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

Climate Change And California

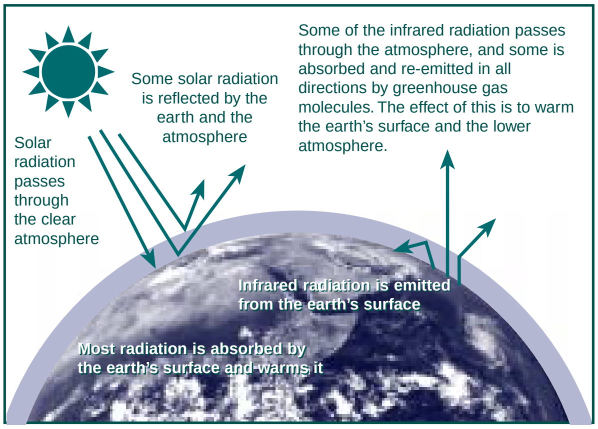
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

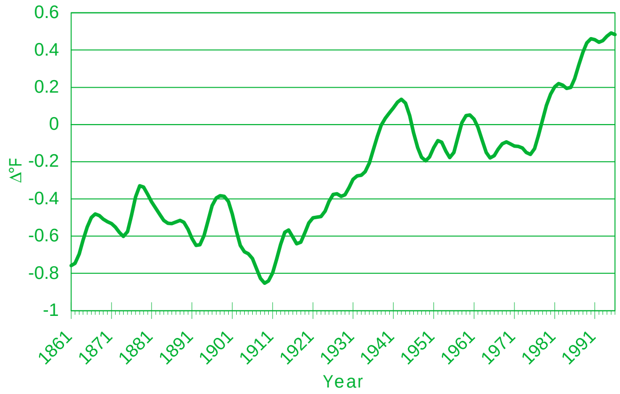
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

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 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.

Global Temperature Changes (1861–1996)



Source: IPCC (1995), updated

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. Scientists are reasonably confident 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, and associated fire and pest outbreaks) could increase.

Local Climate Changes

Over the last century, the average temperature in Fresno, California, has increased from 61.9°F (1899-1928 average) to 63.3°F (1966-1995 average), and precipitation has decreased by up to 20% in many parts of the state.

Over the next century, California'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 accounts for both greenhouse gases and aerosols, by 2100 temperatures in California could increase by about 5°F (with a range of 2-9°F) in the winter and summer and slightly less in the spring and fall. Appreciable increases in precipitation are projected: 20-30% (with a range of 10-50%) in spring and fall, with somewhat larger increases in winter. Little change is projected for summer.

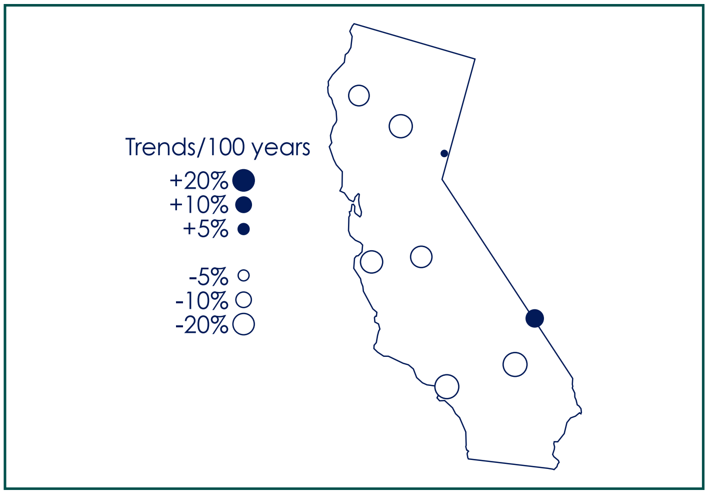
The amount of precipitation on extreme wet days most likely would increase, especially in the winter and fall, and there could be a decrease in the number of long dry spells and an increase in the number of long wet spells.

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.

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. Cities such as Los Angeles that experience occasional very hot, dry weather may be especially susceptible. One study estimates that a 3°F warming could almost double heat-related deaths in Los Angeles, from about 70 today to 125 (although increased air conditioning use may not have been fully accounted for). Little change in winter mortality is expected in Los Angeles. 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.

In the Bay Area and the Central Valley, with no other changes in weather or emissions, a 7.2°F warming would increase ozone concentrations by 20% and almost double the size of the area not meeting national health standards for air quality. Currently, the national standards for ozone are not attained throughout much of the state. 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 agricultural crop yields and impairs ecosystem health.

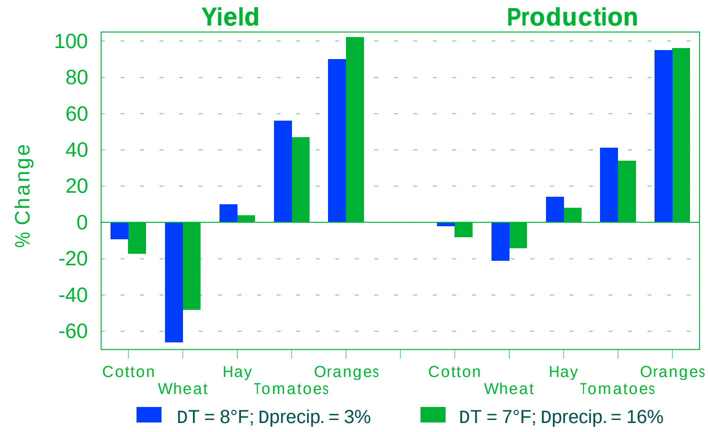
Agriculture

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.

In California, agriculture is about a $19 billion annual industry, one-third of which comes from livestock. About 3% of total U.S. farm acres is in California. The principal crops are cotton, wheat, hay, tomatoes, and oranges, as well as many other vegetables and fruits. About 87% of the acres farmed is irrigated. While climate change could decrease cotton yields by 9-17% and wheat yields by 48-66%, hay, orange, and tomato yields could increase. Total

Changes In Agricultural Yield And Production



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

acres farmed and irrigated acres could fall slightly, and farm income could remain unchanged or increase by up to 40% because of possible price increases.

Coastal Areas

Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads, causeways, and bridges. In addition, sea level rise could increase the vulnerability of coastal areas to storms and associated flooding.

Along much of California's coast, sea level already is rising by 3-8 inches per century (3 inches at Los Angeles, 5 inches at San Francisco, and 8 inches at San Diego), and it is likely to rise by another 13-19 inches by 2100. The beaches stretching from Santa Barbara to San Diego have been replenished with sand, and undoubtedly will be replenished further or protected with structures if threatened by sea level rise. Cumulative costs for sand replenishment to protect California's coastline from a 20-inch sea level rise through 2100 could be $174 million to $3.5 billion.

San Francisco Bay contains the most extensive salt marshes on the West Coast, most of which have been modified dramatically by dredging and filling activities. A 1-3 foot increase in sea level may move the existing salt marshes in the bay to nearby lowlands and freshwater marshes, but development probably will limit the extent to which these marshes can "migrate" to new areas.

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.

The seasonal pattern of runoff into California's reservoirs could be susceptible to climatic warming. Winter runoff most likely would increase, while spring and summer runoff would decrease. This shift could be problematic, because the existing reservoirs are not large enough to store the increased winter flows for release in the summer. Increased winter flows to San Francisco Bay could increase the risk of flooding. The fragile environment of the bay's delta islands could be at risk from increased flooding and the upstream movement of saltwater from the bay.

Because the Colorado River, the major water source for southern California, has extensive storage capacity, the reliability of this water supply to California is not vulnerable to seasonal changes. However, it is not known if flow in the Colorado River will increase or decrease under climate change.

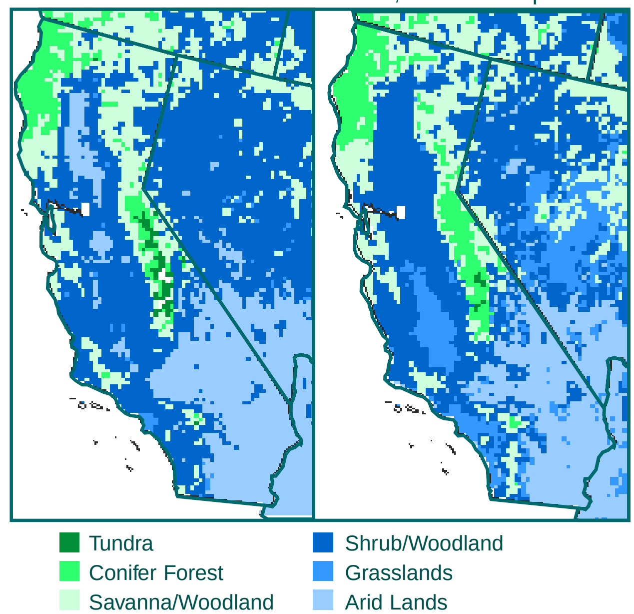
California's groundwater supplies are likely to be affected by climate change as well. Unless precipitation increases, the increased evaporation that would accompany warmer temperatures probably would reduce groundwater supplies.

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 California could change little or decline by as much as 25-50%. The uncertainties depend on many factors, including whether soils become drier and, if so, by how much drier. Hotter, drier weather could increase the frequency and intensity of wildfires, threatening both property and forests. Along the Sierras, drier conditions could reduce the range and productivity of conifer and oak forests. Farther north and along the northern coast, drier conditions could reduce growth of the Douglas fir and redwood forests. A significant increase in the extent of grasslands and chaparral throughout the state could result. These changes would affect the character of California forests and the activities that depend on them.

Changes In Forest Cover



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

Ecosystems

California is an ecologically diverse state, with 134 endangered and threatened species, including the sea otter, the California condor, and the American bald eagle. California's unique ecosystems include 25,000 square miles of desert (such as the Mojave desert and the Colorado desert). California's mountain ecosystems in the Sierra Nevada, including Yosemite National Park's 1,200 square miles, contain alpine wilderness areas with large numbers of sequoia trees. The ranges of many species of plants and animals are restricted and fragmented because of both natural and human causes. Many invading species have colonized large areas and displaced native species in the wake of environmental changes in recent centuries.

Climate change could have an impact on many of California's species and ecosystems. For example, between 1992 and 1996 the range of the bay checkerspot butterfly shifted 130 miles to the north and to higher altitudes as a result of climate change. Without natural corridors to allow migration, isolated species could be limited in their ability to adapt to climate change. Plant and animal species near the borders of their ranges are likely to be most affected. Climate change could create more opportunity for the establishment and spread of weeds and pests. Increased fire from climate change could further threaten species in California.

Cold water species such as mountain whitefish and brook trout could lose all of their habitat because of climate change. Other cold water species such as cold water guild, chinook salmon, and kokanee salmon could lose most of their habitat.

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.