



ICAP

University of Hawai'i Sea Grant College Program
Center for Island Climate Adaptation and Policy

Hawai'i's Changing Climate

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Hawai'i's Changing Climate



Average rainfall has declined in Hawai'i, yet rain intensity has increased. Hanalei Valley, Kaua'i, before (left) and after (right) intense rainfall in Fall, 2009.

The average temperature of Earth's surface and shallow ocean have increased over the past century, markedly so since the 1970's. Globally, 2009 tied with several other years as the second warmest year on the instrumental record (since 1880).

How is global warming influencing the climate in Hawai'i? The purpose of this briefing sheet is to describe what is known in answer to this question as published in peer-reviewed scientific journals and in government reports and websites. Hawai'i's climate is changing in ways that are consistent with the influence of global warming.

In Hawai'i:

- Air temperature has risen;
- Rainfall and stream flow have decreased;
- Rain intensity has increased;
- Sea level and sea surface temperatures have increased; and,
- The ocean is acidifying.

Because these trends are likely to continue, scientists anticipate growing impacts to Hawai'i's water resources and forests, coastal communities, and marine ecology. There is a significant need for sustained and enhanced climate monitoring and assessment activities in Hawai'i; and a compelling requirement for focused research to produce models of future climate changes and impacts in Hawai'i.

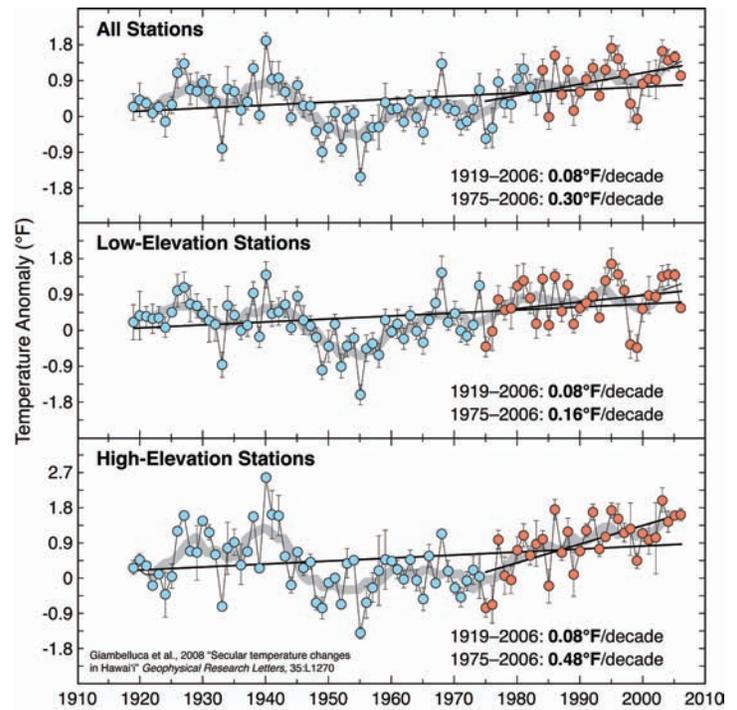
Surface Air Temperature

Hawai'i is getting warmer. Data¹ show a rapid rise in air temperature in the past 30 years (averaging 0.3°F per decade), with stronger warming at high elevations (above 2600 feet). The rate of temperature rise at low elevations (below 2600 feet), 0.16°F per decade, is less than the global rate (about 0.36°F per decade); however, the rate of warming at high elevations in Hawai'i, 0.48°F per decade, is faster than the global rate. Most of the warming is related to a larger increase in minimum temperatures compared to the maximum—a net warming about 3 times as large—causing a reduction of the daily temperature range. This response to global warming is consistent with similar trends² observed in North America. Despite recent years where the rate of global warming was low³, surface temperatures in Hawai'i have remained high. The greater warming trend at high elevations threatens water resources and may have significant ecological impacts such as the spread of avian disease, decreased rainfall and cloud water, and threats to native forests⁴.

Rainfall and Stream Discharge

Perhaps nothing is as critical to life in the islands as rain, and in Hawai'i there are two principal delivery systems: trade winds, and Kona storms. Cloud formation by trade winds is the most reliable and abundant source of water to the aquifers we rely upon. Although atmospheric circulation in the tropical Pacific has decreased and global warming is identified⁵ as the cause, it is not yet clear how the Hawaiian trade winds will change in the future. It also remains unclear how future rainfall will respond to global warming; the results of modeling studies⁶ have been equivocal although to some extent they indicate that we should expect decreased rainfall. Indeed, studies of rainfall records in Hawai'i confirm this. Rainfall in Hawai'i has steadily declined⁷ about 15% over the past 20 years.

Streams are one beneficiary of rain. Rainfall feeds streams in two ways: storm flow and base flow. Storm flow responds very quickly to rainfall and causes stream levels to rise and stream discharge to increase during and immediately after rainfall. Base flow, on the other hand, is supplied by groundwater discharge and maintains streamflow during periods between rainfall events. Base flow also responds to changes in rainfall over time, but much more slowly than storm flow. Beginning in the early 1940's, base flow has declined around the state⁸ and the cause is likely related to decreased rainfall. In Hawai'i, rainfall combines with steep geographic features to produce unique ecosystems that support diverse plants and animals. This pattern is threatened by rising air temperatures and decreased rainfall and stream discharge. Taro farming, a form of wetland agriculture common on low-lying coastal plains, is also tied to stream flow, but vulnerable to sea level rise. Between intruding salt water and declining stream flow, some farmers may be experiencing the impacts of global warming.



Air temperature data in Hawai'i show a warming trend that has accelerated in recent decades.



Rain Intensity

Between 1958 and 2007, the amount of rain falling in the very heaviest downpours (defined as the heaviest 1% of all events) has increased approximately 12% in Hawai'i⁹. Heavy rainfall in Hawai'i means more than simply getting wet; it is a major challenge for civil defense agencies and emergency responders. Intense rains trigger a domino effect of other impacts including flash flooding, mudslides and debris flows, road and business closure, infrastructure damage, and loss of public services to isolated communities. It was heavy rain that caused over \$80 million dollars of damage in Mānoa Valley, O'ahu, isolated Hana, Maui for weeks, flooded the first floors of homes in Laie, O'ahu, and swept houses off their foundations in Hilo, Hawai'i. When intense rains struck on New Year's Eve 1987, 40,000 people in Hawai'i Kai, Waimanalo, Aina Haina and other east Honolulu communities went without power, emergency aid, communication, and road access for up to 24 hours. While these events cannot be directly tied to global warming, they illustrate the severe impacts associated with intense rains. Ironically, global warming appears to be taking Hawai'i into a time of declining fresh water resources while enduring more intense rainstorms.

Other Potential Water Cycle Impacts

Look to the mountains and see the nearly perpetual band of clouds on their slopes. Scientists infer that rising temperatures in Hawai'i could result in a shallower cloud zone because of a possible rise in the lifting condensation level, which controls the bottom of the cloud, and a decline in the height of the trade wind inversion, which controls the top of the cloud. Where clouds intercept the land (forming fog) they deposit water droplets directly on the vegetation and soil. This process is a significant source of water to the mountain ecosystems of Hawai'i; especially

at windward exposures. With a smaller cloud zone, less cloud water would be available to these important forests.

Another concern is changes in the process of evapotranspiration. While rainfall and cloud water are the sources of water to the ecosystem, evaporation and transpiration (the emission of water vapor through the leaves of plants) return water to the atmosphere, thus reducing the amount going into streams and groundwater. Effects of warming on evapotranspiration are as yet unknown, but changes could further impact water resources already being affected by reduced rainfall.

Because surface air temperature, cloudiness, and rainfall depend on the trade winds, forecasting Hawai'i climate is dependent on accurately modeling trade wind changes. Intergovernmental Panel on Climate Change¹⁰ models do not agree on these aspects of climate for the region around Hawai'i. Other modeling¹¹ has shown that wind and rainfall responses to warming around the Pacific are not uniform, and depend strongly on the climate model being used. Skillful projections of island climate must take into account the interaction of trade winds with island topography and will rely on continued and enhanced monitoring of key climate variables.

Sea Level

Sea level has risen in Hawai'i at approximately 0.6 inches per decade over the past century¹² and probably longer¹³. This may not seem like a substantial rate, however, long-term sea-level rise, when considered over a century, can lead to chronic coastal erosion, coastal flooding, and drainage problems, all of which are experienced in Hawai'i. This long-term trend has increased the impact of short-term fluctuations on coastal sea level¹⁴ leading to episodic flooding and erosion along the coast due to extreme tides.



Although coastal erosion is not uniquely tied to global warming, it is a significant factor in managing the problem of high sea levels. Waves, currents, and human impacts to sand availability are the principal causes of erosion. Sea-level rise accelerates and expands erosion, potentially impacting beaches that were previously stable. Chronic erosion in front of developed lands has historically led to seawall construction resulting in beach loss¹⁵. Approximately 25% of beaches on O‘ahu have been lost to seawall construction. Losses are similar on other islands, where the average long-term rate of coastal erosion is about 1 foot per year¹⁶. On Kaua‘i for instance, 72% of beaches are chronically eroding and 24% of these are accelerating.



Although the rate of global mean sea level rise has approximately doubled since 1990¹⁷ sea level not only did not rise everywhere, but actually declined in some large areas. The pattern of sea level change is complex¹⁸ due to the fact that winds and ocean currents affect sea level, and those are changing also. In Hawai‘i, improving our understanding of sea level impacts requires attention to local variability with careful monitoring and improved modeling efforts. Because of global warming, sea level rise is expected to continue, and accelerate, for several centuries. Research¹⁹ indicates that sea level may exceed 3 feet above the 1990 level by the end of the 21st century. Continued sea-level rise will increase marine inundation of coastal roads and communities. Salt intrusion will intensify in coastal wetlands and groundwater systems, taro lo‘i, estuaries, and elsewhere. Extreme tides already cause drainage problems in developed areas and Hawaiian communities located at the intersection of intensifying storm runoff and rising ocean waters will endure increased flooding.

Sea Surface Temperature

At Station ALOHA (62 miles north of Kahuku Point, O‘ahu), marine researchers at the University of Hawai‘i and cooperating institutions have measured an increase

of sea surface temperature of 0.22°F per decade, a result that is consistent with other estimates²⁰ for the latitudes of Hawai‘i in the eastern North Pacific. Because of global warming this rate is likely to rise, potentially exposing coral reefs and other marine ecosystems to negative impacts related to temperature increases, including coral bleaching²¹. Bleaching results when corals lose the symbiotic algae that provide them with their principal source of food. Hawai‘i is located in the cooler subtropical waters of the North Pacific. Although bleaching has become a major ecosystem catastrophe for many reefs around the world, Hawaiian reefs have largely escaped major, widespread bleaching events. However, continued warming of Hawaiian surface waters may eventually lead to bleaching.

Ocean Acidification

As rising carbon dioxide in the atmosphere mixes with seawater, the ocean acidifies. Measurements²² at station ALOHA over two decades document that the surface ocean around Hawai‘i has grown more acidic at exactly the rate expected from chemical equilibration with the atmosphere. Continued acidification may have a host of negative impacts on marine biota, and has the potential to alter the rates of ocean biogeochemical processes.

When carbon dioxide reacts with seawater it reduces the availability of dissolved carbonate. Carbonate (CO₃) is vital to shell and skeleton formation in corals, marine plankton, some algae, and shellfish. Ocean acidification could have profound impacts on some of the most fundamental biological and geochemical processes of the sea in coming decades. Plankton is a critical food source that supports the entire marine food chain. Declining coral reefs will impact coastal communities, tourism, fisheries, and overall marine biodiversity. Abundance of commercially important shellfish species may decline, and negative impacts on finfish may occur. This rapidly emerging scientific issue and its potential ecological impacts have raised concerns across the scientific and fisheries communities.



Reefs in Hawai‘i are generally in good health and continue to be deserving of our careful management.

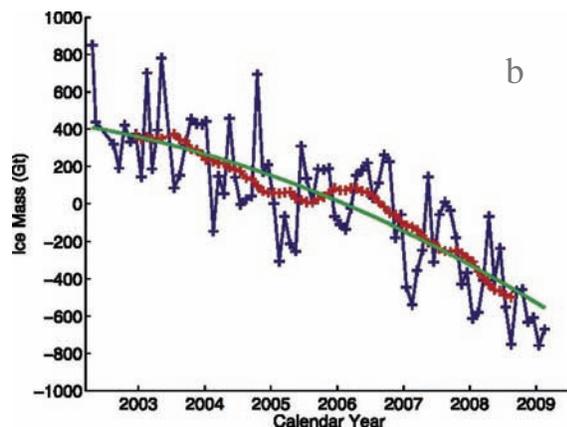
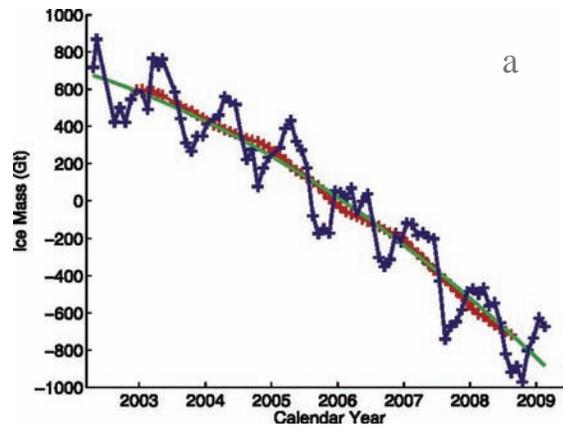


Sea level is projected to reach over 3 feet (1 meter) above present by the end of the century. The blue line marks the 1 meter contour above modern high tide.

Global Warming

From one year to the next global warming may not be evident. But measured by decade, the instrumental record beginning in 1880 shows that the temperature of Earth's surface and shallow ocean have increased over the past century, and accelerated since the 1970's. According to the National Aeronautics and Space Administration²³ global surface temperatures have increased about 1.44°F since the late-19th century, and the linear trend for the past 50 years of 0.36°F per decade is nearly twice that for the past 100 years. 2009 was only a fraction of a degree cooler than 2005, the warmest year on record, and tied with a cluster of other years — 1998, 2002, 2003, 2006 and 2007— as the second warmest year since record keeping began. Scientific analysis of modern and past climates has shown that Earth is warmer now than at any time in the past 1300 years²⁴ and perhaps longer.

Global warming is having measurable impacts on human communities and natural ecosystems²⁵ (for instance, because of climate change, ecosystems have to migrate an average 0.25 miles per year to stay within their natural climate zone²⁶). Antarctica has warmed²⁷ at a rate commensurate with global patterns, about 0.22°F per decade since 1957, for a total average temperature rise of 1°F. In Greenland, 2007²⁸ marked an overall rise in the summertime melting trend over the highest parts of the ice sheet. Melting in areas above 6,560 feet rose 150% above the long-term average, with melting occurring on 25-30 more days in 2007 than the average in the previous 19 years. As measured by satellite, melting from Greenland and Antarctic ice sheets has accelerated²⁹ during the period April 2002 to February 2009.

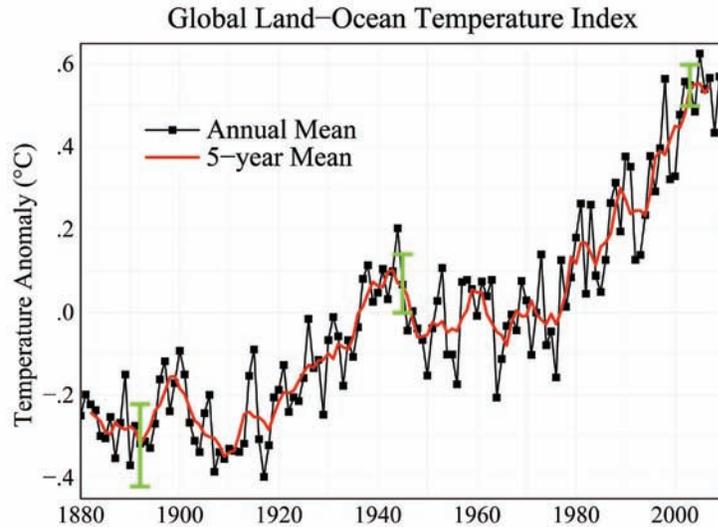


Ice loss from (a) Greenland and (b) Antarctic ice sheets (gigatons/year).

Conclusions

Global warming is evident in Hawai'i: surface temperature is rising, rainfall and stream flow has decreased, rain intensity has increased, sea level and sea surface temperatures have increased, and the ocean is acidifying. Because these trends are likely to continue:

- Scientists anticipate growing impacts to Hawai'i's water resources and forests, coastal communities, and marine ecology;
- It is timely to consider adaptation and mitigation strategies;
- There is significant need for sustained and enhanced climate monitoring and assessment activities;
- There is a compelling requirement for focused research to produce models of future climate changes and impacts.



Although 2008 was the coolest year of the decade -- due to strong cooling of the tropical Pacific Ocean -- 2009 saw a return to near-record global temperatures. The past year was only a fraction of a degree cooler than 2005, the warmest year on record, and tied with a cluster of other years -- 1998, 2002, 2003, 2006 and 2007 -- as the second warmest year since recordkeeping began²³.

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ICAP

Center for Island Climate Adaptation and Policy

The University of Hawai'i Sea Grant College Program (UH Sea Grant) has served Hawai'i and the Pacific for over 40 years and is dedicated to achieving resilient coastal communities characterized by vibrant economies, social and cultural sustainability and environmental soundness. In partnership with the William S. Richardson School of Law, the School of Ocean and Earth Science and Technology, the College of Social Sciences, and the Hawai'i inuiākea School of Hawaiian Knowledge, UH Sea Grant established the Center for Island Climate Adaptation and Policy (ICAP).

FROM UH TO YOU

ICAP connects individuals and institutions to the rich, climate knowledge at the University of Hawai'i. The Center offers work product in the areas of law, policy, planning, and science to mitigate and adapt to climate change while embracing the wisdom of local, traditional cultures.

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