



# Climate Change And Michigan

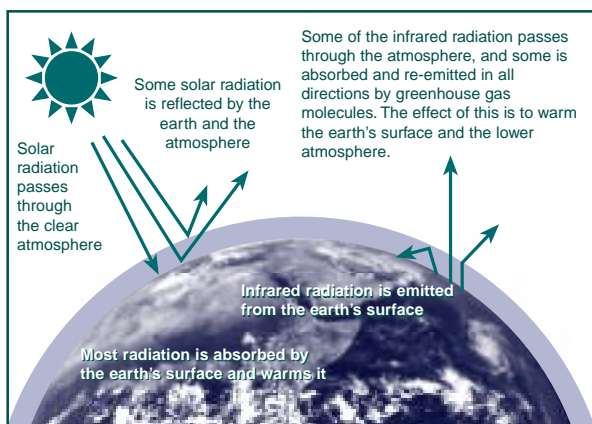
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

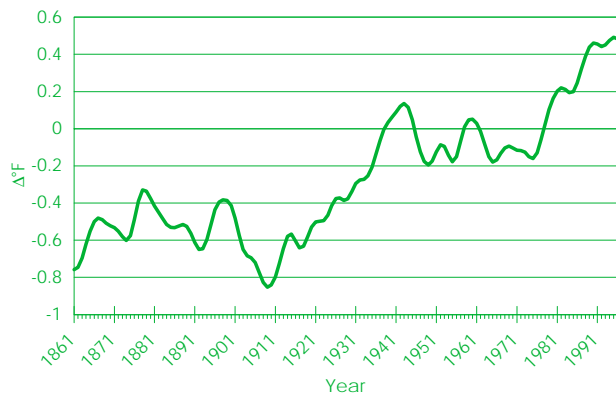
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

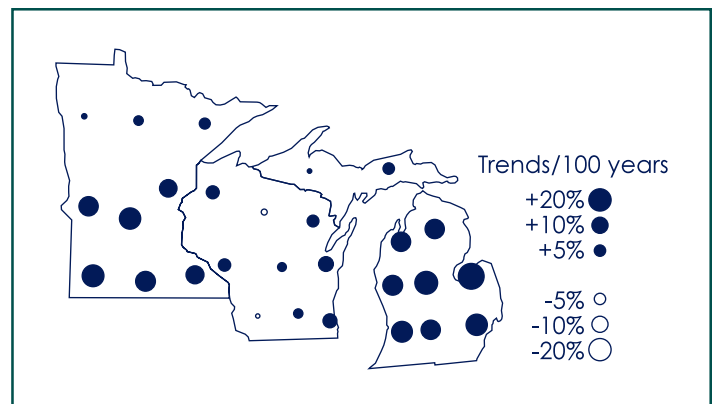
## Local Climate Changes

Over the last century, the average temperature in Ann Arbor, Michigan, has increased from 46.6°F (1876-1905 average) to 47.7°F (1962-1991 average), and precipitation in some locations in the state has increased by up to 20%.

Over the next century, Michigan’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 Michigan could increase by about 4°F in all seasons (with a range of 2-8°F). Precipitation is projected to increase by 5-15% in winter, spring, and fall, and by around 20% (with a range of 10-40%) in summer.

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.

## Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

## 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 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. Michigan, with its irregular, intense heat waves, seems somewhat susceptible.

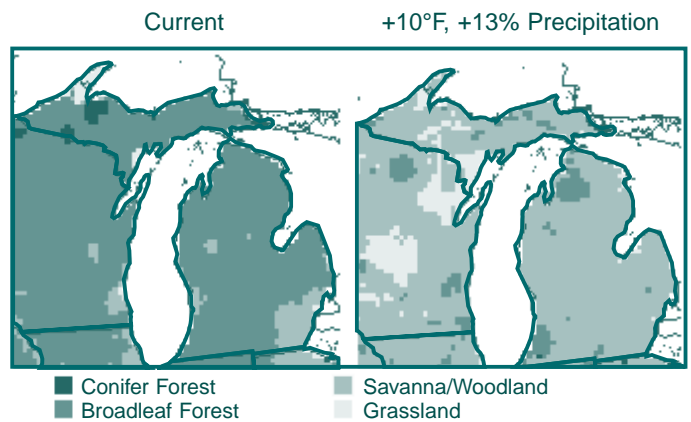
In Detroit, one study projects that a 3°F warming could increase heat-related deaths during a typical summer from 110 to possibly over 200 (although increased air conditioning use may not have been fully accounted for). If the warming is 5°F, heat-related deaths could be about 250 during a typical summer. Winter-related deaths could drop from 35 in Detroit per winter to about 20 if winter temperatures warm by 3-5°F. The elderly, particularly those living alone, are at greatest risk.

There is concern that 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. Air pollution also is made worse by increases in natural hydrocarbons emissions during hot weather. If a warmed climate causes increased use of air conditioners, air pollutant emissions from power plants also will increase.

A 4°F warming in the Midwest, with no other change in weather or emissions, could increase concentrations of ground-level ozone, a major component of smog, by as much as 8%. Perhaps more important, however, is that the area not meeting national health standards for ozone could almost triple. Currently, Muskegon is the only county in Michigan that does not attain the National Ambient Air Quality Standards for ozone. Ground-level ozone has been shown to aggravate existing respiratory illnesses such as asthma, reduce lung function, and induce respiratory inflammation. In addition, ambient ozone reduces crop yields and impairs ecosystem health.

Warming and other climate changes may expand the habitat and infectivity of disease-carrying insects, increasing the potential for transmission of diseases such as malaria and dengue (“break

## Changes In Forest Cover



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

bone”) fever. Mosquitoes flourish in Michigan, and some carry St. Louis encephalitis. The mosquitoes 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 could 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 grasslands and pasture. Even a warmer and wetter climate would lead to changes; trees that are better adapted to these conditions, such as oaks and redwoods, would thrive. 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 Michigan could change little or decline by as much as 50-70%. The uncertainties depend on many factors, including whether soil becomes drier and, if so, by how much drier. Hotter, drier weather could increase the frequency and intensity of wildfires. The mixed aspen, birch, beech, maple, and pine forests found in the north could be replaced over time by a combination of grasslands, savannah, and hardwood forests of oak, elm, and ash. The predominant hardwood forests in the south could give way to pine and oak forests. These changes could affect the character of Michigan 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.

All but a fraction of Michigan streams drain to one of the three upper Great Lakes (Superior, Michigan, and Huron). In a warmer climate, the seasonal flow in the state's streams and rivers would peak earlier. Because evaporation would increase in a warmer climate, summer streamflows probably would decrease, which could have important implications for stream health.

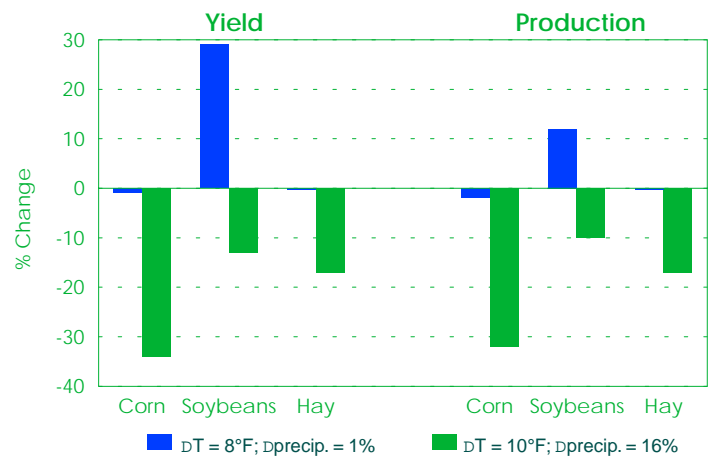
Shorter ice-cover seasons and increased lake evaporation could have major effects on the Great Lakes. Fresh water flowing into the Great Lakes could decrease by 20% with a 4°F warming, potentially reducing lake levels by a foot or more. Flood damage could be reduced, but shorelines could be more susceptible to erosion damage from wind and rain. Reduced fresh water in the Great Lakes could impede shipping to and from Michigan ports, primarily because of lower water levels in the shipping channels connecting the lower Great Lakes.

## 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.

## Changes In Agricultural Yield And Production



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

In Michigan, agriculture is about a \$3 billion annual industry, 50% of which comes from livestock. The principal crops are corn, soybeans, and hay. About 4% of the state's farm acres is irrigated. If climate warms, corn yields are projected to remain unchanged or could decrease by up to 34%. Soybean yields could either decrease or increase, and hay yields could remain unchanged or decrease by 17%. Acres farmed could remain unchanged, and farm income could decrease by 10-40%. Irrigated acreage could increase. This could further increase the demands for available water, and water quality could be further degraded.

## Ecosystems

A rise in water temperatures in the Great Lakes would reduce the size of favorable habitat for trout, whitefish, and other coldwater fish species. If groundwater-fed streams experienced an increase in temperature, brook trout could lose all their habitat, and brown and rainbow trout could lose most of their habitat. Warm water fish, both native and introduced, could experience longer growing seasons and flourish in a warmer climate.

The well-known Kirtland's warbler breeds only in the jack pine forests of northern lower Michigan. Because the jack pines may not survive in Michigan if the climate warms, the existence of the Kirtland's warbler could be threatened.

*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.*