



# Climate Change And Colorado

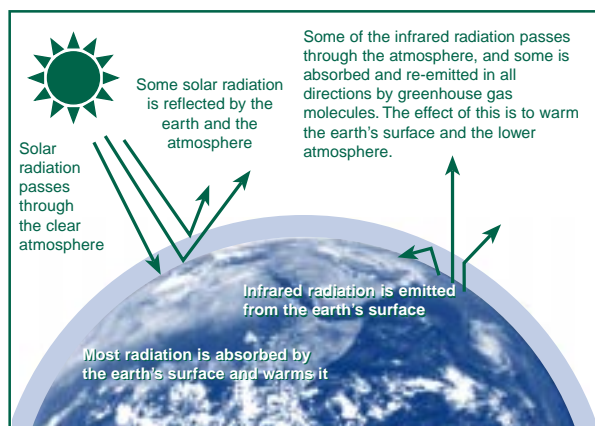
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

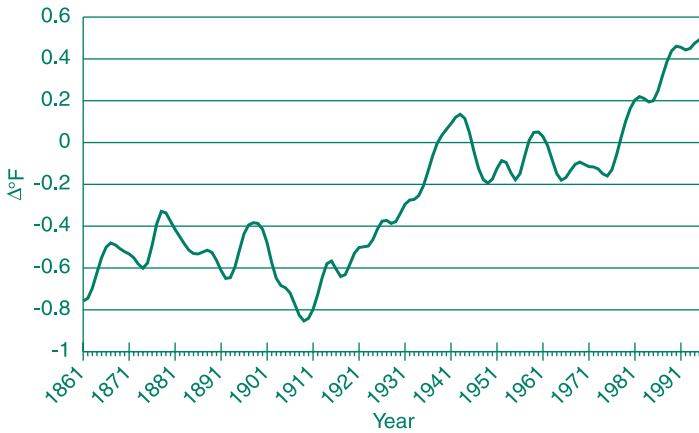
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

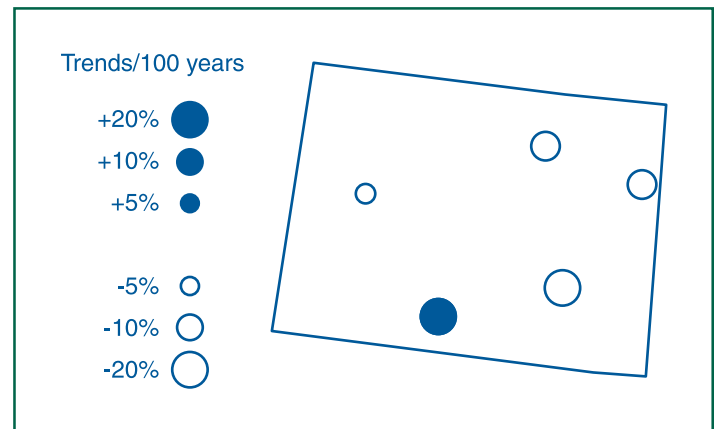
Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. The frequency and intensity of some extreme weather of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency 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 Fort Collins, Colorado, has increased 4.1°F, and precipitation has decreased by up to 20% in many parts of the state.

Over the next century, climate in Colorado 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 Colorado could increase by 3-4°F in spring and fall (with a range of 1-8°F) and 5-6°F in summer and winter (with a range of 2-12°F). Precipitation totals are estimated to change little in summer, although there could be an increase in the frequency of summer thunderstorms associated with moisture flow from the Gulf of Mexico. In spring and fall, precipitation is estimated to increase by 10%, and winter increases could have a range of 20-70%. Other climate models may show different results. 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

## Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

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 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

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 hydrocarbon emissions during hot weather. If a warmed climate causes increased use of air conditioners, air pollutant emissions from power plants also will increase.

Although Colorado is in compliance with current air quality standards, increased temperatures could make future compliance more difficult. Ground-level ozone has been shown to aggravate respiratory illnesses such as asthma, reduce existing 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, 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. Mosquitoes capable of transmitting this disease already are present in Colorado. If Colorado's climate becomes warmer and wetter, mosquito populations could increase and conditions may become more favorable for disease transmission.

In 1993, hantavirus pulmonary syndrome emerged in the Four Corners area. Ecological and climatic changes may have contributed to a tenfold increase in 1992-1993 in the deer mouse population, the primary reservoir for hantaviruses. Infection may have occurred because more people were exposed to the virus following the increase in the deer mouse population, although this is still uncertain.

## Water Resources

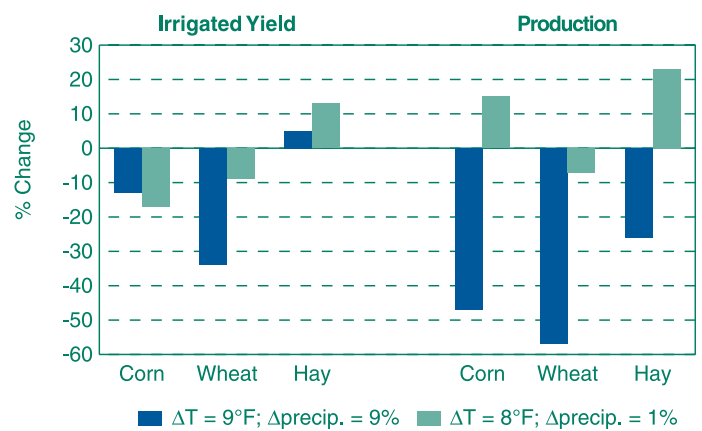
Water resources are affected by changes in precipitation as well as by temperature, humidity, wind, and sunshine. Changes in streamflow tend to magnify changes in precipitation. Water resources in drier climates tend to be more sensitive to climate changes. Because evaporation is likely to increase with 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.

Colorado's rivers are used heavily both within Colorado and in downstream states. Most of the western third of Colorado eventually drains to the Colorado River, and the eastern two-thirds drains more or less equally to the Arkansas and Platte rivers. A small share drains into the Rio Grande. A warmer climate would lead to earlier spring snowmelt, resulting in higher streamflows in winter and spring and lower streamflows in summer and fall. Most of Colorado's reservoirs are small in relation to total runoff; therefore, earlier snowmelt could reduce the reliability of many water supply systems within the state by limiting the amount stored for use in summer. The reliability of water systems for downstream states (e.g., Arizona and California) in the Colorado basin, however, is protected by the large storage capacities in Lakes Powell and Mead. These effects could be mitigated if summer rainfall increases.

## 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

### Changes In Agricultural Yield And Production



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

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.

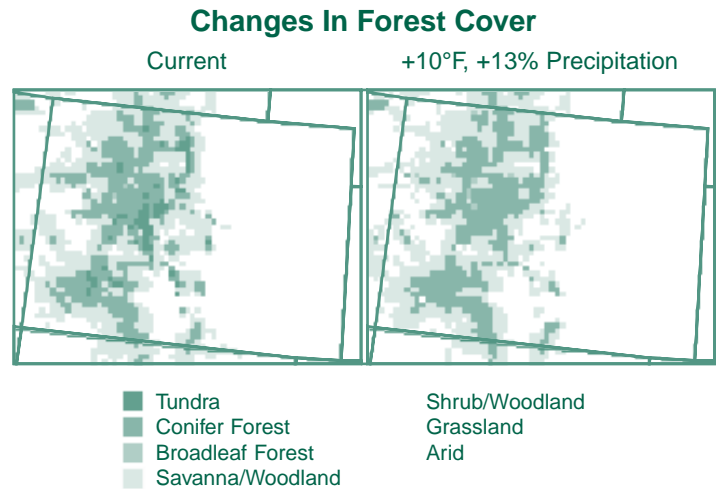
Understandably, most studies have not fully accounted for changes in climate variability, water availability, and imperfect responses by farmers to changing climate. Including these factors could change modeling results substantially. Analyses that assume changes in average climate and effective adaptation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

In Colorado, agriculture is a \$4 billion annual industry, three-fourths of which comes from livestock, mainly cattle. Almost half the crop acreage is irrigated. The major crops in the state are corn, wheat, and hay. Climate change could reduce grain yields 8-33%. Hay and pasture yields could fall by 6% or rise by 13%, depending on whether irrigation is used, leading to changes in acres farmed and production. For example, yields could fall while production rises because of an increase in acres farmed.

## 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 Colorado 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. Along the Front Range, 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, and piñon-juniper forests in



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

the southern part of the state could expand northward. 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 affect the character of Colorado forests and the activities that depend on them. However, increased rainfall could reduce the severity of these effects.

## Ecosystems

Ecosystems in Colorado 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 health of these ecosystems.

Warming 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 Rocky Mountain National Park could shift upslope, reducing habitat for many subalpine species. Changes in rainfall and snowfall could alter streamflows and affect wetlands and wildlife, and possibly accelerate the invasion of non-native plants into streamside habitats. Aquatic species that are sensitive to water temperature could be affected adversely by climate change. Cold-water fish such as trout could lose important habitat in Colorado, and endangered species such as the Colorado squawfish could have difficulty adapting.

*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.*

