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Climate Change in Northern New Hampshire: Past, Present and Future

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PAST, PRESENT, AND FUTURE

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EXECUTIVE SUMMARY

EARTH'S CLIMATE CHANGES. It always has and always will. However, an extensive and growing body of scientific evidence indicates that human activities—including the burning of fossil fuel (coal, oil, and natural gas) for energy, clearing of forested lands for agriculture, and raising livestock—are now the primary force driving change in the Earth's climate system. This report describes how the climate of northern New Hampshire has changed over the past century and how the future climate of the region will be affected by a warmer planet due to human activities.

Overall, northern New Hampshire has been getting warmer and wetter over the last century, and the rate of change has increased over the last four decades. Detailed analysis of data collected at three U.S. Historical Climatology Network meteorological stations (Bethlehem, First Connecticut Lake, and Hanover) show that, since 1970:

- Average annual maximum temperatures have warmed 0.5 to 2.1°F (depending on the station) with the greatest warming occurring during the fall (2.4 to 3.9°F) and winter (1.5 to 3.5°F).
- The number of days with minimum temperatures less than 32°F has decreased by two weeks, and the coldest winter nights are warming.
- The length of the growing season is two to three weeks longer.
- Annual precipitation has increased 7 to 18 percent.
- Extreme precipitation events have increased at some locations (Berlin and Pinkham Notch) and showed little change at other sites (Errol and Hanover).
- The number of snow-covered days has decreased by across northern New Hampshire.

In addition, more than a century of observations shows that spring lake ice-out dates on Lake Umbagog and First Connecticut Lake are occurring seven to ten days earlier today than in the past.

To generate future climate projections for northern New Hampshire, simulated temperature and precipitation from four global climate models (GCMs) were statistically downscaled using historical weather observations. We accounted for a range of potential future fossil fuel use by using two very different future global emission scenarios. In the lower emissions scenario, improvements in energy efficiency, combined with the development of renewable energy, reduce global emissions of heat-trapping gases (also known as greenhouse gases) below 1990 levels by the end of the twenty-first century. In the higher emissions scenario, fossil fuels are assumed to remain a primary energy resource, and emissions of heat-trapping gases grow to three times those of today by the end of the century. Although both scenarios are possible, the current global emissions trend from 2000 through 2012 suggests that, in the absence of concerted international efforts to reduce emissions, climate change will likely track or exceed that projected under the higher emissions scenario over the course of this century.

As heat-trapping gases continue to accumulate in the atmosphere, temperatures will rise in northern New Hampshire. Depending on the emissions scenario, mid-century annual average temperatures may increase on average by 3 to 5°F, and end-of-century annual average temperatures may increase as much as 4°F under a lower to 9°F under a higher emission scenario. The frequency of extreme heat days is projected to increase dramatically, and the hottest days will be hotter, raising concerns regarding the impact of extreme, sustained heat on human health, infrastructure, and the electrical grid.

Extreme cold temperatures are projected to occur less frequently, and extreme cold days will be warmer than in the past. Winter warming may reduce heating bills and the risk of cold-related accidents and injury. However, warming winters will reduce opportunities for snow and ice related recreation (and related economic activity). Winter warming would also reduce cold temperature constraints that currently limit the spatial extent of some marginally over-wintering pests and invasive species.

The growing season will get longer, which may provide opportunities for farmers to grow new crops. However, many existing crops will likely experience yield losses associated with increased frequency of high temperature stress, an increase in soil erosion and crop failure resulting from more frequent extreme precipitation events, inadequate winter chill period for optimum fruiting, and increased pressure from invasive weeds, insects, or disease.

Annual average precipitation is projected to increase 14 to 17 percent by end-of-century. Larger increases are expected for winter and spring, exacerbating concerns regarding rapid snowmelt, high peak stream flows, and flood risk. Northern New Hampshire can also expect to experience more extreme precipitation events in the future. For example, under the high emissions scenario, events that drop more than four inches of precipitation in forty-eight hours are projected to increase two- to three-fold across much of northern New Hampshire by the end of the century.

Observed changes in climate over the past several decades are already having a significant impact on New Hampshire. The projected changes in the climate of northern New Hampshire over the next century will continue to impact our environment, ecosystems services, economy, and society in a myriad of ways. Because some future changes are inevitable, smart choices must be made to help our society and our ecosystems adapt to the new climate. With prompt action that improves the efficiency with which we use energy and significantly enhances sources of renewable energy, many of the most extreme consequences of climate change can be avoided and their worst impacts reduced. Our hope is that the focused information presented in this report provides local and regional stakeholders with relevant input for decision-making, serving as a foundation for the development of local and regional climate change adaptation plans, as well as regional mitigation plans to reduce emissions of heat-trapping gases.

I. INTRODUCTION

"Climate change is occurring, is very likely caused by human activities, and poses significant risks for a broad range of human and natural systems. Each additional ton of greenhouse gases emitted commits us to further change and greater risks." [1]

Over most of Earth's 4.5 billion year history, large-scale climate variations were driven by natural causes including gradual shifts in the Earth's orbital cycles, variations in solar output, changes in the location and height of continents, meteorite impacts, volcanic eruptions, and natural variations in the amount of greenhouse gases in the atmosphere.[2] Today, however, the story is noticeably different. Since the Industrial Revolution, atmospheric concentrations of heat-trapping gases, or greenhouse gases, such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) have been rising as a result of increasing emissions from human activities.[3] The primary source of CO_2 comes from the burning of fossil fuels such as coal, oil, and natural gas. Carbon dioxide is also produced by land use changes, including tropical deforestation. Agricultural activity and waste treatment are critical sources of CH_4 and N_2O emissions. Atmospheric particles released during fossil fuel combustion, such as soot and sulfates, also affect climate.

As human-derived emissions of heat-trapping gases continue to rise, analysis of data collected around the globe clearly documents ongoing and increasingly dramatic changes in our climate system. These changes include increases in global atmospheric and ocean temperatures, atmospheric water vapor, precipitation and extreme precipitation events, and sea levels. They also include reductions in the volume and areal extent of spring and summer Arctic sea ice, reductions in northern hemisphere snowcover, melting of mountain glaciers, increases in the flux of ice from the Greenland and West Antarctic ice sheets into the ocean, and thawing permafrost and methane hydrates.[4] Detailed reviews of the extensive body of evidence from peer-reviewed climate science publications conclude that it is extremely likely that the majority of warming observed over the last fifty years have been caused by emissions of heat-trapping gases derived from human activities.[5]

The northeast United States has already experienced an overall warming over the past century, with an increase in the rate of warming over the past four decades. This change in our regional climate has been documented in a wide range of indicators, including increases in temperature (especially in winter), in overall precipitation, in the number of extreme precipitation events, and in the proportion of winter precipitation falling as rain (as opposed to snow). Observed changes also include a decrease in snow cover days, earlier ice-out dates, earlier spring runoff, earlier spring bloom dates for lilacs, longer growing seasons, and rising sea levels.[6]

To examine how climate change might impact our region in the future, we used scenarios of future emissions of heat-trapping gases as input to global climate models (GCMs). However, GCMs operate on the scale of hundreds of miles, too large to resolve the changes over northern New Hampshire. For that reason we used state-of-the-art statistical techniques to downscale the regional temperature and precipitation simulations generated by the GCMs to observed conditions at individual weather stations across northern New Hampshire.[7] The results show that, over the coming century, northern New Hampshire's climate is expected to continue to become warmer and wetter in response to increasing emissions of heat-trapping gases from human activities. The implications for northern New Hampshire are significant: hotter summers and warmer winters, more invasive pests and weeds, and an increase in precipitation and the frequency of extreme precipitation events. All of these impacts are greater under a higher emissions scenario versus a lower emissions scenario, and by the end of the century as compared to earlier time periods.

These changes will have repercussions on the region's environment, ecosystem services, economy, and society. A detailed analysis of the impacts of climate change on specific natural resources and other sectors (including forests, agriculture, recreation, water resources, human health, and invasive pests) is beyond the scope of this climate assessment. Fortunately, there is a wealth of analysis on the potential impacts of climate change across New England and the northeast United States in the peer-reviewed scientific literature.[8] For example, warmer temperatures affect the types of trees, plants, and crops likely to grow in the area but will also allow an expansion of invasive pests and weeds. Long periods of very hot conditions in the summer are likely to increase demands on electricity and water resources. Hot summer weather can also have damaging effects on agriculture, human and ecosystem health, and outdoor recreational opportunities. Less frequent extreme cold in the winter will likely lower heating bills and reduce cold-related injury and death, but rising minimum temperatures in winter will likely open the door to invasion of cold-intolerant pests that prey on the region's forests and crops. Warmer winters will also have an impact on a wide range of snow and ice related winter recreation.[9] More extreme precipitation events, combined with an expansion of impervious surface associated with development, will increase the risk for both the frequency and magnitude of flooding.

In addition to the changes described above and in the body of this report, Earth's climate history, as read through the analysis of natural archives, including ocean sediments, ice cores, and tree rings, reveals several "tipping points"—thresholds beyond which major and rapid changes occur that can lead to abrupt changes in the climate system.[10] The current rate of emissions of heat trapping gases is changing the climate system at an accelerating pace, making the chances of crossing tipping points more likely. There is a growing recognition that gradually changing climate can push both natural systems and human systems across key tipping points. However, accurately predicting if and when these tipping points will be crossed has proven challenging. Because of this uncertainty, the potential impact of crossing these tipping points is not discussed in detail in this report. However, the potential to cross key tipping points in the climate system should, where feasible, be integrated into our decision-making processes.

If we respond regionally and globally to the grand challenge of significantly reducing our emission of heat-trapping gases (this is called mitigation), we can avoid the more catastrophic climate change. And if we begin to plan locally and regionally for the unavoidable climate change that we have already baked into the climate system over the next several decades, we can adapt and avoid, manage, or reduce the consequences of our changing climate. This is called adaptation. Both mitigation and adaptation are necessary components of a sustainable future. We must reduce the impact we are having on climate, and we must prepare to adapt to the changes that are already underway.

The research and writing of this report, and a companion report for southern New Hampshire, were completed with support from the Granite State Future project (Sidebar). For this report, we define meteorological stations located north of 43.75°N latitude as falling within northern New Hampshire. This region extends south of the notches but lies north of Lake Winnipesauke. For the climate assessment for southern New Hampshire, we define meteorological stations located south of 43.90°N latitude as falling within southern New Hampshire. This provides an overlap of 0.15 degrees latitude, or about seventeen miles. Communities that lie within this overlap (for example, Plymouth, West Rumney, and Tamworth) can use either report. In addition, while Hanover technically lies within the region we have defined as southern New Hampshire, we have included analysis of meteorological data from the Hanover United States Historical Climatology Network (USHCN) station in Chapter II (Historical Climate Change) of this report so the analysis includes three stations instead of just two (Bethlehem and First Connecticut Lakes). There is also site-specific climate information provided in the climate grids (Appendix B) which contain historical and projected future thirty-year climatologies for fifteen Global Historical Climatology Network-Daily (GHCN-Daily) meteorological stations across northern New Hampshire for the historical period (1980–2009) and the future (2010–2039, 2040–2069, 2070–2099).

Other New Hampshire-specific reports provide additional information and analysis beyond what is contained in this report. A climate assessment for New Hampshire's coastal watershed, which includes detailed analysis of sea level rise and coastal flooding, was published in 2011.[11] Under the leadership of the Department of Environmental Services, New Hampshire completed a detailed Climate Action Plan in 2009.[12] New Hampshire Fish and Game has recently updated its Wildlife Plan to include an Ecosystems and Wildlife Climate Adaptation Plan.[13] The New Hampshire Department of Health and Human Services is currently developing an assessment and adaptation plan to respond to the public health impacts of climate change using the Center for Disease Control's BRACE framework (Building Resilience Against Climate Effects).[14] There is also a statewide project funded by the National Science Foundation—Experimental Program to Stimulate Competitive Research (EPSCoR)—that is studying the interactions among climate, land use, ecosystem services, and society.[15] Many additional resources are referenced in Chapter IV.

GRANITE STATE FUTURE[16]

Granite State Future is a project of the nine New Hampshire regional planning commissions (RPCs) to update regional plans. Formed by municipalities in the late 1960s and 1970s, the RPCs are mandated to undertake technical studies and develop comprehensive plans for their regions. In 2011, the RPCs jointly applied for and were awarded a U.S. Housing and Urban Development—Sustainable Communities Regional Planning Grant to carry out their legislated duty, believing that a coordinated effort would be a more efficient use of resources. Throughout the state, regions and localities are facing difficult decisions about investments in the future. Decision makers often have to prioritize and make tough choices. The nine regional plans will provide a concise story of what the citizens and communities in each region value, what they want for the future, and their ideas for getting there. The regional plans will be supplemented with a robust suite of statewide research, including climate assessments for northern and southern New Hampshire. These regional stories will be accompanied by technical analyses including: regional housing needs and fair housing and equity assessment, transportation, economic development, environment, water infrastructure, climate change impacts assessments, energy efficiency and green building, and other issues identified by the regions.

II. HISTORICAL CLIMATE CHANGE

"Global climate is changing now and this change is apparent across a wide range of observations. Much of the climate change of the past fifty years is due primarily to human activities." [17]

Annual and Seasonal Temperature Trends

Annual and seasonal minimum and maximum temperatures have been increasing across northern New Hampshire over the past one hundred years, and the rate of warming has increased over the past four decades. The largest temperature increases over the past four decades have occurred in the fall and winter seasons.

Temperature is one of the most commonly used indicators of climate change. Today, temperatures have risen as a result of increased emission of heat-trapping gases from human activities and will likely continue to rise across northern New Hampshire over the foreseeable future. The temperature records from three long-term United States Historical Climatology Network (USHCN)[18] meteorological stations in northern New Hampshire (Hanover, Bethlehem, and First Connecticut Lake; Figure 1) provide a continuous record of temperature change for the last century in northern New Hampshire. A detailed description of the sources of high-quality meteorological data used in this report, quality control procedures, and statistical methods used to quantify historical trends in climate across northern New Hampshire and assess the statistical significance of those trends are described in detail in Appendix A.

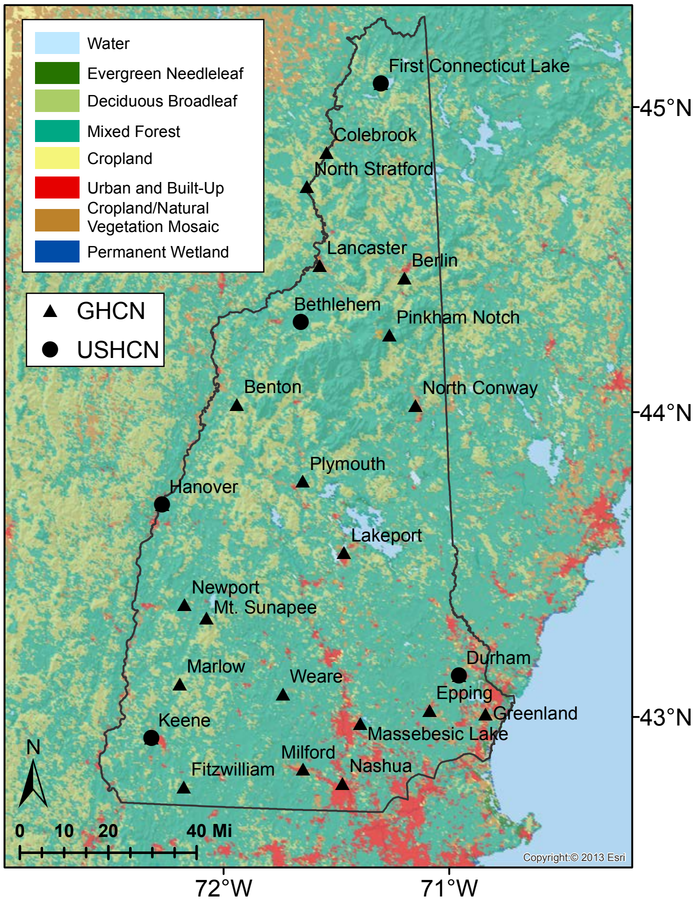


FIGURE 1. Map of New Hampshire showing land cover and the location of United States Historical Climate Network (USHCN) stations (black dots) and Global Historical Climatology Network-Daily (GHCN) stations. For this report, the USHCN stations are the source of historical climate data in New Hampshire over the time period 1895–2012, while the GHCN-Daily stations are the source of data since 1960. For this report we define northern New Hampshire as all those meteorological stations that are north 43.75°N latitude.

Long-Term Temperature Trends: 1895–2012

All three weather stations show long-term temperatures increases over the period of record; increases in minimum temperatures are greater compared to increases in maximum temperatures at the First Connecticut Lakes and Hanover stations (Figures 2 and 3). As is common in New England, significant year-to-year and decadal variability is evident at all three stations. However, all stations show long-term increases in both minimum and maximum temperatures.

Mean annual and seasonal temperature trends for the period 1895–2012 are summarized in Table 1. Over the past century, maximum temperatures show a statistically significant warming of +0.10°F/decade at Bethlehem and +0.14°F/decade at First Connecticut Lakes; Hanover has also warmed (0.05°F/decade), however the trend is not significant. Significant warming trends in annual minimum temperature records have occurred at First Connecticut Lakes (+0.24°F/decade) and Hanover (+0.25°F/decade).

Almost every season at all three stations displays a warming trend, even while seasonal rates of warming vary across the region. All three sites show the greatest warming trend for maximum temperatures during the fall season, while the greatest warming trend for minimum temperatures occurs during the winter.

CLIMATE VERSUS WEATHER

> *"Climate is what we expect. Weather is what we get."*
>
> –Robert Heinlein

Weather refers to the hourly and daily changes in local conditions, such as temperature, precipitation, humidity, and wind. Climate is the long-term average of these indicators. Climate normals are often expressed as thirty-year averages of climatological variables, including temperature, precipitation, and growing degree days. Because climate is a long-term average, shifts in climate are harder to observe than changes in weather. However, by tracking temperature and precipitation trends and patterns over long periods of time (decades to centuries) and in response to changing atmospheric conditions—such as rising concentrations of heat-trapping gases or changes in solar output or volcanic eruptions—researchers can identify long-term patterns in climate as distinct from day-to-day weather patterns. In other words, even if we are in the middle of a record cold snap this week (that's weather), long-term temperature can still be rising (that's climate).

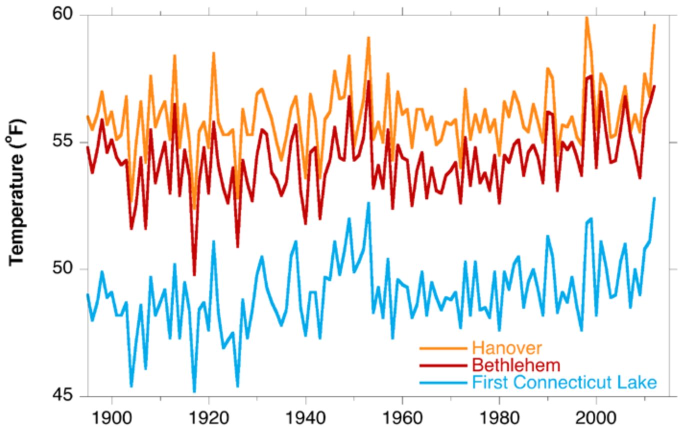


FIGURE 2. Annual *maximum* temperature records for USHCN stations in northern New Hampshire for the period 1895–2012.

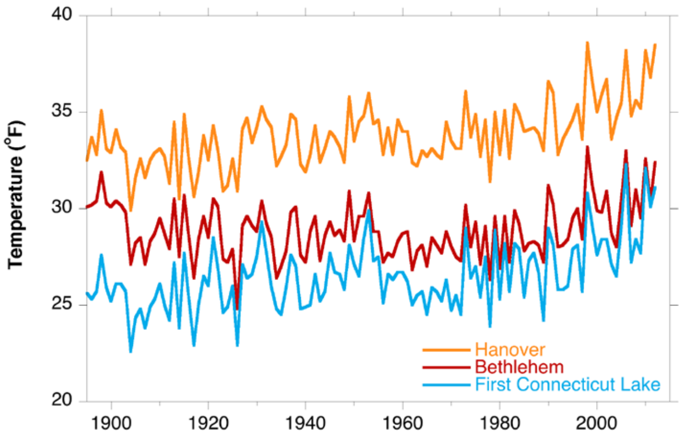


FIGURE 3. Annual *minimum* temperature records for USHCN stations in northern New Hampshire for the period 1895–2012.

Regardless of the range in seasonal rates of warming, the long-term USHCN temperature records are clear—northern New Hampshire has warmed over the past century.

The long-term climate trends at any given location result from a combination of local, regional, and global factors. For example, temperature trends at the three stations in northern New Hampshire are the result of global-scale climate change, local factors that can change over time (such as land use change) that can act to cool or warm their immediate environment, and local factors that do not change over time (such as location next to large body of water or in a valley bottom) but that act to moderate the effects of global change at the local scale. These local influences explain why three stations in northern New Hampshire can show slightly different warming trends; the influence of global change is being moderated by unique features at each location.

Recent Temperature Trends: 1970–2012

We also analyzed temperature trends for the same three stations over the last forty-three years, 1970–2012 (Table 1). This period coincides with a

Parameter	**Bethlehem**		**First Connecticut Lake**		**Hanover**	
	1895–2012	1970–2012	1895–2012	1970–2012	1895–2012	1970–2012
TMAX (°F per decade)						
Annual	**0.10**	**0.50**	**0.14**	**0.36**	0.05	0.25
Winter	0.11	**0.84**	**0.16**	0.61	0.08	0.37
Spring	**0.17**	0.22	**0.20**	0.33	**0.15**	0.29
Summer	**0.11**	0.15	0.09	0.04	0.08	-0.05
Fall	0.07	**0.98**	**0.13**	**0.56**	-0.05	**0.60**
TMIN (°F per decade)						
Annual	0.03	**0.77**	**0.24**	**0.86**	**0.25**	**0.74**
Winter	0.19	**1.57**	**0.38**	**1.44**	**0.36**	**1.45**
Spring	0.05	0.61	**0.21**	**0.72**	**0.23**	**0.60**
Summer	-0.04	0.32	**0.19**	**0.50**	**0.27**	**0.60**
Fall	0.00	**0.78**	**0.24**	**0.95**	**0.22**	**0.61**
Growing Season (Days per decade)						
	NA	4.0	NA	NA	NA	5.9
Precipitation (inches per decade)						
Annual	**0.39**	0.68	-0.03	**1.74**	**0.39**	1.16
Winter	**0.14**	-0.09	-0.05	0.03	**0.12**	-0.11
Spring	0.02	-0.07	0.01	0.32	0.02	0.22
Summer	0.15	0.17	0.16	0.66	0.10	0.55
Fall	0.06	0.13	-0.05	0.52	**0.18**	0.19
Snowfall	NA	-4.29	NA	-3.94	NA	-3.44
Snow-Covered Days (days per decade)						
Winter	NA	-0.4	NA	0.0	NA	-2.9

*NA means data not available. *Growing season, snowfall,and snow-covered days data not available for Bethlehem; instead data from Pinkham Notch for 1970–2012 reported here.*

TABLE 1. Annual and seasonal trends in temperature, precipitation, and snow-covered days for the period 1895–2012 and 1970–2012 for three USHCN stations located in northern New Hampshire. Trends were estimated using Sen's slope; trends that meet the Mann-Kendall non-parametric test for statistical significance (p<0.05) are highlighted in **bold and underlined**.

marked increase observed in global temperatures as a result of human activities,[19] and also defines what we would consider "typical" climate today. Over the more recent time period, all three USHCN stations show significant warming trends in annual and most seasonal minimum temperatures (only the warming trends from spring and summer in Bethlehem are not significant). Warming also dominates trends in maximum temperature, but only one-third of these warming trends are significant.

Warming trends since 1970 tend to be much higher for both annual and seasonal temperatures relative to the long-term 1895–2012 rates of warming, consistent with the greater increase in global temperature over the same time period.

At the seasonal level, there is a dramatic increase in the rate of fall and winter warming, which surpasses all other seasonal rates of warming over the last four decades at all three stations for both minimum and maximum temperatures.

Extreme Temperature Trends

While the number of hot days has not changed much across northern New Hampshire since 1960, the number of cold days has decreased and temperature on the coldest day of the year has increased, reflecting the greater warming the region has experienced during the winter compared to summer.

Trends in annual and seasonal temperature may be too subtle for individuals to detect from personal experience. However, temperature extremes may provide more obvious evidence of warming. Changes in the distribution of both hot and cold extreme temperatures can lead to increased duration, frequency, and intensity of heat waves,[20] lengthening of the growing season, and northward expansion of invasive insects like the woolly adelgid (Adelges tsugae), an aphid-like insect that has decimated stands of eastern hemlock from Georgia to Connecticut since the 1950s[21] and ticks that carry Lyme disease.[22] Increasing trends in minimum daily temperature are indicators of nighttime warming, while trends in maximum daily temperature provide insight to daytime processes.

Location	Days > 90°F		TMAX(°F) Hottest Day of Year	
	1960-2012 average	Trend (days/ decade)	1960-2012 average	Trend (°F/ decade)
Berlin	2.5	**-0.4**	92.1	**-0.4**
Pinkham Notch	0.2	0.0	87.4	0.2
Hanover	6.0	0.1	94.4	0.0

Location	Days < 32°F		TMIN(°F) Coldest Day of Year	
	1960-2012 average	Trend (days/ decade)	1960-2012 average	Trend (°F/ decade)
Berlin	168	**-3.2**	-20.2	**2.0**
Pinkham Notch	180	**-3.5**	-18.0	**1.3**
Hanover	151	**-3.8**	-18.9	**1.3**

TABLE 2. Extreme temperature trends for three GHCN-Daily stations in northern New Hampshire for the period 1960–2012. Trends are estimated using Sen's slope; statistically significant trends ($p<0.05$) are highlighted in **bold and underlined.**

Daily temperature records are available back to 1960 for Berlin, Pinkham Notch, and Hanover from the Global Historical Climatology Network-Daily (GHCN-Daily)[23]; these daily temperature records have been homogenized.[24] In this analysis, we use a suite of simple indicators for tracking changes in temperature extremes over the period 1960–2102 (Table 2), consisting of trends in the: (1) number of "hot days" per year warmer than 90°F, (2) number of "cold days" per year colder than 32°F, (3) maximum temperature on the hottest days of the year, and (4) minimum temperature on the coldest day of the year. These four indicators of extreme temperature were analyzed for the period 1960–2012 as that is the longest period for which consistent daily records are available for the four stations analyzed here.

The number of hot days and maximum temperature on the hottest day of the year have changed little at Pinkham Notch and Hanover, but have decreased slightly in Berlin. Conversely, there is a significant reduction in the number of cold days at all three sites (trends ranging from -3.2 to -3.8 days per decade). The minimum temperature on the coldest day of the year at all four stations has also shown a significant increase of +1.3 to +2.0ºF per decade, consistent with the much greater warming in winter temperature compared to summer.

Length of the Growing Season

Since 1960, the length of the growing season in northern New Hampshire has increased by twelve to forty-two days.

While freezing temperatures affect all commercial, agricultural, industrial, recreational, and ecological systems, the human system most sensitive to changes in the length of the growing season is agriculture.[25] The length of the growing season is defined as the number of days between the last frost of spring and the first frost of winter. For our analysis, we have used a threshold of 28ºF for a hard frost. This period is called the growing season because it roughly marks the period during which plants, especially agricultural crops, grow most successfully. A late spring or early fall hard frost may lead to crop failure and economic misfortune for the farmer. Earlier starts to the growing season may provide an opportunity to diversify crops and create new opportunities for farmers with sufficient capital to take risks on new crops. A longer growing season may also result in increased frequency of heat stress, inadequate winter chill period, and increased pressure from invasive weeds, pests, or disease.

While it might seem that switching to alternative warm-season crops represents a beneficial response to a longer growing season, farmers would then have new competitors who might have advantages such as better soils and a yet longer growing season.[26] It is possible that a significant change in the length of the growing season could alter the ecology of the landscape across New Hampshire, including an increase in transpiration (release of water vapor from plants) and a consequent decrease in soil moisture,[27] perhaps necessitating more use of irrigation.

The length of the growing season has been getting longer across northern New Hampshire, and especially since the late 1980s (Figure 4), with a significant increase of +4.0 to +5.7 days per decade across northern New Hampshire (Table 3). Since 1960, the length of the growing season has therefore increased by two to three weeks.

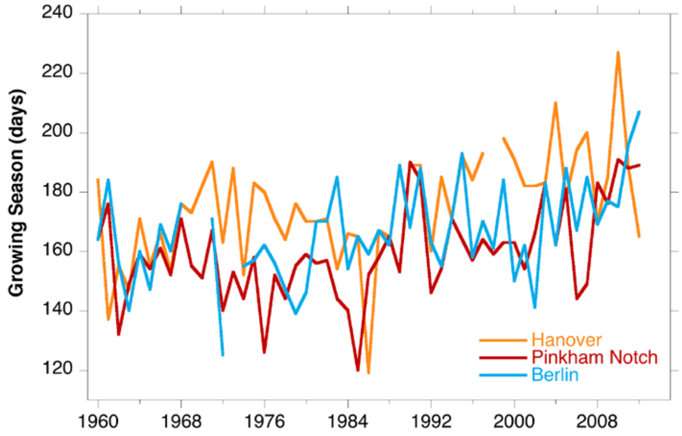


FIGURE 4. Length of the growing season for three GHCN-Daily stations in northern New Hampshire, 1960–2012.

Location	Growing Season	
	1960–2012 mean (days)	Trend (days/decade)
Berlin	168	**4.5**
Pinkham Notch	159	**4.0**
Hanover	176	**5.7**

TABLE 3. Length of growing season for three GHCN-Daily stations in northern New Hampshire for the period 1960–2012. Trends are estimated using Sen's slope; statistically significant trends (p<0.05) are highlighted in **bold and underlined.**

The impact of the increase in temperatures across New England is also documented by the changes in USDA plant hardiness zones, defined as the average annual minimum winter temperature, divided into 10°F zones.[28] As winter temperatures have risen over the past several decades (Table 1), an update of the 1990 USDA hardiness zone map in 2006 revealed a northward shift in hardiness zones, with approximately one-third of New Hampshire shifting to a warmer zone.[29] Across the northeast, lilacs, apples, and grapes also show earlier bloom dates, consistent with the warming trend across the region.[30]

Annual and Seasonal Precipitation Trends

Annual precipitation has increased slightly over the past century. However, over the past four decades, the rate of the increase is two to three times greater than the long-term average.

Temperature and precipitation trends are linked in the Earth's climate system by the hydrological cycle (Figure 5). Increases in precipitation may accompany increases in temperature because warmer air masses can hold more moisture. Regions with abundant moisture sources, such as New England, can therefore expect to see increases in the total amount and intensity of precipitation as temperatures continue to rise.[31]

Long-Term Precipitation Trends: 1895–2012

The USHCN historical precipitation records have undergone rigorous quality checks for outliers and missing values.[32] Over the period 1895–2012, Bethlehem and Hanover have experienced statistically significant increases in annual precipitation (Figure 6; Table 1). Seasonal trends are variable with Bethlehem showing the greatest significant increase in winter precipitation (0.14 inches per decade), and Hanover showing the

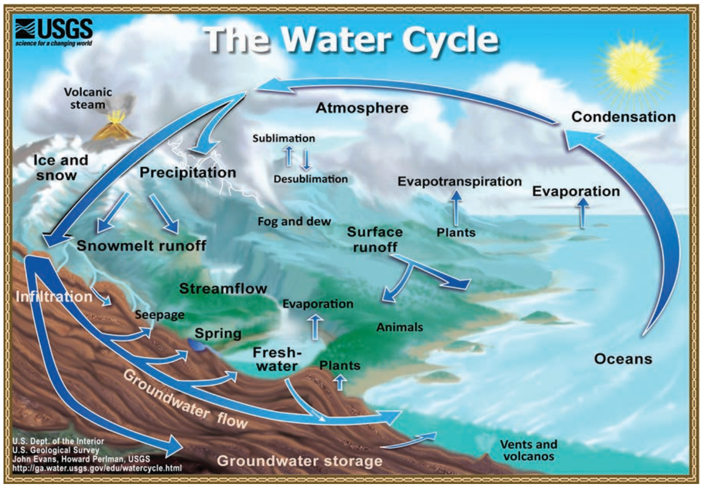


FIGURE 5. A schematic representation of Earth's water cycle that depicts the movement of water among key reservoirs (the oceans, atmosphere, snow and ice, lakes, groundwater) via key water cycle processes (evaporation, condensation, precipitation, transpiration, runoff, infiltration). Image from US Geological Survey (USGS). More information on the Earth's water cycle available online at: http://ga.water.usgs.gov/edu/watercycle.html.

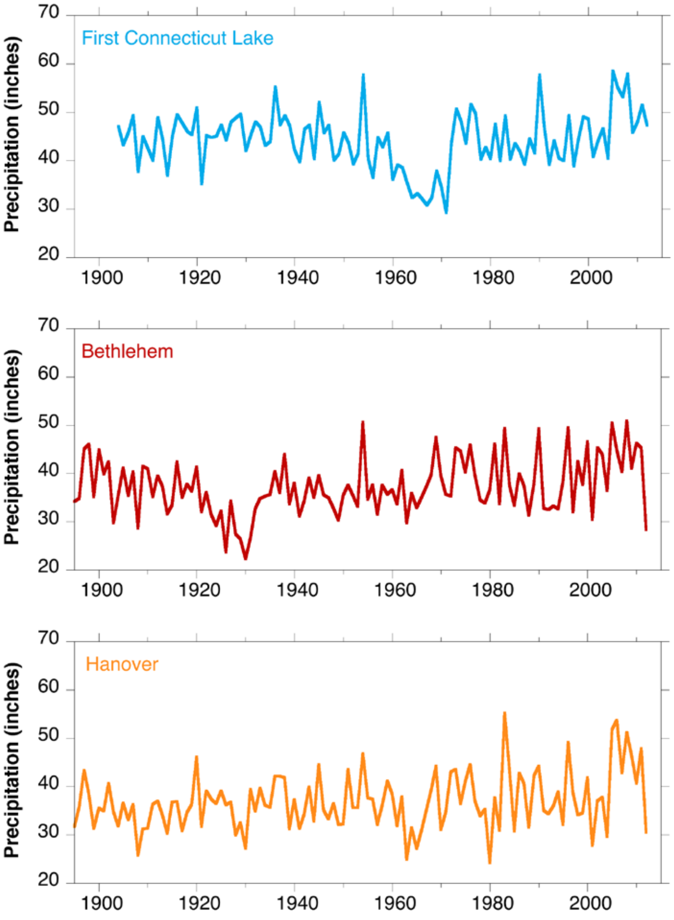


FIGURE 6. Annual precipitation records for USHCN stations in northern New Hampshire, 1895–2012.

greatest increase in fall precipitation (0.18 inches per decade). No significant trends are apparent in precipitation at First Connecticut Lakes. The First Connecticut Lakes and Hanover sites also show a consistent record of low precipitation during the mid-1960s, indicative of the region-wide drought that occurred at that time (Figure 6; also see Sidebar).

Recent Precipitation Trends: 1970–2012

Since 1970, all three stations show an increase in annual precipitation, although only the trend at First Connecticut Lake was significant (1.74 inches per decade; Table 1). The rate of increase in annual precipitation from 1970–2012 is substantially larger compared to the long-term (1895–2012) trend. These increasing trends in precipitation are being driven by higher than average precipitation totals over the last decade (Figure 6).

Seasonal precipitation (Table 1) show variable trends across the three sites; none of the trends are statistically significant. Decreases in winter precipitation at Bethlehem and Hanover are primarily the result of decreasing snowfall between December and February (see *Snowfall* section on page 17).

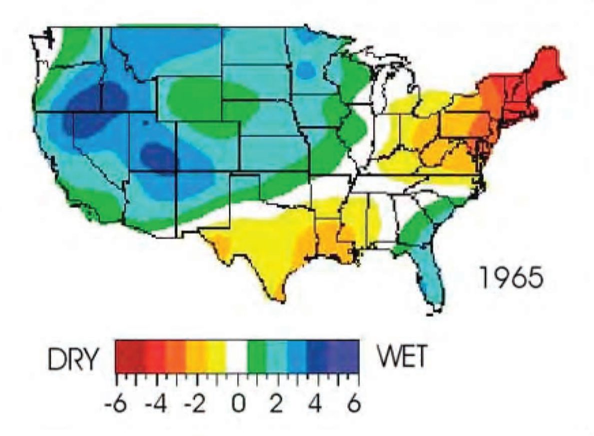
Extreme Precipitation Trends

The frequency of the most extreme precipitation events has either remained the same or increased since 1960, depending on the location of the station.

Climatologists have many metrics for defining a precipitation event as extreme. Using data from the USGCN-Daily stations, we quantify trends in three categories of extreme precipitation events: (1) greater than 1 inch in 24 hours, (2) greater than 4 inches in 48 hours, and (3) wettest day of the year.

Of the four USGCN-Daily stations in northern New Hampshire that have sufficiently complete data

1960s DROUGHT ACROSS THE NORTHEAST UNITED STATES[33]



The drought of the 1960s was the most severe drought experienced by New Hampshire and New England over the past several hundred years. The drought had numerous negative impacts, including severe water shortages, degraded water quality, fish kills, increases in the number and severity of forest fires, and severely degraded pasture conditions. Extreme drought conditions affected over 60,000 square miles by the summer of 1965, when the drought reached its peak.

Precipitation shortfalls during spring and summer were the primary cause of the drought, but what caused the decrease in precipitation? Prevailing circulation patterns showed an unusually deep mid-tropospheric trough positioned just off the Atlantic Seaboard that pulled northerly cold, dry air masses over the Northeastern United States. The exact causes of the unusual jet stream pattern remain a mystery, but some scientists have concluded that colder than average sea surface temperatures along the continental shelf triggered the drought pattern of the 1960s.

to be included in our analysis (see Appendix A for details), all show increasing trends in the number of events that produce more than 1 inch of precipitation (water equivalent) in 24 hours since 1960 (Table 4), although only the trends in Berlin (+1.0 events per decade) and Pinkham Notch (+1.2 events per decade) are significant. These results are consistent with previous analyses.[34] Similar spatial trends are apparent when records of the largest precipitation events are examined—those that produce over 4 inches of precipitation (water equivalent) in a 48-hour period, and which commonly result in flooding of our communities. Of the four stations in northern New Hampshire, two show an increase in the number of 4-inch precipitation events (Berlin and Pinkham Notch; Figure 7); no trend is apparent in the records from Errol and Hanover.

The amount of precipitation falling on the wettest day of the year is also rising (Table 4), with overall increases of about +0.8 to +0.19 inches per decade, equivalent to about half to one inch more rain on the wettest day of the year over the past five decades.

Location	1 inch in 24 hrs		Wettest Day of the Year	
	1960–2012 mean (events/yr)	Trend (events/decade)	1960–2012 mean (inches)	Trend (inches/decade)
Errol	6.0	0.3	1.93	**0.14**
Berlin	7.8	**1.0**	2.52	**0.15**
Pinkham Notch	15.1	**1.2**	3.61	0.19
Hanover	7.6	0.4	2.21	0.08

TABLE 4. Extreme precipitation trends (greater than 1 inch in 24 hours) and wettest day of the year trends for USGCN-Daily stations located in northern New Hampshire for the period 1960–2012. Trends are estimated using Sen's slope; statistically significant trends (p<0.05) are highlighted in **bold and underlined**.

Snowfall and Snow-Covered Day Trends

Overall, snowfall and the number of snow-covered days have decreased across northern New Hampshire since 1970.

If all else remains the same, warmer winters would be expected to reduce snowfall as more precipitation falls as rain versus snow. However, the response of snowfall trends to warmer winter temperatures is not

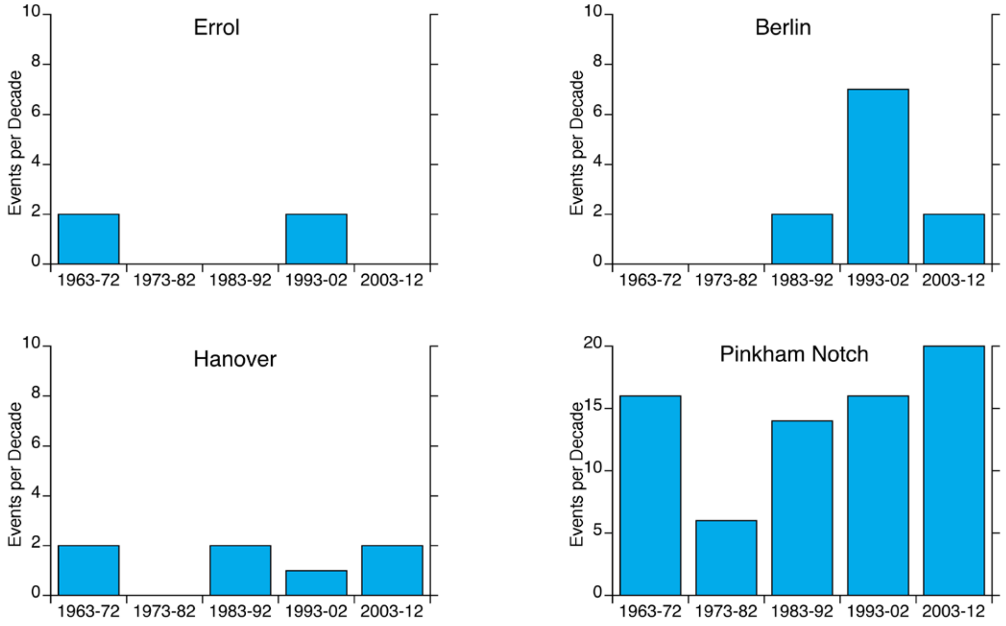


FIGURE 7. Trends in extreme precipitation events per decade (greater than 4 inches of precipitation in 48 hours) for four GHCN-Daily stations in northern New Hampshire, 1963–2012.

as straightforward as might be expected. Warmer air masses hold more moisture; as long as temperatures remain below freezing, snowfall can be expected and may even increase in a slightly warmer climate. Only when temperatures rise above the freezing point can the region expect to see less snowfall in response to winter warming.

Observations show large spatial variability in snowfall trends throughout the northeastern United States.[35] Using data from the USGCN-Daily stations in northern New Hampshire, we calculate winter snowfall totals as the sum of all daily snowfall values for the months of December, January, February, and March (Table 5). Although traditionally designated as a spring month, we also include March in the winter analysis because snowfall and snow depth totals in March typically exceed those observed in December.

Overall, ten northern New Hampshire stations show a decrease in snowfall ranging from -1.8 to -4.3 inches per decade since 1970, although none of the trends are statistically significant. Two stations show an increase in snowfall (+1.5 inches per decade at Lancaster and +3.2 inches per decade at Berlin; also not statistically significant trends) since 1970. Most of the reduction in snowfall is driven by decreases in December and March.

The number of snow-covered days in winter is closely tied to the amount of snowfall but also to temperature trends through feedback processes related to the high reflectivity (albedo) of freshly fallen snow (think of how bright it is after a snowstorm). Following a fresh snowfall event, the overall reflectivity of the ground decreases as the overlying snow pack melts, ages, and retreats. The retreat exposes bare ground that has a significantly lower albedo. The decrease in reflectivity causes a surface to warm as it absorbs more and reflects less of the sun's energy.

In this analysis, we consider a day "snow-covered" if the daily snow depth value is greater than 1 inch. Monthly snow-covered days for December to March are summed to calculate the total number of snow-covered days in a given winter.

Location	1970–2012 mean (inches)	Trend (inches/decade)
First Connecticut Lake	116.0	-3.9
Colebrook	74.1	-1.8
North Stratford	71.7	-2.5
Lancaster	63.4	1.5
Berlin	72.5	3.2
Pinkham Notch	105.4	-4.3
Benton	62.8	2.4
North Conway	73.5	-2.7
Plymouth	65.5	-3.1
Hanover	56.3	-3.4

TABLE 5. Annual mean snowfall amount and decadal trends for USGCN-Daily stations located in northern New Hampshire for the period 1970–2012. Stations list is sorted from north (top of the table) to south (bottom of the table). Trends are estimated using Sen's slope; statistically significant trends ($p<0.05$) are highlighted in **bold and underlined**.

Overall, the mean number of snow-covered days in northern New Hampshire has been decreasing at a rate of -1.5 days per decade (Table 6). Of the eight USGCN-Daily stations that have reliable snow cover data, only Colebrood shows statistically significant decreasing trends (-4.4 days per decade). Six other stations show decreasing trends, one station show no trend, and one station (Berlin) shows a weak increasing trend. The stations with decreasing trends are consistent with broader scale declines in North American mid-latitude snow cover extent quantified from analysis of satellite records.[36]

Lake Ice-Out Trends: First Connecticut Lake and Lake Umbagog

Since 1970, ice-out dates on Lakes First Connecticut Lake and Lake Umbagog are occurring about seven to ten days earlier.

Lake ice-out dates are frequently used as an indicator of winter/early spring climate change due to the close correlation with surface air temperature in the months before ice break-up.[37] Changes in the timing of lake ice-out can increase phytoplankton productivity[38] and subsequently deplete summer oxygen levels[39] as the phytoplankton blooms are decayed through bacterial respiration. Earlier ice-out dates also impact the ice fishing and snowmobiling industry by shortening the winter recreation season or, worse, eliminating it altogether during years when lakes do not ice over completely.

Records of lake ice-out have been kept on First Connecticut Lake since 1920, and reliably on Lake Umbagog since 1900. Overall, the ice-out dates have been getting earlier over the past century on Lake Umbagog, while on First Connecticut Lake the ice out dates got later during the 1970s. However, since 1970, ice-out dates are occurring on average about a week earlier on Lake Umbagog and ten days earlier on First Connecticut Lake. The recent trends of earlier ice-out dates on these two lakes are consistent with twenty-eight other long-term ice-out records from New Hampshire, Maine, and Massachusetts.[40] In addition, the ice extent on the Great Lakes has decreased substantially since 1973 due to warmer winters[41]; less ice corresponds with more open water, which can result in heavier lake-effect snow in regions downwind of the Great Lakes.

Impacts of Weather Disruption

One measure of the impact of weather disruption on New Hampshire is the money that the Federal Emergency Management Administration (FEMA) has spent on Presidentially Declared Disasters and Emergency Declaration (Figure 9).[42] From the period 1986 to 2004, there was only one event (the 1998 ice storm) where damages paid out by FEMA were greater than $10 million (in 2012 dollars). Conversely, five of the seven years between 2005 and 2012 had weather

Location	1970–2012 mean (days)	Trend (days/decade)
First Connecticut Lake	115	0.0
Colebrook	99	**<u>-4.4</u>**
Lancaster	98	-3.9
Berlin	96	1.3
Pinkham Notch	111	-0.4
Benton	82	-2.5
North Conway	96	-1.8
Hanover	85	-2.9

TABLE 6. Annual mean snow-covered days and decadal trends for USGCN-Daily stations located in northern New Hampshire for the period 1970–2012. Stations list is sorted from north (top of the table) to south (bottom of the table). Trends are estimated using Sen's slope; statistically significant trends (p<0.05) are highlighted in **<u>bold and underlined</u>**.

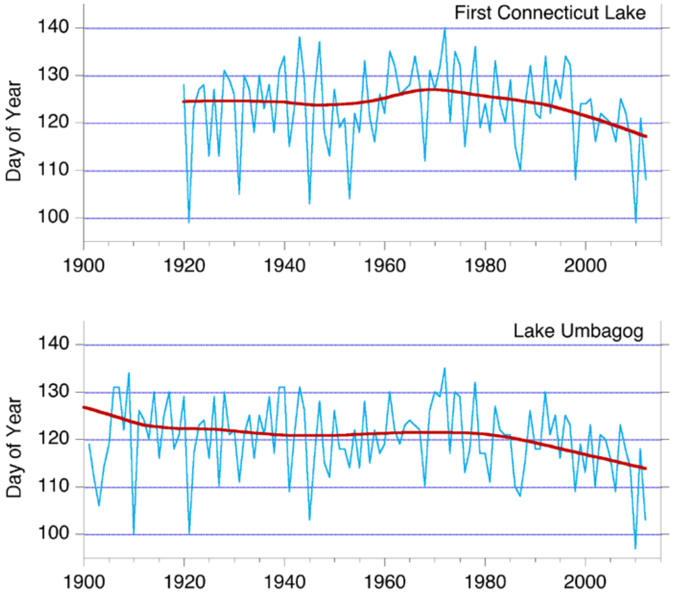


FIGURE 8. Annual ice-out dates (blue) in Julian days (number of days past January 1st) for First Connecticut Lake (1920–2012; top) and Lake Umbagog (1900–2012; bottom). Weighted smooth of the annual data shown in red.

events where damages paid out by FEMA were greater than $10 million (in 2012 dollars). The most significant damages between 2005 and 2012 resulted from floods and ice storms. The shift in 2005 is not only due to an increase in extreme weather events, but also reflects the fact that our infrastructure (buildings, roads, electrical grid) has been developed in ways that make them vulnerable to damage from these extreme events.

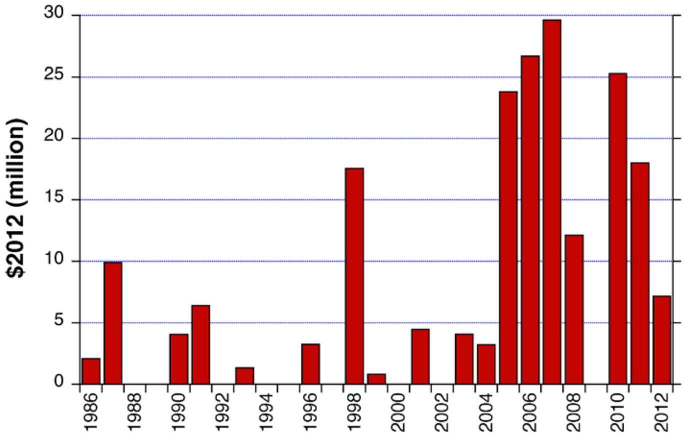


FIGURE 9. Federal expenditures on Presidentially Declared Disasters and Emergency Declarations in New England from 1999 to 2012. Expenditures adjusted to $2012 using the consumer price index. Note increase in expenditures since 2005.

III. FUTURE CLIMATE CHANGE

"Human-induced climate change is projected to continue and accelerate significantly if emissions of heat-trapping gases continue to increase. Heat-trapping gases already in the atmosphere have committed us to a hotter future with more climate-related impacts over the next few decades. The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases emitted globally, now and in the future."[43]

Projections of future climate were developed using four global climate models (GCMs)—complex, three-dimensional coupled models that incorporate the latest scientific understanding of the atmosphere, oceans, and Earth's surface—using two different scenarios of future global emissions of heat-trapping gases as input. The GCM simulations were then statistically downscaled using the Asynchronous Regional Regression Model.[44] Here, downscaling was conducted using the entire record from 1960 to 2012 to include as broad a range of observed variability as possible. Downscaling was conducted and tested using observed daily minimum and maximum temperature for fifteen GHCN-Daily stations in northern New Hampshire (south of latitude 43.9 N; Figure 10, Table 7) and observed 24-hour cumulative precipitation for twenty-three GHCN-Daily stations in northern New Hampshire (Figure 11, Table 8). Details of the methods used to develop projections of future climate, including global emission scenarios, GCMs, statistical downscaling model, and a discussion of uncertainty, are provided in Appendix A.

Station Name	Latitude (N)	Longitude	Elevation (ft)	StationID
First Connecticut Lake	45.09	-71.29	506	272999
Colebrook	44.86	-71.54	341	271647
York Pond	44.50	-71.33	466	279966
Lancaster	44.49	-71.57	262	274556
Berlin	44.45	-71.18	284	270690
Monroe	44.32	-72.00	201	275500
Bethlehem	44.31	-71.66	360	270706
Bethlehem2	44.28	-71.68	421	270703
Fabyan	44.27	-71.45	494	272898
Pinkham Notch	44.26	-71.26	613	276818
Benton	44.03	-71.95	366	270681
North Conway	44.03	-71.14	166	275995
Woodstock	43.98	-71.68	220	279940
Tamworth	43.90	-71.30	241	278612
Plymouth	43.78	-71.65	201	276945

TABLE 7. Location of fifteen GHCN-Daily stations in northern New Hampshire with minimum and maximum temperature data for the period 1960–2009 that were used to downscale Global Climate Model simulations. Station list is sorted from north (top of the table) to south (bottom of the table).

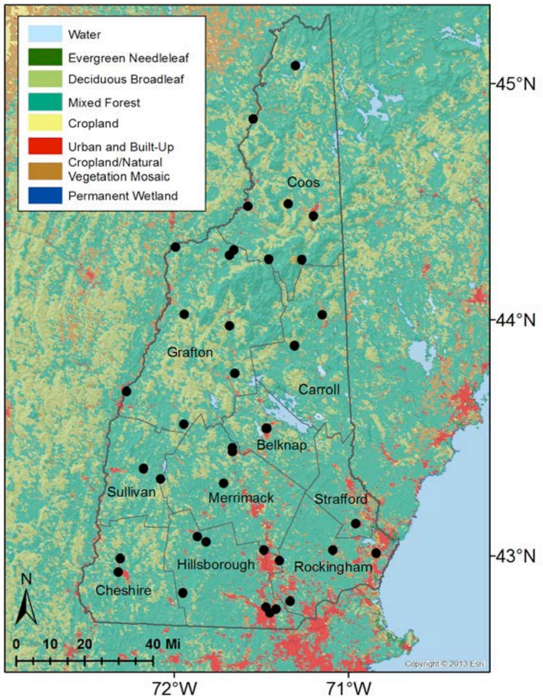


FIGURE 10. Location map for Global Historical Climatology Network (GHCN)-Daily stations (black dots) in New Hampshire with daily minimum and maximum temperature records. Data used to investigate climate change in northern New Hampshire comes from the fifteen stations above 43.75°N latitude.

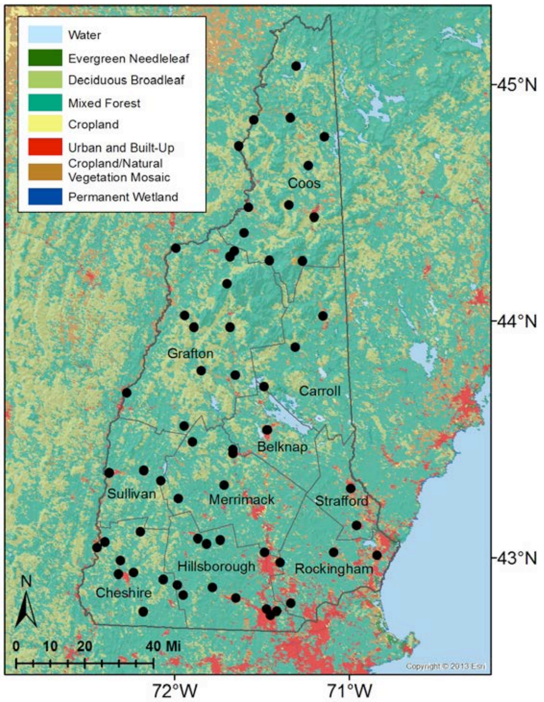


FIGURE 11. Location map for Global Historical Climatology Network (GHCN)-Daily stations (black dots) in New Hampshire with daily precipitation records. Data used to investigate climate change in northern New Hampshire comes from the twenty-three stations above 43.75°N latitude.

Station Name	Latitude (N)	Longitude	Elevation (ft)	StationID
First Connecticut Lake	45.09	-71.29	506	272999
Dixville Notch	44.87	-71.32	515	272023
Colebrook	44.86	-71.54	341	271647
Errol	44.79	-71.12	390	272842
North Stratford	44.75	-71.63	277	276234
Milan	44.67	-71.22	360	275400
York Pond	44.50	-71.33	466	279966
Lancaster	44.49	-71.57	262	274556
Berlin	44.45	-71.18	284	270690
Whitefield	44.38	-71.60	332	279618
Monroe	44.32	-72.00	201	275500
Bethlehem	44.31	-71.66	360	270706
Bethlehem2	44.28	-71.68	421	270703
Fabyan	44.27	-71.45	494	272898
Pinkham Notch	44.26	-71.26	613	276818
Cannon Mtn.	44.17	-71.70	1220	271187
Benton	44.03	-71.95	366	270681
North Conway	44.03	-71.14	166	275995
Glencliff	43.98	-71.89	329	273415
Woodstock	43.98	-71.68	220	279940
Tamworth	43.90	-71.30	241	278612
West Rumney	43.80	-71.85	171	279474
Plymouth	43.78	-71.65	201	276945

TABLE 8. Location of twenty-three GHCN-Daily stations in northern New Hampshire with precipitation data for the period 1960–2009 that were used to downscale Global Climate Model simulations. Station list is sorted from north (top of the table) to south (bottom of the table).

Future Annual and Seasonal Temperature

Average annual temperatures are projected to increase by about 2°F in the short-term (2010–2039). Over the long-term (2070–2099), the amount of projected warming under the higher emissions scenario (+8 to +9°F) is twice that compared to the lower emissions scenario (+4°F).

Temperatures in northern New Hampshire will continue to rise regardless of whether the future follows a lower or higher emissions scenario. This is due to two reasons: first, because some amount of change is already entailed by past emissions; and second, because it is impossible to stop all emissions of heat-trapping gases today and still supply society's energy needs. For both of those reasons, the warming expected over the next few decades is nearly identical under a higher or a lower scenario. However, it is clear that the magnitude of warming that can be expected after the middle of this century will depend on which emissions pathway is followed during the first-half of the century (Figure 12 and 13; Table 9).

During the first part of the twenty-first century (2010–2039), annual temperature increases are similar for the lower (B1) and higher (A1fi) emissions scenarios for maximum and minimum temperatures. The warming by 2040 (Figures 12 and 13) therefore represents an amount of warming that we have already baked into the climate system (regardless of the emissions scenario followed) and an amount of warming we need to begin preparing for and adapting to.

The magnitude of warming begins to diverge during the middle part of the century (2040–2069), with the higher emissions scenario resulting in greater rates and overall amounts of warming compared to the lower emissions scenario. Temperature increases under the higher emissions scenario are nearly twice that expected under the lower emissions scenario by the end of the twenty-first century (2070–2099). Overall,

CLIMATE GRIDS AND MAPS OF FUTURE CLIMATE CHANGE

Chapter III of this report discusses many of the projected changes in climate under a higher and a lower future scenario. Additional detailed information is provided in the climate grids (Appendix B), which contain historical and projected future 30-year climatologies for fifteen Global Historical Climatology Network-Daily (GHCN-Daily) meteorological stations in northern New Hampshire (that is, north of 43.75° north latitude) for the historical period (1980–2009) and the future (near-term [2010–2039], medium-term [2040–2069], and long-term [2070–2099]). The projected values represent the statistically downscaled average of daily simulations from four GCMs. Temporal averages were first calculated for each individual GCM, and then the results of all four GCMs were averaged. The climate grids include thirty-year averages of daily measures for minimum and maximum temperature (annual, seasonal, extremes), length of the growing season, precipitation (annual, seasonal, extremes), and snow-covered days.

In addition, maps (similar to those shown in Figures 15 and 19) for the state of New Hampshire for all twenty-five climate indicators listed in Table 9 for the historical time period and for three thirty-year time periods in the future can be viewed online at the New Hampshire Experimental Program to Stimulate Competitive Research (EPSCoR)—Data Discovery Center.[45]

northern New Hampshire can expect to see increases in annual maximum and minimum temperature ranging from +4°F to +9°F by 2070–2099.

Historically, average winter temperatures showed the greatest warming over the past four decades.[46] While annual and seasonal maximum temperatures all increase, the largest increase occurs in the summer seasons for both the higher emissions scenario (+9.6°F by end of century) and spring for the lower emissions scenario (+6.6°F by end of century). Minimum temperatures experience the largest increase in winter (+10.7°F by end of century, higher emission scenario) and spring (+6.2°F by end of century, lower emission scenario).

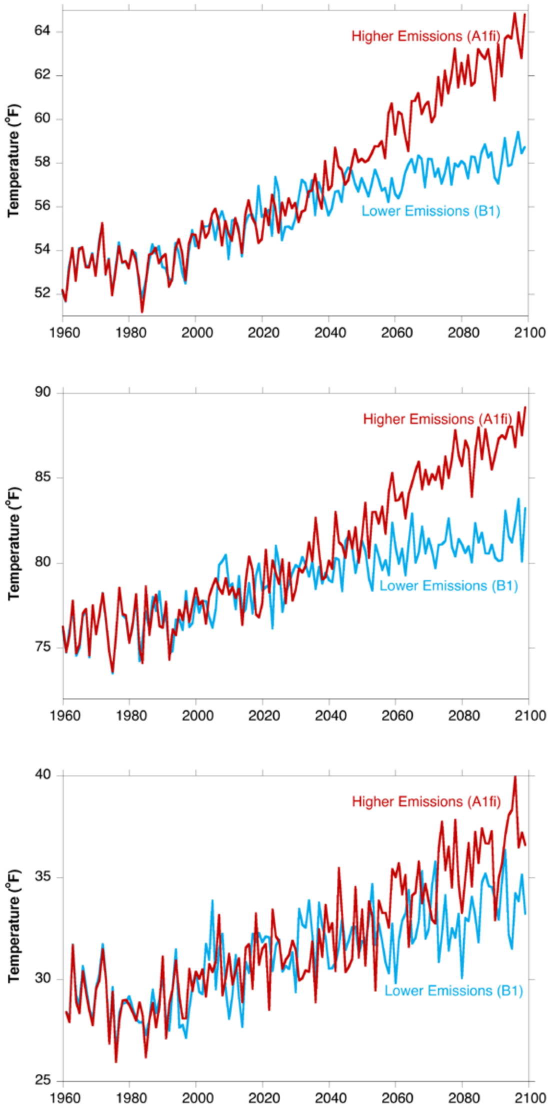


FIGURE 12. Modeled *maximum* temperatures for northern New Hampshire (averaged over fifteen sites) from the higher emission scenario (A1fi; red line) and lower mission scenario (B1; blue line) for a) annual (top), b) summer (middle), and c) winter (bottom), 1960–2099.

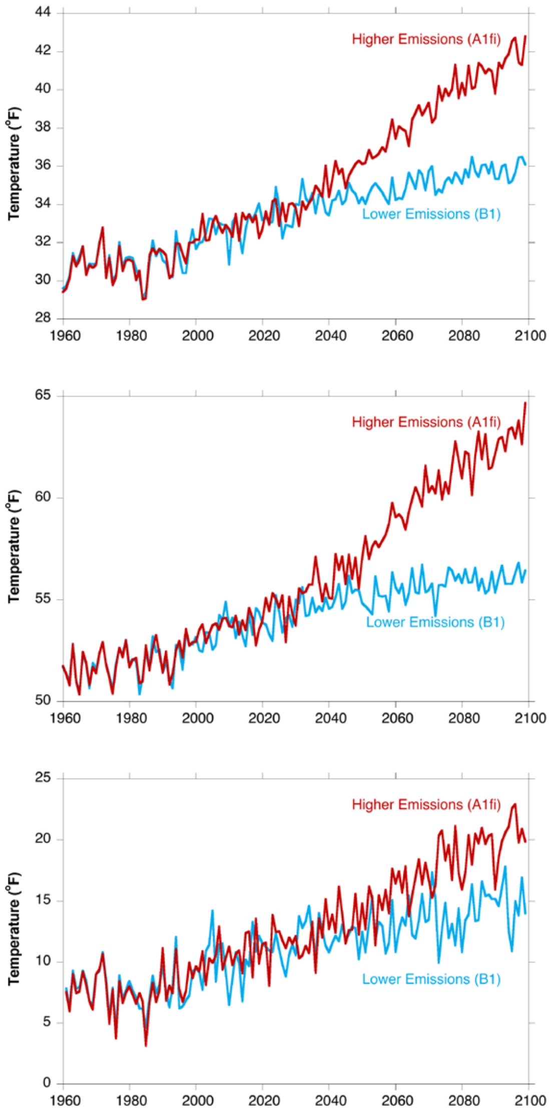


FIGURE 13. Modeled *minimum* temperatures for northern New Hampshire (averaged over fifteen sites) from the higher emission scenario (A1fi; red line) and lower mission scenario (B1; blue line) for a) annual (top), b) summer (middle), and c) winter (bottom), 1960–2099.

With regard to climate impacts, the projected increases in northern New Hampshire winter maximum and minimum temperature will very likely push regional average winter temperatures above the freezing point. With average winter temperatures above freezing, the region can expect to see a greater proportion of winter precipitation falling as rain (as opposed to snow), earlier lake ice-out dates, and a decrease in the number of days with snow cover. Warmer summer temperatures will likely lead to an increase in drought (through increased evaporation, heat waves, and more frequent and extreme convective precipitation events).

Future Extreme Temperature

As temperatures increase in northern New Hampshire, the number of very hot days is expected to become more frequent and the hottest days hotter, while extreme cold is expected to become less frequent and the coldest days less severe.

Extreme Heat

Increases in extreme heat are calculated using three metrics: (1) number of days above 90°F, (2) number of days above 95°F, and (3) average temperature on the hottest day of the year (Table 9). During the historical baseline period from 1970–1999, northern New Hampshire experienced, on average, three to four days per year above 90°F each year, with fewer hot days at sites in the far northern regions of New Hampshire (for example, Colebrook; Figure 14). By 2070–2099, northern New Hampshire on average can expect fourteen days per year with daytime maximum temperatures above 90°F under the lower emissions scenario and over thirty-eight days per year under the higher emissions scenario, about eight to nine times the historical average (Figure 14). Under the higher emissions scenario, North Conway would experience almost sixty days per summer with temperatures above 90°F, essentially making two-thirds of the summer a prolonged heat wave. Under the lower emissions scenario, Manchester would experience twenty-five

IMPACTS OF FUTURE CLIMATE CHANGE ON NORTHERN NEW HAMPSHIRE

This report provides a detailed assessment of how climate will change across northern New Hampshire depending on the levels of future emissions of heat-trapping gases from human activities. The next step is to examine how climate change will impact the region's environment, ecosystem services, economy, and society. A detailed analysis of the impacts of climate change in northern New Hampshire is beyond the scope of this report. Fortunately, there is a wealth of analysis on the potential impacts of climate change across New England and the northeast United States provided in the reports and peer-reviewed scientific papers written as part of the Northeast Climate Impacts Assessment (NECIA).[47] The NECIA Executive Summary, Full Report, and state-based analysis are all available on the NECIA website.[48]

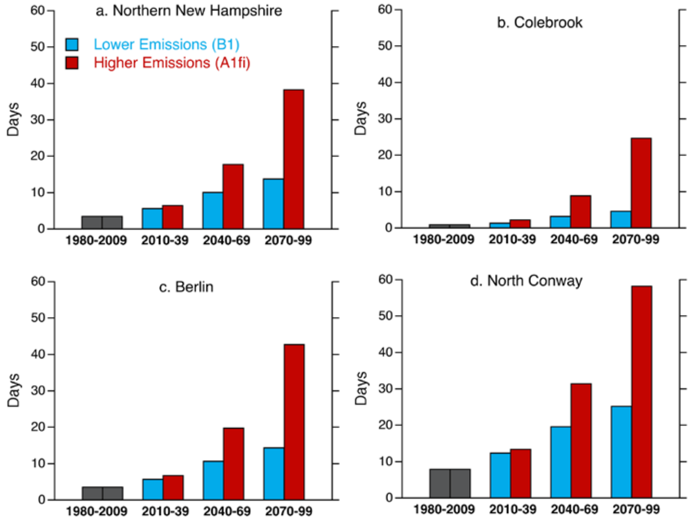


FIGURE 14. Historical (grey) and projected lower emissions (blue) and higher emissions (red) average number of days above 90°F per year, shown as thirty-year averages for a) northern New Hampshire (average of fifteen stations), b) Colebrook, c) Berlin, and d) North Conway.

days per summer with temperatures above 90°F.

Between 1980–2009, extreme daytime maximum temperatures above 95°F were historically rare, occurring on average less than one day per year across northern New Hampshire. Under the lower emissions scenario, northern New Hampshire can expect to experience three days per year above 95°F (Table 9). Under the higher emissions scenario, the number of days above 95°F is expected to increase to thirteen days per year by end of century.

As the number of extremely hot days per year increases, the average daytime maximum temperature on the hottest day of the year is also expected to increase (Figure 15). By the 2070–2099 period, the temperature on the hottest day of the year could climb to 95°F under the lower emissions scenario and upwards of 100°F under the higher emissions scenario compared to the historical average of 91°F.

Extreme Cold

Increases in extreme cold are calculated using three metrics: (1) number of days below 32°F, (2) number of days below 0°F, and (3) average nighttime minimum temperature on the coldest day of the year. Over the period 1980–2009, northern New Hampshire experienced on average 178 days per year with nighttime minimum temperatures below 32°F (Table 9), roughly the length of the winter season from November through April. Over the next century, these numbers are expected to decrease considerably. By the end of the century, northern New Hampshire could experience forty-five fewer days per year with minimum temperatures below 32°F under the higher emissions scenario, or about a 25 percent decline. Under the lower emissions scenario, twenty fewer days per year are expected, or about an 11 percent decline by end of century.

Decreases in the number of extreme cold days below 0°F are more noticeable compared to days below 32°F. Northern New Hampshire currently experiences on average twenty-eight days per year when minimum temperatures fall below 0°F (Table 9). That number will be halved by 2070–2099 to about thirteen days per year under the lower emissions scenario, and only

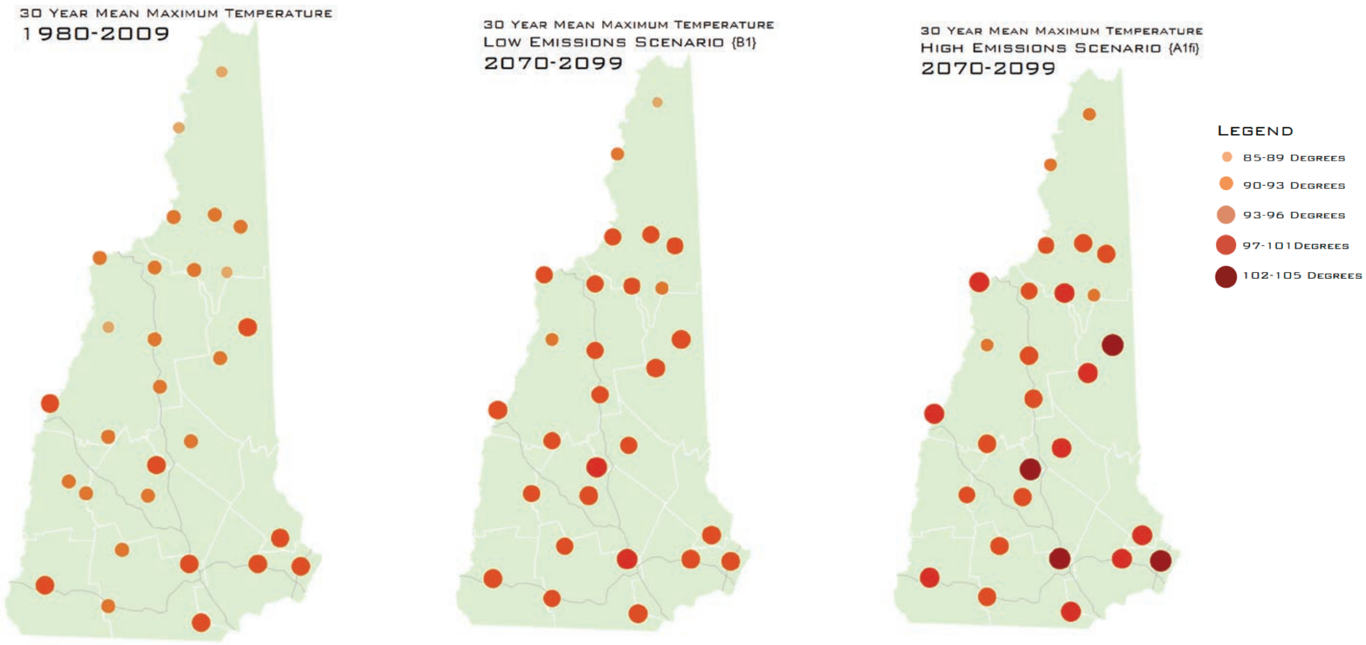


FIGURE 15. Historical (top) and projected (2070–2099) lower emissions (bottom left) and higher emissions (bottom right) average maximum temperature per year across New Hampshire.

seven days under the higher emissions scenario. By the end of the twenty-first century, results indicate a decrease of 76 percent under the higher emissions scenario and a decrease of 48 percent under the lower emissions scenario in the number of days with minimum temperatures less than 0°F.

The average nighttime minimum temperature on the coldest day of the year in northern New Hampshire currently averages -22°F. This is projected to gradually warm over this century. By the end of the century, the minimum temperature per year is expected to warm +8°F under lower emissions and +18°F under higher emissions (Table 9).

Future Growing Season

By the end of the century, the growing season is projected to lengthen by about twenty-one days under the lower emission scenario or fifty days under the higher emission scenario. However, hotter temperatures, reduced chilling hours, enhanced evapotranspiration, and more extreme precipitation will likely result in a decrease in crop yields.

A longer growing season may provide opportunities for farmers to grow new crops that require a longer (frost-free) growing season. However, analysis of the impact of future climate on agricultural production indicates that many crops will have yield losses associated with increased frequency of high temperature stress, inadequate winter chill period for optimum fruiting, and increased pressure from invasive weeds, insects, or disease that are currently not a significant factor in New Hampshire.[49] Furthermore, several weeds are likely to benefit more than crops from higher temperatures and increasing concentrations of atmospheric carbon dioxide.[50] Another concern involves the northward spread of invasive weeds like privet and kudzu, which are already present in the South.[51] More hot days also indicate a substantial potential negative impact on milk production from dairy cows, as milk production decreases with an increase in the thermal heat index.[52] Higher CO_2 levels result in stronger growth and more toxicity in poison ivy,[53] while higher temperatures combined with higher CO_2 levels also lead to substantial increases in aeroallergens that have significant implication for human health.[54]

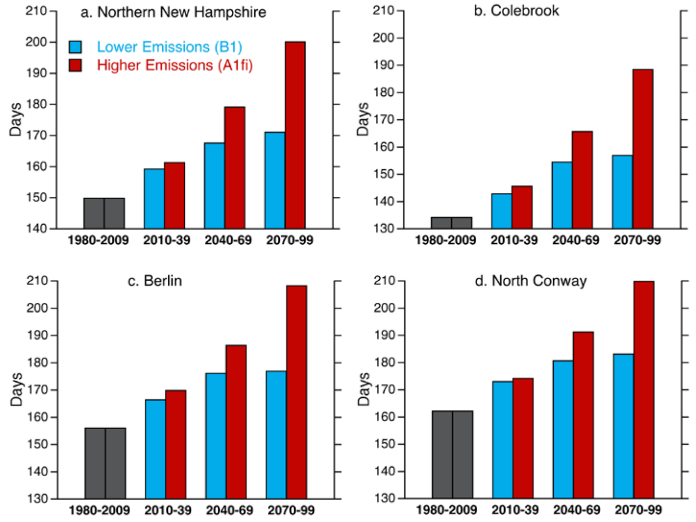


FIGURE 16. Historical (grey) and projected lower emissions (blue) and higher emissions (red) average length of the growing season (using a threshold of 28°F), shown as thirty-year averages for a) northern New Hampshire (average of fifteen stations), b) Colebrook), c) Berlin, and d) North Conway.

The length of the growing season will continue to increase under both emission scenarios (Figure 16). In the short term (2010–2039), the average growing season is likely to be extended by nine to ten days across northern New Hampshire, an increase of about 6 percent. By the end of the century, the growing season is projected to increase by twenty-one days under the lower emission scenarios (14 percent increase) to fifty days under the higher emissions scenario (30 percent).

Northern New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	31.5	1.9	2.1	3.1	5.4	4.1	9.2
Winter TMIN	8.5	2.6	2.9	4.1	6.4	5.7	10.7
Spring TMIN	29.3	3.2	1.7	5.0	4.6	6.2	8.0
Summer TMIN	52.5	1.6	2.1	2.8	5.5	3.4	9.5
Fall TMIN	37.5	0.2	1.8	0.5	5.1	1.0	8.5
Maximum Temperature (°F)							
Annual TMAX	53.9	1.8	1.8	3.2	5.0	4.3	8.5
Winter TMAX	29.3	2.0	1.8	2.8	3.9	4.1	6.7
Spring TMAX	52.6	2.5	1.6	4.9	4.8	6.6	8.8
Summer TMAX	77.0	1.8	2.1	3.4	5.8	4.2	9.6
Fall TMAX	56.4	1.0	1.7	1.4	5.5	1.6	8.7
Temperature Extreme (days per year)							
<32°F	178.0	-9.7	-11.3	-16.5	-26.3	-20.2	-45.5
<0°F	28.0	-7.1	-7.0	-11.0	-15.8	-13.4	-21.2
>90°F	3.4	2.3	3.0	6.7	14.4	10.3	34.9
>95°F	0.4	0.3	0.6	1.2	3.6	2.3	12.5
Temperature Extreme (°F)							
TMAX on hottest day of year	90.8	1.7	1.5	2.8	4.9	4.1	8.8
TMIN on coldest day of year	-21.8	4.0	4.2	5.9	10.4	7.9	18.3
Growing Season (days)	150	9	11	18	29	21	50
Precipitation (inches)							
Annual mean	43.2	3.5	2.2	4.4	5.2	6.2	7.3
Winter mean	8.9	1.1	0.9	1.3	1.5	1.8	2.4
Spring mean	10.1	1.0	0.8	1.7	1.6	1.9	2.5
Summer mean	12.6	1.4	0.4	0.6	1.4	1.9	0.7
Fall mean	11.5	0.1	0.2	0.9	0.9	0.8	1.7
Extreme Precipitation (events per year)							
1” in 24 hrs	8.1	1.1	1.1	1.8	2.3	2.4	4.7
2” in 48 hours	2.8	1.3	1.3	0.3	2.4	1.4	4.9
Extreme Precipitation (events per decade)							
4” in 48 hours	2.5	1.9	1.2	1.9	3.0	4.0	6.3
Snow-Covered Days	144	-14.6	-5.0	-19.3	-21.1	-27.3	-42.2

TABLE 9. Climate grid with historical and projected future 30-year climatologies for temperature (fifteen stations) and precipitation (twenty-three stations) variables averaged across northern New Hampshire (i.e., north of 43.75° north latitude). Daily meteorological data was not available for all sites for the entire period of record, so the historical values (1980–2009) in these tables were derived from the downscaled GCM simulations. A climate grid for each of the fifteen GHCN-Daily stations that recorded both temperature and precipitation are provided in Appendix B.

Future Precipitation

The amount of annual precipitation is projected to continue to increase over this century.

Future trends in annual and seasonal precipitation point toward wetter conditions in northern New Hampshire over the coming century, continuing the historical trend observed over the past four decades. Annual precipitation is projected to increase 14 to 16 percent under both emission scenarios by the end of the century, slightly more under the high emissions scenario compared to the low emissions scenario by the end of the century (Figure 17; Table 9). Under both emission scenarios, precipitation increases are largest during winter and spring.

Future Extreme Precipitation and Drought

The frequency of extreme precipitation events is projected to more than double by the end of the century under both lower and higher emission scenarios.

There are potential benefits that may result from an increase in total annual precipitation—alleviation of scarce water resources, less reliance on irrigation, and increased resilience to drought. In a world where freshwater resources will likely be stressed by the combination of precipitation reductions and warmer temperatures in some regions (for example, the south-western United States[55]) and increasing demand, increases in annual precipitation could be extremely valuable in many respects for New Hampshire and New England. However, those benefits may not occur if the increase in precipitation is primarily the result of an increase in extreme precipitation events, which can lead to excessive runoff, flooding, damage to critical infrastructure (including buildings, roads,

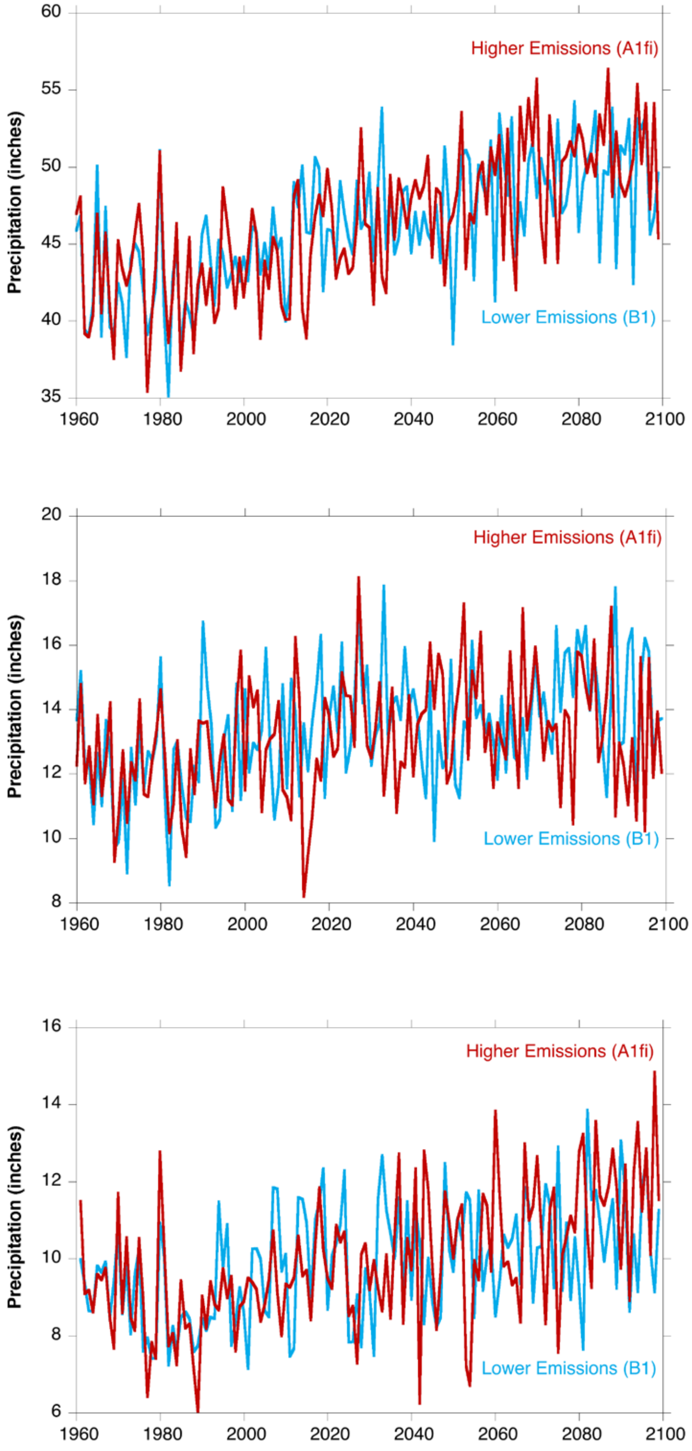


FIGURE 17. Historical and projected a) annual (top), b) summer (middle), and c) winter (bottom) *precipitation* for northern New Hampshire (averaged over twenty-three sites) from the higher emission scenario (A1fi; red line) and lower mission scenario (B1; blue line), 1960–2099.

dams, bridges, and culverts), increased erosion, and degradation of water quality.

The same three metrics described in the historical analysis are presented for higher and lower future emissions scenarios: (1) greater than 1 inch in 24 hours, (2) greater than 4 inches in 48 hours, and (3) wettest day of the year (Table 9). For all three metrics, it is clear that northern New Hampshire can expect to see more extreme precipitation events in the future, and more extreme precipitation events under the higher emissions scenario relative to the lower emissions scenario.

Historically, northern New Hampshire experienced 8.1 events per year with greater than 1 inch of precipitation in 24 hours. By 2070–2099, that will increase to 10.5 events under the lower emissions scenario and to 12.8 events for the higher emissions scenario. For events with greater than 2 inches in 48 hours, northern New Hampshire averaged 2.8 events per year from 1980–2009, but that will increase to 3.2 events per year under the lower emissions scenario and triple to 7.7 events per year under the higher emissions scenario. However, the largest changes are projected to occur for the more extreme precipitation events, here defined as greater than 4 inches in 48 hours. These events are expected to increase from the current 2.5 events per decade (again, averaged across northern New Hampshire; see Figure 7 for an example of the large spatial variability of these events across the region) to more than 6.5 events per decade under the lower emissions scenario, and 8.8 events per decade under the higher emissions scenario (Figures 18 and 19).

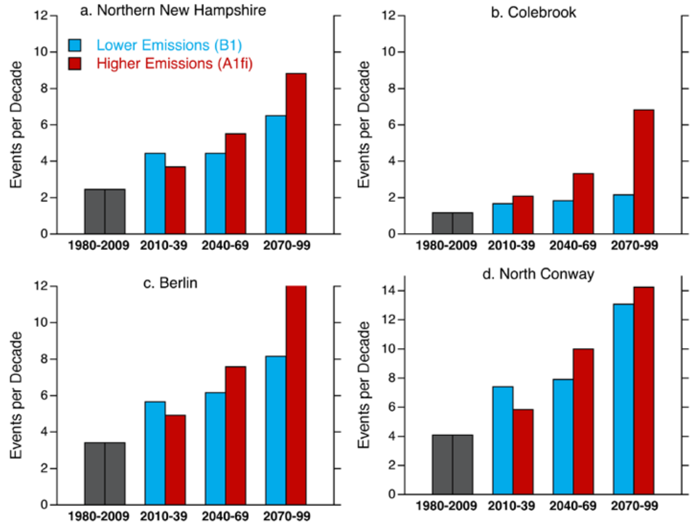


FIGURE 18. Historical (grey) and projected lower emissions (blue) and higher emissions (red) average number of precipitation events per decade with more than 4 inches of rain in forty-eight hours, shown as thirty-year averages for a) northern New Hampshire (average of twenty-three stations), b) Colebrook, c) Berlin, and d) North Conway.

No new analysis of future drought was performed for this report. However, hydrologic simulations from the Variable Infiltration Capacity (VIC) model are available, which use the same GCM inputs as the analysis presented in this report.[56] VIC is a hydrological model that simulates the full water and energy balance at the Earth's surface and provides a daily measure of soil moisture resulting from a broad range of hydrological processes, including precipitation and evaporation. Based on VIC simulations of soil moisture, a drought event was defined as the number of consecutive months with soil moisture percentile values less than 10 percent, with droughts being classified as short- (one to three months), medium- (three to six months), and long-term (six plus months). The results[57] indicate that over the long-term (2070–2099) under the higher emissions scenario, New Hampshire, New England, and upstate New York can expect to experience a two- to three-fold increase in the frequency of short-term drought and more significant increases in medium-term drought. These droughts are driven primarily by an increase in evapotranspiration resulting from hotter summers. Under the lower emissions scenario, the frequency of short- and medium-term drought increases only slightly by the end of the century, while under the high-emission scenario, the frequency of short-term drought across northern New Hampshire doubles or triples. The frequency of long-term drought does not change substantially across New Hampshire in the future under either emissions scenario compared to the frequency of long-term drought in the past.

The projections of hotter summers and more frequent short- and medium-term droughts suggest potentially serious impacts on water supply and agriculture. Even very short water deficits (on the order of one to four weeks) during critical growth stages can have profound effects on plant productivity and reproductive success. During a drought, evapotranspiration continues to draw on surface water resources, further depleting supply. As a water deficit deepens, productivity of natural vegetation and agriculture drops. The projected drought also poses a risk to the summertime drinking water supply across the region.

Future Snow Cover

By the end of the century, snow-covered days are projected to decrease by 20 percent under the lower emissions scenario or 50 percent under the higher emissions scenario.

Changes in future snow cover will depend on both temperature and precipitation. As shown earlier, the projected increases in winter maximum and minimum temperature in northern New Hampshire will very likely push the regional average winter temperatures above the freezing point by the end of the twenty-first century. This suggests that a greater proportion of winter precipitation will fall as rain as opposed to snow. At the same time, precipitation is expected to increase in winter and spring, potentially increasing total snowfall in the near term as long as below-freezing temperatures continue to occur on days when precipitation is falling. Projected changes in the

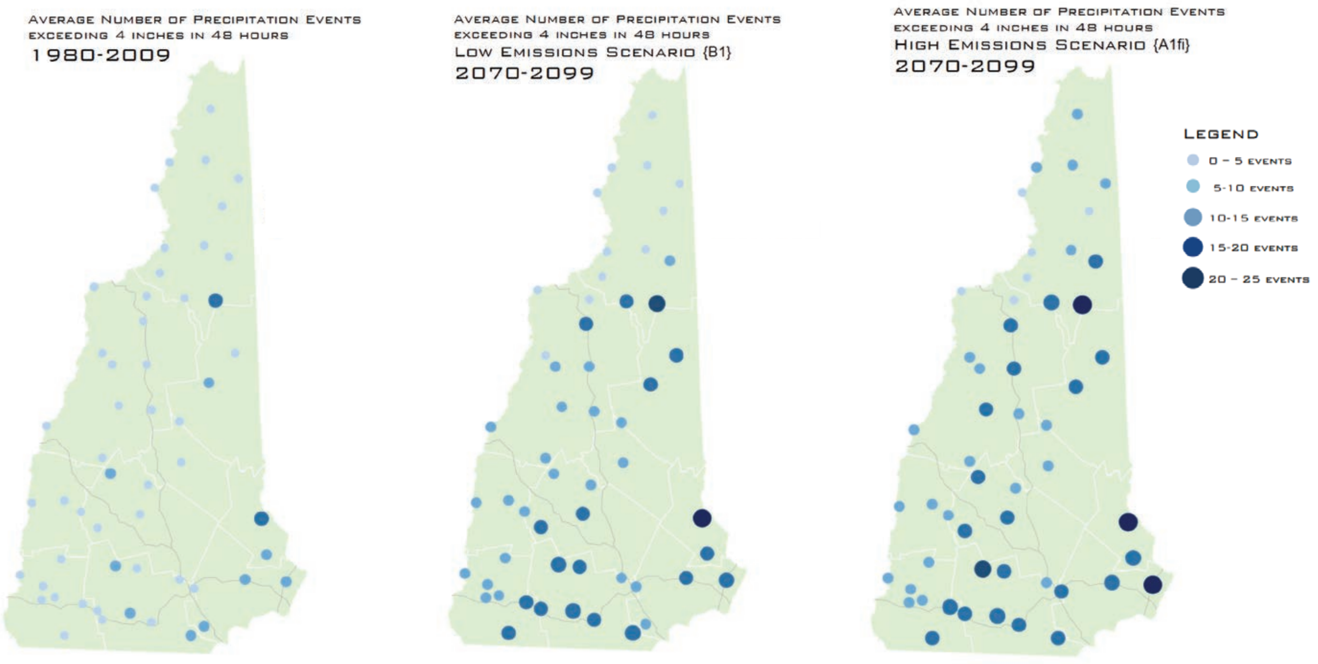


FIGURE 19. Historical (left) and projected (2070–2099) lower emissions (center) and higher emissions (right) average number of precipitation events per year that drop greater than 4 inches in 48 hours across New Hampshire.

number of winter days with snow cover (greater than 1 inch) are examined for short- (2010–2039), medium- (2040–2069), and long-term (2070–2099) to evaluate which factor will dominate: temperature increases (which will decrease snow cover days) or precipitation increases (which would potentially increase snow cover days if the temperature remains below freezing).

Over the long-term, the influence of warming winter and spring temperatures will dominate over expected increases in winter precipitation. This means that the number of snow-covered days is projected to decrease for the rest of this century under both emissions scenarios (Figure 20; Table 9). Historically, northern New Hampshire experienced on average 144 days per year with snow cover. During the early part of the century, decreases in snow-covered days are expected to drop to 130–140 days. This trend continues through mid-century. By 2070–2099, snow-covered days are projected to number 117 days under the low emissions scenarios, and drop to 102 days (a reduction of 30 percent) under the higher emissions scenario.

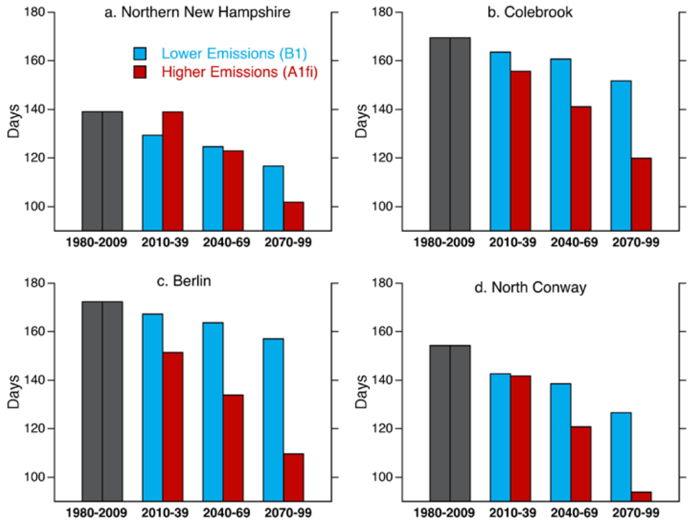


FIGURE 20. Historical (grey) and projected lower emissions (blue) and higher emissions (red) average snow-covered days, shown as thirty-year averages, for a) northern New Hampshire (average of twenty-three stations), b) Colebrook, c) Berlin, and d) North Conway.

IV. HOW CAN NEW HAMPSHIRE'S COMMUNITIES RESPOND?

"America's response to climate change is ultimately about making choices in the face of risks: choosing, for example, how, how much, and when to reduce greenhouse gas emissions and to increase the resilience of human and natural systems to climate change." [58]

The results presented in Chapters II and III of this report (with results for specific towns in northern New Hampshire summarized in Appendix B), combined with the findings of recent regional,[59] national,[60] and international[61] assessments, summarize the risks posed by climate change and provide strong motivation for assessing and implementing a wide range of proactive anticipatory and response efforts. A pressing need for significant action to limit the magnitude of climate change (via mitigation) and to prepare for its impacts (via adaptation) is clearly warranted given the environmental, economic, and humanitarian risks associated with our changing climate.[62]

Mitigation and Adaptation

There are two broad responses for dealing with our changing climate: 1) mitigation of climate change through the reduction of emissions of heat-trapping gases and enhancing carbon sinks (for example, enhancing and preserving carbon storage in forests and soils), and 2) adaptation to the impacts of climate change, which refers to preparing and planning for climate change to better respond to new conditions, thereby reducing harm and disruption and/or taking advantage of opportunities. Mitigation and adaptation are linked; effective mitigation reduces the need for adaptation. Both are essential parts of a comprehensive dual-path response strategy.

Mitigation and adaptation at the global and continental level have been comprehensively addressed in the IPCC 2007 Working Group II (Impacts, Adaptation, and Vulnerability) and Working Group III (Mitigation of Climate Change) Fourth Assessment Reports.[63] More recent research will be summarized in the IPCC Fifth Assessment Reports from Working Groups II and III due out in the spring of 2014.[64] On the national level, a series of reports on America's Climate Choices and the recent National Climate Assessment provide advice on the most effective steps and most promising strategies that can be taken to respond to climate change, including adaptation and mitigation efforts.[65]

Effective responses aimed at reducing the risks of climate change to natural and human systems involve a portfolio of diverse adaptation and mitigation strategies. Even the most stringent mitigation efforts will not alleviate the climate change we have committed to over the next two-to-three decades (due to the long lived nature of carbon dioxide already in the atmosphere combined with the inertia within the climate system), which makes adaptation critical. Conversely, without significant mitigation efforts, a magnitude of climate change will very likely be reached that will make adaptation impossible for some natural systems, and many human systems will exact very high social and economic costs. A dual-path strategy of pursuing and integrating mitigation and adaptation strategies will reduce the negative consequences resulting from future climate change to a far greater extent than pursuing either path alone or doing nothing at all.

Mitigation

The single most effective adaptation strategy is mitigation of climate change through the reduction of emissions of heat-trapping gases. As is clearly illustrated by the very different climate futures that result from a higher emission versus a lower emission scenario, reducing emissions of heat-trapping gases reduces the amount of change to which we have to adapt. To be effective, mitigation requires concerted efforts from individuals, communities, businesses, not-for-profits, and governments (municipal, state, and federal), locally, nationally, and abroad. Such mitigation measures range from protecting our forests and soils (for carbon sequestration) to increasing energy efficiency in buildings, electricity generation, transportation systems, and other infrastructure to increasing the amount of energy produced from renewable sources.

The New Hampshire Climate Action Plan[66] was developed via the combination of a highly collaborative process involving hundreds of diverse stakeholders, transparent quantitative analysis, and application of decision-relevant information.[67] The plan calls for a reduction in greenhouse gas emissions of 20 percent below 1990 emissions by 2025, and 80 percent below 1990 emissions by 2050.[68] To move toward this long-term goal and provide the greatest economic opportunity to the state of New Hampshire, the Climate Action Plan recommends sixty-seven actions to:

- Reduce greenhouse gas emissions from buildings, electric generation, and transportation
- Protect our natural resources to maintain and enhance the amount of carbon sequestered
- Support regional and national initiatives to reduce greenhouse gases
- Develop an integrated education, outreach, and workforce-training program
- Adapt to existing and potential climate change impacts

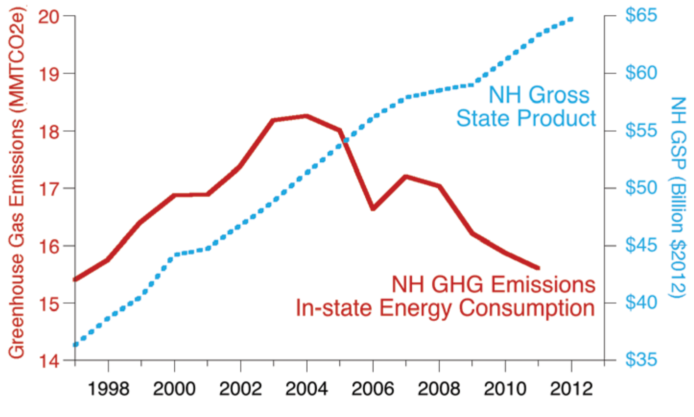


FIGURE 21. Comparison of New Hampshire's greenhouse gas emissions (red) versus its Gross State Product (blue) (see endnote 69 for more information), 1997–2012.

These actions serve not only to reduce emissions of heat trapping gases, but also to support a wide range of economic development. In fact, following an initial investment period, almost all of the recommendations provide a net positive economic benefit to the state of New Hampshire.

The New Hampshire Energy and Climate Collaborative is tracking progress toward meeting key targets set forth in the Climate Action Plan.[69] Overall, New Hampshire has experienced a decline in overall emissions of heat-trapping gases since 2004, even while the state gross product has continued to rise (Figure 21). This separation of economic growth from emissions of heat-trapping gases is exactly what must continue if we are to achieve the vision for emissions reduction targets set out in New Hampshire's 2009 Climate Action Plan, while also providing economic opportunities for New Hampshire residents.

A few examples of successful mitigation efforts in New Hampshire include the Regional Greenhouse Gas Initiative, the Greenhouse Gas Emission Reduction Fund, Better Buildings project, NH Energy Efficiency Core programs, New Hampshire Office of Energy and Planning, Jordan Institute energy efficiency projects, University of New Hampshire EcoLine, 2009 Corporate Fuel Efficiency Standards, and Revolution Energy and ReVision Energy projects.[70] Additional recommendations for energy efficiency and renewable energy projects are provided in the Independent Study of Energy Policy Issues Report[71] and subsequent New Hampshire Energy Efficiency and Sustainable Energy (EESE) Board recommendations.[72]

Adaptation

Adaptation is the second key component of a dual-path strategy that serves as an effective response to the risks posed by climate change. Adaptation for communities essentially involves preparing and planning for the expected impacts of climate change to avoid, manage, and/or reduce the consequences.

Climate change affects everything from transportation, infrastructure, land use, and natural resources to recreation, public health and safety, and sense of place. Fortunately for New Hampshire communities, there are opportunities for adaptation available within existing planning and regulatory processes. Virtually every community member is either a stakeholder or an implementer. Gathering and applying local knowledge concerning the impacts and consequences of weather disruption will enhance the effectiveness of local adaptation. Every community should discuss, analyze, and then determine which adaptation strategies to implement based on its specific vulnerabilities to climate change and local economic, environmental, and social conditions. Therefore efforts to address climate change should seek input, participation, and support from all members of your community. This may be achieved through specific outreach to neighborhoods or interest groups, municipal meetings, or through larger community events.

> ***"Efforts to address climate change should seek input, participation, and support from all members of your community. This may be achieved through specific outreach to neighborhoods or interest groups, municipal meetings, or through larger community events."***

Adaptation strategies to protect the built environment fall into four broad categories:

No Action: To do nothing. This approach ignores the risks posed by climate change and continues a "business as usual" response.

Protect and Fortify: To keep an asset in place for a period of time. For flood protection, this commonly involves building physical barriers such as levees, berms, flood/tide gates, or sea walls. Protection is likely to be a common approach in low-lying population centers due to extensive development and investment. These strategies should be viewed as short-term solutions that do not necessarily improve community resilience (for example, when a physical barrier such as a levee fails, the impacts can be devastating).

Accommodate: To retrofit existing structures and/or design them to withstand specific extreme weather events. Freeboard requirements in building codes are a common accommodation strategy (essentially putting a building on stilts). This approach provides a safety factor and avoids damage by requiring that structures be elevated above a certain flood elevation, such as the 100-year flood elevation.

Retreat: To relocate or phase-out development in hazardous areas. In existing flood-prone areas, retreat can be the most effective and long-term solution. While a rightly contested option, it may be best supplemented with a "wait and see" approach within areas identified as vulnerable in the future, commonly after a triggering event or when a particular threshold is reached (for example, when an asset in a high-risk area is damaged by over 50 percent of its original value and it is then relocated rather than repaired).

Adaptation actions may be implemented immediately or as iterative or delayed actions:

Here and Now: Actions taken in the near-term to build or improve existing infrastructure so that it is robust and resilient to a range of climate conditions. This approach may also involve the preparation of plans to implement future actions.

Prepare and Monitor: Options are identified to preserve assets and climate conditions are monitored so that appropriate response actions can be taken in the future.

In preparing a phased adaptive management strategy, policy and decision makers must recognize the tradeoffs between selecting one action over another (that is, investing now to protect for the long-term versus cost over time and risk associated with delaying such action). Sustained actions and investment need to be weighed against changing climate conditions over the long-term with incremental investment to protect and accommodate changing climate conditions in the short-term. Integrated actions that build upon one another to increase resiliency and decrease risk and vulnerability are preferred. Adaptation often provides both co-benefits and no-regrets actions. *Co-Benefits* refers to integrated efforts to address climate change impacts through proactive actions and mitigation that result in building capacity, resiliency, and protection of assets and resources that can also meet economic, societal, and environmental needs. For example, preserving floodplain forests and coastal buffers provides a carbon sink (mitigation) and keeps development out of a high-risk area (proactive adaptation), while also providing benefits to wildlife, recreation, sense of place, and more. *No Regrets* refers to actions that generate direct or indirect benefits that are large enough to offset the costs of implementing the options. For example, siting new infrastructure in areas that have no or low risk of flooding today and are not projected to be flooded in the future.

Planning Framework and Approaches for Adaptation

Using the climate assessment (such as this report) as a foundation, communities should conduct a vulnerability assessment of local assets and resources that can help guide common sense and flexible adaptation strategies and recommendations for local governments, businesses, and citizens to enable them to implement appropriate programs, policies, regulations, and business practices (Figure 22). Analysis and data from a vulnerability assessment can help identify priority assets, actions, and planning needs or identify deficits in data, information, or processes necessary to move forward in adapting to climate change. Once the vulnerability assessment is complete, communities should develop a flexible,

FIGURE 22. Key steps for moving from a climate assessment to local and regional adaptation plans.

staged, adaptation plan that is periodically updated and designed to be easily integrated into existing plans, policies, or practices. Communities also need to ensure that future development is consistent with the plan.

The Granite State Future project has developed a framework for the range of planning issues for New Hampshire communities as they prepare for and respond to climate change.[73] Material culled from that document relating to community planning is provided below.

> ***"Using the climate assessment as a foundation, communities should then conduct a vulnerability assessment of local assets and resources that can help guide common sense and flexible adaptation strategies and recommendations for local governments, businesses, and citizens to enable them to implement appropriate programs, policies, regulations, and business practices."***

To leverage the effectiveness and benefits of climate adaptation, key strategies and actions should be institutionalized across all levels of regional and local planning. As a matter of efficiency and practicality, planning for climate change should utilize existing plans, policies, and practices with the goal of reorienting them using the "climate lens" to incorporate future projected conditions or the new climate normal. Because state statute gives municipalities broad authority to regulate, significant components of climate adaptation planning will occur at the local level. To accomplish this, effective adaptation planning should seek to:

- Identify vulnerable assets and resources
- Guide planning, regulation, and policies at all scales
- Inform prioritization of state, regional, and private investments in areas at risk to future conditions
- Identify possible strategies and actions that provide economic, social, and environmental benefits
- Protect public health and safety
- Improve community awareness about the region's changing climate
- Preserve regional and community character and ensure sustainable outcomes

Planning Strategies

Ultimately, planning for climate change means using the wide range of planning tools and procedures available to integrate climate adaptation across all sectors. Just as the dual path of mitigation and adaptation are central to addressing climate change, a comprehensive multi-pronged planning approach is critical for ensuring that decisions are balanced, equitable, and long-lasting. It is equally important to recognize the values and benefits that ecosystem services provide for human enjoyment and survival. However, inevitably "tradeoffs" will be necessary to achieve desired goals and priorities. Following are examples of planning strategies that support comprehensive and effective implementation of climate adaptation. Many of these strategies can easily be combined or include mitigation strategies.

- Integrate planning for transportation, land use, human health, natural resources, and ecosystem services
- Integrate zoning, land use, and resource conservation—environmental and floodplain regulation, conservation subdivision incentives in high-risk areas, village center zoning, transfer of development rights, open space, and land preservation
- Encourage Sustainability and Smart Growth planning (mixed use development and village development, conservation/open space subdivision, alternative transportation access, and preservation of agricultural lands)

- Conduct a Municipal Audit to identify barriers and incentives to implement climate change planning and adaptation at the local level (zoning, regulations, and master plan)
- Encourage integration of climate change into local plans—master plans, hazard mitigation plans, open space/land conservation plans, and regional health assessments
- Adopt long-range infrastructure investments and improvements into capital improvement plans (CIPs) and maintenance plans
- Encourage municipal participation in the FEMA Community Rating System[74] to reduce flood insurance premiums
- Encourage cooperative agreements among municipalities (that is, for water and sewer services; equipment and inspectional staff/consultants; and integrated transportation, land use, and environment planning)
- Community participation and support (warrant articles, budget, and voluntary stewardship)
- Develop an action plan for regional implementation of recommended actions from the NH Climate Action Plan

Community Engagement and Laying the Foundation for Implementation

This section provides examples of how some New Hampshire communities have begun discussions and planning around adaptation. They also provide examples of external expertise and other support that is available.

Dover: Climate Change Role Play Simulation[75]

City officials and project partners gathered area residents to participate in a series of “climate change games,” wherein people experience the challenge of negotiating through climate change planning while playing the role of a city official or resident. The goal of this effort was to assess local climate change risks, identify key challenges and opportunities for adaptation, and to test the use of role-play simulations as a means to engage the community about climate change threats while exploring ways of decreasing its vulnerability to climate change impacts. Dover was one of four towns participating in the National Oceanic and Atmospheric Administration (NOAA) funded New England Climate Adaptation Network.

Hampton, Hampton Falls, and Seabrook: Planning for Sea Level Rise[76]

With funding support from EPA’s Climate Ready Estuaries Program, three communities of the Hampton-Seabrook Estuary used a cost-benefit analysis tool to evaluate potential impacts from storm surge and sea level rise to private real estate and public facilities. This effort considered lower and higher global emission and resulting climate change scenarios, the costs and benefits of taking action, and when it makes the most sense to implement adaptation strategies. As a result of their collaborative approach, the communities identified shared concerns and priorities such as preserving marshes to buffer shorefront properties from coastal storms, and a need to further consider climate change as a three-town working group.

Newfields: Extreme Weather Preparedness Action Plan[77]

The small coastal town of Newfields developed an extreme weather preparedness action plan. To begin, local leaders convened over thirty-five community members for dinner and discussion following a presentation of local climate change research from the University of New Hampshire. This information formed the basis for a series of small roundtable discussions about: (1) how extreme weather affects the people of Newfields and their natural resources and infrastructure, and (2) what possible actions the town could take to reduce these impacts. Two focus areas emerged (stormwater management and emergency preparedness), and community members continued to meet for six months to finalize an action plan to increase resiliency.

As a result, the town developed and immediately began implementing eighteen action items, including a discount generator purchase program led by the Chief of Police and an updated stormwater management regulation led by the planning board.

Exeter: Climate Adaptation Plan[78]

The Climate Adaptation Plan for Exeter (CAPE) initiative aspires to create a flexible science-based plan for managing local impacts to infrastructure, public safety, and natural resources (for example, fisheries, stormwater, and water quality). Residents and leaders of the "Citizens Working Group" worked closely with the science team to ensure the plan was informed by local concerns and priorities. The broader community was engaged periodically through large "community conversation" gatherings and presentations to town boards.

Durham: Climate Adaptation Chapter for Hazard Mitigation Plan[79]

The Town of Durham's "Leadership Team" developed a climate adaptation chapter for its Hazard Mitigation Plan. The plan provides a broad overview assessment of likely impacts from sea level rise and areas likely to experience future increases in flooding. The plan also outlines over a dozen regulatory and non-regulatory approaches appropriate for the community to take as next steps.

Lamprey River Watershed: Assessing Flood Risk[80]

Both the magnitude and frequency of freshwater flooding is on the rise in seacoast New Hampshire and around much of New England. This NOAA-funded research and outreach project analyzed changes in the extent of the 100-year floodplain in the Lamprey River watershed and projected future changes based on different scenarios of land use and climate change. The results clearly show that the 100-year floodplain and associated peak flood water discharge, as well as flood water surface elevations, have increased significantly between the production of the effective Flood Insurance Rate Maps (FIRMs, based on discharge data from 1935–1987) to current (2005) conditions, and will continue to increase in the future under the build-out scenarios developed as part of this research. Low impact development zoning was shown to have its greatest mitigation value in terms of resiliency in high impervious cover areas. This increase in the 100-year floodplain and 100-year flood discharge has important ramifications for natural resources, human well-being, emergency management, planning, and infrastructure. In addition, the risk of municipal legal liability associated with using the new 100-year floodplain maps is low, so long as municipalities follow sound planning principles.

City of Portsmouth, Coastal Resiliency Initiative[81]

The Coastal Resilience Initiative is the City of Portsmouth's first look at the potential impact from a changing climate focusing on impacts of sea level rise and coastal storm surge. The objectives of the study were to:

- Describe the range of climate change and sea level rise scenarios that researchers have identified for the New Hampshire Seacoast region

- Map four sea level elevations to show how these scenarios would impact the City of Portsmouth in the next forty to ninety years
- Using these maps, identify physical assets (buildings and infrastructure) and natural resources that are vulnerable to sea level rise and coastal storm surge
- Develop preliminary strategies for adapting to future conditions, as well as estimates of the costs of these adaptation actions
- Provide recommendations to guide adaptation planning, including policies and regulations

The study products include a set of flood elevation maps, a vulnerability assessment, a preliminary outline of potential adaptation strategies, and recommendations for future planning, regulation, and policies. This report represents a starting point for the city to identify avenues to implement adaptation measures that impart resiliency in the built environmental and protect natural systems.

Keene Cities for Climate Protection (CPC) Committee[82]

The Keene City Council officially created the CPC Committee in 2000. Its mission is to aid in the reduction of greenhouse gas emissions and increase the community's adaptive capacity to the expected impacts of a changing climate in order to protect the viability of the community and to protect public health, safety, and welfare. The city has adopted both a Climate Change Action Plan and a Climate Change Adaptation Action Plan, both of which are being implemented.

ADDITIONAL RESOURCES FOR ADAPTATION TO CLIMATE CHANGE

The Adaptation Toolkit for New Hampshire Communities[83] provides communities with a path to plan for future extreme weather events.

The Climate Adaptation Knowledge Exchange[84] features a vast library of concise case studies of climate adaptation from around the country and the world. It also provides links to funding sources for adaptation.

Extreme Precipitation in New York and New England[85] provides an updated extreme precipitation analysis via an interactive web tool.

Forging the Link: Linking the Economic Benefits of Low Impact Development and Community Decisions[86] documents, through a series of case studies, the advantages of Low Impact Development in the economic terms of how municipal land use decisions are commonly made.

The Georgetown Climate Center[87] provides resources to help communities prepare for climate change, including the Adaptation Clearinghouse, Adaptation Tool Kits, lessons learned, and case studies.

Home Grown: The Economic Impact of Local Food Systems in New Hampshire[88] seeks to provide an answer to the question: What are local, healthy foods, and the food system that supports them, worth?

The Infrastructure and Climate Network[89] (ICNet) is dedicated to accelerating climate science and engineering research in the Northeastern United States. It focuses on climate change and sea level rise impacts and adaptation for sustainable bridges, roads, and transportation networks.

ADDITIONAL RESOURCES FOR ADAPTATION TO CLIMATE CHANGE (CONTINUED)

New Hampshire Building Energy Code Compliance Roadmap Report[90] maps out New Hampshire's existing energy code landscape, identifies barriers to energy code compliance across the state's residential and commercial building sectors, and presents a plan outlining New Hampshire-specific recommendations for achieving 90 percent energy code compliance by 2017.

NH Granit[91] is New Hampshire's Statewide Geographic Information System Clearinghouse. It offers an array of geospatial services, including: data development and distribution, spatial analysis, online mapping (including 100-year flood plain maps), cartography, and related technical services.

New Hampshire Lives on Water[92] is the final report of the New Hampshire Water Sustainability Commission and makes recommendations to ensure that the quality and quantity of New Hampshire's water in twenty-five years is as good as or better than it is today.

New Hampshire Local Energy Solutions[93] provides a gateway to information and resources that promote local energy solutions in New Hampshire. It is intended to empower those on energy committees, in municipalities, and schools to tackle the complexities of reducing our reliance on fossil fuel energy.

New Hampshire Office of Energy and Planning—Cost of Sprawl Tool[94] has been designed as a decision-support tool for New Hampshire's local and regional planners to evaluate the financial impact on local governments related to new development.

New Hampshire's Changing Landscape[95] explores the relationships between population growth, land use change, and the impact of development upon the state's natural resources, including our forest and agricultural lands, critical water supply resources, and biodiversity.

The **New Hampshire Storm Smart Coast**[96] provides a well developed example of a web resource dedicated to helping community decision makers address the challenges of storms, flooding, sea level rise, and climate change. The website also features efforts by the NH Coastal Adaptation Workgroup (NHCAW), a collaboration of nineteen organizations working to help communities in New Hampshire's Seacoast area prepare for the effects of extreme weather events and other effects of long-term climate change. NHCAW provides communities with education, facilitation, and guidance.

Transportation and Climate Change Clearinghouse[97] is the U.S. Department of Transportation website that provides information on transportation and climate change.

The **Upper Valley Adaptation Workgroup**[98] is building climate resilient communities in the Upper Valley through research, information sharing, and education.

V. CONCLUSIONS

An extensive and growing body of scientific evidence clearly shows that global climate is changing, and that human activities are the primary driver of that change over the past four decades. Climate change is already affecting the northeast United States and northern New Hampshire in many ways. Temperatures have begun to rise, particularly in winter. Precipitation is increasing, as is the frequency of extreme precipitation events. Lake ice-out dates are occurring earlier.

These and many other trends are projected to continue in the future. With few exceptions, much greater changes are anticipated under a higher emissions scenario as compared to a lower emissions scenario. In other words, depending on the amount of heat trapping gases that human activities pump into the atmosphere, annual average temperatures in northern New Hampshire could increase between 4°F and 9°F before the end of the twenty-first century. Warmer temperatures mean increased frequency of extreme heat events and decreases in extreme cold and days. Precipitation, especially in winter and spring, is expected to rise, as is the frequency of extreme precipitation events, exacerbating the risk of flooding. Snow-covered days are expected to decrease.

Because climate change is already affecting northern New Hampshire, and some additional warming is inevitable, it is essential to prepare to adapt to the changes that cannot be avoided. However, immediate and committed action to reduce emissions is the most effective means to keep future climate changes at those projected under the lower emissions scenario. The more we can reduce our fossil fuel emissions, the more ecosystems, human communities, and economic sectors will be able to adapt to those coming changes we cannot avoid.

> ***"Because climate change is already affecting northern New Hampshire, and some additional warming is inevitable, it is essential to prepare to adapt to the changes that cannot be avoided. However, immediate and committed action to reduce emissions is the most effective means to keep future climate changes at those projected under the lower emissions scenario. The more we can reduce our fossil fuel emissions, the more ecosystems, human communities, and economic sectors will be able to adapt to those coming changes we cannot avoid."***

APPENDIX A. METHODS

Historical Climate Change

To quantify historical trends in temperature and precipitation across New Hampshire, we used data from two high-quality meteorological data sets. Monthly temperature and precipitation observations for the time period 1895–2012 for three stations across northern New Hampshire (Figure 1; Hanover, Bethlehem, and First Connecticut Lake) come from the U.S. Historical Climatology Network (USHCN) Version 2.5.[99] The observations from the USHCN data sets have been subjected to numerous quality assurance and quality control procedures that have corrected temperature records for time-of-observation biases and other non-climatic changes such as station relocations, instrument changes, changes in observer, and urban heat island effects through homogeneity testing.[100]

Daily temperature and precipitation observations are available for many stations across New Hampshire from the Global Historical Climatology Network-Daily (GHCN-Daily) Version 3.02-upd-2013051005[101]; these daily temperature records have been subjected to a number of quality assurance and quality control procedures[102] and have been homogenized.[103] We only used GHCN-Daily data for stations that had near complete records for the time period 1960—2012 (meteorological data from the GHCN-Daily data set prior to 1960 for New Hampshire were limited). For temperature and total precipitation, we excluded a year of data from our analysis if more than 10% of the data was missing for that year for a particular station. We also excluded the entire station from our analysis if more than 10% of the years were missing. For snowfall and snow-covered days, the criteria we used for temperature eliminated all of the stations from our analysis. We therefore used different criteria for records of snowfall and snow-covered days: we excluded a year of data from our analysis if more than 20% of the data was missing for that year for a particular station. We also excluded the entire station from our analysis if more than 20% of years were missing.

All of the data we used in our analysis of historical climate trends across New Hampshire are available from the New Hampshire Experimental Program to Stimulate Competitive Research (EPSCoR)—Data Discover Center.[104]

All historical climate trends are calculated using Sen's slope[105] and expressed as change in units per decade. Sen's estimation of slope is succinctly described as the median slope of all possible slopes in an evenly spaced time series. As such, it provides a more robust trend estimation than the commonly used least squares linear regression, which may be sensitive to the start and end dates in a time series. The statistical significance of the slope is evaluated using the Mann-Kendall non-parametric test. Trends are considered statistically significant if $p<0.05$.

Historical Global Climate Model (GCM) Simulations and Future Emission Scenarios

Historical climate model simulations use external forcings or climate drivers (including atmospheric levels of greenhouse gases, solar radiation, and volcanic eruptions) consistent with observed values for each year of the simulation. The historical forcings used by the GCM simulations presented in this report are the Coupled Model Intercomparison Project's "20th Century Climate in Coupled Models" or 20C3M total forcing scenarios.[106] These simulations provide the closest approximation to actual climate forcing from the beginning of the historical simulation to the year 2000.

The historical simulation provides the starting conditions for simulations of future climate. To ensure the accuracy of the historical forcing scenario, it is customary in the climate modeling community for historical simulations to end at least five years before present. So although the GCM simulations were typically conducted after 2005, the historical total-forcing scenario ends and "future" scenarios begin in 2000. In the future scenarios, most external natural climate drivers are fixed, and human emissions correspond to a range of plausible pathways rather than observed values.

Future emissions scenarios depend on a myriad of factors, including: how human societies and economies develop over the coming decades; what technological advances are expected; which energy sources will be used in the future to generate electricity, power, transportation, and serve industry; and how all of these choices affect future emissions from human activities.

To address these questions, in 2000 the Intergovernmental Panel on Climate Change (IPCC) developed a series of scenarios described in the Special Report on Emissions Scenarios (SRES).[107] These scenarios describe internally consistent pathways of future societal development and corresponding emissions.

This analysis used the SRES emission scenarios A1fi higher and B1 lower emissions scenarios (Figure A1). These scenarios were chosen because they cover a broad range of plausible futures in terms of human emissions of carbon dioxide and other radiatively active species and resulting impacts on climate. At the higher end of the range, the SRES high emissions or fossil fuel intensive scenario (A1fi for fossil-intensive) represents a world with fossil fuel-intensive economic growth and a global population that peaks mid-century and then declines. New and more efficient technologies are introduced toward the end of the century. In this scenario, atmospheric CO_2 concentrations reach 940 parts per million by 2100, more than triple pre-industrial levels of 280 ppm. At the lower end, the SRES low emissions scenario (B1) also represents a world with high economic growth and a global population that peaks mid-century and then declines. However, this scenario includes a shift to less fossil fuel-intensive industries and the introduction of clean and resource-efficient technologies. Emissions of greenhouse gases peak around mid-century and then decline. Atmospheric carbon dioxide levels reach 550 parts per million by 2100, about double pre-industrial levels. Associated global temperature changes by end-of-century range from 4 to 9°F based on the best estimate of climate sensitivity.

As diverse as they are, the SRES scenarios do not cover the entire range of possible futures. Since 2000, CO2 emissions have already been increasing at an

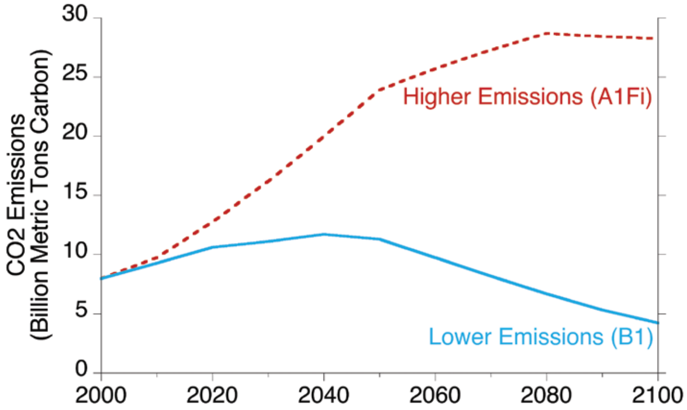


FIGURE A1. Projected future global emissions of carbon dioxide from fossil fuel burning for the "high emissions" (A1fi, red) and "low emissions" (B1, blue) scenarios. Data from endnote reference #107.

average rate of 3 percent per year. If they continue at this rate, emissions will eventually outpace even the highest of the SRES scenarios.[108] On the other hand, significant investments in renewable energy and energy efficiency could reduce CO2 emissions below the lower B1 emission scenario within a few decades.[109] Nonetheless, the substantial difference between the high- versus the low-emission scenarios used here provides a good illustration of the potential range of changes that could be expected, and how much these depend on future emissions and human choices.

Global Climate Models (GCMs)

Future emission scenarios are used as input to GCMs, complex, three-dimensional coupled models that continually evolve to incorporate the latest scientific understanding of the atmosphere, oceans, and Earth's surface. As output, GCMs produce geographic grid-based projections of temperature, precipitation, and other climate variables at daily and monthly scales. These physical models were originally known as atmosphere-ocean general circulation models (AO-GCMs). However, many of the newest generation of models are now more accurately described as GCMs as they incorporate additional aspects of the Earth's climate system beyond atmospheric and oceanic dynamics.

Because of their complexity, GCMs are constantly being enhanced as scientific understanding of climate improves and as computer computational power increases. Some models are more successful than others at reproducing observed climate and trends over the past century.[110] However, all future simulations agree that both global and regional temperatures will increase over the coming century in response to increasing emissions of heat-trapping gases from human activities.[111]

Historical GCM simulations are initialized in the late 1800s, externally "forced" by the human emissions, volcanic eruptions, and solar variations represented by the historical 20C3M scenario described above. They are also allowed to develop their own pattern of natural chaotic variability over time. This means that, although the climatological means of historical simulations should correspond to observations at the continental to global scale, no temporal correspondence between model simulations and observations should be expected on a day-to-day or even year-to-year basis. For example, while a strong El Niño event occurred from 1997 to 1998 in the real world, it may not occur in a model simulation in that year. Over several decades, however, the average number of simulated El Niño events should be similar to those observed. Similarly, although the central United States suffered the effects of an unusually intense heat wave during the summer of 1995, model simulations for 1995 might show that year as average or even cooler-than-average. However, a similarly intense heat wave should be simulated some time during the climatological period centered around 1995.

In this study, we used GCM simulations archived by the Program for Climate Model Diagnosis and Intercomparison (PCMDI). This collection of climate model simulations, assembled between 2005 and 2006, consists of models that contributed to phase three of the Coupled Model Intercomparison Project (CMIP3)[112] and were the basis for results presented in the 2007 IPCC Fourth Assessment Reports.[113] The CMIP3 GCM simulations used in this project consist of all model outputs archived by PCMDI with daily maximum and minimum temperature and precipitation available for the SRES A1fi and B1 scenarios. Additional simulations were obtained from the archives of the Geophysical Fluid Dynamics Laboratory, the National Center for Atmospheric Research, and the U.K.

Meteorological Office. The list of GCMs used, their origin, the scenarios available for each, and their equilibrium climate sensitivity are provided in Table A1.[114]

We chose the GCMs used in this study based on several criteria. First, only well-established models were considered—those already extensively described and evaluated in the peer-reviewed scientific literature. Models had to be evaluated and shown to adequately reproduce key features of the atmosphere and ocean system. Second, the models had to include the greater part of the IPCC range in climate sensitivity. Climate sensitivity is defined as the temperature change resulting from a doubling of atmospheric carbon dioxide concentrations relative to pre-industrial times, after the atmosphere has had decades to adjust to the change. In other words, climate sensitivity determines the extent to which temperatures rise under a given increase in atmospheric concentrations of greenhouse gases.[115] The third and final criterion is that the models chosen must have continuous daily time series of temperature and precipitation archived for the global emisison scenarios used here (SRES A1fi and B1). The GCMs selected for this analysis are the only models that meet these criteria.

Origin	**Model**	**Scenarios**	**Equilibrium Climate Sensitivity (oC)***
National Center for Atmospheric Research, USA	CCSM3	A1fi, B1	2.7
National Center for Atmospheric Research, USA	PCM	A1fi, B1	2.1
Geophysical Fluid Dynamics Laboratory, USA	GFDL CM2.1	A1fi, B1	3.4
UK Meteorological Office Hadley Centre	HadCM3	A1fi, B1	3.3

**data from IPCC 2007 Fourth Assessment Report, Chapter 8.*

TABLE A1. Coupled Model Intercomparison Project 3 (CMIP3) global climate modeling groups and their Global Climate Models (GCMs) used in this analysis for generating projections of future climate change. The HaDCM3 model only has 360 days per year. All other models archived full daily time series from 1960 to 2099.

For some regions of the world (including the Arctic, but not the continental United States), there is evidence that models better able to reproduce regional climate features may produce different future projections.[116] Such characteristics include large-scale circulation features or feedback processes that can be resolved at the scale of a global model. However, it is not valid to evaluate a global model on its ability to reproduce local features, such as the bias in temperature over a given city or region. Such limitations are to be expected in any GCM, as they are primarily the result of a lack of spatial resolution rather than any inherent shortcoming in the physics of the model. Here, no attempt was made to select a sub-set of GCMs that performed better than others, as previous literature has shown that it is difficult, if not impossible, to identify such a sub-set for the continental United States.[117]

Statistical Downscaling Model

Global climate models (GCMs) cannot accurately capture the fine-scale changes experienced at the regional to local scale. GCM simulations require months of computing time, effectively limiting the typical grid cell sizes of the models to one or more degrees per side. And, although the models are precise to this scale, they are actually skillful, or accurate, to an even coarser scale.[118]

Dynamical and statistical downscaling represent two complimentary ways to incorporate higher-resolution information into GCM simulations in order to obtain local- to regional-scale climate projections. Dynamical downscaling, often referred to as regional climate modeling, uses a limited-area, high-resolution model to simulate physical climate processes at the regional scale, with grid cells typically ranging from 4 to 50 km per side. Statistical downscaling models capture historical relationships between large-scale weather features and local climate, and they use these to translate future projections down to the scale of any observations—here, to individual weather stations.

Statistical models are generally flexible and less computationally demanding compared to regional climate models and are able to use a broad range of GCM inputs to simulate future changes in temperature and precipitation for a continuous period covering more than a century. Hence, statistical downscaling models are best suited for analyses that require a range of future projections reflecting the uncertainty in future emissions scenarios and climate sensitivity, at the scale of observations that may already be used for planning purposes. If the study is more of a sensitivity analysis, where using only one or two future simulations is not a limitation, or if it requires multiple surface and upper-air climate variables as input and has ample financial resources to support multi-year analyses, then regional climate modeling may be more appropriate.

In this project, we used a relatively new statistical downscaling model, the Asynchronous Regional Regression Model (ARRM).[119] Our analysis expands on original applications with modifications specifically aimed at improving the ability of the model to simulate the shape of the distribution including the tails, the use of a piecewise rather than linear regression to accurately capture the often non-linear relationship between modeled and observed quantiles, and bias correction at the tails of the distribution. It is a flexible and computationally efficient statistical model that can downscale station-based or gridded daily values of any variable that can be transformed into an approximately symmetric distribution and for which a large-scale predictor exists. A quantile regression model is derived for each individual weather station that transforms historical model simulations into a probability distribution that closely resembles historical observations (Figure A2a). This model can then be used to transform future model simulations into distributions similar to those observed (Figure A2b).

Both statistical and dynamical downscaling models are based on a number of assumptions, some shared, some unique to each method. Two important shared assumptions are the following: first, that the inputs received from GCMs are reasonable (that is, they

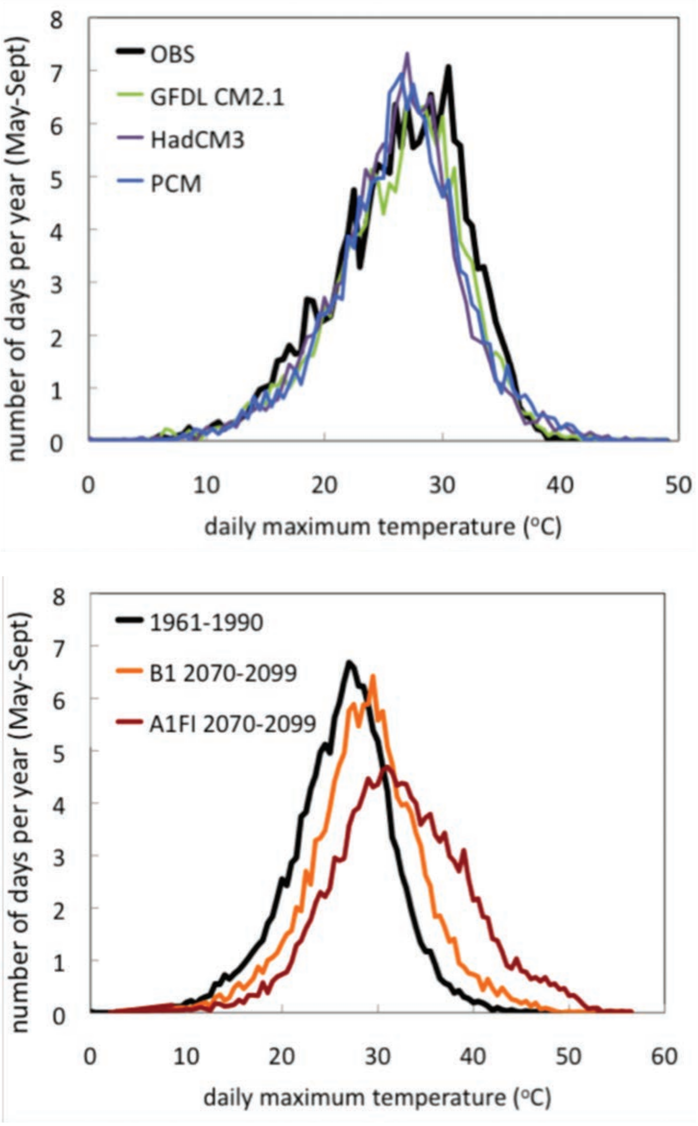


FIGURE A2. (a) Observed (black) and historical simulated distribution of daily maximum summer temperatures by three Global Climate Models for a weather station in Chicago for evaluation period 1980–1999 (top); (b) historical simulated (black) and future projected daily maximum summer temperature under the A1Fi higher (red) and B1 lower (orange) emission scenarios (bottom).

adequately capture the large-scale circulation of the atmosphere and ocean at the skillful scale of the global model); and second, that the information from the GCM fully incorporates the climate change signal over that region. In addition, all statistical models are based on a crucial assumption often referred to as stationarity. Stationarity assumes that the relationship between large-scale weather systems and local climate will remain constant over time. This assumption may be valid for lesser amounts of change, but could lead to biases under larger amounts of climate change.[120]

In a separate project, we are currently evaluating the stationarity of three downscaling methods, including the ARRM method used here. Preliminary analyses show that the assumption of stationarity holds true over much of the world for the lower and middle of the distribution. The only location where ARRM performance is systematically non-stationary is at high temperatures (at and above the 99.9th quantile) along coastal areas, with warm biases up to 6°C. (This bias is therefore only important for days hotter than the 1-in-1000 historical day, so in other words days that historically occur no more than one day every 2.7 years.) This may be due to the statistical model's inability to capture dynamical changes in the strength of the land-sea breeze as the temperature differences between land and ocean are exacerbated under climate change; the origins of this feature are currently under investigation. For precipitation, the ARRM method is characterized by a spatially variable bias at all quantiles that is generally not systematic, and varies from approximately -30 to +30 percent for higher quantiles of precipitation (above the 90th percentile) depending on location.

The methods used to statistically downscale GCM simulation using asynchronous quantile regression are described in detail in a published paper.[121] In terms of training the downscaling model using meteorological data from New Hampshire weather stations, the observed record must have an adequate length and quality of data. A minimum of twenty consecutive years of daily observations with less than 5 percent missing data is commonly required in order to appropriately sample from the range of natural climate variability at most of the station locations examined. Here, downscaling was conducted using the entire record from 1960 to 2012 to include as broad a range of observed variability as possible. Downscaling was conducted and tested using observed daily minimum and maximum temperature for twenty-five GHCN-Daily stations in northern New Hampshire (south of latitude 43.9 N; Table 7; Figure 10) and observed 24-hour cumulative precipitation for forty-one GHCN-Daily stations in northern New Hampshire (Table 8; Figure 11). Although GHCN-Daily station data have already undergone a standardized quality control,[122] before using the station data for downscaling, they were filtered using a quality control algorithm to identify and remove erroneous values previously identified in the GHCN database. This additional quality control step included three tests for errors, removing 1) data on any days where the daily reported minimum temperature exceeded the reported maximum, 2) any temperature values above (below) the highest (lowest) recorded values for North America, or with precipitation below zero or above the highest recorded value for the state of New Hampshire, and 3) repeated values of more than five consecutive days with identical temperature or non-zero precipitation values to the first decimal.

Addressing Uncertainty

The primary challenge of a climate assessment is the reliability of information concerning future climate. A common axiom warns that the only aspect of the future that can be predicted with any certainty is the fact that it is impossible to do so. However, although it is not possible to predict the future, it is possible to project it. Projections can describe what is likely to occur under a set of consistent and clearly articulated assumptions. For climate change, these assumptions should encompass a broad variety of the ways in which energy, population, development, and technology might change in the future.

There is always some degree of uncertainty inherent in any future projections. In order to accurately interpret and apply future projections for planning purposes, it is essential to quantify both the magnitude of the uncertainty as well as the reasons for its existence. Each of the steps involved in generating projections—future scenarios, global modeling, and downscaling—introduces a degree of uncertainty into future projections; how to address this uncertainty is the focus of this section.

> ***"A common axiom warns that the only aspect of the future that can be predicted with any certainty is the fact that it is impossible to do so. However, although it is not possible to predict the future, it is possible to project it."***

Another well-used axiom states that all models are wrong, but some models are useful. The Earth's climate is a complex system. It is only possible to simulate those processes that have been observed and documented. Clearly, there are other feedbacks and forcing factors at work that are challenging to capture or have yet to be documented. Hence, it is a common tendency to assign most of the range in future projections to model, or scientific, uncertainty.

Future projections will always be limited by scientific understanding of the system being predicted. However, there are other important sources of uncertainty that must be considered—some that even outweigh model uncertainty for certain variables and time scales. Uncertainty in climate change at the global to regional scale arises primarily due to three different causes: (1) natural variability in the climate system, (2) scientific uncertainty in predicting the response of the Earth's climate system to human-induced change, and (3) socio-economic or scenario uncertainty in predicting future energy choices and hence emissions of heat-trapping gases.[123]

Scenario uncertainty is very different, and entirely distinct, from scientific uncertainty in at least two important ways. First, while scientific uncertainty can be reduced through coordinated observational programs and improved physical modeling, scenario uncertainty arises due to the fundamental inability to predict future changes in human behavior. It can only be reduced by the passing of time, as certain choices (such as depletion of a non-renewable resource) can eliminate or render certain options less likely. Second, scientific uncertainty is often characterized by a normal distribution, where the mean value is more likely than the outliers. Scenario uncertainty, however, hinges primarily on whether or not the primary emitters of heat-trapping gases, including traditionally large emitters such as the United States and nations with rapidly-growing contributions such as India and China, will enact binding legislation to reduce their emissions. If they do enact legislation, then the lower emission scenarios become more probable. If they do not, then the higher emission scenarios become more probable. The longer such action is delayed, the less likely it becomes to achieve a lower emissions scenario because of the emissions that continue to accumulate in the atmosphere. Consequently, scenario uncertainty cannot be considered to be a normal distribution. Rather, the consequences of a lower versus a higher emissions scenario must be considered independently, in order to isolate the role that human choices are likely to play in determining future impacts.

Over timescales of years to several decades, natural chaotic variability is the most important source of uncertainty (Figure A3). By mid-century, scientific or model uncertainty is the largest contributor to the range in projected temperature and precipitation change. By the end of the century, scenario uncertainty is most important for temperature projections, while model uncertainty continues as the dominant source of uncertainty in precipitation. This is consistent with the results of the projections discussed in this report, where there is a significant difference between the changes projected under high versus low emission scenarios for temperature-based and heavy precipitation indicators, but little difference for mean precipitation-based indicators.

The first source of uncertainty can be addressed by always averaging or otherwise sampling from the statistical distribution of future projections over a climatological period—typically, twenty to thirty years. In other words, the average winter temperature should be averaged over several decades, as should the coldest day of the year. No time stamp more precise than twenty to thirty years should ever be assigned to any future projection. In this report and accompanying data files, simulations are always averaged over four thirty-year climatological time periods: historical (1980–2009), near-term (2010–2039), mid-century (2040–2069), and end-of-century (2070–2099).

The second source of uncertainty, model or scientific uncertainty, can be addressed by using multiple global climate models to simulate the response of the climate system to human-induced change. As noted above, the climate models used here cover a range of climate sensitivity (Table A1); they also cover an even wider range of precipitation projections, particularly at the local to regional scale. Only models that demonstratively fail to reproduce the basic features of large-scale climate dynamics (for example, the Jet Stream or El Niño) should be eliminated from consideration. Multiple studies have convincingly demonstrated that the average of an ensemble of simulations from a range of climate models (even ones of varied ability) is generally closer to reality than the simulations from one individual model, even one deemed "good" when evaluated on its performance over a given region.[124] Hence, wherever possible, impacts should be summarized in terms of the values resulting from multiple climate models, while uncertainty estimates can be derived from the range or variance in model projections. This is why all plots and tables in this report show multi-model mean values.

The third and final primary source of uncertainty in future projections can be addressed through generating climate projections for multiple futures: for example, a "higher emissions" future where the world continues to depend on fossil fuels as the primary energy source (SRES A1fi), as compared to a "lower emissions" future focusing on sustainability and conservation (SRES B1).

Over the next two-to-three decades, projections can be averaged across emission scenarios as there is no significant difference between scenarios over that time frame due to the inertia of the climate system in responding to changes in heat-trapping gas levels in the atmosphere.[125] Past mid-century, however, projections should never be averaged across scenarios; rather, the difference in impacts resulting from a higher as compared to a lower scenario should always be clearly delineated. That is why, in this report, future projections are always summarized in terms of what is expected for each scenario individually.

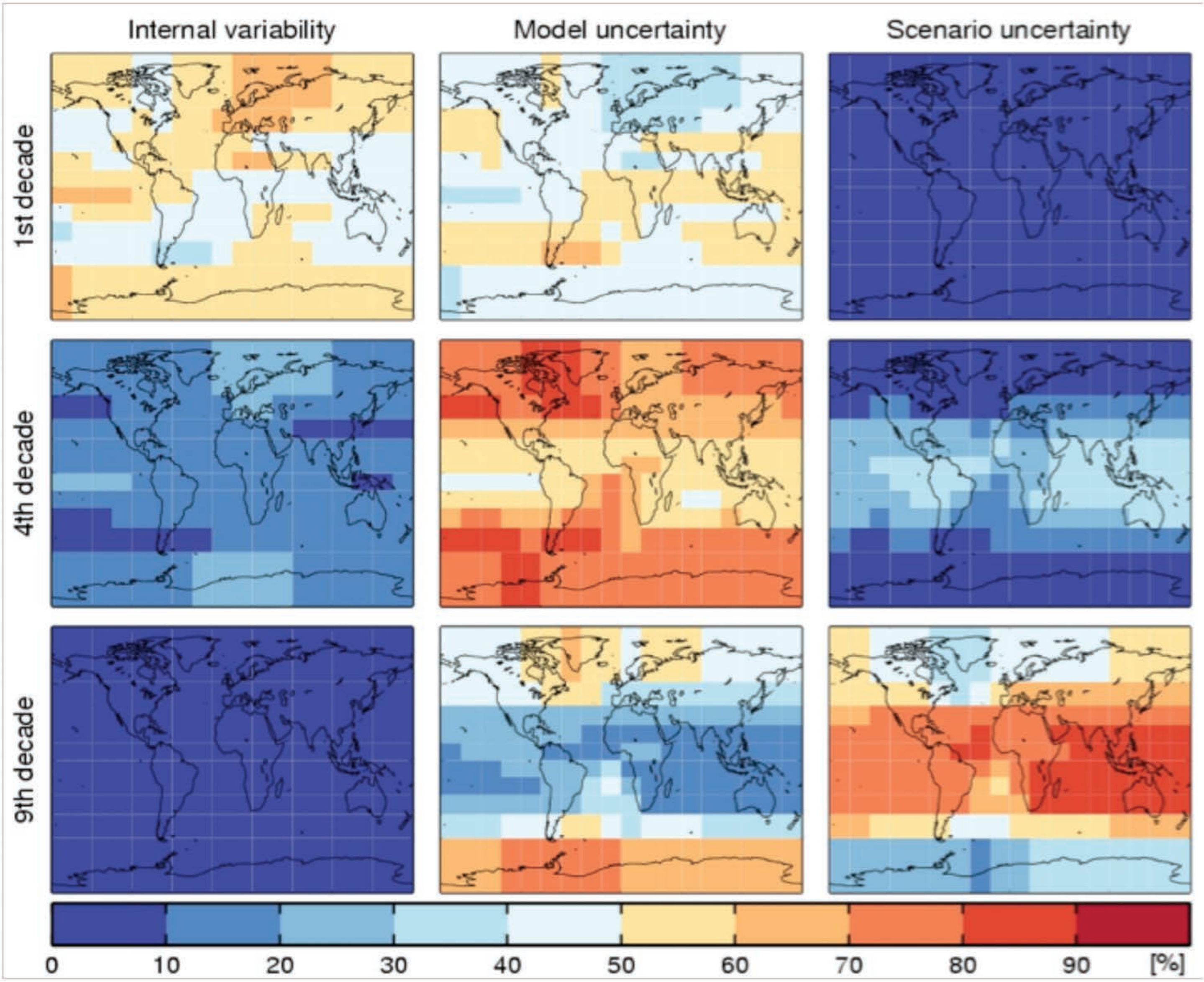


FIGURE A3. Percentage of uncertainty in future temperature projections one decade in the future (top row), four decades in the future (middle row) and nine decades in the future (bottom row) that can be attributed to natural variability (left column), model uncertainty (center column), and scenario uncertainty (right column). Figure from Hawkins & Sutton (endnote reference 124).

APPENDIX B.

CLIMATE GRIDS FOR FIFTEEN STATIONS IN NORTHERN NEW HAMPSHIRE

This Appendix contains climate grids with historical and projected future thirty year climatologies for fifteen Global Historical Climatology Network-Daily (GHCN-Daily) meteorological stations (Table B1) in northern New Hampshire (that is, north of 43.75° north latitude) for the historical period [1980–2009] and the future (near-term [2010–2039], medium-term [2040–2069] and long-term [2070–2099]). The projected values represent the average of daily simulations four Global Climate Models (GCM) (see Table A1 in the report for more information on the GCMs). Each average was first calculated for each individual GCM, then the results of all four GCMs were averaged.

The climate grids include thirty-year averages of daily measures for minimum and maximum temperature (annual, seasonal, extremes), length of the growing season (number of days between the last hard freeze in the spring and first hard freeze in the fall, using a threshold of 28°F), precipitation (annual, seasonal, extremes), and snow-covered days. There were significant gaps in the daily data from some NH GHCN-Daily stations for the period 1980–2009. Instead, the historical values in these tables were derived from the downscaled GCM model output. The climate grids are arranged in alphabetical order based on the station name.

Station Name	Latitude (N)	Longitude	Elevation (ft)	StationID
First Connecticut Lake	45.09	-71.29	506	272999
Colebrook	44.86	-71.54	341	271647
York Pond	44.50	-71.33	466	279966
Lancaster	44.49	-71.57	262	274556
Berlin	44.45	-71.18	284	270690
Monroe	44.32	-72.00	201	275500
Bethlehem	44.31	-71.66	360	270706
Bethlehem2	44.28	-71.68	421	270703
Fabyan	44.27	-71.45	494	272898
Pinkham Notch	44.26	-71.26	613	276818
Benton	44.03	-71.95	366	270681
North Conway	44.03	-71.14	166	275995
Woodstock	43.98	-71.68	220	279940
Tamworth	43.90	-71.30	241	278612
Plymouth	43.78	-71.65	201	276945

TABLE B1. List and location of fifteen GHCN-Daily stations in northern New Hampshire for which climate grids are provided.

Benton, New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	32.8	1.9	2.0	3.1	5.3	4.0	9.1
Winter TMIN	10.5	2.5	2.8	4.0	6.2	5.5	10.5
Spring TMIN	30.8	3.1	1.6	4.8	4.6	6.1	8.0
Summer TMIN	53.3	1.6	2.1	2.7	5.4	3.3	9.4
Fall TMIN	36.2	0.3	1.7	0.6	5.0	1.2	8.3
Maximum Temperature (°F)							
Annual TMAX	53.3	1.7	1.7	3.0	4.8	4.0	8.2
Winter TMAX	29.2	2.1	1.9	3.0	4.1	4.3	7.1
Spring TMAX	51.9	2.5	1.7	4.9	4.8	6.6	8.7
Summer TMAX	75.8	1.6	1.9	3.0	5.3	3.8	8.8
Fall TMAX	55.7	1.0	1.6	1.3	5.2	1.5	8.3
Temperature Extreme (days per year)							
<32°F	169	-10	-11	-17	-26	-21	-45
<0°F	23	-7	-7	-11	-15	-12	-20
>90°F	1	1	1	3	8	5	24
>95°F	0	0	0	0	0	1	4
TMAX on hottest day of year	88.5	1.6	1.4	2.7	4.3	3.9	7.4
TMIN on coldest day of year	-18.5	3.5	3.6	5.3	9.6	7.3	17.3
Growing Season (days)	156.0	12.0	12.0	19.0	29.0	20.0	51.0
Precipitation (inches)							
Annual mean	39.0	2.9	2.0	3.4	4.7	5.6	6.7
Winter mean	7.3	1.0	0.6	0.8	1.1	1.4	2.1
Spring mean	8.9	0.7	0.5	1.3	1.0	1.4	1.8
Summer mean	11.8	1.3	0.6	0.6	1.9	2.1	1.4
Fall mean	11.0	0.1	0.3	0.6	0.6	0.6	1.5
Extreme Precipitation (events per year)							
1” in 24 hrs	7.3	1.1	0.9	1.3	1.7	2.0	3.0
2” in 48 hours	2.4	1.1	0.4	0.7	1.6	1.8	2.6
Extreme Precipitation (events per decade)							
4” in 48 hours	1.3	1.5	0.8	0.3	2.5	2.8	5.5
Snow-Covered Days	172	-5	-6	-8	-18	-15	-40

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Berlin, New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	31.4	1.9	2.1	3.1	5.4	4.1	9.3
Winter TMIN	7.8	2.6	3.0	4.2	6.6	5.8	11.1
Spring TMIN	29.5	3.3	1.7	4.9	4.7	6.2	8.1
Summer TMIN	52.7	1.6	2.0	2.7	5.3	3.3	9.3
Fall TMIN	35.2	0.4	1.7	0.7	5.0	1.2	8.5
Maximum Temperature (°F)							
Annual TMAX	53.8	1.9	1.9	3.3	5.2	4.3	8.9
Winter TMAX	29.2	2.1	1.8	3.0	4.1	4.3	7.1
Spring TMAX	52.1	2.7	1.7	5.1	5.0	6.8	9.1
Summer TMAX	77.1	1.8	2.1	3.4	5.9	4.3	9.9
Fall TMAX	56.6	1.0	1.7	1.4	5.6	1.7	9.1
Temperature Extreme (days per year)							
<32°F	173	-10	-11	-17	-27	-21	-46
<0°F	30	-8	-7	-12	-17	-14	-25
>90°F	3	3	4	8	17	11	40
>95°F	0	0	1	1	4	1	14
TMAX on hottest day of year	91.3	1.5	1.8	2.4	5.4	3.3	9.4
TMIN on coldest day of year	-22.2	3.7	3.9	5.7	10.1	7.7	18.1
Growing Season (days)	156.0	10.0	14.0	20.0	30.0	21.0	52.0
Precipitation (inches)							
Annual mean	39.8	3.5	2.8	4.7	6.2	5.8	9.0
Winter mean	8.0	1.1	0.7	1.1	1.3	1.6	2.2
Spring mean	9.4	1.1	1.1	1.5	1.6	1.7	2.8
Summer mean	11.1	1.1	0.3	0.5	1.4	1.3	0.7
Fall mean	11.3	0.3	0.7	1.5	1.9	1.1	3.3
Extreme Precipitation (events per year)							
1” in 24 hrs	7.4	1.1	1.3	1.8	2.1	2.1	3.2
2” in 48 hours	3.0	1.4	1.1	1.7	2.4	2.2	3.3
Extreme Precipitation (events per decade)							
4” in 48 hours	3.1	2.6	1.8	3.1	4.5	5.1	9.8
Snow-Covered Days	161	-8	-10	-14	-27	-21	-51

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Bethlehem(1), New Hampshire

Indicators	**Historical* 1980–2009**	**Change from historical (+ or -)**					
		Short Term 2010–2039		**Medium Term 2040–2069**		**Long Term 2070–2099**	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	31.8	1.9	2.1	3.1	5.4	4.0	9.1
Winter TMIN	8.9	2.5	3.0	4.0	6.5	5.5	10.8
Spring TMIN	30.1	3.5	1.5	5.2	4.5	6.5	8.0
Summer TMIN	52.7	1.5	2.1	2.7	5.2	3.2	8.8
Fall TMIN	35.1	0.1	2.0	0.4	5.3	1.0	8.7
Maximum Temperature (°F)							
Annual TMAX	53.4	1.7	1.7	3.0	4.8	4.0	8.1
Winter TMAX	28.3	1.9	1.8	2.7	3.9	4.0	6.7
Spring TMAX	53.1	2.7	1.6	5.1	4.7	6.7	8.5
Summer TMAX	76.7	1.7	1.9	3.1	5.2	3.9	8.6
Fall TMAX	55.0	0.8	1.8	1.2	5.4	1.4	8.6
Temperature Extreme (days per year)							
<32°F	177	-10	-12	-16	-26	-20	-46
<0°F	26	-7	-7	-11	-16	-13	-22
>90°F	1	2	2	5	10	8	27
>95°F	0	0	0	1	1	2	4
TMAX on hottest day of year	89.4	1.8	1.0	3.5	3.9	4.7	7.2
TMIN on coldest day of year	-20.1	3.5	3.9	5.2	9.9	7.1	17.7
Growing Season (days)	150.0	9.0	13.0	19.0	30.0	21.0	51.0
Precipitation (inches)							
Annual mean	39.2	2.8	1.8	3.7	4.5	5.4	6.3
Winter mean	7.8	1.0	0.6	1.0	1.1	1.5	2.2
Spring mean	8.9	0.8	0.5	1.4	1.1	1.7	2.0
Summer mean	12.6	1.2	0.5	0.6	1.6	1.8	1.0
Fall mean	10.0	-0.2	0.1	0.5	0.5	0.4	1.0
Extreme Precipitation (events per year)							
1” in 24 hrs	5.8	1.3	0.9	1.4	1.9	2.1	3.3
2” in 48 hours	2.1	1.0	0.5	0.9	1.1	1.5	1.9
Extreme Precipitation (events per decade)							
4” in 48 hours	2.1	-0.1	-0.3	-0.2	1.2	2.5	2.7
Snow-Covered Days	130	-13	-14	-18	-35	-28	-56

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Bethlehem(2), New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	29.6	2.0	2.1	3.3	5.5	4.3	9.4
Winter TMIN	6.4	2.9	3.1	4.6	6.9	6.3	11.6
Spring TMIN	27.4	3.0	2.0	4.7	5.0	6.0	8.5
Summer TMIN	50.5	1.6	2.0	2.8	5.4	3.4	9.5
Fall TMIN	33.6	0.7	1.3	0.9	4.6	1.4	7.9
Maximum Temperature (°F)							
Annual TMAX	53.1	2.0	1.9	3.4	5.2	4.4	8.8
Winter TMAX	28.2	2.3	2.0	3.3	4.3	4.7	7.5
Spring TMAX	51.4	2.5	1.9	5.0	5.3	6.7	9.4
Summer TMAX	76.2	1.8	2.1	3.4	5.8	4.2	9.6
Fall TMAX	56.3	1.3	1.5	1.6	5.2	1.8	8.4
Temperature Extreme (days per year)							
<32°F	190	-10	-12	-17	-27	-20	-47
<0°F	35	-9	-8	-13	-18	-16	-27
>90°F	2	1	2	4	12	6	32
>95°F	0	0	0	0	2	1	7
TMAX on hottest day of year	89.9	1.4	1.7	2.3	4.9	3.7	8.4
TMIN on coldest day of year	-26.1	4.2	4.4	6.4	11.1	8.7	19.4
Growing Season (days)	139.0	6.0	10.0	17.0	29.0	21.0	51.0
Precipitation (inches)							
Annual mean	41.1	2.5	2.3	3.3	4.8	4.8	6.0
Winter mean	7.9	1.0	0.9	1.0	1.5	1.6	2.4
Spring mean	9.3	0.8	0.6	1.4	1.1	1.4	1.6
Summer mean	12.6	1.2	0.3	0.4	1.2	1.6	0.2
Fall mean	11.3	-0.3	0.6	0.4	1.0	0.2	1.9
Extreme Precipitation (events per year)							
1” in 24 hrs	6.8	1.1	1.2	1.5	1.9	2.0	2.6
2” in 48 hours	2.4	0.9	0.4	0.9	1.6	1.6	2.2
Extreme Precipitation (events per decade)							
4” in 48 hours	0.9	1.9	2.5	0.9	2.6	1.6	6.0
Snow-Covered Days	130	-13	-14	-18	-35	-28	-56

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Colebrook, New Hampshire

Indicators	**Historical* 1980–2009**	**Change from historical (+ or -)**					
		Short Term 2010–2039		**Medium Term 2040–2069**		**Long Term 2070–2099**	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	29.3	2.2	2.3	3.5	6.0	4.6	10.1
Winter TMIN	4.9	3.0	3.5	4.8	7.6	6.7	12.8
Spring TMIN	27.1	3.6	1.9	5.5	5.3	6.9	9.0
Summer TMIN	50.7	1.8	2.3	3.0	5.8	3.7	10.0
Fall TMIN	34.0	0.4	1.8	0.7	5.3	1.3	8.6
Maximum Temperature (°F)							
Annual TMAX	52.4	1.8	1.8	3.1	5.0	4.1	8.5
Winter TMAX	27.2	2.1	1.9	3.0	4.2	4.4	7.2
Spring TMAX	51.4	2.6	1.7	5.0	4.9	6.5	8.7
Summer TMAX	75.5	1.7	1.9	3.1	5.4	3.9	8.9
Fall TMAX	55.1	1.1	1.7	1.4	5.5	1.7	8.8
Temperature Extreme (days per year)							
<32°F	186	-9	-14	-18	-30	-21	-52
<0°F	40	-9	-9	-14	-20	-18	-31
>90°F	1	0	1	2	8	4	24
>95°F	0	0	0	0	1	1	4
TMAX on hottest day of year	88.6	1.6	1.5	2.6	4.3	3.8	7.7
TMIN on coldest day of year	-29.9	4.6	4.7	6.4	12.0	9.2	21.2
Growing Season (days)	134.0	9.0	12.0	20.0	32.0	23.0	54.0
Precipitation (inches)							
Annual mean	39.8	2.8	1.9	2.8	4.7	4.0	6.4
Winter mean	7.6	1.0	0.7	0.9	1.2	1.4	2.0
Spring mean	8.6	0.8	0.5	1.0	1.0	0.9	1.4
Summer mean	13.1	0.8	0.7	-0.2	1.8	0.8	1.6
Fall mean	10.6	0.2	0.0	0.9	0.6	0.8	1.4
Extreme Precipitation (events per year)							
1” in 24 hrs	6.6	1.0	0.6	1.0	1.8	1.4	3.2
2” in 48 hours	2.2	0.9	0.7	0.6	1.6	1.4	2.4
Extreme Precipitation (events per decade)							
4” in 48 hours	1.0	0.7	1.1	0.8	2.3	1.2	5.8
Snow-Covered Days	164	-7	-8	-12	-23	-18	-44

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Fabyan, New Hampshire

Indicators	**Historical* 1980–2009**	**Change from historical (+ or -)**					
		Short Term 2010–2039		**Medium Term 2040–2069**		**Long Term 2070–2099**	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	28.7	2.0	2.4	3.4	6.1	4.5	10.2
Winter TMIN	5.0	2.8	3.4	4.5	7.4	6.2	12.2
Spring TMIN	26.6	3.8	1.5	5.7	4.8	7.1	8.5
Summer TMIN	49.4	1.8	2.4	3.1	6.2	3.8	10.7
Fall TMIN	33.4	-0.1	2.1	0.2	5.7	0.8	9.4
Maximum Temperature (°F)							
Annual TMAX	52.9	1.8	1.8	3.2	5.1	4.2	8.7
Winter TMAX	27.3	2.0	1.9	2.7	4.0	4.0	6.8
Spring TMAX	51.2	3.0	1.4	5.6	4.7	7.3	8.8
Summer TMAX	76.1	1.8	2.0	3.3	5.6	4.2	9.5
Fall TMAX	56.3	0.9	2.2	1.2	6.3	1.6	9.9
Temperature Extreme (days per year)							
<32°F	195	-11	-13	-18	-30	-22	-51
<0°F	39	-9	-9	-13	-21	-17	-31
>90°F	2	1	1	5	8	9	27
>95°F	0	0	0	1	2	3	10
TMAX on hottest day of year	90.4	2.0	1.3	3.7	5.8	5.1	11.0
TMIN on coldest day of year	-30.1	5.1	5.8	7.3	13.5	9.3	22.4
Growing Season (days)	123.0	10.0	13.0	19.0	36.0	25.0	61.0
Precipitation (inches)							
Annual mean	45.1	3.3	2.1	4.3	5.0	6.6	7.4
Winter mean	9.6	1.5	1.1	1.8	2.3	2.4	4.4
Spring mean	10.5	0.9	1.0	1.3	1.8	1.8	2.4
Summer mean	12.8	1.1	0.3	0.3	0.8	1.9	-0.3
Fall mean	12.1	0.0	0.0	1.0	0.2	0.6	0.9
Extreme Precipitation (events per year)							
1” in 24 hrs	7.7	1.2	1.1	1.6	1.9	2.2	2.9
2” in 48 hours	4.2	1.2	0.8	1.3	2.2	2.3	3.4
Extreme Precipitation (events per decade)							
4” in 48 hours	5.0	2.1	2.8	3.3	5.7	5.1	12.8
Snow-Covered Days	179	0	0	-2	-3	-2	-9

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

First Connecticut Lake, New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	26.7	2.1	2.2	3.5	5.8	4.5	9.8
Winter TMIN	1.1	3.0	3.4	4.8	7.6	6.7	12.8
Spring TMIN	23.8	3.8	1.9	5.6	5.4	7.0	9.1
Summer TMIN	49.2	1.7	2.1	2.8	5.4	3.4	9.1
Fall TMIN	32.1	0.3	1.6	0.6	5.0	1.2	8.3
Maximum Temperature (°F)							
Annual TMAX	48.6	1.9	1.9	3.2	5.1	4.3	8.6
Winter TMAX	23.7	2.2	2.0	3.2	4.4	4.6	7.6
Spring TMAX	46.8	2.6	1.7	5.0	4.9	6.6	8.9
Summer TMAX	71.9	1.8	2.0	3.3	5.5	4.1	9.0
Fall TMAX	51.6	1.1	1.7	1.4	5.6	1.7	8.8
Temperature Extreme (days per year)							
<32°F	199	-10	-10	-17	-26	-21	-45
<0°F	52	-10	-10	-15	-23	-21	-36
>90°F	0	0	0	0	1	1	7
>95°F	0	0	0	0	0	0	1
TMAX on hottest day of year	85.4	1.4	1.3	2.2	4.0	3.3	6.9
TMIN on coldest day of year	-32.1	4.1	3.8	5.6	10.4	7.9	19.3
Growing Season (days)	129.0	7.0	10.0	17.0	29.0	23.0	51.0
Precipitation (inches)							
Annual mean	44.3	3.2	1.5	3.8	3.8	4.9	5.1
Winter mean	8.3	1.0	0.7	1.0	1.1	1.3	1.8
Spring mean	10.0	0.9	0.4	1.7	1.1	1.7	1.8
Summer mean	14.1	1.5	0.4	0.4	1.2	1.5	0.6
Fall mean	11.7	0.2	0.2	0.9	0.5	0.7	1.1
Extreme Precipitation (events per year)							
1” in 24 hrs	6.2	1.5	0.7	1.5	1.9	1.9	2.4
2” in 48 hours	1.9	1.1	0.5	1.1	1.5	1.5	2.2
Extreme Precipitation (events per decade)							
4” in 48 hours	0.5	1.1	1.5	1.5	1.3	1.1	4.6
Snow-Covered Days	169	-6	-7	-10	-20	-15	-38

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Lancaster, New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	30.1	2.1	2.2	3.4	5.7	4.4	9.6
Winter TMIN	6.0	3.0	3.3	4.7	7.3	6.5	12.2
Spring TMIN	28.1	3.4	1.8	5.1	4.9	6.5	8.4
Summer TMIN	51.4	1.6	2.1	2.8	5.4	3.4	9.2
Fall TMIN	34.6	0.3	1.6	0.6	5.0	1.1	8.2
Maximum Temperature (°F)							
Annual TMAX	54.1	1.8	1.8	3.1	4.9	4.1	8.2
Winter TMAX	28.4	2.0	1.7	2.8	3.9	4.1	6.8
Spring TMAX	53.4	2.6	1.7	5.0	4.9	6.6	8.8
Summer TMAX	77.7	1.7	1.9	3.1	5.3	3.9	8.7
Fall TMAX	56.5	1.0	1.7	1.4	5.4	1.6	8.6
Temperature Extreme (days per year)							
<32°F	184	-10	-11	-17	-27	-21	-47
<0°F	36	-8	-8	-13	-19	-16	-28
>90°F	2	2	3	6	14	9	34
>95°F	0	0	0	0	1	1	6
TMAX on hottest day of year	90.4	1.4	1.3	2.2	3.8	3.4	6.4
TMIN on coldest day of year	-28.5	4.6	4.7	6.7	11.9	9.2	21.1
Growing Season (days)	143.0	8.0	10.0	17.0	28.0	20.0	51.0
Precipitation (inches)							
Annual mean	38.3	3.3	1.4	3.9	3.9	5.8	4.8
Winter mean	7.2	0.8	0.6	0.8	1.0	1.2	1.6
Spring mean	8.8	0.8	0.3	1.6	0.7	1.7	0.9
Summer mean	12.2	1.6	0.5	0.9	1.6	2.3	1.1
Fall mean	10.0	0.2	0.3	0.7	0.6	0.7	1.2
Extreme Precipitation (events per year)							
1” in 24 hrs	5.7	1.2	0.5	1.4	1.6	2.2	2.4
2” in 48 hours	1.6	1.1	0.5	1.0	1.1	1.5	1.8
Extreme Precipitation (events per decade)							
4” in 48 hours	0.3	0.9	0.7	0.5	1.1	2.1	2.3
Snow-Covered Days	171	-4	-6	-9	-18	-14	-39

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Monroe, New Hampshire

Indicators	**Historical* 1980–2009**	**Change from historical (+ or -)**					
		Short Term 2010–2039		**Medium Term 2040–2069**		**Long Term 2070–2099**	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	31.9	2.0	2.2	3.3	5.5	4.3	9.3
Winter TMIN	7.2	2.9	3.2	4.6	7.0	6.3	11.8
Spring TMIN	29.9	3.5	1.6	5.3	4.7	6.5	8.1
Summer TMIN	54.1	1.5	2.0	2.6	5.2	3.3	9.0
Fall TMIN	36.0	0.2	1.8	0.5	5.0	1.0	8.2
Maximum Temperature (°F)							
Annual TMAX	53.9	1.8	1.8	3.2	5.1	4.2	8.7
Winter TMAX	28.5	2.0	1.7	3.0	3.8	4.2	6.8
Spring TMAX	52.8	2.6	1.7	5.0	4.9	6.7	8.8
Summer TMAX	78.1	1.8	2.2	3.4	6.1	4.4	10.3
Fall TMAX	55.8	1.0	1.7	1.4	5.5	1.6	8.9
Temperature Extreme (days per year)							
<32°F	171	-10	-12	-17	-26	-20	-45
<0°F	33	-7	-7	-12	-17	-15	-26
>90°F	5	3	4	9	18	13	41
>95°F	1	0	1	1	6	3	19
TMAX on hottest day of year	92.5	1.8	1.8	3.0	5.9	4.3	10.9
TMIN on coldest day of year	-25.3	4.1	4.2	6.1	10.6	8.2	19.2
Growing Season (days)	157.0	10.0	14.0	19.0	29.0	20.0	52.0
Precipitation (inches)							
Annual mean	36.4	2.9	1.9	3.3	4.9	4.6	6.1
Winter mean	7.0	0.9	0.8	0.9	1.3	1.3	2.0
Spring mean	7.9	0.7	0.7	1.0	1.2	1.1	1.9
Summer mean	11.4	1.2	0.4	0.7	1.3	1.5	0.4
Fall mean	10.1	0.1	0.1	0.6	1.0	0.7	1.8
Extreme Precipitation (events per year)							
1” in 24 hrs	5.5	1.0	1.1	1.0	2.2	1.5	3.2
2” in 48 hours	1.8	0.8	0.4	0.8	1.2	1.1	1.8
Extreme Precipitation (events per decade)							
4” in 48 hours	0.8	0.5	0.4	0.0	0.0	0.9	2.0
Snow-Covered Days	115	-12	-13	-18	-32	-24	-47

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

North Conway, New Hampshire

Indicators	**Historical* 1980–2009**	**Change from historical (+ or -)**					
		Short Term 2010–2039		**Medium Term 2040–2069**		**Long Term 2070–2099**	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	33.7	1.7	1.9	2.8	4.9	3.7	8.3
Winter TMIN	11.6	2.3	2.5	3.6	5.6	5.0	9.4
Spring TMIN	31.7	2.8	1.6	4.4	4.3	5.5	7.3
Summer TMIN	54.8	1.5	1.9	2.5	4.9	3.1	8.6
Fall TMIN	36.3	0.4	1.5	0.7	4.6	1.2	7.8
Maximum Temperature (°F)							
Annual TMAX	56.3	1.8	1.8	3.1	5.0	4.1	8.6
Winter TMAX	32.4	1.8	1.6	2.6	3.5	3.7	6.2
Spring TMAX	54.6	2.5	1.7	4.9	4.9	6.5	9.0
Summer TMAX	79.2	2.0	2.3	3.7	6.4	4.6	10.9
Fall TMAX	58.5	1.0	1.5	1.4	5.2	1.6	8.4
Temperature Extreme (days per year)							
<32°F	170	-10	-11	-16	-25	-20	-43
<0°F	17	-5	-5	-9	-11	-10	-15
>90°F	8	4	5	12	23	17	50
>95°F	1	1	2	4	11	6	30
TMAX on hottest day of year	94.4	1.9	2.2	3.2	6.2	4.8	11.6
TMIN on coldest day of year	-14.8	3.6	3.6	5.3	9.1	7.1	15.8
Growing Season (days)	162.0	11.0	12.0	19.0	29.0	21.0	48.0
Precipitation (inches)							
Annual mean	49.4	4.4	2.9	5.8	6.8	8.3	9.4
Winter mean	11.1	1.4	0.9	1.4	1.5	2.2	2.8
Spring mean	12.3	1.3	1.0	2.3	1.8	2.6	2.6
Summer mean	12.5	1.3	0.4	0.7	1.7	2.3	1.3
Fall mean	13.5	0.5	0.7	1.3	1.6	1.2	2.8
Extreme Precipitation (events per year)							
1” in 24 hrs	13.7	1.4	1.6	2.4	3.1	3.2	4.2
2” in 48 hours	6.3	1.9	1.2	2.5	2.7	3.4	4.5
Extreme Precipitation (events per decade)							
4” in 48 hours	4.5	2.9	1.3	3.4	5.5	8.6	9.8
Snow-Covered Days	154	-11	-12	-15	-33	-27	-60

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Pinkham Notch, New Hampshire

Indicators	**Historical* 1980–2009**	**Change from historical (+ or -)**					
		Short Term 2010–2039		**Medium Term 2040–2069**		**Long Term 2070–2099**	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	30.3	1.8	1.9	2.9	5.0	3.8	8.7
Winter TMIN	8.2	2.3	2.6	3.6	5.7	5.0	9.7
Spring TMIN	27.8	3.0	1.6	4.6	4.4	5.9	7.6
Summer TMIN	50.8	1.5	1.9	2.6	5.1	3.2	9.0
Fall TMIN	34.0	0.3	1.7	0.6	4.9	1.1	8.2
Maximum Temperature (°F)							
Annual TMAX	50.4	1.8	1.8	3.1	5.0	4.1	8.5
Winter TMAX	27.5	2.1	1.8	2.9	4.0	4.3	7.0
Spring TMAX	48.2	2.5	1.6	4.9	4.8	6.5	8.7
Summer TMAX	72.2	1.8	2.0	3.3	5.8	4.2	9.6
Fall TMAX	53.2	1.0	1.7	1.4	5.4	1.6	8.7
Temperature Extreme (days per year)							
<32°F	186	-9	-11	-15	-25	-19	-44
<0°F	26	-7	-7	-11	-16	-13	-22
>90°F	0	0	1	1	4	2	16
>95°F	0	0	0	0	0	0	1
TMAX on hottest day of year	86.3	1.7	1.6	2.7	4.5	3.8	7.6
TMIN on coldest day of year	-17.7	3.3	3.4	5.0	8.8	6.6	15.6
Growing Season (days)	148.0	9.0	10.0	17.0	28.0	19.0	47.0
Precipitation (inches)							
Annual mean	59.9	5.9	3.5	6.9	7.1	10.0	11.0
Winter mean	13.7	1.7	1.2	1.8	2.1	2.8	3.6
Spring mean	14.4	2.0	1.3	2.7	2.2	2.8	4.4
Summer mean	14.9	1.9	0.4	0.8	0.9	2.9	-0.5
Fall mean	16.9	0.4	0.8	1.5	1.8	1.6	3.6
Extreme Precipitation (events per year)							
1” in 24 hrs	15.3	1.6	1.3	2.7	2.7	3.5	4.0
2” in 48 hours	9.7	1.7	1.9	2.2	3.0	3.8	5.4
Extreme Precipitation (events per decade)							
4” in 48 hours	10.5	8.8	4.3	8.2	12.6	13.9	19.2
Snow-Covered Days	175	-1	-3	-4	-9	-6	-28

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Plymouth, New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	30.7	1.8	2.0	2.9	5.1	3.9	8.8
Winter TMIN	8.5	2.4	2.7	3.8	5.9	5.2	9.8
Spring TMIN	28.8	3.0	1.5	4.6	4.3	5.8	7.5
Summer TMIN	51.3	1.6	2.1	2.8	5.5	3.4	9.4
Fall TMIN	33.8	0.3	1.7	0.6	5.0	1.1	8.3
Maximum Temperature (°F)							
Annual TMAX	55.1	1.8	1.8	3.1	4.9	4.1	8.4
Winter TMAX	30.6	1.9	1.7	2.7	3.6	3.8	6.3
Spring TMAX	53.5	2.6	1.7	5.0	4.8	6.7	8.8
Summer TMAX	78.3	1.8	2.0	3.4	5.7	4.3	9.6
Fall TMAX	57.7	1.0	1.6	1.4	5.3	1.6	8.7
Temperature Extreme (days per year)							
<32°F	187	-9	-11	-16	-25	-19	-45
<0°F	26	-7	-7	-11	-15	-13	-22
>90°F	4	4	4	10	18	15	43
>95°F	0	1	1	2	4	3	15
TMAX on hottest day of year	92.1	1.8	1.4	3.0	4.5	4.0	8.8
TMIN on coldest day of year	-19.7	4.1	4.4	6.0	10.0	7.8	17.1
Growing Season (days)	140.0	7.0	11.0	16.0	29.0	20.0	49.0
Precipitation (inches)							
Annual mean	43.1	4.2	2.4	4.9	4.9	6.9	7.4
Winter mean	9.8	1.1	0.7	1.1	1.2	1.7	2.5
Spring mean	10.5	1.1	0.8	1.5	1.4	1.7	2.8
Summer mean	11.6	1.5	0.4	0.9	1.2	2.3	0.5
Fall mean	11.3	0.5	0.4	1.2	0.9	1.1	1.6
Extreme Precipitation (events per year)							
1” in 24 hrs	9.9	1.3	1.5	1.9	2.5	2.6	3.9
2” in 48 hours	3.9	1.4	1.0	1.4	1.8	2.4	3.5
Extreme Precipitation (events per decade)							
4” in 48 hours	2.2	3.5	1.4	2.1	2.6	6.6	5.9
Snow-Covered Days	144	-10	-12	-16	-31	-26	-55

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Tamworth, New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	30.8	1.9	2.1	3.1	5.4	4.0	9.2
Winter TMIN	9.1	2.5	2.8	4.0	6.1	5.5	10.3
Spring TMIN	29.6	3.1	1.5	4.7	4.3	5.9	7.5
Summer TMIN	51.0	1.6	2.2	2.9	5.8	3.6	10.1
Fall TMIN	33.3	0.2	1.7	0.5	5.0	1.0	8.5
Maximum Temperature (°F)							
Annual TMAX	55.3	1.7	1.7	3.0	4.8	3.9	8.2
Winter TMAX	31.6	1.8	1.5	2.5	3.4	3.6	6.0
Spring TMAX	54.0	2.4	1.6	4.7	4.6	6.3	8.4
Summer TMAX	78.3	1.8	2.1	3.4	6.0	4.3	10.2
Fall TMAX	56.9	0.9	1.5	1.3	5.1	1.5	8.2
Temperature Extreme (days per year)							
<32°F	189	-9	-12	-17	-29	-20	-49
<0°F	26	-7	-7	-11	-15	-13	-22
>90°F	4	4	5	10	19	14	43
>95°F	1	0	0	1	5	3	18
TMAX on hottest day of year	92.4	1.8	1.7	3.2	5.6	5.2	11.1
TMIN on coldest day of year	-20.0	3.8	3.9	5.7	9.9	7.4	17.3
Growing Season (days)	138.0	8.0	9.0	17.0	27.0	20.0	48.0
Precipitation (inches)							
Annual mean	51.2	5.7	3.0	7.2	7.8	9.7	10.8
Winter mean	11.6	1.3	0.9	1.5	1.4	2.4	2.7
Spring mean	12.7	1.7	1.3	2.5	2.5	2.4	3.4
Summer mean	13.6	1.9	0.6	1.0	2.3	3.0	2.0
Fall mean	13.2	0.9	0.4	2.1	1.6	1.9	2.8
Extreme Precipitation (events per year)							
1” in 24 hrs	13.3	2.1	1.2	3.2	3.3	4.1	5.0
2” in 48 hours	6.6	2.2	1.3	3.0	3.4	3.6	5.2
Extreme Precipitation (events per decade)							
4” in 48 hours	5.4	4.5	1.4	5.2	5.7	8.4	9.5
Snow-Covered Days	134	-13	-14	-18	-36	-30	-60

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

Woodstock, New Hampshire

Indicators	Historical* 1980–2009	Change from historical (+ or -)					
		Short Term 2010–2039		Medium Term 2040–2069		Long Term 2070–2099	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	33.0	1.7	2.1	2.8	5.2	3.7	8.8
Winter TMIN	11.0	2.3	2.8	3.7	6.0	5.1	9.9
Spring TMIN	31.0	3.1	1.3	4.7	4.0	5.9	7.2
Summer TMIN	53.3	1.5	2.1	2.6	5.4	3.3	9.3
Fall TMIN	36.3	0.0	2.0	0.3	5.3	0.8	8.6
Maximum Temperature (°F)							
Annual TMAX	55.8	1.7	1.7	2.9	4.8	3.9	8.2
Winter TMAX	31.0	1.7	1.6	2.4	3.4	3.5	5.9
Spring TMAX	54.4	2.6	1.4	4.9	4.5	6.5	8.4
Summer TMAX	79.0	1.7	2.0	3.3	5.5	4.1	9.2
Fall TMAX	58.2	0.9	2.0	1.3	5.9	1.5	9.4
Temperature Extreme (days per year)							
<32°F	174	-9	-11	-15	-25	-19	-43
<0°F	19	-5	-6	-9	-13	-10	-17
>90°F	6	3	4	10	20	16	46
>95°F	1	0	0	1	4	3	18
TMAX on hottest day of year	92.9	1.7	1.1	2.9	4.6	4.0	7.8
TMIN on coldest day of year	-17.8	3.8	4.3	5.7	10.3	7.5	18.0
Growing Season (days)	153.0	10.0	13.0	19.0	30.0	20.0	53.0
Precipitation (inches)							
Annual mean	45.6	4.0	1.7	5.1	5.1	7.3	6.9
Winter mean	9.6	1.2	1.0	1.3	1.5	1.9	2.9
Spring mean	11.2	0.8	0.5	1.6	1.3	1.7	2.0
Summer mean	13.1	1.8	0.3	1.2	1.3	2.7	0.4
Fall mean	11.7	0.3	0.0	0.9	0.8	1.0	1.6
Extreme Precipitation (events per year)							
1” in 24 hrs	9.3	1.5	0.9	2.1	2.2	2.5	3.4
2” in 48 hours	3.9	1.4	0.8	1.7	2.3	2.5	3.3
Extreme Precipitation (events per decade)							
4” in 48 hours	3.4	2.4	0.6	1.6	3.9	6.1	7.3
Snow-Covered Days	170	-4	-5	-7	-15	-12	-40

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

York Pond, New Hampshire

Indicators	**Historical* 1980–2009**	**Change from historical (+ or -)**					
		Short Term 2010–2039		**Medium Term 2040–2069**		**Long Term 2070–2099**	
		Low Emissions	High Emissions	Low Emissions	High Emissions	Low Emissions	High Emissions
Minimum Temperature (°F)							
Annual TMIN	29.4	2.0	2.1	3.3	5.5	4.3	9.6
Winter TMIN	6.2	2.8	2.9	4.4	6.6	6.0	11.2
Spring TMIN	27.1	3.1	1.9	4.8	4.9	6.2	8.4
Summer TMIN	50.4	1.6	2.1	2.9	5.7	3.6	10.8
Fall TMIN	33.6	0.6	1.3	0.9	4.6	1.4	8.2
Maximum Temperature (°F)							
Annual TMAX	52.1	2.0	1.9	3.3	5.2	4.4	8.8
Winter TMAX	28.1	2.2	1.8	3.2	4.1	4.6	7.2
Spring TMAX	50.1	2.5	1.9	5.0	5.1	6.6	9.3
Summer TMAX	74.8	1.8	2.1	3.4	5.9	4.3	9.9
Fall TMAX	55.1	1.3	1.5	1.6	5.3	1.8	8.6
Temperature Extreme (days per year)							
<32°F	187	-10	-11	-17	-26	-21	-45
<0°F	36	-9	-9	-14	-20	-17	-29
>90°F	1	1	2	3	11	5	29
>95°F	0	0	0	0	1	1	6
TMAX on hottest day of year	89.3	1.6	1.9	2.7	5.6	4.1	9.6
TMIN on coldest day of year	-24.5	3.9	4.1	6.0	10.5	8.0	18.4
Growing Season (days)	143.0	9.0	10.0	18.0	28.0	20.0	48.0
Precipitation (inches)							
Annual mean	44.8	3.2	2.1	4.1	5.0	5.9	6.6
Winter mean	9.3	1.0	0.6	1.1	1.0	1.5	1.8
Spring mean	10.8	1.0	0.6	1.7	0.9	1.7	1.6
Summer mean	13.1	1.3	0.5	0.5	1.7	2.0	1.1
Fall mean	11.7	-0.1	0.5	0.6	1.2	0.6	2.1
Extreme Precipitation (events per year)							
1” in 24 hrs	8.4	1.2	1.1	1.5	2.3	2.3	2.9
2” in 48 hours	2.7	1.2	0.6	0.8	1.6	1.9	2.5
Extreme Precipitation (events per decade)							
4” in 48 hours	1.5	1.8	0.8	3.2	2.4	2.6	5.3
Snow-Covered Days	130	-15	-15	-19	-35	-29	-57

*There were significant gaps in the daily data from some NH sites for the period 1980-2009. Instead, the historical values in these tables were derived from the downscaled GCM model output.

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