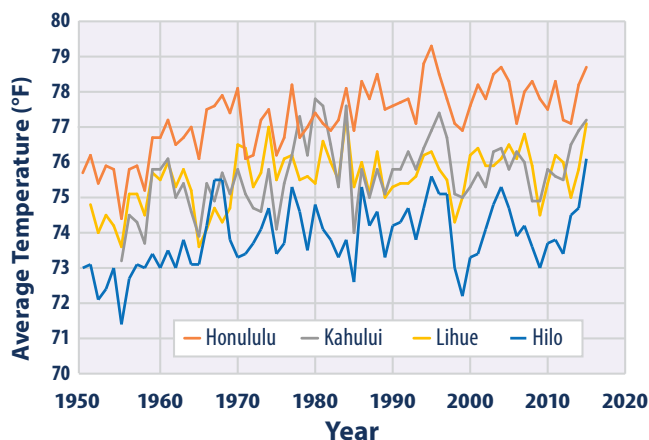


What Climate Change Means for Hawaii

Hawaii's climate is changing. In the last century, air temperatures have increased between one-half and one degree (F). Warming in the oceans around Hawaii has damaged coral reefs, and, in recent decades, increased ocean acidity has threatened reefs and other marine ecosystems. Average precipitation decreased in the last century, reducing freshwater availability on some islands and affecting delicate land-based ecosystems, often harming native species. In the last 50 years, sea level has risen along Hawaii's shores, increasing erosion and threatening coastal communities and infrastructure.

Climate is changing because the earth is warming. People have increased the amount of carbon dioxide in the air by 40 percent since the late 1700s. Other heat-trapping greenhouse gases are also increasing. These gases have warmed the surface and lower atmosphere of our planet about one degree during the last 50 years. Evaporation increases as the atmosphere warms, which increases humidity, average rainfall, and the frequency of heavy rainstorms in many places—but contributes to drought in others.

Greenhouse gases are also changing the world's oceans and ice cover. Carbon dioxide reacts with water to form carbonic acid, so the oceans are becoming more acidic. The surface of the ocean has warmed about one degree during the last 80 years. Warming is causing snow to melt earlier in spring, and mountain glaciers are retreating. Even the great ice sheets on Greenland and Antarctica are shrinking. Thus the sea is rising at an increasing rate.



Average annual temperatures have increased across Hawaii since 1950. Source: NOAA

Ocean Warming and Acidification

The waters around Hawaii are warming, which is harming Hawaii's coral reefs and marine ecosystems. The El Niño-Southern Oscillation ("El Niño") and other natural cycles cause ocean temperatures in the Pacific to fluctuate from year to year and from decade to decade. Even after accounting for these natural patterns, the waters around Hawaii have been warming since the 1950s, with temperatures rising by several degrees from the ocean surface down to at least 600 feet. Rising water temperatures can harm the algae that live inside corals. Because algae provide food for the coral, a loss of algae weakens corals and can eventually kill them. This process is commonly known as "coral bleaching," because the loss of the algae also causes the corals to turn white. Mass bleaching events are becoming more common, with documented cases in the north-western Hawaiian Islands in 1996 and 2002. Water temperature spikes in Hawaii have also been linked to coral disease outbreaks.



Bleached corals in Kaneohe Bay, Oahu, in the fall of 2014. Credit: XL Catlin Seaview Survey

Increasing ocean acidity can also damage corals, as well as shellfish and other organisms that depend on minerals in the water to build their skeletons and shells. The acidity of the Pacific Ocean has increased by about 25 percent in the past three centuries, and it is likely to increase another 40 to 50 percent by 2100.

Warming and acidification could result in widespread damage to the entire marine ecosystem in the waters off Hawaii. Hawaii's isolation in the Central Pacific makes it home to a wide range of fish species not found anywhere else in the world. Many of these fish rely on healthy coral reefs for habitat, and even with substantial cuts to greenhouse gas emissions, up to 40 percent of coral



Tourism infrastructure and nearshore coral reefs, both threatened by climate change, in Maui. Credit: Hudson Slay, EPA Region 9.

reef fish could lose their habitats by 2100. Reefs also protect nearshore fish nurseries and feeding grounds. Damage to coral and reduced fish populations could negatively impact the state's economy, as these natural resources bring an estimated \$385 million to Hawaii each year through tourism, direct consumption, and commercial fisheries.

Water Availability

Rainfall in Hawaii has been decreasing, but scientists do not know whether that trend will continue. El Niño will probably continue to dominate precipitation patterns from year to year in the tropical Pacific. Climate change-related increases in air temperatures will lead to more evaporation and more moisture in the air. As a result, the variability in El Niño-related precipitation is likely to increase, making rainfall predictions difficult.

Although projections of future rainfall are uncertain, streams and rivers on the Hawaiian Islands have experienced a reduction in flow over the last century, resulting in less fresh water available for people and ecosystems. Additionally, increased drought may threaten taro and breadfruit, which are important traditional food sources for Hawaii's native peoples.

Land Ecosystem Changes

Ecosystems on land are also experiencing impacts from a warming climate. Many native plant species could lose ground to invasive species better adapted to the changing climate, or simply fail to thrive in altered habitats. For example, higher temperatures and increased drought have caused dramatic declines among native plant species such as Haleakalā silver-sword. Some native species display the ability to adapt to climate change, such as a few types of fire-adapted grasses that have shifted to higher altitudes in Hawaii Volcanoes National Park. However, some insects such as mosquitoes have also been able

to expand their ranges into higher elevations, infecting native birds with diseases like avian malaria.

Shoreline Loss

Since 1960, sea level has risen between two and eight inches relative to Hawaii's shoreline. Sea level rise can make Hawaii's existing coastal hazards—such as waves, hurricanes, tsunamis, and extreme tides—even worse. Additionally, rising sea level has accelerated coastal erosion, which has resulted in wetland migration and cliff collapse. Chronic erosion has affected more than 70 percent of Kauai and Maui's beaches over the last century.

Sea level rise and the associated coastal impacts due to increased flooding, elevated ground water tables, storm surge, and erosion have the potential to harm an array of natural and built environments in Hawaii. Dying coral reefs add to this problem, as they leave the shoreline more vulnerable to erosion and damage from waves. In the Northwestern Hawaiian Islands Marine National Monument, sea level rise threatens native species, especially those that nest on beaches, such as green sea turtles, Hawaiian monk seals, and the endangered Laysan finch. Damage to coastal infrastructure may also hurt Hawaii's economy, more than a quarter of which stems from tourism. Waikīki Beach alone brings in \$2 billion per year in visitor spending. Furthermore, many of Hawaii's native communities are in vulnerable coastal areas. Sea level rise and associated flooding are expected to destroy land, coastal artifacts, and structures of significant cultural value, and may force these communities to relocate.



A seawall built in Ukumehame, Maui, to protect the shoreline and coastal infrastructure from erosion. Credit: Hudson Slay, EPA Region 9.

Health and Vulnerable People

Climate change is likely to amplify some threats to health in Hawaii. Certain people are especially vulnerable, including children, the elderly, the sick, and the poor.