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

EPA

Climate Change And Hawaii

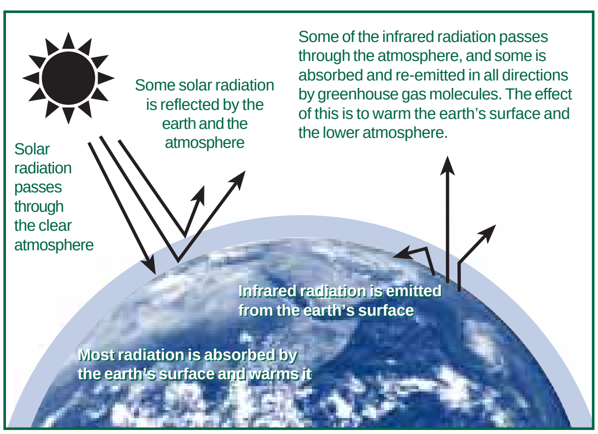
The earth's climate is predicted to change because human activities are altering the chemical composition of the atmosphere through the buildup of greenhouse gases — primarily carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons. The heat-trapping property of these greenhouse gases is undisputed.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

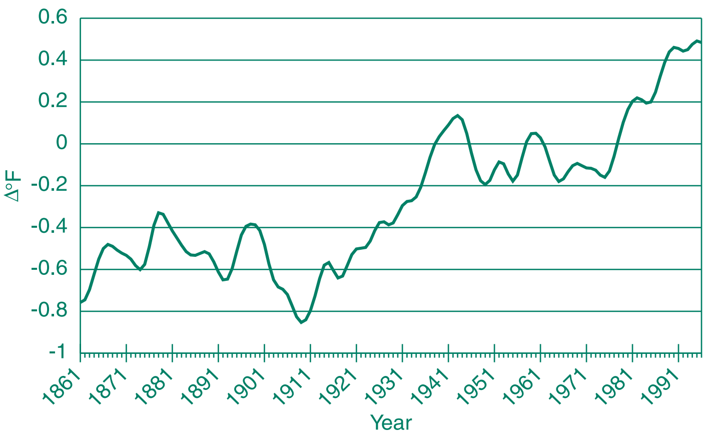
Although many greenhouse gases already are present in the atmosphere, oceans, and vegetation, their concentrations in the future will depend in part on present and future emissions. Estimating future emissions is difficult, because they will depend on demographic, economic, technological, policy, and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

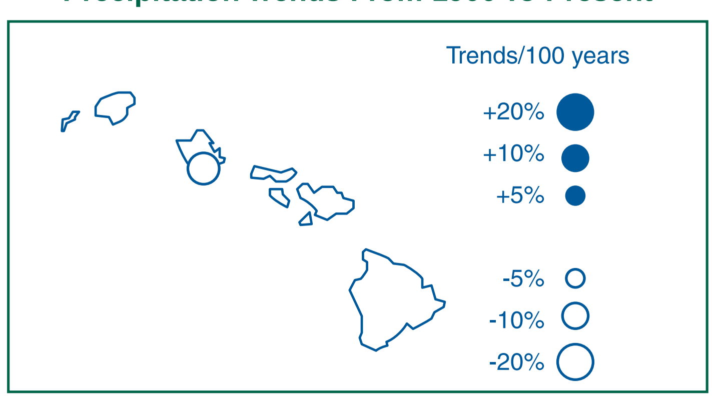
In Honolulu, Hawaii, the average temperature has increased 4.4°F over the last century, and precipitation has decreased approximately 20% over the last 90 years. These past trends may or may not continue in the future.

Over the next century, climate in Hawaii 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 Hawaii could increase by 3°F (with a range of 1-5°F) in all seasons, slightly more in fall. Future changes in precipitation are highly uncertain because they depend in part on how El Niño might change, and reliable projections of changes in El Niño have yet to be made. It is possible that quite large precipitation increases could occur in summer (particularly) and fall. 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 such as hurricanes might be affected, although an increase in the frequency and intensity of summer thunderstorms 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. The elderly, particularly those living alone,

Precipitation Trends From 1900 To Present



Source: Karl et al. (1996)

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. Although Hawaii 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.

Warmer seas could enhance the growth of toxic algae, and can lead to harmful algal blooms, that is, red tides. The increased intensity, duration, and extent of harmful algal blooms can damage habitat and shellfish nurseries. These blooms can be toxic to humans and can carry bacteria like those causing cholera. Viral and bacterial contamination of shellfish has repeatedly caused illness, and warmer waters could contribute to these illnesses. Future warming combined with local pollution most likely would continue to damage fish and shellfish and thus affect human health.

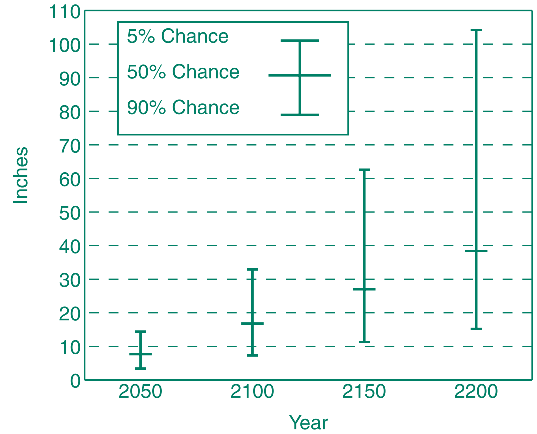
Warming and other climate changes may expand the habitat and infectivity of disease-carrying insects, increasing the potential for transmission of diseases such as malaria and dengue ("break bone") fever. Although dengue fever is currently uncommon in the United States, conditions already exist in Hawaii that make it vulnerable to the disease. Warmer temperatures resulting from climate change could increase this risk. Developed countries such as the United States should be able to minimize the impacts of these diseases through existing disease prevention and control methods.

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.

The 1,000-mile tidally influenced shorelines of the Hawaiian islands contain some of the world's most famous white-sand beaches as well as steep cliffs. Hawaii's beaches are generally not subject to erosion by waves because of the protective influence of offshore coral reefs. The coral reefs, which are the source of the white sand, could provide sufficient natural nourishment to the beaches under sea level rise. However, the effects of accelerated sea level rise on coral reef ecosystems are poorly understood, and these beaches may require additional sand replenishment.

Future Sea Level Rise At Honolulu



Sources: Lyles et al. (1988); EPA (1995)

At Honolulu, Nawiliwili, and Hilo, sea level already is rising by 6-14 inches per century, and it is likely to rise another 17-25 inches by 2100. Possible responses to sea level rise include building walls to hold back the sea, allowing the sea to advance and adapting to it, and raising the land (e.g., by replenishing beach sand, elevating houses and infrastructure). Each of these responses will be costly, either in out-of-pocket costs or in lost land and structures. For example, the cumulative cost of sand replenishment to protect the coast of Hawaii from a 20-inch sea level rise by 2100 is estimated at $340 million to $6 billion. However, sand replenishment may not be cost-effective for all coastal areas in the state, and costs may be lower (although some coastal areas would be inundated).

Water Resources

In a warmer climate, runoff and water availability in Hawaii would be influenced primarily by higher temperatures, increased evaporation, and changes in rainfall. Increased rainfall and runoff could recharge aquifers and ease water supply problems; however, it also could increase flooding. In Hawaii, hurricanes, severe storms, storm runoff, and high surf (including tsunamis) cause flooding, extensive property damage, and loss of life. Although the effect of a warmer climate on the frequency and severity of tropical cyclones is uncertain, the combination of rising sea level and increased rainfall could exacerbate flooding. The northern and western coasts of each island are particularly vulnerable to high surf, which often damages homes, roads, and resort complexes. The extensively developed coasts of Oahu are particularly susceptible to costly damages. Additionally, in a warmer climate, heavier rains are expected. The resulting increase in runoff could also impair water quality by increasing sediment and pollutant runoff from agricultural lands, overgrazed pasture lands, and urban areas.

Hawaii's water resources are very susceptible to prolonged droughts. During these periods, low rainfall and streamflow often lead to increased usage of groundwater, which causes ground-water levels to decline and increases the likelihood of salt water intrusion. Severe droughts also result in crop damage, livestock losses, and water-use restrictions. Under warmer conditions, the variability of climate is expected to increase, which could lead to more frequent and intense droughts.

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 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 Hawaii, production agriculture is a $500 million annual industry, 80% of which comes from crops. Almost one-half of the farmed acres are irrigated. The major crops in the state are sugarcane and pineapple. Climate change could increase their yields by about 10%. Farmed acres could remain fairly constant.

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 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.

The native Hawaiian tree 'ohi'a appears to be strongly influenced by long-term changes in climate, and older trees are particularly sensitive to both drought and heavy rains. 'Ohi'a is a widely distributed species that is essential habitat for many important Hawaiian animals, especially the endangered Hawaiian honeycreeper found in old-growth 'ohi'a forests. Native Hawaiian forests are being reduced and in some cases eliminated by competition by non-native trees and plants. Changes in climate could cause further stress because the non-native species are more tolerant of temperature and rainfall changes than native species. Climatic stress on trees also tends to make them more vulnerable to fungal and insect pests. For example, one fungus, Phytophthora cinnamomi, is a widespread cause of declining forests in Hawaii, and is often triggered by unusual climatic conditions that stress trees. Warmer conditions could alter the extent and composition of the unique forests surrounding the taller mountains of the island of Hawaii. Worldwide, tropical cloud forests are one of the rarest of natural habitats, and may be among the most sensitive to climate change. At present, this cloud forest is one of the wettest ecosystems on earth. Even small changes in climatic conditions could cause major changes in the cloud cover and precipitation regimes that maintain the rain forests of Haleakala. The upper limit of the cloud forest zone is determined by the altitude of the upper cloud zone (a function of climate). Climate change could cause a shift in distribution of cloud forest species. The increased possibility of forest fire under drought conditions is especially damaging in tropical forests, where species are not adapted to this type of disturbance. Fire is typically a primary mechanism whereby non-native species invade ecosystems. Increased frequency or intensity of hurricanes will exacerbate the problems associated with fire and invasive species. An increase in severity or frequency of hurricanes and tropical storms could alter forest composition on the island.

Ecosystems

Hawaii is surprisingly diverse geographically, from atolls to snow capped peaks more than 12,000 feet high. The remote and unpopulated outer islands are home to some of the largest seabird colonies in the world — up to 10 million albatrosses, frigatebirds, shearwaters, boobies, sooty and fairy terns, and petrels breed here. The diversity of environments and the extreme isolation of the state have resulted in a spectacular variety of species, many of which are endemic to the islands. An estimated 91% of flowering plants species, 81% of birds, and 99% of terrestrial snails and arthropods are found only here. At the same time, Hawaii is the world's capital for species extinction and endangerment. Of the known U.S. extinctions, 70% have occurred here. Since 1778, the year of European contact, 263 species are known to have become extinct, including 50% of the bird fauna and perhaps 50% of plants and 90% of native land snails. Currently, there are more endangered species per square mile on these islands than any other place on the planet. Twenty-five percent of U.S. endangered species are found here, including 2 mammals, 30 birds, 5 reptiles and amphibians, 1 snails genus, and 279 plant taxa. Important contributors to this wave of loss and endangerment are habitat loss, introduced diseases, and impacts from introduced organisms, especially pigs, goats, sheep, and cattle.

The estimated increases in temperature and changes in precipitation due to climate change adds another threat to this onslaught of human-created problems. One of nine endemic bird species in the Hawaiian honeycreeper family found in the cloud forests of East Maui, the endangered i'iwi has survived in the higher forests of Haleakala National Park because mosquitos that transmit deadly avian malaria apparently cannot breed at higher elevations because of the cooler temperatures. A warmer climate might allow the mosquito to move farther up the mountain.

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.