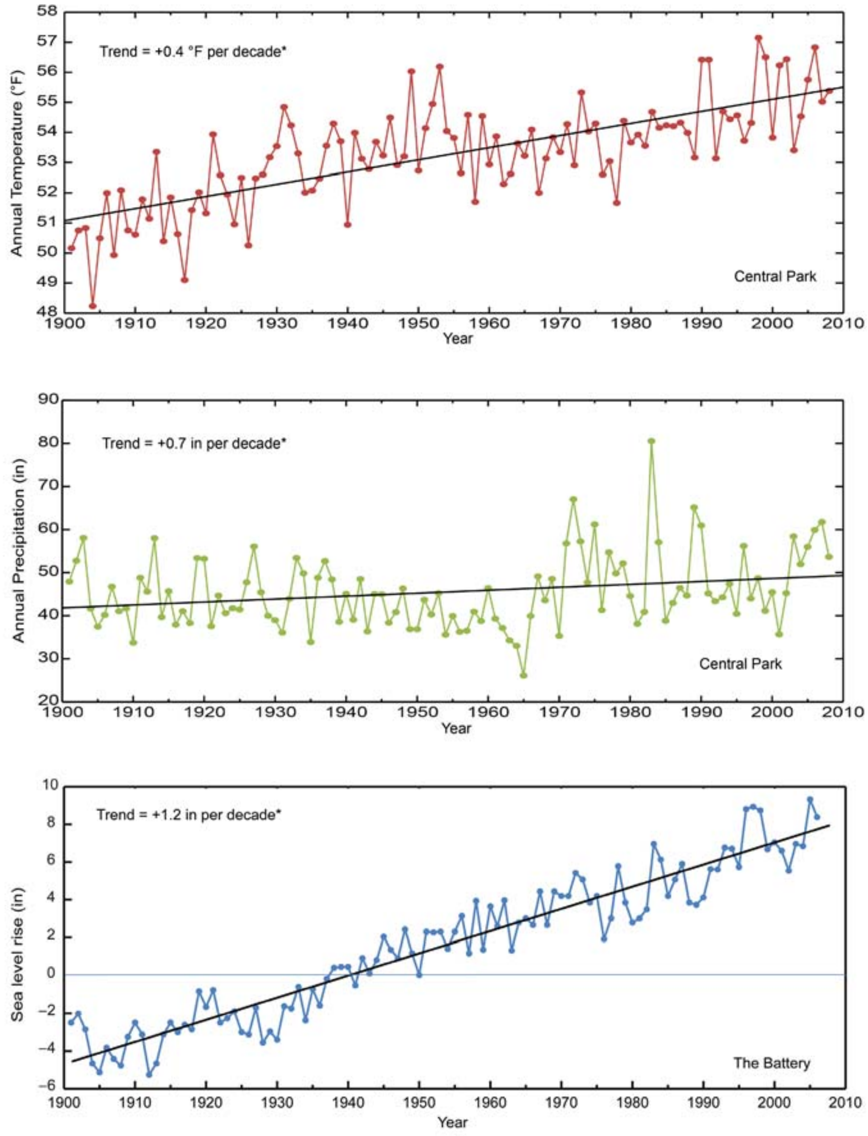


Figure 4. Observed Annual Temperature, Precipitation, and Sea Level Rise Over the 20th Century for New York City (ClimAID Region 4)

***All trends significant at the 1 percent level.**

Future Projections

To produce future climate scenarios, experts use global climate models with a number of possible GHG emissions scenarios. Each emissions scenario represents a set of different demographic, social, economic, technological, and environmental assumptions about the future, called "storylines" (IPCC, 2000). The ClimAID team used three GHG emissions scenarios, as shown in Figure 5. The three scenarios and the storylines the team used in the ClimAID Assessment are described in Table 1.

Scenario	Storyline
A2	Relatively rapid population growth and limited sharing of technological change combine to produce high GHG levels by the end of the 21st century, with emissions growing throughout the entire century.
A1B	Effects of economic growth are partially offset by the introduction of new technologies and decreases in global population after 2050. This trajectory is associated with relatively rapid increases in GHG emissions and the highest overall CO2 levels for the first half of the 21st century, followed by a gradual decrease in emissions after 2050.
B1	This scenario combines the A1/A1B population trajectory with societal changes tending to reduce GHG emissions growth. The net result is the lowest GHG emissions of the three scenarios, with emissions starting to decrease by 2040.

Table 1. Greenhouse Gas Emissions Scenarios and Storylines

Other emissions scenarios yield different GHG concentrations by the end of the 21st century as compared to the three scenarios ClimAID used. The IPCC's "A1FI" scenario, for example, projects even higher CO_2 concentrations than those shown in Figure 5. The A1FI scenario was not included, however, because very few global climate model results are available for the scenario. However, experts should continue to reassess high-end climate change scenarios such as this over time.

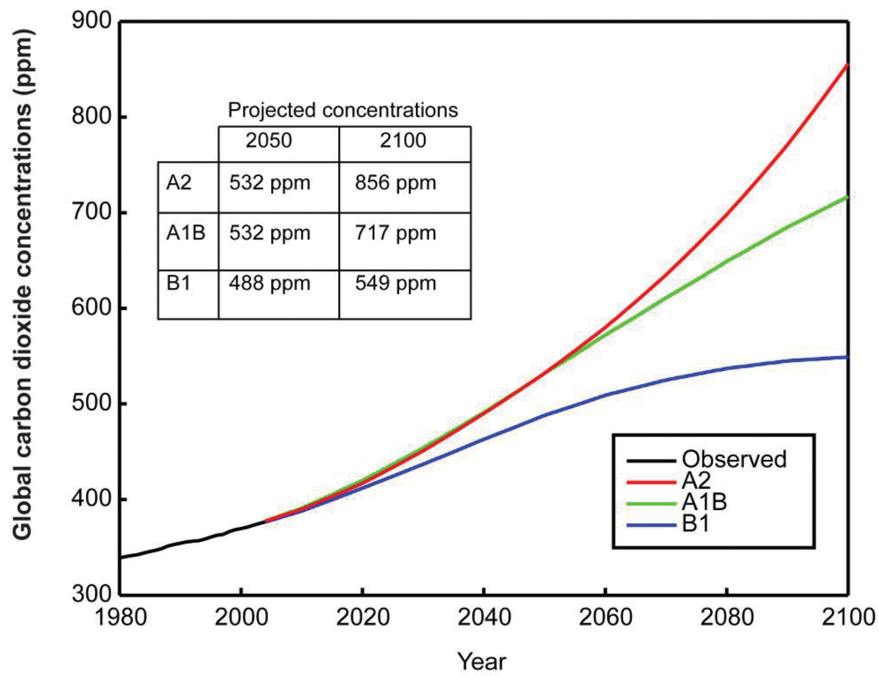


Figure 5. Observed Carbon Dioxide Concentrations Through 2003 and Future Carbon Dioxide Concentrations in the A2, A1B, and B1 Scenarios (2004–2100)

Source: IPCC (2000)

The ClimAID team divided the projections produced from the global climate models into two categories: mean annual changes and changes in extreme events. For the ClimAID Assessment, the team produced projections for each of the seven regions shown in Figure 3. The sections below present projections for a few of the regions, as examples. For the full suite of the ClimAID Assessment projections, please see the full Technical Report.

Mean Annual Changes

The maps and graphs shown in Figures 6 and 7 display temperature, precipitation, and sea level rise projections, based on a range of climate models and scenarios of possible future GHG concentrations. Table 2 and Figure 8 display both the global climate model-based sea level rise projections and a second set of higher projections (the rapid ice-melt scenario) based on the possibility of accelerated melting of land-based ice sheets and glaciers.

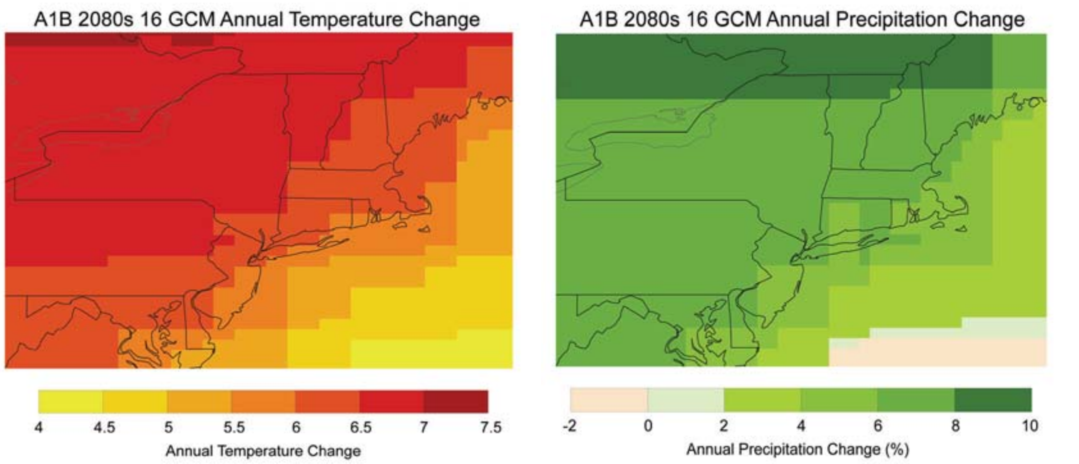


Figure 6. Projected Change in Annual Temperature and Precipitation in the Northeast for the 2080s, Relative to the 1980s Baseline (Under the A1B Emissions Scenario)

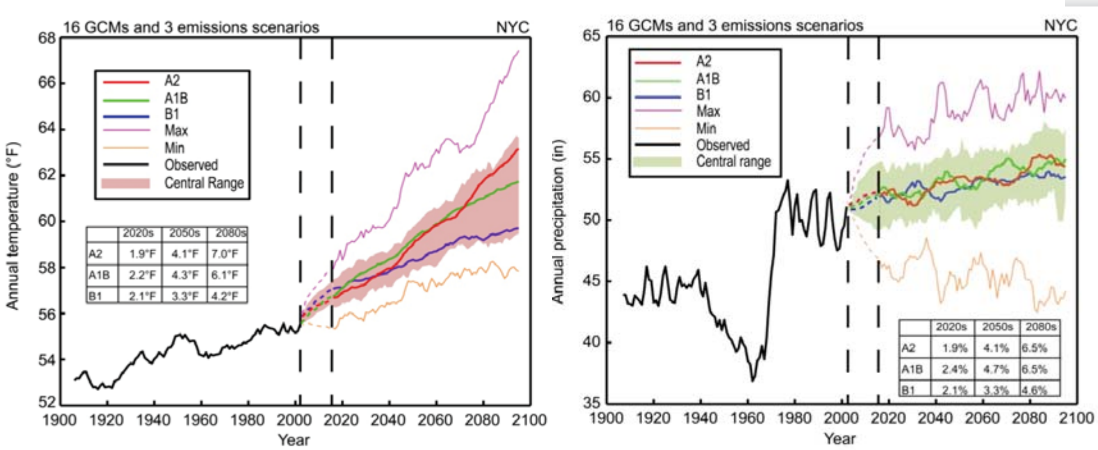


Figure 7. Temperature and Precipitation Observations and Projections for the New York City Area (ClimAID Region 4)

Projected model changes through time are applied to the observed historical data. The three thick lines (green, red, and blue) show the average for each emissions scenario across the 16 GCMs. Shading shows the central range (middle 67%). The bottom and top lines, respectively, show each year s minimum and maximum projections across the suite of simulations. A ten year filter has been applied to the observed data and model output. The dotted area between 2003 and 2015 represents the period that is not covered due to the smoothing procedure.

Region 4: Lower Hudson Valley & Long Island	Baseline (1971–2000)	2020s	2050s	2080s
Sea level rise[1] GCM-based	NA*	+ 2 to 5 in**	+ 7 to 12 in	+ 12 to 23 in
Sea level rise[2] Rapid ice-melt	NA	~ 5 to 10 in	~ 19 to 29 in	~ 41 to 55 in
Region 5: Mid Hudson Valley & Capital Region	**Baseline (1971 – 2000)**	**2020s**	**2050s**	**2080s**
Sea level rise[1] GCM-based	NA	+ 1 to 4 in	+ 5 to 9 in	+ 8 to 18 in
Seal level rise[2] Rapid ice-melt	NA	~4 to 9 in	~ 17 to 26 in	~ 37 to 50 in

Table 2. Sea Level Rise Projections

***NA: not applicable**
****in: inch**

[1] The central range (middle 67 percent) of values from GCM-based probabilities rounded to the nearest inch is shown.
[2] The rapid ice-melt scenario is based on acceleration of recent rates of ice melt in the Greenland and West Antarctic ice sheets and paleoclimate studies.

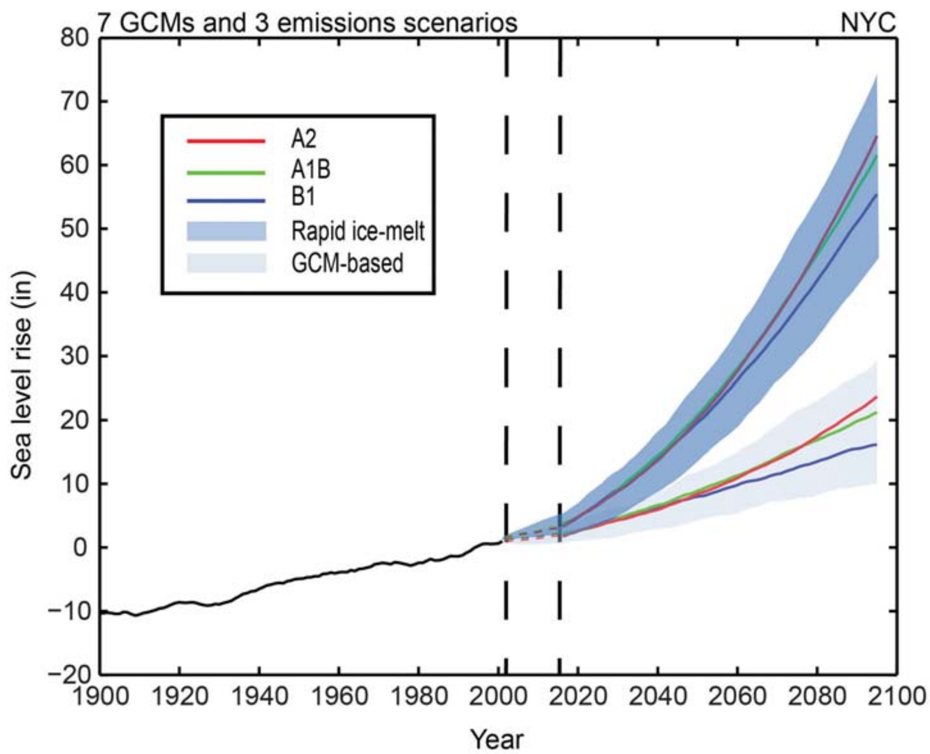


Figure 8. Sea Level Rise Observations and Projections Using Global Climate Model-Based and Rapid Ice-Melt Scenario

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. Dark blue shows the range of projections for the NPCC rapid ice melt scenario, while light blue shows the range of projections for the GCM based sea level rise approach. The three thick lines (green, red, and blue) within each sea level rise scenario show the average for each emissions scenario across 7 GCMs. A ten year filter has been applied to the observed data and modeled output.

Higher temperatures and sea level rise are extremely likely for New York State in the future. All global climate models project continuing temperature and sea level rise increases over the century, with the central range (the middle 67 percent of all projections) projecting more rapid temperature and sea level rise than what occurred over the 20th century. Although most projections indicate small increases in precipitation, some do not, and decade-by-decade precipitation variability is large; therefore, precipitation projections are less certain than temperature projections.

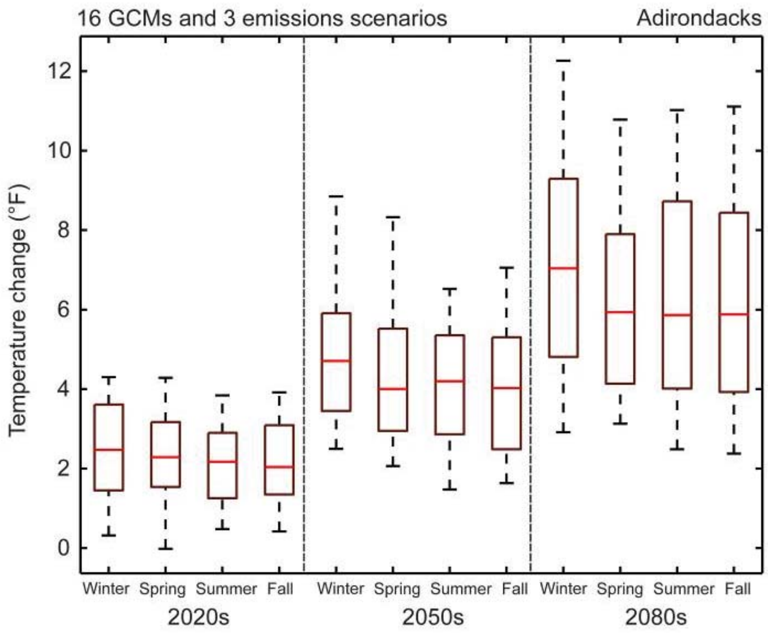
Region-specific projections of mean changes in temperature and precipitation are provided in Table 3. Figure 9 shows seasonal projections for the Adirondacks (ClimAID Region 7).

		Baseline[1] 1971–2000	2020s	2050s	2080s
Region 1					
Stations used for Region 1 are Buffalo, Rochester, Geneva and Fredonia.	Air temperature[2]	48ºF	+1.5 to 3.0ºF	+3.0 to 5.5ºF	+4.5 to 8.5ºF
	Precipitation	37 in	0 to +5%	0 to +10%	0 to 15%
Region 2					
Stations used for Region 2 are Mohonk Lake, Port Jervis, and Walton.	Air temperature[2]	48ºF	+1.5 to 3.0ºF	+3.0 to 5.0ºF	+4.0 to 8.0ºF
	Precipitation	48 in	0 to +5%	0 to +10%	+5 to 10%
Region 3					
Stations used for Region 3 are Elmira, Cooperstown, and Binghamton.	Air temperature[2]	46ºF	2.0 to 3.0ºF	+3.5 to 5.5ºF	+4.5 to 8.5ºF
	Precipitation	38 in	0 to +5%	0 to +10%	+5 to 10%
Region 4					
Stations used for Region 4 are New York City (Central Park and LaGuardia Airport), Riverhead, and Bridgehampton.	Air temperature[2]	53ºF	+1.5 to 3.0ºF	+3.0 to 5.0ºF	+4.0 to 7.5ºF
	Precipitation	47 in	0 to +5%	0 to +10%	+5 to 10%
Region 5					
Stations used for Region 5 are Utica, Yorktown Heights, Saratoga Springs, and the Hudson Correctional Facility.	Air temperature[2]	50ºF	+1.5 to 3.0ºF	+3.0 to 5.5ºF	+4.0 to 8.0ºF
	Precipitation	51 in	0 to +5%	0 to +5%	+5 to 10%
Region 6					
Stations used for Region 6 are Boonville and Watertown.	Air temperature[2]	44ºF	+1.5 to 3.0ºF	+ 3.5 to 5.5ºF	+4.5 to 9.0ºF
	Precipitation	51 in	0 to +5%	0 to +10%	+5 to 15%
Region 7					
Stations used for Region 7 are Wanakena, Indian Lake, and Peru.	Air temperature[2]	42ºF	+1.5 to 3.0ºF	+3.0 to 5.5ºF	+4.0 to 9.0ºF
	Precipitation	39 in	0 to +5%	0 to +5%	+5 to 15%

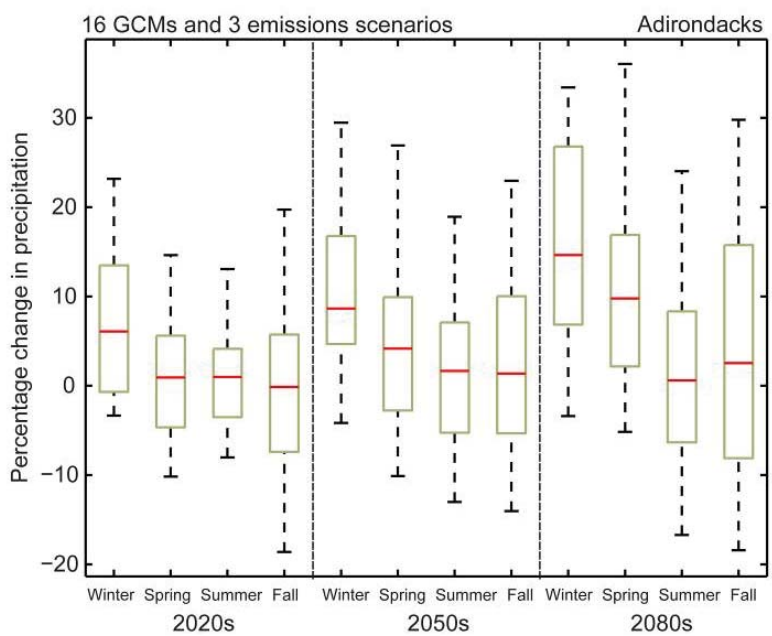
Table 3. Projections of Mean Annual Changes in Air Temperature and Precipitation for New York State Climate Regions

[1] The baselines for each region are the average of the values across all the stations in the region.
[2] The central range (middle 67 percent) of values from model-based probabilities is shown; temperature ranges are rounded to the nearest half-degree and precipitation to the nearest 5 percent.

Source: Columbia University Center for Climate Systems Research. Data are from USHCN and PCMDI.



Increases in temperature are projected to be approximately the same across all seasons



Increases in precipitation may be greatest in winter

Figure 9. Seasonal Temperature Projections for the Adirondacks (ClimAID Region 7)

The full range of values across the 16 GCMs and three emissions scenarios and key points in the distribution are shown here. The central 67 percent of values are shown in the boxed areas; the median is indicated by the red line. Winter runs from December to February, while Spring runs from March through May, Summer from June through August, and Fall from September through November.

Extreme Events

Extreme events can have disproportionate effects on both urban and rural systems throughout New York State. During the 21st century:

- Heat waves are expected to become more frequent and intense
- Intense precipitation events are expected to become more frequent
- Storm-related coastal flooding is expected to increase due to rising sea levels

Table 4 presents projections for some extreme events for the Southern Tier (ClimAID Region 3).

Elmira (Region 3): Full range of changes in extreme events: minimum, (central range*), and maximum					
	Extreme event	Baseline	2020s	2050s	2080s
Heat Waves & Cold Events	Number of days per year with maximum temperature exceeding				
	90°F	10	11 (14 to 19) 25	15 (21 to 33) 45	19 (26 to 56) 70
	95°F	1	2 (2 to 4) 7	2 (4 to 10) 18	4 (7 to 24) 38
	Number of heat waves per year[2]	1	1 (2 to 3) 3	2 (3 to 4) 6	2 (3 to 8) 9
	average duration	4	4 (4 to 5) 5	4 (4 to 5) 5	4 (5 to 5) 7
	Number of days per year with min. temp. at or below 32°F	152	116 (122 to 124) 145	86 (106 to 122) 168	68 (87 to 114) 124
Intense Precipitation	Number of days per year with rainfall exceeding:				
	1 inch	6	5 (6 to 7) 8	5 (6 to 7) 8	5 (6 to 8) 10
	2 inches	0.6	0.5 (0.6 to 0.9) 1	0.5 (0.6 to 1) 1	0.4 (0.7 to 1) 2

Table 4. Extreme Event Projections for the Southern Tier

The minimum, central range (middle 67 percent), and maximum of values from global climate model based probabilities across the GCMs and GHG emissions scenarios are shown.

[1] Decimal places are shown for values less than 1, although this does not indicate higher precision/certainty. The high precision and narrow range reflect model-based results. Due to multiple uncertainties, actual values and range are not known to the level of precision shown in this table.
[2] Defined as three or more consecutive days with maximum temperature exceeding 90°F.

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

Figure 10. Qualitative Changes in Extreme Events for New York City/Long Island (ClimAID Region 4)

Potential for changes in other variables are described in a more qualitative manner, as quantitative information is either unavailable or considered less reliable. Figure 10 shows the likelihood of each of these changes occurring in New York City/Long Island.

[1] Likelihood definitions: Very likely = >90 percent probability of occurrence; Likely = >66 percent probability of occurrence; More likely than not = >50 percent probability of occurrence.
[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).

IV. Adaptation Assessment Steps

Adaptation to climate change focuses on actions that stakeholders take in response to a changing climate. Adaptation strategies do not directly include actions that reduce the likelihood of climate change from occurring (i.e., climate change *mitigation*) but instead present actions to lessen the impact of climate change or take advantage of changes unleashed by a shifting climate. In the context of the ClimAID assessment, the ClimAID team examined the following two categories of adaptation strategies:

- Those that reduce the level of physical, social, or economic impact of climate change and variability
- Those that take advantage of new opportunities emerging from climate change

The process of adaptation assessment can be summarized in an eight-step process (see Figure 11), which can be adjusted as needed depending on varying circumstances.

1. Identify current and future climate hazards
2. Inventory vulnerabilities and opportunities
3. Prioritize vulnerabilities
4. Identify and categorize adaptation strategies
5. Evaluate and prioritize adaptation strategies
6. Link strategies to capital and rehabilitation cycles
7. Create an adaptation plan
8. Monitor and reassess

Developing adaptation strategies starts with learning about current climate and how climate is projected to change in the future (see Section III). After understanding how the climate in New York State is projected to change, the next step in developing adaptation strategies is identifying the vulnerabilities a change in climate might create, as well as assessing risk levels. Vulnerabilities and risks can then be prioritized based on several criteria. The risk ratings resulting from the process of prioritizing vulnerabilities can help in the development of adaptation strategies. Several different types of adaptation strategies can be developed in response to a particular climate risk, and a set of factors can be used to evaluate and prioritize these strategies. The final step of the adaptation process is monitoring and reassessing climate changes, impacts, and adaptation strategies (see Figure 11).

These adaptation assessment steps are intended to be general enough to be useful for a range of jurisdictions and infrastructure sectors, yet specific enough to serve as the template for developing and implementing a sector's adaptation efforts. These steps may be used to develop climate change adaptation in any urban area, with region-specific adjustments related to climate risk information, critical infrastructure, and protection levels.

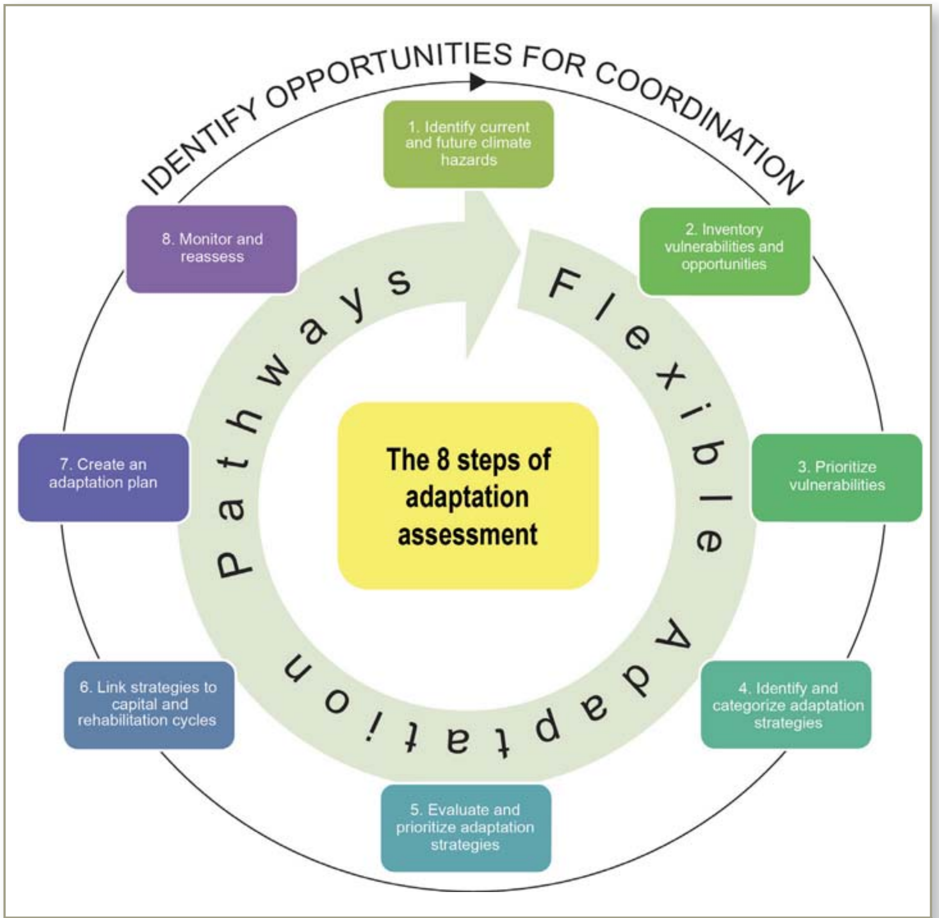


Figure 11. Adaptation Assessment Steps

Step 1: Identify Current and Future Climate Hazards

The first step in developing adaptation strategies is learning about current climate and how climate is projected to change in the future. For more information on the climate of New York State and future projections, see Section III.

Step 2: Inventory Vulnerabilities and Opportunities

A focus on key vulnerabilities is necessary to help policymakers and stakeholders assess the level of risk, prioritize, and design pertinent response strategies. In most instances, inventories of vulnerabilities will be qualitative, based on expert knowledge and relevant climate hazards. Factors that help characterize vulnerability include:

- Magnitude
- Timing
- Persistence and reversibility
- Likelihood
- Distributional aspects
- Importance of the at-risk systems
- Potential for adaptation
- Thresholds or trigger points that could exacerbate the change

Based on these factors, the ClimAID team developed an inventory of key vulnerabilities for New York State; examples of key vulnerabilities for New York State by climate factor, for each of the ClimAID sectors, are shown in Table 5.

Climate Hazard / Sector	Water Resources	Coastal Zones	Ecosystems	Agriculture	Energy	Transportation	Telecommunications	Public Health
Temperature and Heat Waves	Increased wear and tear on materials Potential changes in drinking supply	Shifts in marine species due to warmer waters	Increased frequency of summer heat stress on plants Potential changes in pest populations and habits Changes in species composition due to warmer winters	Changes in distribution of primary crops such as apples, cabbage, and potatoes Decline in dairy milk production	Increased demand on energy supply Increased vulnerability of energy infrastructure	Increased wear and tear on infrastructure Extreme event-related delays and hazards	Increased wear and tear on materials	More heat-related deaths Decline in air quality
Precipitation, Extreme Precipitation, and Drought	Increased vulnerability of infrastructure Potential changes in drinking supply Increased risk of changes in river flooding	Potential permanent inundation of coastal lands, including critical wetland habitat	Potential changes in pest populations and habits	Changes in distribution of primary crops such as apples, cabbage, and potatoes	Increased vulnerability of energy infrastructure Greater uncertainty around future availability of alternative energy sources	Flooding of key rail lines, roadways, and hubs Increased wear and tear of materials Extreme event-related delays and hazards	Flooding of central facilities Increased wear and tear on materials	Outbreaks of illness related to water-borne pathogens
Sea Level Rise and Coastal Flooding	Saltwater intrusion into freshwater aquifers	Increased risk of storm surge-related flooding Potential permanent inundation of coastal lands, including critical wetland habitat	Effects on marine and freshwater species	Salinization of coastal agriculture areas	Increased vulnerability of energy infrastructure	Episodic and permanent inundation of key rail lines, roadways, and hubs Extreme event-related delays and hazards	Flooding of central facilities Increased wear and tear on materials	Direct physical harm and trauma

Table 5. Examples of Key Vulnerabilities for New York State by Climate Factor

Step 3: Prioritize Vulnerabilities

Vulnerabilities are prioritized depending upon those systems or regions whose failure or reduction in function is likely to carry the most significant consequences. One tool used in risk assessment is a matrix that assesses the magnitude of consequence of an event against the likelihood of the event occurring. For climate adaptation assessment, there are at least three layers of uncertainty that need to be considered to yield an approximate overall risk of a particular climate hazard and a particular impact (see Figure 12). The overall risk rating can then assist in the creation of adaptation strategies. Risk categories to be considered include:

Probability of a given climate hazard – The general probability for change in a climate hazard (such as temperatures or extreme precipitation events) occurring. Using climate risk information as a guide, these can be defined as:

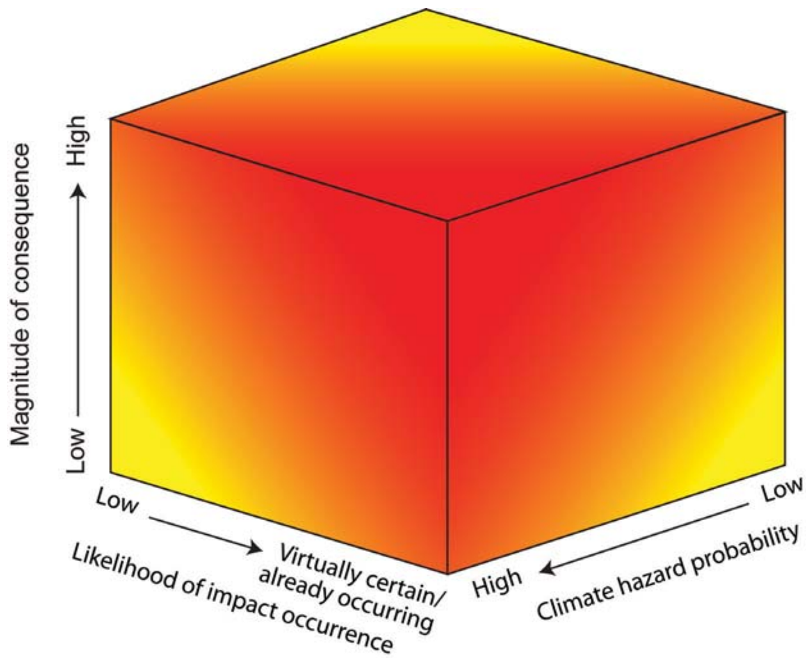
- **High** probability of the climate hazard occurring
- **Medium** probability of the climate hazard occurring
- **Low** probability of the climate hazard occurring

Likelihood of impact occurrence – The likelihood that a change in a given climate hazard (e.g., temperature rise) will result in a particular impact (e.g., material failure). Examples of likelihood categories include:

- **Virtually certain/already occurring** – Nearly certain likelihood of the impact occurring over the useful life of the infrastructure, and/or the climate hazard may already be impacting infrastructure
- **High** likelihood of the impact occurring over the useful life of the infrastructure
- **Moderate** likelihood of the impact occurring over the useful life of the infrastructure.
- **Low** likelihood of the impact occurring over the useful life of the infrastructure.

Magnitude of consequence – The combined impacts should a given hazard occur, taking into account such factors as:

- **Internal operations**, including the scope and duration of service interruptions, reputational risk, and the potential to encounter regulatory problems
- **Capital and operating costs**, including all capital and operating costs to the stakeholder and revenue implications caused by the climate change impact
- **Number of people impacted**, including considerations related to any impacts on vulnerable populations (including, but not limited to seniors, low-income communities, mentally or physically disabled citizens, homebound residents, and children).
- **Public health**, including worker safety
- **Economy**, including any impacts to the city's economy, the price of services to customers, and clean-up costs incurred by the public
- **Environment**, including the release of toxic materials and impacts on biodiversity, the state's ecosystems, and historic sites



RED	*Risks for which adaptation strategies should be developed.*
ORANGE	*Risks for which adaptation strategies may need to be developed or for which further information is needed.*
YELLOW	*Risks for which impacts should be monitored but which may not need actions at this time.*

Figure 12. Three-Dimensional Climate Risk Assessment Matrix

Step 4: Identify and Categorize Adaptation Strategies

Building on internal risk-management and assessment policies, stakeholders can begin to brainstorm strategies for those infrastructure classes that fall into the red and orange categories of the risk matrix (Figure 13). Adaptation strategies may be divided into a set of categories, including:

- The **type** of adaptation strategy depends on whether the strategy is focused on management and operations, infrastructural change (particularly with the physical component of the sector), or policy adjustments.
- The **administration** element of adaptation strategies defines the strategy as either emerging from the public or private sectors, and from which level of government (i.e., local/municipal, county, state, or national).
- **Condition** is defined by whether an adaptation strategy is an incremental action or a larger-scale paradigm shift.
- **Timing** highlights the period during which the adaptation strategy will be implemented. Given what is understood about the rate of climate change and the sensitivities of the system, a primary question is whether the adaptation should take place in the short term (less than 5 years), medium term (5 to 15 years), or long term (more than 15 years). A crucial consideration regarding the issue of timing is whether there are tipping points associated with dramatic shifts

in the level of impacts and/or vulnerabilities and whether these tipping points become triggers for new policies and regulations.

- **Geography** relates to the overall spatiality of the adaptation impacts, specifically, cataloging if the adaptation strategy is widespread, clustered, or isolated/unique (e.g., if the impact is associated with a specific site or location) throughout the state.

Potential adaptation strategies can be further defined within a range of elements including economics and institutional organization. Economic issues include the costs and benefits of adaptation, and the relative distribution of both. A critical economic issue is the overall cost-to-benefit ratio and how much economic advantage there is to taking a specified action. It is also important to determine potential opportunity costs, as well as the capacity (e.g., human and capital resources) and capability (e.g., regulatory mandate, legal ability) of the entity considering the adaptation.

Step 5: Evaluate and Prioritize Adaptation Strategies

Prioritization of which adaptation to undertake is a critical component of developing an adaptation strategy. Prioritization criteria include considerations of climate risk levels, vulnerability and exposure, maximum benefit-cost ratio, cost effectiveness, distributional and equity concerns, and institutional capacity and capability. Other criteria include the spatial and temporal character of a strategy's impact and the potential for flexible adaptation.

There may be multiple strategies to consider during adaptation planning. Once stakeholders have an initial list of adaptation strategies, they can evaluate these strategies in order to determine an order in which they should be implemented, and begin to create a broader agency- or organization-wide adaptation plan. There are a variety of available methods and perspectives to aid in evaluating individual actions and strategies (see example in Table 6). Elements to consider as part of evaluating adaptation strategies could include:

- **Cost** – What are the general costs of the proposed strategy, including human and other resources? General costs can yield a rough measure of benefits and costs to the extent that the consequences are measured in economic terms. There will also be important non-economic consequences in most decision problems.
- **Timing** – Timing of implementation should be considered relative to the timing of impact. Specifically, if the impact will occur in a time frame comparable to the time required for implementation, there is need for immediate consideration.
- **Feasibility** – How feasible is the strategy for implementation both within an organization and from perspectives such as engineering, policy, legal, and insurance? Are there expected technological changes that would impact future feasibility?
- **Efficacy** – To what extent will the strategy, if successfully implemented, reduce the risk?
- **Robustness** – Is there the potential to install equipment or upgrade infrastructure that is designed to withstand a range of climate hazards? Are there opportunities for flexible adaptation pathways?
- **Co-benefits** – Will strategies have a negative or positive impact on other stakeholders or sectors? Is there potential for cost sharing? Are there impacts on mitigation of greenhouse gases? Are there impacts on the environment or a vulnerable population?

Other factors to consider include equity, social justice, sustainability, institutional context, and unique circumstances.

Adaptation Strategy	Strategy Cost (1=low to 3 high)	Strategy Feasibility (1=low to 3 high)	Timing of implentation (1=low to 3 high)	Efficacy (1=low to 3 high)	Resiliency rating (1=low to 3 high)	Co-benefits (1=low to 3 high)	Average*	Notes & institutional considerations
Clean drains	1	1	1	2	2	2	1.8	
Build flood walls	3	2	2	1	3	2	2.2	

Table 6. Strategy Prioritization Framework with Adaptation Strategy Examples

***1=high priority strategy, 2=medium priority strategy, 3 low priority strategy**

Source: NPCC (2010)

Step 6: Link Strategies to Capital and Rehabilitation Cycles

Stakeholders have capital budgets that extend over a variety of time periods; in some cases, budgets extend over decades. Stakeholders should review these budgets to determine which adaptation strategies can be undertaken within existing funding constraints and what additional resources need to be identified. Linking adaptation strategies to planned projects or other non-adaptation efforts can result in significant cost savings. In turn, stakeholders are advised to put priority on exploring low-cost adaptation strategies, especially in times of fiscal austerity.

Step 7: Create an Adaptation Plan

The conclusion of the climate adaptation assessment process is really just the beginning. Stakeholders can combine and distill the knowledge gained from the assessment into an adaptation plan, which, in turn, can help operationalize adaptation planning.

An adaptation plan could include the following components:

- Discussion of key climate vulnerabilities
- List of prioritized adaptation strategies
- Consideration of other adaptation tools
- Plan for establishing indicators and monitoring
- Timeline to reassess strategies as new information comes to light

An adaptation plan should be seen as a living document and be revisited on a semi-regular basis to ensure that it incorporates the latest research and knowledge. By doing so, stakeholders can develop flexible adaptation pathways that lead to an ongoing adaptive capacity for systems, sectors, regions, and groups.

Step 8: Monitor and Reassess

Monitoring climate change on a regular basis, as well as other factors that might directly or indirectly influence climate change risks, will help development of flexible adaptation pathways. Consistent monitoring protocols are needed for climate change indicators, particularly those related to changes in the climate, climate science updates, climate impacts, and adaptation activities. Monitoring of key indicators can help stakeholders initiate course corrections in adaptation policies and/or changes in timing of their implementation. These indicators need to be developed and tracked over time to provide targeted quantitative measures of climate change, its impacts, and adaptation. This will provide useful information to decision-makers regarding the timing and extent of needed adaptation actions.

V. Other Adaptation Tools

There are other climate change adaptation tools to consider that include regulatory, design, and engineering standards; legal structures; and insurance opportunities.

Climate Protection Levels

Climate protection levels (CPLs) refer to building and construction codes and regulations, design standards, and best practices that pertain to climate, as adopted by the professional engineering community and various government entities.

The general framework for the development of CPLs and/or recommendations for future study are summarized in the following steps:

1. Develop regional/local-specific climate change projections.
2. Select climate hazards of focus (e.g., coastal flooding and storm surge, inland flooding, heat waves, and extreme events).
3. Solicit feedback from operators and regulators of infrastructure through questionnaires to identify potential impacts of climate change hazards on infrastructure.
4. Identify existing design and/or performance standards relevant to critical infrastructure
5. Review and reassess these standards in light of the climate change projections.
6. Highlight those standards that may be compromised by climate change and/or need further study to determine if revised CPLs are necessary to facilitate climate resiliency.

To meet the criteria for development of a recommended CPL, a regulation, policy, or practice needs to:

- Guide the formation or maintenance of critical infrastructure at risk to climate-related hazards.
- Dictate action in order to maintain acceptable risk levels with respect to climate-related hazards.
- Allow for adjustments that will enable a stable level of risk protection in response to a changing climate.

CPL recommendations can take multiple forms and offer content that is broad-based, design-specific, measurable/quantifiable, policy relevant, or suggestive of future studies. The following examples illustrate the types of recommendations for CPLs:

- **Quantitative statements** – Statements that emerge from the interplay between quantitative design, performance standards, and quantitative climate risk information.
- **General statements** – Narrative comments on the relevance of climate risk information to existing design standards.
- **Infrastructure analysis** – Recommendations for further analysis of critical parts of the infrastructure for which more information is needed to create CPLs. For example, more specific information on the existing design standards of street catch basins for inland street level flooding is required to determine if a CPL is needed to address the issue.
- **Engineering-based studies** – Suggestions for engineering studies such as hydrologic studies that need to be performed in order to determine if and/or how current standards need to be changed. These are necessary in situations where there are limitations in the knowledge of the system/material-level response to climate change and variability (e.g., responses of materials to increased heat).
- **Policy and planning issues** – Evaluation of system-wide processes such as the distribution of impervious surfaces, land-use changes, and public health alerts.

Legal Framework

Another climate change adaptation tool is the updating of laws and legal frameworks that guide planning, zoning, building codes, health codes, and materials usage. In many cases, the addition of a climate change component to an Environmental Impact Statement or equivalent regulation could be an efficient way to encourage the consideration of climate change impacts. Current federal, state, and local laws could be reassessed; new regulations should incorporate climate change into their formulations.

Insurance

Insurance can be a powerful risk-sharing tool for climate adaptation. Insurance companies are now being brought into discussions about climate change adaptation. As an example, insurance companies influence the level of development in coastal areas. If potential future changes in sea level rise are taken into account, insurance companies could factor these risks into their hazard models and help to disperse certain risks associated with climate change.

VI. Summary

The risk-management adaptation strategies described in this guidebook will be useful in helping stakeholders reduce climate impacts in the future. Climate change is extremely likely to bring warmer temperatures to New York State, while climate hazards are likely to produce a range of impacts on the urban and rural fabric of the state in the coming decades. Heat waves are very likely to become more frequent, intense, and longer in duration. An increase in total annual precipitation is more likely than not; brief, intense rainstorms are also likely to increase. Additionally, rising sea levels are extremely likely, and are very likely to lead to more frequent and damaging flooding related to coastal storm events in the future.

It is important to note that adaptation strategies are also likely to produce benefits today, as such strategies will help to lessen impacts of climate extremes that cause current damage. Given the scientific uncertainties in projecting future climate change, however, monitoring of climate and impacts indicators is critical so that flexible adaptation pathways for the region can be achieved.

Climate variables should be monitored and assessed on a regular basis. Indirect climate change impacts, such as those caused by climate change in other regions, should also be taken into consideration. By evaluating this evolving information, New York State can be well positioned to develop robust and flexible adaptation pathways that maximize climate and societal benefits while minimizing climate hazards and costs.

References

Intergovernmental Panel on Climate Change (IPCC). 2000. *Emissions Scenarios: A Special Report of IPCC Working Group III*. Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2007. *The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report*. Cambridge University Press.

Lowe, J., T. Reeder, K. Horsburgh, and V. Bell. 2009. "Using the new TE2100 science scenarios." United Kingdom Environment Agency.

New York State Climate Action Council. November 2010. *Climate Action Plan Interim Report*. http://www.nyclimatechange.us.

New York State Sea Level Rise Task Force. December 2010. *Report to the Legislature*. http://www.dec.ny.gov/docs/administration_pdf/slrtffinalrep.pdf.

New York City Panel on Climate Change. (NPCC). 2010. *Climate Change Adaptation in New York City: Building a Risk Management Response*. C. Rosenzweig and W. Solecki, Eds. Prepared for use by the New York City Climate Change Adaptation Task Force. Annals of the New York Academy of Science: New York, NY.

United States Global Change Research Program. 2009. *Global Climate Change Impacts in the United States*. T, R. Karl, J.M. Melillo, and T.C. Peterson, Eds. Cambridge University Press.

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