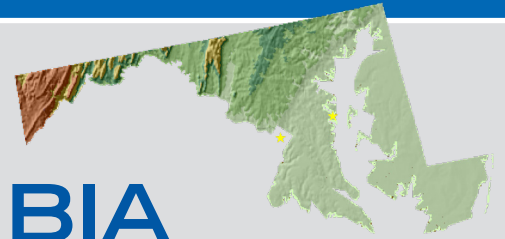


MARYLAND AND THE DISTRICT OF COLUMBIA



Key Messages

Temperatures in Maryland have risen about 2.5°F since the beginning of the 20th century. Historically unprecedented warming is projected during this century under a higher emissions pathway. Heat waves are projected to be more intense, while cold waves are projected to be less intense.

Precipitation is projected to increase, particularly in the winter and spring. The frequency and intensity of extreme precipitation events are also projected to increase, which could increase the risk of flooding.

Global sea level is projected to rise, with a likely range of 1 to 4 feet by 2100. Sea level has been rising along the Maryland coastline, and large additional increases (in the likely range of 1 to 4 feet by 2100) are projected, with potential significant environmental and economic impacts, including more low-lying coastal flooding, shoreline erosion, and property and infrastructure damage.

Maryland and the District of Columbia (DC) are located on the eastern coast of the North American continent. Their geographic location exposes them to both the cold winter and warm summer air masses from the continental interior and the moderate and moist air masses from the Atlantic Ocean. Maryland and DC's climates are characterized by moderately cold and occasionally snowy winters and warm, humid summers. Due to their mid-latitude location, the jet stream is often located near the state and city, particularly in the late fall, winter, and spring. Precipitation is frequent because of low-pressure storms associated with the jet stream. In winter, the contrasting influences of cold air masses from the interior and moist air masses from the Atlantic provide the energy for occasional intense storms commonly known as nor'easters. Maryland has a west-to-east contrast in temperature. Larger seasonal variations occur in the highland west in the Appalachian Mountains, while temperatures in the east are moderated by the Chesapeake Bay and the Atlantic Ocean. The annual number of nights below freezing ranges from more than 100 nights in the northwest to fewer than 20 nights in the southeast. Similar gradients exist for the annual number of very hot days, which varies from 0 to 1 days in the

Observed and Projected Temperature Change

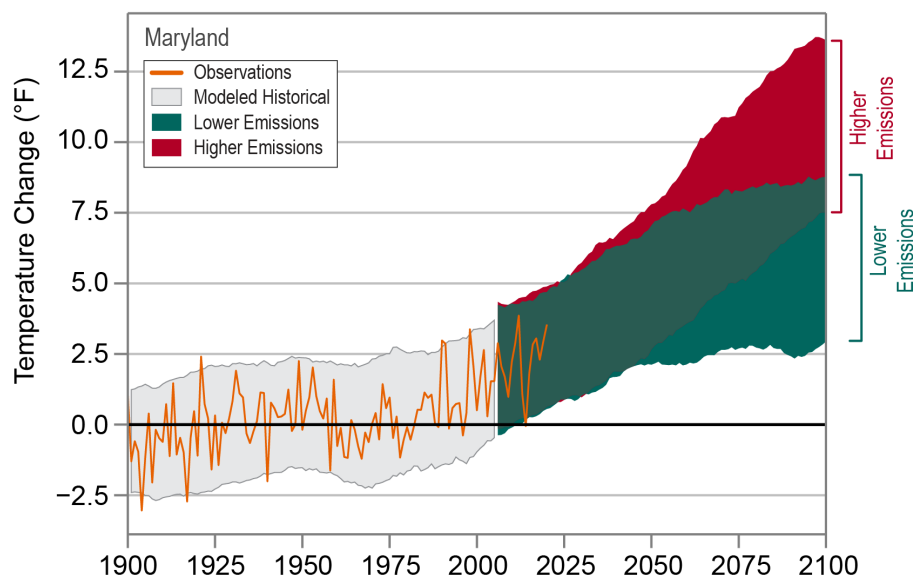
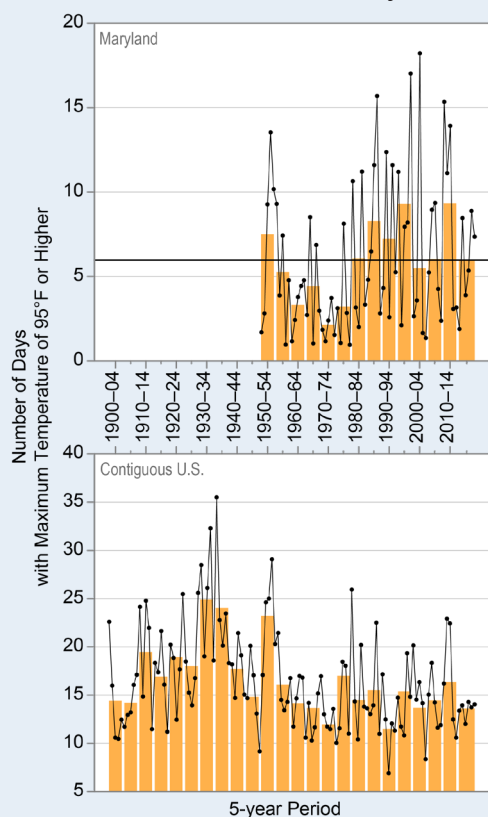


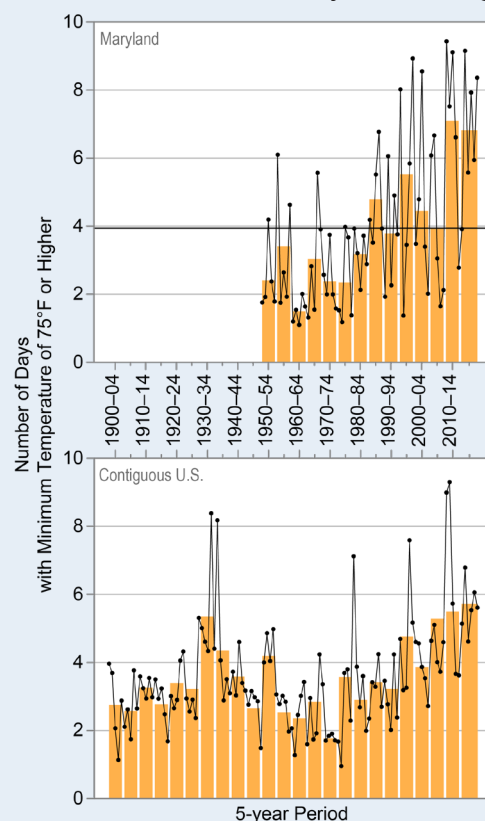
Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Maryland. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Maryland (orange line) have risen about 2.5°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-century projections being about 2.5°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.

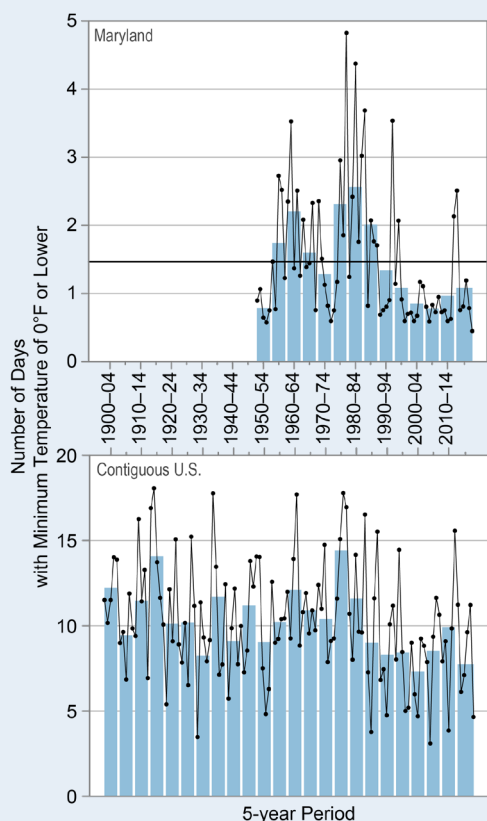
a) Observed Number of Very Hot Days



b) Observed Number of Very Warm Nights



c) Observed Number of Very Cold Nights



d) Observed Annual Precipitation

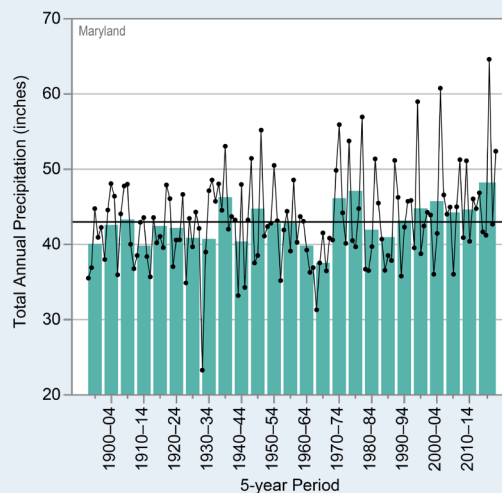


Figure 2: Observed (a) annual number of very hot days (maximum temperature of 95°F or higher), (b) annual number of very warm nights (minimum temperature of 75°F or higher), (c) annual number of very cold nights (minimum temperature of 0°F or lower), and (d) total annual precipitation for Maryland from (a, b, c) 1950 to 2020 and (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 Maryland: (a) 6.0 days, (b) 3.9 nights, (c) 1.5 nights, (d) 43.0 inches. Values for the contiguous United States (CONUS) from 1900 to 2020 are included for Figures 2a, 2b, and 2c to provide a longer and larger context. Long-term stations dating back to 1900 were not available for Maryland. The annual

number of very hot days has varied over the period of record; however, the number of very warm nights has generally been rising since 1950, with the highest multiyear averages occurring during the last two periods (2010–2014 and 2015–2020). The number of very cold nights has been below average since 1990. Annual precipitation has been variable but shows a slight upward trend. Sources: CISESS and NOAA NCEI. Data (a, b, c) GHCN-Daily from 10 (MD) and 655 (CONUS) long-term stations, (d) nClimDiv.

Allegheny Plateau to 2 to 11 days in north-central Maryland and 3 to 8 days in the Lower Eastern Shore.

The Chesapeake Bay, which divides Maryland in the east, is the largest estuary in North America and one of the most productive in the world, with more than 64,000 square miles of watershed. This area is particularly vulnerable to climate change in several ways: through sea level rise, changes in river discharge from precipitation extremes, increased water temperatures, and potential acidification (ocean and biological). Increasing urban development, excessive pollution levels, and changes in water temperature and salinity have impacted some plant and animal species, affecting Chesapeake Bay area ecosystems.

Temperatures in Maryland have risen about 2.5°F since the beginning of the 20th century (Figure 1), and temperatures in this century have been warmer than in any other period. The warmest year on record was 2012, and 7 of the 10 warmest years have occurred since 2000. The second-warmest year was 2020, and July 2020 was the all-time hottest month for both the city of Baltimore and the state as a whole. The annual number of very hot days and annual number of very warm nights have averaged 7 days and 5 nights since 1985, compared to 6 days and 3 nights for the 1950–1984 interval (Figures 2a and 2b).

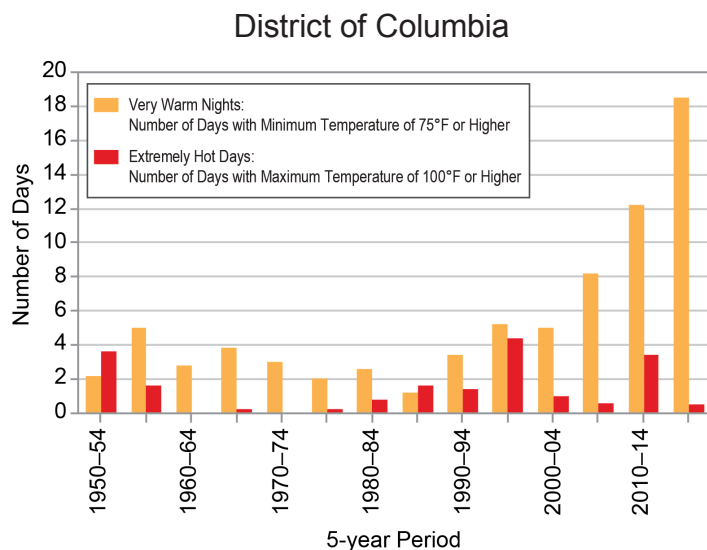


Figure 3: Observed annual number of very warm nights (minimum temperature of 75°F or higher) and extremely hot days (maximum temperature of 100°F or higher) for the District of Columbia from 1950 to 2020. Bars show averages over 5-year periods (last bar is a 6-year average). Since 1950, there has been no trend in extremely hot days. By contrast, the number of very warm nights has been steadily increasing since 1985, with the highest multiyear averages occurring during the 2005–2020 interval. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 1 long-term station (National Arboretum).

A winter warming trend is reflected in a below average number of very cold nights since the mid-1990s (Figure 2c). Since 1950, there has been no trend in extremely hot days in the District of Columbia (Figure 3). However, from 2015 to 2020, DC averaged more than 18 very warm nights per year, compared to the 1950–2009 average of 3.7 nights per year.

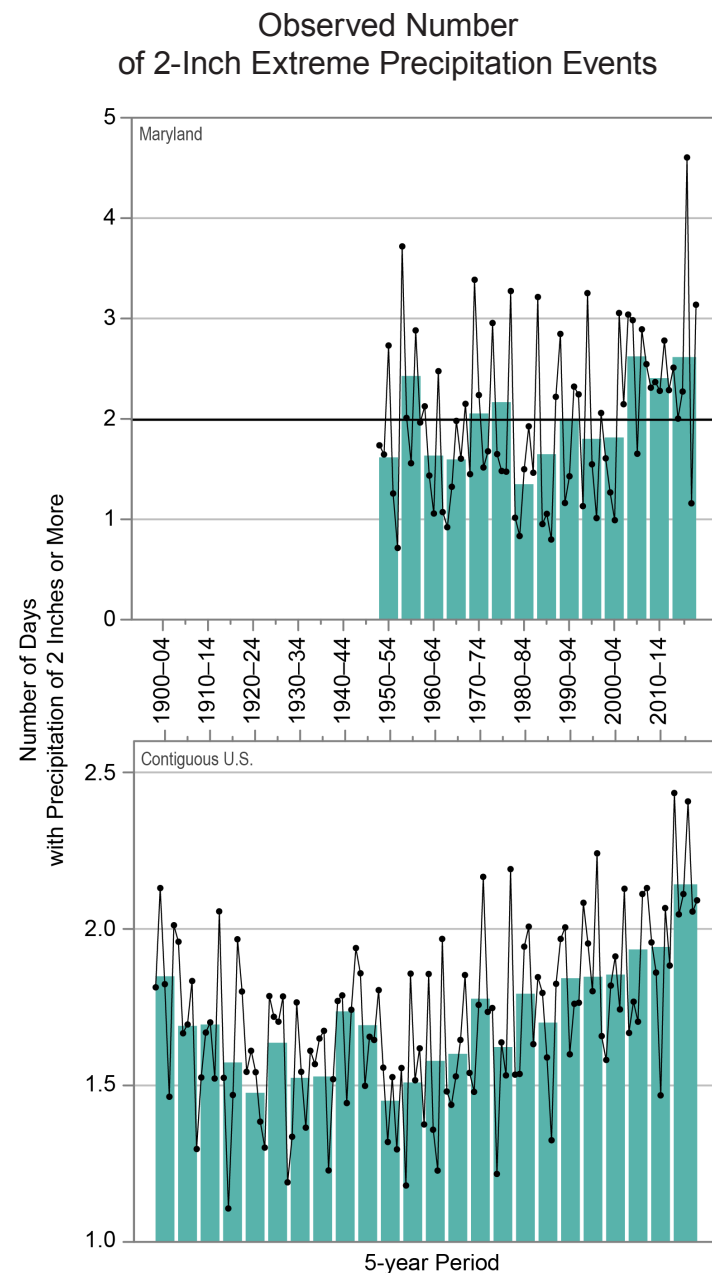


Figure 4: Observed annual number of 2-inch extreme precipitation events (days with precipitation of 2 inches or more) for Maryland from 1950 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average for Maryland of 2.0 days. A typical reporting station experiences about 2 events per year. Values for the contiguous United States (CONUS) are included to provide a longer and larger context. Long-term stations dating back to 1900 were not available for Maryland. The number of extreme precipitation events has been above average since 2005. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 11 long-term stations.

Annual average precipitation in Maryland varies from about 40 inches in the Appalachian Mountain region to about 50 inches in the western and eastern areas of the state. The wettest decade was the 1970s, with the wettest consecutive 5-year interval (1971–1975); the driest decade was the 1960s, with the driest consecutive five-year interval (1962–1966). **Total annual precipitation has been above the long-term average for the last 26 years (1995–2020; Figure 2d).** The annual number of 2-inch extreme precipitation events averaged 2.5 days per year during the 2005–2020 interval, compared to 1.8 days per year during the 1950–2004 interval (Figure 4).

Maryland and the District of Columbia are susceptible to several extreme weather types, including tropical storms and hurricanes, severe thunderstorms, tornadoes, nor'easters, blizzards and ice storms, flooding, drought, and heat and cold waves. Multiple snowstorms impacted the Mid-Atlantic in February 2010, bringing heavy snowfall and shutting down the federal government for 4 and a half days. Hurricane Irene, in 2011, caused considerable wind damage along the coast. In 2012, Superstorm Sandy (a post-tropical storm) caused damage from wind and a storm surge of 4 to 5 feet, which destroyed a large portion of Ocean City's fishing pier and caused widespread flooding in Crisfield and other low-lying areas of Maryland's Lower Eastern Shore. On June 29, 2012, a derecho (a widespread, long-lived line of thunderstorms with very strong winds) moved through the Ohio Valley and the Mid-Atlantic states; Maryland and the District of Columbia were two of the hardest hit areas. One-third of Maryland residents and one-quarter of DC residents were left without power after the storm, with some outages lasting longer than a week. Both mountainous terrain in the narrow, western portion of Maryland and dense urbanized areas are highly vulnerable to flash flooding. During August 12–13, 2014, torrential rainfall of up to 6 to 10 inches resulted in flooding along the coastal plain from Baltimore into New Jersey. An extreme precipitation event occurred on July 30, 2016, impacting Ellicott City, MD, with 6 inches of rain in several hours and causing two fatalities. Less than 2 years later, on May 27, 2018, another extreme precipitation event impacted the Ellicott City and Catonsville area; 6–12 inches of rain caused catastrophic damage and one fatality. Catonsville recorded 84.6 inches of precipitation that year, the state record.

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. In addition, the intensity of summer heat waves is projected to increase, with important implications for human health, while cold wave intensity is projected to decrease.

Annual average precipitation is projected to increase in Maryland over this century, particularly during winter and spring (Figure 5). This is part of a large-scale pattern of projected increases in precipitation over northern and central portions of North America. An increase in the frequency and intensity of extreme precipitation events is projected, potentially increasing flooding events in urban areas and likely expanding flood hazard areas (areas inundated by a flood event). The 100-year storm

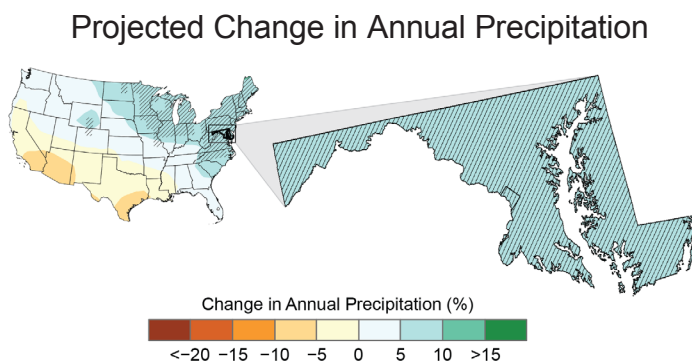


Figure 5: Projected changes in total annual precipitation (%) for the middle of the 21st century relative to the late 20th century under a higher emissions pathway. Hatching represents areas where the majority of climate models indicate a statistically significant change. Annual precipitation is projected to increase in Maryland. Sources: CISESS and NEMAC. Data: CMIP5.

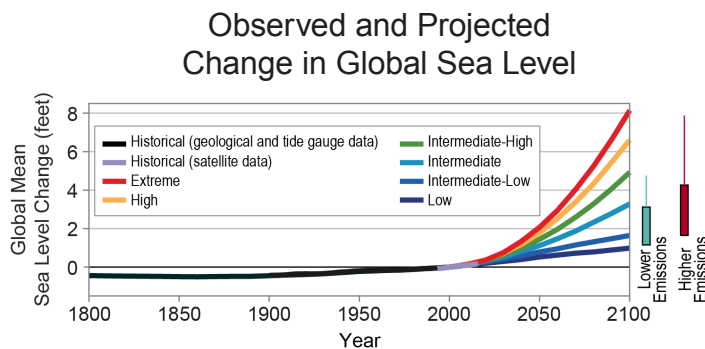


Figure 6: Global mean sea level (GMSL) change from 1800 to 2100. Projections include the six U.S. Interagency Sea Level Rise Task Force GMSL scenarios (Low, navy blue; Intermediate-Low, royal blue; Intermediate, cyan; Intermediate-High, green; High, orange; and Extreme, red curves) relative to historical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

event, as defined by historical data, is expected to occur every 20 to 50 years by the end of the century. Naturally occurring droughts will also continue to be a part of the climate, even if precipitation increases. Such droughts are projected to be more intense because higher temperatures will increase the rate of soil moisture loss during dry spells.

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).

The Chesapeake Bay area is the third most vulnerable area of the United States to sea level rise (SLR), behind Louisiana and South Florida. The foremost impacts of SLR on the state include more frequent and severe coastal flood events, increased shore erosion, inundation of wetlands and low-lying lands, and saltwater intrusion into groundwater. Tide-gauge records show that sea level in the Chesapeake Bay has been increasing at an average rate of 1.3 to 1.5 inches per decade over the past 100 years, 50% more than the global historical average

observed over the same time period. For the Chesapeake Bay, global SLR is compounded by substantial rates of land subsidence (sinking; an average rate of 3.1 mm per year was found between 2006 and 2011 due to a combination of groundwater withdrawal and natural geologic effects associated with post-glaciation adjustments). A recent study specific to Maryland states that the likely range (66% probability) of SLR between 2000 and 2050 is 0.8 to 1.6 feet; if emissions continue to increase, the likely range of SLR is 2.0 to 4.2 feet over this 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 Maryland coastline, the number of tidal flood days (all days exceeding the nuisance-level threshold) has also increased, with the greatest number occurring in 2018 (Figure 7).

Observed and Projected Annual Number of Tidal Floods for Baltimore, MD

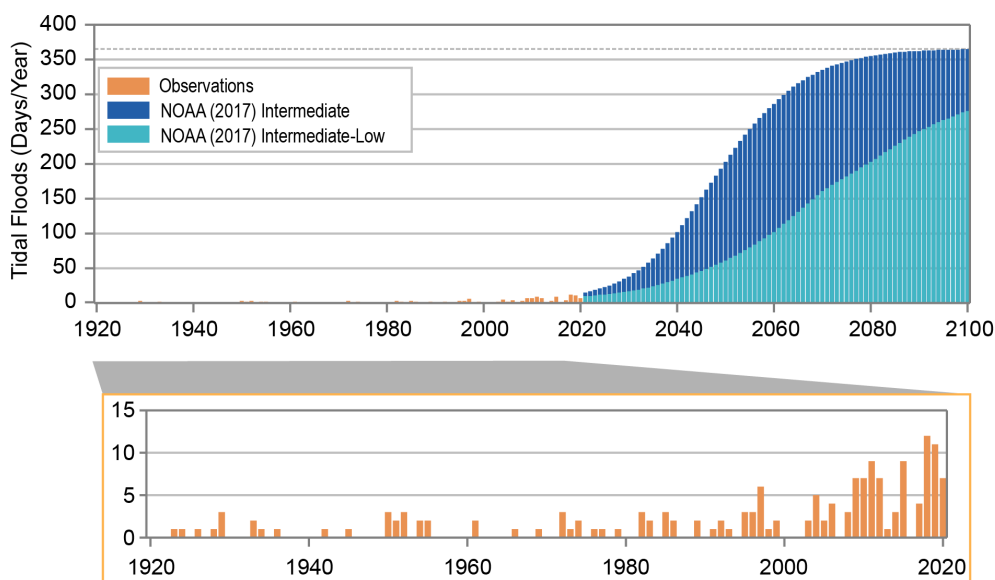


Figure 7: Number of tidal flood days per year at Baltimore, MD, for the observed record (1920–2020; orange bars) and projections for 2 NOAA (2017) sea level rise scenarios (2021–2100): Intermediate (dark blue bars) and Intermediate-Low (light blue bars). The NOAA (2017) scenarios are based on local projections 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 2018 at Baltimore. Projected increases are large even under the Intermediate-Low scenario. Under the Intermediate scenario, tidal flooding is projected to occur 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.

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