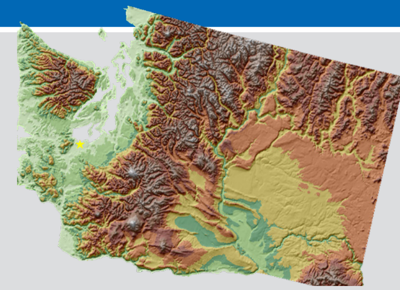


WASHINGTON

Key Messages

Temperatures in Washington have risen almost 2°F since the beginning of the 20th century. Winter warming has been evident in the below average number of freezing days and very cold nights since 1990. Under a higher emissions pathway, historically unprecedented warming is projected to continue through this century.

Rising temperatures will lead to earlier melting of the snowpack, which plays a critical role in spring and summer water supplies. The combination of this earlier melting and more precipitation falling as rain instead of snow may lead to an increase in springtime flooding.

Wildfires during the dry summer months are a particular concern for Washington, and the frequency and severity of wildfires are projected to increase.

Washington's location in the heart of the middle latitudes exposes it to frequent storm systems associated with the mid-latitude jet stream. Due to the physical barrier of the Cascade Mountains, the climate differs greatly in the western and eastern parts of the state. The Pacific Ocean provides abundant moisture, causing frequent precipitation west of the Cascade Mountains, with some locations experiencing orographic enhancement (the increase of rainfall with elevation on the upwind side of mountain ranges). The region east of the Cascades receives less precipitation due to the reduced availability of ocean moisture. Temperatures in the central and eastern portions of the state are not as strongly moderated by the ocean and exhibit a greater annual range than those in the western portion.

Since the beginning of the 20th century, temperatures in Washington have risen almost 2°F (Figure 1)**, and since 1986, all but 5 years have been above the long-term (1895–2020) average.** The hottest year on record was 2015, with a statewide average temperature of 50.0°F, which was 3.7°F above the long-term average. The overall warming trend is evident in an increased number of warm nights. Since 1990, the numbers of very cold nights in Eastern Washington and freezing days in Western Washington have both been below average (Figure 2a). However, the numbers of very warm nights in Eastern Washington and warm nights in Western Washington have both been above average since 1990 (Figure 3). The numbers of very hot days in Eastern Washington and hot days in Western Washington have been quite variable but were both generally above average during the 2015–2020 period, after below average numbers during the 2010–2014 period (Figure 2b).

Observed and Projected Temperature Change

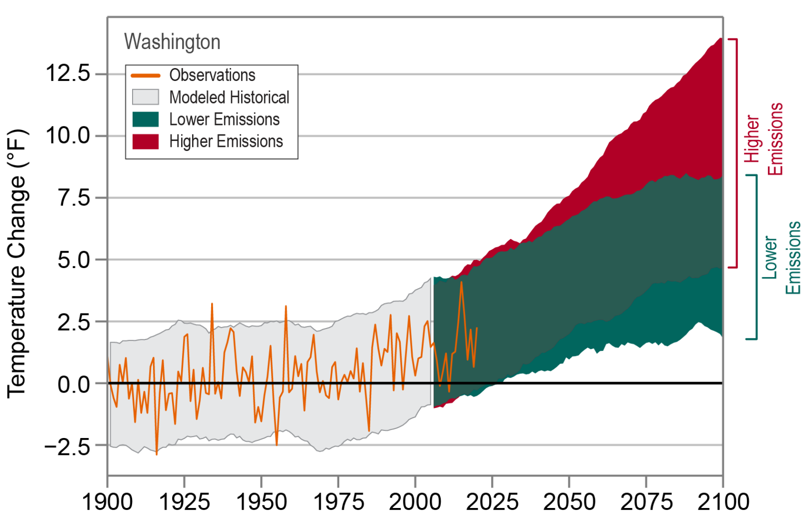
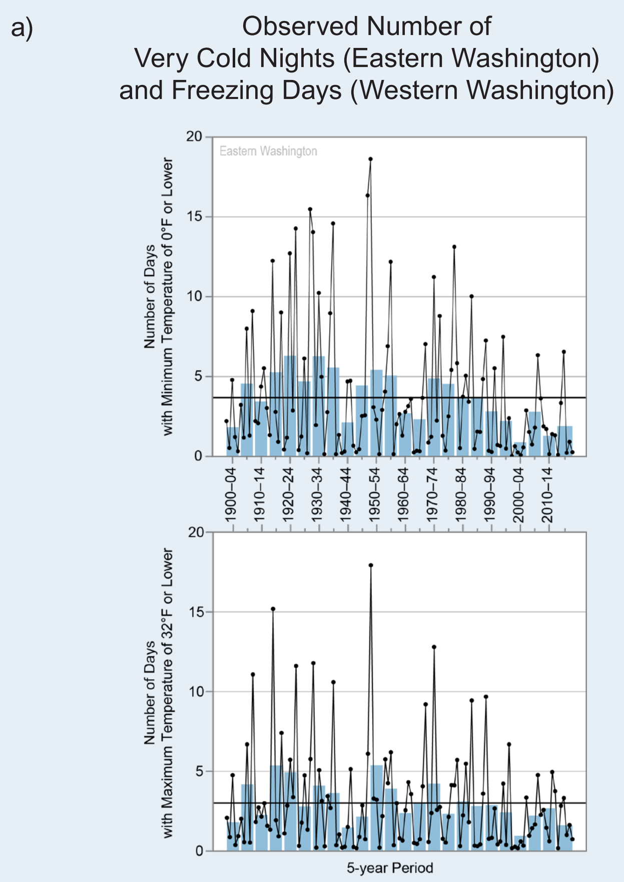
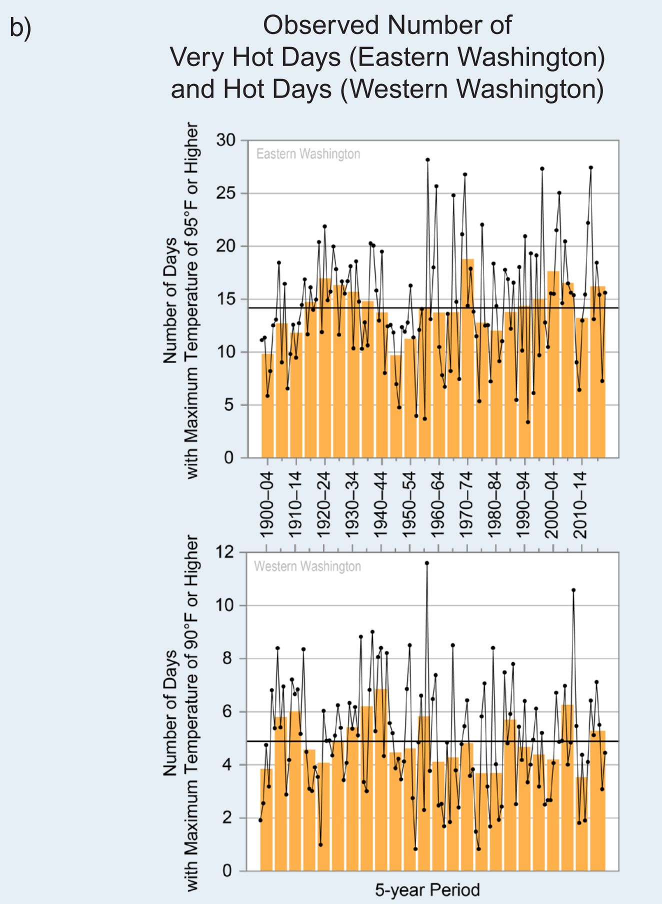
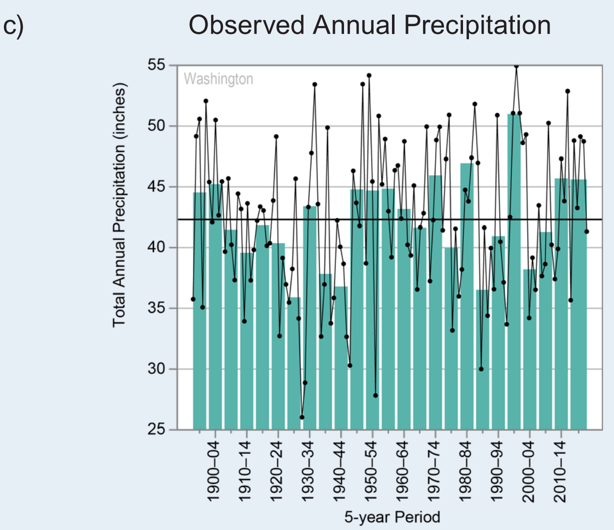


Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Washington. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Washington (orange line) have risen almost 2°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 continue through this century. Less warming is expected under a lower emissions future (the coldest end-of-century projections being about 1°F warmer than the historical average; green shading) and more warming under a higher emissions future (the hottest end-of-century projections being about 10°F warmer than the hottest year in the historical record; red shading). Sources: CISESS and NOAA NCEI.







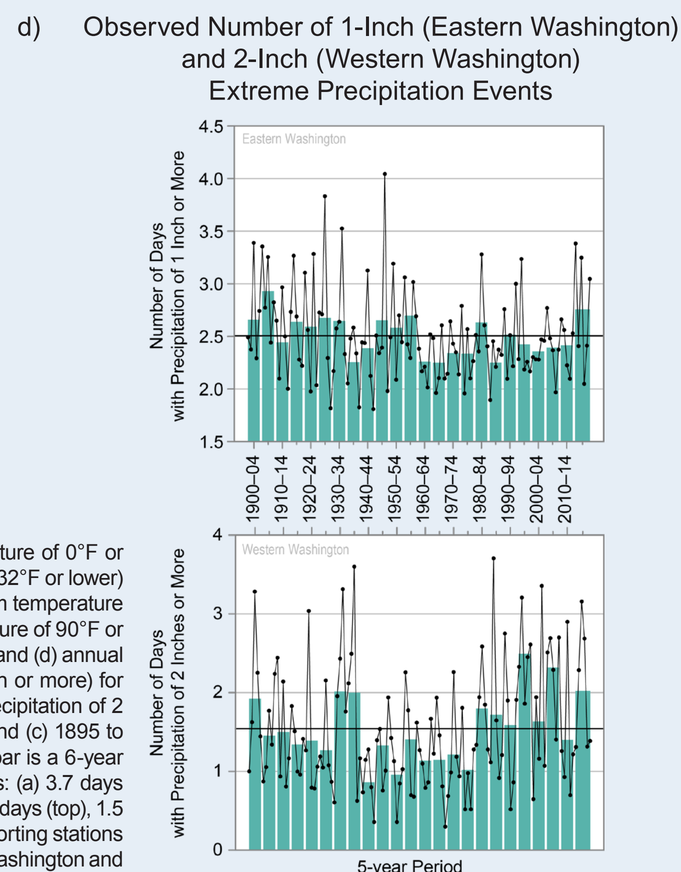


Figure 2: Observed (a) annual numbers of very cold nights (minimum temperature of 0°F or lower) for Eastern Washington (top) and freezing days (maximum temperature of 32°F or lower) for Western Washington (bottom), (b) annual numbers of very hot days (maximum temperature of 95°F or higher) for Eastern Washington (top) and hot days (maximum temperature of 90°F or higher) for Western Washington (bottom), (c) total statewide annual precipitation, and (d) annual numbers of 1-inch extreme precipitation events (days with precipitation of 1 inch or more) for Eastern Washington (top) and 2-inch extreme precipitation events (days with precipitation of 2 inches or more) for Western Washington (bottom) from (a, b, d) 1900 to 2020 and (c) 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: (a) 3.7 days (top), 3.0 days (bottom); (b) 14 days (top), 5.0 days (bottom); (c) 42.3 inches; (d) 2.5 days (top), 1.5 days (bottom). (Note that for Figures 2a, 2b, and 2d, the average for individual reporting stations varies greatly because of the state's large elevation range.) Since 1990, Eastern Washington and Western Washington have experienced below average numbers of very cold nights and freezing days, respectively, which is indicative of warming in the region. The numbers of very hot days in Eastern Washington and hot days in Western Washington have both been variable since 1990. Both annual precipitation and the number of extreme precipitation events have varied widely since the beginning of the 20th century. A typical station in Eastern Washington experiences between two and three 1-inch extreme precipitation events per year. A typical station in Western Washington experiences between one and two 2-inch events per year. Sources: CISESS and NOAA NCEI. Data: (a, b) GHCN-Daily from 17 long-term stations; (c) nClimDiv; (d) GHCN-Daily from 23 long-term stations.

Annual precipitation exhibits wide regional variations across the state. Portions of the Olympic Peninsula receive upwards of 150 inches of precipitation annually, while areas along the Columbia River in eastern interior Washington average less than 10 inches. Statewide total annual precipitation has ranged from a low of 26.0 inches in 1929 to a high of 55.0 inches in 1996. The driest multiyear periods were in the late 1920s, early 1940s, and late 1980s, and the wettest were in the early 1970s, early 1980s, and late 1990s (Figure 2c). The driest consecutive 5-year interval was 1926–1930, with an annual average of 34.6 inches, and the wettest was 1995–1999, with an annual average of 51.0 inches. Washington has not experienced any long-term trend in the number of extreme precipitation events (Figure 2d).

Most of Washington's precipitation falls during the winter months, and the Cascades can receive upwards of 400 inches of snowfall annually. **Snowpack in the mountains provides an important source of water during the drier summer months** (Figure 4)**.** Precipitation falling as rain rather than snow can have negative impacts on critical industries, such as timber and agriculture, which are also vulnerable to extreme temperatures. Wildfires during the drier summer months are a particular concern. The 2015 wildfire season was the most destructive in Washington's history, with more than 1 million acres burned (more than 6 times the average).

Under a higher emissions pathway, historically unprecedented warming is projected to continue through the end of this century (Figure 1)**.** Even under a lower emissions pathway, 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 (Figure 1). Overall, warming will lead to increases in heat wave intensities but decreases in cold wave intensities. Unlike other locations in the United States, Seattle and other urban areas are rarely exposed to very high temperatures. Future heat waves, particularly an increase in the frequency of warm nights, could stress these communities, which are not well adapted to such events.

Temperature increases will affect basins with significant snowmelt contributions to their streamflow. Projected rising temperatures will raise the elevation of the snow line—the average lowest elevation at which snow falls. This will increase the likelihood that precipitation will fall as rain instead of snow, reducing water storage in the snowpack, particularly at those lower mountain elevations that are now on the margins of reliable snowpack accumulation. Rainfall is expected to be the dominant form of precipitation across the majority of the state by the end of this century. Higher spring temperatures will also result in earlier melting of the snowpack, with average snowpack projected to decline by up to 70% by the end of this century. This will further decrease water availability during the already dry summer months, and due to earlier spring peak flows, it will increase the risk of spring

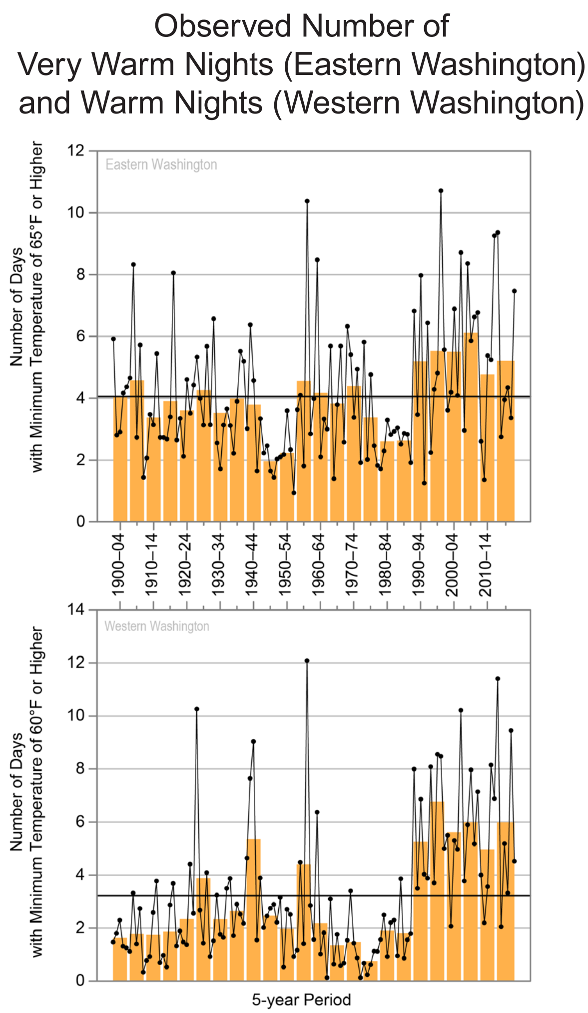


Figure 3: Observed annual numbers of very warm nights (minimum temperature of 65°F or higher) for Eastern Washington and warm nights (minimum temperature of 60°F or higher) for Western Washington from 1900 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black lines show the long-term (entire period) averages of 4.0 nights (top) and 2.5 nights (bottom; note that the average for individual reporting stations varies greatly because of the state's large elevation range). The numbers of very warm nights in Eastern Washington and warm nights in Western Washington have both been above average since 1900. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 17 long-term stations.

flooding. Projected increases in heavy rainfall events by midcentury could further increase flood risk. Reductions in summer flow (projected to occur in 80% of the state's watersheds) will have important ecological implications and are a particular concern for hydropower and irrigation water supplies.

Increasing temperatures raise concerns for sea level rise in coastal areas. 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). 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 Washington coastline, the number of tidal flood days has also increased at Seattle, with the greatest number (11) occurring in 1997 during a strong El Niño event (Figure 7). Some areas of the coast are rising, which has mitigated the impacts of recent sea level rise and will reduce somewhat the local projected sea level rise.

Although projections of overall annual precipitation are uncertain, summer precipitation is projected to decrease (Figure 5)**.** Drier conditions during the summer could increase reliance on diminishing snowmelt for irrigation. Additionally, the combination of drier summers, higher temperatures, and earlier melting of the snowpack would tend to increase the frequency and extent of wildfires.

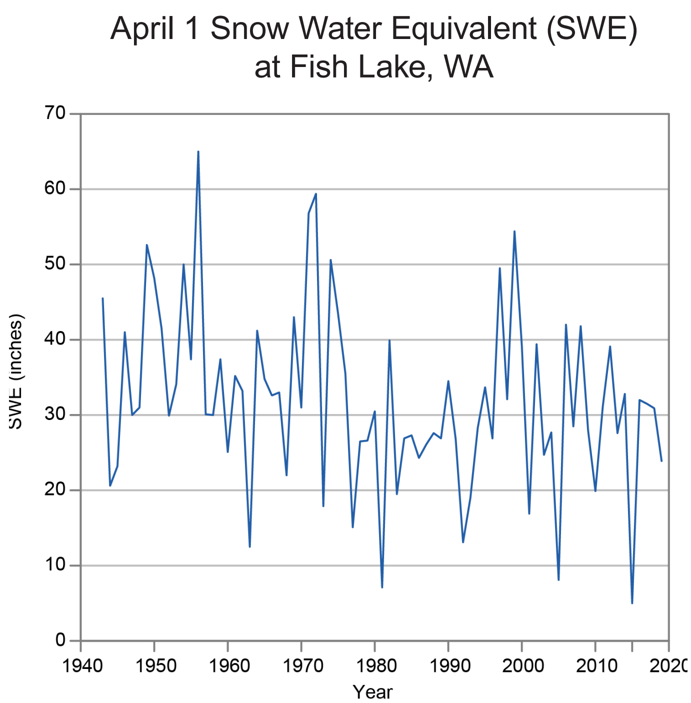


Figure 4: Variations in April 1 snow water equivalent (SWE) at the Fish Lake, Washington, snow course site from 1943 to 2019. SWE, the amount of water contained within the snowpack, varies widely from year to year, but there is a general downward trend. The extremely low snowpack levels in 2005 (third lowest) were due to below average winter precipitation and above average winter temperatures. In 2015 (record lowest), warmer than normal winter temperatures were the main driver of the drought, causing more precipitation to fall as rain rather than snow. Source: NRCS NWCC.

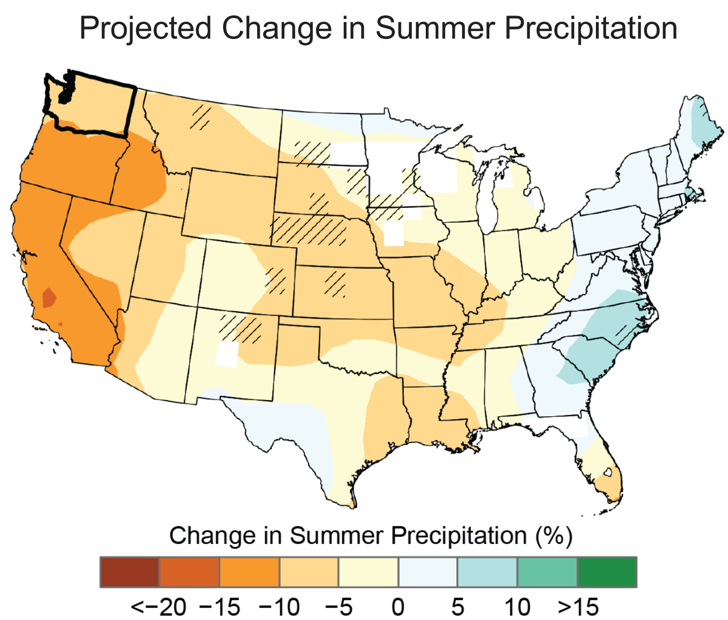


Figure 5: Projected changes in total summer (June–August) precipitation (%) for the middle of the 21st century compared to the late 20th century under a higher emissions pathway. Whited-out areas indicate that the climate models are uncertain about the direction of change. Hatching represents areas where the majority of climate models indicate a statistically significant change. Washington is projected to see a decrease in summer precipitation. Source: CISESS and NEMAC. Data: CMIP5.

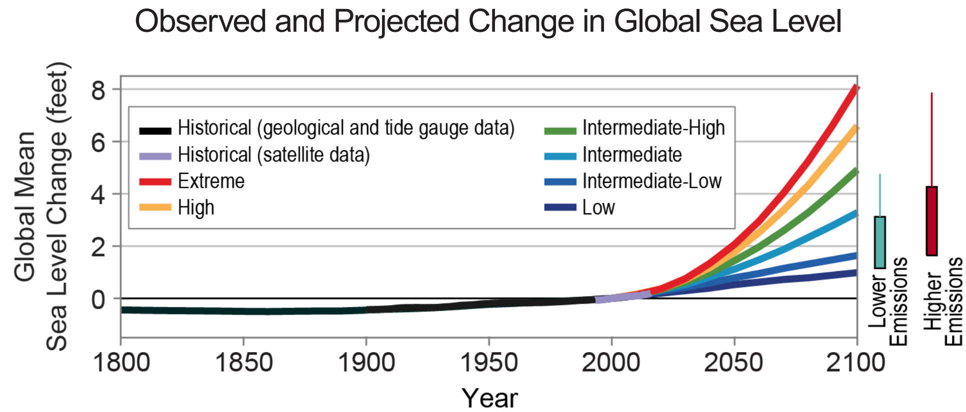


Figure 6: Global mean sea level (GMSL) change from 1800 to 2100. Projections include the six U.S. Interagency Sea Level Rise Task Force GMSL scenarios (Low, navy blue; Intermediate-Low, royal blue; Intermediate, cyan; Intermediate-High, green; High, orange; and Extreme, red curves) relative to historical 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.

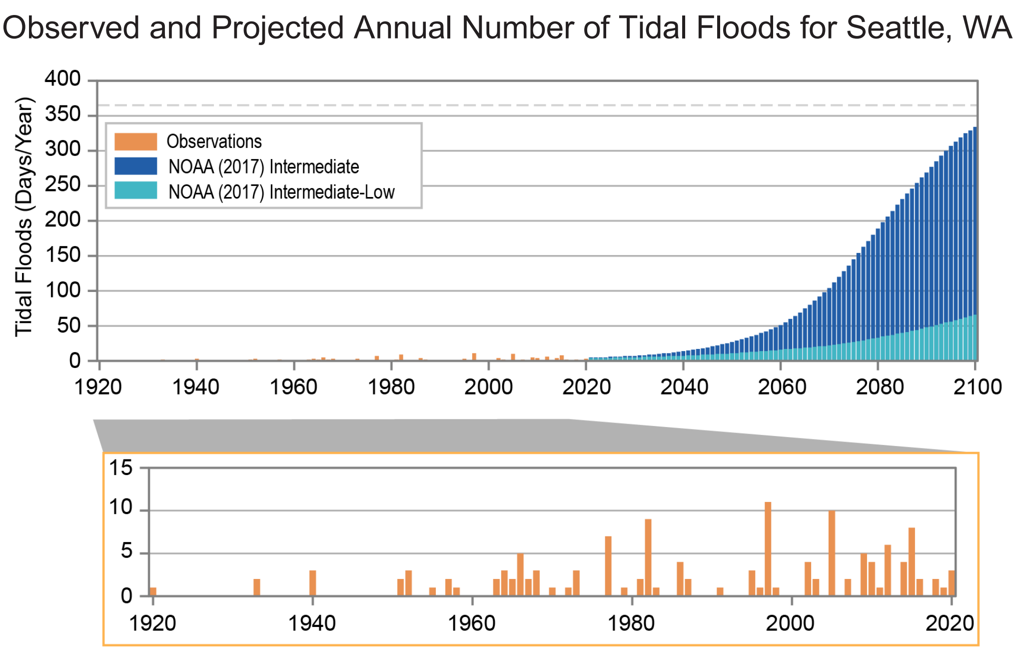


Figure 7: Number of tidal flood days per year at Seattle, Washington, for the observed record (1920–2020 orange bars) and projections for two NOAA (2017) sea level rise scenarios (2021–2100): Intermediate (dark blue bars) and Intermediate-Low (light blue bars). The NOAA (2017) scenarios are based on local projections of the GMSL scenarios shown in Figure 5. 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 1997 at Seattle. 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 online at https://statesummaries.ncics.org/technicaldetails. Sources: CISESS and NOAA NOS.

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

WWW.NCEI.NOAA.GOV | HTTPS://STATESUMMARIES.NCICS.ORG/CHAPTER/WA/ | LEAD AUTHORS: REBEKAH FRANKSON, KENNETH E. KUNKEL
CONTRIBUTORS: SARAH M. CHAMPION, DAVID R. EASTERLING, LAURA E. STEVENS, KARIN BUMBACO, NICK BOND, JOE CASOLA, WILLIAM SWEET