The Importance of Land Stewardship in the Face of Climate Change in Hawaiʻi

Thomas Giambelluca
Director
Water Resources Research Center
University of Hawaiʻi at Mānoa

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Changing Climate: Global Temperature

Global Land and Ocean
January–December Temperature Anomalies

Human influence has warmed the climate at a rate that is unprecedented in at least the last 2000 years

Changes in global surface temperature relative to 1850-1900

- a) Change in global surface temperature (decadal average) as reconstructed (1-2000) and observed (1850-2020)
- b) Change in global surface temperature (annual average) as observed and simulated using human & natural and only natural factors (both 1850-2020)
Human activities affect all the major climate system components, with some responding over decades and others over centuries.
Climate Change in Hawai‘i

How much change have we already seen?

How much more should we expect?
Hawai‘i Temperature Index

RESEARCH ARTICLE


Marie M. McKenzie | Thomas W. Giambelluca | Henry F. Diaz

Department of Geography and Environment, University of Hawai‘i at Mānoa, Honolulu, Hawai‘i

Correspondence
Marie M. McKenzie, Department of Geography and Environment, University of Hawai‘i at Mānoa, 2424 Maili Way, Saunders Hall 445, Honolulu, HI 96822.
Email: mariemm@hawaii.edu

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University of Hawai‘i at Hilo

Based on a revised and extended multi-station Hawai‘i Temperature Index (HTI), the mean air temperature in the Hawaiian Islands has warmed significantly at 0.055°C/decade ($p < 0.01$) over the past 100 years (1917–2016). The year 2016 was the warmest year on record at 0.924°C above the 100-year mean (0.202°C). During each of the last four decades, mean state-wide positive air temperature anomalies were greater than those of any of the previous decades. Significant warming trends for the last 100 years are evident at low (0.055°C/decade, $p < 0.001$) and high elevations (0.047°C/decade, $p < 0.01$). Warming in Hawai‘i is largely attributed to significant increases in minimum temperature (0.072°C/decade, $p < 0.001$) resulting in a corresponding downward trend in diurnal temperature range ($-0.055°C/decade, p < 0.001$) over the 100-year period. Significant positive correlations were found between HTI, the Pacific Decadal Oscillation, and the Multivariate ENSO Index, indicating that natural climate variability has a significant impact on temperature in Hawai‘i. Analysis of surface air temperatures from NCEP/NCAR reanalysis data for the region of Hawai‘i over the last 69 years (1948–2016) and a mean atmospheric layer temperature time series calculated from radiosonde-measured thickness (distance between constant pressure surfaces) data over the last 40 years (1977–2016) give results consistent with the HTI. Finally, we compare temperature trends for Hawai‘i’s highest elevation station, Mauna Loa Observatory (3,397 m), to those on another mountainous subtropical island station in the Atlantic, Mt. Izaña Observatory (2,373 m), Tenerife, Canary Islands. Both stations sit above the local temperature inversion layer and have virtually identical significant warming trends of 0.19°C/decade ($p < 0.001$) between 1955 and 2016.

KEYWORDS
climate change, El Niño-southern oscillation, Hawai‘i, Pacific decadal oscillation, radiosonde observations, temperature trends
Hawaiʻi Temperature Index


100-yr change = +0.52°C (+0.94°F)
Spatial Patterns and Trends in Surface Air Temperatures and Implied Changes in Atmospheric Moisture Across the Hawaiian Islands, 1905–2017

A. K. Kagawa-Viviani¹ and T. W. Giambelluca¹,²

¹Department of Geography and Environment, University of Hawaii at Mānoa, Honolulu, HI, USA. ²Water Resources Research Center, University of Hawaii at Mānoa, Honolulu, HI, USA

Abstract While the Hawaiian Islands are experiencing long-term warming, spatial and temporal patterns are poorly characterized. Drawing on daily temperature records from 309 stations (1905–2017), we explored relationships of surface air temperatures (Tmax, Tmin, Tamv, and diurnal temperature range) to atmospheric, oceanic, and land surface variables. Statistical modeling of spatial patterns (2006–2017) highlighted the strong negative influence of elevation and moisture on air temperature and the effects of distance inland, cloud frequency, wind speed, and the local trade wind inversion on the elevation dependence of surface air temperature. We developed time series of sea level air temperature and surface lapse rate by modeling surface air temperature as a simple function of elevation and found a strong long-term (1905–2017) warming trend in sea level Tmin, twice that of Tmax (+0.17 vs +0.07°C/decade), suggesting regional warming, possibly enhanced by urbanization and cloud cover effects. Removing this trend, sea level Tmax and Tmin tracked SST and rainfall at decadal time scales, while Tmax increased with periods of weakened trade winds. Sea level air temperatures correlated with North Pacific climate indices, reflecting the influence of regional circulation via SST, rain, clouds, and trade winds that modulate environmental warming across the Hawaiian Islands. Increasing (steeper) Tmax surface lapse rates for the 0- to 1,600-m elevation range (into the cloud zone) over 1978–2017 coincide with observations of marine boundary layer drying and rising cloud base heights, suggesting a need to better understand elevation-dependent warming in this tropical/subtropical maritime environment and associated changes to cloud formation and persistence.

1. Introduction
How About Rainfall Change in Hawaiʻi?
Changing Rainfall

500-yr Hawaiian Winter Rainfall Reconstruction

Hawai‘i Climate Change

Decreases RF trends statewide

Model Projections of Future Rainfall


Rainfall Extremes

Kaua‘i: April 2018 – 49.69 inches – A new US record for 24-hr rainfall
What about changing ecosystems and climate change?
Areas dominated by the most widespread invasive tree species in Hawai‘i use more water than native dominated areas

**LE/Rn:** the fraction of net radiation used for evapotranspiration

**Thurston:** native dominated field site in Hawai‘i Volcanoes National Park

**Ola‘a:** non-native (strawberry guava – dominated field site in Hawai‘i Volcanoes National Park

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Projected future climate change will increase ET, especially in non-native forests.

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<th>ET Sensitivity: Native Site</th>
<th>ET Sensitivity: Non-Native</th>
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This statistical analysis was used to predict how future climate changes will affect evapotranspiration in native and non-native forest communities in Hawai‘i.

Land Stewardship in the Face of Climate Change

**Changing Climate**
- Higher temperatures
  - Higher ET
- Changing rainfall
  - Lower average RF likely in some areas – more frequent droughts
  - Higher extreme rainfall likely – more extreme flooding
- For areas getting drier
  - Need more water for irrigation
  - Greater fire frequency

**Changing Vegetation**
- Some invasive forest species use more water
- Increasing water use with climate change greater for non-native ecosystems

**Land Stewardship**

*Natural Areas*
- Preventing expansion of non-native species into native ecosystems
- Controlling/eradicating invasive species
- Maintain clear stream channels

*Working Lands*
- Promoting sustainable agricultural practices
- Reducing fire risk