



VERMONT

KEY MESSAGES

Average temperatures have increased by more than 2°F since the beginning of the 20th century. The last decade was the warmest on record. Under a higher emissions pathway, historically unprecedented warming is projected by the end of the 21st century. The intensity of extreme winter cold is projected to decrease.

Average annual precipitation has increased nearly 6 inches since the early 20th century, with the largest increases occurring in mountainous regions of the state. Increased winter and spring precipitation is projected for the 21st century, and warming will increase the proportion falling as rain.

Extreme weather events, particularly floods and severe storms, are having an increased impact on Vermont. Extreme rainfall events are projected to become more frequent and intense in the future.

Vermont's northerly latitude and geographic location on the eastern edge of the North American continent exposes it both to the moderating and moistening influence of the Atlantic Ocean, as well as the effects of the hot and cold air masses from the interior of the continent. Its climate is characterized by cold, snowy winters and pleasantly warm summers. The polar jet stream is often located near the state giving it highly variable weather patterns, widely ranging daily and annual temperatures, and generally abundant precipitation throughout the year. Variations in climate across the state are due to changes in elevation, terrain, and proximity to Lake Champlain and the Atlantic Ocean. The western part of the state is moderated by the lake and experiences higher temperatures and a longer growing season than the more mountainous northeastern region (also referred to as the Northeast Kingdom). Southeastern Vermont, with its lower elevation and landlocked location tends to be warmer and more drought-prone than the rest of the state.

Observed and Projected Temperature Change

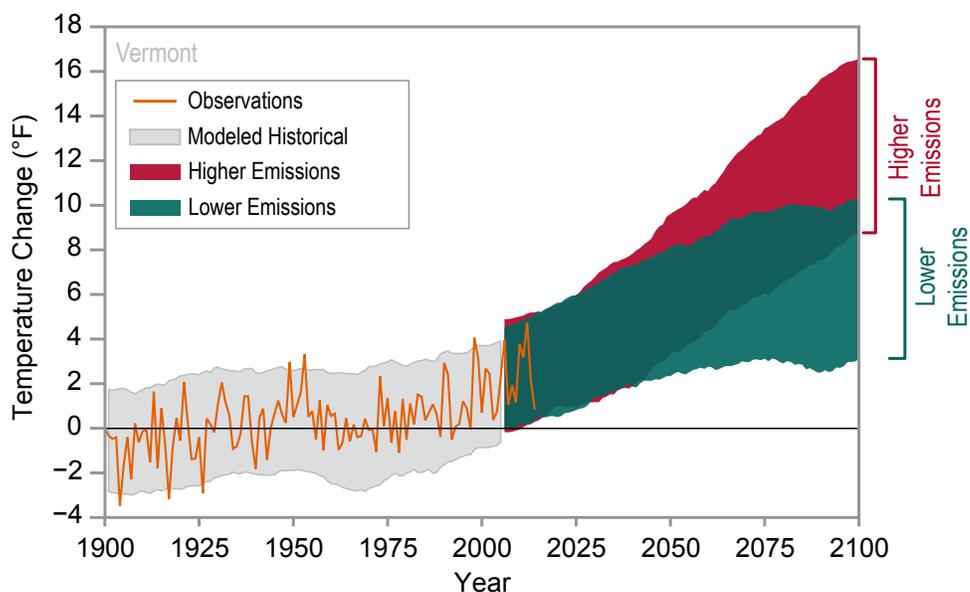
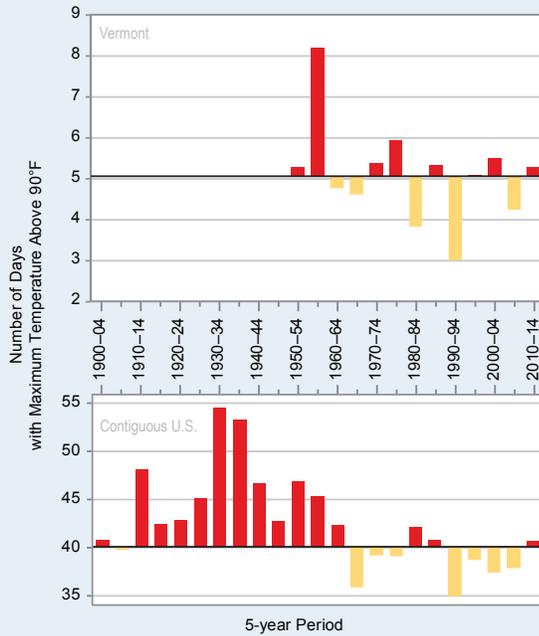


Figure 1: Observed and projected changes (compared to the 1901–1960 average) in near-surface air temperature for Vermont. Observed data are for 1900–2014. Projected changes for 2006–2100 are from global climate models for two possible futures: one in which greenhouse gas emissions continue to increase (higher emissions) and another in which greenhouse gas emissions increase at a slower rate (lower emissions)¹. Temperatures in Vermont (orange line) have risen by more than 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 (grey shading). Historically unprecedented warming is projected to continue through the 21st

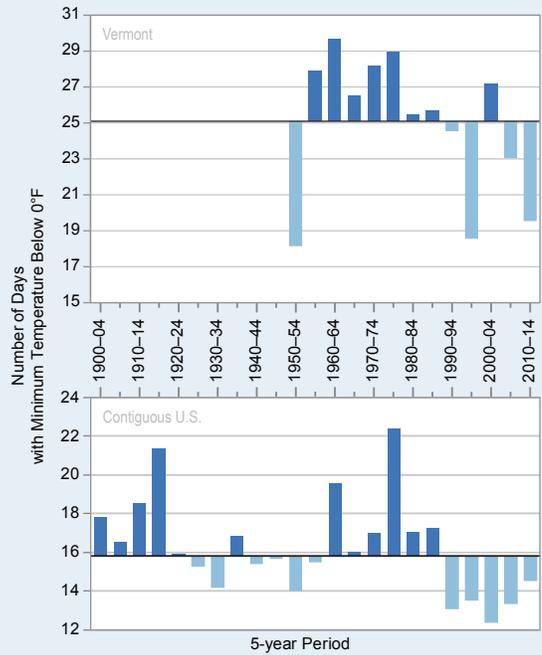
century. Less warming is expected under a lower emissions future (the coldest years being about 2°F warmer than the historical average; green shading) and more warming under a higher emissions future (the hottest years being about 12°F warmer than the hottest year in the historical record; red shading). Source: CICS-NC and NOAA NCEI.

¹Technical details on models and projections are provided in an appendix, available online at: <https://statesummaries.ncics.org/vt>.

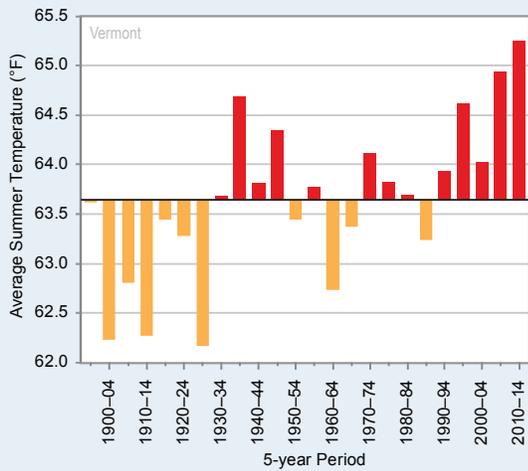
a) Observed Number of Hot Days



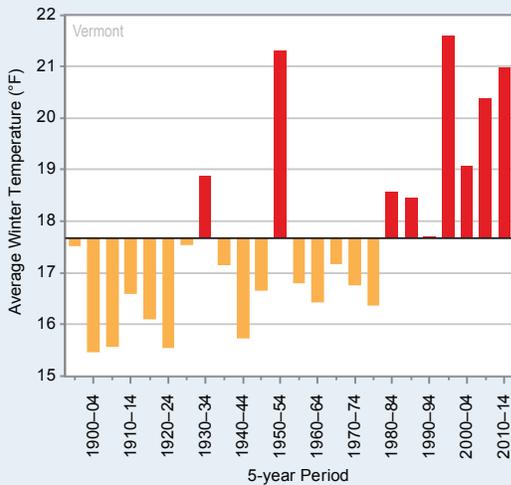
b) Observed Number of Very Cold Nights



c) Observed Summer Temperatures



Observed Winter Temperatures



d) Observed Number of Extreme Precipitation Events

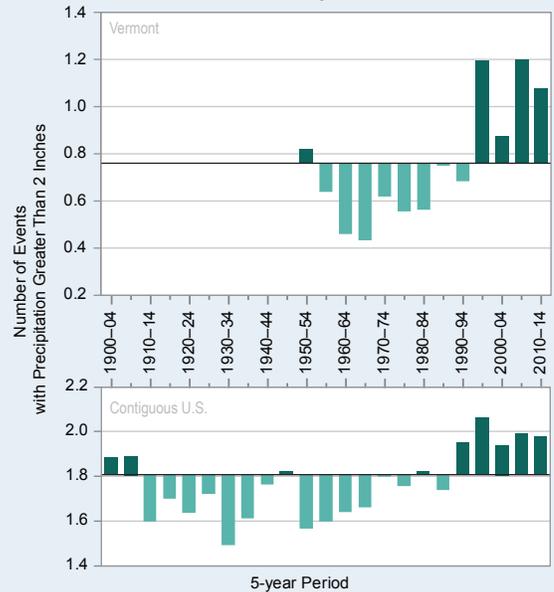


Figure 2: The observed (a) number of hot days (annual number of days with maximum temperature above 90°F), (b) number of very cold nights (annual number of days with minimum temperature below 0°F), (c) annual winter and summer temperatures, and (d) number of extreme precipitation events (annual number of events with greater than 2 inches), averaged over 5-year periods. The values in figures 2a, 2b, and 2d are averages from long-term reporting stations (seven for temperature and fifteen for precipitation). The values in figures 2c are from NCEI’s version 2 climate division dataset. The dark horizontal lines represent the long-term averages. 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 Vermont. Over the past two decades (1995–2014), Vermont has experienced the highest winter and summer temperatures and the greatest number of extreme precipitation events observed in the historical record. There is no trend in the number of hot days while the number of very cold nights has been below average over the last 10 years. Source: CICS-NC and NOAA NCEI.

Temperatures in Vermont have increased more than 2°F since the beginning of the 20th century (Figure 1). While there is no trend in the number of hot days (maximum temperature above 90°F; Figure 2a), the annual number of warm nights (minimum temperature above 70°F) has been above average for the past 15 years (2000–2014), with a historically high peak from 2005 to 2009 (Figure 3). Both winter and summer temperatures have increased considerably in the past two decades (Figure 2c). The winter warming trend is reflected in a below-average annual number of very cold nights (minimum temperature below 0°F) since the early 1990s (Figure 2b). Higher spring and fall temperatures have resulted in corresponding changes in the length of the growing season from later “first-fall freeze” and earlier “last-spring freeze” dates. Over the past four decades, the growing season in Vermont has lengthened by an average of 4 days each decade.

Annual mean precipitation has been above average for the last several decades (Figure 4). The driest multi-year periods were in the 1910s and the early 1960s. The wettest periods have been observed since 2005 to the present. The driest 5-year period was 1961–1965 and the wettest was 2007–2011. The annual number of extreme precipitation events (number of days with greater than 2 inches) has been above the long-term average over the past two decades (1995–2014), with the highest number of events occurring during the period from 2005 to 2009 (Figure 2d). Average annual precipitation has increased nearly 6 inches since the 1960s.

Extreme weather events in Vermont can take the form of prolonged heavy snowstorms, flash floods, river floods (following snowmelt and heavy rains), severe thunderstorms, droughts, tornadoes, and temperature extremes. Some of the heaviest flooding in the state’s history has been due to tropical cyclones or their remnants. In 2011, Tropical Storm Irene transitioned into an extratropical cyclone as it moved quickly northeastward along the Vermont/New Hampshire border. Roughly 3 to 7 inches of rain fell in less than 18 hours, causing the worst flooding in Vermont since the Great Flood of November 1927. Many rivers reached stages that were second to only the 1927 flood. The flooding resulted in an estimated \$733 million in damage across the state.

Observed Number of Warm Nights

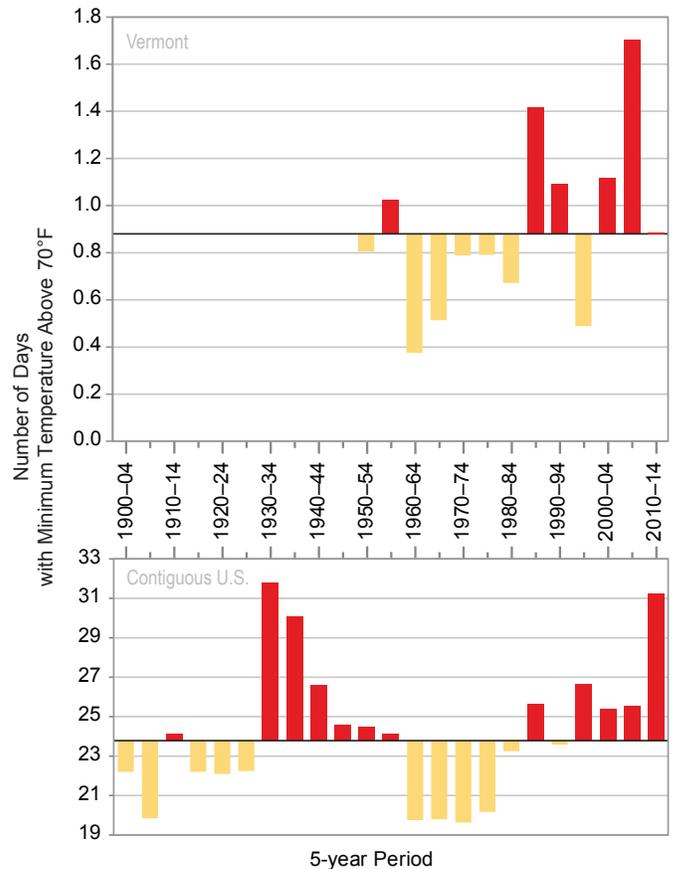


Figure 3: The observed number of warm nights (annual number of days with minimum temperature above 70°F) for 1950–2014, averaged over 5-year periods; these values are averages from seven long-term reporting stations. The number of warm nights in Vermont has been above average during the early 21st century. A historically high number of warm nights (1.7 days per year) occurred during 2005–2009. The dark horizontal line is the long-term average of 0.9 days per year. The number of warm nights for the contiguous United States (bottom panel) is also shown to provide a longer and larger context. Very few long-term stations are available back to 1900 for Vermont. Source: CICS-NC and NOAA NCEI.

Severe winter storms are common in Vermont’s cold winter climate and may include snowstorms, blizzards, and icing events. In addition to ice jams and melting snowpack as winter hazards, freezing rain and frozen ground conditions can also give rise to flooding. During the first week of January 1998, a prolonged storm brought 2 to 5 inches of rain to Vermont. Particularly across the Champlain Valley and parts of northern Vermont, temperatures were below freezing for much of the storm. This resulted in the “Great Ice Storm of ‘98” where heavy ice accumulations of 1 to 2 inches caused severe damage to trees and utility lines. Total damage from the ice storm across the whole of the northeastern

United States was about \$2 billion (\$1.4 billion in 1998 dollars).

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 (Figure 1). Increases in the number of hot days

and decreases in the number of very cold nights are projected to accompany the overall warming.

Average annual precipitation is projected to increase in Vermont over the 21st century, particularly during winter and spring (Figure 5). Corresponding increases in temperature will increase the proportion of precipitation falling as rain rather than snow. In addition, extreme precipitation is projected to increase, potentially increasing the frequency and intensity of floods.

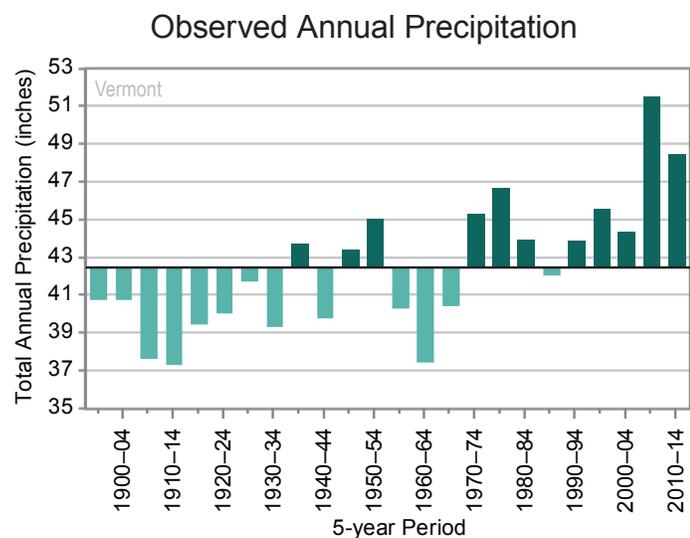


Figure 4: The observed annual precipitation for 1895–2014, averaged over 5-year periods; these values are averages from NCEI’s version 2 climate division dataset. Below average annual precipitation occurred in Vermont during the first half of the 20th century. Annual precipitation has largely remained above average since 1970. The dark horizontal line is the long-term average of 42.4 inches per year. Source: CICS-NC and NOAA NCEI.

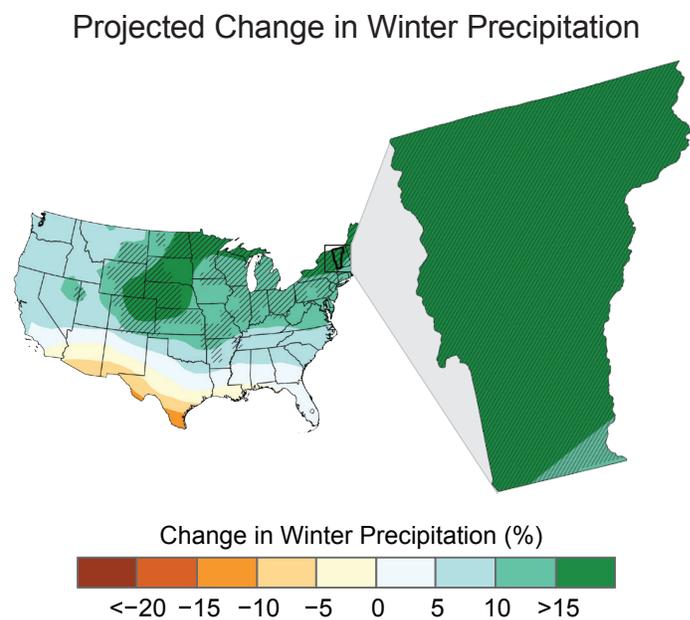


Figure 5: Projected change in winter precipitation (%) by the middle of the 21st century compared to the late 20th century under a higher emissions pathway. Hatching represents areas where the majority of climate models indicate a statistically significant change. Vermont is part of a large area of the Northeast that is expected to experience increases in winter precipitation. Source: CICS-NC and NOAA NCEI.