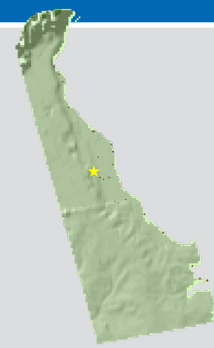

DELAWARE

Key Messages

Temperatures in Delaware have risen more than 3°F since the beginning of the 20th century. Under a higher emissions pathway, historically unprecedented warming is projected during this century. Heat waves are projected to be more intense and cold waves less intense.

Precipitation is projected to increase, as are the number and intensity of extreme precipitation events.

Since 1900, global sea level has risen by about 7–8 inches and is projected to continue to rise, with a likely range of 1–4 feet. Delaware sea level rise has been higher due to land subsidence (sinking). The number of tidal floods has been increasing. The low-elevation areas of Delaware are highly vulnerable to sea level rise.

Delaware is located on the eastern coast of the North American continent. Its mid-latitude location and proximity to the Atlantic Ocean greatly influence its climate, which is characterized by cold winters and warm summers. The jet stream is often located near the state, particularly in winter and spring. Storm systems associated with the jet stream bring frequent precipitation and fluctuating temperatures. The state often experiences strong winter storms known as nor'easters, which derive their energy from the contrast between cold air in the continental interior and warmer air over the western Atlantic Ocean. Delaware, with the lowest average elevation of all the U.S. states, experiences land subsidence. Its shoreline spans more than 250 miles. The entire state is classified as a coastal zone due to the proximity of inland areas to tidal waters: no geographic location within the state is more than 8 miles from tidal waters. The moderating influences of the Atlantic Ocean and the Delaware Bay tend to lessen temperature extremes. Slight variations in average (1991–2020) temperatures across this small, relatively flat state range from 53°F in the north to 58°F along the coast in the south. The statewide annual average (1991–2020) precipitation is 45.9 inches, with large interannual variability ranging from 27.4 inches in 1930 to 60.1 inches in 1948. Annual average snowfall ranges from 9 to 20 inches.

Temperatures in Delaware have risen more than 3°F since the beginning of the 20th century (Figure 1). The number of very hot days at Dover has been highly variable, with no long-term trend since 1910 (Figure 2a). By contrast, the number of very warm nights at Dover has been increasing since the early 1960s, reaching a peak during the 2015–2019 period (Figure 3). The number of freezing days has been generally below the long-term average since the early 1990s (Figure 2b).

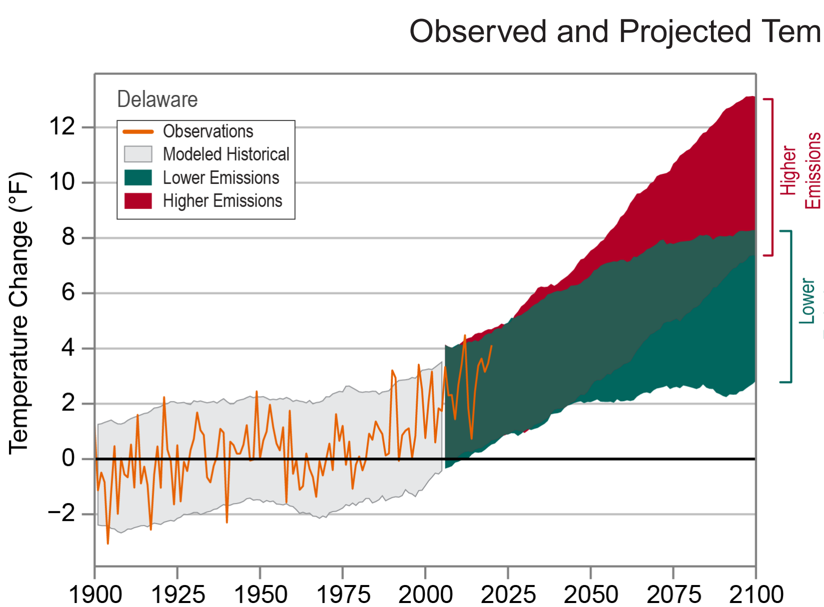

Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Delaware. Observed data are for 1900–2020. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions). Temperatures in Delaware (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 during this century. Less warming is expected under a lower emissions future (the coldest end-of-century projections being about 2°F warmer than the historical average; green shading) and more warming under a higher emissions future (the hottest end-of-century projections being about 9°F warmer than the hottest year in the historical record; red shading). Sources: CISESS and NOAA NCEI.

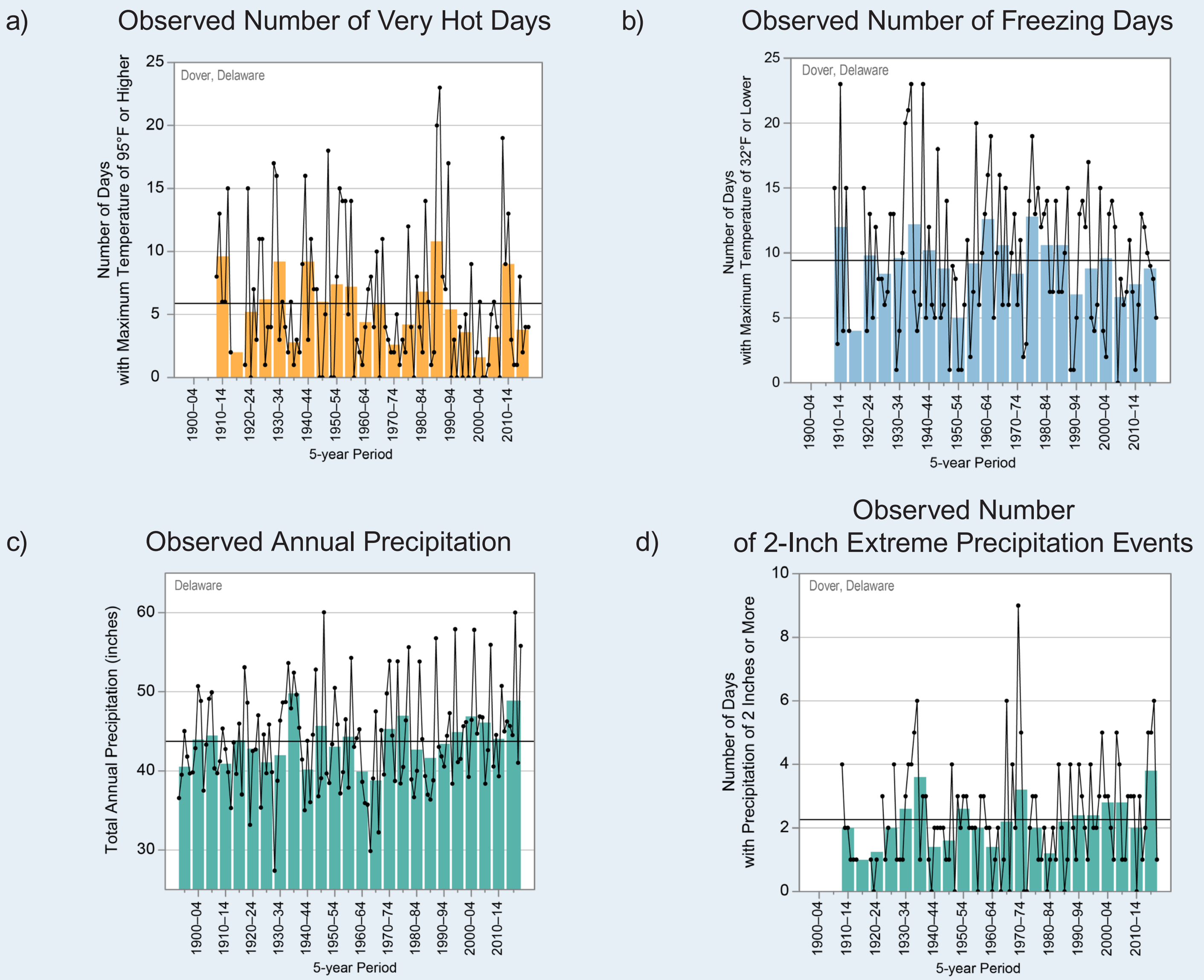

Figure 2: Observed (a) annual number of very hot days (maximum temperature of 95°F or higher) at Dover from 1910 to 2019, (b) annual number of freezing days (maximum temperature of 32°F or lower) at Dover from 1910 to 2019, (c) total annual precipitation for Delaware from 1895 to 2020, and (d) annual number of 2-inch extreme precipitation events (days with precipitation of 2 inches or more) at Dover from 1910 to 2019. Dots show annual values. Bars show averages over 5-year periods (last bar in Figure 2c is a 6-year average). The horizontal black lines show the long-term (entire period) averages: (a) 5.9 days, (b) 9.4 days, (c) 43.7 inches, (d) 2.3 days. (For Figures 2a, 2b, and 2d, data were not recorded for 1916 to 1919.) At Dover, there is no overall trend in the number of very hot days; however, the number of freezing days has been generally below average since the early 1990s. Statewide, total annual precipitation has been above average since the mid-1990s. The number of 2-inch extreme precipitation events at Dover has been mostly above average since the early 1990s; a typical reporting station experiences between 2 and 3 events per year. Sources: CISESS and NOAA NCEI. Data: (a, b, d) GHCN-Daily from 1 long-term station, (c) nClimDiv.

Statewide, total annual precipitation has shown a slight upward trend since 1895 and has been above average since the mid-1990s (Figure 2c). The number of 2-inch extreme precipitation events at Dover has generally been above average since the early 1990s (Figure 2d).

The state's coastline is highly vulnerable to damage from coastal and tropical storms. Nor'easters, the most common coastal storms, bring strong winds, heavy precipitation, and coastal flooding. They are most active from mid-winter through spring, with peak activity during March. The Ash Wednesday nor'easter of March 6–8, 1962, was the worst in Delaware history and illustrates the potential danger of such storms. The strong northeast winds, broad fetch (upwind distance traveled), and high angle of wave approach caused record flooding and beach erosion in Delaware and along the eastern seaboard from New England to Florida. Most houses near the beach that were not protected by a wide beach and dunes were destroyed. February 2010 brought multiple snowstorms to Delaware, which closed schools, disrupted transportation, and contributed to several snowfall records (greatest daily snow depth, greatest monthly snowfall, and greatest seasonal snowfall). During a blizzard in January 2016, gusts up to 75 mph caused dangerous storm surge and flooding. Tropical storms and hurricanes occasionally affect Delaware in the late summer and fall. In New Castle County, densely populated areas along major streams are at significant risk of flooding due to heavy precipitation and possible surges up Delaware Bay. Hurricanes Irene (2011) and Sandy (2012) caused significant economic and infrastructure damage to the state. Hurricane Sandy, which made landfall in New Jersey as a post-tropical storm, caused record flooding along the Atlantic and Delaware Bay coasts. Tornadoes and heavy rains trailing Hurricane Irene resulted in power outages for at least 119,000 residents and damages in the millions of dollars for the state.

Under a higher emissions pathway, historically unprecedented warming is projected during his century (Figure 1). Even under a lower emissions pathway, annual average temperatures are projected to most likely exceed historical records 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. According to the Delaware Climate Change Impact Assessment, annual maximum (daytime) temperature is projected to increase by an average of 2°–2.5°F and annual minimum (nighttime) temperature by an average of 1.5°–2.5°F by 2039. In the near term (2020–2039), extreme heat waves are projected to occur 3 out of every 5 years. Projections for midcentury show an average of 1 extreme heat wave per year under the lower scenario and up to 10 extreme heat waves per year by the end of the century under the higher scenario. Higher temperatures and extreme heat events in the future may result in decreased air quality and related health risks for Delaware residents. However, future cold waves are projected to be not as cold.

Total annual precipitation is projected to increase for Delaware (Figure 4), **with the greatest increases occurring in winter and spring**. This change is characteristic of a large area of the Northern

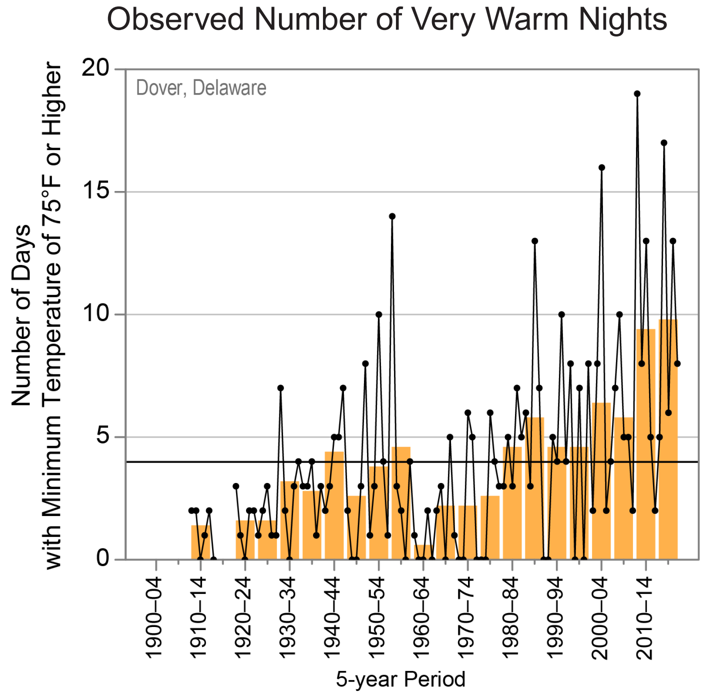

Figure 3: Observed annual number of very warm nights (minimum temperature of 75°F or higher) at Dover from 1910 to 2019. Dots show annual values. Bars show averages over 5-year periods. The horizontal black line shows the long-term (entire period) average of 4.0 nights. (Data were not recorded for 1916 to 1919.) The number of very warm nights at Dover has consistently been above average since 1980, with the highest multiyear average occurring during the 2015–2019 period. Sources: CISESS and NOAA NCEI. Data: GHCN-Daily from 1 long-term station.

Hemisphere in the higher mid-latitudes that is projected to see increases in both total precipitation and extreme precipitation events. On average, the state experiences about 2 days each year with 2 or more inches of rain. State-level projections show an increase of 0.5 to 1 day each year with 2 inches of rainfall by the end of the century. These precipitation projections may also result in increased flooding risks throughout the state.

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 5). The rise on Delaware's coasts has been greater due to land subsidence. Findings from the 2012 Sea Level Rise Vulnerability Assessment for the state project increases in sea level rise based on three levels of global warming: (1) 1.6 feet rise for low levels of global warming, (2) 3.3 feet for moderate levels, and (3) 4.9 feet for high levels (see the Delaware Climate Change Impact Assessment [http://www.dnrec.delaware.gov/energy/Documents/Climate%20Change%202013-2014/DCCIA%20interior_full_dated.pdf] for more sea level rise resources). Sea level rise has important future cross-sector implications for public health, water resources, coastal ecosystems and wildlife, agriculture, and transportation infrastructure. Demographic trends may increase the risks of coastal flooding. Due to the relocation of retirees, coastal communities show increases in their vulnerable elderly populations. Sea level rise has also 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 Delaware coastline, the number of tidal flood days (all days exceeding the nuisance-level threshold) has also increased, with the greatest number (15) occurring at Lewes in 2009 and 2017 (Figure 6).

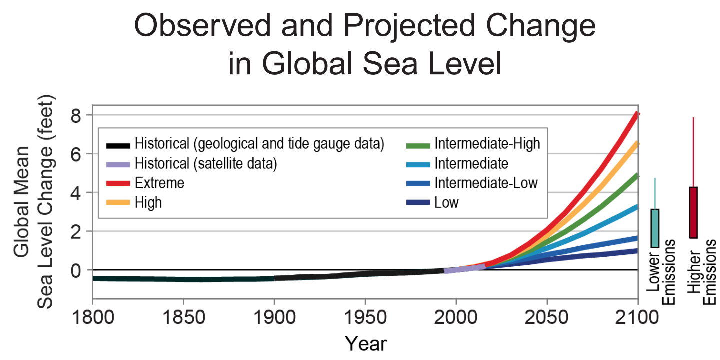

Figure 5: Global mean sea level (GMSL) change from 1800 to 2100. Projections include the six U.S. Interagency Sea Level Rise Task Force GMSL scenarios (Low, navy blue; Intermediate-Low, royal blue; Intermediate, cyan; Intermediate-High, green; High, orange; and Extreme, red curves) relative to historical 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.

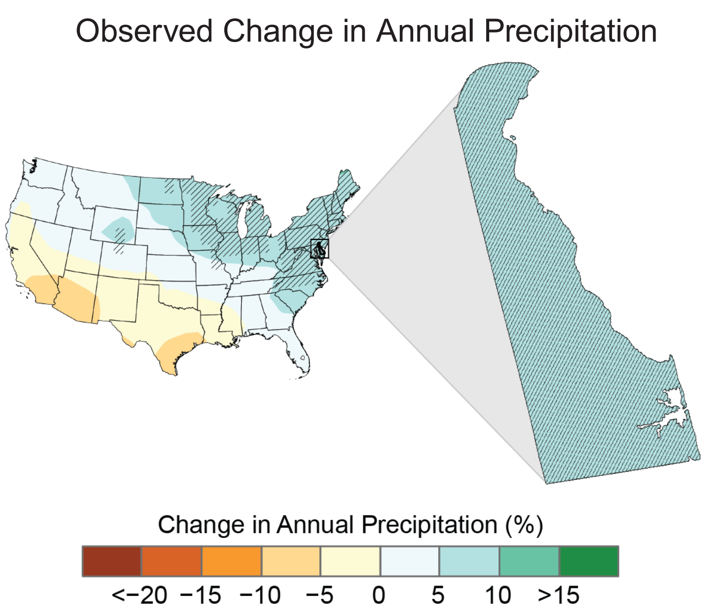

Figure 4: Projected changes in total annual precipitation (%) by the middle of the 21st century relative to the late 20th century under a higher emissions pathway. Hatching represents areas where the majority of climate models indicate a statistically significant change. Delaware is part of a large area of projected increases in the Northeast. Sources: CISESS and NEMAC. Data: CMIP5.

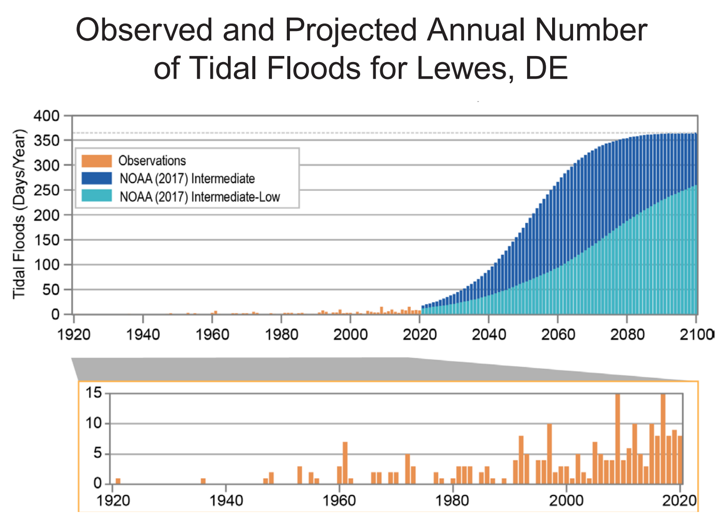

Figure 6: Number of tidal flood days per year for Lewes, Delaware, for the observed record (1921–2020; orange bars) and projections for two NOAA (2017) sea level rise scenarios (2021–2100): Intermediate (dark blue bars) and Intermediate-Low (light blue bars). The NOAA (2017) scenarios are based on local 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 2009 and 2017 at Lewes. 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.

 LEAD AUTHORS: JENNIFER RUNKLE, KENNETH E. KUNKEL
CONTRIBUTORS: DAVID R. EASTERLING, REBEKAH FRANKSON, SARAH M. CHAMPION, BROOKE C. STEWART, WILLIAM SWEET, DANIEL LEATHERS, ARTHUR T. DEGAETANO, JESSICA SPACCIO