Observed and Projected Climate Change in New York State: An Overview

Developed for the Community Risk and Resiliency Act (CRRA) Drafting Teams

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Background

In January 2015, Governor Cuomo released his 2015 Opportunity Agenda, which included goals for a "Climate Smart NY." The programs and initiatives outlined in Climate Smart NY advance implementation of the Community Risk and Resiliency Act (CRRA), which requires State agencies to incorporate consideration of future physical climate risks caused by storm surges, sea-level rise, and flooding in certain permitting, funding, and regulatory decisions.

Based on the most current information on observed and projected climate change for New York State, the Department of Environmental Conservation (DEC), Department of State (DOS) and its partner agencies (including Department of Agriculture and Markets (DAM); Department of Transportation (DOT); Office of Parks, Recreation and Historic Preservation (OPRHP); Department of Health (DOH); Energy Research and Development Authority (NYSDERA); Environmental Facilities Corporation (EFC); and Dormitory Authority (DASNY)) have developed implementation guidance describing application requirements for applicants in programs covered by CRRA, and review procedures for agency staff.

This document provides a summary of observed and projected climatic conditions, and potential effects of changes in these conditions, for New York State. This information is primarily derived from "ClimAID: the Integrated Assessment for Effective Climate Change Adaptation Strategies in New York State," published in 2011 by NYSERDA. In 2014, the ClimAID assessment was updated using new datasets, improved baseline scenarios, and the latest generation of climate models and emissions projections. The 2014 update provides the latest observations and projections for changes in climate in New York through 2100, while the full 2011 report articulates, by sector, the likely impacts these kinds of changes will have across the state.[1] This information is consistent with, and builds upon, the observations of observed climate change reported for the northeastern United States in the Third National Climate Assessment.[2]

As noted in the ClimAID reports, climate projections have uncertainty embedded within them. The projections are derived by downscaling global climate models, and it is possible that climate sensitivity could exceed or fall below the range in the models used. For New York in

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[1] Rosenzweig, C., W. Solecki, A. DeGaetano, M. O'Grady, S. Hassol, P. Grabhorn (Eds.). 2011. Responding to Climate Change in New York State: The ClimAID Integrated Assessment for Effective Climate Change Adaptation. Technical Report. New York State Energy Research and Development Authority (NYSERDA), Albany, New York; Horton, R., D. Bader, C. Rosenzweig, A. DeGaetano, and W.Solecki. 2014(a). Climate Change in New York State: Updating the 2011 ClimAID Climate Risk Information. New York State Energy Research and Development Authority (NYSERDA), Albany, New York. Both reports available at http://www.nyserda.ny.gov/climaid.

[2] Horton, R., G. Yohe, W. Easterling, R Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, and F. Lipschultz, 2014(b): Ch. 16: Northeast. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 16-1-nn. (http://nca2014.globalchange.gov/report/regions/northeast); Horton et al., 2012. Climate Change in the Northeast: A Sourcebook. Draft Technical Input Report prepared for the U.S. National Climate Assessment (http://data.globalchange.gov/file/390430f9-9cbf-4710-ba43-2ffa762754dc).

particular more research is needed on climate variability in the future, as well as on how microclimates may differ from regional projections.

Climate Change in New York State

Historically, New York State's climate can be described as humid continental. The average annual temperature varies from about 40ºF in the Adirondacks to about 55ºF in the New York City metropolitan area. The wettest parts of the state – including parts of the Adirondacks and Catskills, the Tug Hill Plateau, and portions of the New York City metropolitan area – average approximately 50 inches of precipitation per year. Mountain effects produce localized amounts of precipitation in excess of 60 inches at inland locations.[3] Parts of western New York are relatively dry, averaging about 30 inches of precipitation per year. In all regions, precipitation is relatively consistent in all seasons, although droughts and floods are not uncommon.

***Observed Climate Change*[4,5]**

Changes from the historical climate have already been observed across New York State, mirroring observations for the northeastern United States as a whole.

Temperature
The annual average temperature statewide has risen about 1.3° C (2.4 °F) since 1970, with winter warming exceeding 2.4° C (4.4 °F); New York has warmed at an average rate of 0.14° C (0.25 °F)/decade since 1900. Annual average temperatures increased in all regions.

Precipitation
All seven stations used for the trend analysis in the 2014 ClimAID update show increasing average annual precipitation since 1900. In addition to increased mean annual precipitation across New York State, year-to-year (and multiyear) variability of precipitation has become more pronounced.[6] The pattern of precipitation has changed with increased precipitation in the winter and decreased precipitation in the summer, raising the risk of drought while adversely affecting drinking water supply.[7]

The northeastern United States has experienced a greater recent increase in extreme precipitation than any other region in the United States; between 1958 and 2010, the northeast saw more than a 70% increase in the amount of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events).[8]

[3] Horton et al., 2014(b) and Horton et al., 2012.
[4] Rosenzweig et al., 2011; Horton et al., 2014(a).
[5] Horton, R. et al., 2014(b); Horton et al., 2012.
[6] Horton et al., 2014(a).
[7] NYS 2100 Commission, 2013. http://www.governor.ny.gov/sites/governor.ny.gov/files/archive/assets/documents/NYS2100.pdf
[8] Melillo, Jerry M., Terese (T.C.) Richmond, and Gary W. Yohe, Eds., 2014: Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

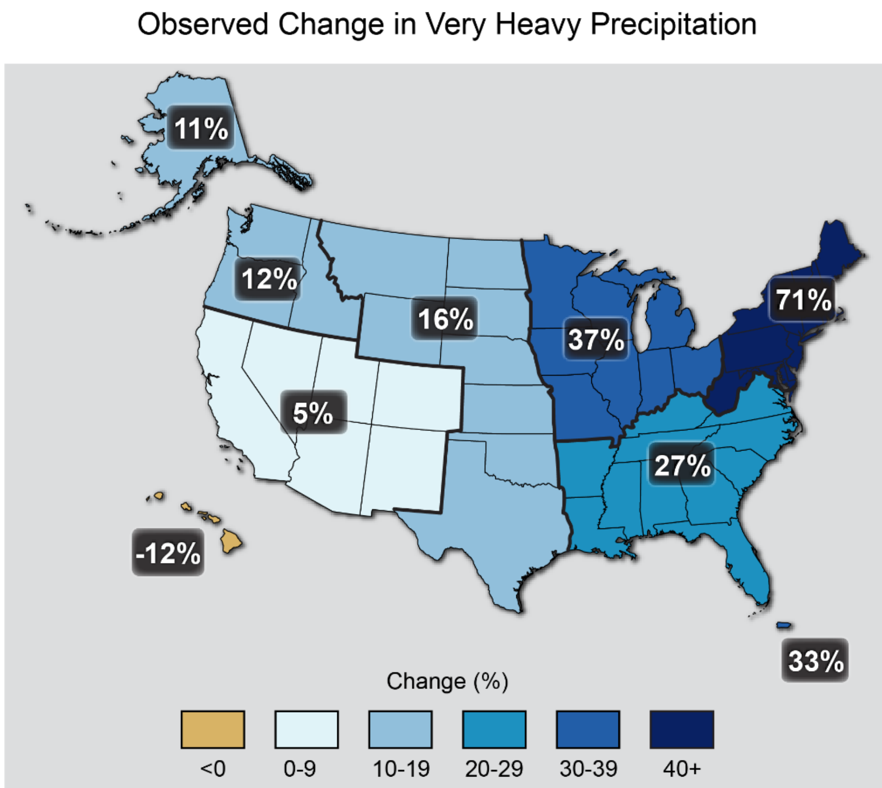

Figure 1. Observed increase in precipitation 1958-2010.[9]

New York State averages more than 40 inches per year of snow, varying regionally depending on topography and the proximity to large lakes and the Atlantic Ocean. The warming influence of the Atlantic Ocean keeps snow in the New York metropolitan region and Long Island below 36 inches per year, but snowfall amounts occasionally exceed 20 inches during nor'easters.

In addition to increased mean annual precipitation, year-to-year (and multiyear) variability of precipitation has become more pronounced. For all ClimAID stations, the standard deviation of annual precipitation (a measure of variability) was greater over the 1956 to 2012 period compared to 1900 to 1955.

Lake-Effect Snow

Lake-effect snows are an extreme precipitation phenomenon affecting areas adjacent to Lakes Ontario and Erie (and, to a lesser extent, the Finger Lakes). Arctic air masses moving over the relatively warm eastern Great Lakes are warmed, humidified, and destabilized, often leading to intense bands of heavy snowfall, generating as much as 48 inches of snow in a single storm. These events can last anywhere from an hour to a few days. Maximum seasonal snowfall in the state is more than 175 inches in parts of the Adirondacks and Tug Hill Plateau. Lake-

[9] The changes shown in this figure are calculated from the beginning and end points of the trends for 1958 to 2012. Figure source: updated from Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.), 2009. Global Climate Change Impacts in the United States. Cambridge University Press. Taken from Melillo, J.M. et al., 2014.

enhanced snowfall is localized; areas within miles of each other can experience large differences in snowfall totals.

There is also evidence of an increase in lake-effect snowfall along and near the southern and eastern shores of the Great Lakes since 1950.[10] Lake-effect snow is produced by the strong flow of cold air across large areas of relatively warmer ice-free water. As the climate has warmed, ice coverage on the Great Lakes has fallen. The maximum seasonal coverage of Great Lakes ice decreased at a rate of about 8 percent per decade from 1973 through 2008, amounting to a roughly 30 percent decrease in ice coverage.[11]

Extreme Precipitation and Coastal Storms

From 1851-2014, 12 hurricanes struck New York State.[12] The frequency, intensity, and duration of extreme precipitation events and coastal storms and flooding are increasing, exemplified by the pattern of extreme weather in 2011 (Hurricane Irene and Tropical Storm Lee), 2012 (Hurricane Sandy), 2013 (Niagara County and Mohawk Valley flooding), and 2014 (Long Island flooding).

Sea-level Rise[13]

Sea level along New York's ocean coast and in the Hudson River has risen by more than one foot since 1900, or about 1.2 in/decade. CRRA directed DEC to adopt science-based sea-level rise projections and to provide guidance to help State agencies apply these projections. The projections should be used as the basis for State adaptation decisions and are available for use by all decision makers. The projections allow decision makers to consider the probability that specified levels of sea-level rise will be exceeded as well as the consequences of the exceedance and the costs of preparing for it.

To comply with CRRA, DEC has adopted 6 NYCRR Part 490, Projected Sea-level Rise. Part 490 is applicable in three regions of New York State - the tidal coast of Long Island; New York City and the Lower Hudson River upstream to Kingston; and the Mid-Hudson River from Kingston, NY upstream to the federal dam in Troy, NY (see Figure XX). All three regions exhibit small differences in relative sea-level rise due to local conditions. Five projections are provided for each of the three regions, *i.e.*, low (L), low-medium (L-M), medium (M), high-medium (H-M) and high (H), qualitative terms referring to the rate of rise and not to ultimate water level itself.[14] Warming of the Earth to date has already locked us in to at least six feet of global sea-level rise above current levels;[15] we simply do not know the precise rate at which this rise will occur. Finally, each of these projections is presented for four different time

[10] Cook, E.R., P.J. Bartlein, N. Diffenbaugh, R. Seager, B.N. Shuman, R.S. Webb, J.W. Williams, and C. Woodhouse, 2008: Hydrological variability and change. In: Abrupt Climate Change. Synthesis and Assessment Product 3.4. U.S. Geological Survey, Reston, VA, pp. 143-257.

[11] Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.), 2009. Global Climate Change Impacts in the United States. Cambridge University Press.

[12] National Weather Service, National Hurricane Center, Miami, FL; Chronological List of all Hurricanes: 1851-2014. Revised May 2015. NOAA Atlantic Oceanographic and Meteorological Laboratory Hurricane Research Division (http://www.aoml.noaa.gov/hrd/hurdat/All_U.S._Hurricanes.html).

[13] NYS Sea-level Rise Projections, 6 NYCRR Part 490

[14] **L** = Low projection, the amount of sea-level rise that is very likely (the 10th percentile of ClimAID model outputs) to be exceeded by the specified time interval. **L-M** = Low-medium projection, the amount of sea-level rise that is likely (the 25th percentile of ClimAID model outputs) to be exceeded by the specified time interval. **M** = Medium projection, the amount of sea-level rise that is about as likely as not (the mean of the 25th and 75th percentiles of ClimAID model outputs) to be exceeded by the specified time interval. **H-M** = High-medium projection, the amount of sea-level rise that is unlikely (the 75th percentile of ClimAID model outputs) to be exceeded by the specified time interval. **H** = High projection, the amount of sea-level rise that is very unlikely (the 90th percentile of ClimAID model outputs) to be exceeded by the specified time interval.

[15] Strauss, B.H., 2013. Rapid accumulation of committed sea-level rise from global warming. Proceedings of the National Academy of Sciences, vol. 110 no. 34, pp. 13699–13700. (www.pnas.org/cgi/doi/10.1073/pnas.1312464110)

periods: the 2020s, 2050s, 2080s, and the year 2100 (see Table 1).[16] As shown, along the seacoast and tidal portion of the Hudson River (to the Federal Dam at Troy), sea-level rise could be up to 30 inches by the 2050s, up to four feet by the 2080s, and up to six feet by 2100.

Table 1. New York State Sea-level Rise Projections, 6 NYCRR Part 490

Region	Long Island					NYC/Lower Hudson					Mid-Hudson				
Descriptor	L	L-M	M	H-M	H	L	L-M	M	H-M	H	L	L-M	M	H-M	H
2020s	2	4	6	8	10	2	4	6	8	10	1	3	5	7	9
2050s	8	11	16	21	30	8	11	16	21	30	5	9	14	19	27
2080s	13	18	29	39	58	13	18	29	39	58	10	14	25	36	54
2100	15	21	34	47	72	15	22	36	50	75	11	18	32	46	71

Values represent inches of rise over baseline level, which is defined as the average level of the surface of marine or tidal water over the years 2000 through 2004.

Projected Climate (see Tables 2-9)

Without a dramatic decrease in the global generation of greenhouse gases like carbon dioxide, critical changes can be expected in New York's climate over the next century:

- **Annual average temperatures** in New York State are projected to rise 2.2° C to 5° C (4° F to 9° F) by the 2080s.[17]
- The number and duration of **extreme heat events** are likely to increase.
- **Short-term droughts** are anticipated to become more frequent.
- **Average precipitation** is projected to increase five to 15 percent by the 2080s, with most of the increase occurring in winter. Intense downpours will likely become more frequent.
- **Extreme weather events** are predicted to occur with increasing frequency as a result of the changing climate.
- The probability of **extreme lake-effect snows**, such as affected western New York in 2014, is likely to increase in the near future.

Given these trends and projections of future changes, past climate will likely be a less consistent predictor of future climate, and, in turn, past climate records may not suffice as benchmarks for forecasting.

Temperature

New Yorkers can expect an increase in average temperature ranging from 4 to 10°F by 2100, primarily in the form of warmer winters. Climate change modeling predicts that the anticipated increases in temperature will not be uniform across New York State and some areas may be more affected by these changes than others. By 2100, the greatest warming is projected in the northern parts of the state. Summers will become warmer and winters milder. Climate change

[16] Consistent with ClimAID, all parameters except sea-level rise throughout are presented for 30-year timeslices. For sea-level rise, the multidecadal approach is not necessary due to lower interannual variability; the 2020s timeslice for sea level (for example) therefore refers to the period from 2020–2029.

[17] Consistent with ClimAID, all parameters except sea-level rise throughout are presented for 30-year timeslices centered on the 2020s, 2050s, and 2080s. For example, the 2080s timeslice refers to the period from 2070 to 2099. For sea-level rise, the multidecadal approach is not necessary due to lower interannual variability; the 2020s timeslice for sea level (for example) therefore refers to the period from 2020–2029.

will extend growing seasons for species where temperature predominates growth, with photoperiod-controlled species being less affected by warming.

Precipitation

Projected changes in precipitation show variation across New York State. The greatest increases in precipitation are projected in the northern parts of the state, with much of this additional precipitation anticipated to occur during winter but increasingly as rain rather than snow.

Precipitation intensity is projected to increase everywhere, with the largest increases projected to occur in areas in which average precipitation increases the most (such as the northeastern United States). The northeast (and, therefore, New York State) is expected to experience the largest increases in heavy precipitation events.[18]

If intensity of sub-daily rainfall[19] (particularly in periods of less than an hour) is considered, there is evidence from historical data and regional climate modeling to suggest that the intensity of sub-daily rainfall events will increase as temperatures increase. Short, intense precipitation events can often exceed the absorption rate or ability of rainwater to infiltrate into the ground, which can dramatically increase runoff and the potential for flooding.

There also is a strong correlation between increased rainfall amounts and increases in air temperature. Warmer air is able to hold more moisture and if the atmosphere is able to hold more water, rainfall amounts would be expected to increase, particularly for the sub-daily rainfall events. According to a recent study,[20] one-hour rainfall amounts increased 7% for every degree Fahrenheit of air temperature increase.

Lake-Effect Snow

Models suggest the decreasing trend in ice cover on the Great Lakes will lead to increased lake-effect snow in the next several decades through greater moisture availability. In the longer term, lake-effect snows are likely to decrease as temperatures continue to rise, with the precipitation then falling as rain.[21]

Extreme Weather Events and Coastal Storms

Extreme weather events, ranging from heat waves to extreme precipitation events, are forecast to increase in both frequency and intensity.

The total number of hot days per year in New York State is expected to increase as the century progresses. The frequency and duration of heat waves, defined as three or more consecutive days with maximum temperatures at or above 90ºF, are also expected to increase. Extreme cold events, defined both as the number of days per year with minimum temperature at or below 32ºF, and those at or below 0ºF, are expected to decrease.

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[18] Karl et al., 2009.

[19] Measured precipitation for a period of time shorter than 24 hours.

[20] Lenderink, G. and E. Van Meijgarrd, 2008. Increase in hourly precipitation extremes beyond expectations from temperature changes. Nature Geoscience 1, 511 – 514.

[21] Karl et al., 2009; Rosenzweig et al., 2011; Kunkel, K.E., N.E. Westcott, and D.A.R. Knistovich, 2002: Assessment of potential effects of climate changes on heavy lake-effect snowstorms near Lake Erie. Journal of Great Lakes Research, 28(4), 521-536; Burnett, A.W., M.E. Kirby, H.T. Mullins, and W.P. Patterson, 2003: Increasing Great Lake-effect snowfall during the twentieth century: a regional response to global warming? Journal of Climate, 16(21), 3535-3542.

By the end of the century, the number of droughts is likely to increase, as the effect of higher temperatures on evaporation is likely to outweigh the increase in precipitation, especially during the warm months.

By the end of this century, sea-level rise alone may contribute to a significant increase in large coastal floods; coastal flood levels that currently occur once per decade on average may occur once every one to three years, and flooding at the level currently associated with the 100-year flood may occur about four times as often by the end of the century.

Climate change predictions indicate that precipitation from storms is likely to dramatically increase. The 1% annual chance storm event or “100-year storm” is expected to increase by 0.2 inches of rainfall and is likely to become more frequent, meaning larger storms are expected more often. Intense mid-latitude, cold-season storms, including nor’easters, are projected to become more frequent and take a more northerly track.[22]

Effects of Climate Change in New York

Climate change will continue to impose new risks to New Yorkers and to New York’s economy and infrastructure. Without preemptive action, projected climatic changes will have deleterious effects on New York’s transportation, water and energy infrastructure, and on sectors on which New York’s economy depends, including agriculture, ecosystems, tourism, and water resources. These projected effects combine to threaten the livability and economic vitality of many of New York’s communities, as well as the health and safety of the residents of these communities.

Rising sea levels will have major consequences for New York’s coastal communities including but not limited to[23]

- Magnification of dangerous storm surges caused by high winds and tides, which increase the risk of flooding, beach erosion, and damage to infrastructure in low-lying areas;
- Increased areas of coastal inundation during regular tidal cycles;
- Regular inundation of coastal wastewater infrastructure and the direct transmission of pathogen and nitrogen pollution to ground and surface waters; and
- Increased salinity of the drinking water supply in communities along the Hudson due to saltwater intrusion.

Given projections of sea-level rise, by 2050, the number of New York City residents living within the 100-year floodplain (using current data) would increase from approximately 400,000 to 800,000 people.[24]

[22] Kunkel, K.E., P.D. Bromirski, H.E. Brooks, T. Cavazos, A.V. Douglas, D.R. Easterling, K.A. Emanuel, P.Ya. Groisman, G.J. Holland, T.R. Knutson, J.P. Kossin, P.D. Komar, D.H. Levinson, and R.L. Smith. 2008. “Observed changes in weather and climate extremes.” In Weather and Climate Extremes in a Changing Climate: Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands, edited by Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray, 35-80. Synthesis and Assessment Product 3.3. U.S. Climate Change Science Program, Washington, DC.

[23] NYS 2100 Commission, 2013.

[24] NYC Special Initiative for Rebuilding and Resiliency, 2013. A Stronger, More Resilient New York. Chapter 2: Climate Analysis. (http://www.nyc.gov/html/sirr/downloads/pdf/final_report/Ch_2_ClimateAnalysis_FINAL_singles.pdf)

Other consequences of warming and changes in precipitation include northward expansion of certain invasive species and parasites that threaten native plants, ecosystems, and human beings. Warming also potentially creates significant adverse effects on key New York regional economic activities, including winter sports; and maple syrup, apple, and dairy production. Sustained heavy downpours of rain heighten the risk of localized flash flooding and erosion. Heat waves, defined as three consecutive days with maximum temperatures above 90°F, are associated with heat-related illnesses, which disproportionately affect the elderly and children. Droughts, in addition to having agricultural impacts, also affect water resources. Water-use restrictions, and in some cases, water rationing, occur during drought periods in metropolitan and suburban areas.

The 2011 ClimAID report provides a table[25] of sector-specific climate change vulnerabilities that should be consulted for additional detail on the projected impacts of climate change in New York State.

[25] Table 12.2, pp. 444-453 in Roszensweig et al., 2011.

Figure 2. The seven ClimAID regions.

Table 2. Baseline climate and mean annual changes for the seven ClimAID regions of New York State.

Regions		Baseline	2020s	2050s	2080s
1 Rochester	Temperature Precipitation	47.7°F 34 in	+1.8 to 4.0°F 0 to +8%	+3.7 to 7.3°F +2 to +12%	+4.2 to 12.0°F +1 to +17%
2 Port Jervis	Temperature Precipitation	50°F 46 in	+1.6 to 3.5°F -1 to +10%	+3.1 to 6.9°F +1 to +14%	+4.0 to 10.7°F +2 to +18%
3 Elmira	Temperature Precipitation	47.5°F 35 in	+1.8 to 3.8°F -4 to +9%	+3.6 to 7.1°F +2 to +15%	+4.2 to 11.6°F +3 to +16%
4 New York City	Temperature Precipitation	54.6°F 49.7 in	+1.5 to 3.2°F -1 to +10%	+3.1 to 6.6°F +1 to +13%	+3.8 to 10.3°F +2 to +19%
5 Saratoga	Temperature Precipitation	47.6°F 38.6 in	+1.7 to 3.7°F -1 to +10%	+3.5 to 7.1°F +2 to +15%	+4.1 to 11.4°F +3 to +17%
6 Watertown	Temperature Precipitation	45.4°F 42.6 in	+1.9 to 3.9°F 0 to +8%	+3.7 to 7.2°F +2 to +13%	+4.3 to 11.8°F +3 to +15%
7 Indian Lake	Temperature Precipitation	39.9°F 40.8 in	+1.8 to 3.8°F 0 to +9%	+3.7 to 7.4°F +2 to +15%	+4.2 to 11.8°F +3 to +17%

Baseline data are for the 1971 to 2000 base period and are from the NOAA National Climatic Data Center (NCDC). Based on 35 GCMs and two Representative Concentration Pathways. Shown is the range between the low-estimate (10^{th} percentile) and the high-estimate (90^{th} percentile).

Tables 3-9. Baseline and projected changes in frequency of severe weather events in seven ClimAID regions of New York State.

3. Rochester (Region 1). Full range of changes in extreme events: Low Estimate (10th Percentile), Middle Range (25th – 75th Percentile), High Estimate (90th Percentile).

	Extreme event	Baseline	2020s	2050s	2080s
Heat Waves & Cold Events	Number of days per year with maximum temperature exceeding				
	90°F	8	12 (14 to 17) 19	18 (22 to 34) 42	22 (27 to 57) 73
	95°F	0.8	0.9 (2 to 4) 6	2 (3 to 9) 17	3 (6 to 22) 38
	Number of heat waves per year	0.7	2 (2 to 2) 2	2 (3 to 4) 5	3 (3 to 8) 8
	average duration	4	4 (4 to 4) 4	4 (4 to 5) 5	4 (5 to 6) 6
	Number of days per year with min. temp. ≤ 32°F	133	99 (103 to 111) 116	78 (84 to 96) 102	59 (68 to 88) 97
Intense Precipitation	Number of days per year with rainfall exceeding				
	1 inch	5	4 (5 to 5) 6	4 (5 to 5) 6	4 (5 to 6) 7
	2 inches	0.6	0.6 (0.6 to 0.7) 0.8	0.5 (0.6 to 0.8) 0.9	0.5 (0.6 to 0.9) 1

4. Port Jervis (Region 2). Full range of changes in extreme events: Low Estimate (10th Percentile), Middle Range (25th – 75th Percentile), High Estimate (90th Percentile).

	Extreme event	Baseline	2020s	2050s	2080s
Heat Waves & Cold Events	Number of days per year with maximum temperature exceeding				
	90°F	12	16 (19 to 25) 27	24 (31 to 47) 56	31 (38 to 77) 85
	95°F	2	2 (2 to 5) 10	3 (5 to12) 20	4 (7 to 28) 39
	Number of heat waves per year	1	2 (3 to 3) 4	3 (4 to 6) 8	4 (5 to 9) 9
	average duration	4	4 (5 to 5) 5	5 (5 to 6) 6	5 (5 to 7) 8
	Number of days per year with min. temp. ≤ 32°F	138	106 (108 to 116) 120	79 (86 to 100) 108	59 (65 to 89) 101
Intense Precipitation	Number of days per year with rainfall exceeding				
	1 inch	12	11 (12 to 13) 14	12 (13 to 14) 15	12 (13 to 15) 16
	2 inches	2	2 (2 to 2) 3	2 (2 to 3) 3	1 (2 to 3) 3

5. Elmira (Region 3). Full range of changes in extreme events: Low Estimate (10th Percentile), Middle Range (25th – 75th Percentile), High Estimate (90th Percentile).

	Extreme event	Baseline	2020s	2050s	2080s
Heat Waves & Cold Events	Number of days per year with maximum temperature exceeding				
	90°F	10	15 (17 to 21) 23	22 (26 to 41) 47	28 (33 to 67) 79
	95°F	1	2 (2 to 4) 7	2 (4 to10) 18	4 (7 to 24) 38
	Number of heat waves per year	1	2 (2 to 3) 3	3 (3 to 6) 6	3 (4 to 9) 9
	average duration	4	4 (4 to 5) 5	5 (5 to 5) 5	5 (5 to 6) 7
	Number of days per year with min. temp. ≤ 32°F	152	119 (122 to 130) 134	94 (100 to 114) 120	72 (79 to 103) 116
Intense Precipitation	Number of days per year with rainfall exceeding				
	1 inch	6	6 (6 to 7) 7	6 (6 to 7) 8	6 (7 to 8) 8
	2 inches	0.6	0.6 (0.7 to 0.9) 1	0.7 (0.8 to 1) 1	0.7 (0.8 to 1) 1

6. New York City (Region 4). Full range of changes in extreme events: Low Estimate (10th Percentile), Middle Range (25th – 75th Percentile), High Estimate (90th Percentile).

	Extreme event	Baseline	2020s	2050s	2080s
Heat Waves & Cold Events	Number of days per year with maximum temperature exceeding				
	90°F	18	24 (26 to 31) 33	32 (39 to 52) 57	38 (44 to 76) 87
	95°F	4	4 (9 to 18) 28	6 (9 to18) 28	9 (12 to 32) 47
	Number of heat waves per year	2	3 (3 to 4) 4	4 (5 to 7) 7	5 (6 to 9) 9
	average duration	4	5 (5 to 5) 5	5 (5 to 6) 6	5 (5 to 7) 8
	Number of days per year with min. temp. ≤ 32°F	71	50 (52 to 58) 60	37 (42 to 48) 52	25 (30 to 42) 49
Intense Precipitation	Number of days per year with rainfall exceeding				
	1 inch	13	13 (14 to 15) 16	13 (14 to 16) 17	14 (15 to 17) 18
	2 inches	3	3 (3 to 4) 5	3 (4 to 4) 5	2 (4 to 5) 5

7. Saratoga Springs (Region 5). Full range of changes in extreme events: Low Estimate (10th Percentile), Middle Range (25th – 75th Percentile), High Estimate (90th Percentile).

	Extreme event	Baseline	2020s	2050s	2080s
Heat Waves & Cold Events	Number of days per year with maximum temperature exceeding				
	90°F	10	14 (17 to 22) 23	22 (27 to 41) 50	27 (35 to 70) 82
	95°F	1	1 (2 to 4) 7	3 (3 to10) 18	3 (6 to 25) 42
	Number of heat waves per year	1	2 (2 to 3) 4	3 (4 to 6) 7	4 (5 to 8) 9
	average duration	4	4 (5 to 5) 5	5 (5 to 6) 6	5 (5 to 7) 9
	Number of days per year with min. temp. ≤ 32°F	155	123 (127 to 136) 139	98 (104 to 119) 125	77 (84 to 109) 120
Intense Precipitation	Number of days per year with rainfall exceeding				
	1 inch	10	10 (10 to 11) 12	10 (11 to 12) 13	10 (11 to 13) 14
	2 inches	1	1 (1 to 2) 2	1 (1 to 2) 2	1 (1 to 2) 2

8. Watertown (Region 6). Full range of changes in extreme events: Low Estimate (10th Percentile), Middle Range (25th – 75th Percentile), High Estimate (90th Percentile).

	Extreme event	Baseline	2020s	2050s	2080s
Heat Waves & Cold Events	Number of days per year with maximum temperature exceeding				
	90°F	3	5 (6 to 8) 10	9 (12 to 21) 26	12 (17 to 44) 57
	95°F	0	0 (0.1 to 0.9) 2	0.2 (0.6 to3) 7	0.8 (2 to 11) 23
	Number of heat waves per year	0.2	0.6 (0.8 to 0.9) 1	1 (1 to 3) 3	1 (2 to 6) 7
	average duration	4	3 (4 to 4) 4	4 (4 to 4) 5	4 (4 to 6) 6
	Number of days per year with min. temp. ≤ 32°F	147	116 (119 to 126) 130	96 (102 to 113) 119	78 (85 to 104) 114
Intense Precipitation	Number of days per year with rainfall exceeding				
	1 inch	6	6 (7 to 8) 8	7 (7 to 8) 9	7 (7 to 9) 10
	2 inches	0.8	0.6 (0.7 to 1) 1	0.7 (0.7 to1) 1	0.7 (0.8 to 1) 1

9. Indian Lake (Region 7). Full range of changes in extreme events: Low Estimate (10th Percentile), Middle Range (25th – 75th Percentile), High Estimate (90th Percentile).

	Extreme event	Baseline	2020s	2050s	2080s
Heat Waves & Cold Events	Number of days per year with maximum temperature exceeding				
	90°F	0.3	0.5 (0.8 to 2) 2	2 (3 to 6) 10	3 (5 to 19) 27
	95°F	0	0 (0 to 0.1) 0.2	0.1 (0.1 to 0.3) 0.6	0.1 (0.2 to 2) 6
	Number of heat waves per year	0	0 (0.1 to 0.2) 0.2	0.2 (0.3 to 0.7) 1	0.2 (0.5 to 2) 3
	average duration	3	3 (3 to 4) 4	3 (3 to 4) 4	4 (4 to 4) 5
	Number of days per year with min. temp. ≤ 32°F	193	159 (162 to 172) 177	131 (138 to 154) 161	107 (118 to 143) 156
Intense Precipitation	Number of days per year with rainfall exceeding				
	1 inch	7	7 (7 to 8) 9	7 (8 to 9) 10	8 (8 to 10) 11
	2 inches	0.8	0.7 (0.8 to 1) 1	0.8 (0.9 to 1) 1	0.8 (0.9 to 1) 1

Projections for temperature and precipitation are based on 33 GCMs and 2 RCPs. Baseline data are for the 1971 to 2000 base period and are from the NOAA National Climatic Data Center (NCDC). Shown are the low-estimate (10th percentile), middle range (25th to 75th percentile), and high-estimate (90th percentile) 30-year mean values from model-based outcomes. Decimal places are shown for values less than one, although this does not indicate higher precision/certainty. Heat waves are defined as three or more consecutive days with maximum temperatures at or above 90°F.

Glossary

Adaptation - The process of adjustment to actual or expected climate and its physical, social, or economic effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. (IPCC/ClimAID)

Adaptive capacity - The ability of systems, institutions, humans and other organisms to adjust to potential stress or damage, to take advantage of opportunities, or to respond to consequences. (IPCC, derived from previous IPCC reports and MEA, 2005/ClimAID)

Climate - Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The typical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system. (IPCC)

Critical Facilities - In the context of floodplain management, critical facilities are defined as facilities designed for bulk storage of chemicals, petrochemicals, hazardous or toxic substances or floatable materials; hospitals, rest homes, correctional facilities, dormitories, patient care facilities; major power generation, transmission or substation facilities, except for hydroelectric facilities; major communications centers, such as civil defense centers; or major emergency service facilities, such as central fire and police stations. (6 NYCRR Part 502.4(a)(17))

Ecosystem - An ecosystem is a functional unit consisting of living organisms, their non-living environment and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases they are relatively sharp, while in others they are diffuse. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms, or are influenced by the effects of human activities in their environment. (IPCC)

Exposure - The degree to which elements of a climate-sensitive system are in direct contact with climate variables and/or may be affected by long-term changes in climate conditions or by changes in climate variability, including the magnitude and frequency of extreme events. (ClimAID)

Flood - The overflowing of the normal confines of a stream or other body of water, or the accumulation of water over areas not normally submerged. Floods include river (fluvial) floods, flash floods, urban floods, pluvial floods, sewer floods, coastal floods and glacial lake outburst floods. (IPCC)

Hazard - The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. (IPCC)

Impacts (consequences, outcomes) - Effects on natural and human systems. Effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. (IPCC)

Mean sea level - Sea level measured by a tide gauge with respect to the land upon which it is situated. Mean sea level is normally defined as the average relative sea level over a period, such as a month or a year, long enough to average out transients such as waves and tides. See Sea-level change. (IPCC SREX)

Percentile - One of the values of a variable that divides the distribution of the variable into 100 groups having equal frequencies, *e.g.*, ninety percent of the values lie at or below the ninetieth percentile, ten percent above it.

Representative Concentration Pathways (RCPs) – Scenarios developed by the IPCC that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. RCPs usually refer to the portion of the pathway extending to 2100. Four RCPs were selected from the published literature and are used in the present IPCC Assessment as a basis for the climate predictions and projections presented in the AR5. (IPCC, based on Moss et al., 2008 and Moss et al., 2010)

Resilience - The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation. (IPCC, derived from Arctic Council, 2013)

Risk - The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability or likelihood of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Used to refer to the potential, when the outcome is uncertain, for adverse consequences on lives, livelihoods, health, ecosystems and species, economic, social and cultural assets, services (including environmental services) and infrastructure. (IPCC)

Sea-level rise - Increases in sea level, globally or locally, due to (i) changes in the shape of the ocean basins, (ii) changes in the total mass and distribution of water and land ice, (iii) changes in water density, and (iv) changes in ocean circulation. Sea-level changes induced by changes in water density are called steric. Density changes induced by temperature changes only are called thermosteric, while density changes induced by salinity changes are called halosteric. See also Mean sea level. (IPCC SREX)

Sensitivity - The degree to which a system will respond to a change in climate, either beneficially or detrimentally. (ClimAID)

Storm surge - The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as being the excess above the level expected from the tidal variation alone at that time and place. (IPCC)

Storm water - Storm water means storm water runoff, snow melt runoff, and surface runoff and drainage. (NPDES 40 CFR 122.26(b)(13))

Sustainability – A dynamic process that guarantees the persistence of natural and human systems in an equitable manner. (IPCC)

Vulnerability - The propensity to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. (IPCC)

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