United States Environmental Protection Agency
Office of Policy (2111)
EPA 236-F-98-007aa
September 1998

Climate Change And Vermont

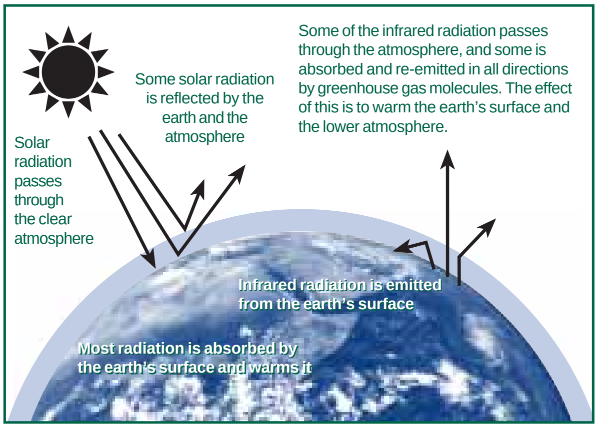
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed. Although there is uncertainty about exactly how and when the earth's climate will respond to enhanced concentrations of greenhouse gases, observations indicate that detectable changes are under way. There most likely will be increases in temperature and changes in precipitation, soil moisture, and sea level, which could have adverse effects on many ecological systems, as well as on human health and the economy.

The Climate System

Energy from the sun drives the earth's weather and climate. Atmospheric greenhouse gases (water vapor, carbon dioxide, and other gases) trap some of the energy from the sun, creating a natural "greenhouse effect." Without this effect, temperatures would be much lower than they are now, and life as known today would not be possible. Instead, thanks to greenhouse gases, the earth's average temperature is a more hospitable 60°F. However, problems arise when the greenhouse effect is ***enhanced*** by human-generated emissions of greenhouse gases.

Global warming would do more than add a few degrees to today's average temperatures. Cold spells still would occur in winter, but heat waves would be more common. Some places would be drier, others wetter. Perhaps more important, more precipitation may come in short, intense bursts (e.g., more than 2 inches of rain in a day), which could lead to more flooding. Sea levels would be higher than they would have been without global warming, although the actual changes may vary from place to place because coastal lands are themselves sinking or rising.

The Greenhouse Effect



Source: U.S. Department of State (1992)

Emissions Of Greenhouse Gases

Since the beginning of the industrial revolution, human activities have been adding measurably to natural background levels of greenhouse gases. The burning of fossil fuels — coal, oil, and natural gas — for energy is the primary source of emissions. Energy burned to run cars and trucks, heat homes and businesses, and power factories is responsible for about 80% of global carbon dioxide emissions, about 25% of U.S. methane emissions, and about 20% of global nitrous oxide emissions. Increased agriculture and deforestation, landfills, and industrial production and mining also contribute a significant share of emissions. In 1994, the United States emitted about one-fifth of total global greenhouse gases.

Concentrations Of Greenhouse Gases

Since the pre-industrial era, atmospheric concentrations of carbon dioxide have increased nearly 30%, methane concentrations have more than doubled, and nitrous oxide concentrations have risen by about 15%. These increases have enhanced the heat-trapping capability of the earth's atmosphere. Sulfate aerosols, a common air pollutant, cool the atmosphere by reflecting incoming solar radiation. However, sulfates are short-lived and vary regionally, so they do not offset greenhouse gas warming.

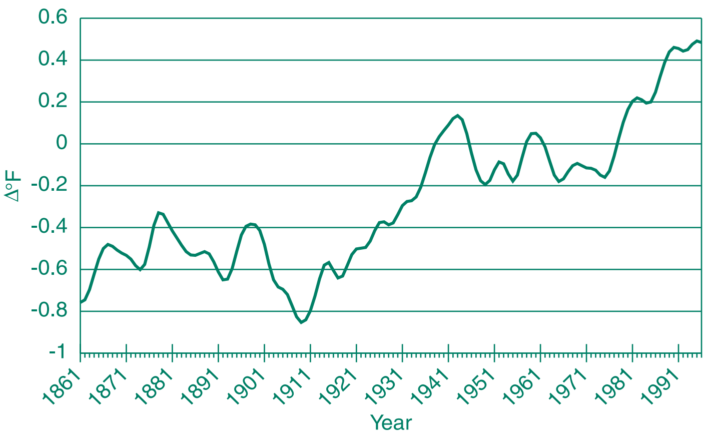
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and institutional developments. Several emissions scenarios have been developed based on differing projections of these underlying factors. For example, by 2100, in the absence of emissions control policies, carbon dioxide concentrations are projected to be 30-150% higher than today's levels.

Current Climatic Changes

Global mean surface temperatures have increased 0.6-1.2°F between 1890 and 1996. The 9 warmest years in this century all have occurred in the last 14 years. Of these, 1995 was the warmest year on record, suggesting the atmosphere has rebounded from the temporary cooling caused by the eruption of Mt. Pinatubo in the Philippines.

Several pieces of additional evidence consistent with warming, such as a decrease in Northern Hemisphere snow cover, a decrease in Arctic Sea ice, and continued melting of alpine glaciers, have been corroborated. Globally, sea levels have risen

Global Temperature Changes (1861–1996)



Source: IPCC (1995), updated

4-10 inches over the past century, and precipitation over land has increased slightly. The frequency of extreme rainfall events also has increased throughout much of the United States.

A new international scientific assessment by the Intergovernmental Panel on Climate Change recently concluded that ***"the balance of evidence suggests a discernible human influence on global climate."***

Future Climatic Changes

For a given concentration of greenhouse gases, the resulting increase in the atmosphere's heat-trapping ability can be predicted with precision, but the resulting impact on climate is more uncertain. The climate system is complex and dynamic, with constant interaction between the atmosphere, land, ice, and oceans. Further, humans have never experienced such a rapid rise in greenhouse gases. In effect, a large and uncontrolled planetwide experiment is being conducted.

General circulation models are complex computer simulations that describe the circulation of air and ocean currents and how energy is transported within the climate system. While uncertainties remain, these models are a powerful tool for studying climate. As a result of continuous model improvements over the last few decades, scientists are reasonably confident about the link between global greenhouse gas concentrations and temperature and about the ability of models to characterize future climate at continental scales.

Recent model calculations suggest that the global surface temperature could increase an average of 1.6-6.3°F by 2100, with significant regional variation. These temperature changes would be far greater than recent natural fluctuations, and they would occur significantly faster than any known changes in the last 10,000 years. The United States is projected to warm more than the global average, especially as fewer sulfate aerosols are produced.

The models suggest that the rate of evaporation will increase as the climate warms, which will increase average global precipitation. They also suggest increased frequency of intense rainfall as well as a marked decrease in soil moisture over some mid-continental regions during the summer. Sea level is projected to increase by 6-38 inches by 2100.

Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. The frequency and intensity of some extreme weather of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency of hot or cold spells, and the intensity of associated fire and pest outbreaks) could increase.

Local Climate Changes

Over the last century, the average temperature in Burlington, Vermont, has increased 0.4°F, and precipitation has increased by up to 5% in many parts of the state. These past trends may or may not continue into the future.

Over the next century, Vermont's climate may change even more. For example, based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre climate model (HadCM2), a model that accounts for both greenhouse gases and aerosols, by 2100 temperatures in Vermont could increase by 4°F (with a range of 2-9°F) in spring and 5°F (with a range of 2-10°F) in the other seasons. Precipitation is projected to show little change in spring, to increase by about 10% in summer and fall (with a range of 5-20%), and by 30% (with a range of 10-50%) in winter. Other climate models may show different results, especially regarding estimated changes in precipitation. The impacts described in the sections that follow take into account estimates from different models. The amount of precipitation on extreme wet or snowy days in winter is likely to increase. The frequency of extreme hot days in summer would increase because of the general warming trend. Although it is not clear how the severity of storms might be affected, an increase in the frequency and intensity of winter storms is possible.

Precipitation Trends From 1900 To Present

Source: Karl et al. (1996)

Human Health

Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and the incidence of heat-related illnesses. The elderly, particularly those living alone, are at greatest risk. These effects have been studied only for populations living in urban areas; however, even those in rural areas may be susceptible.

Climate change could increase concentrations of ground-level ozone. For example, high temperatures, strong sunlight, and stable air masses tend to increase urban ozone levels. In New England, a 4°F warming, with no other change in weather or emissions, could increase concentrations of ozone, a major component of smog, by 4%. Although Vermont is in compliance with current air quality standards, increased temperatures could make remaining in compliance more difficult. Ground-level ozone is associated with respiratory illnesses such as asthma, reduced lung function, and respiratory inflammation. Air pollution also is made worse by increases in natural hydrocarbon emissions such as emissions of terpenes by trees and shrubs during hot weather. If a warmed climate causes increased use of air conditioners, air pollutant emissions from power plants also will increase. Respiratory and eye allergies increase in warm, humid conditions.

Warmer temperatures could increase the incidence of Lyme disease and other tick-borne diseases in Vermont, because populations of ticks, and their rodent hosts, could increase under warmer temperatures and increased vegetation.

Warmer winters, warmer temperatures, and heavy precipitation also can increase harmful algal blooms in lakes and ponds, reduce water quality, and increase outbreaks of cryptosporidiosis and giardia.

Water Resources

The eastern portion of Vermont is drained by the Connecticut River, which forms the border between Vermont and New Hampshire. The western half of the state is drained by tributaries that traverse the Green Mountains and flow into Lake Champlain and the Hudson River. These surface waters provide water for half of the state's population, are an important source of water for industry and hydroelectric generation, and support recreation uses. Winter snow accumulation and spring snowmelt strongly affect all the state's rivers. A warmer climate would lead to an earlier snowmelt, resulting in higher streamflows in winter and spring and lower streamflows in summer and fall. Warmer summer temperatures and longer summers could exacerbate water quality problems such as excessive growth of aquatic weeds in Lake Champlain and other lakes. Warmer water temperatures also reduce dissolved oxygen levels, adversely affecting fish habitat, and lower summer streamflows could reduce the ability of rivers to assimilate waste. Changes in the timing and accumulation of snow could affect skiing conditions in positive and negative ways, such as the timing and length of season and snow depth.

Increased rainfall could result in localized flooding and exacerbate levels of pesticides and fertilizers in runoff from agricultural lands, major causes of degraded water quality in Vermont. Less rainfall, particularly during the summer when temperatures and evaporation are high, could reduce streamflow, lake levels, and groundwater levels. This could reduce water supplies for those areas of the state experiencing the highest rates of growth, including Chittenden, Rutland, Washington, and Windsor counties. Declining aquifers would also affect small municipalities and rural populations that depend on wells.

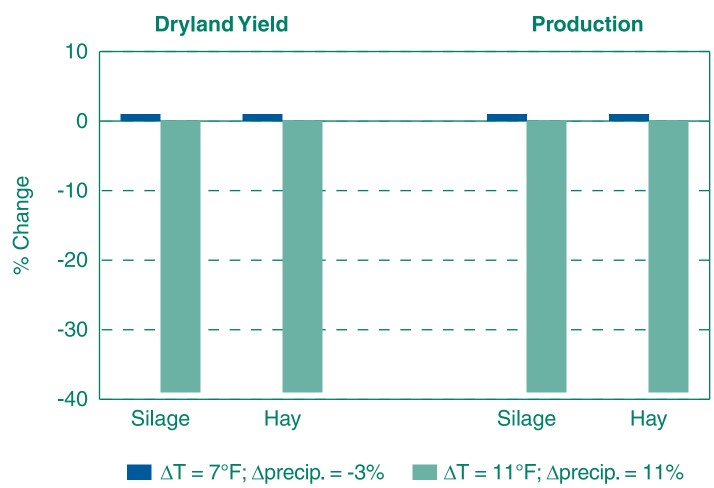
Lower water levels in freshwater lakes such as Lake Champlain would reduce flood damage, but shorelines could be more susceptible to erosion from wind and rain.

Agriculture

The mix of crop and livestock production in a state is influenced by climatic conditions and water availability. As climate warms, production patterns could shift northward. Increases in climate variability could make adaptation by farmers more difficult. Warmer climates and less soil moisture due to increased evaporation may increase the need for irrigation. However, these same conditions could decrease water supplies, which also may be needed by natural ecosystems, urban populations, industry, and other users.

Understandably, most studies have not fully accounted for changes in climate variability, water availability, crop pests, changes in air pollution such as ozone, and adaptation by farmers to changing climate. Including these factors could change modeling results substantially. Analyses that assume changes in average climate and effective adaptation by farmers suggest that aggregate U.S. food production would not be harmed, although there may be significant regional changes.

Changes In Agricultural Yield And Production



Sources: Mendelsohn and Neumann (in press); McCarl (personal communication)

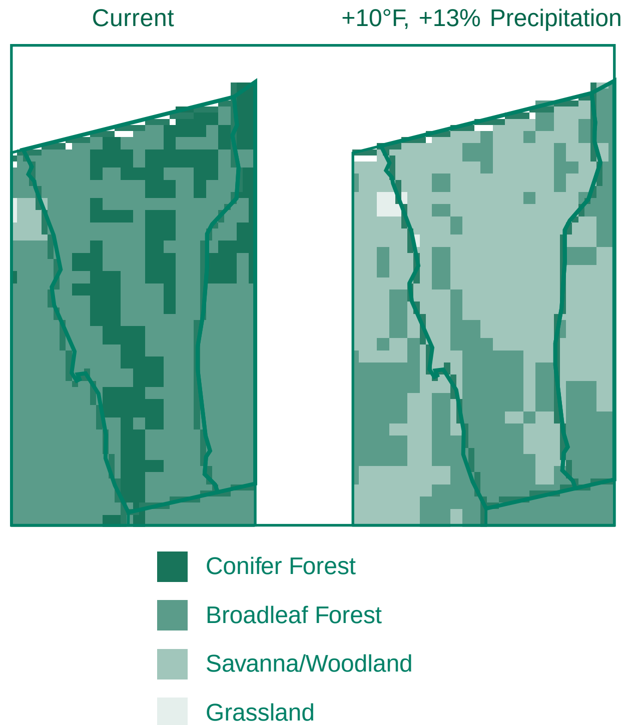
In Vermont, production agriculture is a $440 million annual industry, three-fourths of which comes from livestock, mainly dairy operations. Very few of the farmed acres are irrigated. The major crops in the state are silage and hay. Yields of these crops and pasture could fall by as much as 39% under severe conditions as temperatures rise beyond the tolerance levels of the crop and are combined with increased stress from decreased soil moisture. The extent of farmed acres, however, is projected to remain fairly constant. Estimated changes in yield vary, depending on whether land is irrigated. Livestock and dairy production may not be affected, unless summer temperature rises significantly and conditions become significantly drier. Under these conditions, livestock gain less weight and pasture yields decline, limiting forage.

Forests

Trees and forests are adapted to specific climate conditions, and as climate warms, forests will change. These changes could include changes in species composition, geographic range, and health and productivity. If conditions also become drier, the current range of forests could be reduced and replaced by grasslands and pasture. Even a warmer and wetter climate could lead to changes; trees that are better adapted to warmer conditions, such as oak, hickory, and pines, would prevail. Under these conditions, forests could become more dense. These changes could occur during the lifetimes of today's children, particularly if the change is accelerated by other stresses such as fire, pests, and diseases. Some of these stresses would themselves be worsened by a warmer and drier climate.

Although the extent of forested areas in Vermont could change little because of climate change, a warmer climate could change the character of those forests. Maple-dominated hardwood forests could give way to forests with more oaks and conifers, species more tolerant of higher temperatures. This change would diminish the brilliant autumn foliage as the number of maple trees declines. The spruce-fir forests in Vermont (and other New England states) are near the southern limit of their extent. These forests are sensitive to climatic stresses and have experienced significant declines in recent decades. Across the state, as much as 30-60% of the hardwood forests could be replaced by warmer-climate forests with a mix of pines and hardwoods. The extent and density of the spruce and fir forests at higher altitudes and in the north, which support a large variety of songbirds, also could be reduced. The change in temperature also could cause maple sap to run earlier and more quickly, thus shortening the length of the season for gathering sap.

Changes In Forest Cover



Sources: VEMAP Participants (1995); Neilson (1995)

Ecosystems

Seven endangered animals and plants are found in Vermont, including the Indiana bat, the dwarf wedge mussel, and Jessup's milk vetch. These animal and plant populations could be further stressed by changes in climate and habitat. Higher-than-normal winter temperatures could boost temperatures inside cave bat roosting sites, which has been shown to cause higher mortality due to increased winter body weight loss in endangered Indiana bats (e.g., an increase of 9°F during winter hibernation has been associated with a 42% increase in the rate of body mass loss). The marshes of the Missisquoi River delta on the northeastern shore of Lake Champlain support hundreds of species of waterfowl, which depend on the water and marsh habitat. Climate change could alter the water balance and affect the health and range of the marshlands.

As forests change in both range and composition, the habitat that supports the mixture of plants and animals changes. Animal species specific to cooler conifer forests, such as spruce grouse, gray jays, moose, and marten, could experience moderate to severe range reductions. Waterfowl and other migratory birds could be especially vulnerable to climate change-induced shifts in the timing that food resources become available. If wetlands are reduced by a drier climate or increased frequency of droughts, waterfowl populations also could decline.

For further information about the potential impacts of climate change, contact the Climate and Policy Assessment Division (2174), U.S. EPA, 401 M Street SW, Washington, DC 20460, or visit http://www.epa.gov/globalwarming/impacts.