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Climate Change And Minnesota

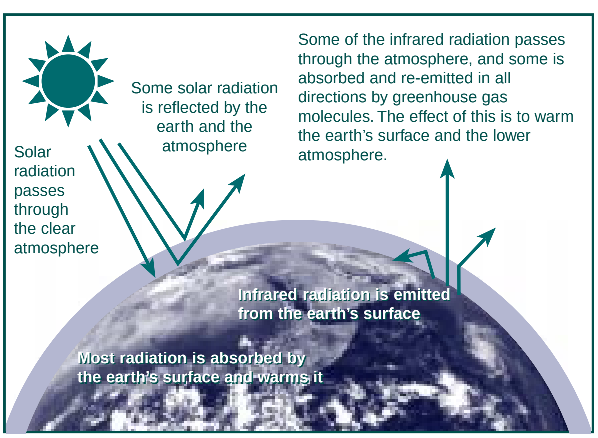
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

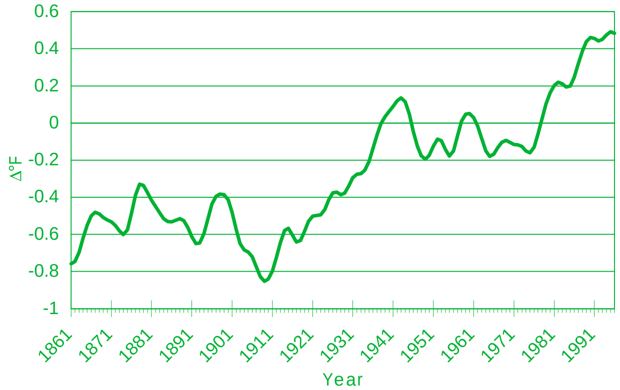
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and 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 since the late 19th century. 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 Minneapolis, Minnesota, has increased slightly from 43.9°F (1888-1917 average) to 44.9°F (1963-1992 average), and precipitation in some areas of the state has increased by up to 20%, especially in the southern half.

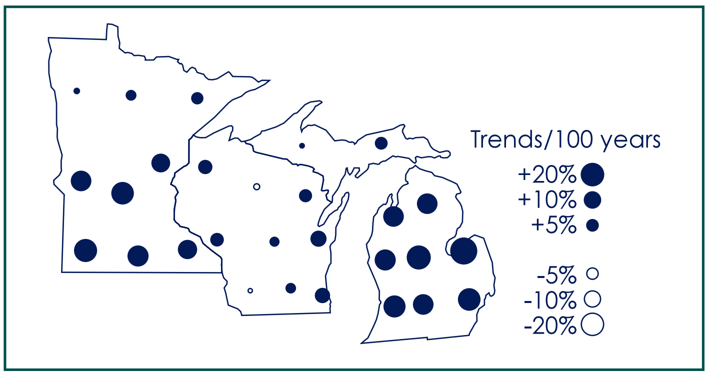
Over the next century, Minnesota's climate may change even more. Based on projections given by the Intergovernmental Panel on Climate Change and results from the United Kingdom Hadley Centre's climate model (HadCM2), a model that has accounted for both greenhouse gases and aerosols, it is projected that by 2100, temperatures in Minnesota could increase by about 4°F (with a range of 2-7°F) in winter, spring, and fall, and by somewhat less in summer. Precipitation is projected to increase by around 15% in winter, summer, and fall, with little change projected for spring.

The amount of precipitation on extreme wet days in summer most likely would increase. The frequency of extreme hot days in summer is expected to increase along with the general warming trend. It is not clear how severe storms would change.

Climate Change Impacts

Global climate change poses risks to human health and to terrestrial and aquatic ecosystems. Important economic resources such as agriculture, forestry, fisheries, and water resources also

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

may be affected. Warmer temperatures, more severe droughts and floods, and sea level rise could have a wide range of impacts. All these stresses can add to existing stresses on resources caused by other influences such as population growth, land-use changes, and pollution.

Similar temperature changes have occurred in the past, but the previous changes took place over centuries or millennia instead of decades. The ability of some plants and animals to migrate and adapt appears to be much slower than the predicted rate of climate change.

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. Minnesota, with its irregular, intense heat waves, seems somewhat susceptible.

In Minneapolis, one study projects that a 3°F warming could triple heat-related deaths from 60 during a typical summer to about 180 (although increased air conditioning use may not have been fully accounted for). The elderly, particularly those living alone, are at greatest risk.

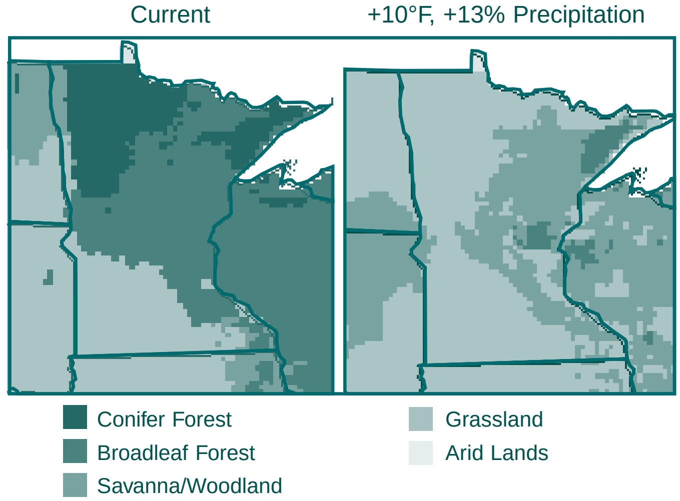
Warming and other climate changes could expand the habitat and infectivity of disease-carrying insects, increasing the potential for transmission of diseases such as malaria and dengue ("break bone") fever. Mosquitoes flourish in Minnesota, and some carry St. Louis encephalitis. The mosquito populations that carry this disease could increase with climate change. Also, the mosquitoes that carry yellow fever, dengue fever, Eastern equine encephalitis, and La Crosse encephalitis recently have spread as far north as Chicago. Global warming could shift the region where these mosquitoes breed and overwinter farther north. If conditions become warmer and wetter, mosquito populations can increase, thereby increasing the risk of transmission of these diseases.

Forests

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

With changes in climate, the extent of forested areas in Minnesota could change little or decline by as much as 50-70%. The uncertainties depend on many factors, including whether soil

Changes In Forest Cover



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

becomes drier and, if so, by how much drier. Hotter, drier weather could increase the frequency and intensity of wildfires. The unique boreal forests in the northern part of the state and in the Boundary Waters Canoe Area could be replaced by mixed forests better adapted to warmer conditions. The mixed aspen, birch, beech, maple, and pine forests in the northern and eastern areas of the state would shrink in range and be replaced by a combination of grasslands and hardwood forests consisting of oak, elm, and ash. Grasslands and savanna eventually could replace much of the forests and woodlands in the state. These changes would significantly affect the character of Minnesota forests and the activities that depend on them.

Water Resources

Water resources are affected by changes in precipitation as well as by temperature, humidity, wind, and sunshine. Changes in streamflow tend to magnify changes in precipitation. Water resources in drier climates tend to be more sensitive to climate changes. Because evaporation is likely to increase with warmer climate, it could result in lower river flow and lower lake levels, particularly in the summer. In addition, more intense precipitation could increase flooding. If streamflow and lake levels drop, groundwater also could be reduced.

Minnesota is known as the "Land of 10,000 Lakes." About two-thirds of the state lies within the headwaters of the Mississippi River. The remainder is drained by the Red River and small tributaries of Lake Superior. If climate warms, the ice cover on Minnesota's lakes and streams would not last as long as it does today. Streamflows could peak sooner in the spring because of earlier snowmelt and ice breakup. Reduced summer flows could decrease water quality. Lake surface temperatures would be warmer in the summer, although the temperature changes generally would be less than the increase in air temperature. As a result, lake evaporation would increase considerably, perhaps by as much as 20% for a 4°F warmer climate.

Shorter ice-cover seasons and increased lake evaporation could have major effects on Lake Superior. Fresh water flowing into Lake Superior could decrease with global warming, potentially reducing lake levels and degrading water quality. Flood damage could be reduced, but shorelines could be more susceptible to erosion damage from wind and rain. Reduced fresh water in the Great Lakes could negatively affect shipping to and from Duluth, for example, primarily because of lower water levels in the shipping channels connecting the lower Great Lakes. However, this could be offset by a longer ice-free season.

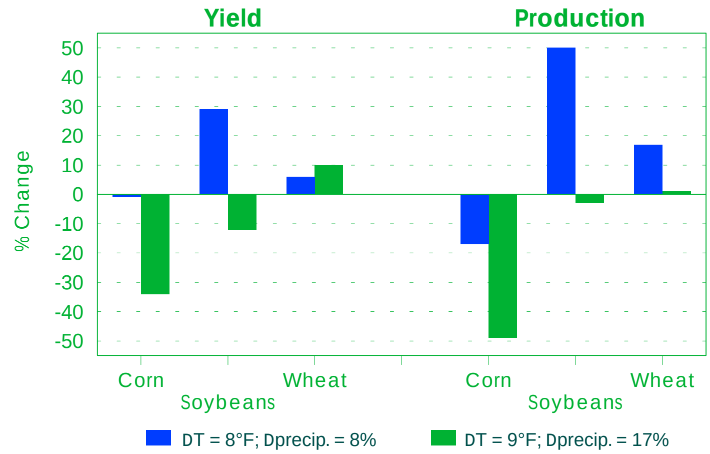
Agriculture

The mix of crop and livestock production in a state is influenced by climatic conditions and water availability. As climate warms, production patterns will 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, and other economic sectors.

Understandably, most studies have not fully accounted for changes in climate variability, water availability, and imperfect responses by farmers to changing climate. Including these factors could substantially change modeling results. Analyses based on changes in average climate and which assume farmers effectively adapt suggest that aggregate U.S. food production will not be harmed, although there may be significant regional changes.

In Minnesota, agriculture is about a $7 billion annual industry, 50% of which comes from crops. About 5% of all farm acres in the nation is in Minnesota. The principal crops are corn, soybeans, and wheat. About 2% of the state's farm acres are irrigated. If climate warms, corn yields could remain unchanged or could decrease by up to 34%. Wheat yields could increase by 6-10%, and projected soybean yields are mixed: they could increase by up to 28% or decrease by 12%. The number of acres farmed could fall by 12-18%, and farm income could decrease by 10-25%. Irrigated acreage could increase. This could further stress water supplies, which could be lower in the summer, and water quality could be degraded further.

Changes In Agricultural Yield And Production



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

Ecosystems

The prairie potholes of Minnesota are the single most important breeding area for North American waterfowl such as mallards, pintails, and blue-winged teals. The drying effects of climate change could reduce the size and number of prairie potholes, with damaging effects to the waterfowl.

The forest ecosystems in the Boundary Waters Canoe Area are an important habitat for Kirtland's warblers. If the birch, balsam fir, white cedar, and quaking aspen found there were replaced by sugar maples, Kirtland's warblers could disappear in Minnesota.

Aquatic ecosystems also could be affected by climate change; for example, brown trout could lose most of their habitat.

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.