FINAL REPORT

1. ADMINISTRATIVE

Recipient Organization (Name and Address)
University of Hawaiʻi, 2530 Dole Street, Sakamaki D-200, Honolulu, HI 96822

Project Title
Field Monitoring and Analysis of Climate Change Across a Wide Range of Ecosystems in Hawaiʻi

Award Number
12200-A-J027 / F10AC00079

PD/PI Name, Title and Contact Information (e-mail address and phone number)
Thomas W. Giambelluca; thomas@hawaii.edu; 808 230-1408

Report Date
31 March 2015

Period of Time Covered by the Report
1 October 2010 to 30 September 2014

Reporting Period End Date
1 October 2012 to 31 March 2013

2. PUBLIC SUMMARY

This project provided for the maintenance and improvement of the HaleNet Climate Network. This project supported the work necessary to keep the climate stations running, retrieve the stored data, repair and replace instruments, and subject the data to rigorous analysis to remove errors. By measuring climate across a range of elevations and on windward and leeward slopes of Haleakalā, we are adding significant new information about the spatial patterns of climate in Hawaiʻi. This information has been used to map climate patterns statewide, including rainfall, temperature, solar radiation, humidity, wind, and other variables. Knowledge of the patterns of climate are valuable for resource managers who restore and protect forests and other natural areas that provide habitat for native animals, such as forest birds, and serve as watersheds. Our measurements also allow us to determine how much climate has varied over time, including possible trends related to global warming. For example, we have found that because of declines in cloud cover, solar radiation has increased in high elevation areas over the past 25 years. Analysis of the records have shown us how much of the year-to-year differences in climate are the result of natural variability related to, for example, El Niño. We found that El Niños cause drought in winter and La Niñas cause drier than normal conditions in summer. We showed that

these dry periods are caused by changes in the number of days with a stable layer in the atmosphere, the "trade wind inversion" (TWI). Days with the TWI present are drier. El Niño and La Niña have effects on the proportion of days with and without a TWI, and, hence, on the dryness of the climate during different seasons. As we continue to add new measurements to the HaleNet data set, the value of this resource grows.

3. PROJECT REPORT

A. TECHNICAL SUMMARY:

Observations and analysis conducted in this project have led to significant advances in our knowledge of climate patterns statewide, including rainfall (Giambelluca et al., 2013), solar radiation (Longman et al., 2012, 2013), and net radiation, air temperature, relative humidity, wind speed, and potential and actual evapotranspiration (Giambelluca et al., 2014). The HaleNet data set has also been critically important in analyses of ecosystem response to climate change (Krushelnycky et al., 2013) and climate extremes (Crausbay et al., 2014). The role of the trade-wind inversion (TWI), analysis of changes in the TWI, and the effects of those changes has been addressed within this project by Longman (2015). A study, supported in part by this project, resulted in a set of statewide, high-spatial-resolution maps of monthly rainfall for each month from 1920 to 2012 (Frazier et al., in review). This set of maps allowed temporal trends in rainfall in Hawaiʻi to be studied in unprecedented detail (Frazier et al., in preparation). Trends in other climate variables were studied for high elevation stations in HaleNet. These include analyses of trends in solar radiation and cloud attenuation of solar radiation (Longman et al., 2014), and net radiation, air temperature, relative humidity, vapor pressure deficit, wind speed, and zero precipitation days (Longman, 2015). HaleNet data were used to calibrate proxy data for a paleoecological study of fluctuations in the height of the forest line along the windward slope of Haleakalā

B. PURPOSE AND OBJECTIVES:

PURPOSE AND OBJECTIVES: The overarching goal of this project was to ensure continued operation and maintenance of the HaleNet system, including field operations, equipment maintenance and replacement, sensor recalibration, data communication improvements, data screening/archival, data analysis, and dissemination of results. Achieving the overarching goal of this project has supported many research objectives. Below is a list of research objectives listed in the project proposal, with a brief explanation of how these objectives were met in this project.

i. Improve knowledge of the current spatial distribution of important climate variables across elevations and exposures in Hawaiʻi. Continued monitoring of these climate variables will facilitate validation of ecological models and support management actions.

   Our work on statewide climate patterns, including rainfall (Giambelluca et al., 2013), solar radiation (Longman et al., 2012, 2013), and net radiation, air temperature, relative humidity, wind speed, and potential and actual evapotranspiration (Giambelluca et al., 2014), and ecosystem response to climate change (Krushelnycky et al., 2013) and climate extremes (Crausbay et al., 2014), address this objective.

ii. Evaluate the influence of the trade-wind inversion on climate, ecosystem function, and ecosystem services on high mountains in Hawaiʻi.

   The role of the trade-wind inversion (TWI), analysis of changes in the TWI, and the effects of those changes has been addressed within this project by Longman (2015).

iii. Detect trends in climate in Hawaiʻi, including not only temperature and rainfall, but also solar radiation, humidity, wind, and other variables.

   The work of Longman et al. (2014) and Longman (2015) on high elevation trends in rainfall, temperature, solar radiation, humidity, wind, and other variables, and the work of Frazier et al., in review) to develop and analyze statewide maps of monthly rainfall over the 1920-2012 period address this objective.

iv. Estimate the spatial patterns and possible temporal trends in evapotranspiration across a range of environments.

   The time series of potential evapotranspiration was estimated at each HaleNet station and analyzed for trends (Longman et al., in preparation).

v. Facilitate investigations of past climates in Hawaiʻi, especially as revealed through paleoecological evidence of past shifts in the forest-grassland ecotone on Haleakalā.

   HaleNet data were used to calibrate proxy data for a paleoecological study of fluctuations in the height of the forest line along the windward slope of Haleakalā.

vi. Provide detailed climate information relevant to resources management decisions and conservation biology activities of Haleakalā National Park. Information is needed to improve understanding and prediction of responses of invasive species, rare native species, and common native species to climate variability and climate change.

   Resource managers, including Haleakalā National Park Resources Management, The Nature Conservancy and others make use of HaleNet-derived data products to plan and conduct conservation activities on the mountain. Climate variability and climate change can act as as ecosystem stressors. A good example can be seen in the decline in the Haleakalā Silversword since 1990, despite vigorous efforts to protect this iconic plant and promote its recovery from decades of degradation. The study by

Krushelnycky et al. (2013) demonstrated that declining moisture availability, especially during the dry season, coupled with increases in air temperature and solar radiation are the likely causes of the observed decline. This analysis was made possible by the availability of 20+ years of HaleNet data.

C. ORGANIZATION AND APPROACH: The research activities of the project are listed below:

i. Operated and maintained the HaleNet system throughout the period of the project. This included regular site visits to retrieve data, change out sensors and other system components (for repair, recalibration, and replacement), and conduct routine maintenance of structural support, power supply, and weatherproofing.

ii. Completed the installation of replacement sensors at all HaleNet sites (funding provided by PIERC, USGS).

iii. Implemented data quality control procedures for all HaleNet data. A complete reevaluation of all past data was conducted, leading to the conclusion that a major effort was needed to homogenize solar radiation, net radiation, relative humidity, and wind speed time series affected by calibration drift and shifts resulting from past changes in calibration coefficients and sensor replacement.

iv. Completed development of new method of homogenizing HaleNet relative humidity data to correct spurious data shifts and trends

v. Completed development of new method of homogenizing HaleNet wind speed data to correct spurious data shifts and trends arising from sensor replacement and calibration drift.

vi. Completed development of new method of homogenizing HaleNet net radiation data to correct spurious data shifts and trends arising from sensor replacement and calibration drift.

vii. Completed homogenization of HaleNet temperature data to correct spurious data shifts and trends arising from sensor replacement and calibration drift.

viii. With additional support from the EPSCoR project and through collaboration with the EPSCoR CYBER team at the University of Hawaiʻi at Hilo, began development of a new data archival system, automated data quality assessment/quality control system, and data analysis system, using HaleNet data as the test data set.

ix. Completed analysis of climate variations contributing to the observed decline in the population of the Haleakalā silversword.

x. Completed data analysis and mapping of monthly, seasonal, and annual values of various climate variables for the forest-grassland ecotone area along Kalapawili Ridge on the upper eastern slope of Haleakalā.

xi. Completed an analysis of long-term trends in solar radiation at high elevations, using the homogenized HaleNet solar radiation data set.

xii. Used HaleNet solar radiation data to test the REST-2 clear day radiation model across a range of elevations in Hawaiʻi.

xiii. Published a paper on modeling of clear sky radiation in Hawaiʻi (Longman et al., 2012)

xiv. Analyzed the ENSO dependency of key climate variables.

xv. Tested potential evapotranspiration (PET) methods, Penman, Penman-Monteith, and Priestley-Taylor, in relation to evaporation measured at some HaleNet stations using atmometers.

xvi. Calculated PET time series for all stations.

xvii. Conducted cloud fraction analysis to support finding of increased solar radiation at high elevation stations on Haleakalā.

xviii. Used HaleNet data to help validate clear-sky and all sky-solar radiation estimates (Giambelluca et al., 2014).

xix. Published a paper on a new technique for homogenizing solar radiation data (Longman et al., 2013)

xx. Published a paper on solar radiation trends at high elevations in Hawaiʻi (Longman et al., 2014)

xxi. Analyzed variations in PET, including the effects of TWI on PET at high elevations during distinct ENSO phases for winter season (DJF).

xxii. Presented project-derived findings at the annual American Geophysical Union meetings (Barnes et al., 2012; Frazier et al., 2012, 2013, 2014; Giambelluca et al., 2011, 2013, 2014; Longman et al., 2011, 2012, 2013, 2014).

xxiii. Completed draft Climatology of Haleakalā report (Longman et al., 2015).

D. PROJECT RESULTS: Project results are described in detail in the following documents:

- Longman, R.J., Giambelluca, T.W., Nullet, M.A., and Loope, L.L. 2015. Climatology of Haleakalā. Draft Technical Report submitted to the Pacific Islands Climate Change Cooperative, March 2015.
- Longman, R.J. 2015. Trade wind inversion variability and its effects on high elevation climates in Hawaiʻi. PhD dissertation, Department of Geography, University of Hawaiʻi at Mānoa.

E. KEY FINDINGS: Following is a list of key scientific findings, derived mainly from the PhD dissertation of Longman (2015).

Spatial and Temporal Climate Variations on Haleakala

- Both leeward and windward microclimates above ~2000 m are strongly influenced by the presence of the TWI in both the dry and wet seasons.

- No leeward precipitation gradient was found, but other moisture variables such as potential evapotranspiration, relative humidity, vapor pressure deficit, and soil moisture decreases with height above the mean inversion base height.
- The rainfall, soil moisture, and relative humidity are much greater on the windward slope even at high-elevations when compared with leeward locations at similar elevations.
- Period-of-record (up to 25 years) changes in the climate are apparent across both leeward and windward elevation gradients for both the dry and wet seasons.
- For the dry season, a decadal-scale drying trend was identified for all of the moisture variables analyzed at the stations located above 1000 m along both leeward and windward transects. Significant decreases in precipitation were found at four HaleNet stations located between1640 and 2990 m along the leeward transect. Significant decreases in relative humidity and significant increases in vapor pressure deficit, potential evapotranspiration and the occurrence of zero rainfall days were found at one or more of the three highest elevation (2120 – 2990 m) leeward observation sites. Along the windward transect, significant decreases in precipitation were found at all three stations across the 810 m gradient (1650 – 2460 m) and a significant decrease in relative humidity was identified at the windward summit station (2640 m).
- Many of the climate variables showed wet-season trends opposite to their dry season trends. Regarding moisture variables, results were mixed. Decreases in precipitation were observed at all of the leeward stations and one windward station. However, only the trend from the 2120 m leeward station (HN-151) was determined to be statistically significant. Decreases in relative humidity and vapor pressure deficit ere also observed at this station, where are not consistent with the other leeward high elevation sites.
- The significant changes observed at station HN-151 suggest that TWI frequency or base height characteristics have changed over time. This is not surprising considering this station is located very near to the TWI mean base height (2160 m) and, therefore, is the most sensitive to changes in TWI characteristics.
- Temperature trends were negative at most stations for both the dry and wet season, suggesting that the global warming temperature hiatus, which persisted for most of the period of HaleNet data, was captured in the temperature record.

Trade Wind Inversion Characteristics and Variations

- Mean trade wind inversion (TWI) characteristics for the dry and wet season, respectively, are base height: 2200 and 2110 m; frequency: 80 and 76 %; and strength: 0.005 and 0.006 °C m^{-1}.
- TWI frequency of occurrence has increased over the past ~4 decades for both the dry and wet seasons, most notably defined by an abrupt upward (13%) shift in the early 1990s.
- Increases in the vertical velocity of wind variable omega have been identified in four reanalysis datasets and are in agreement with changes in the TWI.

- TWI frequency data are significantly correlated with omega, which suggests that increases in the intensity of Hadley Cell subsidence are driving increases in the TWI frequency of occurrence.
- Correlations between omega, and the ENSO and PDO indices are weak and not statistically significant. In addition, the sign of these relationships is opposite for the dry and wet seasons which suggests that phase changes in Pacific-centered modes of climate variability do not explain the abrupt shift in TWI frequency.
- Rainfall stations that were significantly correlated with TWI frequency data show decreases in rainfall during the TWI post-shift period relative to the pre-shift period. On average, mean rainfall was 16 and 40% lower during this pre-shift period for the dry and wet seasons, respectively, for those stations at which rainfall was significantly correlated with TWI frequency.
- Dry-season rainfall at all of the 21 high elevation stations was significantly correlated with omega and TWI frequency.

Effects of ENSO and PDO on TWI and on Haleakalā Climate since 1991

- The Multivariate ENSO (El Niño-Southern Oscillation) Index (MEI) is significantly correlated with TWI frequency during the dry and wet seasons.
- Mean TWI frequency during the dry (wet) season is 8% (5%) higher during the La Niña (El Niño) phase when compared to the mean during El Niño (La Niña) phase.
- No significant differences were found in mean TWI frequency between neutral phase in comparison with either the El Niño and La Niña phases.
- TWI frequency is significantly correlated with the Pacific Decadal Oscillation (PDO) index during the dry and wet seasons.
- Mean TWI frequency during the dry (wet) season is 7% (3%) higher during the positive (negative) PDO phase when compared to the mean during negative (positive) PDO phase.
- High-elevation observations of solar radiation, rainfall and relative humidity are all significantly correlated with TWI frequency during the dry and wet seasons.
- Mid-elevation observations of rainfall are significantly correlated with TWI frequency during the dry (1/3 sites) and wet (3/3 sites) seasons and mid-elevation observations of solar radiation are significantly correlated with TWI frequency during the wet season (2/2 sites).
- The ENSO and PDO time series show a predominantly negative (cool) pattern over the time period analyzed.
- The predominantly cool ENSO and cool PDO phase conditions may explain a 4% per decade increase in TWI frequency during the dry season and a 2% per decade decrease in TWI frequency during the wet season over the time period analyzed.
- For the dry season, the 4% per decade increase in dry season TWI frequency partially explains the average increase in solar radiation (3% decade^{-1}), and decreases in rainfall (-5% decade^{-1}) and relative humidity (-6% decade^{-1}) identified at high elevations and the decrease in rainfall (-7% decade^{-1}) identified at the leeward mid-elevation site.

- For the wet season, the 2% per decade decrease in TWI frequency partially explains the decreases in solar radiation observed at high (-4% $decade^{-1}$) and mid (-6.4% $decade^{-1}$) elevations and the high elevation increase in relative humidity (5.4% $decade^{-1}$).

F. CONCLUSIONS AND RECOMMENDATIONS:

All the major objectives of the project were accomplished. The HaleNet system was maintained and improved. The data set was improved by correcting and homogenizing data to remove the effects of calibration drifts and sensor changes over the 26-year period of record of the network. The data were made available through an online data access system. Analysis of HaleNet data established the spatial patterns, diurnal and annual cycles, and temporal fluctuations and trends of all measured variables. Analysis was done to identify the proximal causes of the observed variations, with particular attention to the effects of natural sources of variability, e.g., ENSO and PDO, and to differentiate them from the possible effects of anthropogenic climate change. HaleNet data were also used in numerous other studies of ecosystem patterns and changes and of statewide spatial patterns of climatic and hydrological variables. The value of the HaleNet system can be seen in the volume and significance of the research it supports and in the information it provides to resource managers in Hawaiʻi. To give one example, this project has given new insights on the interactions between variations in large-scale climate circulation (Hadley cell) and high elevation climate fluctuations. We found that a major shift in trade wind inversion frequency occurred around the beginning of 1991 as a result of a change in Hadley cell subsidence with major consequences for high elevation climate. While the TWI is responsive to ENSO and PDO, we showed that this shift cannot be explained by these natural sources of variability. This information gives us a better understanding of the nature of the changes in climate observed on Haleakalā in recent decades and provides a basis for anticipating changes in the coming decades. Next steps involve finding a mechanism to provide financial sustainability for HaleNet (and other environmental observation networks in Hawaiʻi) and associated data analysis activities.

G. OUTREACH: Outreach activities are listed below:

Presentations in public meetings and workshops:

Giambelluca, T.W., Elison Timm, O., Diaz, H., Takahashi, M., Frazier, A., and Longman, R. 2014. Climate variability and change in Hawaiʻi. Molokaʻi Climate Change Collaboration Project: Workshop 1, Ka Honua Momona, Kawela, Molokaʻi, Hawaiʻi, September 2014.

Giambelluca, T.W., Elison Timm, O., Takahashi, M., Frazier, A., Diaz, H., Longman, R., and Nullet, M. 2014. Observed and projected changes in Hawaiʻi's climate. Environmental Council Planning Session, Hawaiʻi State Capitol, Honolulu, Hawaiʻi, August 2014.

Giambelluca, T.W. 2014. The 2015-15 El Niño: What to expect in Hawaiʻi. Hawaiʻi Ecosystems Meeting, Hilo, Hawaiʻi, June 2014.

Giambelluca, T.W., Ostertag, R., Litton, C., Fortini, L., Huang, M., Asner, G., and Miyazawa, Y. 2014. Understanding the response of native and non-native forests to climate variability and change to support resource management in Hawaiʻi. Three Mountain Alliance Meeting, Hilo, Hawaiʻi, June 2014.

Giambelluca, T.W. 2014. Climate change and Hawaiʻi's forests. 8th Annual Dryland Forest Symposium, Kailua-Kona, Hawaiʻi, February 2014.

Giambelluca, T.W. 2013. Setting the stage: Climate assessments and trends. Sponsored session: Coping with Decreased Water Supplies: A Cross-Sector Dialogue Regarding Hawaiʻi's Legal and Policy Options to Respond to Climate Change. Hawaiʻi Conservation Conference, Honolulu, July 2013.

Giambelluca, T.W. 2013. Global climate change and Hawaiʻi's water future. Water Resources and Climate Change in Hawaiʻi: An Open Forum, Honolulu, March 2013.

Giambelluca, T.W. 2012. Changing climate and Hawaiʻi's water future. Learning from Traditional Ecological Knowledge to Understand Climate Change Impacts and Preserve Key Cultural and Natural Resources in Kaʻūpūlehu, Hawaiʻi, Kona, Hawaiʻi, November 2012.

Meeting organized to commemorate the 25th anniversary of the HaleNet Climate Network (19 July 2013, East-West Center)

Meeting Agenda:

Introduction, Tom Giambelluca

The importance of climate networks in elevational gradients, Henry Diaz

Developing a climate network for Mauna Kea, and the search for sustainable funding, Fritz Klasner

Effects of recent climate on population trends of Haleakalā Silverswords, Paul Krushelnycky

How HaleNet gave me a new appreciation for rainfall and life itself, Trae Menard

Lunch Break and Poster Viewing

The Bovine Menace and other research considerations, David Penn

Little HaleNet: climate and vegetation at a landscape scale, Sara Hotchkiss

Characterizing the climate of Haleakalā using 25 years of HaleNet observations, Ryan Longman

HaleNet – Past and Present, and the Future of Climate Monitoring in Hawaiʻi, Tom Giambelluca

General Discussion—How to sustain climate monitoring networks

Outreach activities incorporated into UH Mānoa course offering, GEOG 401

UHM students enrolled in course were required to engage a local teacher or teachers in an effort to improve climate science content in the school curricula. Students met with teachers, worked with them to plan a teaching/learning segment, and visited classes to present material and interactive with school students.

Spring 2013: Waikiki Elementary School 5th grade; Kaimuki Middle School 7th and 8th grades; Ka'elepulu Elementary School 4th grade; Mid-Pacific Institute 6th grade.

Spring 2014: Kaimuki Middle School 7th and 8th grades; Waikiki Elementary School 6th grade; Mid-Pacific Institute 6th grade; Ewa Makai Middle School; Kapolei High

School; Farrington High School; Le Jardin Academy; American Renaissance Academy.

Spring 2015: in progress.

H. SCIENCE OUTPUTS:

Peer reviewed publications

Crausbay, S.D., Frazier, A.G., Giambelluca, T.W., Longman, R., and Hotchkiss, S.C. 2014. Moisture status during a strong El Niño explains a tropical montane cloud forest's upper elevation limit. *Oecologia* 175: 273-284, doi: 10.1007/s00442-014-2888-8.

Frazier, A.G. and Giambelluca, T.W. In preparation. Spatial trend analysis of Hawaiian rainfall from 1920-2012.

Frazier, A.G., Giambelluca, T.W., Diaz, H.F., and Needham, H.L. In review. Comparison of geostatistical approaches to spatially interpolate month-year rainfall maps of the Hawaiian Islands. Submitted to *International Journal of Climatology*.

Giambelluca, T.W., Chen, Q., Frazier, A.G., Price, J.P., Chen, Y.-L., Chu, P.-S., Eischeid, J.K., and Delparte, D.M. 2013. Online rainfall atlas of Hawaiʻi. *Bulletin of the American Meteorological Society* 94: 157-160, doi: 10.1175/BAMS-D-11-00228.1.

Gotsch, S.G., Crausbay, S.D., Weintraub, A., Giambelluca, T.W., Longman, R., Asbjornsen, H., Hotchkiss, S.C., and Dawson, T. 2014. Water relations and microclimate around the upper limit of cloud forest in Maui, Hawaiʻi. *Tree Physiology* 34: 766-777, doi: 10.1093/treephys/tpu050.

Krushelnycky, P.D., Loope, L.L., Giambelluca, T.W., Starr, F., Starr, K. Drake, D., Taylor, A., and Robichaux, R.H. 2013. Climate-associated population declines threaten future of an iconic plant. *Global Change Biology* 19: 911-922, doi: 10.1111/gcb.12111.

Longman, R.J., Giambelluca, T.W., and Frazier, A.G. 2012. Modeling clear sky solar radiation across a range of elevations in Hawaiʻi: Comparing the use of input parameters at different temporal resolutions. *Journal of Geophysical Research-Atmospheres* 117, D02201, doi: 10.1029/2011JD016388.

Longman, R.J., Giambelluca, T.W, and Nullet, M.A. 2013. Use of a clear-day solar radiation model to homogenize solar radiation measurements in Hawaiʻi. *Solar Energy* 91: 102-110.

Longman, R.J., Giambelluca, T.W., Alliss, R.J., and Barnes, M. 2014. Temporal solar radiation change at high elevations in Hawaiʻi. *Journal of Geophysical Research-Atmospheres*, 119: 6022-6033, doi: 10.1002/2013JD021322.

Longman, R.J., Diaz, H.F., and Giambelluca, T.W. In review. Sustained increase in lower tropospheric subsidence over the central tropical North Pacific. Submitted to *Journal of Climate*.

Mora, C., Frazier, A.G., Longman, R.J., Dacks, R.S., Walton, M.M., Tong, E.J., Sanchez, J.J., Kaiser, L.R., Stender, Y.O., Anderson, J.M., Ambrosino, C.M., Fernandez-Silva, I., Giuseffi, L.M., and Giambelluca, T.W. 2013. The projected timing of climate departure from recent variability. *Nature* 502: 183-187, doi: 10.1038/nature12540.

Conference and workshop presentations

Giambelluca, T.W., Crausbay, S.D., Hotchkiss, S.C., Gotsch, S.G., Frazier, A.G., and Longman, R.J. 2014. Drought as a determinant of tropical forest line position. Abstract B22A-03 presented at the American Geophysical Union Fall Meeting, San Francisco, December 2014.

Longman, R. Diaz, H., and Giambelluca, T. 2014. Sustained increases in lower tropospheric subsidence over the central tropical North Pacific drives a decline in high elevation precipitation in Hawaiʻi. Abstract GC23B-0626 presented at the American Geophysical Union Fall Meeting, San Francisco, December 2014. Presented by Ryan Longman.

Giambelluca, T.W., Elison Timm, O., Takahashi, M., Frazier, A., Diaz, H., Longman, R., and Nullet, M. 2014. Observed and projected changes in Hawaiʻi's climate. Workshop on Regional Climate Change and Environmental Response in Hawaiʻi, Honolulu, Hawaiʻi, July 2014.

Giambelluca, T.W., Crausbay, S.D., Krushelnycky, P.D., Loope, L.L., Nullet, M.A., Longman, R.J., Hotchkiss, S.C., and Frazier, A.G. 2014. Evidence of climate change and ecosystem response at Hawaiʻi's high-elevation forest-shrubland ecotone. Mountain Observatories Global Fair and Workshop on Long-Term Observing Systems of Mountain Social-Ecological Systems, Reno, Nevada, July 2014.

Giambelluca, T.W., Nullet, M.A., Loope, L.L., and Longman, R.J. 2014. HaleNet: The Haleakalā climate network, Maui, Hawaiʻi. Mountain Observatories Global Fair and Workshop on Long-Term Observing Systems of Mountain Social-Ecological Systems, Reno, Nevada, July 2014.

Giambelluca, T.W. 2014. Climate change—ecosystem change—hydrological change: Tropical forests in the 21st century. Hydrological change in the humid tropics: identification, processes and forecasting, Third International Tropical Hydrology Workshop, Sabah, Borneo, Malaysia, February 2014. (Invited)

Longman, R.J., Giambelluca, T.W., Shuai, X., Barnes, M., Alliss, R.J., Miura, T., Chen, Q., and Nullet, M.A. 2013. Development of high spatial resolution solar radiation maps for Hawaiʻi. Abstract A43B-0240 presented at the American Geophysical Union Fall Meeting, San Francisco, December 2013. Presented by Ryan Longman.

Crausbay, S., Hotchkiss, S., Giambelluca, T., Frazier, A., Diaz, H., and Elison Timm, O. 2013. Little HaleNet: Climate and vegetation at a landscape scale. HaleNet Climate Network 25th Anniversary Meeting, Honolulu, July 2013. Presented by Sara Hotchkiss.

Longman, R.J., Giambelluca, T.W., and Elison Timm, O. 2012. The spatial dynamics of evapotranspiration in Hawaiʻi: How driving variables are influenced by the trade wind inversion. Abstract B23E-505 presented at the American Geophysical Union Fall Meeting, San Francisco, December 2012. Presented by Ryan Longman.

Giambelluca, T.W. 2012. Climate trends on Hawaiʻi's mountains. 14th Pacific Entomology Conference, Honolulu, February 2012. (Invited)

Reports

Giambelluca, T.W., X. Shuai, M.L. Barnes, R.J. Alliss, R.J. Longman, T. Miura, Q. Chen, A.G. Frazier, R.G. Mudd, L. Cuo, and A.D. Businger. 2014. Evapotranspiration of Hawaiʻi. Final report submitted to the U.S. Army Corps of Engineers—Honolulu District, and the Commission on Water Resource Management, State of Hawaiʻi.

Longman, R.J., Giambelluca, T.W., Nullet, M.A., and Loope, L.L. 2015. Climatology of Haleakalā. Draft Technical Report submitted to the Pacific Islands Climate Change Cooperative, March 2015.

PhD dissertation

Longman, R.J. 2015. The effects of trade wind inversion variability on high elevation climates in Hawaiʻi. PhD dissertation, Department of Geography, University of Hawaiʻi at Mānoa.