1. **Award Title**: The Pacific RISA: Supporting Integrated Decision Making Under Climatic Variability and Change in Hawai‘i and the US-Affiliated Pacific Islands
2. **Performance Period**: June 1, 2017 to May 31, 2018
3. Who are your **team members**? Please include graduate students and post-doctoral researchers in this list.

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4. Do you have any **NEW areas of focus or partnership** that have begun this past year? Please provide some context for why you are expanding into this area or partnership. Include any NEW cross-RISA partnerships.

Building Climate and Disaster Resilient Health Systems in the Pacific Islands: The impacts of climate variability and change on human health in the Pacific Islands continue to garner interest from stakeholders across the region. In addition to vector- and water-borne diseases, Pacific Islands populations experience very high rates of non-communicable diseases, including obesity, diabetes, and hypertension. There is a need to build resilient communities and health systems in the Pacific Islands in the context of limited resources, the inherent isolation of islands, and demographic and socioeconomic challenges. Building off of scoping research into climate-health interactions in the Republic of the Marshall Islands in the context of the Pacific Islands Regional Climate Assessment (PIRCA), the East-West Center and the Pacific RISA collaborated with the Aspen Global Change Institute (AGCI) to host a week-long workshop in Honolulu during May 2018 on "Integrating Climate Change Adaptation and Disaster Risk Management to Protect Health in the Pacific Islands" (Figure 1).

Figure 1. *Participants from 11 Pacific Island states and 10 federal and regional institutions met in Honolulu for a week to share information about local climate and health problems and responses. (photo credit: AGCI)*

Despite sharing common goals, efforts to promote climate change adaptation are often conducted independently of efforts to promote disaster risk management and sustainable development. The workshop took a holistic approach to promoting population health and health system resilience in the face of increases in the frequency and intensity of extreme weather and climate events, and the possible consequences of these events. The workshop brought together experts on climate variability and change, population health, social science, epidemiology, disaster risk management, and communication to encourage multidisciplinary exchanges and build institutional coordination and collaboration. Outcomes included the recognized need for creation of a regional climate professional and health department communication link to update managers on regional El Niño Southern Oscillation (ENSO) conditions and impacts; longer-term evaluation of health-adaptation projects with indicators to measure the process and benefits of adaptation; and identifying successful projects in which Pacific Island countries already had started to build out different pieces of climate and disaster resilient health systems. Finally, it was noted that there was existing strength in cross-jurisdictional communication between public health professions, but that within countries there was limited cross-sectoral communication. Cross-sectoral links between health departments and other agencies within a country were identified as key outcomes to building integrated climate resilient health systems. The Pacific RISA is scoping future projects with this group of motivated regional stakeholders.

'Ike Wai: Securing Hawai'i's Water Future: The National Science Foundation recently awarded a $20 million EPSCoR project to the University of Hawaiʻi to address critical gaps in the understanding of Hawaiʻi's fresh water supply. ʻIke Wai (knowledge of water) spans multiple scientific disciplines and connects university researchers to state and federal agencies, as well as community groups. Led by the University of Hawaiʻi Economic Research Organization (UHERO), the research team is using new technology to measure the volume and interconnectivity of several groundwater aquifers throughout the state. New geophysical data will in turn reveal how much water is available to support both human uses and nearshore ecosystems, and consequently, the long term effects of current and projected demands on existing water resources. In collaboration with the US Geological Survey (USGS) and the Pacific RISA, and other groups at the state and local level, this project relies heavily on community engagement for the development of practical decision-making tools. RISA PI Brewington has led the development of future land cover maps for the Pearl Harbor aquifer system on the island of Oʻahu. These maps were created following a similar process that the Pacific RISA used for the Maui Groundwater Project to reflect future land use options under a variety of plausible management scenarios. The Pearl Harbor aquifer region is heavily developed and dedicated to industrial, residential, and agricultural uses, with conservation lands at the higher elevations. The future scenarios reflect both transit-oriented development (dense development around the projected corridor for the Honolulu light rail project) and sprawl-type development (a business-as-usual approach), in combination with varying degrees of agricultural intensification or reduction and native forest protections (Figure 2). Spatially explicit land cover files will be provided to the USGS for use in a water budget model to predict groundwater recharge under the different future conditions. Following completion of the Pearl Harbor scenario runs, the project will then use a similar approach for the Hualalai aquifer sector in the north Kona district of Hawaiʻi Island.

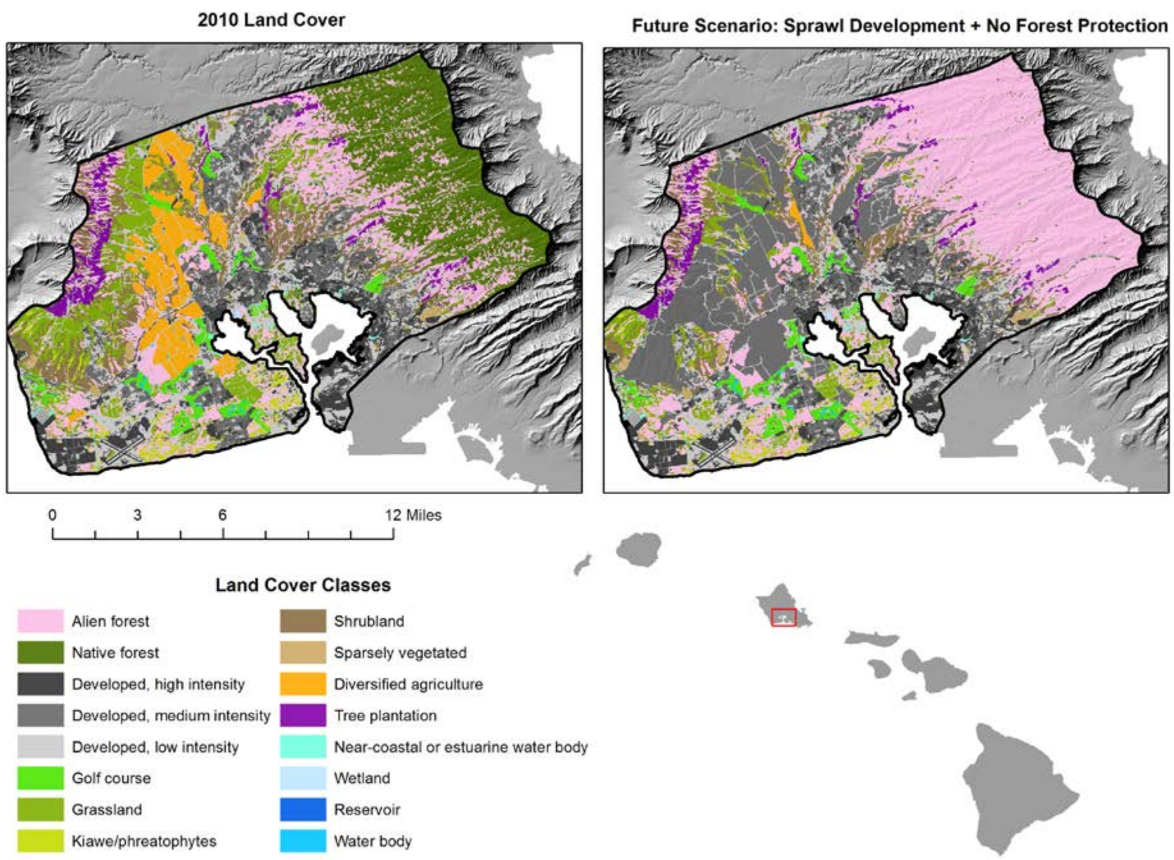

Figure 2. *Current and future land cover scenario maps for the Pearl Harbor aquifer system.*

Pacific Islands Biosecurity and the Pacific Invasives Partnership: In June 2017, the Pacific Invasives Partnership (PIP) invited RISA PI Brewington to represent the East-West Center and the Pacific RISA at the annual meeting, and the East-West Center subsequently joined the PIP as its newest member. The PIP is the umbrella regional coordinating body for agencies working on invasive species (pests, weeds, and diseases introduced from other places) in more than one country of the Pacific and promotes coordinated planning and assistance from regional and international agencies to meet the invasive species management needs of the countries and territories of the Pacific. Islands are exceptionally vulnerable to invasive species, but most small island nations do not have the human or financial resources to tackle invasive species threats adequately alone. National agencies and local NGOs working within Pacific countries on invasive species are isolated from their counterparts in other countries and from international agencies that can provide them with assistance. PIP members include existing Pacific RISA partners in the region, such as the Secretariat of the Pacific Community (SPC), the Secretariat of the Pacific Regional Environment Programme (SPREP), and the University of the South Pacific. In November, PI Brewington facilitated a meeting held at the Guam Department of Agriculture with the Micronesia Regional Invasive Species Council to review the terms of the Regional Biosecurity Plan for Micronesia and Hawaiʻi. Gaps and opportunities for stronger engagement across sectors were identified, in particular with respect to the impacts of climate change on invasive species movements and establishment. The updates to the plan are continuing into 2018 with a revised document to be reviewed at the PIP annual meeting in June.

5. Please tell us which States or territories in your region are using new or tailored climate services (tools, information, technical assistance, or products) as a result of your interaction with decision makers over the past year. Please describe at least one new/tailored climate service per State/territory that you include.

Future Water Supply for DoD Installations on Guam: In this US Department of Defense (DoD) SERDP funded project, the Pacific RISA worked in collaboration with the USGS-Pacific Water Science Center (USGS-PIWSC), the University of Hawaiʻi, and the University of Guam to investigate the impact of projected changes in Guam's climate on surface and groundwater resources, and the potential effects on DoD installations and the civilian Guam Waterworks Authority (GWA) ability to supply the island's population with freshwater. With the current plans to relocate 4,000 Marines from Okinawa to Guam by 2024, the government of Guam and the DoD need to know how population growth and climate change will impact projected water resources. This project consisted of investigating future impacts of RCP8.5 on regional climate, sea level rise, typhoon tracks, groundwater recharge and salinity of wells, and streamflow. RISA PIs Finucane and Keener led the stakeholder outreach and response component throughout the project. In a series of engagements, they examined the effect of alternative information presentation formats (e.g., tabular, graphical, spatial/map-based, range) on decision makers' understanding and use of climate and hydrology information. Final science products for Guam from the projects included:

- Projections of climate impacts for 2080-2099 under RCP8.5 using a downscaled dynamical regional climate model;
- Projections of future typhoon magnitude and occurrence; and,
- Estimates of future sea level, streamflow, reservoir sedimentation, groundwater recharge, and groundwater salinity under future climate projections.

Guam's water resources are projected to diminish relative to current climate conditions. Future average temperature increases and average rainfall decreases will lead to reduced streamflow in southern Guam and reduced groundwater recharge. In the predicted future climate, average temperatures in southern Guam will increase by about 3.2°C and overall rainfall will decrease by about 7%, leading to an 18% decrease in streamflow (Figure 3). Higher sea level and reduced future recharge will decrease water availability from the NGLA. The composite chloride concentration from production wells will increase to 304 mg/L (well above the drinking water standard of 250 mg/L) for future climate conditions and at current withdrawal rates, compared with 126 mg/L under historic climate conditions. Most of this increase is due to reduced recharge as higher sea level only plays a small role in increasing salinity. A redistributed withdrawal scenario in which the composite concentration is 291 mg/L offers only slight improvement. Should future droughts reduce recharge proportionally to the decreases observed during historic droughts, the composite concentration would be about 900 mg/L and more than 70% of Guam's production wells would produce water unsuitable for drinking.

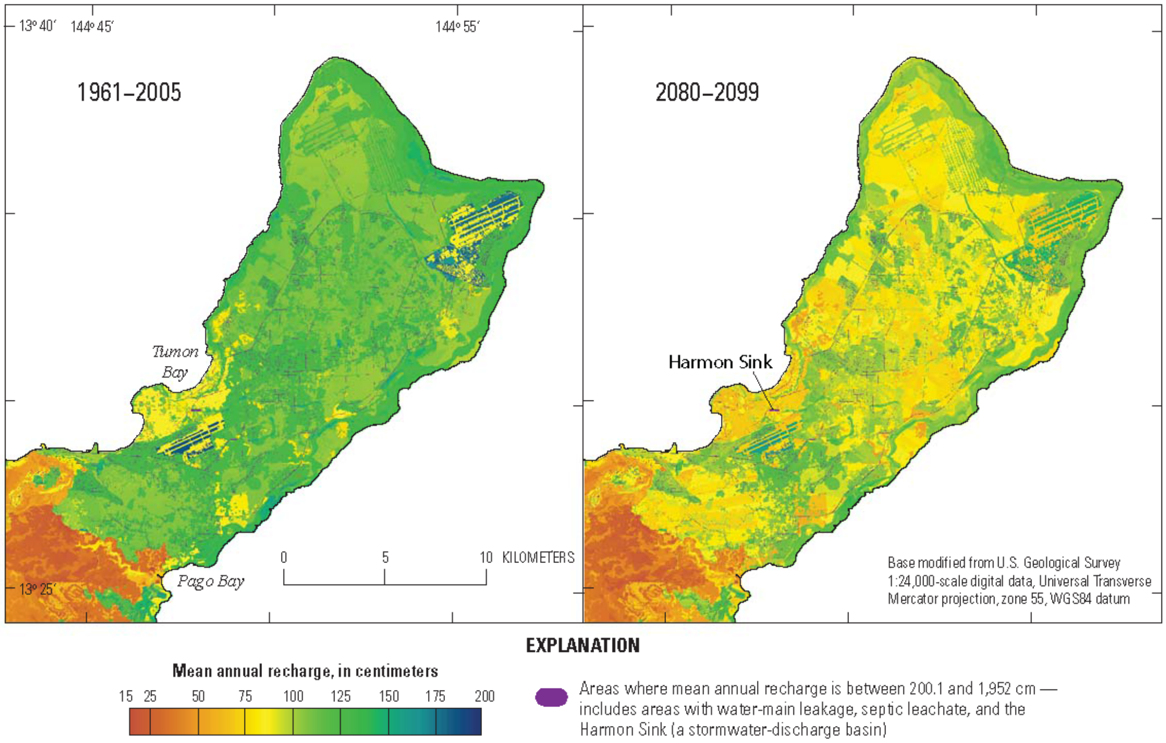

Figure 3. *The distribution of mean annual groundwater recharge estimated for the Northern Guam Lens Aquifer for historic (1961–2005) climate conditions (modified from Johnson, 2012) and future (2080–2099) climate conditions under RCP8.5. From Johnson A. G. 2017 Monthly Water-Budget Components for Guam, 2080–2099, Data Release.*

Through engagement, several key themes emerged: 1) decision makers value engagement with scientists; 2) decision makers identified diverse climate-sensitive decisions that could be supported with information about future climate conditions; 3) existing resources varied in familiarity and perceived usefulness to decision makers; 4) climate information seemed harder to understand than water information; 5) preferred information formats depend on the intended use and potential audiences; 6) several suggestions were made about how to improve climate and water information for fresh water managers; 7) information users need training, collaboration, and technical information; and 8) the new research results were perceived as interesting and useful for decision makers. Upon request from stakeholders, several products were created in addition to the many technical reports and peer-reviewed manuscripts, that clearly and concisely summarize the project's background, simplified main findings, and were written in a manager-oriented style. Products included 1) an information sheet summarizing Guam's historic hydrological and climatological trends with respect to temperature, precipitation, ENSO impacts, sea level, and typhoons; 2) a briefing sheet for managers outlining the watersheds and water systems of Guam, and how climate information is relevant to their future planning, and; 3) an executive summary of key findings from the study summarizing future climate impacts and management options and scenarios. These products were distributed in hard copy to all stakeholders and university partners, and are available electronically on the Pacific RISA website.

Future Land Cover Maps for Maui: Version 1 of the future land cover scenario maps for the island of Maui, associated with the Maui Groundwater Project, was completed in early 2015 and the maps have been used extensively as educational tools, modifiable GIS layers for research projects, and outreach materials for those interested in visualizing the potential impacts of future land management decisions. Their utility and broad usage has continued to increase Pacific RISA visibility in Hawaiʻi and led to a new collaboration between the NSF-funded **ʻ**Ike Wai project, hosted at the University of Hawaiʻi, and the Pacific RISA (see ***New Areas of Focus***, above). In late 2015, however, a major stakeholder, Hawaiʻi Commercial & Sugar (HC&S), announced that they would no longer be cultivating sugarcane in a large (33,000 acre) area of Maui's central isthmus. This decision has had dramatic implications for water use and groundwater recharge in the island, particularly East Maui where numerous streamflow diversions exist to supply sugarcane operations with water for irrigation. As a result of the decision, in 2017 the USGS-PIWSC and the Pacific RISA decided to modify the initial maps to reflect the cessation of sugarcane and produced Version 1-1, which contains updated land cover categories for Maui's central agricultural zone as well as additional classifications of forest to indicate whether the type of forest is in the fog drip zone (above 2,000 feet elevation) or not. The updated maps were published in early 2018 and have been well received by stakeholders who were concerned about the continued presence of sugarcane in the previous version. The USGS-PIWSC continues their process of running the water budget model for the entire island based on current and future land use conditions and future climate. Results from the Maui Groundwater Project are anticipated in September 2018.

6. A. How are you measuring the overall program-level impact of your RISA team? Please provide information on your evaluation model, including metrics or indicators that you use to evaluate your program.

In November 2017, independent Pacific RISA evaluator Dr. Susi Moser conducted a two-part workshop with PIs and collaborators to improve evaluation efforts and tracking metrics for the program. The goal of the workshop was to generate metrics of progress and impact for internal purposes and for NOAA reporting by improving the tracking process and engaging the entire team to ensure they measure what is needed, identify new metrics, and eliminate metrics they are currently capturing that may be unnecessary. PIs reviewed the Action-Logic Model, which was developed during Pacific RISA Phase II and is being updated to a theory of impact built on the stakeholder responses from previous evaluation efforts about the four types of activities and functions a RISA team represents:

1. Responding (identify goals, resources, meet stakeholder needs, provide training);
2. Supporting (engage dialog, education and training, connecting stakeholder groups);
3. Generating (new policy options, new implementation strategies, data/models/analysis, synthesizing documents, producing papers reports or videos); and
4. Being critical (provide commentary, evaluate implementation and outcomes).

The processes of evaluation and establishing meaningful metrics enable the Pacific RISA to improve as a team as they interface between science and policy. All PIs participated in an exercise to walk through research and outreach activities and identify their function, relevant outputs, and desired outcomes, while identifying what is needed to achieve such outputs (both internal and external factors), and finally think of how to measure and track indicators of success. The workshop enabled the Pacific RISA to cross-walk each section of the annual tracking sheet to determine which metrics are relevant and meaningful, and which ones may not be needed. Ultimately, the relationships that the Pacific RISA has in the region and the different strengths, services, and products they provide for different stakeholders can help construct a narrative about the program's broader impact and outcomes, and how various partner organizations play substantial supporting roles in achieving those goals.

B. Please describe your overall program-level impact including (if applicable) a summary of the results from your evaluation efforts.

Dr. Moser's final evaluation report for the Pacific RISA year three is still pending a summary of the workshop efforts described above. However, through internal tracking sheets, Dr. Moser has concluded that since 2010, the Pacific RISA has firmly established mechanisms for internal and external tracking and evaluation of its work. Dr. Moser found that the Pacific RISA is a boundary organization of remarkable stability and productivity and is also a well-managed program, navigating staff and efforts through staff turnover as well as funding delays and declines – accomplishing much with remarkably little. In its core mainstay projects the Pacific RISA program is well integrated, as is apparent from the mutual dependency of the work being done, the complementarity of the themes, and the evolution of projects over time, as well as through the overlap of staff/team members in various projects. While research clearly dominates the Pacific RISA's work, as evident from a number of indicators, almost all projects involve the wide range of stakeholders they are designed to serve. This deep engagement with stakeholders has contributed most to ensuring that the Pacific RISA is seen as the trusted go-to information source in the region. Despite the heavy emphasis on science, typical scientific outputs – peer-reviewed publications – are not the dominant output. Instead, products for, and encounters with, stakeholders are by far the most prominent outputs of the organization. As such, the Pacific RISA has emerged as a model transdisciplinary program in the region.

7. How have you helped to build the expertise and ability of local/regional decision-makers to prepare and adapt to climate variability and change?

Impacts of Future Climate on Honolulu BWS Planning and Infrastructure: The Honolulu Board of Water Supply (BWS) on the island of Oʻahu has one of the largest municipal water systems in the United States, delivering 145 MGD to about one million people. In 2015, the BWS partnered with the Pacific RISA, the University of Hawaiʻi, and Brown & Caldwell consultants to assess projected climate change impacts on their infrastructure and identify vulnerabilities at short (2020-30), mid (2030-50), and long term (2050-2100) time frames. Building off of work on Maui for the Maui Groundwater Project, a scenario planning approach was used that would consider a range of plausible future climate and socioeconomic conditions. The future climate projections included local sea level rise projections as well as statistical and dynamically downscaled end-of-century precipitation and temperature scenarios for both RCP 4.5 and 8.5 from Pacific RISA research, and were applied at both an island-wide and watershed management unit scale (Figure 4). The goal of the project was to develop a suite of "no-regrets" strategies and policy guidance to address the anticipated changes.

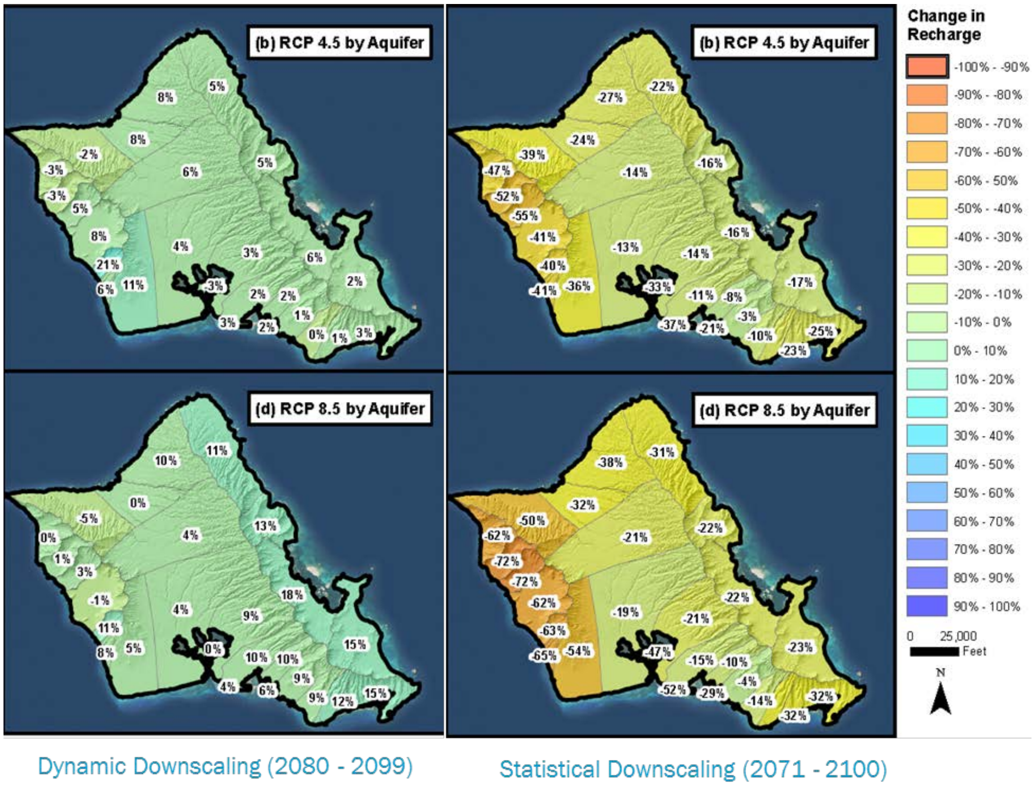

Figure 4. *Using a regression modeling approach with two RCP scenarios and both dynamical and statistical climate projections, aquifer level recharge was calculated for the island of O'ahu. Statistical results continue to show the current drying trend across Hawai'i, while dynamical results project future changes in a warmer and wetter atmosphere using the pseudo-global warming method. (figure credit: Honolulu Board of Water Supply, 2018)*

While statistical downscaling results for 2100 show an overall dryer future with rainfall decreases as much as -70% in leeward areas, dynamical downscaling shows a range of drying trends in leeward O'ahu and increased rainfall in windward areas and parts of Honolulu. Working with researchers, the BWS considered both future scenarios in estimating projected changes in recharge as equally likely, and used the ranges to identify potentially vulnerable areas with respect to future development, water supply, and infrastructure. Using regression models, the BWS identified the ranges in future recharge as -0.3 to +21.5% (dynamical) and -4 to -72% (statistical). Mapping these results against currently designated sustainable yields, they also identified watersheds with potentially vulnerable future supplies, and have started to outline preliminary mid and long term place-based adaptation strategies including:

- Aggressive water conservation;
- Storm water capture in Nu'uanu and on-site in new developments;
- Expanded Reuse at Honouliuli, Mililani, Wahiawa and Schofield Treatment Plants;
- On-site reuse;
- Increased transfers from wetter areas to Waianae and Honolulu;
- Assertion of domestic use water rights over agriculture;
- Desalination in Ewa and possibly Honolulu; and
- Desalinated reuse in Honolulu, Waianae and Hawai'i Kai where wastewater effluent is too salty for irrigation.

The Pacific RISA will continue to work with the BWS to develop a collaboration framework across city and state agencies to share climate adaptation data and strategies.

8. What is the accomplishment from this past year of which your team is most proud? Why?

Causes and Impacts of Climate-Induced Migration in the US-Affiliated Pacific Islands: This multidisciplinary project led by RISA PI Burkett investigates the relationships between climate change, ecosystem services impacts, and Marshallese migration within and from the Republic of the Marshall Islands. As one of the lowest-lying island nation-states in the world, the Marshall Islands is acutely vulnerable to sea level rise, flooding, and the associated intrusion of saltwater into crucial freshwater supplies. Persistent drought is further affecting agricultural production and access to drinking water. Many Marshallese communities are already experiencing these changes. Within the Marshall Islands there are substantial migration flows between islands and particularly from outer islands to the capital Majuro. In addition, many are migrating to other countries, particularly the United States. The number of Marshallese residing in the US has rapidly risen over the past two decades, from 7,000 in the year 2000 to 22,000 in 2010. While it is known that climate change is already affecting the Marshall Islands and that there are significant migration flows, it is not known to what extent Marshallese people are already migrating because of climate change and its impact on ecosystem services. The last year of this project has explored the multi-causal nature of Marshallese migration and its effects on migrants themselves and communities in source and destination areas. In-depth fieldwork in sending (Marshall Islands) and receiving (Hawaiʻi and the Pacific Northwest) communities, GIS data acquisition and analysis, and literature reviews comprised the research activities for this reporting period.

Fieldwork in the Marshall Islands involved interviews and surveys that were conducted in March-April 2017. The team surveyed a total of 201 households in the following three sites: 101 households in Majuro, 50 households in Maloelap Atoll, and 50 households on Mejit Island. The two outer islands from the southern part of the Marshall Islands were selected because they represent an important difference between a very low-lying atoll (Maloelap), which is highly exposed to sea level rise, and an island (Mejit) that is slightly less exposed because it is not as low. Additionally, in the more northern islands, migration patterns have been significantly influenced by nuclear testing, radiation, and compensation payments. Therefore, such sites were deemed less suitable for studying the impacts of climate change on human mobility. Fieldwork in Hawaiʻi and Portland, OR consisted of interviews and surveys with an additional 80 migrant households. Only the islands of Oʻahu and Hawaiʻi were surveyed within the state, as these communities are where census data indicates that most Marshallese migrants reside. All interviews and surveys mainly consisted of closed questions generating quantitative information, but with a few open questions that generated qualitative information. Some preliminary results are shown in Figure 5. Information was collected on the following:

- Basic socio-demographic data: Households composition, gender, age, education level, marital status, occupation, land ownership, income, etc.;
- Housing: the quality and risk-proneness of respondents' house and access to amenities such as drinking water, sanitation, and electricity;
- Impacts of environmental stressors: focus on what kind of environmental stressors affect households in the study sites, trends therein, and how respondents were affected;
- Perceived importance, state, and trends in ecosystem services;
- Respondents' own migration history, including reasons to stay put and perception on how migration changed their lives;
- Migration of relatives, remittances, use of remittances, and perceptions of impacts of relatives' migration;
- Migration intentions (future); and
- Policy interventions: what have the government and NGOs done to protect people against impacts of climate change; what should they do?

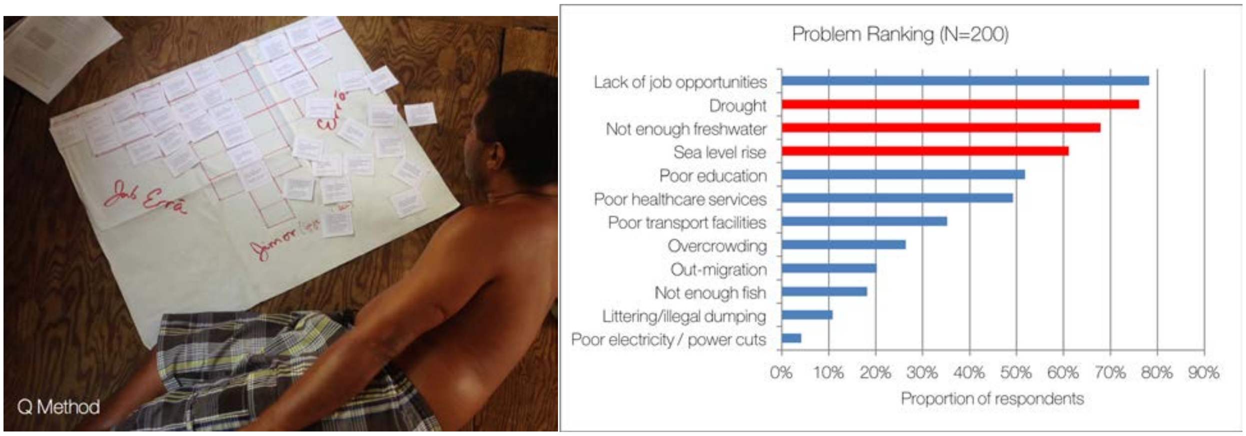

Figure 5. *(Left) Researchers used the Q Method in the RMI, a semi-qualitative, semi qualitative approach to discern the existing patterns of 'decision-making styles' regarding migration. (Right) Initial results of a problem ranking exercise with a sample of 200 households in RMI included 3 climate-related stressors (red bars), which proved to be very important to respondents, ranking 2nd (drought), 3rd (not enough freshwater) and 4th (sea level rise).*

Through project partner Mark Stege of the Marshall Islands Conservation Society the team had access to locally available spatial data that were gathered as part of the Reimaanlok process:

- Elevation and flood risk data for Majuro Atoll;
- 1979, 2006, and 2014 flood event data for Majuro Atoll;
- 2015 flood event data for Mejit;
- 2013 and 2016 groundwater salinity data for Mejit and Maloelap;
- 1880s-2006 historic storm frequency data for Majuro, Mejit, and Maloelap; and
- Food tree and vegetation data for Mejit.

GPS locations of respondent households were collected during fieldwork in the Marshall Islands, which will be used to link the above spatial data representing levels of vulnerability to environmental change and climate impacts to household responses. Thematic maps are being produced that depict the links between climatic stressors, ecosystems services, and migration patterns.

As preliminary products and research results become available, numerous presentations, briefings, and webinars have been conducted based on this work. PI Burkett has met with Marshall Islands President Hilda Heine and Foreign Minister John Silk in Honolulu, as well as with David Anitok, the Lead Community Developer for the COFA Alliance National Network (CANN), in Portland, OR. A workshop entitled "The Marshall Islands Migration Project: Climate Change Forum" was held at the Marshallese Consulate General in Honolulu in October 2017, and two upcoming workshops are planned for Honolulu and Majuro. Fact sheets that synthesize the findings and case study reports are in preparation along with a summary of ecosystem services impacts in the Marshall Islands. Social science data that has been collected analyzed will be core inputs for exploring the legal and policy implications of a possible uptick in Marshallese migration to the use due to worsening climate change impacts and degradation of ecosystems. The goal of the next year of work is to identify decision-makers' needs for information about climate change-related thresholds and tipping points for migration in the Marshall Islands and propose a framework to manage migration effectively under circumstances of uncertainty.

9. Please provide a list of up to 5 **research findings** – Please try to include examples that span disciplinary and interdisciplinary work. Examples might be: a) dust-on-snow reduces Colorado River runoff by 5%, or b) analysis revealing the presence or absence of adaptive capacity in legal and policy frameworks for managing resources. **Please include a brief description of the**

rationale for the research, including stakeholders engaged, the relevance/importance of the research, and, if applicable, any notable impacts of the research on decision making.

Assessing Sustainability of Ground Water Resources Under Future Climate Conditions: During the reporting period, RISA PI El-Kadi and post-doctoral researcher Leta used the previously developed, calibrated, and validated SWAT model of the Nuʻuanu area watersheds to assess the impact of climate change on streamflow duration curves (FDC) and hydrological extreme values (peak and low flows) of the Kalihi and Nuʻuanu watersheds, which are located on the leeward side of Oʻahu. The team also used the statistically downscaled future rainfall anomalies data over the Hawaiian Islands reported for two periods: 2041-2070 and 2071-2100, including temperature and solar radiation changes based on previous studies in Hawaiʻi (Figure 6). The future rainfall anomalies data were projected based on the IPCC Fifth Assessment Report RCPs 4.5 and 8.5.

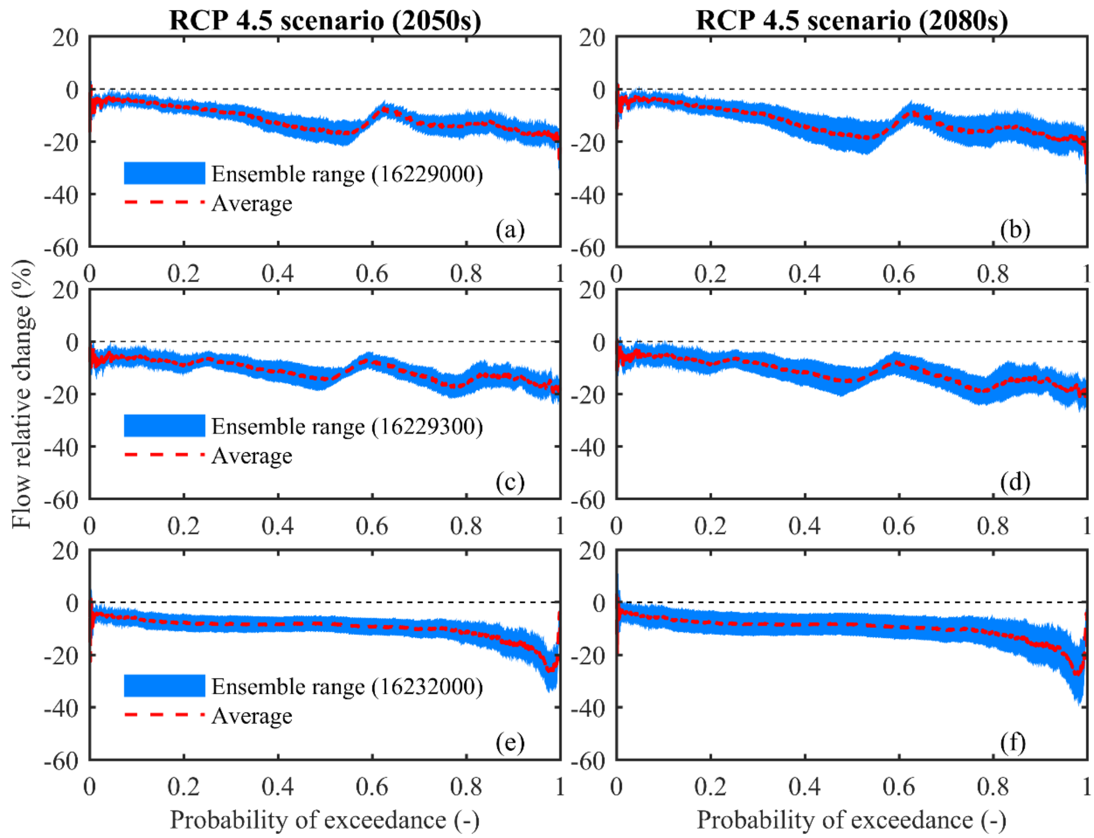

Figure 6. *Ensemble range and average relative changes in flow duration curves compared to baseline for Kalihi (a-d) and Nuʻuanu (e-f) watersheds by 2050s (left) and 2080s (right) for RCP 4.5 scenario.*

Similarly, previously developed SWAT model of the Faga'alu watershed (Tutuila, American Sāmoa) was leveraged to assess the impacts of Best Management Practices (BMPs) on sediment yield reduction from the heavily human impacted Faga'alu watershed. For the implementation of retention pond and corresponding required data, the team collaborated with researchers and faculty from San Diego State University (SDSU). Additionally, hydro-meteorological data collected by the University of Hawaiʻi Water Resources Research Center (WRRC) were also used to extend the existing SWAT model of Faga'alu. The model was also used for nitrogen budget modeling of the Faga'alu watershed.

For climate variability impacts assessment, the team analyzed the correlation between rainfall, maximum and minimum temperature anomalies, and multivariate ENSO index (MEI). They used the daily time series rainfall and temperature data of NOAA measured at Pago Pago airport in American Sāmoa and bi-monthly MEI data from NOAA for region 3.4. On the basis of ENSO events classified as El-Niño, Neutral, and La Niña years, they estimated the correlation between climate variables and the MEI data of the three classified ENSO years. They found that the coefficients of determinations (R^2) between observed rainfall and temperature anomalies and MEI data of the three ENSO years were less than 0.3, indicating a weak correlation between the climate variables and ENSO events. In addition, further analysis on drought occurrence that was based on the standardized precipitation index (SPI) method and long-term historical rainfall data (1960-2014) indicated that American Sāmoa will likely face more flooding, in contrast to droughts. Due to weak correlations between aforementioned climate variables and ENSO events as well as less likely occurrence of more droughts, the team will focus on flood modeling and assessing its impacts on the low-lying coastal communities of American Sāmoa. This is ongoing work whereby they have currently built a hydraulic model that uses the Hydrologic Engineering Center (HEC) River Analysis System (HEC-RAS) model coupled with HEC Hydrologic Modeling System (HEC-HMS) for the lower part of Faga'alu watershed. Such works will also be extended for the Maloata watershed, which is classified as a pristine watershed by the USDA Natural Resources Conservation Service (USDA-NRCS) watershed boundaries dataset. The approach of considering the two contrasting watersheds will allow the team to fully assess and compare the possible impacts of flooding in the low-lying areas of pristine and heavily impacted watersheds. They will use historical, NOAA 50 years, and 100 years storm events and corresponding composite hydrographs data for flood modeling and inundation mapping. The hydraulic model of Faga'alu is currently being calibrated to historical storm hydrographs.

Analysis of Water Supply and Contamination Issues on Tutuila Island: Wells designated as groundwater under the direct influence of surface water (GUDI) have caused an ongoing boil-water-advisory afflicting the island of Tutuila, American Sāmoa for almost a decade. Regulatory testing at these wells found turbidity and indicator bacteria spikes correlated with heavy rainfall events. However, the mechanism of this contamination has remained unknown. Surface water may reach wells through improperly sealed well casings, or through the aquifer matrix itself. In this project led by RISA-funded graduate assistant Schuler, three independent surface-water tracers, turbidity, indicator bacteria, and water isotopes were used to assess recharge timing and determine contamination mechanisms. Results from each method were fairly consistent, revealing average GUDI well breakthrough times of 37 ± 21 hours for turbidity, 18 to 63 hours for bacteria, and 1 to 5 days for water isotopes (Figure 7). These times match well with estimated subsurface flow rates through highly-permeable aquifer materials. In contrast, where one casing was found to be compromised, turbidity breakthrough was observed at 3 to 4 hours. These results inform local groundwater management decisions, since repairing or replacing wells will likely result in continued GUDI contamination. Additionally, differences in observed rainfall response for each tracer provides insight into the recharge dynamics and subsurface flow characteristics of this and other highly-conductive young-basaltic aquifers. Based on recommendations from the team, the American Sāmoa Power Authority has initiated installation of water filtration infrastructure to resolve the boil water advisory.

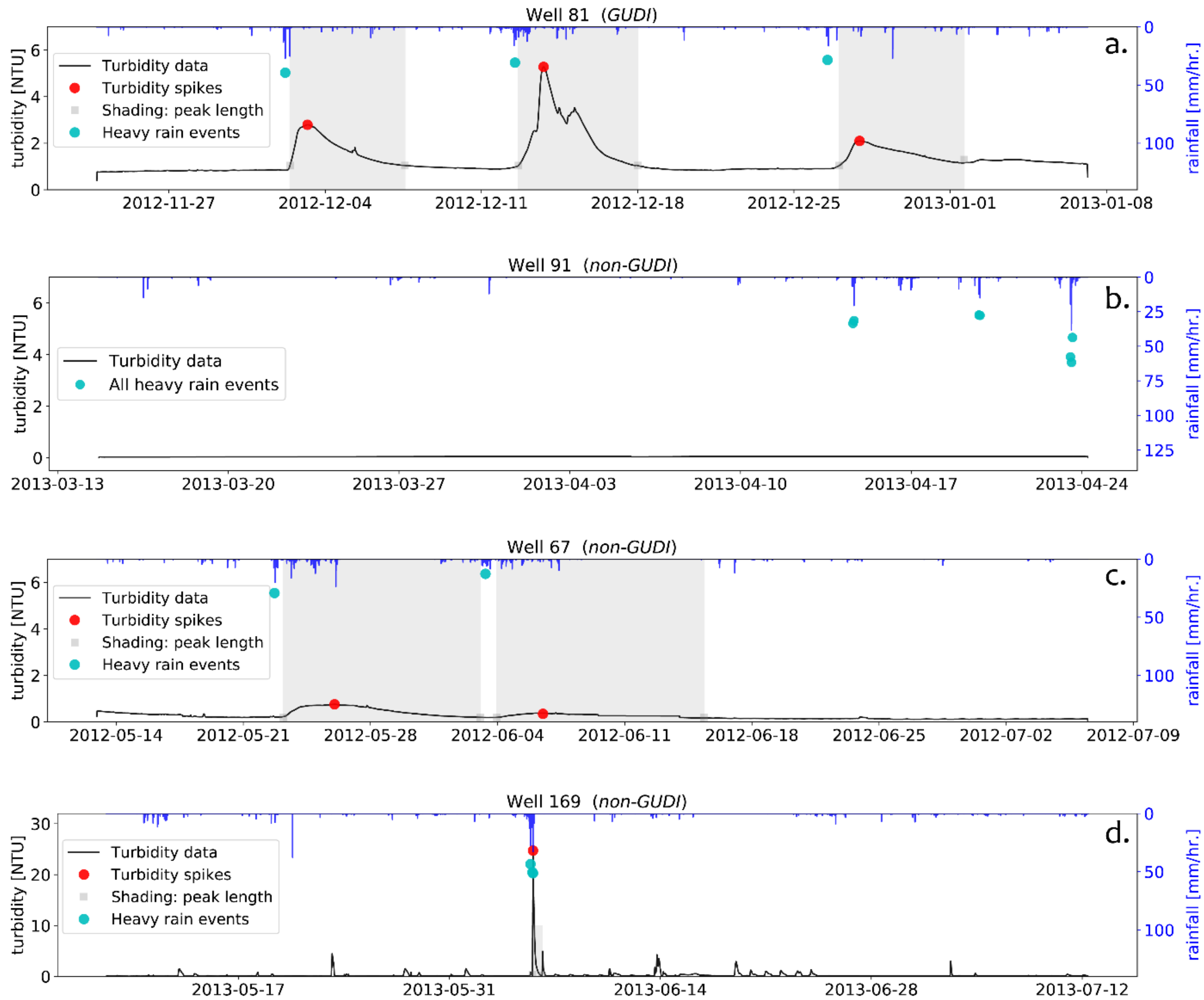

Figure 7. *Selected time-series profiles showing processed turbidity data (black lines) and rainfall (blue bars) from the initial ASPA GUDI well tests. Turbidity peaks (red dots) that correlate with preceding heavy-rainfall events (blue dots) are shown, and grey shaded fields represent durations of turbidity peaks. (a) Data from Well 81 shows the archetypical rainfall – turbidity peak response generally observed at all wells in the Tafuna wellfield. (b) Well 91 exemplifies the lack of response typical in most non-GUDI wells. (c) Well 67, despite being classified as non-GUDI, shows a rainfall – turbidity response similar to Tafuna GUDI wells, albeit quite subdued in magnitude and duration. (d) Well 169 is unique amongst all wells studied, as it is designated non-GUDI, but shows a dramatic response due to a hole in the casing (observed during a video log).*

Evaluating Similarities and Differences Between Statistical and Dynamical Downscaling Projections: The main objective of the team led by RISA PI Giambelluca was to improve statistical downscaling products for Hawai‘i. Two specific research tasks were addressed: 1) testing the skill and biases of a statistical downscaling model that uses as a target variable the logarithm of precipitation amounts instead of precipitation anomalies; and 2) exploring how much predictive skill the inclusion of new climate variables can contribute to the regression model. The linear regression model that was used in the past for estimating local rainfall anomalies had one major drawback. As the climate change pattern increases in amplitude, the linear regression model can produce physically unrealistic rainfall anomalies, in particular for negative rainfall anomalies. Since seasonal precipitation is always a numerical value greater than zero (with rare exceptions it is zero) a natural choice is to apply the logarithm-function to transform the seasonal precipitation data for the Hawaiian Islands. This new target variable is then used to build a multiple linear regression model that predicts the transformed rainfall value. The regression model was tested for the islands of Maui Nui (Maui, Lānaʻi, and Molokaʻi). In the first phase, the calibration regression parameters were compared with results obtained with the original linear regression model. It was found that the correlation coefficients have similar distributions when comparing results for all stations on the islands. Also, the spatial patterns of the associated regression coefficients were very similar. For example, mapping the stations' regression parameters (note, the same four leading modes of regional climate variability were used for each station) shows the same spatial pattern in the two downscaling models.

In the next step, a more rigorous cross-validation of the log-regression model was applied. The data set was split into calibration and validation samples by randomly selecting half of the years for calibration and reserving the others for comparison between downscaled and observed rainfall values. The same method had been applied previously for the linear model. In general, cross-validation highlighted that the logarithm-based downscaling model (log-model, hereafter) has significant skill. The correlation between observed and predicted log-precipitation was similar to that of the linear model validation results. The correlation values were significant for most stations but varied spatially. For example, lower values were found at dry locations. Giambelluca and others concluded that the log-transformed precipitation can be applied and the model achieves similar skills as the linear regression model. The advantage gained is that the log-regression model will give physically more reasonable precipitation estimates for regions where, previously, the linear model projected unrealistically dry future scenarios (e.g., for RCP 8.5 end of 21st century over leeward areas of Maui).

The team also tested how much the downscaled precipitation scenarios depend on the choice of the large-scale climate variables that were used as predictors in the regression model. They downloaded additional reanalysis data sets and prepared the data for statistical downscaling. First they studied total precipitable water content, specific humidity at levels below the trade wind inversion (925 hPa level), and vertical motions in the free atmosphere above the trade wind inversion (500 hPa level). Three rainfall stations were selected (Līhuʻe, Kauaʻi; Honolulu, Oʻahu; Hilo, Hawaiʻi) and for each station the eight wettest and driest years from the period 1979-2012 were compared. Anomalies showed substantial differences between wet and dry years (Figure 8). For all three stations, the climatologically dominant descending motions of the air masses were reduced (enhanced) over Hawaiʻi during wet (dry) years. Total moisture content over the Hawaiian Islands was larger (smaller) than normal in the Hawaiian Island sector during wet (dry) years. The moisture content in the lower atmosphere had a consistent pattern. The amplitude of pattern anomalies over the North Pacific suggested that these climate variables contain important information for the rainfall downscaling. Moreover, the comparison of the pattern showed that Hilo is more influenced by climate anomalies in the tropical Pacific whereas Līhuʻe and Honolulu showed more the influence of extratropical climate on the rainfall. The spatial differences found in the large-scale climate pattern – when compared between composites maps from those three stations - indicated that these climate variables can provide additional information for resolving local details in rainfall projections. The team is currently testing the downscaling skill for all stations (on Maui Nui first, then all islands) using partial regression techniques to find the best combination of extended predictor variables (the old and new variables pooled together).

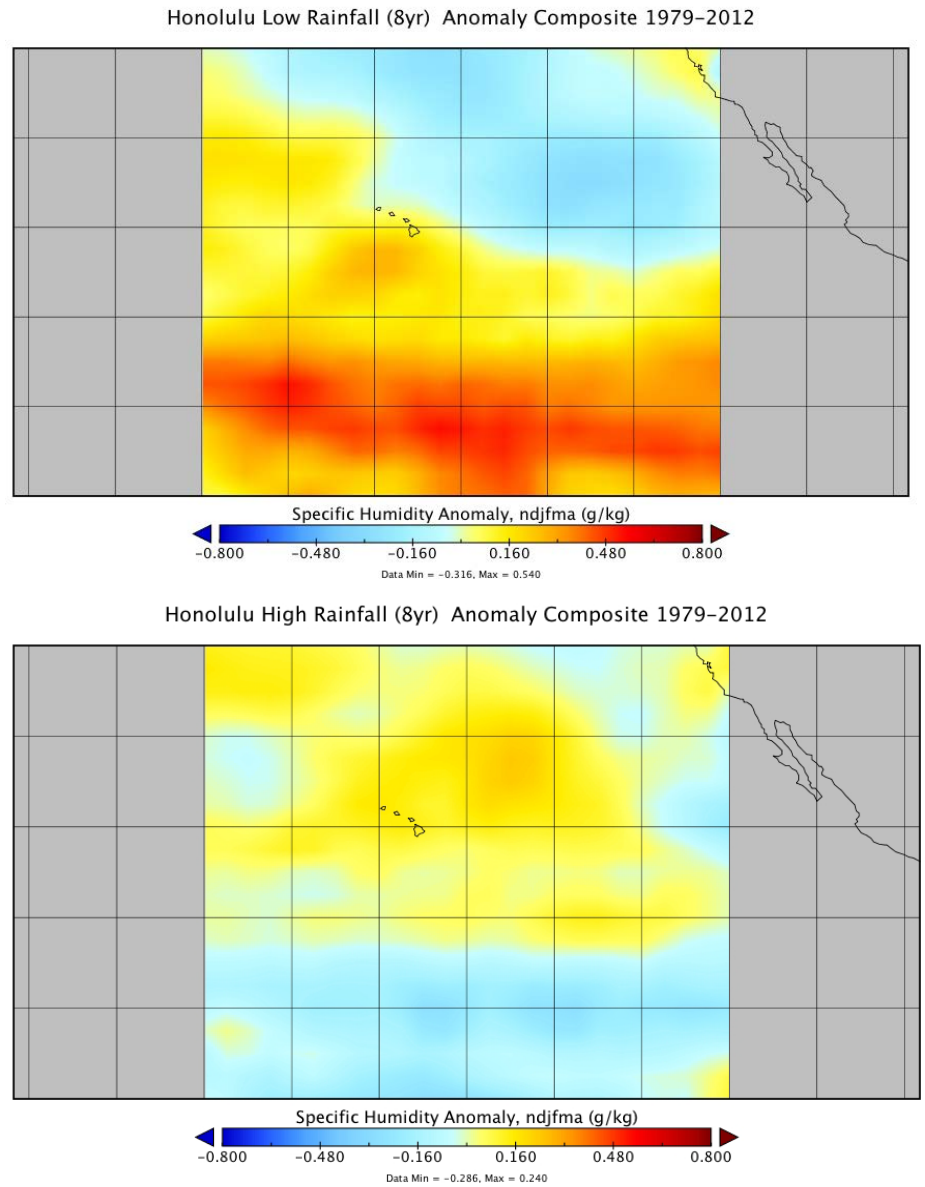

Figure 8. Maps of lower atmospheric (925 hPa level) specific humidity anomaly for the eight driest (upper panel) and wettest (lower panel) years during 1979-2012 at Honolulu, Hawai‘i.

Using Ecosystem Service Valuation to Assess Trade-offs and Opportunities from Climate Change: The ecosystem services project team led by RISA PI Oleson has developed a travel cost model to value the economic benefits that outdoor recreation provides to Maui residents. The model was based on discrete choice specification and it is estimated on data collected in 2017 via a web survey of more than 350 Maui island residents. The survey collected data on their interactions with the natural environment to evaluate the economic benefits of outdoor recreation on Maui. The team recorded all outdoor locations (beaches, city parks, open spaces etc.) visited by each respondent in the month prior to the survey and the number of times that each location was visited. They also collected data on socio-demographic characteristics, including the location of the residence. The model will be used to calculate the economic impact of brown water and/or coral bleaching events that often affect Maui’s beaches. The team is also currently developing a hydrological model that links daily rainfall to sediment and nutrient outputs for the entire island of Maui. This hydrological model is a specification of the Soil and Water Assessment Tool (SWAT) model: a river basin, hydrological response unit (HRU)-scale approach to quantify impact of land management practices in watersheds. It provides water quantity, as well as nutrient and sediment loads, at every outlet point on the island. This model will be able to project how sediment loads will change with the climate and land use change expected in the future. The team is currently liaising with Hawaiʻi State Division of Aquatic Resources (DAR) and The Nature Conservancy (TNC) to include the modelling work developed in this project as part of the "Hawaiʻi 30x30" implementation guidelines. This major policy initiative aims at achieving effective management of 30% of Hawaiian coastline by 2030. PI Oleson and post-doctoral fellow Fezzi have participated in several meetings at TNC and DAR and are involved in the drafting of the 30x30 guidelines.

High-Resolution Regional Atmospheric Model for the Hawaiian Islands: RISA PI Annamalai and team downloaded six hourly 3-dimensional CFSv2 forecasts initialized in September and in November for the 2015-17 ENSO (both El Niño and La Niña). Data from 10 ensemble members were transferred from NOAA and saved locally. This data set was then used to force the High-Resolution Regional Atmospheric Model (HiRAM) for assessing regional distribution of precipitation over the Hawaiian Islands. HiRAM is being used to generate "experimental" seasonal forecasts with a focus on the recent ENSO event (2015-17). The goal is to downscale the NOAA operational forecasts based on CFSv2, and validate the HiRAM results with station-level observations. Results for the 2015-16 El Niño winter and following spring seasons are encouraging and detailed physics based diagnostics are being performed to account for the improvement in the precipitation prediction at various horizontal resolutions in HiRAM. One key finding was the clear improvement in the prediction of seasonal-mean precipitation when the horizontal resolution was reduced from 15 to 3 km. HiRAM solutions will be available for use in other studies (e.g., assessing seasonal changes to ground water, agriculture, landslides, etc.).

The Hawaiian Islands also experienced unusually heavy precipitation events during April 2018. According to the National Weather Service office in Honolulu, the most significant events both in terms of hydrologic magnitude and impacts to the public occurred in mid-April 2018. The Hawaiʻi Emergency Management Agency reported that 532 homes were affected by flooding on Kauaʻi and Oʻahu, and damage estimates were close to $20 million just for public properties. The team will employ HiRAM to assess the model's skill in predicting the heavy rainfall events of April 2018.

10. Please provide a list of up to 5 **outreach or communication activities** that you have undertaken in the past year. OPTIONAL: If applicable, please share the outcomes of these activities. We are particularly interested in measurable or observed changes in areas such as management practices, planning, policy, and behavior.

Climate Resilience Toolkit: The Climate Resilience Toolkit is a national website established under the Obama White House and headed by NOAA. The purpose of the Toolkit is to help stakeholders in different regions and sectors in the United States find climate information that is helpful for their adaptation and planning. The Hawaiʻi and Pacific Islands region is now one of three regions featured on the site. Included in the content are five case studies adapted for the site by the Pacific RISA and NOAA collaborators, as well as two new ones, including "Collaborating for Success: Sustaining Water Supply on a Pacific Island." This case study examined the partnership between the American Sāmoa Power Authority (ASPA) and the University of Hawaiʻi WRRC. The partnership has helped ASPA implement an integrated approach to quantifying ground and surface water resources on the island of Tutuila. Pacific RISA Sustained Assessment Specialist Grecni supervised the interviews and drafting of all case studies, which have been published on the PIRCA website and the US Climate Resilience Toolkit.

Communicating Climate Change and Risk: One of the great challenges facing climate research and communication today is how to effectively communicate the local and regional risks posed by global change. In March 2018, RISA PI Finucane led a workshop on Communicating Climate Change and Risk for climate professionals in Hawaiʻi. The theme of the workshop was how to foster hope and success in situations that seem hopeless, and drawing on the concept of "cultural rich points" from the health literature, Finucane encouraged members of the climate change community to practice the following:

- Face to face engagement, relationships, and participation in research;
- Use a broad range of approaches (academic, experimental, visual, the arts, education);
- Focus on community strengths rather than weaknesses to build resilience from;
- Practice inclusive, cooperative (“peer to peer”) interactions; and
- Evaluate success based on self-reflection and multiple outcomes, such as changing beliefs and practices.

Regional Conference on Ocean Policy: Pacific RISA Sustained Assessment Specialist Grecni provided Pacific Islands climate science expertise during the 2017 Regional Conference on Ocean Policy for East Asia and the Pacific Islands in conference in Nadi, Fiji. The 2-day conference was discussion based and convened regional ocean experts to enhance regional approaches to addressing pressing ocean-related issues facing the Pacific Islands and East Asia in relation to the UN Sustainable Development Goals (emphasizing SDG 14). Grecni presented on the role of sustained scientific assessment in addressing climate change risks and impacts. In addition to providing information from recent climate assessments (the PIRCA and the National Climate Assessment process, see Appendix 1) about oceans and climate change, the presentation explored how assessments quantify uncertainty, identify at-risk resources, and evaluate adaptation strategies.

Resilient Hawaiian Communities Initiative: The Resilient Hawaiian Communities Initiative at Ka Huli Ao Center for Excellence in Native Hawaiian Law invited the Pacific RISA to assist the community of Waiehu, Maui in assessing climate-related risks and providing climate information as context for their efforts to design a community resilience plan. Sustained Assessment Specialist Grecni spent a day with the community in May 2018. The first half of the day consisted of a fieldtrip (huakaʻi) with community members to survey features of the watershed and discuss climate-related issues and ideas for spatial planning and ecosystem restoration. RISA team members Grecni and PI Giambelluca presented at an evening community meeting and provided information on historical trends and projections for local climate and future land cover scenarios that the Pacific RISA previously developed in consultation with Maui stakeholders for the Maui Groundwater Project.

Communications and Media Outreach Training: Sustained Assessment Specialist Grecni serves on a committee to recommend strategies to boost the East-West Center’s media outreach. As the host institution for the Pacific RISA, the East-West Center collaborates to expand and diversify the reach of Pacific RISA’s communications. Grecni is providing facilitative support and communications expertise to an effort of the East-West Center’s Research Program to enhance public communications through traditional, digital, and social media.

11. Please provide a list of **key publications** from the past year. We are seeking ~ 5 publications that you wish to highlight, with a brief abstract/description. These can be either non-peer reviewed or peer-reviewed. For peer-reviewed publications, please list either **published** or in **press**, but ***not*** “in review”. For non peer-reviewed publications, please provide a hyperlink or webpage wherever possible. **Important: include a comprehensive list of publications as an appendix.**

Brewington, L., Keener, V., Finucane, M., & Eaton, P. 2017. Participatory scenario planning for climate change adaptation using remote sensing and GIS. In S. Walsh (Ed), Remote Sensing for Societal Benefits. Amsterdam: Elsevier.

Helweg, D.A. & Keener, V. 2017. Applications of Climate Downscaling in the Main Hawaiian Islands: Balancing Climate Modelers’ Products and Impact Modelers’ Expectations. Report on a Workshop held April 11-12, 2017. East-West Center, Honolulu, HI. doi.org/10.21429/C9CW4R.

Marra, J.J. & Kruk, M.C. (coordinating authors). September, 2017. State of Environmental Conditions in Hawaii and the U.S. Affiliated Pacific Islands under a Changing Climate: 2017. Contributing Authors: M. Abecassis; H. Diamond; A. Genz; S.F. Heron; M. Lander; G. Liu; J. T. Potemra; W.V. Sweet; P. Thompson; M.W. Widlansky; & P. Woodworth-Jefcoats. NOAA NCEI

Schuler, C.K., El-Kadi, A.I., Dulai, H., Glenn, C.R., & Fackrell, J. 2017. Source partitioning of anthropogenic groundwater nitrogen in a mixed-use landscape, Tutuila, American Sāmoa. Hydrogeological Journal: doi 10.1007/s10040-017-1617-x.

Tolessa Leta, O., El-Kadi, A.I., & Dulai, H. 2018. Impact of climate change on daily streamflow and its extreme values in Pacific Island watersheds. Sustainability Journal: doi:10.3390/su10062057.

Geospatial dataset titled "Land-Cover Map for the Island of Maui, Hawaii, circa 2017 (ver. 1.1, February 2018)." Dataset released on ScienceBase on February 7, 2018 and available at https://www.sciencebase.gov/catalog/item/5a0248cce4b0531197b73178.

12. Please provide up to 2 narrative **examples** from the past year of plans, policies, strategies, tools, agreements, etc. that were proposed, adopted, and/or implemented as a result of RISA work. Please describe the role of RISA in achieving the accomplishments described. Include **1 additional narrative** that describes the most significant **economic return** to a stakeholder from RISA projects, research implications, or information provided to decision makers. Express the value in quantitative terms where possible (dollars saved, costs avoided, dollars generated, jobs produced/saved).

Evaluation and Policy Work with the City and County of Honolulu Climate Commission: In 2016, the City and County of Honolulu Commission on Climate Change (HCCC) was established under the Revised Charter of the City and County of Honolulu (amended, 2017). This same amendment also mandated the creation of the Office of Climate Change, Sustainability and Resiliency (OCCSR). The HCCC was approved by a significant margin of voters and created a commission of five members appointed by the mayor to gather the latest science and information on climate change impacts to Hawaiʻi, and to provide advice and recommendations to the mayor, City Council, and executive departments as they look to draft policy and engage in planning for future climate scenarios. RISA PI Keener was nominated and confirmed to the HCCC in January 2018 (Figure 9). To start setting expectations and envisioning the future of the commission, a meeting was also coordinated with the Pacific RISA external evaluator, Dr. Susi Moser. Dr. Moser facilitated the meeting discussions with the pre-commissioners and offered lessons learned from her work on successful climate change adaptation in other US cities. Several themes emerged, such as logistics, the "spirit" of the HCCC, communication, and transparency. A visioning exercise about defining what constituted climate adaptation "success" for Honolulu in 50 years included culture, governance, social systems, economics, energy, water, coasts, and disasters (see right photo, below).

The HCCC recently passed a set of nine progressive and precautionary sea level rise recommendations as guidance for the city to use in planning. These recommendations require city departments to use 3.2 and 6 feet as sea level rise planning benchmarks by mid-century, and require updates of flood hazard areas, shoreline setbacks, and special management areas. Additionally, these guidelines require the disclosure of all lands within the 3.2 and 6 ft sea level rise exposure areas. Next steps for the HCCC involve the formal adoption of these planning recommendations into policy by the mayor and City Council (see Appendix 2).

Figure 9. *(Left) Members of the HCCC at the swearing-in ceremony at Honolulu City Hall, with Mayor Kirk Caldwell (center) and Chief Resilience Officer Josh Stanbro (left) of the OCCSR. (Right) Clustering results of a "visioning" exercise coordinated by the Pacific RISA prior to the confirmation of HCCC members.*

Analysis of Law and Policy Frameworks for Climate Change Adaptation in Water Resource Management: The Pacific RISA law and policy team, led by Project Specialist Wallsgrove, continues to review and analyze law and policy frameworks and decisions that are related to climate change adaptation for water resource management. From these, they identify more generally applicable policies, rubrics, or other tools that if adopted in island settings would be expected to increase adaptive capacity and make law and policy frameworks and decisions more receptive/relevant to scientific research and technical information on climate change impacts in the Pacific. The team found continued evidence of climate change adaptive capacity being enhanced by water law/policy decisions. Recent focus has been on developing case studies of water resource management decisions that result in enhanced adaptive capacity, even though they were largely driven by climate change mitigation and other motivations, and not by climate adaptation. One case was the result of a water allocation dispute, resulting from community concerns over the impact of water diversions on watershed ecology, recreational capacity, and traditional and customary practices. Although these community concerns are relevant to both the impacts of climate change and the legal mandate for climate adaptation, neither the dispute nor its resolution was climate adaptation-driven. This illustrates an opportunity to embed adaptive capacity into broader law and policy frameworks. The team is working to identify more generalized principles to maximize the potential scope of this opportunity and preparing case studies of enhanced adaptive capacity achieved in water resource management decisions in Hawai'i. They are also preparing a set of island-focused model policies that would generally address gaps in the adaptive capacity of existing frameworks.

Putting a Price on Brown Water Events in West Maui: Functioning ecosystems across Maui provide important goods and services that benefit humans in many ways. In West Maui, for example, conservation of forests in the mountains provides habitats and groundwater recharge, well-managed agricultural land retains sediment, and coral reefs provide food and opportunities for recreation. To consider the holistic valuation of these ecosystem services, the Pacific RISA is developing an integrated framework linking economic, hydrological, sediment, and decision models. Led by PI Oleson, researchers have developed a travel cost model to value the economic benefits that outdoor recreation provides to Maui residents, estimated from survey data collected from more than 350 residents. This model can be used to calculate the economic impact of brown water or coral bleaching events on Maui's beaches in terms of willingness to pay (WTP). From this model, the team estimated that a relatively common brown water event lasting 10 days in West Maui (a high tourism area) produces a welfare cost of ~$700,000 to residents. Future work will allow us to explore how brown-water events may change in the future and to identify cost-effective solutions to address this issue.

APPENDIX 1: Regional Chapter for the 4th US National Climate Assessment (NCA4)

Pacific RISA has been extremely active in creating the Hawai‘i and USAPI regional chapter for the 4th National Climate Assessment. RISA researchers on the author team include PIs Keener (Chapter Lead Author), Burkett, Giambelluca, and Sustained Assessment Specialist Grecni. During this time, the Pacific RISA has led:

- The author team edits in response to the public and US Global Change Research Program review editor, consisting of nearly 50 public comments;
- The author team edits in response to the US National Academy of Sciences review, and attendance by Keener, Grecni, and Giambelluca at the NCA4 all-author meeting in Bethesda, MD;
- Regular bi-weekly meetings with the 11-member chapter author team;
- Original figure development and coordination (see Figure 10 below). A number of figures for the chapter have had to undergo significant modification or creation for the chapter, which has required significant investment;
- Maintenance of the PIRCA.org website, which continues to have new content and resources relevant to the NCA4 chapter and the regional PIRCA products; and
- Participation in the national sustained assessment network, both through the NOAA funded network of three SAS, as well as a non-federal Kresge Foundation funded meeting in Washington DC attended by PI Keener.

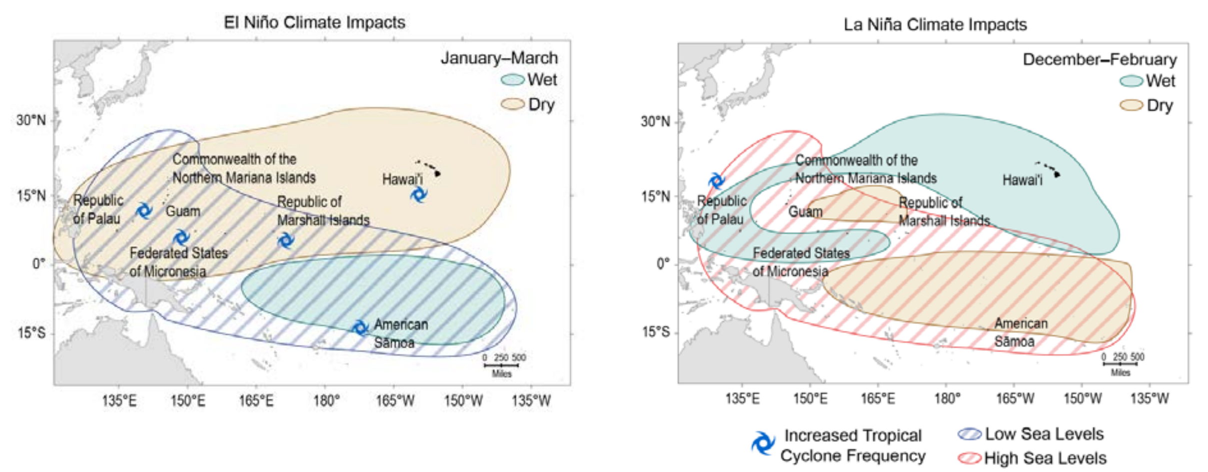

Figure 10. *A prevalent cause of year-to-year changes in climate patterns in the Pacific Islands region is the ENSO phenomenon. These maps show how El Niño (top) and La Niña (bottom) most commonly affect precipitation, sea level, and storm frequency in the Pacific Islands region in the year after an ENSO event. (Figure: V. Keener and M. Kruk, 2018)*

APPENDIX 2: Planning Recommendations for the HCCC

1. The mayor, City Council, and executive departments of the City utilize the 2017 Hawai‘i Sea Level Rise Vulnerability and Adaptation Report (hereafter “Report”) and online Viewer, for baseline planning activity and infrastructure assessment and development with regard to sea level rise.
2. The research finds that it is reasonable to set as a planning benchmark up to 3.2 ft (1 m; 3.2SLR-XA) of GMSL rise by mid-century as it will be an area experiencing chronic flooding.
3. The research finds that it is reasonable to set as a planning benchmark up to 6 ft (1.8 m; 6SLR-XA) of GMSL rise in the later decades of the century, especially for critical infrastructure with long expected lifespans and low risk tolerance.

4. The Special Management Area (SMA) boundary be revised to include parts of the 3.2SLR-XA that are not in the SMA already.
5. Disclosure of all lands be required in the 3.2SLR-XA and 6SLR-XA.
   a. Disclosure on all real estate sales, City Property Information Sheets, and all other real estate transactions.
6. The 3.2SLR-XA and 6SLR-XA be adopted as a vulnerability zone (hazard overlay) for planning by the City.
   a. The hazard overlays should be used for planning purposes, for example in the general plan, all development plans, and sustainable community plans.
7. All City departments and agencies be directed to use the Report, the 3.2SLR-XA, and the 6SLR-XA in their plans, programs, policies, and capital improvement decisions, to mitigate impacts to infrastructure and critical facilities related to sea level rise.
8. City ordinances related to land use, building, and site development shall incorporate the recommendations of this report where appropriate, including but not limited to Revised Ordinances of Honolulu Chapters 21, Land Use Ordinance; 21A, Flood Hazard Areas; 22, Subdivision of Land; 23, Shoreline Setbacks; 24, Development Plans; and 25, Special Management Area.
9. Relevant City departments and agencies be supported with adequate resources and capacity to implement these recommendations and proactively plan for sea level rise, as it will rapidly become a major challenge to City functions and operations.

APPENDIX 3: Additional Publications

Chunxi Z. & Wang Y. 2017. Projected future changes of tropical cyclone activity over the western North and South Pacific in a 20-km-mesh regional climate model: Journal of Climate, doi: http://dx.doi.org/10.1175/JCLI-D-16-0597.1.

Keener, V.W., Helweg, D.A., Asam, S., Balwani, S., Burkett, M., Fletcher, C., Giambelluca, T., Grecni, Z., Nobrega-Olivera, M., Polovina, J., & Tribble, G. 2018, not yet published. Ch. 27: Hawai‘i and U.S. Affiliated Pacific Islands: The Fourth National Climate Assessment. US Global Change Research Program, Washington, DC.