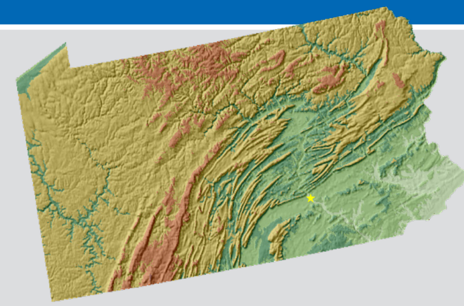
PENNSYLVANIA



Key Messages

Temperatures in Pennsylvania have risen almost 2°F since the beginning of the 20th century. Under a higher emissions pathway, historically unprecedented warming is projected during this century. Extreme heat is a particular concern for densely populated urban areas (such as Philadelphia), where high temperatures and high humidity can cause dangerous heat index values.

Pennsylvania has experienced a large increase in extreme precipitation events. Future increases in winter and spring precipitation expand the risk of springtime flooding along rivers and streams.

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. Sea level rise will increase the frequency, extent, and severity of coastal flooding along the Philadelphia riverfront, where the observed sea level rise over the past century has exceeded the global average.

Pennsylvania has a diverse landscape of mountains, agricultural regions, and large metropolitan areas. The Appalachian Mountains cut across the center of the state, with the Piedmont and Coastal Plain to the east and the Allegheny Plateau and Lake Erie lowlands to the west. The state is bordered by Lake Erie to the northwest and the Delaware River and Delaware Estuary to the east. The state's climate is heavily influenced by several geographic features. The Atlantic Ocean has a moderating effect on coastal areas, while Lake Erie moderates the northwestern part of the state. During much of the year, the prevailing westerly flow brings air masses from the North American interior across the entire region, with occasional episodes of bitter cold during winter. The jet stream, which is often located near or over the region during winter, brings frequent storm systems, causing cloudy skies, windy conditions, and precipitation. Pennsylvania is affected by a number of extreme weather events, including floods, tropical cyclones, heat and cold waves, severe thunderstorms, snow and ice storms, and nor'easters.

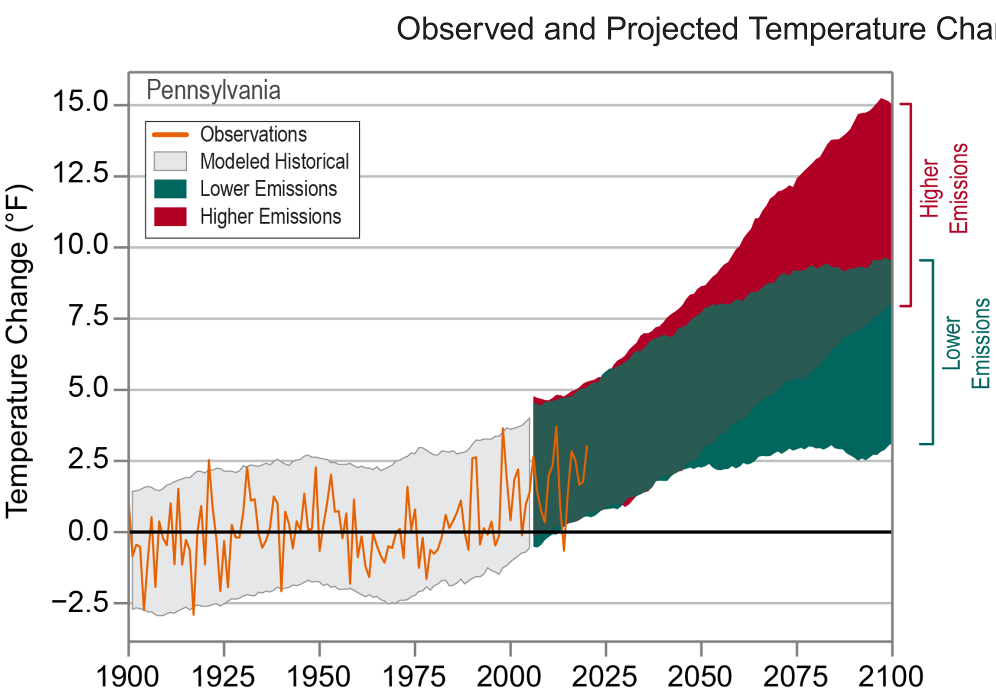


Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Pennsylvania. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Pennsylvania (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 during this century. Less warming is expected under a lower emissions future (the coldest end-of-century projections being about 3°F warmer than the historical average; green shading) and more warming under a higher emissions future (the hottest end-of-century projections being about 11°F warmer than the hottest year in the historical record; red shading). Sources: CISESS and NOAA NCEI.

Since the beginning of the 20th century, temperatures in Pennsylvania have risen almost 2°F, and temperatures in the 2000s have been higher than in any other historical period (Figure 1). This warming has occurred mostly in the winter and spring, while summer and fall have not warmed as much. The small amount of summer warming is evident in the near average occurrence of hot days during the last 11 years (2010–2020; Figure 2a). However, there has been an increase in the number of warm nights and a decrease in the number of very cold nights (Figures 3 and 2b, respectively). Since record keeping began in 1895, the highest annual average temperature for the state was 51.8°F, set in 1998 and tied again in 2012.

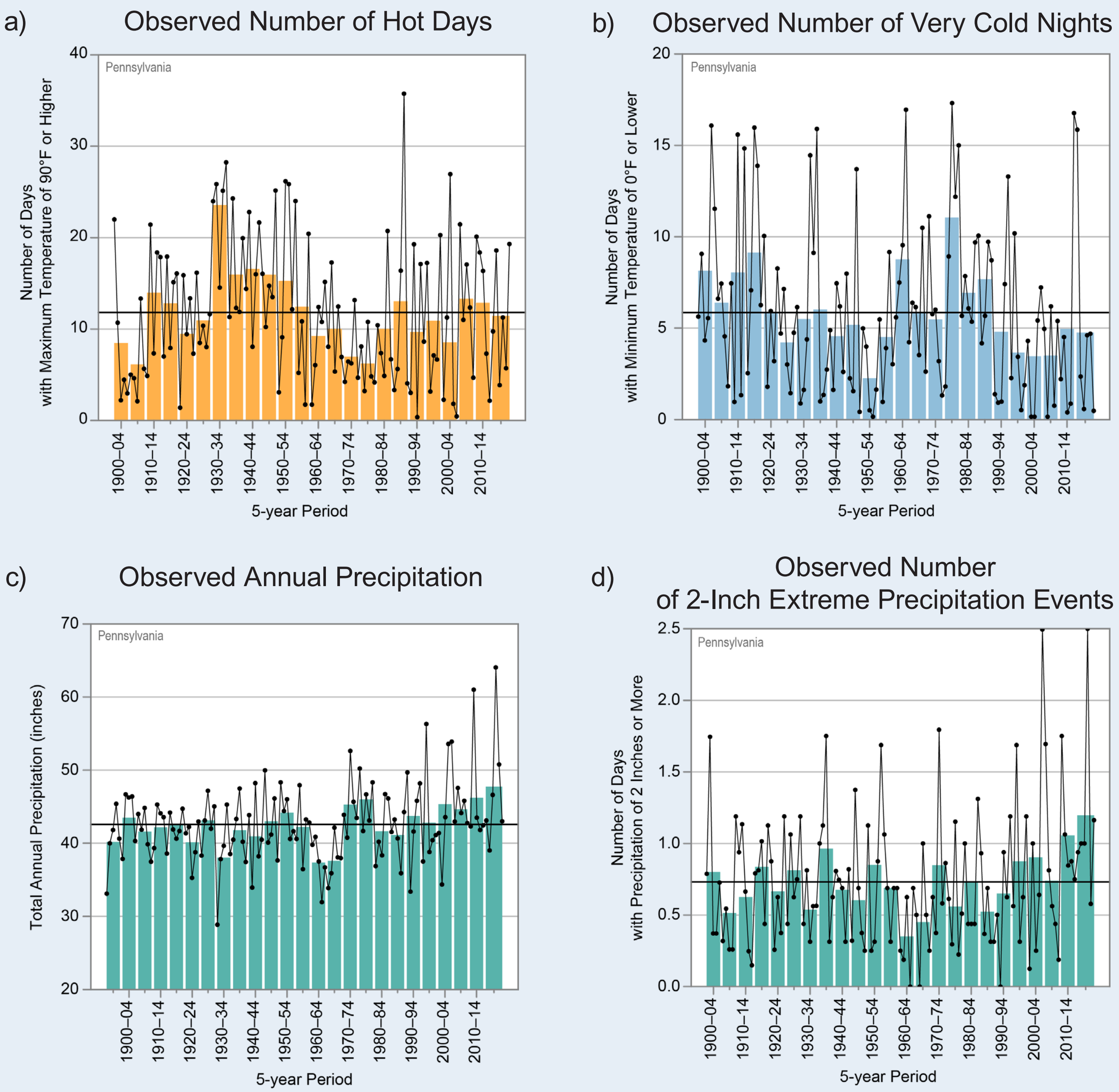


Figure 2: Observed (a) annual number of hot days (maximum temperature of 90°F or higher), (b) annual number of very cold nights (minimum temperature of 0°F or lower), (c) total annual precipitation, and (d) annual number of 2-inch extreme precipitation events (days with precipitation of 2 inches or more) for Pennsylvania 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) 12 days; (b) 5.9 nights; (c) 42.6 inches; (d) 0.7 days. The number of hot days has been near the long-term average since the mid-2000s, and the number of very cold nights has been below average since the 1990s, indicative of a long-term winter warming trend. During the most recent 6-year period (2015–2020), both annual precipitation and the number of 2-inch extreme precipitation events were the highest on record. A typical reporting station experiences a 2-inch event about once every 1 to 2 years. Sources: CISESS and NOAA NCEI. Data: (a, b) GHCN-Daily from 6 long-term stations; (c) nClimDiv; (d) GHCN-Daily from 10 long-term stations.

Pennsylvania experiences abundant precipitation. Statewide annual precipitation has ranged from a low of 28.9 inches in 1930 to a high of 64.0 inches in 2018. The driest multiyear periods were in the 1960s and the wettest in the 1970s and 2010s (Figure 2c). The driest consecutive 5-year interval was 1962–1966, and the wettest was 2016–2020. The above average precipitation the state has recently experienced is primarily due to increases in summer and fall precipitation. **Winter storms are a common occurrence**. Lake effect snows, caused by the warming and moistening of arctic air masses passing over the Great Lakes, are a hazard for the northwestern part of the state, which can receive more than 100 inches of snow annually. The Great Lakes can also experience flooding and erosion due to high water levels. Wet spring conditions contributed to record high water levels and flooding in 2017 and 2019. Cleanup costs, infrastructure damages, and agricultural losses were in the millions of dollars. The area to the east of the Appalachian Mountains is at risk for nor'easters, which are fueled by the large temperature contrast between the cold interior of the eastern United States and the warm moist air over the western Atlantic. The Blizzard of 1996, a classic nor'easter, dropped more than 30 inches of snow in several parts of the state; Philadelphia received 30.7 inches, and 27.6 inches of that fell in 24 hours, a record for the city. February 2010 brought three winter storms to the state, causing Philadelphia, Pittsburgh, and Harrisburg to have their snowiest month on record. The blizzard of 2016 brought high winds and heavy snow; Allentown recorded more than 30 inches.

The number of extreme precipitation events has increased (Figure 2d). These rains can cause devastating flooding, particularly in the state's smaller streams and tributaries. One of the worst natural disasters in the history of the United States was the Great Flood of 1889, which was caused by intense, heavy rains and a catastrophic failure of the South Fork Dam upstream of Johnstown. The flood and subsequent fires killed more than 2,000 people and caused millions of dollars in damages. **Heavy rains can cause particularly damaging floods when they combine with spring snowmelt**. In 1936, runoff from rain falling on snow caused a record flood on the Monongahela River. The state can also experience short-term droughts, such as in 2002, 2016–2017, and 2020, which have an effect on agriculture.

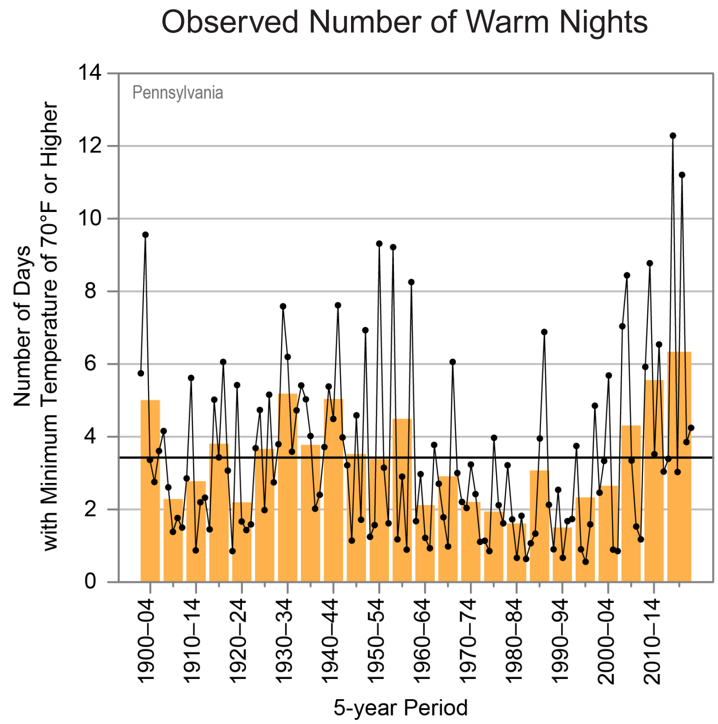


Figure 3: Observed annual number of warm nights (minimum temperature of 70°F or higher) for Pennsylvania from 1900 to 2020. Dots show annual values. Bars show averages over 5-year periods (last bar is a 6-year average). The horizontal black line shows the long-term (entire period) average of 3.4 nights. During the most recent 6-year period (2015–2020), Pennsylvania experienced its highest frequency of warm nights, nearly double the long-term average. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 6 long-term stations.

Tropical cyclones occasionally pass through the state and are yet another cause of heavy rainfall and widespread flooding. Over a 2-week period in 2011, the remnants of both Hurricane Irene and Tropical Storm Lee drenched Pennsylvania in heavy rains and caused historic flooding. Several rivers and creeks reached record-high levels, including the Swatara Creek, which crested at 27.2 feet near Hershey (flood stage is 7 feet), and the Susquehanna River, which hit 42.6 feet in Wilkes-Barre (flood stage is 22 feet). Damages across the state were estimated to exceed $100 million. One of the worst storms to hit the state was Tropical Storm Agnes in 1972. Agnes caused torrential rainfall, dropping more than 10 inches in parts of the state and causing catastrophic flooding, with statewide damages estimated at almost $3 billion.

Thunderstorms are a common occurrence during the warmer months, and the most severe of these can occasionally cause extensive damages and loss of life. On June 30, 2012, a severe derecho (an organized thunderstorm complex with high winds) passed through the state, causing extensive wind damage and power outages. Although Pennsylvania experiences only a few tornadoes each year, these events have the potential to cause widespread destruction. On May 31, 1985, a storm caused 21 tornadoes across the northern and western counties, killing more than 60 people and destroying more than 1,000 homes. One of these tornadoes destroyed much of the town of Wheatland and is the only F5 tornado in the state's history.

Large temperature increases are possible for the future if greenhouse gas concentrations continue to increase (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. **Extreme heat is a particular concern for Philadelphia and other urban areas, where the urban heat island effect raises summer temperatures**. High temperatures combined with high humidity can create dangerous heat index values. Pennsylvania has experienced several heat waves in recent years. One of the worst peaked on July 22, 2011, when most of the state experienced high temperatures above 95°F and many locations experienced temperatures above 100°F. On that date, Reading reported an all-time high of 106°F, while Scranton reported its highest minimum temperature of 80°F. July 2020 was the all-time hottest month for Scranton and Harrisburg; Philadelphia and Scranton recorded their greatest number of 90°F days for any month (21 and 16, respectively). July 2020 also tied for the all-time hottest month for the state. While heat waves are projected to become more intense, cold waves are projected to become less intense.

Pennsylvania's coastline runs along the Delaware Estuary, and increasing temperatures raise concerns for sea level rise in these 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 4). Even if storm patterns remain the same, sea level rise will increase the frequency, extent, and severity of coastal flooding. This is a particularly serious risk for Philadelphia, where the observed sea level rise over the past century has exceeded the global average. 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 Pennsylvania coastline, the number of tidal flooding days (all days exceeding the nuisance level threshold) has also increased, with the greatest number occurring in 2011 (Figure 5).

Winter and spring precipitation is projected to increase for Pennsylvania (Figure 6). In addition, extreme precipitation is projected to increase, expanding the risk for more frequent and intense floods. Heavier precipitation and higher temperatures causing earlier snowmelt increase the risk of springtime flooding, which could pose a threat to Pennsylvania's agricultural industry by delaying planting and reducing yields.

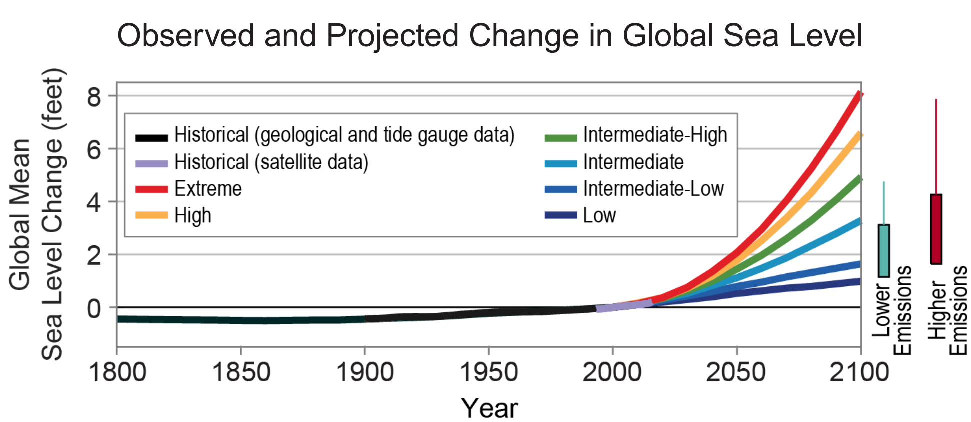


Figure 4: Global mean sea level (GMSL) change from 1800 to 2100. Projections include the six U.S. Interagency Sea Level Rise Task Force GMSL scenarios (Low, navy blue; Intermediate-Low, royal blue; Intermediate, cyan; Intermediate-High, green; High, orange; and Extreme, red curves) relative to historical 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.

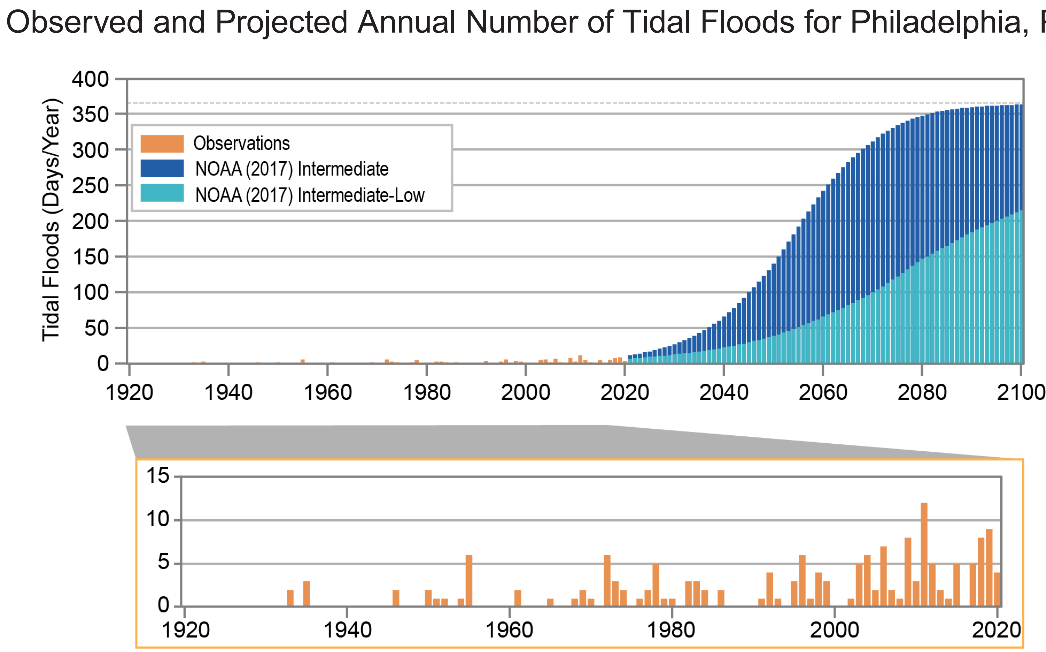


Figure 5: Number of tidal flood days per year at Philadelphia, PA, for the observed record (1920–2020; orange bars) and projections for 2 NOAA (2017) sea level rise scenarios (2021–2100): Intermediate (dark blue bars) and Intermediate-Low (light blue bars). The NOAA (2017) scenarios are based on local projections of the GMSL scenarios shown in Figure 4. 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 2011 at Philadelphia. Projected increases are large even under an 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.

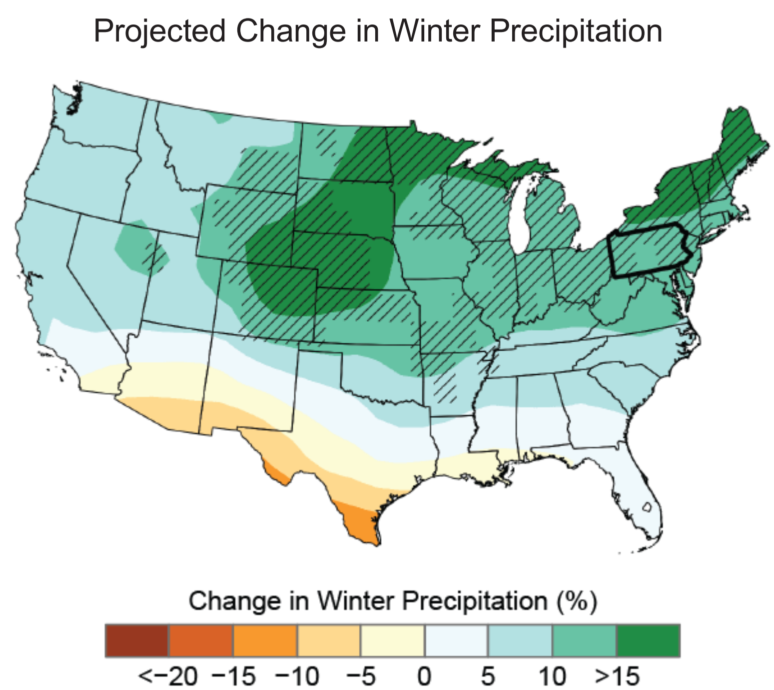


Figure 6: Projected changes in total winter (December–February) precipitation (%) for the middle of the 21st century relative to the late 20th century under a higher emissions pathway. Hatching represents areas where the majority of climate models indicate a statistically significant change. Winter precipitation is projected to increase in Pennsylvania. 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/PA/ | LEAD AUTHORS: REBEKAH FRANKSON, KENNETH E. KUNKEL
CONTRIBUTORS: SARAH M. CHAMPION, BROOKE C. STEWART, ARTHUR T. DEGAETANO, WILLIAM SWEET, JESSICA SPACCIO