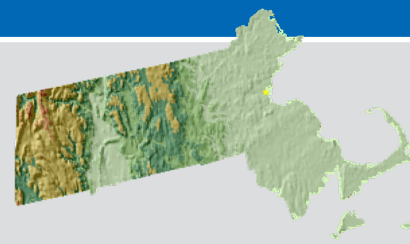
MASSACHUSETTS



Key Messages

Temperatures in Massachusetts have risen almost 3.5°F since the beginning of the 20th century. Under a higher emissions pathway, historically unprecedented warming is projected during this century, with associated increases in heat wave intensity and decreases in cold wave intensity.

Precipitation since 1970 has averaged about 4.7 inches more than during 1895–1969, and a record-setting number of extreme precipitation events occurred during 2005–2014. Winter and spring precipitation is projected to increase, as is the frequency of extreme precipitation events.

Global sea level is projected to rise, with a likely range of 1–4 feet by 2100. Sea level rise poses significant risks, including inundation, erosion-induced land loss, and greater flood vulnerability due to higher storm surge.

Massachusetts is located on the eastern edge of the North American continent. Its northerly latitude and geographic location expose the state to both the moderating and moistening influence of the Atlantic Ocean and the effects of hot and cold air masses from the interior of the continent. Its climate is characterized by cold, snowy winters and warm summers. The jet stream, often located near the state, gives it highly variable weather patterns, wide-ranging daily and annual temperatures, and generally abundant precipitation throughout the year. Massachusetts comprises approximately one-eighth of New England's total land area (8,257 square miles). Although small in size and with forestland covering more than half of the state, Massachusetts is home to more than 6 million residents. The topography, varying from the flat coastal plains in the east to hillier and higher terrain in the west, provides some regional variations in climate. For the most part, summer temperatures are comfortably warm and relatively uniform across the state. Average (1991–2020 normals) temperatures in July range from the upper 60s (°F) to mid-70s (°F), with western portions of the state being cooler and eastern portions being warmer. January temperatures are more variable than summer temperatures, ranging from the low 20s (°F) in the west to around 30°F near the coast. Annual average precipitation varies from 45 to 55 inches across the state.

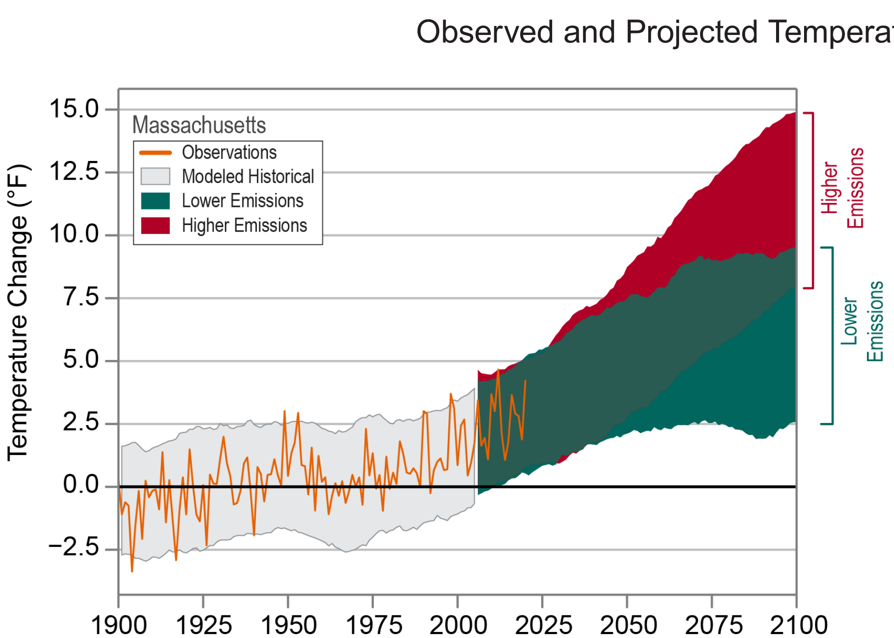


Figure 1. Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Massachusetts. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Massachusetts (orange line) have risen almost 3.5°F since the beginning of the 20th century. Shading indicates the range of annual temperatures from the set of models. Observed temperatures are generally within the envelope of model simulations of the historical period (gray shading). Historically unprecedented warming is projected during this century. Less warming is expected under a lower emissions future (the coldest end-of-year projections being about 2°F warmer than the historical average; green shading) and more warming under a higher emissions future (the hottest end-of-year projections being about 10°F warmer than the hottest year in the historical record; red shading). Sources: CISESS and NOAA NCEI.

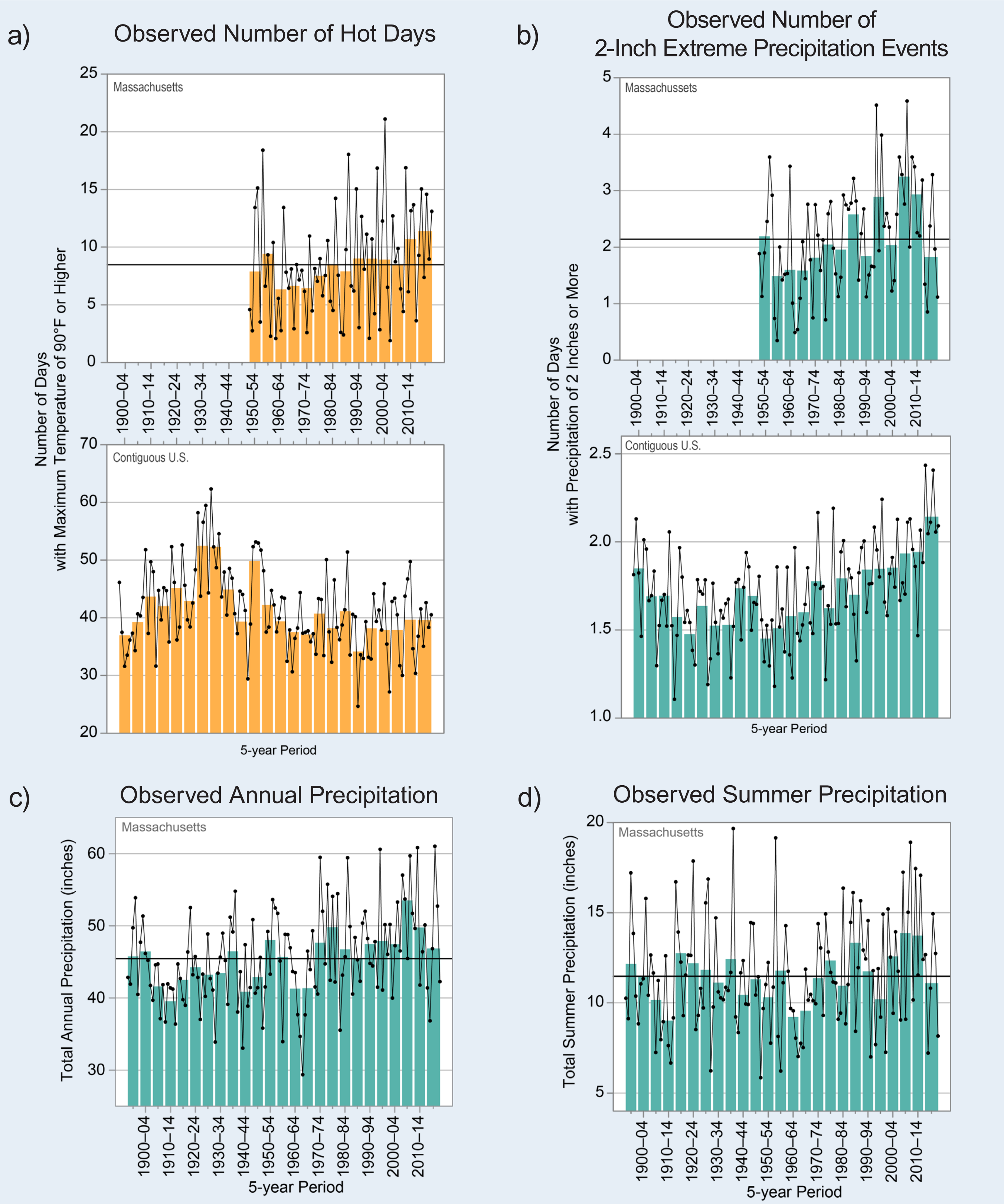


Figure 2. Observed (a) annual number of hot days (maximum temperature of 90°F or higher), (b) annual number of 2-inch extreme precipitation events (days with precipitation of 2 inches or more), (c) total annual precipitation, and (d) total summer (June–August) precipitation for Massachusetts from (a, b) 1950 to 2020 and (c, d) 1895 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black lines show the long-term (entire period) averages for Massachusetts: (a) 8.5 days, (b) 2.1 days, (c) 45.4 inches, (d) 11.5 inches. Values for the contiguous United States (CONUS) from 1900 to 2020 are included for Figures 2a and 2b to provide a longer and larger context. Long-term stations dating back to 1900 were not available for Massachusetts. The number of hot days in Massachusetts has consistently remained above average since 2010, with the 2015–2020 multiyear average setting a record high. All precipitation metrics were highest during the 2005–2014 interval. Sources: CISESS and NOAA NCEI. Data: (a) GHCN-Daily from 15 (MA) and 655 (CONUS) long-term stations, (b) GHCN-Daily from 23 (MA) and 832 (CONUS) long-term stations, (c, d) nClimDiv.

Temperatures in Massachusetts have risen almost 3.5°F since the beginning of the 20th century (Figure 1). The number of hot days has been considerably above the long-term (1950–2020) average since 2010 (Figure 2a); the highest multiyear average since 1950 (11.5 days per year) occurred during the 2015–2020 period. **The number of warm nights has been steadily increasing since 1995**, with the highest multiyear average occurring during the 2015–2020 period (Figure 3). In 2012, Boston experienced the warmest January to July in 85 years. During that span, Boston's average temperature was 53.5°F—almost 4°F warmer than the historical average temperature. Changes in extreme low temperatures also reflect this warming trend. The number of very cold nights has been below average since the early 1990s (Figure 4). Despite this overall trend, the recent winter of 2014–15 was rather severe, when the eastern United States was one of few places globally with colder than normal temperatures. Heavy snowfall was the most prominent feature of that winter, with Boston setting several records for snowfall, including 110 inches for seasonal snowfall and the snowiest month on record; the Massachusetts Bay Transportation Authority rail service also shut down for several days. The winter average temperature was the 30th coldest for Massachusetts.

Precipitation is abundant but highly variable from year to year. The driest conditions were observed in the early 1910s and again in the 1960s, with wetter conditions occurring since the 1970s (Figures 2c and 2d). The wettest consecutive 10-year interval on record was 2005–2014, averaging about 51 inches per year, well above the long-term (1895–2020) annual average of 45.4 inches (Figure 2c). The driest consecutive 5-year interval was 1962–1966, and the wettest was 2005–2009. Massachusetts experienced extreme drought during 2016–2017 and again in 2020, straining water supplies. During 2005–2014, Massachusetts experienced the largest number of 2-inch extreme precipitation events (Figure 2b), about 30% above the long-term average. In March 2010 alone, three intense rainstorms led to extensive flooding throughout the state and southern New England, with estimated damages exceeding $2 billion. The heaviest rain fell in eastern Massachusetts, with more than 19 inches recorded near Jamaica Plain, Middleton, and Winchester.

Periodic weather events include extreme precipitation and flooding, severe storms (coastal, winter, and thunder), drought, and, on occasion, tropical storms and hurricanes. **The state's coastline is highly vulnerable to damage from powerful nor'easters and tropical storms and hurricanes**. Landfalling hurricanes have produced hurricane-force winds in Massachusetts 7 times between 1900 and 2020. In 2012, Superstorm Sandy (a post-tropical storm) was the most extreme and destructive event to affect the northeastern United States in 40 years and the fourth costliest in the Nation's history. Massachusetts was one of more than a dozen northeastern states impacted by Sandy. Storm impacts included strong winds, record high storm

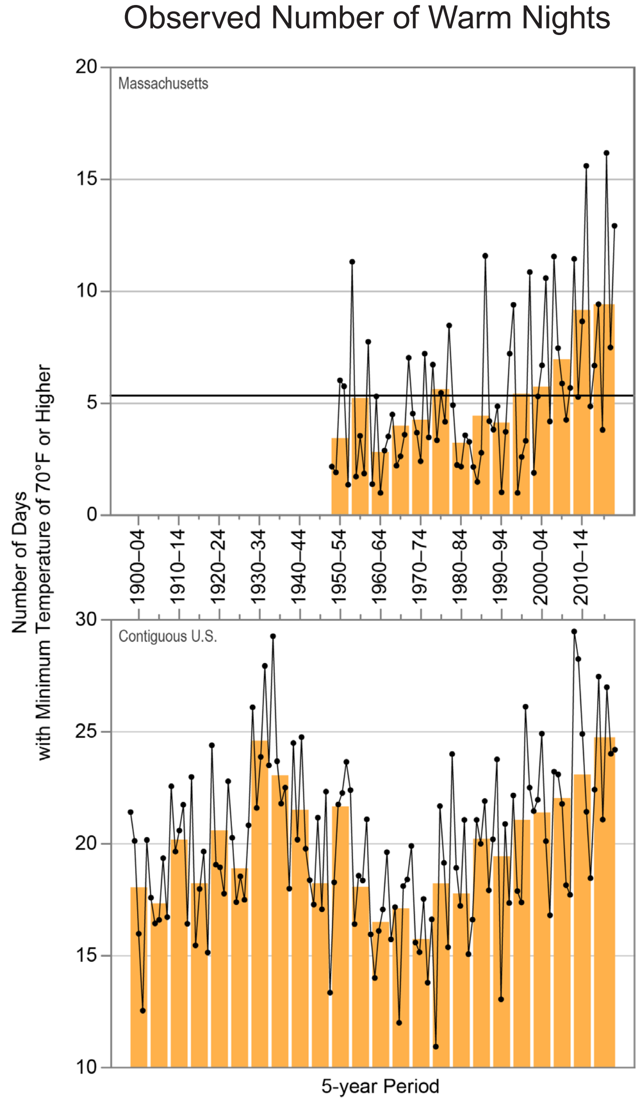


Figure 3. Observed annual number of warm nights (minimum temperature of 70°F or higher) for Massachusetts from 1950 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average for Massachusetts of 5.3 nights. Values for the contiguous United States (CONUS) from 1900 to 2020 are included to provide a longer and larger context. Long-term stations dating back to 1900 were not available for Massachusetts. The number of warm nights in Massachusetts has steadily increased since the mid-1990s, with the highest multiyear average (since 1950) occurring during the 2015–2020 period. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 15 (MA) and 655 (CONUS) long-term stations.

tides, flooding of some coastal areas, and loss of power for 385,000 residents. The state suffered more than $300 million in property losses alone. A year earlier, Hurricane Irene, dubbed the "costliest Category 1 storm" (with more than $15 billion in damages), swept through northern New England. Irene's most severe impact was catastrophic inland flooding in New Jersey, Massachusetts, and Vermont. A number of weather stations in central and western Massachusetts recorded more than 4 inches of rainfall during August 27–29, 2011, with a few locations exceeding 7 inches, including Granville Dam and Westhampton.

Under a higher emissions pathway, historically unprecedented warming is projected during this century (Figure 1). Even under a lower emissions pathway, annual average temperatures are projected to most likely exceed historical record levels by the middle of this century. However, a large range of temperature increases is projected under both pathways, and under the lower pathway, a few projections are only slightly warmer than historical records. Heat waves are projected to increase in intensity, while cold waves are projected to become less intense. Massachusetts is vulnerable to extreme heat because of its densely populated urban areas. Excessive heat exposure is projected to contribute to more heat-related illnesses and, in severe cases, deaths. The annual number of days above 90°F is projected to increase by up to 40 days for parts of Massachusetts by midcentury under a higher emissions pathway.

Winter and spring precipitation is projected to continue to increase for Massachusetts over this century (Figure 5). In response to winter warming, projections indicate that more precipitation (12%–30%) will fall as rain rather than snow, and there will be earlier lake ice-out dates and a reduction in winter snowpack. As winters become warmer, the number of snow events is expected to decline from an average of 5 each month of winter to 1 to 3. The number of extreme precipitation events is also projected to more than double by the end of this century. Projections of above average precipitation totals and more frequent extreme precipitation events may also result in increased coastal and inland flooding, including substantial increases in riverine flooding in Boston by 2050. Increased evaporation from warmer temperatures, alterations in the timing and amount of streamflow following reductions in snowpack, and changes in the amount, timing, and type of precipitation may intensify naturally occurring droughts.

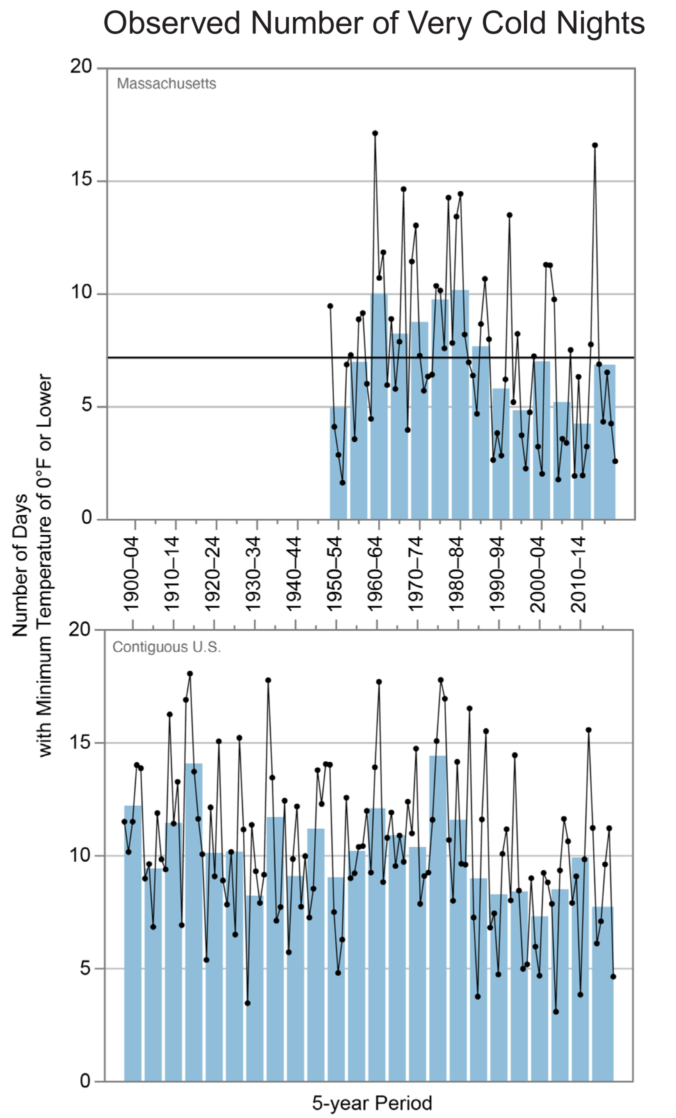


Figure 4. Observed annual number of very cold nights (minimum temperature of 0°F or lower) for Massachusetts from 1950 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average for Massachusetts of 7.2 nights. Values for the contiguous United States (CONUS) from 1900 to 2020 are included to provide a longer and larger context. Long-term stations dating back to 1900 were not available for Massachusetts. The number of very cold nights has been consistently below average since the early 1990s. The lowest number of cold nights occurred during the 2010–2014 period. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 15 (MA) and 655 (CONUS) long-term stations.

Coastal communities are particularly vulnerable to sea level rise and coastal storm surge. **Since 1900, global average sea level has risen by about 7–8 inches. It is projected to rise another 1–8 feet, with a likely range of 1–4 feet by 2100 as a result of both past and future emissions from human activities** (Figure 6). From 1921 to 2020, relative sea level increased 0.11 inches per year in Massachusetts, or approximately 11 inches per century, greater than the global rate. Land in the state is naturally subsiding (sinking); thus, sea level rise has and will continue to contribute to increases in coastal flooding frequency, shoreline erosion, and saltwater intrusion. While local elevation conditions and trends (e.g., subsidence and sediment compaction) need to be accounted for in the adjustment of global sea level rise scenarios to derive relative sea level rise, thermal expansion and melting glacial ice sheets are projected to dominate any local changes in land movement by 2050. State-level findings indicate that sea level rise by 2100 could range from 4 feet (Intermediate scenario) to 10 feet (Extreme scenario), given a high emissions pathway. Sea level rise–induced coastal flooding of densely populated, low-lying coastal communities has important future implications for the state's economy, public health, natural resources, and infrastructure.

Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts. These events can damage infrastructure, cause road closures, and overwhelm storm drains. As sea level has risen along the Massachusetts coastline, the number of tidal flood days (all days exceeding the nuisance-level threshold) has also increased, with the greatest number (22 days) occurring at Boston in both 2009 and 2017 (Figure 7).

Observed and Projected Change in Global Sea Level

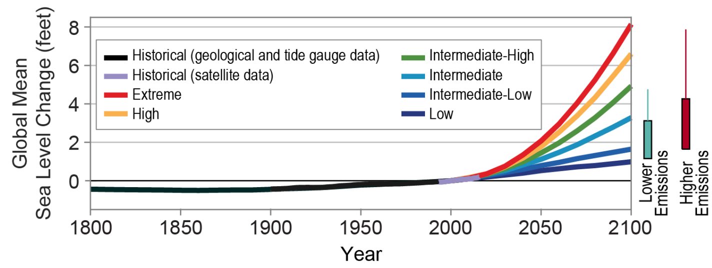


Figure 6. Global mean sea level (GMSL) change from 1800 to 2100. Projections include the six U.S. Interagency Sea Level Rise Task Force GMSL scenarios (Low, navy blue; Intermediate-Low, royal blue; Intermediate, cyan; Intermediate-High, green; High, orange; and Extreme, red curves) relative to historical geological, tide gauge, and satellite altimeter GMSL reconstructions from 1800–2015 (black and magenta lines) and the very likely ranges in 2100 under both lower and higher emissions futures (teal and dark red boxes). Global sea level rise projections range from 1 to 8 feet by 2100, with a likely range of 1 to 4 feet. Source: adapted from Sweet et al. 2017.

Observed and Projected Annual Number of Tidal Floods for Boston, MA

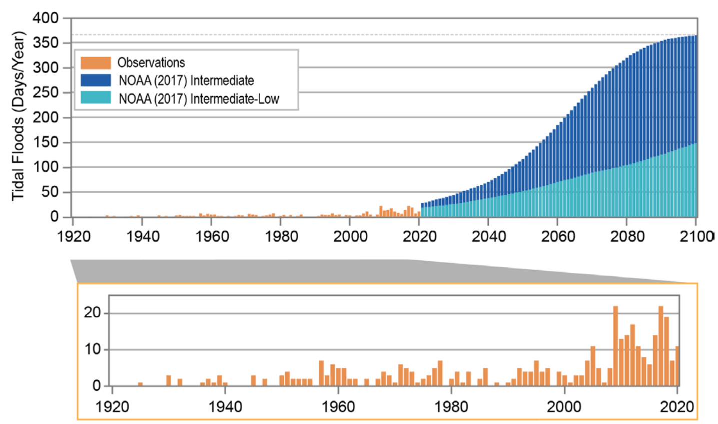


Figure 7. Number of tidal flood days per year at Boston, Massachusetts, for the observed record (1921–2020; orange bars) and projections for two NOAA (2017) sea level rise scenarios (2021–2100): Intermediate (dark blue bars) and Intermediate-Low (light blue bars). The NOAA (2017) scenarios are based on local projections of the GMSL scenarios shown in Figure 6. Sea level rise has caused a gradual increase in tidal floods associated with nuisance-level impacts. The greatest number of tidal flood days (all days exceeding the nuisance-level threshold) occurred in 2009 and 2017 at Boston. Projected increases are large even under the Intermediate-Low scenario. Under the Intermediate scenario, tidal flooding is projected to occur nearly every day of the year by the end of the century. Additional information on tidal flooding observations and scenarios is available at https://statesummaries.ncics.org/technicaldetails. Sources: CISESS and NOAA NOS.

Projected Change in Spring Precipitation

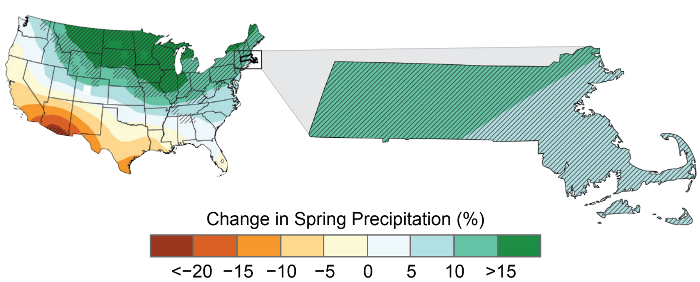


Figure 5. Projected changes in total spring (March–May) precipitation (%) for the middle of the 21st century relative to the late 20th century under a higher emissions pathway. The whited-out area indicates that the climate models are uncertain about the direction of change. Hatching represents areas where the majority of climate models indicate a statistically significant change. Spring precipitation is projected to increase in Massachusetts by midcentury. Sources: CISESS and NEMAC. Data: CMIP5.

Technical details on observations and projections are available online at https://statesummaries.ncics.org/technicaldetails.

WWW.NCEI.NOAA.GOV | HTTPS://STATESUMMARIES.NCICS.ORG/CHAPTER/MA/ | LEAD AUTHORS: JENNIFER RUNKLE, KENNETH E. KUNKEL
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