The Importance of Land Stewardship in the Face of Climate Change in Hawai‘i

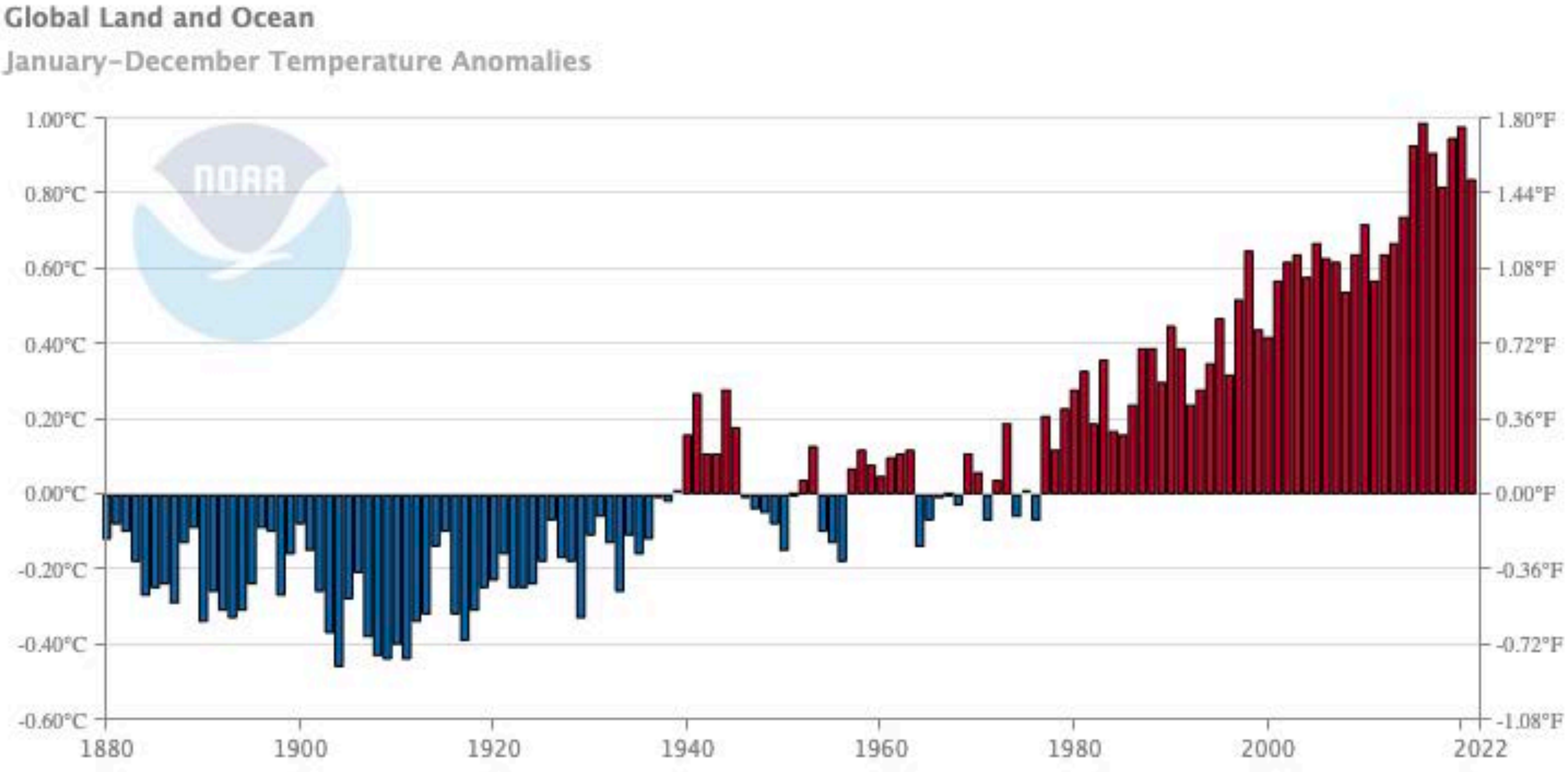
Thomas Giambelluca
Director
Water Resources Research Center
University of Hawai‘i at Mānoa

Hawaiian Homes Commission Meeting
21 March 2022

HAWAIIAN HOME LANDS
HAWAIIAN HOMES COMMISSION · DEPARTMENT OF HAWAIIAN HOME LANDS

G-3

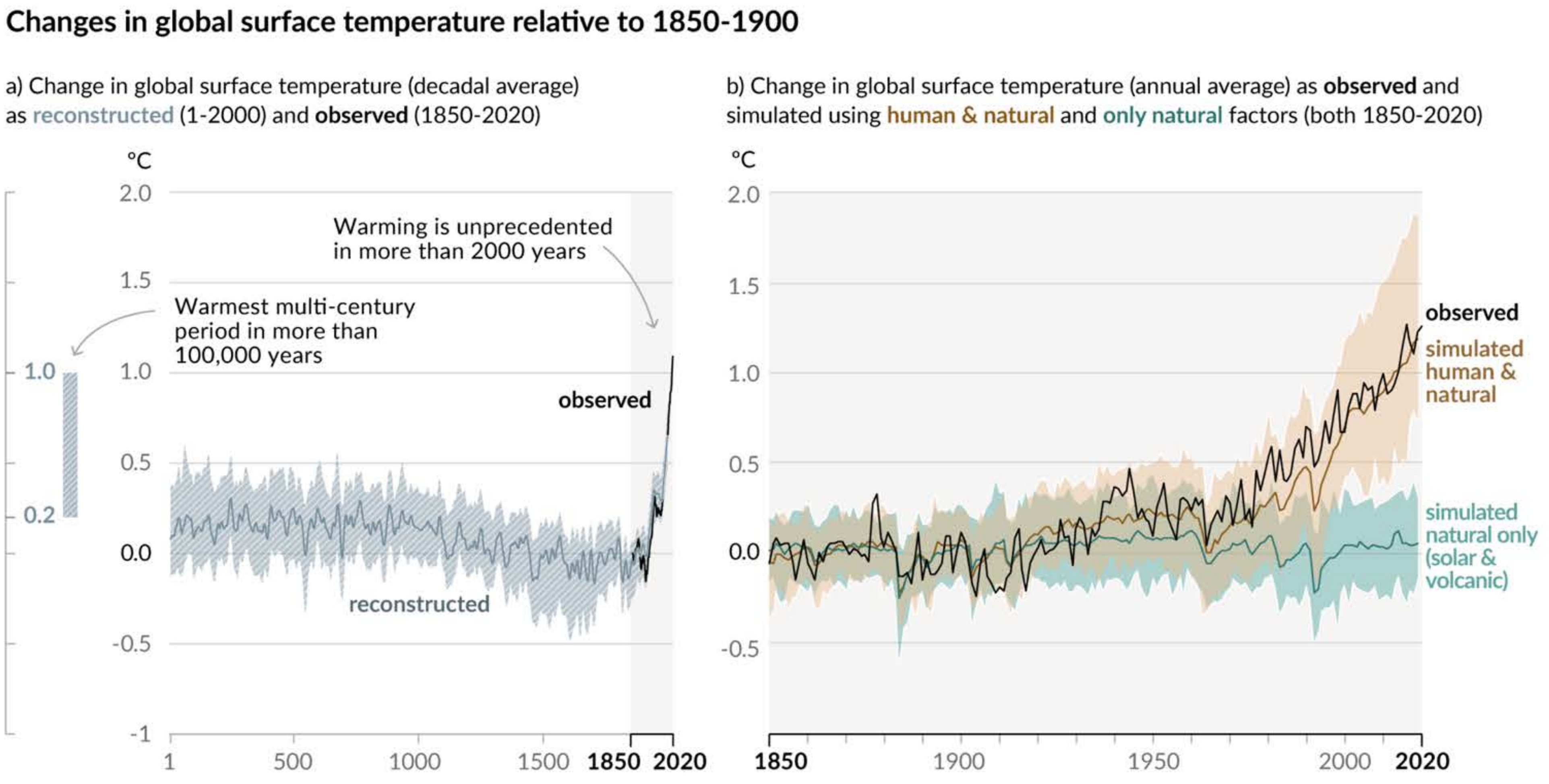
Changing Climate: Global Temperature



NOAA National Centers for Environmental information, Climate at a Glance: Global Time Series, published March 2022, retrieved on March 21, 2022 from https://www.ncdc.noaa.gov/cag/

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

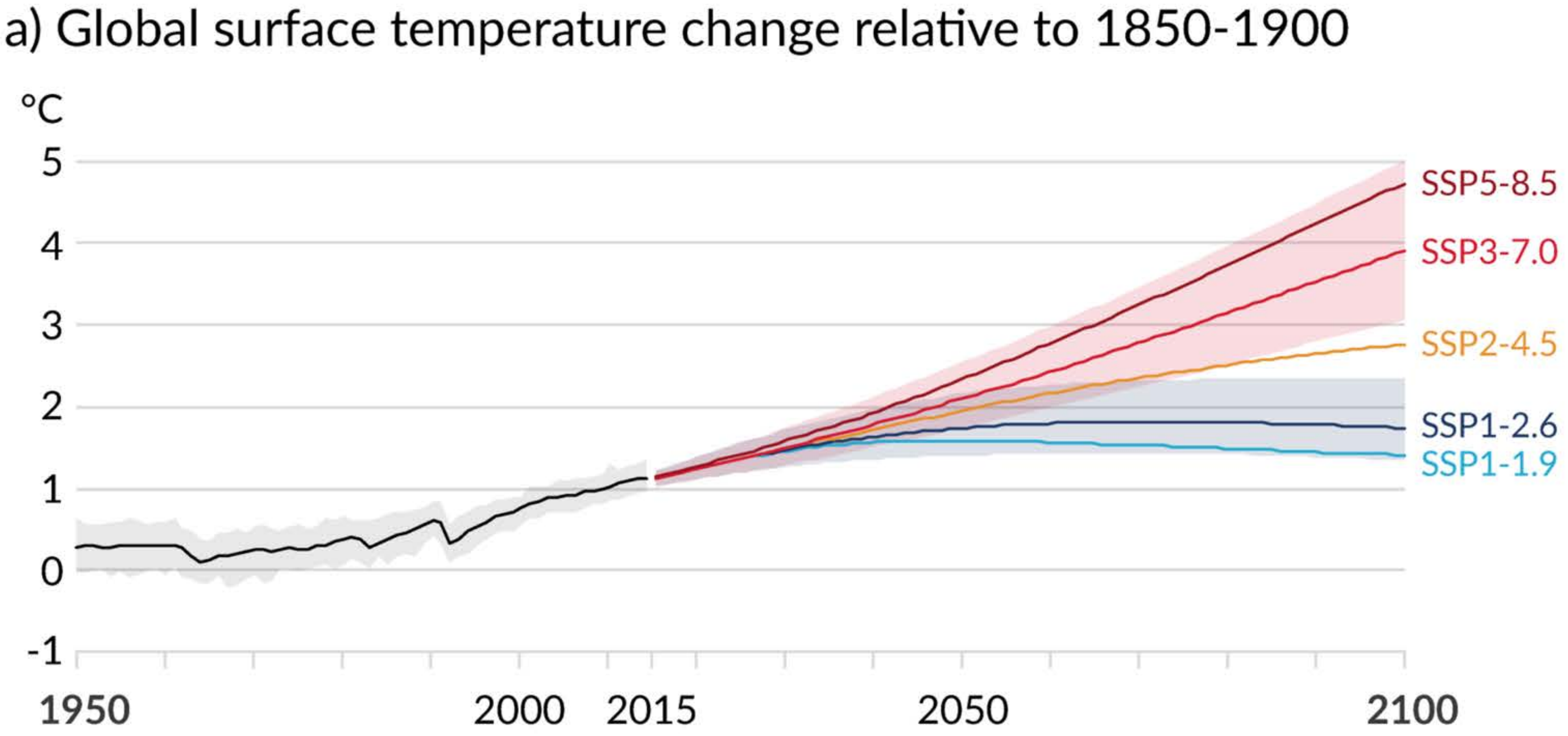
Figure SPM.1



AR6 Climate Change 2021: The Physical Science Basis
https://www.ipcc.ch/report/ar6/wg1/

Human activities affect all the major climate system components, with some responding over decades and others over centuries

Figure SPM.8



AR6 Climate Change 2021: The Physical Science Basis
https://www.ipcc.ch/report/ar6/wg1/

Climate Change in Hawaiʻi

How much change have we already seen?

How much more should we expect?

Hawaiʻi Temperature Index

Received: 16 March 2018 | Revised: 9 February 2019 | Accepted: 19 February 2019

DOI: 10.1002/joc.6053

International Journal of Climatology RMetS

RESEARCH ARTICLE

Temperature trends in Hawaiʻi: A century of change, 1917–2016

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

Department of Geography and Environment, University of Hawaiʻi at Mānoa, Honolulu, Hawaii

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

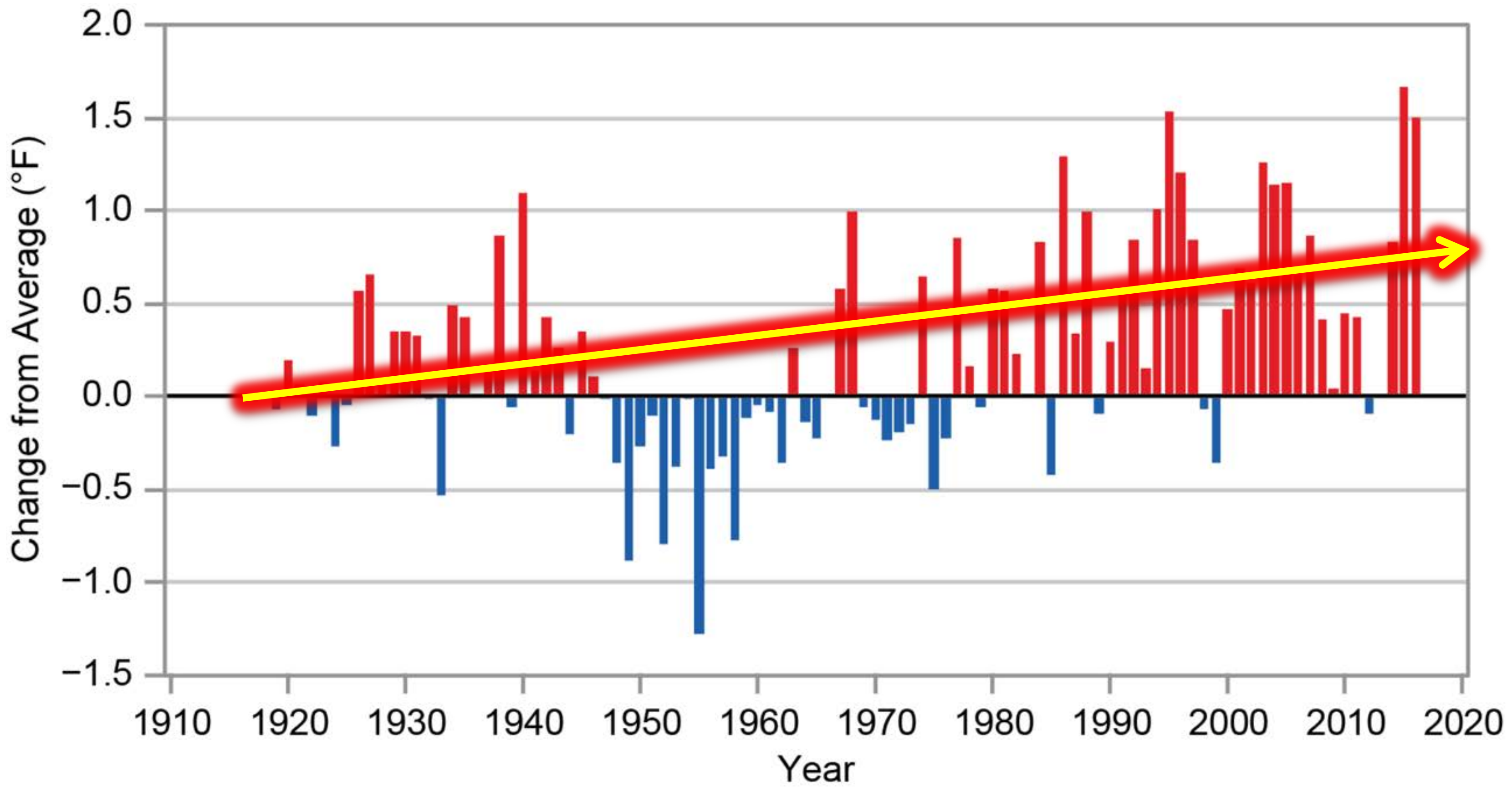
Funding information
University of Hawaiʻi at Hilo

Based on a revised and extended multi-station Hawaiʻi Temperature Index (HTI), the mean air temperature in the Hawaiian Islands has warmed significantly at 0.052°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 (0.056°C/decade, $p < 0.001$) and high elevations (0.047°C/decade, $p < 0.01$). Warming in Hawaiʻi 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 Hawaiʻi. Analysis of surface air temperatures from NCEP/NCAR reanalysis data for the region of Hawaiʻi 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 Hawaii'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, Hawaiʻi, Pacific decadal oscillation, radiosonde observations, temperature trends

Hawaiʻi Temperature Index



100-yr change = +0.52°C (+0.94°F)

McKenzie, M.M., Giambelluca, T.W., and Diaz, H.F. 2019. Regional temperature trends in Hawaiʻi: a century of change, 1917-2016. *International Journal of Climatology*.

JGR Atmospheres

RESEARCH ARTICLE
10.1029/2019JD031571

Key Points:
- Surface air temperature spatial patterns of the Hawaiian Islands are determined by topography, vegetation, and local atmospheric conditions
- New sea level air temperature analysis reveals strong warming at night, while daytime temperatures vary with North Pacific climate modes
- Increasing daytime surface lapse rates appear linked to atmospheric drying within the marine boundary layer

Supporting Information:
- Supporting Information S1

Correspondence to:
A. K. Kagawa-Viviani,
kagawa@hawaii.edu

Citation:
Kagawa-Viviani, A. K., & Giambelluca, T. W. (2020). Spatial patterns and trends in surface air temperatures and implied changes in atmospheric moisture across the Hawaiian Islands, 1905–2017. *Journal of Geophysical Research: Atmospheres*, *125*, e2019JD031571. https://doi.org/10.1029/2019JD031571

Spatial Patterns and Trends in Surface Air Temperatures and Implied Changes in Atmospheric Moisture Across the Hawaiian Islands, 1905–2017

A. K. Kagawa-Viviani[1] and T. W. Giambelluca[1,2]

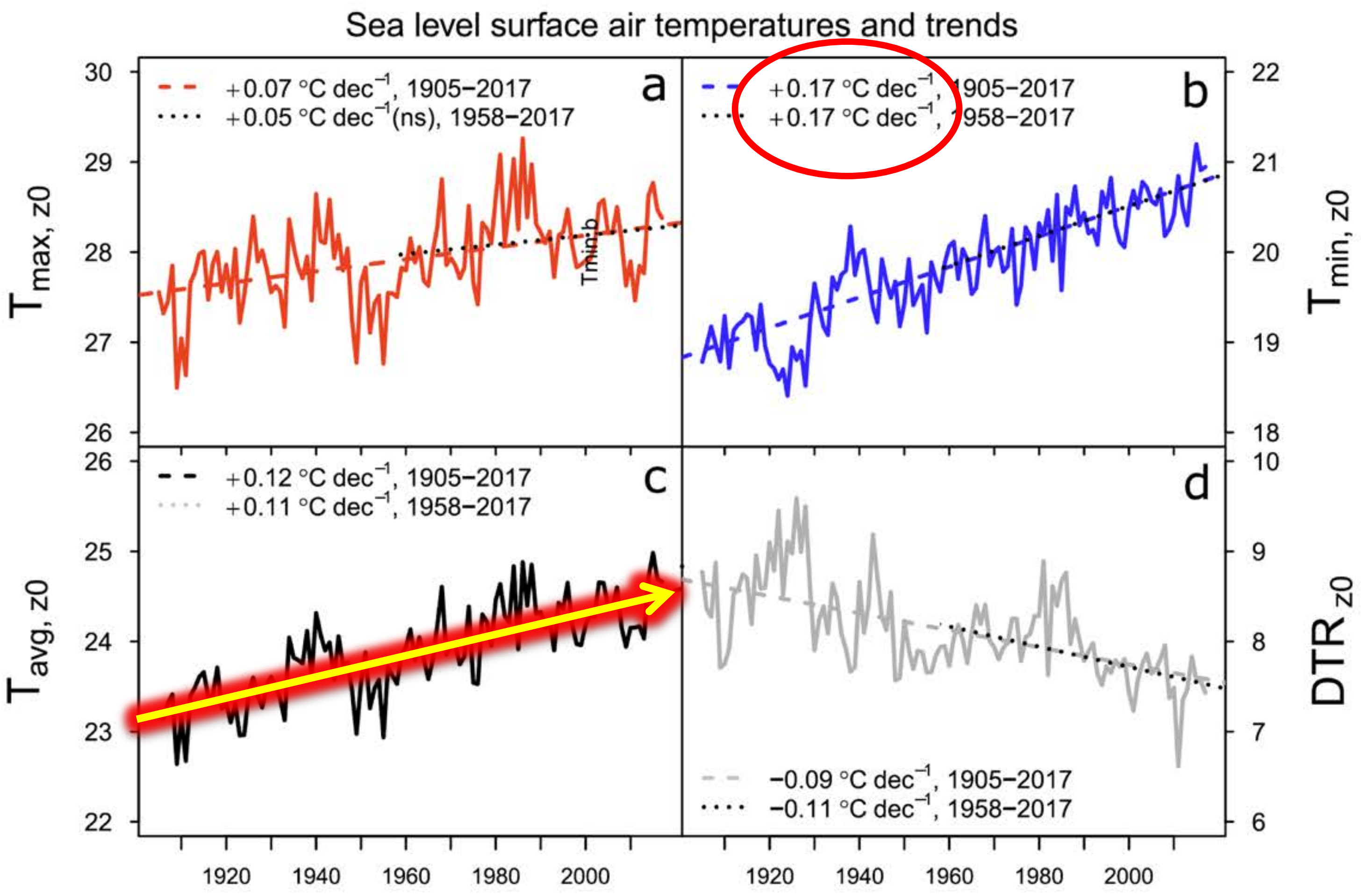
[1]Department of Geography and Environment, University of Hawaii at Mānoa, Honolulu, HI, USA, [2]Water Resources Research Center, University of Hawaii at Mānoa, Honolulu, HI, USA

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 (T_{max}, T_{min}, T_{avg}, 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 T_{min}, twice that of T_{max} (+0.17 vs +0.07°C/decade), suggesting regional warming, possibly enhanced by urbanization and cloud cover effects. Removing this trend, sea level T_{max} and T_{min} tracked SST and rainfall at decadal time scales, while T_{max} 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) T_{max} 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

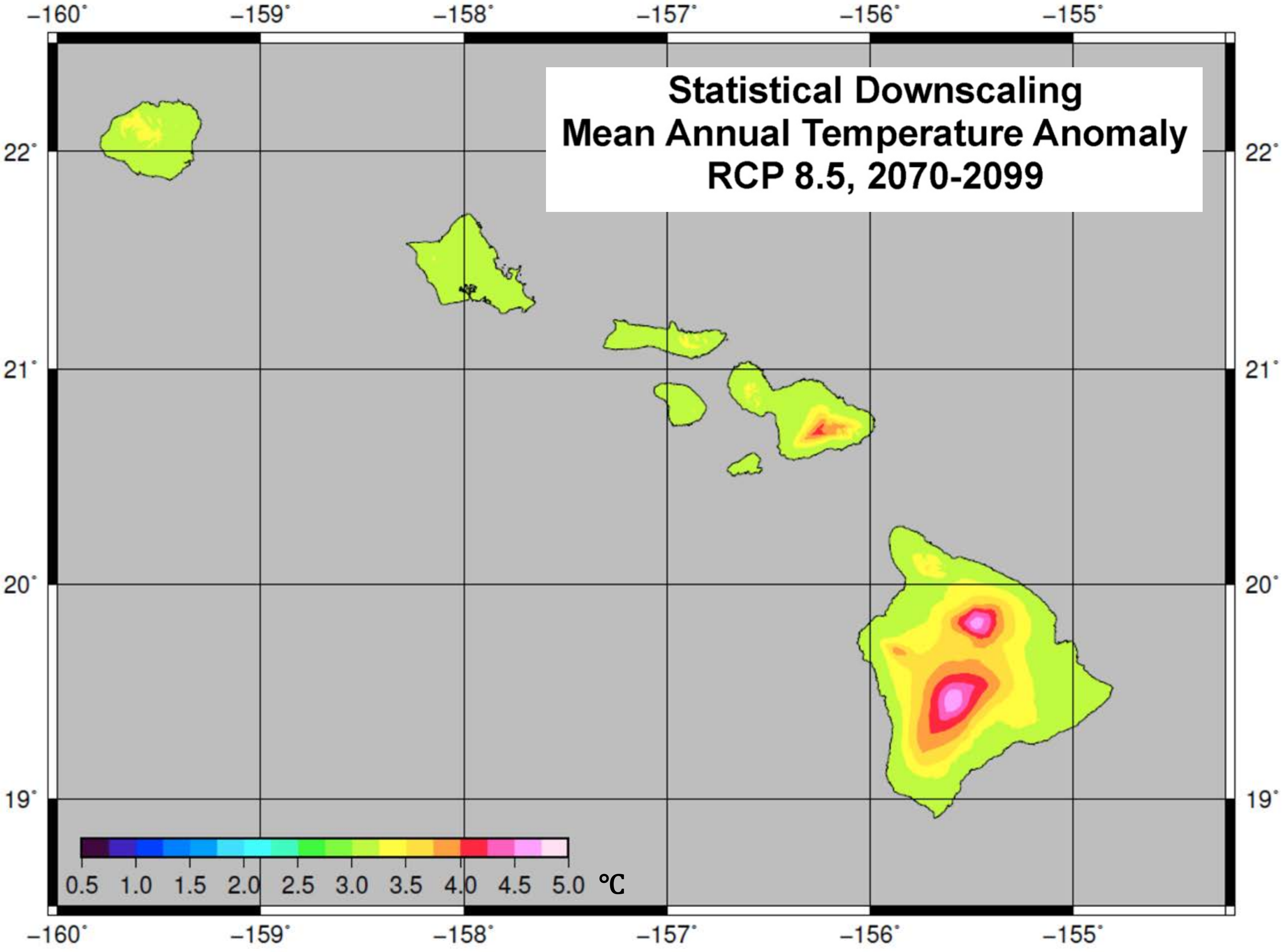
100-yr change = +1.7°C (+3.06°F)

100-yr change = +1.2°C (+2.16°F)



Kagawa-Viviani, A.K., and Giambelluca, T.W. 2020. Spatial patterns and trends in surface air temperatures and implied changes in atmospheric moisture across the Hawaiian Islands, 1905–2017. *Journal of Geophysical Research-Atmospheres* 125(2): e2019JD031571, doi: 10.1029/2019JD031571.

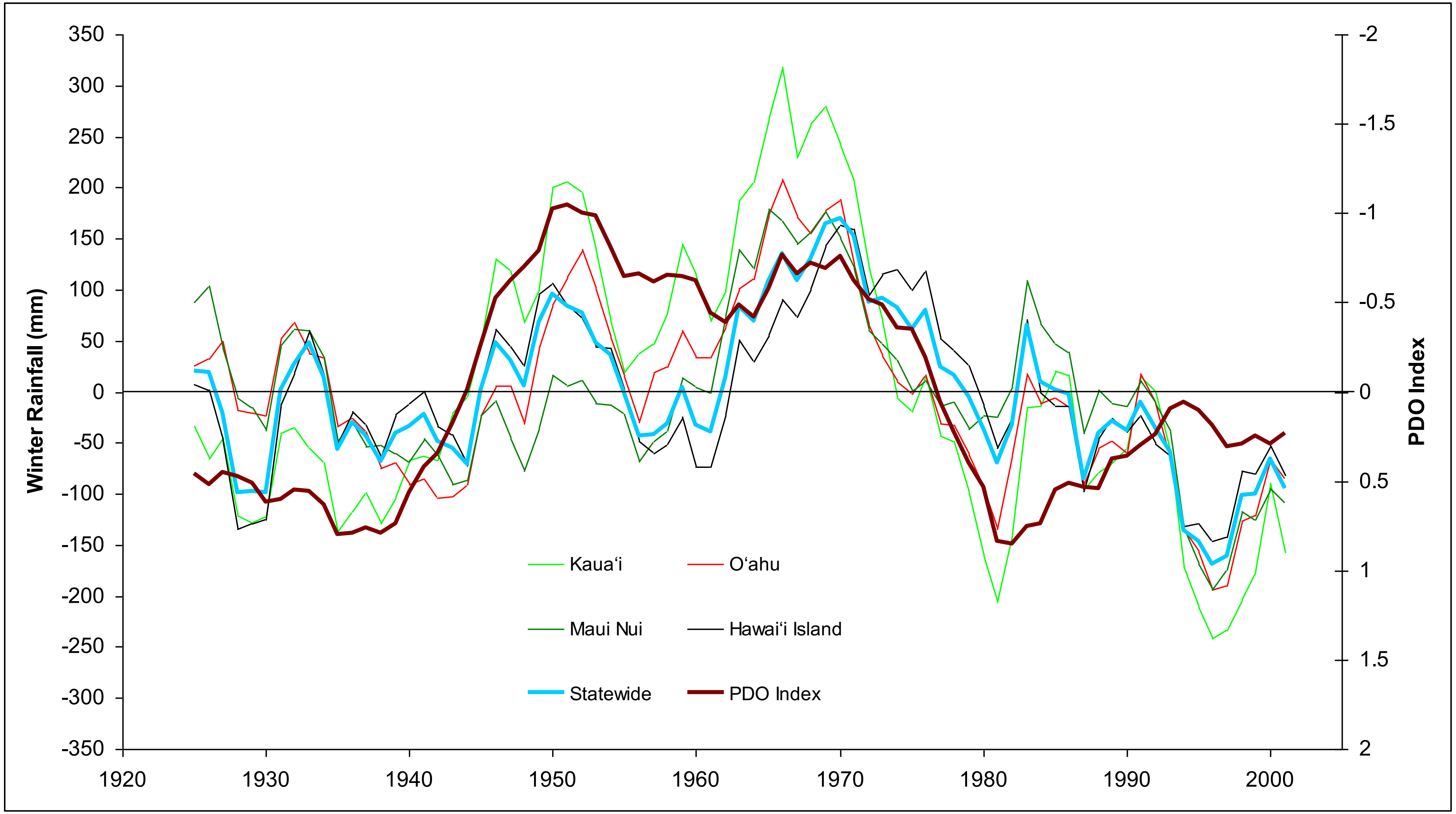
Model Projections



Elison Timm, O. (2017), Future warming rates over the Hawaiian Islands based on elevation-dependent scaling factors. Int. J. Climatol, 37: 1093-1104. https://doi.org/10.1002/joc.5065

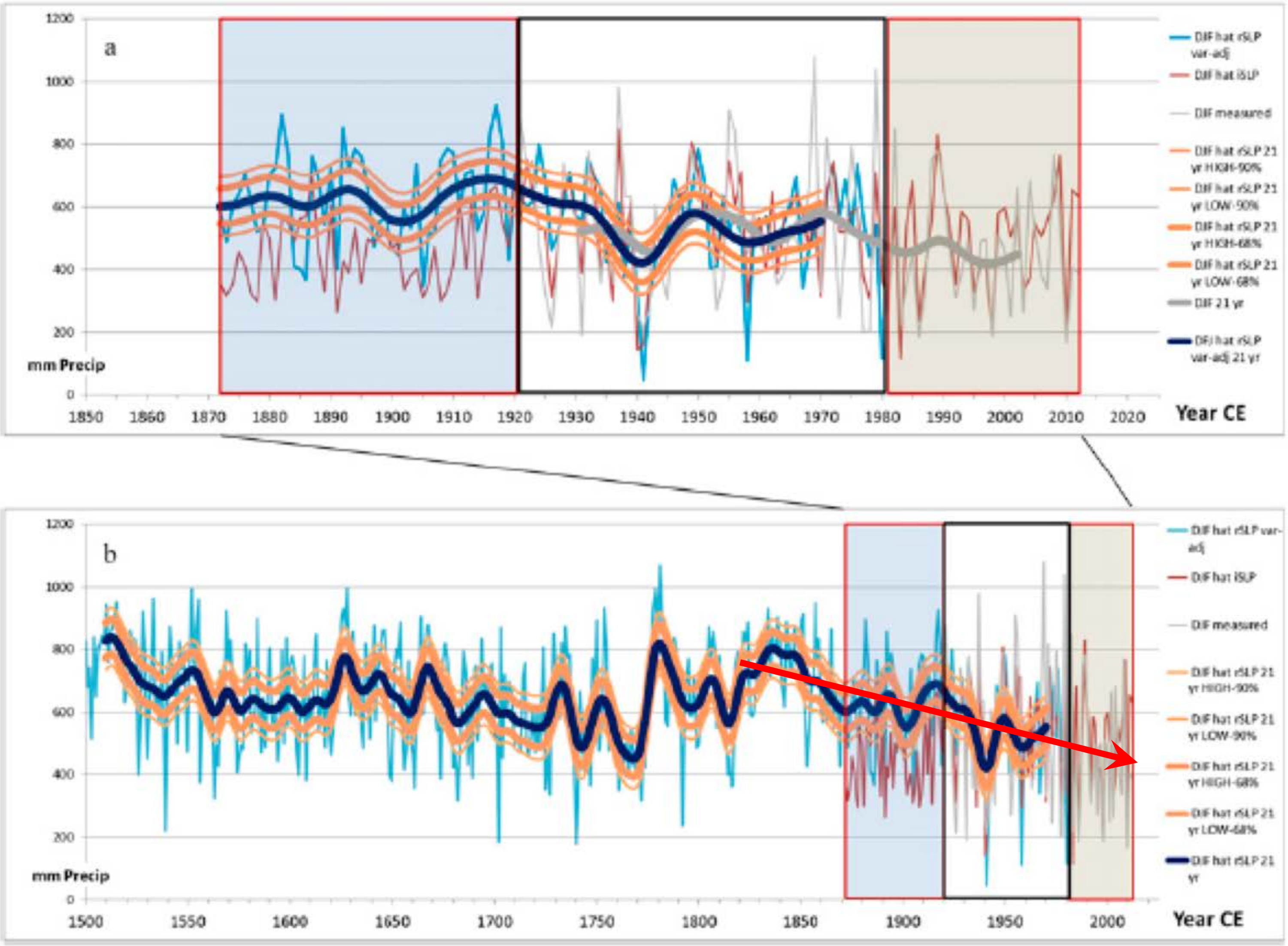
How About Rainfall Change in Hawai‘i?

Changing Rainfall



Diaz, H.F., and Giambelluca, T.W. 2012. Changes in atmospheric circulation patterns associated with high and low rainfall regimes in the Hawaiian Islands region on multiple time scales. *Global and Planetary Change* 98-99: 97-108, doi: 10.1016/j.gloplacha.2012.08.011.

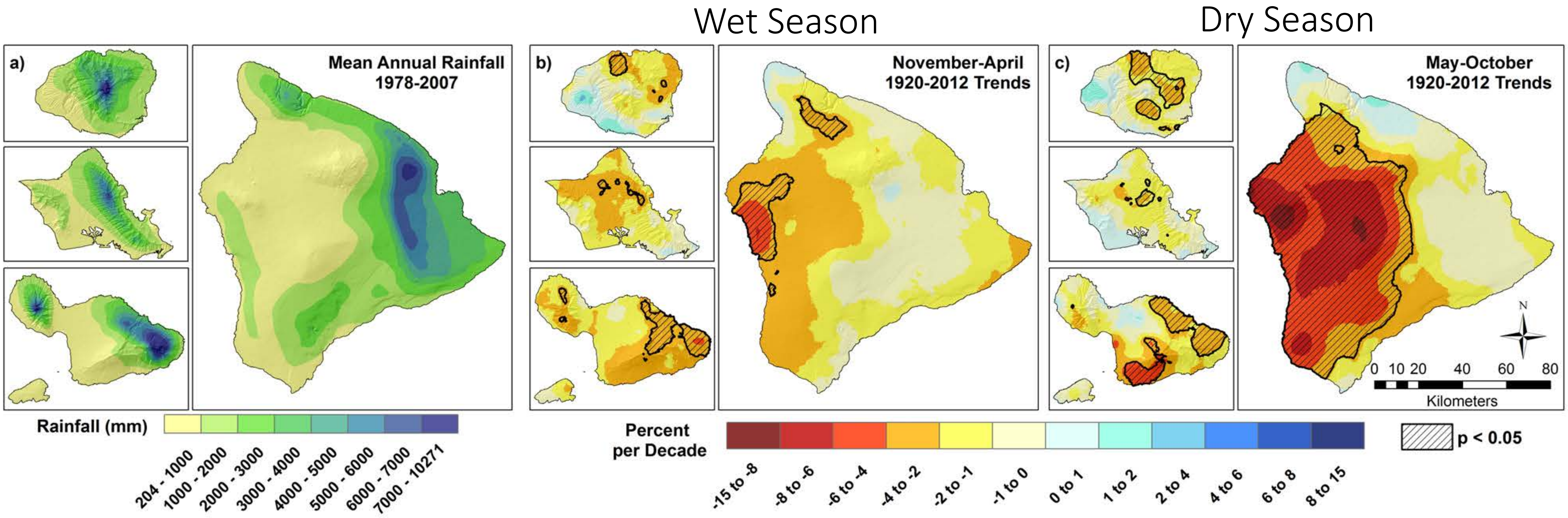
500-yr Hawaiian Winter Rainfall Reconstruction



Diaz, H.F., Wahl, E.R., Zorita, E., Giambelluca, T.W., and Eischeid, J.K. 2016. A five-century reconstruction of Hawaiian Islands rainfall. *Journal of Climate* 29: 5661-5674, doi: 10.1175/JCLI-D-15-0815.1.

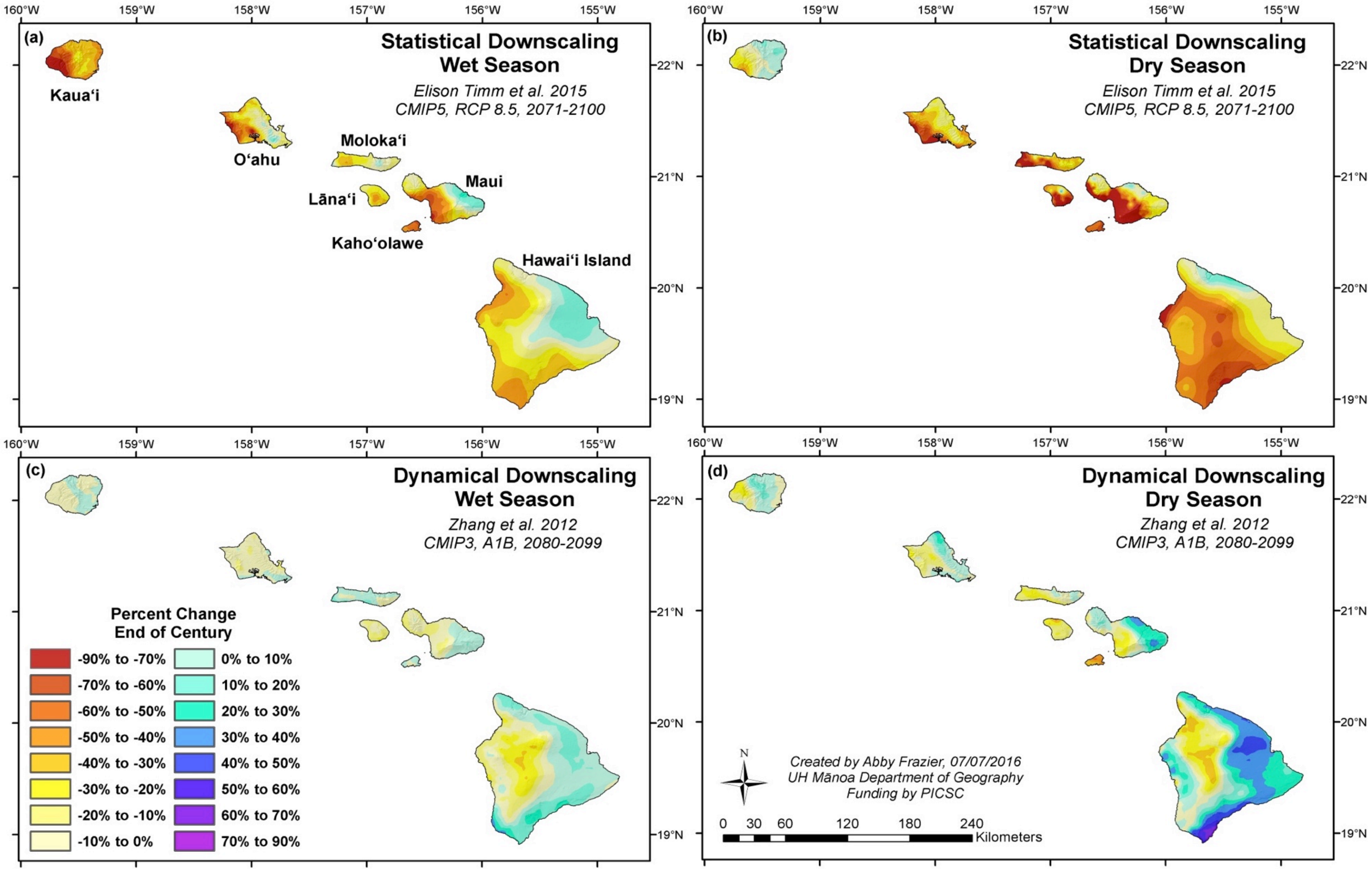
Hawaiʻi Climate Change

Decreases RF trends statewide



Frazier, A.G., and Giambelluca, T.W. 2017. Spatial trend analysis of Hawaiian rainfall from 1920 to 2012. International Journal of Climatology 37: 2522-2531, doi: 10.1002/joc.4862.

Model Projections of Future Rainfall



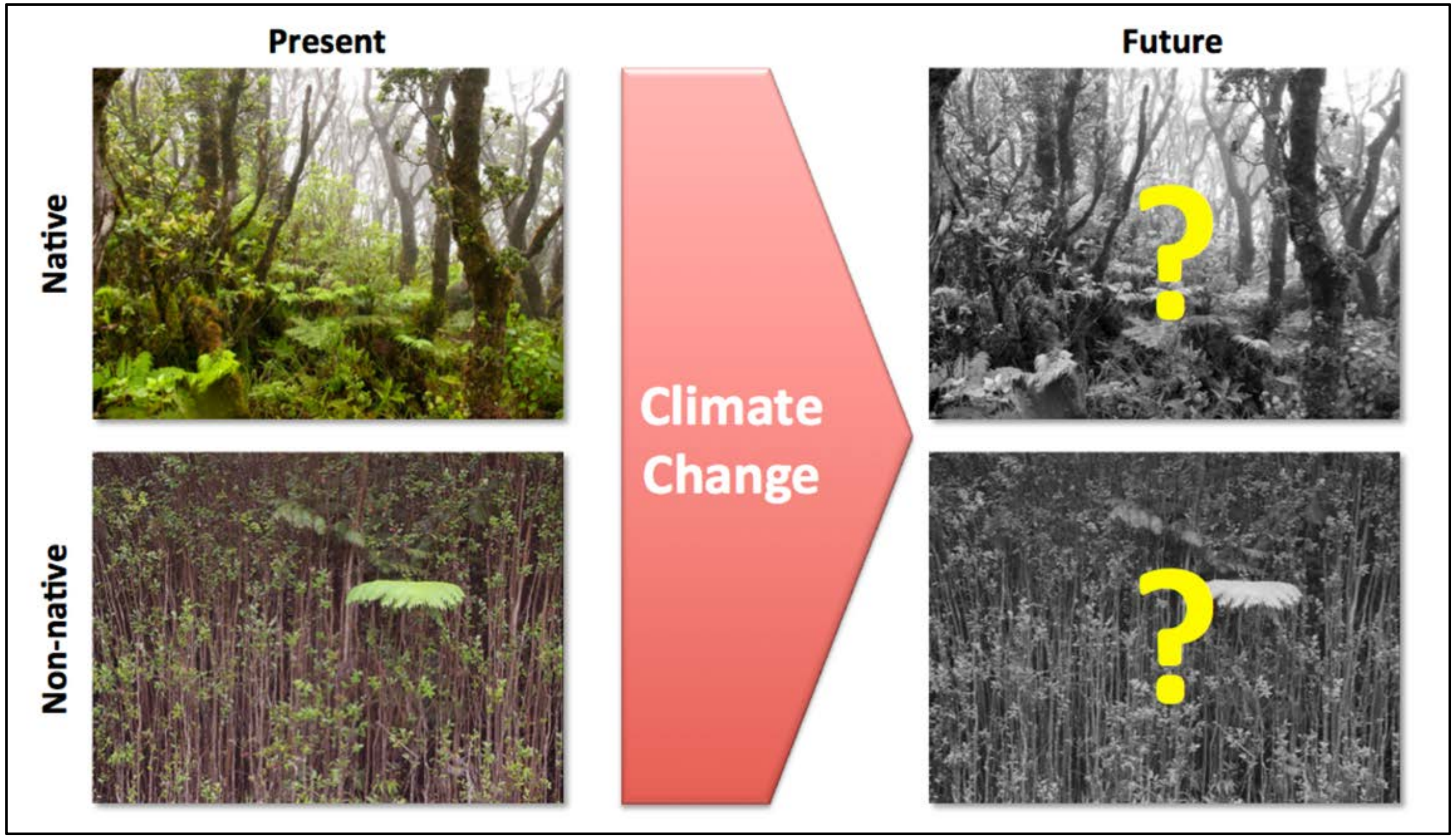
Elison Timm, O., Giambelluca, T.W., and Diaz, H.F. 2015. Statistical downscaling of rainfall changes in Hawai'i based on the CMIP5 global model projections. *Journal of Geophysical Research-Atmospheres* 120: 92-112, doi: 10.1002/2014JD022059.

Zhang, C., Wang, Y., Lauer, A., & Hamilton, K. (2012). Configuration and Evaluation of the WRF Model for the Study of Hawaiian Regional Climate, *Monthly Weather Review*, *140*(10), 3259-3277. https://journals.ametsoc.org/view/journals/mwre/140/10/mwr-d-11-00260.1.xml

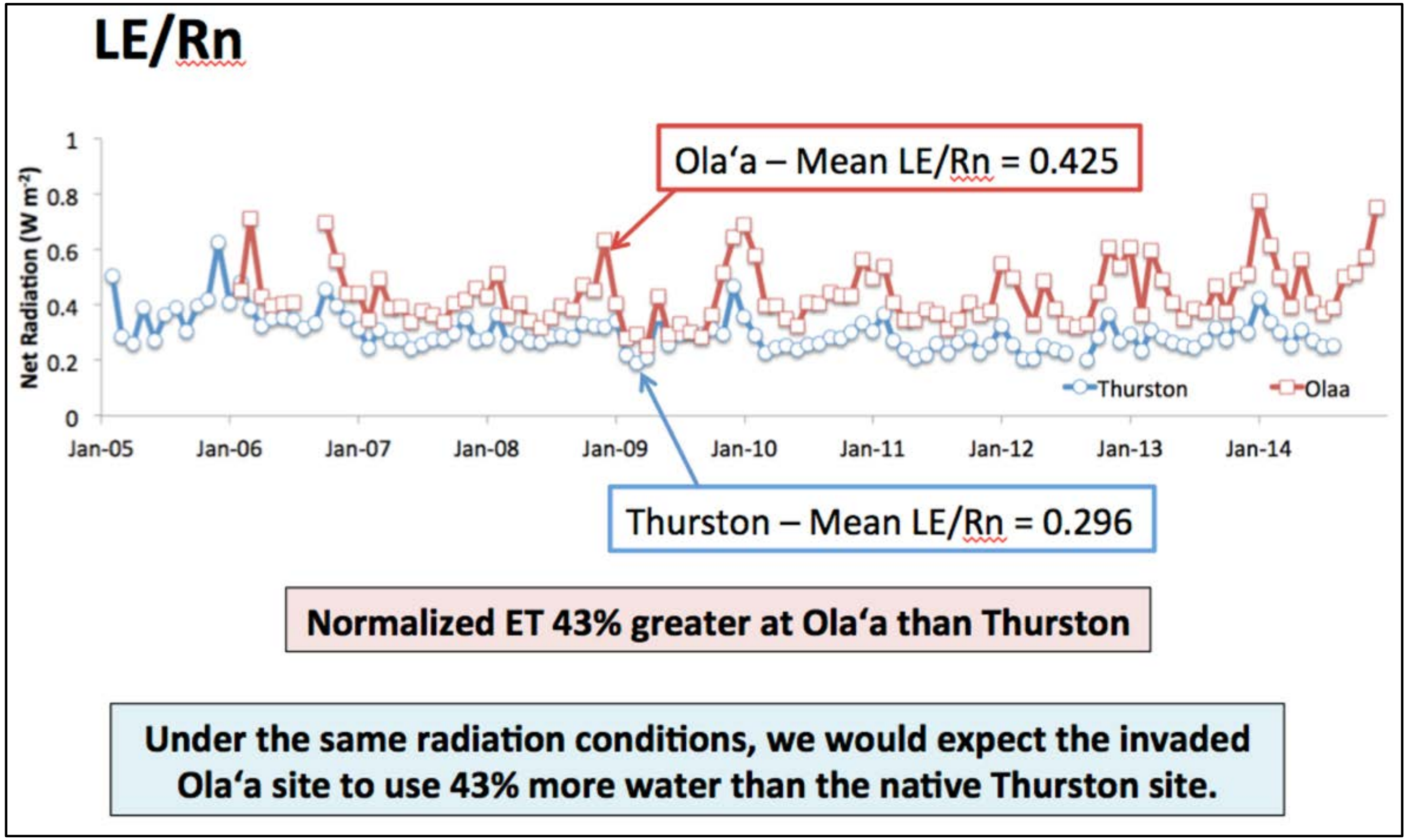
Rainfall Extremes

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

Giambelluca, T.W., Mudd, R.G., Huang, M., Nullet, M.A., Asner, G., Martin, R., Ostertag, R., Miyazawa, Y., Litton, C. 2016. Light availability controls ecosystem fluxes in native and non-native tropical montane wet forests in Hawai‘i. Abstract B31G-0560 presented at the American Geophysical Union Fall Meeting, San Francisco, December 2016.

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

ET Sensitivity: Native Site

Variable	Sign	r^2
Rnet	+	0.385
Kdn	+	0.584
PAR	+	0.627
T	+	0.196
VPD	+	0.581
CO2	0	0.011
RF	-	0.275
WS	+	0.031
SM1	-	0.031
SM2	-	0.280
SM3	-	0.090
FW	-	0.195
PE-e	+	0.431
PE-a	+	0.716
PE	+	0.770

ET Sensitivity: Non-Native

	Sign	r^2
Rnet	+	0.223
Kdn	+	0.406
PAR	+	0.406
T	+	0.179
VPD	+	0.754
CO2	0	0.000
RF	-	0.214
WS	+	0.002
SM1	-	0.198
SM2	-	0.071
SM3	-	0.224
SM4	-	0.076
SM5	-	0.313
SM6	-	0.279
SM7	-	0.227
FW	-	0.000
PE-e	+	0.267
PE-a	+	0.801
PE	+	0.840

Strong positive response to radiation

Strong positive response to humidity

Negative responses to moisture

This statistical analysis was used to predict how future climate changes will affect evapotranspiration in native and non-native forest communities in Hawai‘i.

Giambelluca, T.W., Mudd, R.G., Huang, M., Nullet, M.A., Asner, G., Martin, R., Ostertag, R., Miyazawa, Y., Litton, C. 2016. Light availability controls ecosystem fluxes in native and non-native tropical montane wet forests in Hawai‘i. Abstract B31G-0560 presented at the American Geophysical Union Fall Meeting, San Francisco, December 2016.

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


Mahalo