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Climate Change And Arizona

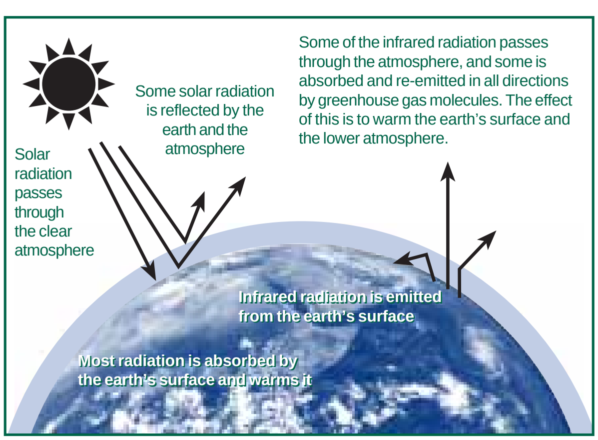
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

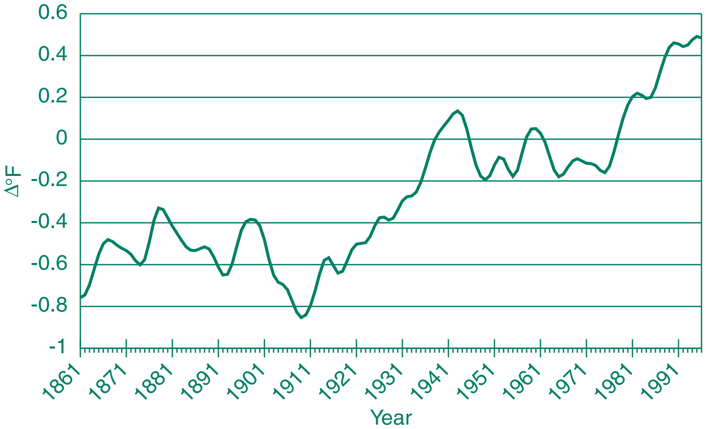
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

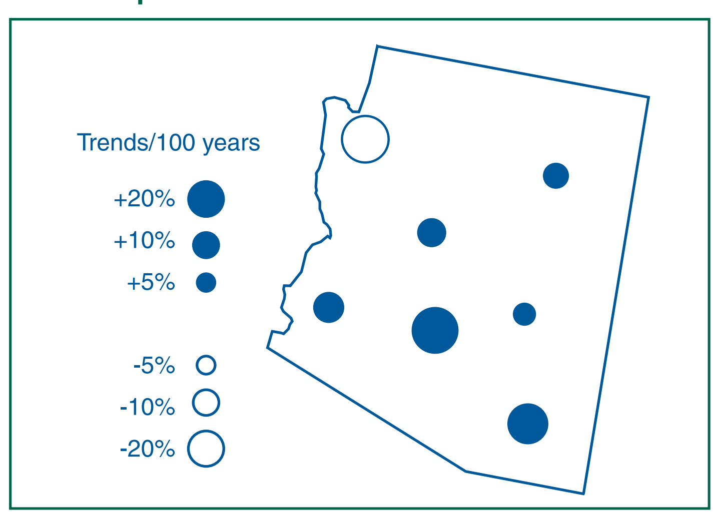
Calculations of regional climate change are much less reliable than global ones, and it is unclear whether regional climate will become more variable. The frequency and intensity of some extreme weather of critical importance to ecological systems (droughts, floods, frosts, cloudiness, the frequency 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 Tucson, Arizona, has increased 3.6°F, and precipitation has increased by up to 20% in many parts of the state, except in the northwest part of the state where precipitation has fallen by 20%. These past trends may or may not continue into the future.

Over the next century, climate in Arizona 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 Arizona could increase by 3-4°F in spring and fall (with a range of 1-6°F), and by 5°F in winter and summer (with a range of 2-9°F). Precipitation is estimated to decrease slightly in summer (with a range of 0 to -15%), to increase by 20% in spring (with a range of 10-40%), to increase by 30% in fall (with a range of 10-50%), and to increase by 60% (with a range of 30-100%) in winter. 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.

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. Currently, the Phoenix metropolitan area is classified as a "moderate" nonattainment area for ozone. Increased temperatures could make attaining compliance more difficult. Ground-level ozone is associated with respiratory illnesses such as asthma, reduced lung function, and respiratory inflammation.

Infected individuals can bring malaria to places where it does not occur naturally. Also, mosquitoes in Arizona 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. In Arizona, water for air conditioning is stored on roofs, so a 2°F warming even without increased precipitation could increase mosquito populations. Increased runoff from heavy rainfall could increase water-borne diseases such as giardia, cryptosporidia, and viral and bacterial gastroenteritides. San Joaquim Valley fever is present in the deserts of southern California, Arizona, and Nevada. There is evidence that populations of this soil-based organism increase when extreme rainfall follows periods of drought.

In 1993, hantavirus pulmonary syndrome emerged in Arizona, and the deer mice that are the primary reservoir for hantaviruses are prevalent in Arizona. Long droughts punctuated by heavy rains can decrease the predators (owls, snakes, and coyotes) of rodents, and the heavy rains can provide the rodents with added food supplies (grasshoppers and piñon nuts).

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

Runoff in Arizona primarily results from summer thunderstorms and winter precipitation. In the mountains, most of the winter precipitation falls as snow. A warmer climate could mean less winter snowfall, more winter rain, and a faster, earlier snowmelt. This could lead to higher winter and spring flows and the passing of flood waters that are usually stored for use later in the summer. Additionally, without large increases in rainfall (approximately 15-20%), higher temperatures and increased evaporation could lower lake levels and streamflows in the summer. Less water would be available to support important uses such as irrigation, hydropower production, public and industrial supply, fish and wildlife habitat, and recreation. Lower streamflows would also concentrate pollutant levels and increase salinity, a critical water problem in Arizona. Although Arizona has an active groundwater management program, declining water levels are a serious problem in parts of the state where withdrawals for irrigation and municipal uses are large. Less spring and summer recharge could result in lower groundwater levels and exacerbate this situation. The surface waters in Arizona are fully allocated through water rights agreements and legal compacts with other states and Mexico. Tribal water rights are also being resolved. Because the state's population is growing rapidly, there is concern that water demand will exceed the available supply. Changes in water availability would complicate these issues.

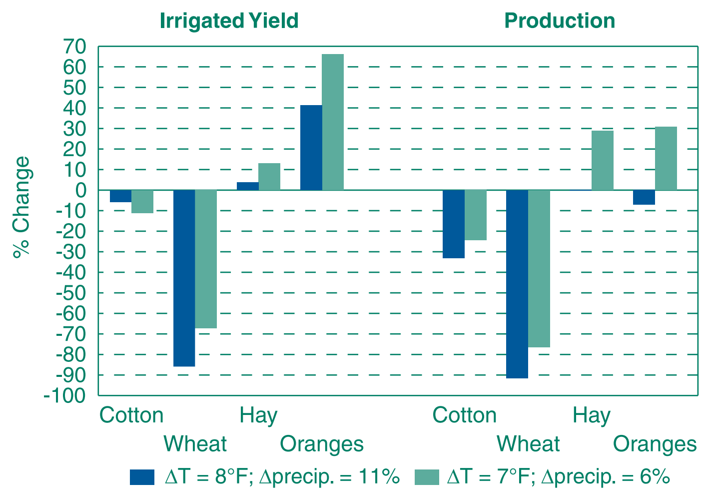
More rain could ease competition for water, but it also could increase flooding. Earlier, more rapid snowmelts are likely to contribute to winter and spring flooding. Flood flows on the upper Colorado River can necessitate large releases from Lakes Powell and Mead, resulting in flooding along the lower Colorado in Arizona. The Salt-Verde systems primarily store water for irrigation and have minimal flood control capacity. Severe flooding can occur in Phoenix when large volumes of water are released from the Salt River reservoirs. In a warmer climate, the intensity of summer storms could increase. Cities such as Tucson, as well as nearby smaller towns, are vulnerable to flash flooding caused by intense, summer thunderstorms.

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 in

Changes In Agricultural Yield And Production



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

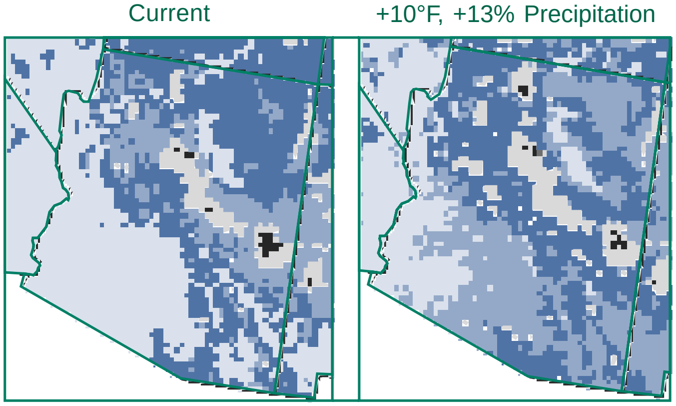
In Arizona, production agriculture is a $1.9 billion annual industry, one-half of which comes from livestock, mainly poultry. Almost all of the farmed acres are irrigated. The major crops in the state are cotton, wheat, hay, and oranges. Climate change could have a significant effect on crop production by reducing cotton yields by 5-11% and wheat yields by about 70% as temperatures rise beyond the tolerance levels of the crop. On the other hand, hay and pasture yields, however, are estimated to rise by 3-12%. Farmed acres could fall by 4-20%, and the share of irrigated acres could rise. 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.

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 Arizona 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. Grassland, rangeland, and even

Changes In Forest Cover



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

desert could expand into some of these previously forested areas. 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 Arizona forests and the activities that depend on them. However, increased rainfall could reduce the severity of these effects.

Ecosystems

Arizona supports a rich diversity of habitats, from deserts to mountain highlands. Narrow strips of riparian vegetation are extremely important to wildlife, especially birds such as the endangered cactus ferruginous pygmy owl, southwestern willow flycatcher, masked bobwhite quail, Mexican spotted owl, and the bald eagle. Riparian habitat along the San Pedro River, for example, hosts hundreds of bird species, more than any other U.S. river. Riverine habitats running through the desert environment are critically important habitat at the southern end of winter migration routes for geese, ducks, sandhill cranes, and shorebirds such as dowitchers and sandpipers. Within the rivers and streams, 24 of Arizona's 28 native fish are threatened or endangered, including the Colorado squawfish, razorback sucker, desert pupfish, Gila topminnow, Yaqui chub, spikedace, and Apache trout. The Sonoran Desert of southern Arizona has the highest plant diversity of the southwestern desert, and is home to fan palms, saguaro cacti, palo verde, and mesquite. Endangered mammals found here include jaguar, ocelot, Mexican gray wolf, Sonoran pronghorn, and Sandborn's lesser long-nose bat. The biological communities of the isolated mountaintops within the desert have diverged remarkably over time. More than 2,000 plant species thrive in this area at the intersection of Arizona, New Mexico, and Mexico, nearly 10% of all the species found in the United States.

The decline of riparian areas threatens many species of fish and wildlife in Arizona. Here, more species are threatened with extinction than nearly any other state. For example, the Gila River is the only U.S. river basin with all 47 of its freshwater fish species either extinct, listed as threatened or endangered, or recommended as candidates of such listings. Climate change could exacerbate these existing threats. Narrow riparian habitats could be greatly influenced by decreasing water availability. This could ultimately alter the number of bird species and community composition, with the loss of many species that rely on riparian vegetation for nesting and food resources, such as the endangered southwestern willow flycatcher and Mexican spotted owl. Higher water temperatures could adversely affect habitat conditions for already endangered fish, and favor the spread of exotic species that already imperil the survival of Arizona's native fish species. In desert areas, many plants and animals already live near their tolerance limits and may be unable to survive under hotter conditions. Mountaintop island habitats are especially vulnerable to climate change.

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.