United States Environmental Protection Agency
Office of Policy, Planning and Evaluation (2111)
EPA 230-F-97-008z
September 1997

Climate Change And Montana

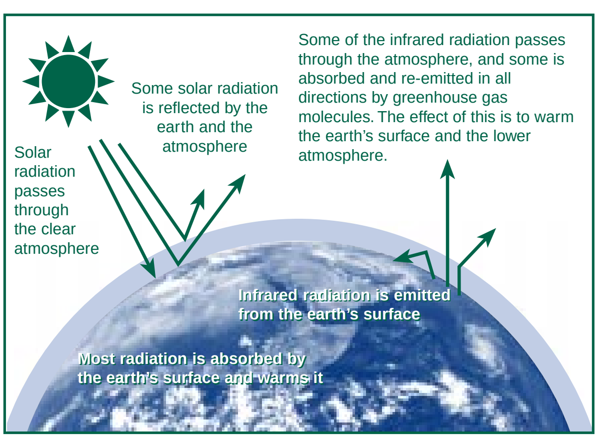
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed. 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, common air pollutants, cool the atmosphere by reflecting incoming solar radiation. However, sulfates are short-lived and vary regionally.

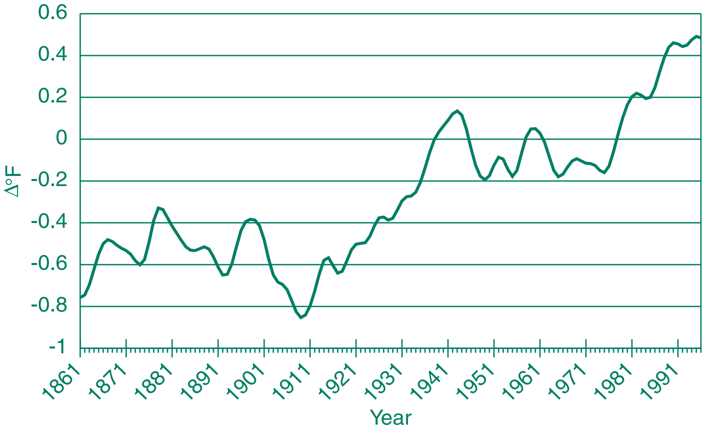
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

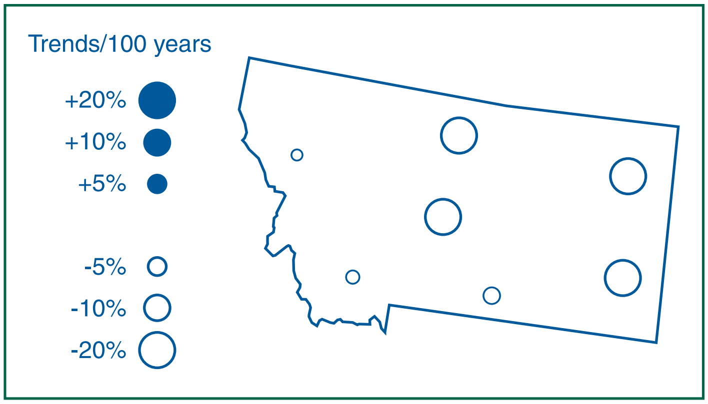
Over the last century, the average temperature in Helena, Montana, has increased 1.3°F, and precipitation has decreased by up to 20% in many parts of the state.

Over the next century, climate in Montana 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's climate model (HadCM2), a model that accounts for both greenhouse gases and aerosols, by 2100 temperatures in Montana could increase by about 4°F in spring and summer (with a range of 1-8°F) and 5°F in fall and winter (with a range of 2-10°F). Precipitation is estimated to increase by roughly 10% in all seasons except winter, when the range of estimated increase is 15-40%. 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 severe storms would change, an increase in the frequency and intensity of winter storms is possible.

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

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

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. Montana, with its irregular, intense heat waves, could be susceptible. The elderly, particularly those living alone, are at greatest risk.

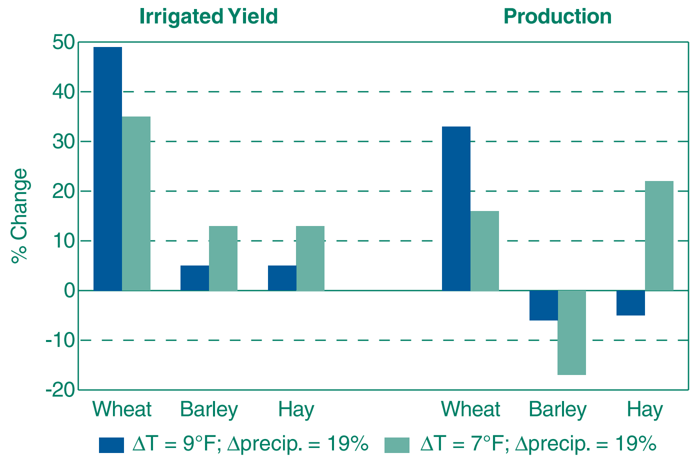
Warming and other climate changes may expand the habitat and infectivity of disease-carrying insects, thus increasing the potential for transmission of diseases. A recent study has concluded that a 5-9°F temperature increase would cause a significant northern shift in Western equine encephalitis outbreaks. Mosquitos capable of transmitting this disease already are present in Montana. If Montana's climate becomes warmer and wetter, mosquito populations could increase and conditions may become more favorable for disease transmission.

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. If streamflow and lake levels drop, groundwater also could be reduced. In addition, more intense precipitation could increase flooding.

Western Montana drains into the Columbia River system, and most of the remaining areas of the state drain to the east into the Missouri River or its major tributary, the Yellowstone River. Winter snow accumulation and spring melt are key processes that affect the runoff of all rivers within the state. A warmer climate would lead to earlier spring snowmelt, resulting in higher streamflows in winter and spring and lower streamflows in summer and fall. Earlier spring snowmelt could reduce the performance of the reservoir system in western Montana, thus reducing summer and fall runoff, which is critical for power generation, fisheries protection, recreation, and other uses. Increased rainfall could mitigate some of these effects, but it also could lead to increased flooding.

Changes In Agricultural Yield And Production



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

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 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 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 Montana, agriculture is a $1.8 billion annual industry, one-half of which comes from livestock, mainly cattle. Just over 20% of the crop acreage is irrigated. The major crops in the state are wheat, barley, and hay. In a warmer climate wheat yields could increase by more than a third, and changes in barley and hay yields could vary between -8% and +13%, depending on whether irrigation is used, leading to changes in acres farmed and production. For example, barley yields could rise while production falls because of a decrease in barley acres farmed. An increased dependence on irrigation is possible, depending on the relative balance between rainfall and increased evaporation.

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 range, 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 could lead to changes; trees that are better adapted to these conditions, such as fir and spruce, would thrive. Under these conditions, forests could become more dense. These changes could occur during the lifetimes of today's children, particularly if 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.

With changes in climate, the extent of forested areas in Montana may change little or could decline by as much as 15-30%. The uncertainties depend on many factors, including whether soils become drier and, if so, how much drier. Hotter, drier weather could increase the frequency and intensity of wildfires, threatening both property and forests. Drier conditions could reduce the range and health of lodgepole and Douglas fir forests, and increase their susceptibility to fire. With increases in rainfall, however, these effects could be less severe. Grass and rangeland could expand into previously forested areas along the eastern slope of the Rocky Mountains and into some of the western valleys. Milder winters could increase the likelihood of insect outbreaks and of subsequent wildfires in the dead fuel left after such an outbreak. These changes would significantly affect the character of Montana forests and the activities that depend on them.

Ecosystems

Ecosystems in Montana are diverse, ranging from grasslands and deserts to mountain shrublands, forests, meadows, and alpine tundra. They also include numerous wetlands and streams. Because of elevation changes and human land use, many habitats are fragmented and restricted in area. Changes in temperature and precipitation caused by climate change could affect the location and productivity of these ecosystems.

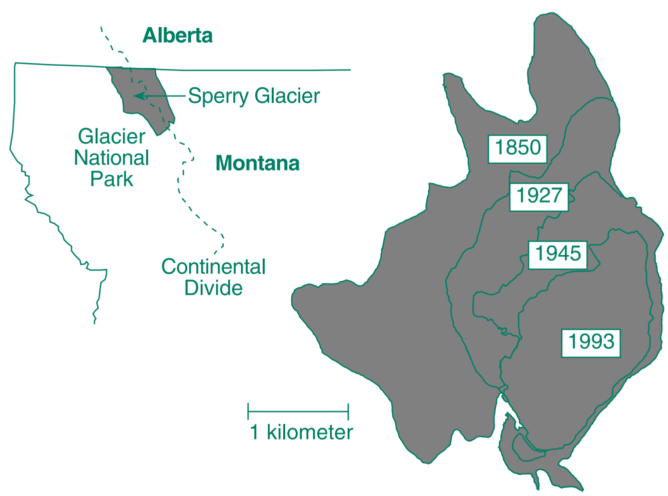
Warming and changes in precipitation could affect alpine areas, causing tree lines to rise by roughly 350 feet for every degree Fahrenheit of warming. Mountain ecosystems such as those found in Glacier National Park could shift upslope, reducing habitat for many subalpine species. Alpine animals and species, many of which are unique to the region, could disappear from the highest elevations. Mountain glaciers such as those found in Glacier National Park are expected to shrink, possibly leading to higher stream temperatures and decreased runoff. This would adversely affect aquatic biota, including trout species. Changes in rainfall and snowfall also could alter streamflows and wetlands, affecting wildlife and possibly accelerating the invasion of non-native plants into streamside habitats. Aquatic species that are sensitive to water temperature could be affected adversely by climate change. Brown trout and rainbow trout could lose habitat.

Glacier National Park

Glacier National Park is located in a pristine mountainous area in northwest Montana. The park provides habitat for an abundance of wildlife, including the most dense population of grizzly bears (an endangered species) in the United States. Other endangered animal species found in the park include the bald eagle and the gray wolf. Over 1,400 different plants live in Glacier Park, 28 of which are found nowhere else in Montana.

Climate change could have a serious impact on Glacier National Park. The park has approximately 50 glaciers today, down from an estimated 150 glaciers in 1850. The recession of Sperry Glacier illustrates the impact of recent warming temperatures in the park. If these warming trends continue, it is estimated that no glaciers will be found in the park by 2030. Without glaciers, stream temperatures are expected to rise, which could affect aquatic ecosystems in the park, including trout species. Climate change also could affect the types of trees found in the forests. Lodgepole pine and western cedar forests could yield to forests dominated by spruce and western hemlock. Six rare alpine plants that are at the southern border of their geographic range would be especially vulnerable to climate change.

Sperry Glacier Recession 1850-1993



Source: USGS Biological Resources Division, Glacier Field Station. Carl H. Key, provisional data (1997)

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.