RHODE ISLAND

Key Messages

Rhode Island has warmed by more than 3°F over the past century. Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century. Increased intensity of heat waves is also projected, but a decreased intensity of cold waves.

Both mean and extreme precipitation has increased during the last century, with the highest number of extreme events occurring over the last decade. Continued increases in frequency and intensity of extreme precipitation events are projected.

Sea level has risen more than 9 inches since 1930 at Newport, faster than the global average. It is projected to rise another 1 to 4 feet by 2100. Increases in sea level will likely increase coastal flooding and erosion during winter storms (nor'easters) and hurricanes.

Rhode Island's geographic position in the mid-latitudes often places it near the jet stream, particularly in the late fall, winter, and spring. Its characteristic of frequently changing weather results from the regular passing of low pressure storms associated with the jet stream. In addition, Rhode Island's location on the East Coast of North America exposes it to both the cold winter and warm summer air masses of the continental interior and the moderate and moist air masses of the western Atlantic Ocean. In winter, the contrast between frigid air masses of the continental interior and the relatively warm Atlantic Ocean provides the energy for occasional intense storms known as nor'easters. In Providence, average temperatures in July are around 74°F and in January about 29°F. Statewide annual average precipitation is about 45 inches. The driest year on record (28 inches) was 1965 while the wettest year on record (63 inches) was 1972. Average accumulated snowfall ranges between 20 inches on Block Island and along the southeastern shores of Narragansett Bay to between 40 and 55 inches in the western portion of the state.

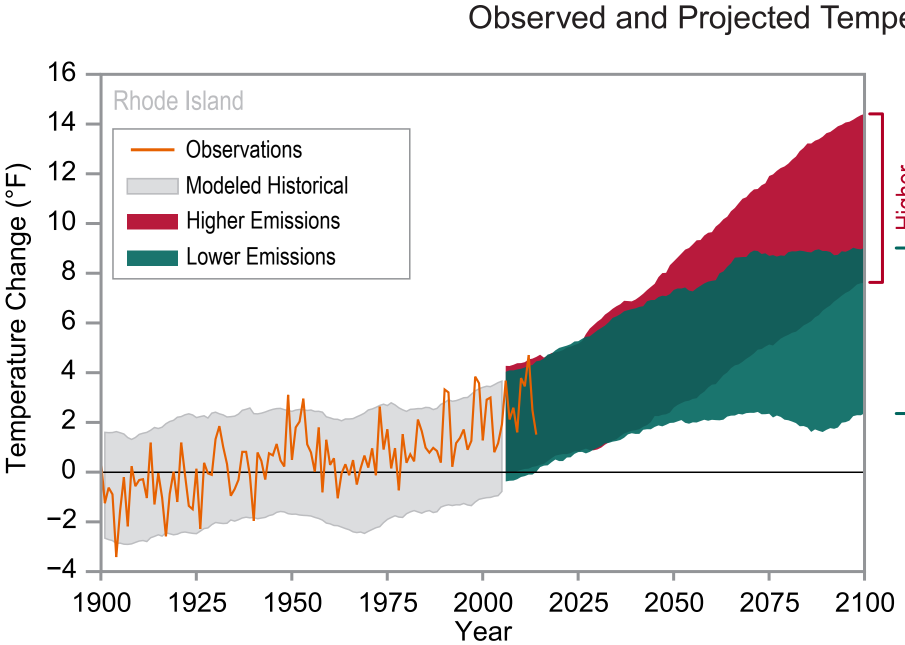

Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Rhode Island. Observed data are for 1900–2014. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions)[1]. Temperatures in Rhode Island (orange line) have risen more than 3°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 to during the 21st century. Less warming is expected under a lower emissions future (the coldest years being slightly cooler than the hottest years in the historical record; green shading) and more warming under a higher emissions future (the hottest years being about 10°F warmer than the hottest year in the historical record; red shading). Source: CICS-NC and NOAA NCEI.

[1]Technical details on models and projections are provided in an appendix, available online at: https://statesummaries.ncics.org/ri.

Temperatures in Rhode Island have increased by more than 3°F since the beginning of the 20th century (Figure 1). The number of hot days (maximum temperature above 90°F) in Rhode Island has been above the long-term average since the mid-1990s with the largest number occurring during the most recent 5-year period of 2010–2014 (Figure 2). The number of warm nights (minimum temperature above 70°F) was also largest during the most recent period (Figure 3a) and very cold nights (minimum temperature below 0°F) have been below average since the mid-1990s (Figure 4).

Average annual precipitation for Rhode Island has generally been above average in recent decades. The driest multi-year period were the 1940s and the latter half of the 1960s, and the wettest in the 2000s, although precipitation has been predominantly above average since the 1970s. The driest 5-year period was 1962–1966; the wettest 5-year period was 2005–2009 with an annual average of 54 inches, about 8 inches above the long-term average (Figure 3c) and summer precipitation has been well above average since 2000 (Figure 3d). Rhode Island has experienced the largest number of extreme precipitation events (precipitation greater than 2 inches) in the most recent decade (2005–2014) (Figure 3b). In 2010, major rainfall from a nor'easter in late March caused the worst flooding in the state's history. This event set an all-time monthly precipitation record in Rhode Island of 16.34 inches, superseding the previous record of 15.38 inches recorded in October 2005. The flooding of 2010 resulted in an estimated $43 million in national flood insurance claims in the state.

Extreme weather events common to Rhode Island include severe storms (coastal, winter, and thunderstorms), often accompanied by flooding, and on occasion, tropical storms and hurricanes. The state's coastline is highly vulnerable to flood damage from winter and hurricane events. FEMA disaster declarations were sought 6 out of the last 10 years, 3 of which were for severe flooding. The Northeast has been affected by 15 landfalling hurricanes since 1900, 7 of which affected Rhode Island. The Great New England Hurricane (Category 3) of 1938 was one of the most destructive and powerful storms ever to impact southern New England. Storm tides of 12 to 15 feet were recorded for Narragansett Bay and downtown Providence was

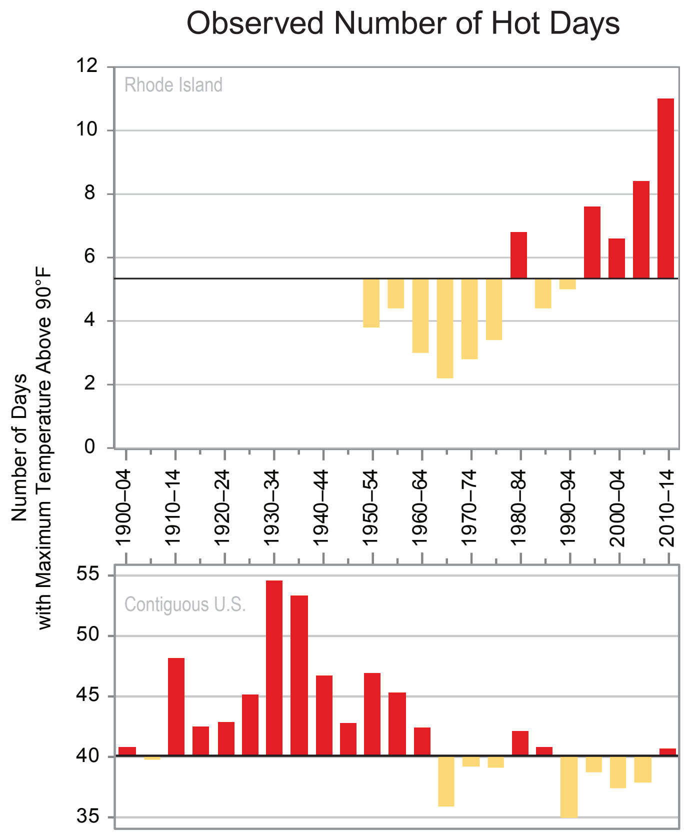

Figure 2: The observed number of hot days (annual number of days with maximum temperature above 90°F) for 1950–2014, averaged over 5-year periods, at Kingston, RI. The number of hot days has been above average since the mid-1990s. The highest number of such days occurred in the most recent 5-year period (2010–2014), with an average of 11 hot days occurring each year. The number of hot days for the contiguous United States (bottom panel) is also shown to provide a longer and larger context. The dark horizontal lines represent the long-term average. Long-term stations back to 1900 were not available for Rhode Island. Source: CICS-NC and NOAA NCEI.

submerged under a storm tide of 20 feet. In October 2012 Superstorm Sandy (a post-tropical storm) caused a storm surge 9.4 feet above normal high tide in Providence resulting in extensive coastal flooding. One year earlier, heavy rainfall and strong southeast winds—up to 70 mph—from Hurricane Irene knocked down power lines, leaving half of Rhode Island's one million residents without power. Both hurricanes demonstrated the region's vulnerability to extreme weather events.

Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century. (Figure 1). Even under a pathway of lower greenhouse gas emissions, average annual temperatures are projected to most likely exceed historical record levels by the middle of the 21st century. However, there is a large range of temperature increases under both pathways, and under the lower pathway, a few

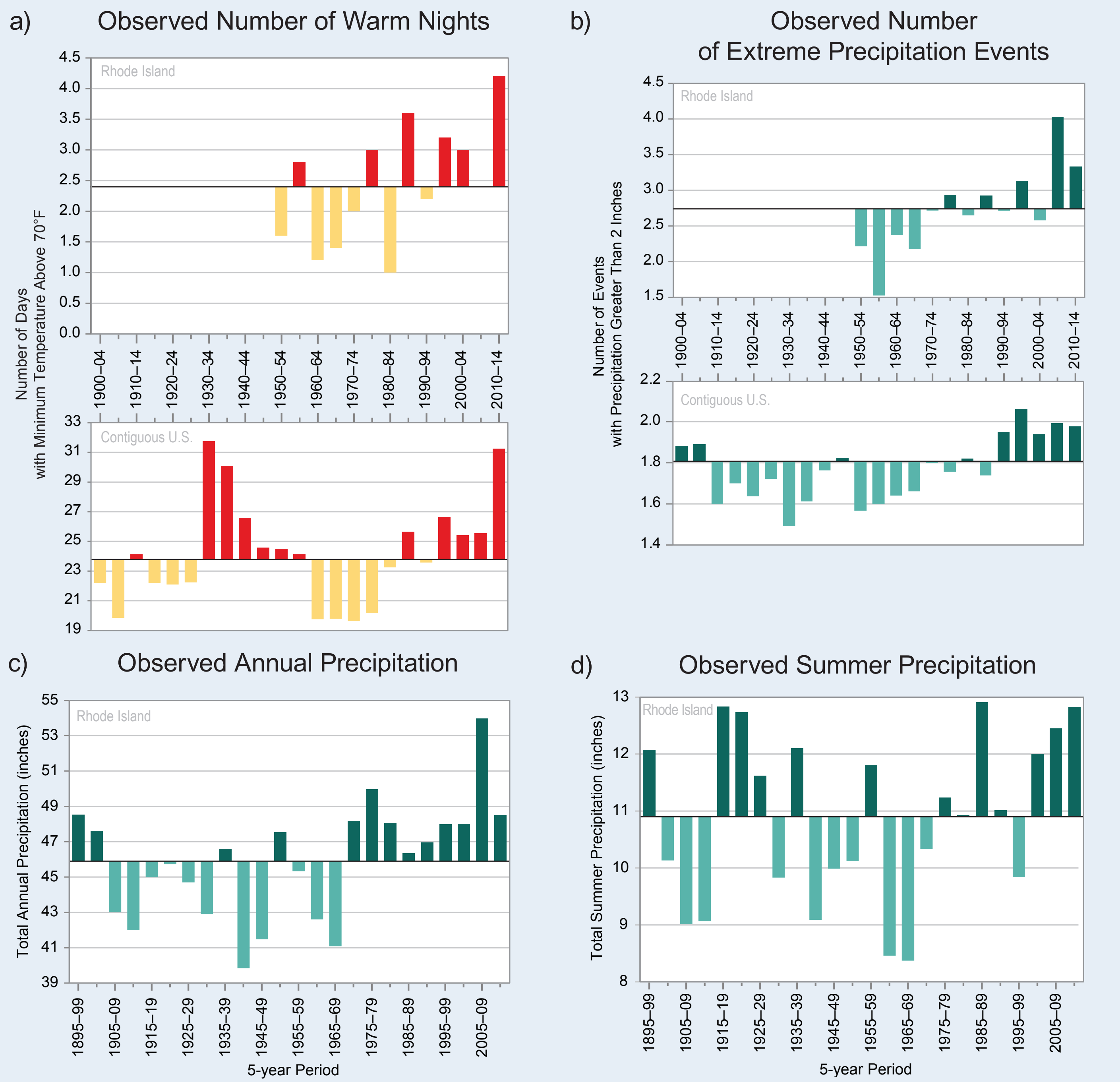

Figure 3: The observed (a) number of warm nights (maximum temperature above 70°F), (b) extreme precipitation events (precipitation greater than 2 inches), (c) total annual precipitation, and (d) total summer precipitation, averaged over 5-year periods. Values in Figures 3a are from Kingston, RI. Values in Figure 3b are averages from two long-term precipitation reporting stations (Kingston and Woonsocket). Values in figures c and d are from NCEI's version 2 climate division dataset. Values for the contiguous United States (bottom panel) are also shown where appropriate to provide a longer and larger context (long-term stations back to 1900 were not available for Rhode Island). The dark horizontal lines represent the long-term average. The number of warm nights has been above average since 1985, with a record high number of 4 or more such nights occurring annually between 2010 and 2014. Since 1970, annual precipitation has remained above the long-term average, with summer rainfall and extreme precipitation events steadily increasing since the first part of the 21st century. The wettest 5-year period on record occurred between 2005 and 2009 with an estimated 54 inches of annual precipitation. Source: CICS-NC and NOAA NCEI.

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. Rhode Islanders may experience more heat-related deaths, and hotter conditions will be most dangerous in urban areas due to the heat-island effect.

Increases in annual mean precipitation are projected for Rhode Island, with those increases coming in the winter and spring. Rhode Island is part of a large area of the Northern Hemisphere in the higher middle latitudes projected to see increases in precipitation, as well as increases in extreme precipitation events. Projections of more precipitation and a greater number of extreme precipitation events may also result in increased flooding risks. Although increased precipitation is projected, naturally-occurring droughts are projected to be more intense because higher temperatures will increase evaporation rates.

Since 1880, global sea level has risen by about 8 inches. Tide gauge recordings between 1931 and 2015 in Newport show an average rate of sea level rise of 2.72 mm (about 0.1 inch) per year, equivalent to more than 10 inches over a century. 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 Rhode Island coastline, the number of tidal flood days (all days exceeding the nuisance level threshold) has also increased, with the greatest number occurring in 2012 (Figure 6). Sea level is projected to rise another 1 to 4 feet by 2100 as a result of both past and future emissions from human activities (Figure 7) and will be accompanied by large increases in tidal flood events.

Higher sea levels will likely increase the probability for major flooding events. According to the National Flood Insurance Program, "the increase in the expected annual flood damage by the year 2100 for a representative National Flood Insurance Program (NFIP) insured property subject to sea level rise is estimated to increase by 36 to 58 percent for a one-foot rise" in sea level. Sea level rise along most of the coastal Northeast is expected to exceed the global average rise due to local land subsidence. A sea level rise of two feet, without any changes in storms, would more than triple the frequency of dangerous coastal flooding throughout most of the Northeast.

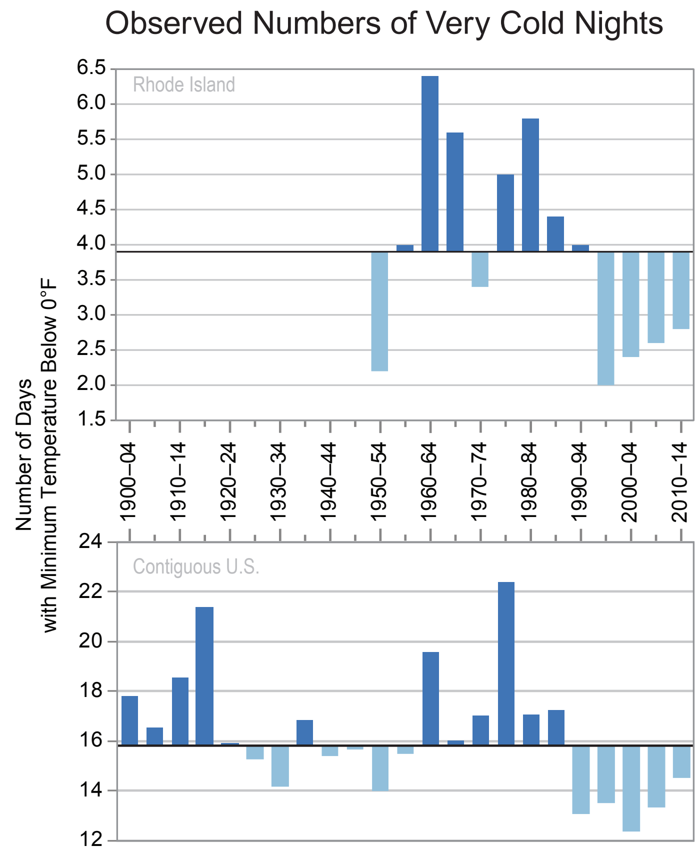

Figure 4: The observed number of very cold nights (annual number of days with minimum temperature below 0°F) for 1950–2014, averaged over 5-year periods at Kingston, RI. The average number of very cold nights was about 5 days each year between 1960 and 1994. Beginning in the mid-1990s and extending into the 2000s, the observed number of such days was below average. Since 2000, the number of very cold nights occurs on average 2.5 days each year. The number of very cold nights for the contiguous United States (bottom panel) is also shown to provide a longer and larger context. The dark horizontal lines represent the long-term average. Long-term stations back to 1900 were not available for Rhode Island. Source: CICS-NC and NOAA NCEI.

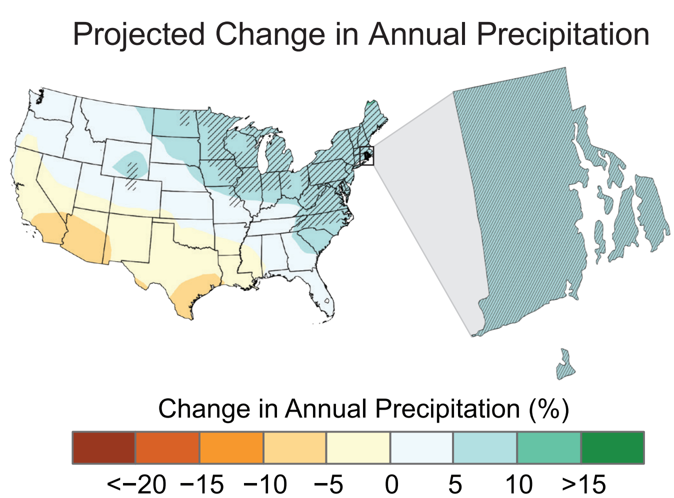

Figure 5: Projected change in annual precipitation (%) for the middle of the 21st century relative to the late 20th century under a higher emissions pathway. Hatching represents portions of the state where the majority of climate models indicate a statistically significant change. Rhode Island is part of a large area of projected increases that includes the Northeast region. Source: CICS-NC, NOAA NCEI, and NEMAC.

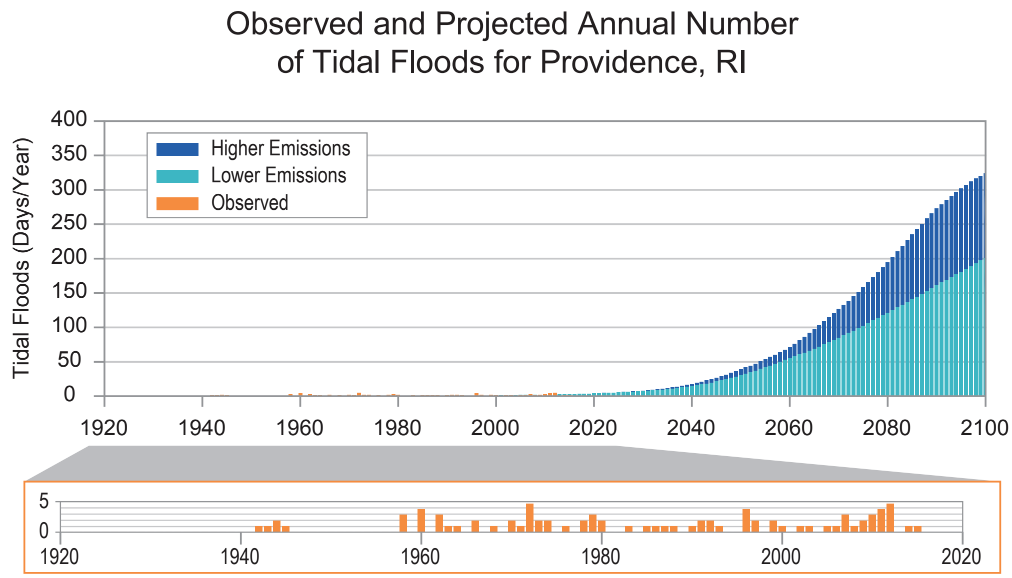

Figure 6: Number of tidal flood days per year for the observed record (orange bars) and projections for two possible futures: lower emissions (light blue) and higher emissions (dark blue) per calendar year for Providence, RI. Sea level rise has caused an increase in tidal floods associated with nuisance-level impacts. Nuisance floods are events in which water levels exceed the local threshold (set by NOAA's National Weather Service) for minor impacts, such as road closures and overwhelmed storm drains. The greatest number of tidal flood days (all days exceeding the nuisance level threshold) occurred in 1972 and 2012 at Providence. Projected increases are large even under a lower emissions pathway. Near the end of the century, under a higher emissions pathway, some models (not shown here) project tidal flooding nearly every day of the year. To see these and other projections under additional emissions pathways, please see the supplemental material on the State Summaries website (https://statesummaries.ncics.org/ri). Source: NOAA NOS.

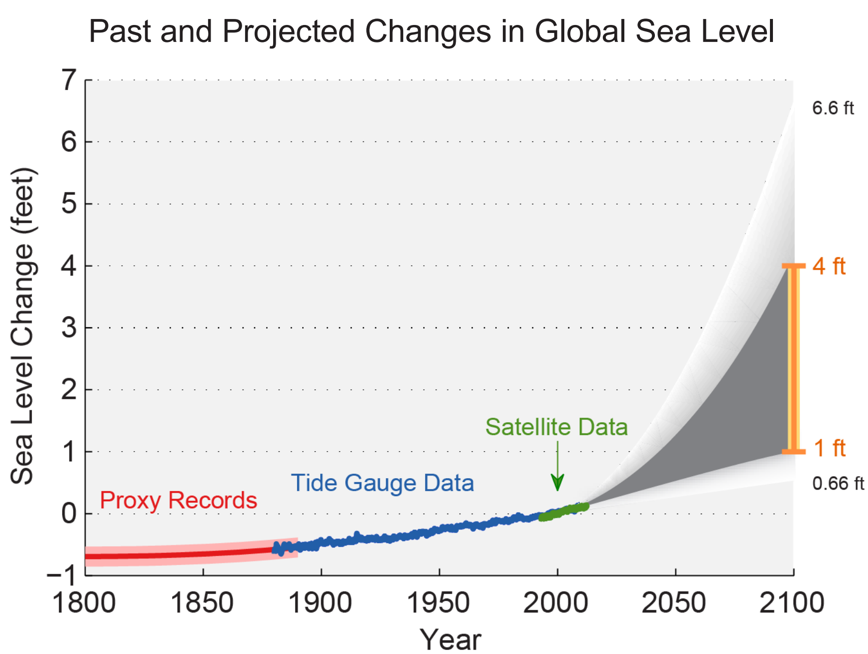

Figure 7: Estimated, observed, and possible future amounts of global sea level rise from 1800 to 2100, relative to the year 2000. The orange line at right shows the most likely range of 1 to 4 feet by 2100 based on an assessment of scientific studies, which falls within a larger possible range of 0.66 feet to 6.6 feet. Source: Melillo et al. 2014 and Parris et al. 2012.