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

Climate Change And South Dakota

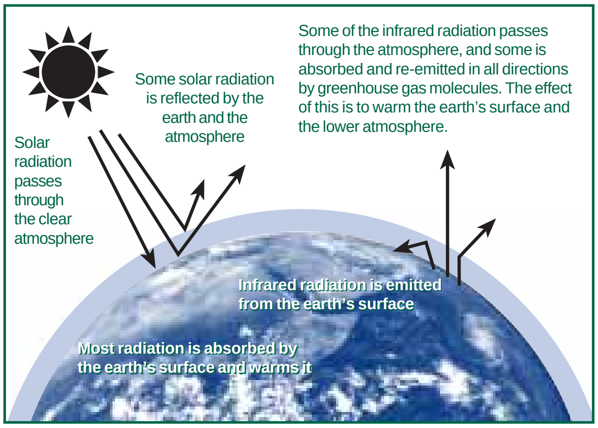
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

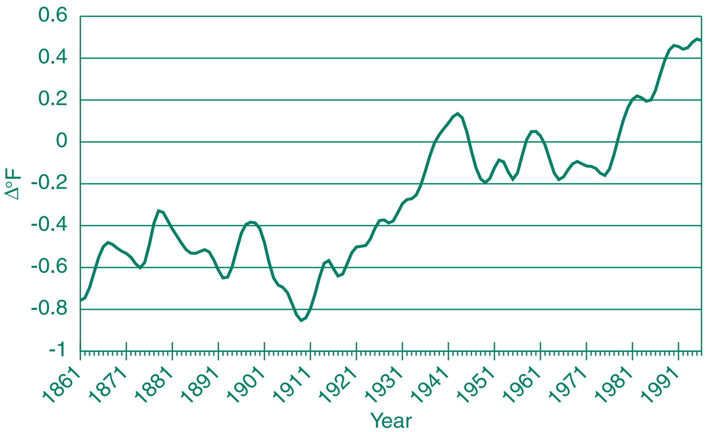
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

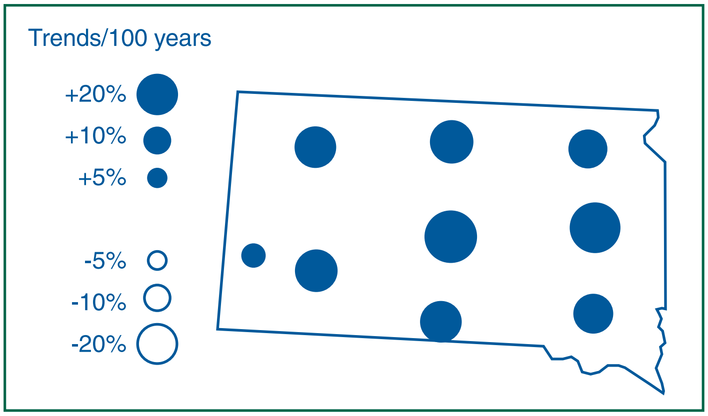
Over the last century, the average temperature in Pierre, South Dakota, has increased 1.6°F, and precipitation has increased by up to 20% in many parts of the state. These past trends may or may not continue into the future.

Over the next century, climate in South Dakota 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 South Dakota could increase by 3°F in spring and summer (with a range of 1-6°F) and 4°F in fall and winter (with a range of 2-7°F). Precipitation is estimated to increase by 10% (with a range of 5-20%) in spring, summer, and fall, and 20% in winter (with a range of 10-40%). The amount of precipitation on extreme wet or snowy days in winter is likely to increase. 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 frequency of extreme hot days in summer would increase because of the general warming trend. It is not clear how the severity of storms might be affected, although an increase in the frequency and intensity of winter storms is possible.

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. South Dakota, with its irregular, intense

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

heat waves, could be susceptible. These effects have been studied only for populations living in urban areas; however, even those in rural areas may be at risk. South Dakota lacks large cities, which are most sensitive to heat waves; however, Minneapolis will experience similar changes in climate and could indicate how populations in South Dakota cities might be affected. One study estimates that in Minneapolis a summer warming of 5°F could increase heat-related deaths by threefold from about 60 to 180 (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 projects little change in winter-related deaths in South Dakota.

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. A 2°F warming in the Midwest, with no other change in weather or emissions, could increase concentrations of ozone, a major component of smog, by as much as 8%. Although South Dakota 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.

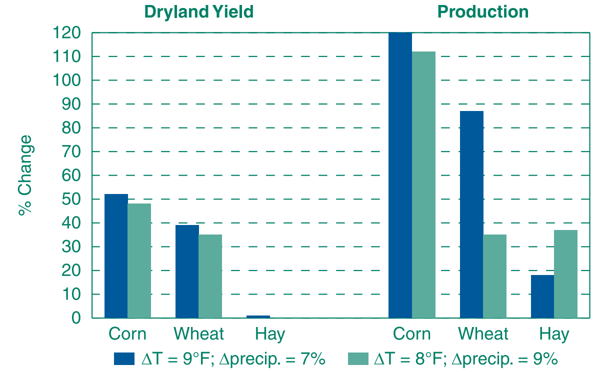
Upper and lower respiratory allergies are influenced by humidity. A 2°F warming and wetter conditions could increase respiratory allergies.

Warming and other climate changes could expand the habitat and infectivity of disease-carrying insects. Infected individuals can bring malaria to places where it does not occur naturally. Also, some mosquitoes in South Dakota can carry malaria, and some can carry western equine encephalitis, which can be lethal or cause neurological damage. If conditions become warmer and wetter, mosquito populations could increase, thus increasing the risk of transmission if these diseases are introduced into the area. Warmer temperatures could increase the incidence of Lyme disease and other tick-borne diseases in South Dakota, because populations of ticks, and their rodent hosts, could increase under warmer temperatures and increased vegetation. Increased runoff from heavy rainfall could increase water-borne diseases such as giardia, cryptosporidia, and viral and bacterial gastroenteritides. Developed countries such as the United States should be able to minimize the impacts of these diseases through existing disease prevention and control methods.

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.

Changes In Agricultural Yield And Production



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

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 South Dakota, production agriculture is a $3.3 billion annual industry, two-thirds of which comes from livestock, mainly cattle. Very few of the farmed acres are irrigated. The major crops in the state are corn, wheat, and hay. Corn and wheat yields could rise by 35-51%, while hay and pasture yields could remain unchanged. Farmed acres in the state could increase by about 30%. Livestock and dairy production may not be affected, unless summer temperatures rise significantly and conditions become significantly drier. Under these conditions, livestock tend to gain less weight and pasture yields decline, limiting forage.

Water Resources

The major river in South Dakota is the Missouri River, which drains almost the entire state. South Dakota is primarily rural, and agriculture is the dominant user of water. The area west of the Missouri, where ranching predominates, principally uses surface water. The area east of the Missouri, which has a farming-based economy, relies heavily on groundwater. Streamflow is highly variable in South Dakota. Except for the Missouri, which has a sustained flow and large storage reservoirs, many streams do not provide a dependable water supply. Particularly in the eastern part of the state, streams are characterized by high flows during the spring and early summer that can cause flooding and by low flows during the summer, fall, and winter that can limit uses. In a warmer climate, this situation could be exacerbated. Warmer winter temperatures would lead to earlier spring snowmelt, resulting in higher streamflows in winter and spring. In the summer, without large increases in precipitation, higher temperatures and increased evaporation would further reduce streamflows and lake levels. For a doubling in CO_2 levels, some studies show a 6-34% reduction in inflow into the Missouri River system. Groundwater levels also could be reduced by lower spring and summer recharge. Although many water control projects have been built to alleviate South Dakota's water shortages, the water demands of the increasing population, mining operations, irrigation, and energy-development activities continue to grow. Lower streamflows and groundwater levels would limit water availability for irrigation, hydropower generation, fish and wildlife habitat, recreation, and water supplies for municipalities, industries, and rural areas. South Dakota is susceptible to periodic droughts that severely damage the state's agriculture-based economy. Droughts could occur more frequently in a warmer climate. Higher summer temperatures and lower flows also could degrade water quality by concentrating pollutants and reducing the capacity of streams to assimilate wastes. Prairie pothole wetlands, which provide important waterfowl habitat, also would be impaired by declining water levels.

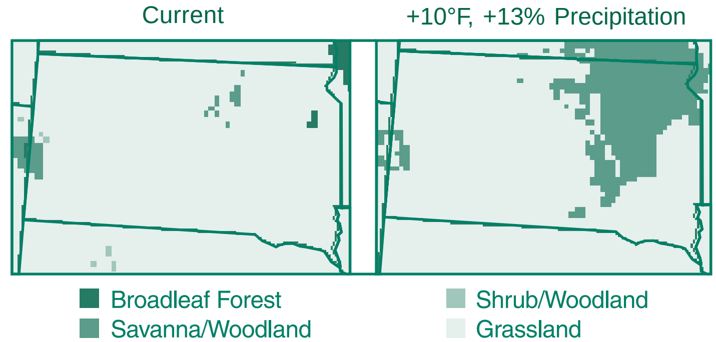
More rain is possible with a warmer climate. Although this could alleviate water shortages, it also could increase flooding. Prairie streams such as the Big Sioux and James rivers in the eastern part of the state do flood agricultural lands. Additionally, in a warmer climate, heavier rains are expected, which could increase flash floods in the western part of the state. Increased rainfall also could increase erosion and exacerbate levels of pesticides and fertilizers in runoff from agricultural lands and exacerbate water quality problems associated with nutrient enrichment and sedimentation of streams and lakes.

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 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 warmer conditions, such as oaks 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.

With changes in climate, the extent of the few forested areas in South Dakota could change. The extent and direction of change depends 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, decreasing the range and density of ponderosa pines, especially in the Black Hills. Grasslands and savanna eventually could replace many of the forests and riparian woodlands in South Dakota. However, some studies indicate increases in rainfall, particularly in the northeastern part of the state, could lead to increases in the extent and character of shrub and woodland areas.

Changes In Forest Cover



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

Ecosystems

South Dakota is a mosaic of terrestrial and aquatic habitats important for both resident and migratory wildlife species. Historical ecosystems included mixed grass plains, tallgrass transition areas, tallgrass prairie, and wooded areas. Construction of dams and channels along the Missouri River has altered or eliminated riparian habitats. Of an original 500 miles of riparian bottomland timber along the Missouri River, less than 80 miles remain. These alterations have directly affected the breeding habitat of the piping plover, interior least tern, and whooping crane, and the wintering habitat of the bald eagle. Spawning habitats and movements of the pallid sturgeon, paddlefish, sturgeon chub, sicklefin chub, and finescale dace have been drastically altered or eliminated. Conversion of native prairie to agricultural use is a second major cause of habitat loss or alteration in the state. It is estimated that more than 75% of the land in eastern South Dakota is under cultivation. Wetlands have been drained, eliminating habitat for fish and wetland-dependent birds, mammals, reptiles, amphibians, and insects. Changes in climate can be expected to further stress ecosystems and wildlife such as the mountain lion, black bear, longnose sucker, fringe-tailed myotis, marten, and bald eagle.

Based on model projections, national wildlife refuges in South Dakota appear to be among the most vulnerable in the United States to changes in climate. The region's national wildlife refuges and prairie pothole systems appear to be especially sensitive to changes in precipitation and temperature. Sixty percent of the annual variation in the number of these wetlands can be explained by year-to-year changes in temperature and precipitation. Smaller wetlands may be particularly vulnerable to climate change. Projections show that warmer annual temperatures affect wetlands by reducing open water and increasing vegetation cover, independent of precipitation. Rising temperatures, if continued for several years, may decrease breeding bird density and diversity in this critically important waterfowl habitat. Major additional threats to ecosystems include habitat loss and species extinction, increased fire frequency, and increased vulnerability to invasive plant and insect species.

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.