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Climate Change And Wyoming

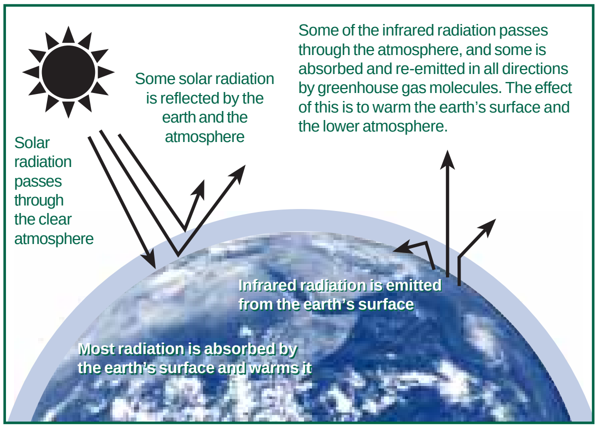
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

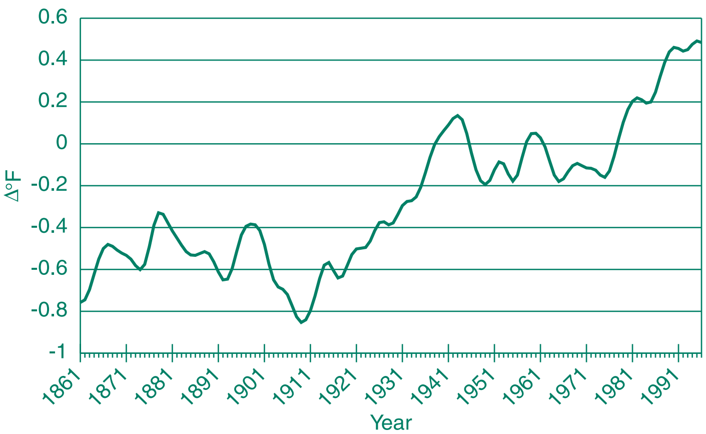
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

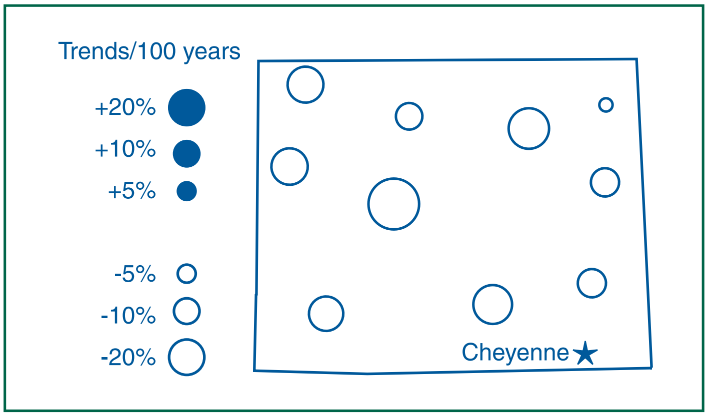
Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. The frequency and intensity of some extreme weather of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency 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 Laramie, Wyoming, has increased 1.5°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, climate in Wyoming 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 Wyoming could increase by 4°F in spring and fall (with a range of 2-7°F), 5°F in summer (with a range of 2-8°F), and 6°F in winter (with a range of 3-11°F). Precipitation is estimated to decrease slightly in summer (with a range of 0-10%), increase by 10% in spring and fall (with a range of 5-20%), 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. 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.

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. The elderly, particularly those living alone, are at greatest risk. These effects have been studied only for populations living in urban areas; however, even those in rural areas may be susceptible.

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 Wyoming can carry malaria. If conditions become warmer and wetter, mosquito populations could increase, thus increasing the risk of transmission if this and other diseases are introduced into the area. Warmer temperatures could increase the incidence of Lyme disease and other tick-borne diseases in Wyoming, 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.

Water Resources

The headwaters of several rivers originate in Wyoming and flow in all directions into the Missouri, Snake, Great, and Colorado river basins. Within the state, water is plentiful in some parts and scarce in others. The mountains receive abundant precipitation, mostly as snow, which support perennial streams. The plains and intermountain areas are semiarid, and most of the rain there comes during summer thunderstorms. The streams in these areas tend to be intermittent and are not dependable water sources; hence, reservoir storage is required to ensure reliable year-round supplies. Surface water is the primary source of water, and irrigation is the largest user. Groundwater is used where surface supplies are inadequate or need to be supplemented.

Winter snow accumulation and spring snowmelt strongly affect many of Wyoming's rivers. A warmer climate could result in less winter snowfall, more winter rain, and faster, earlier spring snowmelt. In the summer, without increases in rainfall of at least 15-20%, higher temperatures and increased evaporation could lower streamflows and lake levels. Less water would be available to support irrigation, hydropower generation, public supply, fish and wildlife habitat, recreation, and mining. Competition for water could increase on the plains, where agricultural and industrial users compete for available water. Similarly, in northeastern Wyoming, which has large deposits of minerals, coal, and petroleum, competition between mining, energy, and other users could intensify for the meager summer streamflows. Groundwater levels in several areas of the state are declining because of increased pumpage for irrigation and urban development. Less spring and summer recharge could lower groundwater levels. Tourism and recreation, important components of Wyoming's economy, also depend on adequate supplies of clean water. Higher temperatures and lower flows could impair water quality by concentrating pollutants and reducing assimilative capacity. Major water quality concerns such as the saline content of irrigation return flows and eutrophication also could be aggravated by a warmer climate. Many streams in Wyoming are fully appropriated for offstream uses. Much of the water in the state belongs to downstream users through interstate compacts and court decrees. Reductions in water availability could complicate water rights issues and interstate agreements. Changes in the timing and accumulation of snow could affect skiing conditions in positive and negative ways, such as the timing and length of season and snow depth.

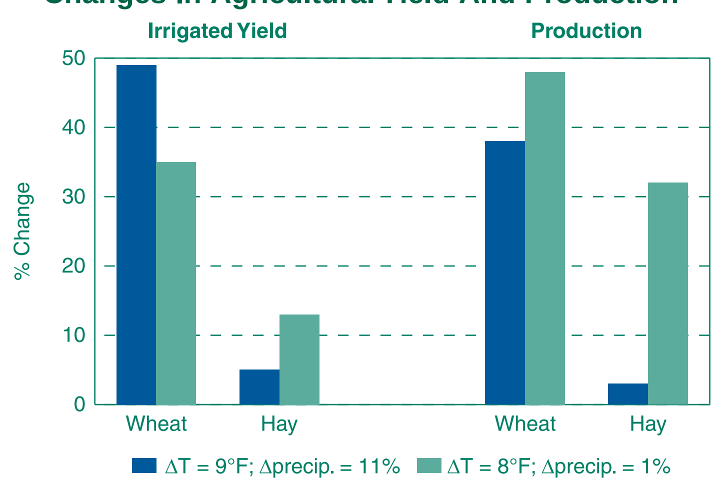
More rain could ease water competition, but it also could increase flooding. Earlier, more rapid snowmelt would contribute to winter and spring flooding. In a warmer climate, more intense rains are expected, which could increase flash floods.

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

Changes In Agricultural Yield And Production



Sources: Mendelsohn and Neumann (in press); McCarl (personal communication) 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 Wyoming, production agriculture is an $800 million annual industry, 80% of which comes from livestock, mainly cattle. Almost 70% of the farmed acres are irrigated. The major crops in the state are wheat and hay. Climate change could increase wheat yields by 35-48%. Hay and pasture dryland yields could fall by 13% or rise by 12% with irrigation, depending on how climate changes and whether irrigation is used. Farmed acres could remain fairly constant or could increase by as much as 12%, with an increased share of acres under irrigation. Livestock 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.

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 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 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 forested areas in Wyoming could change little or 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 would reduce the range and health of ponderosa and lodgepole forests, and increase their susceptibility to fire. Grasslands and rangeland could expand into previously forested areas in the western part of the state. Milder winters could increase the likelihood of insect outbreaks and of subsequent wildfires in the dead fuel left after such an outbreak.

Ecosystems

Wyoming straddles the Continental Divide, and its abrupt topographic relief includes alternating basins and mountain ranges. Major mountain ranges include the Beartooth, Gros Ventre, Teton, Wind River, Bighorn, Sierra Madre, and Medicine Bow. Internal basins and eastern plains are rolling to flat, and in the east are the Great Plains. Typical vegetation includes sagebrush, greasewood, and saltbush shrubs in the intermountain basins, grasses on the Great Plains, juniper and mountain mahogany in the foothills, and forest and alpine meadows in the mountains. Fire plays an important role in several Wyoming ecosystems, including sagebrush steppe, western juniper woodlands, and ponderosa pine forests. In sagebrush steppe, a greater frequency of fires in the last 50 years has resulted in invasion by annual grasses such as cheatgrass and medusahead. In western juniper woodlands, continued grazing and 50 years of attempted fire exclusion have allowed juniper expansion to continue unchecked. Historically, frequent low intensity surface fires perpetuated ponderosa pine stands with grassy undergrowth. Today, after 60 years of fire suppression, many of these forests, along with lodgepole pine forests, have high densities of trees, are plagued by epidemics of insects and diseases, and are subject to severe stand-destroying fires. Whitebark pines have suffered extensive diebacks in Idaho in part because of fire suppression and the introduced white pine blister rust, a non-native fungus that has defied control. This disease is now expanding into northwest Wyoming.

Since the massive fires of 1988, when nearly half of Yellowstone National Park burned, scientists have been paying close attention to the possible threats from climate change. Experts agree that the fires of 1988 came about as result of a winter drought, a hot dry summer, and unusually strong winds. Also important were the large areas of highly flammable, old growth lodgepole pine forest. Under normal conditions, large fires like those of 1988 occur only once in every few generations. But, with approximately 40% of the Yellowstone still vulnerable to large-scale burns, any increased fire risk due to climate change would pose a significant problem. The replacement of old-growth forest stands by younger stands could threaten northern twinflower, fairy slipper, pine martin, and goshawk. Outbreaks of defoliating attacks by western spruce budworms could occur more frequently and become much more damaging for the conifer forests.

Climate change also poses a threat to the high alpine systems, and this zone could disappear in many areas. Local extinctions of alpine species such as arctic gentian, alpine chaenactis, rosy finch, and water pipit could be expected as a result of habitat loss and fragmentation. Even a modest warming and drying could reduce whitebark pine habitat by up to 90% within 50 years. Whitebark pine nuts and army cutworm moth caterpillars, which are found in these forests, provide vital food for Wyoming's grizzly bear population. Whitebark pine forest may be replaced with Douglas fir, and on the lower slopes, forest would give way to treeless landscapes dominated by big sagebrush, Idaho fescue, and bluebunch wheatgrass.

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.