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Climate Change And Maine

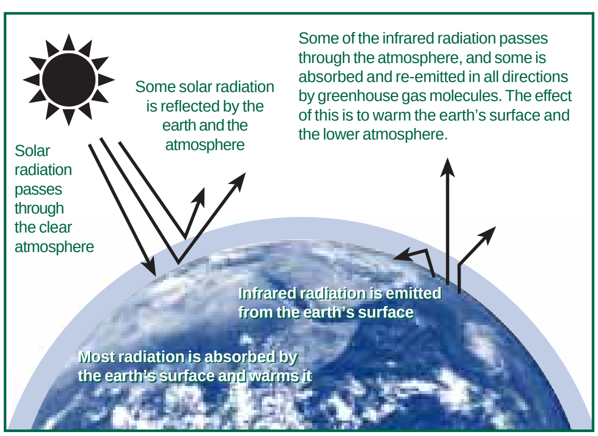
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed. 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.

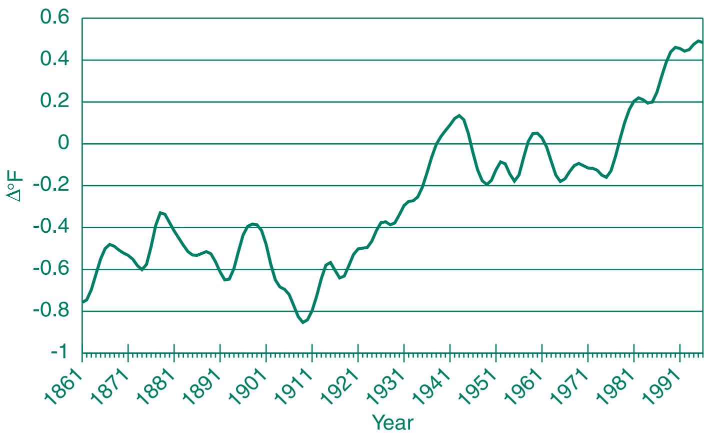
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and 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 planet-wide 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.

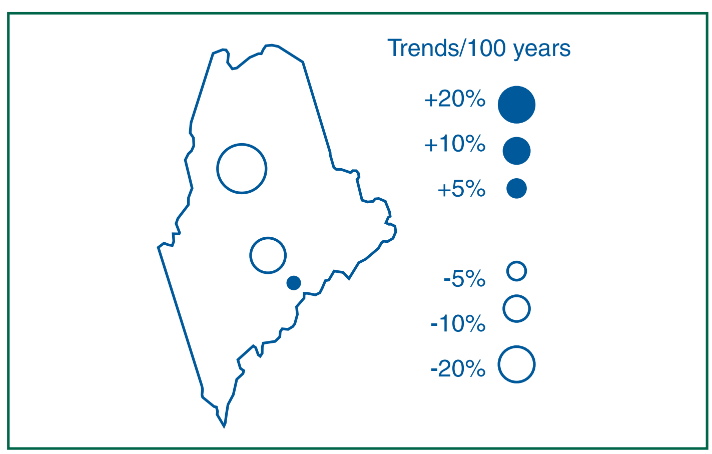
Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. The frequency and intensity of some extreme weather of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency 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 Lewiston, Maine, has increased 3.4°F, and precipitation has decreased by up to 20% in many parts of the state. These past trends may or may not continue into the future.

Over the next century, Maine'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 Maine could increase by 4°F (with a range of 2-8°F), slightly less in spring and fall and slightly more in summer and winter. Precipitation is projected to show little change in spring, increase by 10% in summer and fall (with a range of 5-15%), and increase by 30% in winter (with a range of 10-50%). 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 such as hurricanes 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. Maine, with its occasional heat waves, could be susceptible. In Boston, the nearest city in New England for which heat wave projections have been made, one study projects that a warming of 3°F could increase heat-related deaths during a typical summer by 50-100% (although increased air conditioning use may not have been fully accounted for). The elderly, especially those living alone, are at greatest risk. This study also shows that winter-related deaths will probably be unaffected by climate change in northern New England.

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%. Currently, ground-level concentrations exceed the national ozone health standard to a moderate extent in Portland and in southern counties along the coast. 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 Maine, 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, that is, red tides; reduce water quality; and increase outbreaks of cryptosporidiosis and giardia. In addition, warmer seas could contribute to the intensity, duration, and extent of harmful algal blooms in the coastal waters of Maine. These blooms damage habitat and shellfish nurseries and can be toxic to humans.

Coastal Areas

Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads, causeways, and bridges. In addition, sea level rise could increase the vulnerability of coastal areas to storms and associated flooding.

Maine has almost 3,500 miles of tidally influenced shoreline, consisting of rocky peninsulas and harbors, pocket beaches, islands, and complex estuaries. Because of the steep profile that is characteristic of the Maine coastline and a lack of low-lying land to be colonized by new marshes, there is likely to be a net loss of marshes in Maine under accelerated sea level rise.

At Rockland, sea level already is rising by 3.9 inches per century, and it is likely to rise another 14 inches by 2100. The rocky substrate of Maine may slow erosion due to sea level rise, and could complement efforts to protect the coastline. Possible responses to sea level rise include building walls to hold back the sea, allowing the sea to advance and adapting to it, and raising the land (e.g., by replenishing beach sand, elevating houses and infrastructure). Each of these responses will be costly, either in out-of-pocket costs or in lost land and structures. For example, the cumulative cost of sand replenishment to protect Maine's coastline from a 20-inch sea level rise by 2100 is estimated at $200-$900 million. However, sand replenishment may not be cost-effective for all coastal areas in the state and, therefore, some savings could be possible.

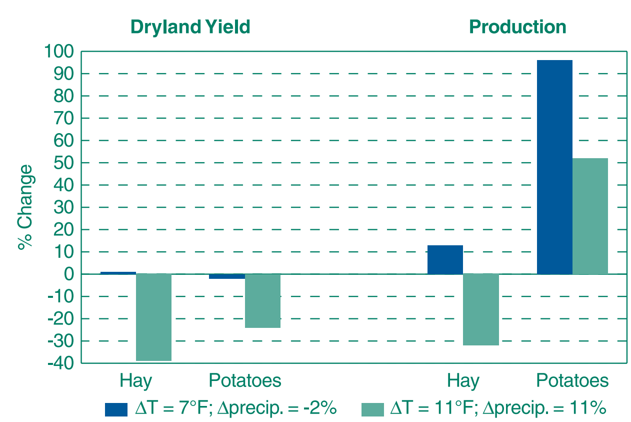
Agriculture

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.

In Maine, production agriculture is a $500 million annual industry, half of which comes from crops and the other half from livestock, mainly poultry and dairy. Very few of the farmed acres are irrigated. The major crops in the state are potatoes and hay.

Changes In Agricultural Yield And Production



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

Climate change could reduce potato yields by 2-23%. Hay and pasture yields could fall by as much as 39% as temperatures rise beyond the tolerance level of the crop. Estimated changes in yield vary, depending on whether land is irrigated. It is possible that Maine farmers could alter their cropping practices to take advantage of longer growing seasons and thus limit income losses due to reductions in hay and potato yields.

Water Resources

A warmer climate would lead to an earlier spring 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 in rivers such as the Androscoggin, where industry is significant and pollution has traditionally been a problem. 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.

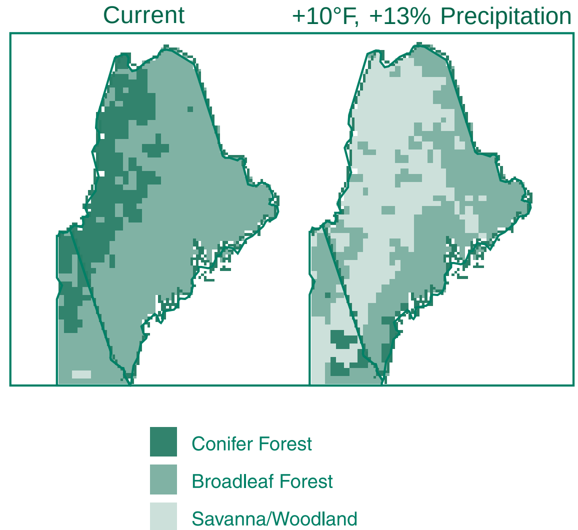
With more intense rainfall, increased flooding is possible, particularly in steep headwater areas and along well-developed floodplains. Greater and more intense rainfall could also increase erosion in agricultural and timber-harvesting areas, resulting in deposition of sediment in lakes and streams. Less rainfall, particularly during the summer, could reduce streamflow, lake levels, and groundwater levels. Streamflow reduction and warmer temperatures would reduce habitat for cold water fish. This could reduce water supplies in areas such as southwestern coastal Maine, which is experiencing growing water demands due to population growth and increased tourism.

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 substantially 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 Maine 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 dominated by oaks and conifers, species more tolerant of higher temperatures, especially along the coast. This change would diminish the brilliant autumn foliage as the number of maple trees declines. The spruce-fir forests in Maine (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 35-60% of the hardwood forests could be

Changes In Forest Cover



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

replaced by warmer-climate forests with a mix of pines and hardwoods and, in some areas in the southeast, by grassland and pasture. The extent and density of the spruce and fir forests at higher altitudes, which support a large variety of songbirds, also could be reduced by as much as 40-50%.

Ecosystems

The state of Maine is blanketed by northern hardwood/pine forests in the south and a mosaic of hardwood/spruce and higher elevation spruce-fir forests in the north and east. Maine's aquatic resources include the St. John River, a section of which is the longest free-flowing river segment in the northeastern United States and home to over 30 species of rare plants, including the endangered Furbish's lousewort. The state's long coastline harbors estuarine barrier islands and marshes that provide habitat for endangered species such as bald eagles, peregrine falcons, piping plovers, and roseate terns.

The conifer forests found in higher elevations in the White Mountains could be especially vulnerable to climate change. Climate change could hasten the expansion of broad-leaved forests into these pine forests, a transition that is already taking place as a result of selective and intensive logging. The ranges of spruce grouse, gray jays, boreal chickadees, snowshoe hares, marten, and moose could be affected by reduced pine forests and shifts in forest types. The already high threat of insect pest outbreaks in the northern forest could be exacerbated by warming-induced changes in the timing of spring frosts. If precipitation and runoff increase, the increased flooding of sensitive riparian areas could destroy valuable and unique aquatic and riverine habitats. Similarly, sensitive coastal ecosystems could be damaged by increased tidal floodings associated with increases in severe storms.

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.