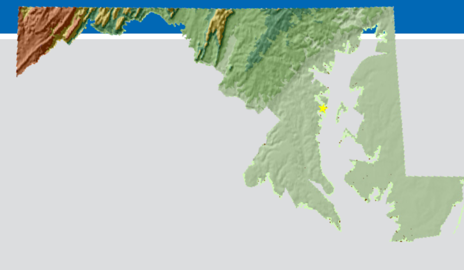

MARYLAND

Key Messages

Average annual temperature has risen by more than 1.5°F in Maryland since the beginning of the 20th century. Historically unprecedented warming is projected by the end of the 21st 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. The frequency of intense rainfall events is also projected to increase. This could enhance the risk of flooding.

Sea level has been rising along the Maryland coastline and large additional increases (likely in the 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's climate is generally moist with a rather large seasonal range of temperatures. Due to Maryland's mid-latitude location, the jet stream is often in the vicinity, particularly in the late fall, winter, and spring. Precipitation is frequent because low pressure storms associated with the jet stream commonly affect the state. In addition, Maryland's location on the East Coast of the North American continent exposes it both to 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 commonly known as nor'easters. As a result of these varying influences, **Maryland's climate is characterized by moderately cold and occasionally snowy winters and warm, humid summers.** There is a west-to-east contrast in temperature with larger seasonal variations in the highland west, which is in the Appalachian Mountains, while temperatures in the east are moderated by the Chesapeake Bay and the Atlantic Ocean. The average annual number of days with average daily temperature below 32°F ranges from a high of 90 days in the northwest to less than 20 days in the southeast. Similar gradients exist for the average number of days above 95°F, which varies from 0 in the Allegheny Plateau to 8 days in North Central Maryland to approximately 5 days near the Southeastern Shore.

Observed and Projected Temperature Change

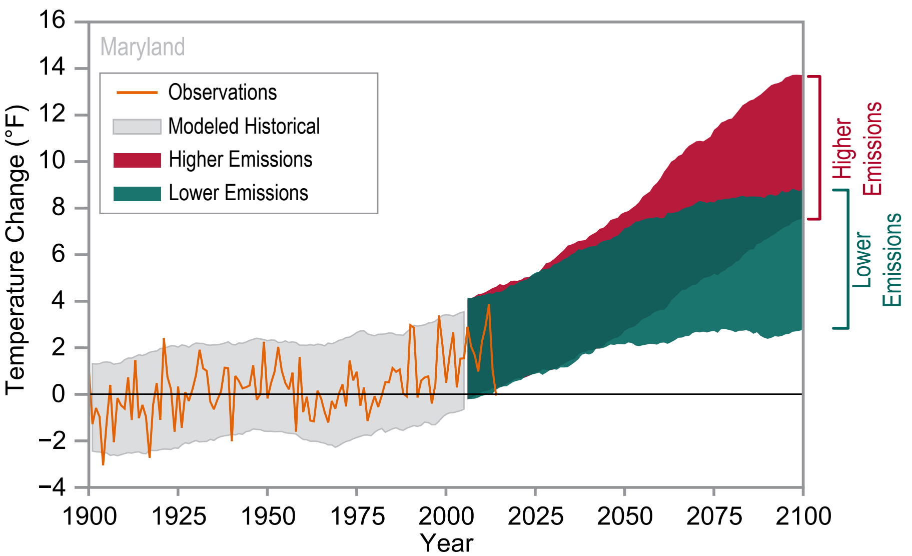

Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Maryland. Observed data are for 1900–2014. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions)[1]. Temperatures in Maryland (orange line) were warmest in the early 1930s, coolest in the 1960s, and within the most recent decade on record have exceeded levels of the 1930s. 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 the 21st century. Less warming is expected under a lower emissions future (the coldest years being about as warm as the hottest year in the historical record; green shading) and more warming under a higher emissions future (the hottest years being about 11°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/md.

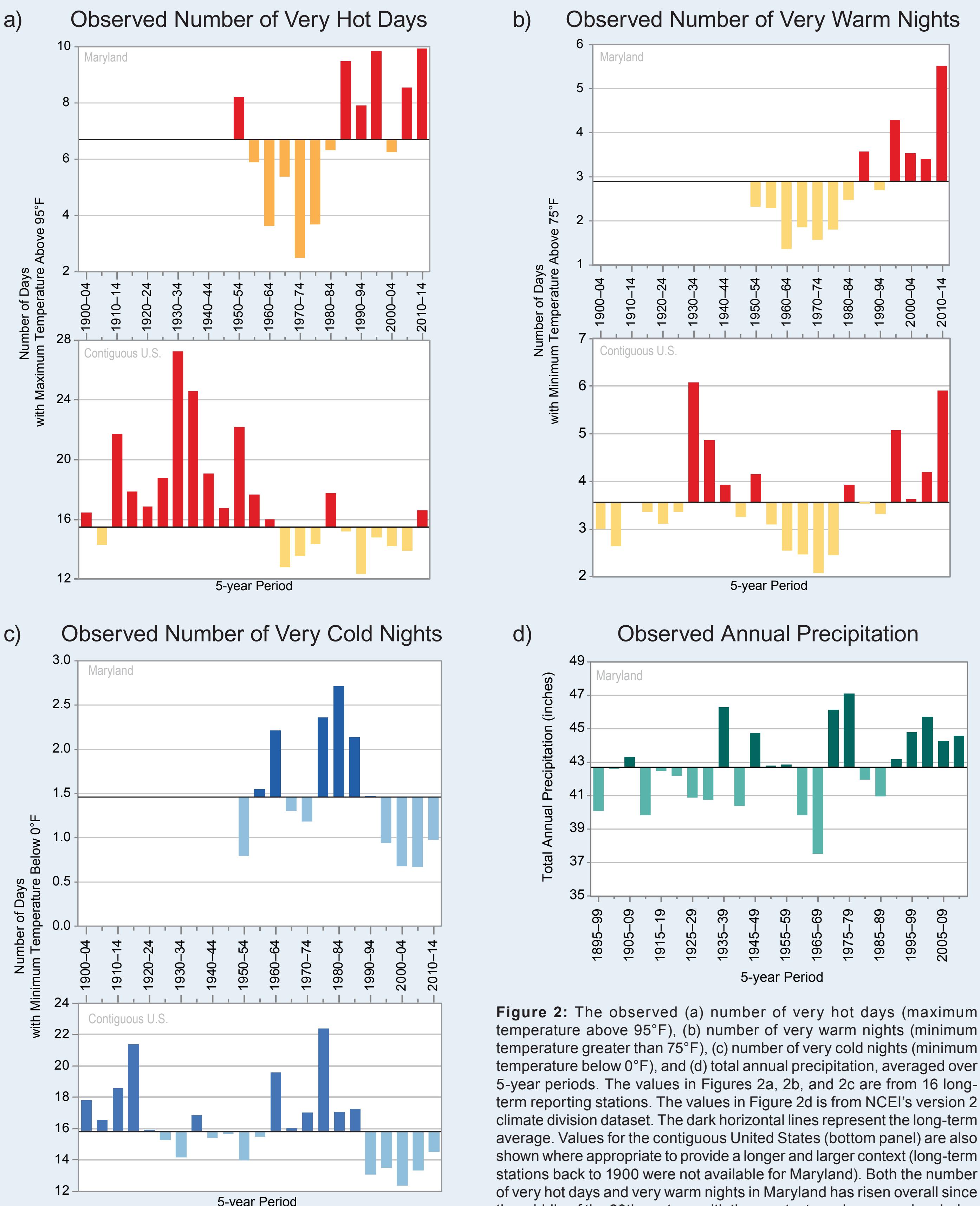

Figure 2: The observed (a) number of very hot days (maximum temperature above 95°F), (b) number of very warm nights (minimum temperature greater than 75°F), (c) number of very cold nights (minimum temperature below 0°F), and (d) total annual precipitation, averaged over 5-year periods. The values in Figures 2a, 2b, and 2c are from 16 long-term reporting stations. The values in Figure 2d is from NCEI's version 2 climate division dataset. The dark horizontal lines represent the long-term average. 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 Maryland). Both the number of very hot days and very warm nights in Maryland has risen overall since the middle of the 20th century, with the greatest number occurring during the most recent 5-year period (2010–2014). Maryland has experienced a downward trend in the number of very cold nights since the middle of the 20th century, whereas for annual precipitation there is no overall trend. Source: CICS-NC and NOAA NCEI.

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

Average annual temperatures in Maryland have increased more than 1.5°F since the beginning of the 20th century (Figure 1) **and temperatures in the 21st Century have been warmer than any other period.** The warmest year on record was 2012 and five of the ten warmest years have occurred since 2000. The numbers of very hot days (maximum temperature above 95°F), and very warm nights (minimum temperature above 75°F) have averaged 9 and 4 days per year, respectively, since 1985, compared to 5 and 2 days per year, respectively for 1950–1984 (Figures 2a and 2b). A winter warming trend is reflected in an average of less than 1 day per year of very cold nights (minimum temperatures below 0°F) since the mid-1990s (Figure 2c) compared to about 2 days per year for 1950–1994. Since 1950 there has been no trend in extremely hot days (maximum temperature above 100°F) in Washington, District of Columbia (D.C.) (Figure 3). However, from 2010 to 2014, D.C. averaged 12 very warm nights (nighttime minimum temperature greater than 75°F) per year compared to the 1950–2009 average of 3 very warm nights per year.

Average annual precipitation varies from around 50 inches in the extreme west to around 40 inches just to the east of the Appalachian Mountains. The wettest multi-year period was the 1970s, with the wettest 5-year period being 1971–1975, while the driest multi-year period was the 1960s, with the driest five-year period being 1962–1966. **Annual mean precipitation has been above average for the last two decades** (Figure 2d). The annual number of extreme precipitation events (days with more than 2 inches) averaged 2.5 days per year during 2005–2014 compared to 1.8 days per year during 1950–2004 (Figure 4).

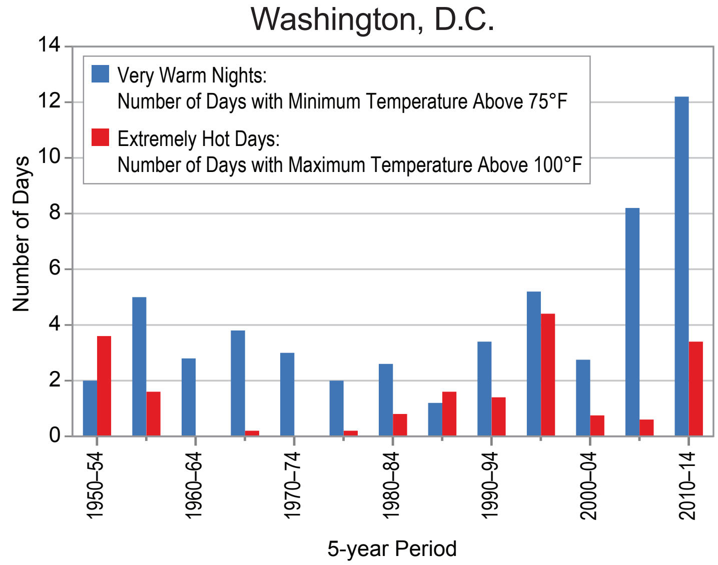

Figure 3: The observed number of very warm nights (annual number of days with minimum temperature above 75°F) and extremely hot days (annual number of days with maximum temperature above 100°F) for 1950–2014, averaged over 5-year periods; these values are averages from the long-term reporting National Arboretum station in Washington, D.C. Since 1950 there has been no trend in extremely hot days. By contrast, the number of very warm nights has been steadily increasing since 1990 with a record number of such nights occurring from 2010 to 2014. Source: CICS-NC and NOAA NCEI.

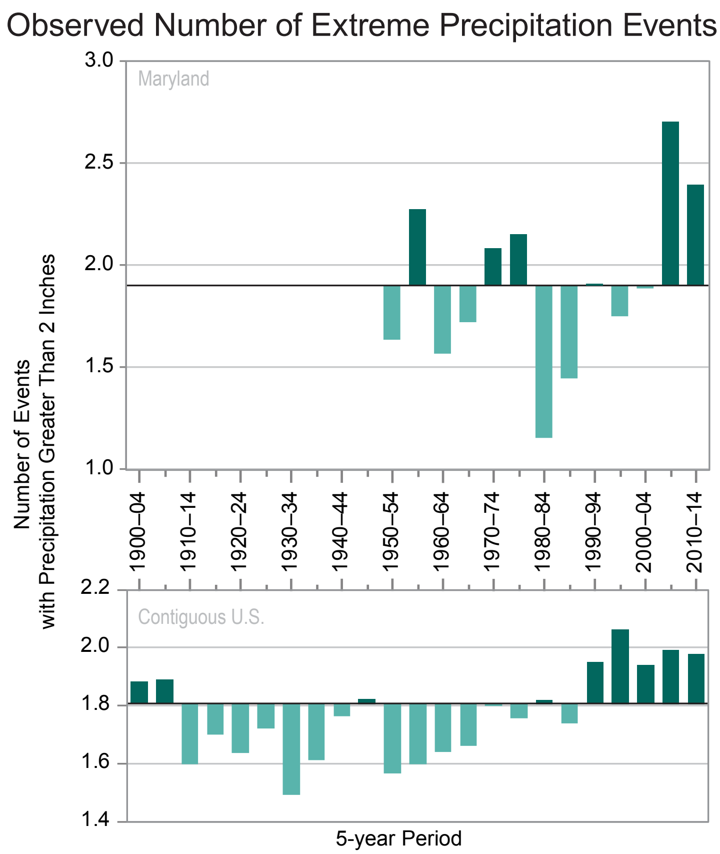

Figure 4: The observed number of extreme precipitation events (days with precipitation greater than 2 inches) for 1950–2014, averaged over 5-year periods; these values are averages from 16 available long-term reporting stations. The dark horizontal lines represent the long-term average. The number of extreme precipitation events has been above average during the last 10 years. The number of extreme precipitation events for the contiguous United States (bottom panel) is also shown to provide a longer and larger context. Long-term stations back to 1900 were not available for Maryland. Source: CICS-NC and NOAA NCEI.

Maryland is 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. Hurricane Irene in 2011 caused considerable wind damage along the coast. Superstorm Sandy (a post-tropical storm) in 2012 caused damage from wind and a storm surge of 4–5 feet, which destroyed a large portion of Ocean City's fishing pier and caused widespread flooding in Crisfield and other low lying areas of the 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 Washington, D.C. were two of the hardest hit areas. One-third of Maryland residents and one-quarter of D.C. residents were left without power after the storm, with some outages lasting longer than a week. Mountainous terrain in the narrow, western portion of the state, and the dense urbanized areas of the state are each highly vulnerable to flash flooding. During August 12–13, 2014, torrential rains of up to 6–10 inches occurred resulting in flooding along the coastal plain from Baltimore into New Jersey. This event resulted in the second highest calendar day precipitation total (6.3 inches on August 13) since 1933. Most recently, an extreme precipitation event occurred on July 30, 2016, impacting Ellicott City with 6 inches of rain in several hours and causing two fatalities.

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 projections are only slightly warmer than historical records. In addition, increased intensity of summer heat waves is projected, with important implications for human health, while cold wave intensity is projected to decrease.

Average annual precipitation is projected to increase in Maryland over the 21st 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. More frequent intense rainfall events are projected, potentially increasing flooding events in urban areas. The 100-year rain storm event, as defined by historical data, is expected to occur every 20 to 50 years by the end of the century. Increasing and more intense extreme precipitation events will likely expand the flood hazard areas (areas that will be inundated by a flood event).

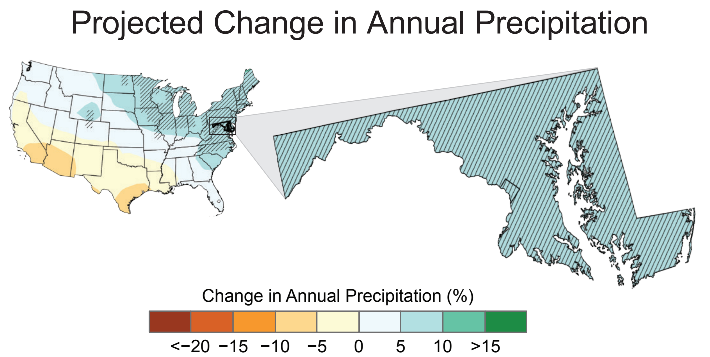

Figure 5: Projected change in annual precipitation (%) for the middle of the 21st century relative to the late 20th century under a higher emissions pathway. Hatching represents portions of the state where the majority of climate models indicate a statistically significant change. Annual precipitation is projected to increase in Maryland. Source: CICS-NC and NOAA NCEI.

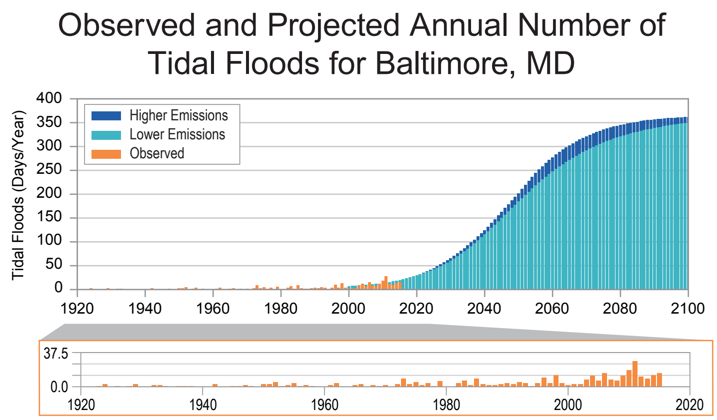

Figure 6: Number of tidal flood days per year for the observed record (orange bars) and projections for two possible futures: lower emissions (light blue) and higher emissions (dark blue) per calendar year for Baltimore, MD. Sea level rise has caused an increase in tidal floods associated with nuisance-level 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 2011 at Baltimore. 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/md). Source: NOAA NOS.

Naturally occurring droughts will continue to be a part of the climate, even if precipitation does increase. Such droughts are projected to be more intense because higher temperatures will increase the rate of soil moisture loss during dry spells.

Since 1880, global sea level has risen by about 8 inches. **The Chesapeake Bay area is the third most vulnerable area of the United States to sea level rise, behind Louisiana and South Florida.** Tide-gauge records show that sea level in the Chesapeake Bay has been increasing at an average rate of 1.2 to 1.4 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 sea level rise is compounded by substantial land subsidence rates (roughly 0.5 inches per decade over the last century) due to the combination of groundwater withdrawal and natural geologic effects associated with post glaciation adjustments. 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 2011 (Figure 6). Global 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). **A recent study specific to Maryland produced best estimates of 1.4 feet rise by 2050 (range of 0.9 to 2.1 feet) and 3.7 feet by 2100 (range of 2.1 to 5.7 feet).**The foremost impacts of sea level rise 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.

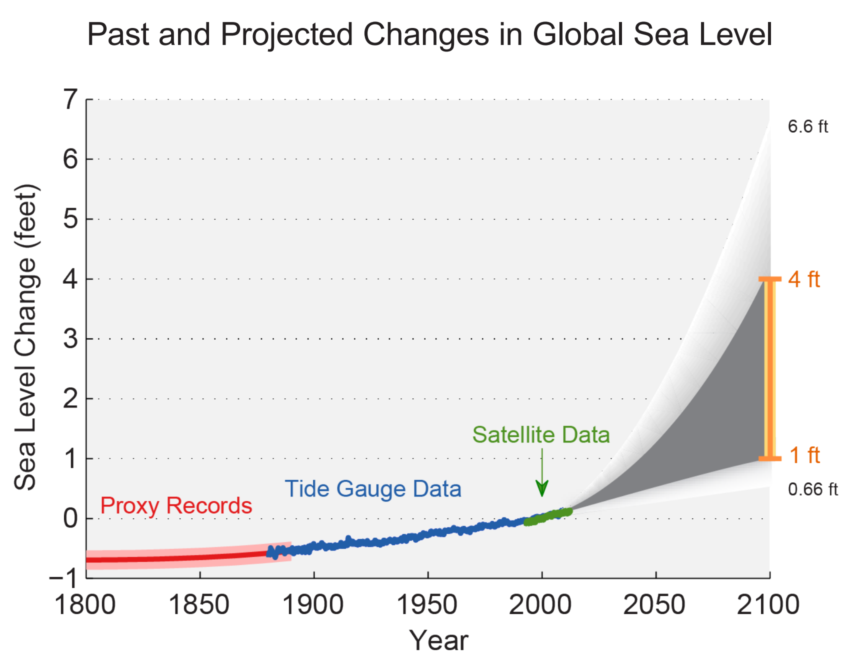

Figure 7: Estimated, observed, and possible future amounts of global sea level rise from 1800 to 2100, relative to the year 2000. The orange line at right shows the most likely range of 1 to 4 feet by 2100 based on an assessment of scientific studies, which falls within a larger possible range of 0.66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

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