

Cross-Sectoral Economic Impact Analysis of Climate Change in New York State

Appendix A: Climate Data Processing

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Cross-Sectoral Economic Impact Analysis of Climate Change in New York State

Appendix A: Climate Data Processing

Final Report

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Notice

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Acronyms and Abbreviations

CDD	cooling degree day
cm	centimeters
CMIP	Coupled Model Intercomparison Project
EPA	U.S. Environmental Protection Agency
GCM	global climate model
GHG	greenhouse gas
GMSL	global mean sea level
HDD	heating degree day
HUC	hydrologic unit code
IPCC	Intergovernmental Panel on Climate Change
MERRA	Modern-Era Retrospective analysis for Research and Applications
NASA	National Aeronautics and Space Administration
NYISO	New York Independent System Operator
NYSERDA	New York State Energy Research and Development Authority
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RCP	Representative Concentration Pathway
SSP	Shared Socioeconomic Pathway
UKESM	UK Earth System Model

A1 Introduction

The New York State Climate Impacts Assessment uses two Shared Socioeconomic Pathways (SSPs): SSP2-4.5 and SSP5-8.5. There have been some arguments made among scientists and policy makers that the greenhouse gas forcing/concentrations associated with the Representative Concentration Pathway (RCP)8.5 may be unrealistic. Here, we enumerate some of the reasons the assessment team chose to include these two RCPs and RCP8.5, especially. First, these scenarios have the same end-of-century radiative forcing as the two RCPs used in previous New York State projections, providing continuity with that work. Second, they match the pathways of greatest interest to stakeholders based on responses to a NYSERDA needs assessment (NYSERDA 2020). Third, relative to many other scenarios, there were also a large number of climate models available for these two SSPs. Fourth, they span a broad range of what we consider plausible climate outcomes, including the high-consequence outcomes that are critical for risk management (Wuebbles 2023); the Intergovernmental Panel on Climate Change (IPCC) does not assign likelihoods to any of the RCPs, which should instead be thought of as scenarios. Fifth, while the balance of evidence may suggest that lower greenhouse gas (GHG) forcing/concentrations are more likely than those associated with RCP8.5, that does not mean that the changes in extreme-event statistics, or climate impacts, associated with RCP8.5 are unrealistically high. As it becomes clearer that current climate impact models underestimate plausible high tails even when driven by only moderate GHG levels, it follows that using projections of only moderate GHG forcing would unrealistically narrow the upper bounds for the model-based distributions for impacts like heat waves and extreme precipitation. The temperature, precipitation, and sea-level rise projections used in this study are based on the projections developed for the New York State Climate Impacts Assessment by Columbia University, as described in the assessment's report on climate projections.¹

¹ See NYSCIA (N.d) for more information on the official New York State Climate Impact Assessment climate projections and the methods used.

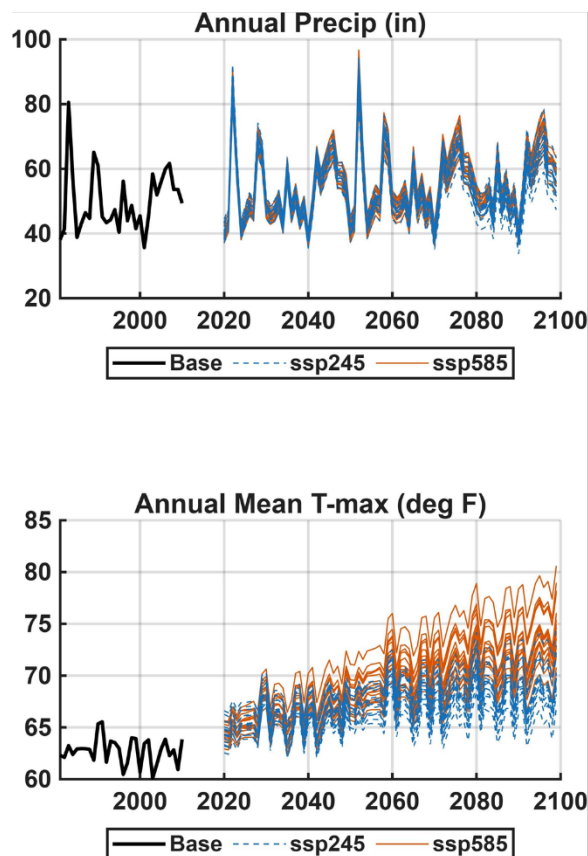
A1.1 Temperature and Precipitation

Examples of the annual temperature and precipitation projections for two New York State locations, New York City and Lake Placid, are provided in Figure A-1. The historical baseline data used in this report are shown in black, and the projections for the six global climate models (GCMs) under SSP2-4.5 are shown in dotted blue lines, and for SSP5-8.5 are shown in solid orange lines. The overall results show familiar outcomes: Temperatures increase over time and are higher in the higher emissions SSP5-8.5 results, particularly after 2040; precipitation is highly variable on an interannual basis without a strong difference between the two SSPs, and, while not shown, is also variable across seasons and on a daily time scale. Substantial differences in absolute temperatures and precipitation are seen across the 12 New York State climate regions.

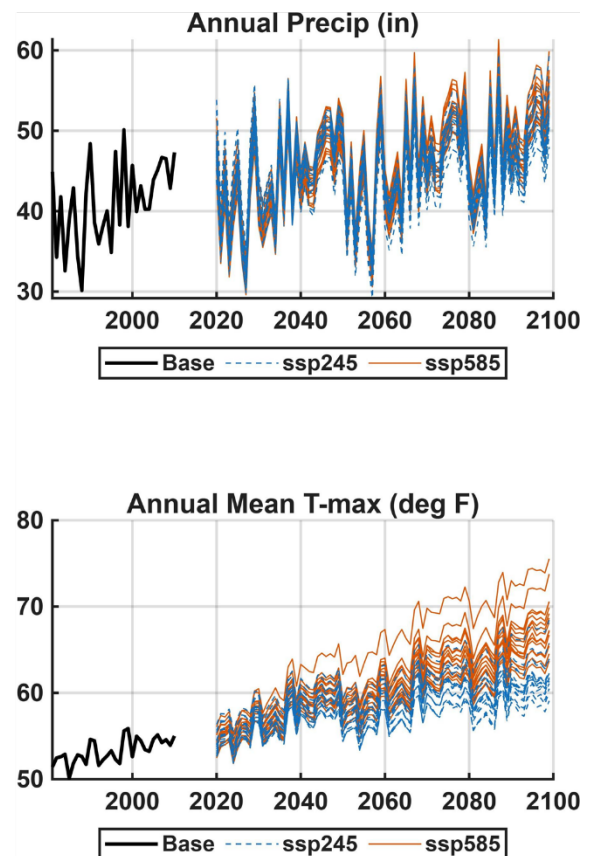
Figure A-1. Historical and Projected Annual Climate Data for Two New York State Locations

Annual precipitation and mean maximum temperature are shown for New York City (Panel A, left graphs) and Lake Placid (Panel B, right graphs).

Panel A: New York City



Panel B: Lake Placid



A1.2 Sea-Level Rise

Relative sea-level rise estimates incorporate changes in global mean sea level (GMSL), local changes in sea level, and local changes in land level (subsidence or uplift). New York State's coast and tidally influenced areas of the Hudson River Valley are subsiding, albeit at a slower rate than areas in some other parts of the U.S., which increases the rate of relative sea-level rise in the region.

Figure A-2 shows the sea level change for New York City and Albany as examples of the range of sea-level rise from the coast and upstream on the tidally influenced Hudson River. The scenarios shown include the probable range of both the SSP2-4.5 and SSP5-8.5 scenarios in blue and red, respectively, as well as low and high extremes for comparison. Sea-level rise for the 25th and 75th percentiles of the two SSPs in New York County range from about 70 centimeters (cm) to 130 cm by the end of the century. For Albany, sea-level rise is expected to be lower, ranging from 55 cm to 120 cm across the 25th and 75th percentiles for the two SSPs. The two SSPs for both locations diverge slightly in the 2040s and more noticeably by the end of the century.

Figure A-2. Sea-Level Rise Scenarios for Albany County

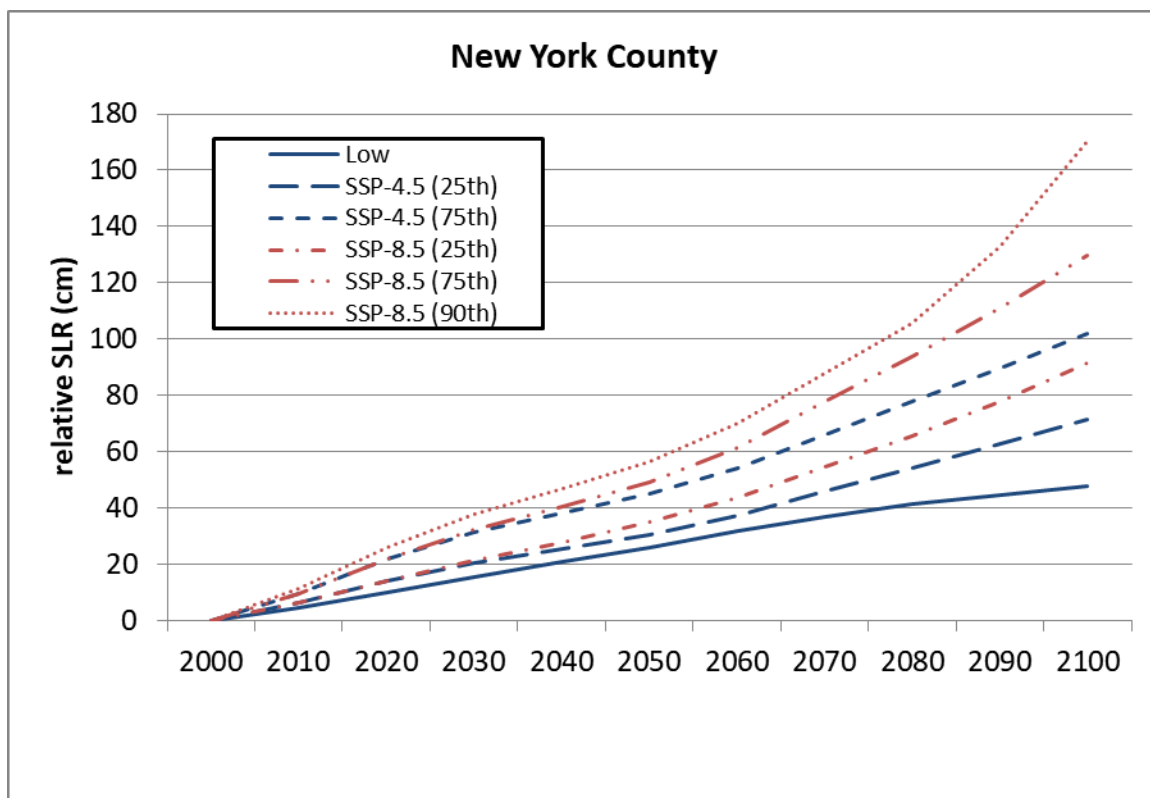
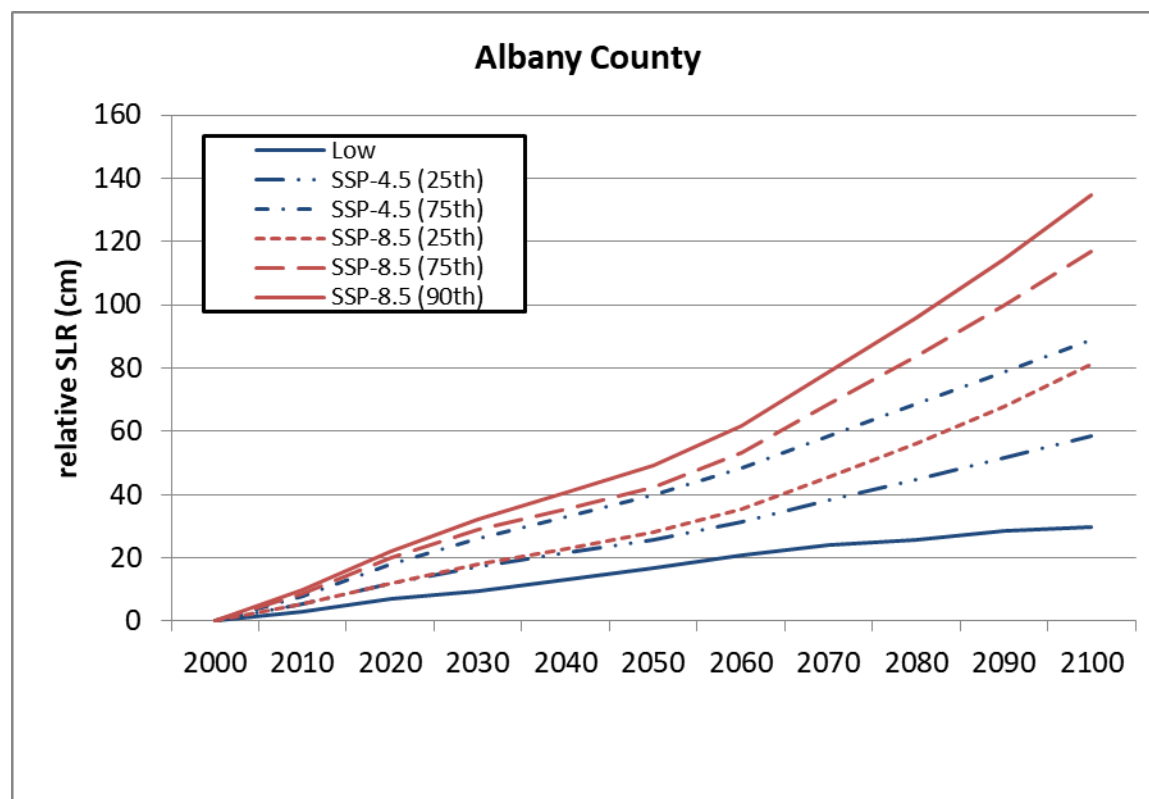


Table A-2. (continued)



Characterizations of storm surge exceedance curves (that is, the storm surge height for a full range of storm annual return periods or annual probabilities of occurrence)² for New York State’s coastal areas are based on the adjustment of historical storm-surge exceedance curves using local tide-gauge data, as recommended in Sweet et al. (2017) and applied in EPA (2017).

A1.3 Processing of Climate Data to Support Modeling of Impacts on the Energy Sector

Some components of the energy sector impact modeling described in detail in Chapter 5, Energy Sector, make use of the daily minimum and maximum temperatures developed for this study and used consistently across the New York State Climate Impacts Assessment. Additional climate scenario detail, however, is needed as input to these energy sector models. The daily data were downscaled using the Mountain Microclimate Simulation Model (Hungerford et al. 1989) to generate a diurnal temperature

² Note that annual return periods and annual probabilities are two terms for effectively the same results—for example, the 100-year return period storm surge height has a 1/100, or 1%, annual probability of occurrence.

profile from the daily data. Wind speeds and surface solar radiation are not available from GCMs, which have limited capability for predicting these meteorological variables, given the large spatial resolution of these models. Instead, historical hourly wind and solar data from the National Aeronautics and Space Administration's (NASA) Modern-era Retrospective Analysis for Research and Applications, version 2 (MERRA-2) reanalysis dataset, were used.

Researchers at Columbia University processed climate data for 16 Coupled Model Intercomparison Project 6 (CMIP6) climate models at 19 weather stations across New York State. We processed these data to create full spatial coverage of climate data from the 19 stations to the entire State and aggregated the data to various spatial levels to meet the needs of specific climate impact analyses performed as part of this report.

The following summarizes the CMIP6 GCMs used in this analysis:

- ACCESS-CM2
- ACCESS-ESM1-5
- AWI-CM-1-1-MR
- BCC-CSM2-MR
- CanESM5
- CNRM-CM6-1
- CNRM-ESM2-1
- GFDL-CM4
- GFDL-ESM4
- HadGEM3-GC31-LL
- INM-CM4-8
- INM-CM5-0
- KACE-1-0-G
- NorESM2-LM
- NorESM2-MM
- UKESM1-0-LL

A2 Constructing Gridded Climate Data

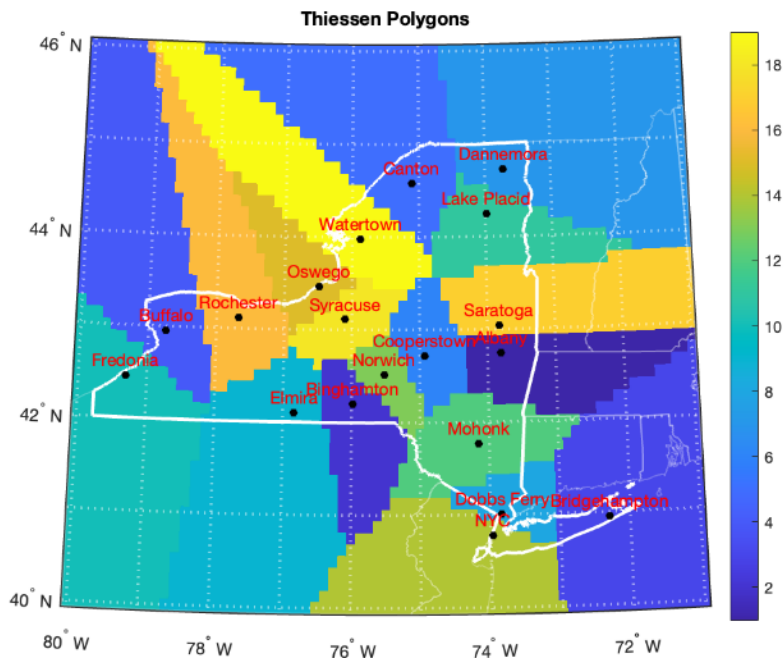
The data received from Columbia is daily for 19 stations in New York State and includes precipitation, and maximum and minimum temperature. Data are available for two RCPs, 16 GCMs, and a 30-year historical time frame and six projected 30-year eras. The first step of the climate processing is to extrapolate the data from stations to a rasterized grid. To do this, we used the historical Parameter-Elevation Regressions on Independent Slopes Model (PRISM) climate dataset, which provides

temperature and precipitation data at a gridded level and matches the historical time frame from the Columbia station data. PRISM is a high-spatial resolution monthly historical climate dataset covering the U.S. (PRISM Group N.d). We scaled the PRISM data from $1/24^\circ$ to $1/8^\circ$ to avoid over precision.

We associate each grid cell with the PRISM data to its closest station for which we have CMIP6 data by dividing the State into Thiessen polygons with the stations as the polygons' internal points, as shown in Figure A-3. Any point within the area defined by each Thiessen polygon is closer to the station within the polygon than any other station.

Figure A-3. Thiessen Polygons Gridded to Match PRISM Grid

Each polygon represents the area that is closest to the station within the polygon compared to any other station.

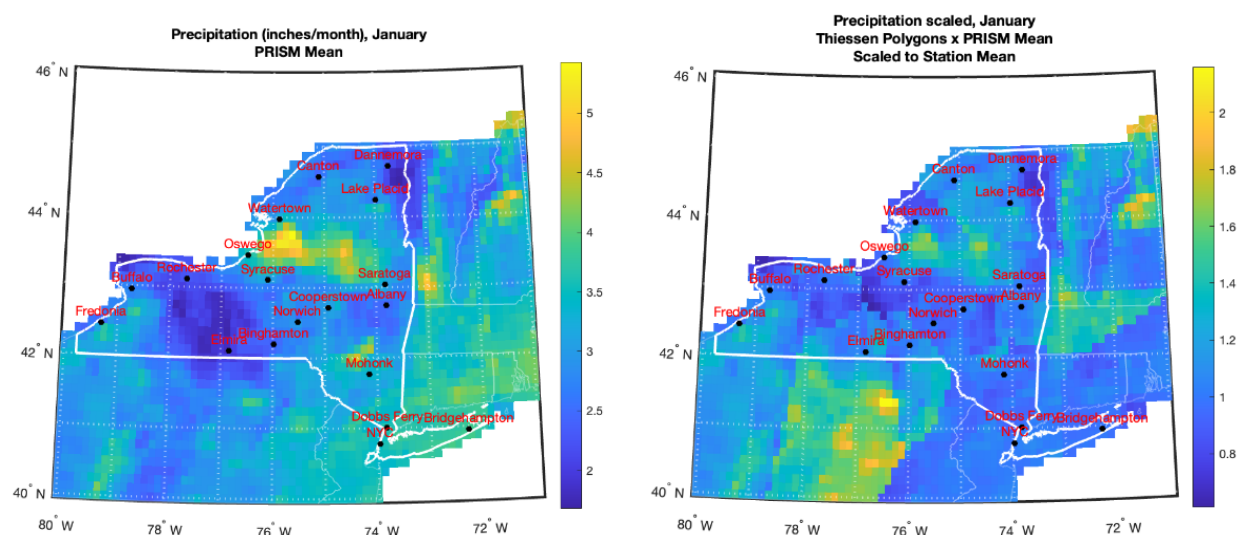


For each polygon, we scaled the historical PRISM mean to the historical value for the same time period at the station's grid cell. For precipitation, this became a multiplication ratio, and for temperature, this was an absolute offset. We did this for each month of the year. Figure A-4 shows an example of this process for precipitation in January.

We used these monthly ratios and offsets—which were developed from the historical relationships between grids and the nearest stations—to project future gridded climates by applying them to station-level time series of climate projections. In other words, these 12 sets of gridded ratios and offsets (i.e., one for each month) were used to extrapolate the station-level data to a grid across the State. We assumed that the monthly scaling factors were appropriate to apply to each day of the month within the station data, thus creating a daily gridded time series of projections.

Figure A-4. PRISM Data for Mean Precipitation in January

The left panel shows the historical average precipitation (inches/month) for January provided by PRISM at the grid level. The right panel shows the adjusted precipitation levels by grid where values in each Thiessen polygon are multiplied by the ratio of the station to grid levels for the grid in each polygon that includes a station.

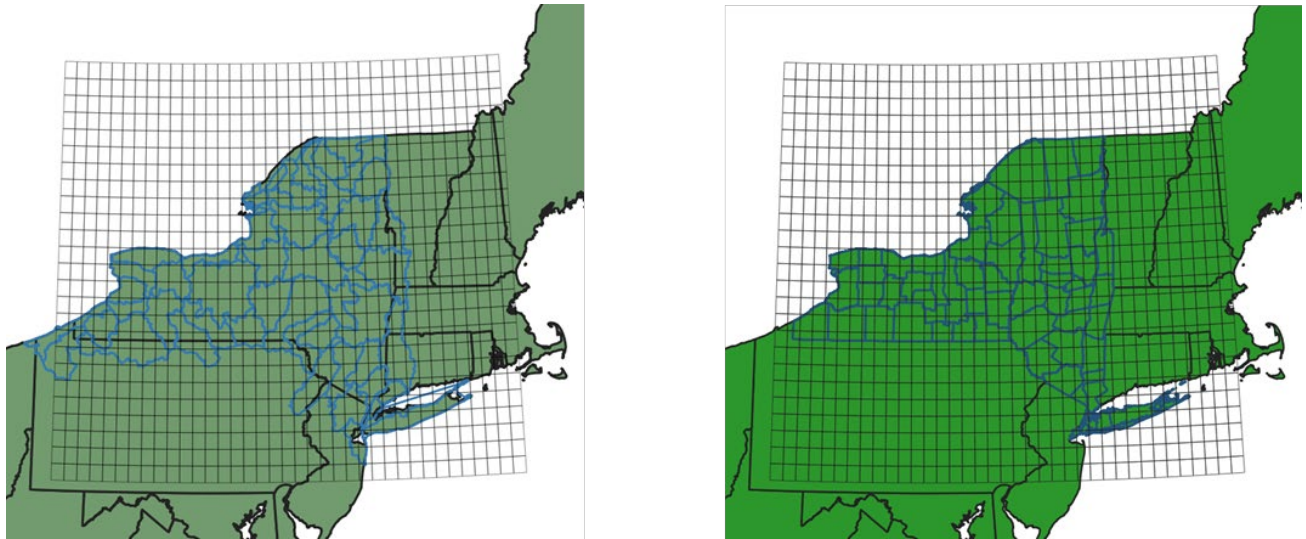


A3 Spatial Aggregations of Climate Data

Specific impact models require climate data at certain spatial scales. We aggregate the gridded climate data to each required spatial scale using area-weighted averaging. Figure A-5 shows the overlays between the climate data grids and hydrologic unit codes (HUCs) at the eight-digit level (left panel) and counties (right panel).

Figure A-5. PRISM Grid Overlayed over Hydrologic Unit Codes and Counties

PRISM grid overlayed over HUCs (left) and counties (right).



By combining 6 GCMs with 2 SSPs, 12 climate projections were available for examination. However, to allow for a focused examination of energy system impacts, this analysis relies on three distinct GCMs that broadly capture a range of climate futures and the corresponding range of potential impacts that climate change might have on the bulk electricity system.

A4 Selection of Climate Scenarios for the Electricity Supply and Demand Impact Category

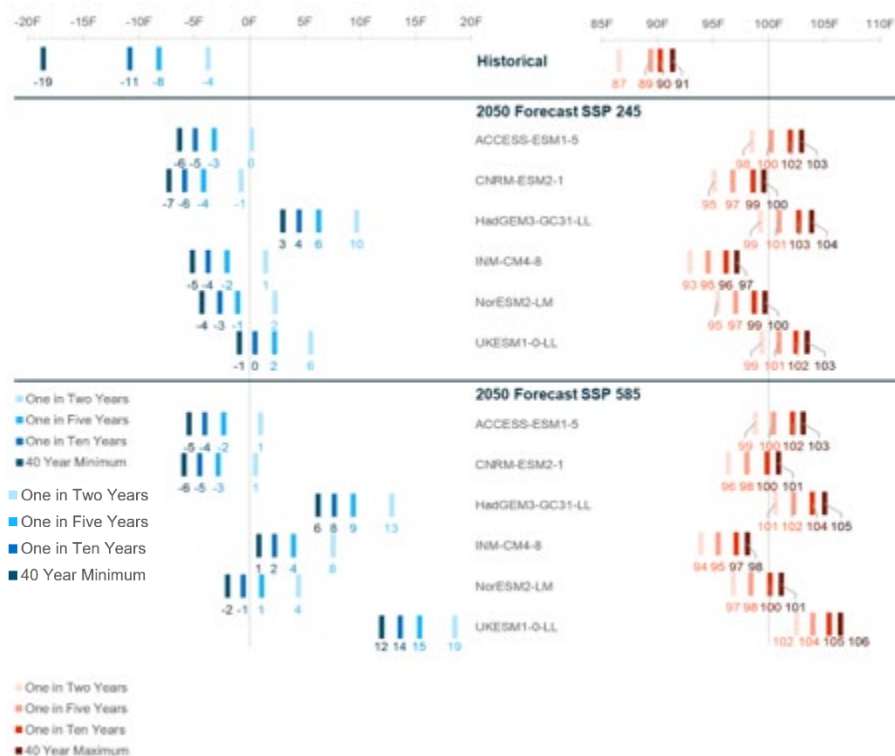
Modeling for the electricity supply and demand impact was the most computationally intensive in the report. As a result, a smaller number of climate scenarios were processed than for other sectors. Three scenarios were chosen for analysis using the process described in this section.³

To determine the range of scenarios to use in its assessment of low and high-end electric infrastructure impacts, the project team focused primarily—but not exclusively—on the seasonal extremes. The team assessed the hottest and coldest temperatures in each year of projected climate realizations and compared climate scenarios using their median (“One in Two”) temperatures as well as outer quantiles (shown in Figure A-6). The median temperature is a particularly important metric because many system planners, including the New York Independent System Operator (NYISO), develop their planning requirements around the median system peak.

³ For more information on the methods discussed here, see the NYSERDA (2023) report on “Impacts of Climate Change on the New York Energy System.” <https://www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Energy-Analysis/23-30-Impacts-of-Climate-Change-on-the-New-York-Energy-System-acc.pdf>

Figure A-6. Historical and Projected Minimum and Maximum Temperatures in New York State

Source: NYSERDA (2023).



NYSERDA’s prior work as part of the Climate Action Council’s Scoping Plan process used a set of proxy assumptions for the impact of climate change on future demand, assuming that cooling demand would grow by 1% per year, and assuming no impact on future heating demand. Based on its review of the range of GCMs provided as candidates for the Climate Impacts Assessment, this assumption set falls most closely to the INM-CM4-8 GCM in SSP2, RCP4.5. In this work, a mild scenario is defined as one that continues the 1% per year Scoping Plan assumption through 2050 and then uses levels of warming projected by INM-CM4-8 for the 2050–2100 period. This mild climate scenario serves effectively as a limited climate change baseline for the other climate scenarios.

Two more scenarios were also chosen: one moderate scenario intended to capture relatively higher summer warming, with extreme summer temperatures on the hottest days, and more muted impacts of warming on cold winter temperatures, relative to other GCM projections. The project team also selected a severe scenario, which reflects some of the highest warming impacts both in the summer, leading to increased cooling demand across the entire summer and extreme hot days, and in the winter,

with climate impacts leading to a substantial increase in winter minimum temperatures and corresponding reductions in heating demand. Based on its assessment of the climate realizations, the team selected the ACCESS GCM under the SSP2, RCP4.5 pathway as its moderate climate scenario, and the UK Earth System Model (UKESM) GCM under the SSP5, RCP8.5 pathway as its severe climate scenario.

Figure A-7 shows a more detailed comparison of the projected distribution of winter and summer extreme temperatures under each scenario. Extreme temperatures shown influence peak demand for electricity. Annual demand for electricity is influenced by the overall temperature distribution comprising of temperature forecasts in each hour of the year. A table in the main text shows the annual change in cooling degree days (CDD) and heating degree days (HDD) forecasted in each climate scenario. The severe scenario shows the highest level of aggregate warming too, with the moderate scenario chosen showing warming roughly in-between the severe and the mild.

Figure A-7. Projected Winter Minimum Temperatures under Selected Scenarios

Source: NYSERDA (2023).

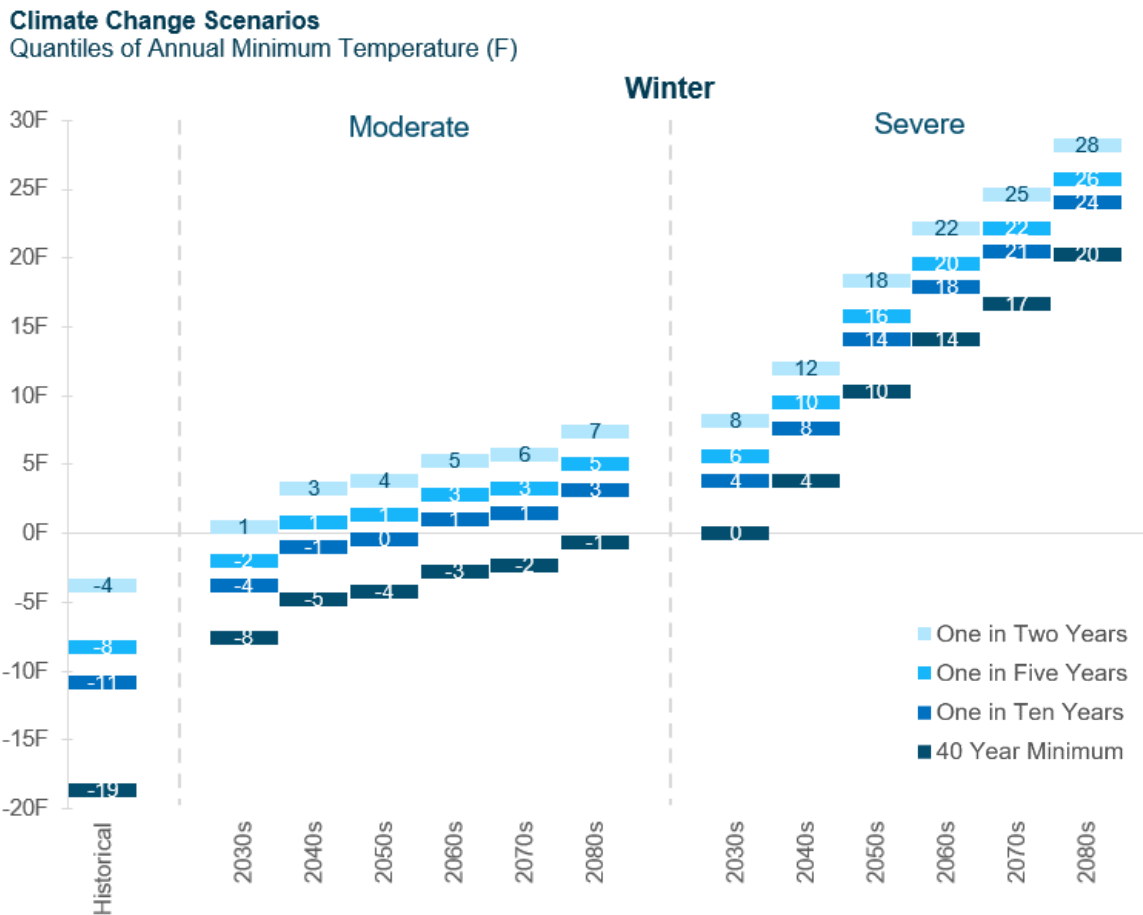
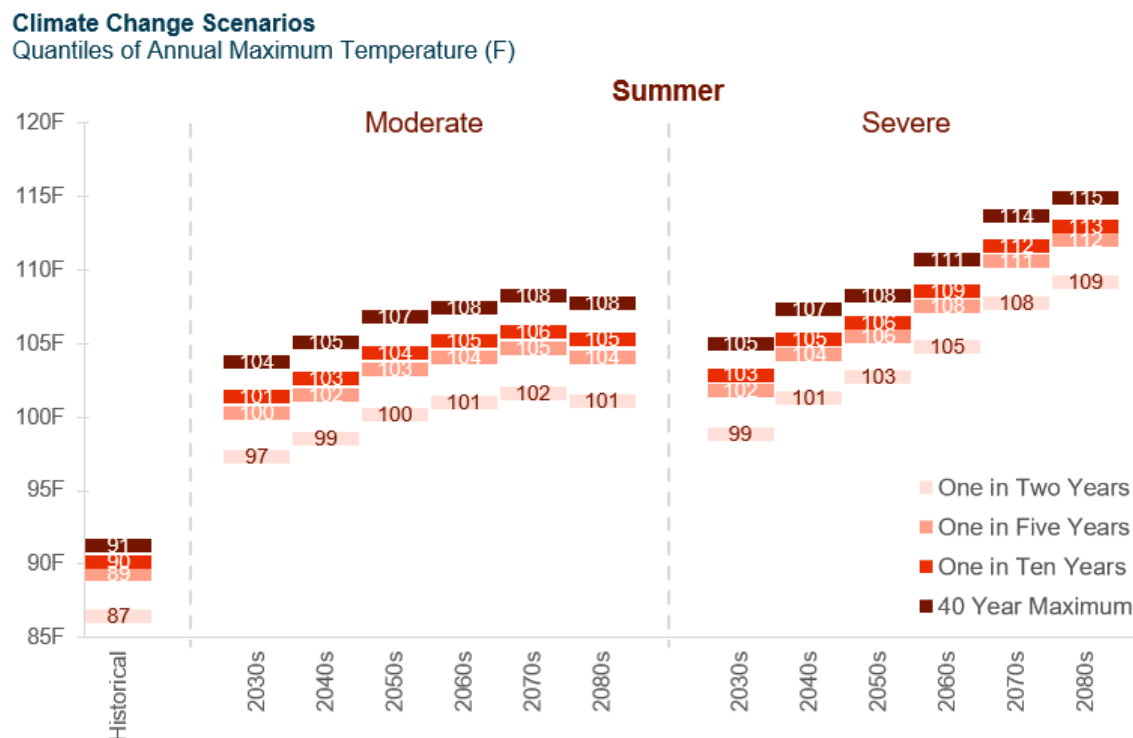


Figure A-8. Projected Summer Maximum Temperatures under Selected Scenarios

Source: NYSERDA (2023).



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