



# Annual Report

The Pacific RISA: Supporting Integrated Decision Making Under Climatic Variability and Change in Hawai'i and the US-Affiliated Pacific Islands

June 1, 2018 to May 31, 2019

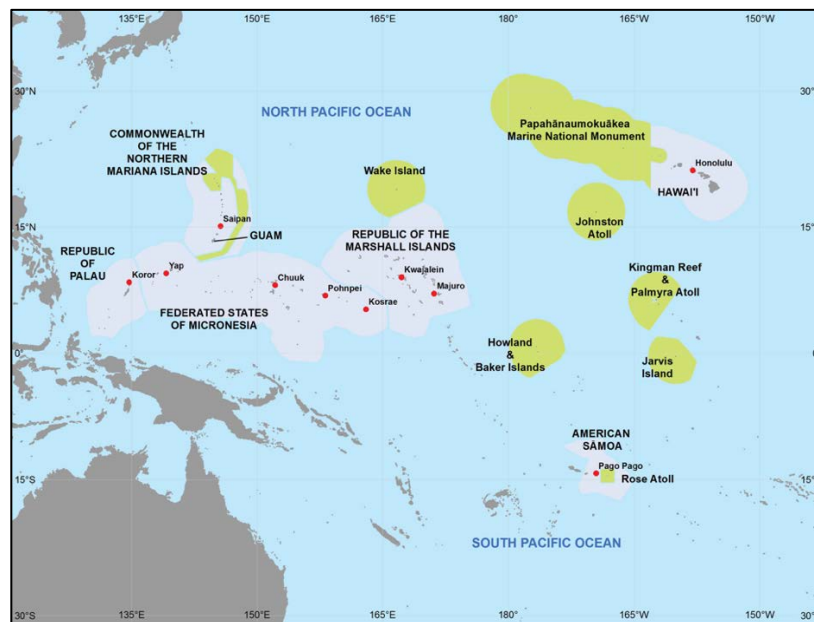


The Pacific Regional Integrated Sciences and Assessments (Pacific RISA) program supports Pacific island and coastal communities in adapting to the impacts of climate variability and change. We strive to enhance Pacific communities' abilities to understand, plan for, and respond to changing climate conditions. Our work is conducted through interdisciplinary research and partnerships with local, national, and regional stakeholders. As one of eleven US RISA programs, Pacific RISA emphasizes the engagement of communities, governments, and businesses in developing effective policies to build resilience in key sectors such as water resource management, coastal and marine resources, fisheries, agriculture, tourism, disaster management and public health.

**Vision** – Resilient and sustainable Pacific communities using climate information to manage risks and support practical decision-making about climate variability and change.

### Mission Objectives

- ◆ Meet critical climate information needs in the Pacific Region through multidisciplinary climate research, assessment, education, and training;
- ◆ Provide integrated, locally relevant climate information to decision-makers and communities in the Pacific Region;
- ◆ Enhance regional and local capabilities to manage climate risks, build resilience in key sectors, and support sustainable development;
- ◆ Promote collaboration among Pacific regional, US national, and international institutions and programs providing climate information products and services.



**Figure 1.** Pacific RISA serves the U.S. Pacific Islands region, which includes the state of Hawai'i and the U.S.-Affiliated Pacific Islands (USAPI): the Territories of Guam and American Sāmoa, the Commonwealth of the Northern Mariana Islands, the Republic of Palau, the Federated States of Micronesia, and the Republic of the Marshall Islands. (Image source: Keeener et al. 2018, USGCRP 2018)

**Cover photo:** The native 'ōhi'a lehua tree (*Metrosideros polymorpha*) has great ecological and cultural significance in Hawai'i; many parts of the tree were used by native Hawaiians to create everything from weapons to leis, and its fiery blooms and reputation for recolonizing barren lava fields means it is often associated with the Hawaiian fire goddess Pele. Native 'ōhi'a forests currently cover almost one million acres of land in the Hawaiian Islands, but in recent years, 'ōhi'a has gained notoriety not for its beautiful blooms but because of a mysterious disease known as Rapid Ohia Death (ROD) that has ravaged native 'ōhi'a forests. (Image: W. Miles)

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## Major Accomplishments

### *Fourth National Climate Assessment and Pacific Islands Regional Climate Assessment (PIRCA)*

The Fourth National Climate Assessment (NCA4), Volume II (NCA4; USGCRP, 2018), was released November 23, 2018. The chapter took over two years to complete, during which Pacific RISA, federal partners, and the U.S. Global Climate Research Program (USGCRP) brought together the expertise of eleven authors and nearly eighty technical contributors from the region – representing more than sixty agencies, departments, and organizations. “Chapter 27: Hawai‘i and U.S.-Affiliated Pacific Islands” provides an authoritative and inclusive examination of the risks and impacts of climate change and variability in the region. Leading up to the publication of the report, Pacific RISA PIs Keener (Chapter Lead Author), Burkett, and Giambelluca, and Sustained Assessment Specialist Grecni responded to multiple rounds of high-level review, created multiple new figures, and coordinated the national and regional release with the official USGCRP event at the fall meeting of the American Geophysical Union in Washington, DC in December of 2018. The findings are based on an assessment of peer-reviewed scientific literature and other sources, and they have undergone extensive review by experts and the general public, as well as the Federal Government. Since its publication, the chapter on Hawai‘i and the USAPI has been widely reported on and referenced in the region – arguably becoming the most trusted resource on the impacts of climate change in Hawai‘i. Dr. Keener represented key findings for all the regions at the AGU meeting in an invited Union Session, and authors Grecni, Giambelluca, and Keener were invited to speak with Senator Hirono (HI) and her staff about detailed findings from the chapter. Recognizing that much of the regional information could not fulfill the needs for locally relevant information in the U.S.-Affiliated Pacific Islands, Pacific RISA has begun developing jurisdictional-level climate science summaries and sectoral impacts through the Pacific Islands Regional Climate Assessment (PIRCA) that will expand upon the findings of NCA4 for the U.S.-Affiliated Pacific Islands. With travel funding support from USGCRP, Pacific RISA has reached out to partners in the region and begun a series of jurisdiction-level workshops that will provide stakeholders and technical experts the opportunity to inform the development of these resources for American Sāmoa, Guam, the Commonwealth of the Northern Mariana Islands, the Republic of the Marshall Islands, the Federated States of Micronesia, and the Republic of Palau. Pacific RISA continues to leverage the NCA chapter and process into creating a robust and inclusive regional network of scientists, resource managers, policy makers, non-profits, and local, state, and regional governments that are committed to understanding and addressing impacts from climate change.



**Figure 2.** Honolulu Mayor Kirk Caldwell called a Press Conference at Honolulu Harbor on November 26, 2018, with Climate Change Commission members Dr. Chip Fletcher (L) and Dr. Victoria Keener (R), and Chief Resilience Officer Josh Stanbro (second from L) two days after the release of the 4<sup>th</sup> National Climate Assessment, to discuss how findings from the report showed that the City needed to advance its policies surrounding climate change adaptation and sea level rise planning. He also called for a larger community discussion about issues surrounding retreat or hardening of shorelines around the island, and asked Dr. Keener to summarize findings from the NCA4 chapter as well as the Commission’s work. (Photo courtesy of: Honolulu Office of Climate Change, Sustainability, and Resilience)

## New Partnerships

### *Climate, Health, and Migration in the Pacific Islands*

The NOAA International Research and Applications Project (IRAP) project, “Climate, Health, and Migration in Pacific Islands”, led by RISA PI Dr. Laura Brewington, was designed in 2018 in collaboration with the Marshall Islands Ministry of Health and Human Services, the US National Oceanic and Atmospheric Administration, and the University of Hawai‘i Sea Level Center to improve climate information delivery to the health sector in the Republic of the Marshall Islands (RMI), and to inform health service providers in Hawai‘i about migration, health, and environmental change in the Pacific Islands region. As one of the lowest-lying nations in the world, residents of RMI are experiencing changes that may affect the very habitability of their land. Storms and sea-level rise threaten island infrastructure, such as homes, hospitals, roads, and essential health services. Drought and rising temperatures reduce freshwater supplies, while heavy rainfall increases the risk of floods and vector-borne diseases. Food supplies are reduced by ocean acidification and increasing reliance on imported goods can exacerbate existing problems with diabetes and obesity.

The public health sector is particularly influenced by sub-seasonal and seasonal changes in temperature, rainfall, and extreme events, as well as the longer-term impacts of sea-level rise and ocean acidification. With a population spread across two million square kilometers, the Marshall Islands’ healthcare systems may be unprepared to confront these impacts. As communities adapt to climate change, migration has also increased. More than three-quarters of Marshall Islanders now live in the urban centers of Majuro and Kwajalein. Internationally, more than 25,000 Marshallese currently live in the United States: an increase of 400% since 2000. About 10,000 Marshallese live in the state of Hawai‘i, where many lack access to healthcare, present with unique diseases, require translation services, and may face discrimination within the system. As this population increases, so does the health sector’s need for information about them. This work will: 1) Identify and provide climate information and services to the Marshall Islands health sector, through interviews with healthcare professionals, administrators, and policy makers in the Marshall Islands, and subsequent workshops based on the Pacific Islands Climate Services Dialogs model; 2) Track and map migration flows from the Marshall Islands through analysis and publication of existing climate and migration data. These will be linked with information on the health challenges faced by Marshall Islands residents at home and in Hawai‘i, which may become worse with climate change; and 3) Provide information and promote partnerships in the Hawai‘i healthcare sector by publishing and disseminating topic briefings and hosting a specialty conference on Micronesian health in Hawai‘i.

### *Water Budget Modeling, Future Land-Use, and Climate Scenario Development in American Sāmoa*

In American Sāmoa, Land-use scenario development is being initiated through expanded partnership with ASCC researchers, existing partnerships with Mark Schmaedick, and Ian Gurr (researchers at ASCC) and new partner Denis Sene (American Sāmoa Lead Territorial Forester). New partnerships have also been developed through stakeholder engagement and interviews with Director of Public Works Faleosina Voigt, and American Sāmoa Department of Commerce American Sāmoa Coastal Zone Programs Manager Gina Faiga-Naseri. El-Kadi, Shuler, Keener, and Brewington have been developing land use/cover change scenarios with American Sāmoa stakeholders and utilizing the data in these models for freshwater assessment, flood modeling, and inundation mapping.

### *City of Honolulu Climate Change Commission and Adaptation Planning*

Pacific RISA partnered with the State of Hawai‘i Climate Commission and the Department of Land and Natural Resources to co-host the first annual Hawai‘i Climate Change Conference on January 14, 2019. Since its establishment, Pacific RISA has partnered with the State of Hawai‘i on a number of projects. This newest partnership offered opportunities for additional integration with science policy at the state level, and also allowed Dr. Keener a way to integrate and streamline her Honolulu Climate Change Commissioner position with similar state level work. The partnership will continue, as planning is underway for the second conference, to be held in January 2020.

## *Fourth National Climate Assessment and Pacific Islands Regional Climate Assessment (PIRCA)*

Upon the release of the Fourth National Climate Assessment (NCA4), several US-Affiliated Pacific Island (USAPI) stakeholders requested authoritative climate risks and impacts summaries specific to their own jurisdictions (e.g., Guam, the Commonwealth of the Northern Mariana Islands, and Palau). To be responsive to these requests, and recognizing that much of the regional information contained in the NCA4 chapter could not fulfil the need for locally relevant information for the USAPI, Pacific RISA decided to create jurisdictional-level climate science summaries. Sustained Assessment Project Specialist Zena Grecni, Dr. Wendy Miles, and Dr. Victoria Keener have reached out to partners in all six of the USAPI countries and territories and begun discussions on these summaries. Later this year, a series of workshops is planned to provide stakeholders and technical experts the opportunity to give input for their production. The United States Global Climate Research Program (USGCRP) is providing travel funding to support these exchanges with decision makers.

## Major Outputs

### *National*

- ◆ U.S. Senators are using the Fourth National Climate Assessment, Chapter 27, to communicate with their constituents about risks to key things of value (e.g., economy, tourism, water) from climate change and variability. Senator Hirono (HI) met with Pacific RISA PI's Keener and Giambelluca, and Sustained Assessment Specialist Grecni, about the findings and needs identified in the chapter (<https://bit.ly/2lGptMz>).

### *Hawai'i*

- ◆ The Honolulu Office of Climate Change, Sustainability, and Resilience is using the figures from the Fourth National Climate Assessment, Chapter 27, in meetings and events to talk with members of the public about climate change impacts on the Island of O'ahu.
- ◆ The Mayor of Honolulu (Kirk Caldwell) is using the National Climate Assessment findings for Hawai'i to justify policies, including updating energy and building codes, the potential for a Carbon Tax, and investments in infrastructure.
- ◆ The *Climate Change Brief* (<https://bit.ly/2UpiDm5>) written by the five-member City and County of Honolulu Climate Change Commission of which Lead PI Keener is a member, describes the local, regional, and global impacts of climate change as documented by the peer-reviewed scientific literature and credible empirical data sources, including the National Climate Assessment and Pacific RISA research. The publication provides a benchmark for the commission, attesting to the Climate Change Commission's concerns, underpinning the Commission's decisions and recommendations, and informing those the Commission serves.
- ◆ The *Sea Level Rise Guidance* document, also written by the City Climate Change Commission, provides nine succinct and specific policy and planning recommendations on how the Mayor and City of Honolulu could best respond to rising sea levels. (<https://bit.ly/2X5lx0v>) The document advises the city to plan for two levels of SLR based on risk tolerance (3.2 and 6.0 feet), by two timelines – mid and late this century, and provides management suggestions include designation of exposure areas as special management districts, mandatory disclosure of public and private lands in these zones, and use of the SLR exposure zones as hazard overlays for all city planning. On July 16, 2019, a few weeks after the SLR Guidance was released, the Mayor issued a directive on climate change indicating that all city departments should use the recommendations in their planning. (see press release at <https://bit.ly/2J4jtfr>)
- ◆ In support of the cross-disciplinary 'Ike Wai project administered by the University of Hawai'i, groundwater recharge results for Pearl Harbor aquifer system under future land cover scenarios and climate change projections have been uploaded for testing within an interactive, online system developed as part of the project, and will be made available for users once system tests are complete.

- ◆ As part of the Resilient Hawaiian Communities Initiative, the Kailapa Community Association on Hawai'i Island utilized climate information produced by Pacific RISA team members to inform their community's resilience plan, *'Ehu 'Ehu I Ka Pono: Thrive in Balance*. Resources utilized in their planning process included publications by Pacific RISA team members Wallsgrove, Keener, Giambelluca, Grecni, and Zhang and the 2018 4th National Climate Assessment chapter on Hawai'i and the USAPI. At least one member of the Hawai'i Commission on Water Resource Management also inquired about prior findings and analysis.

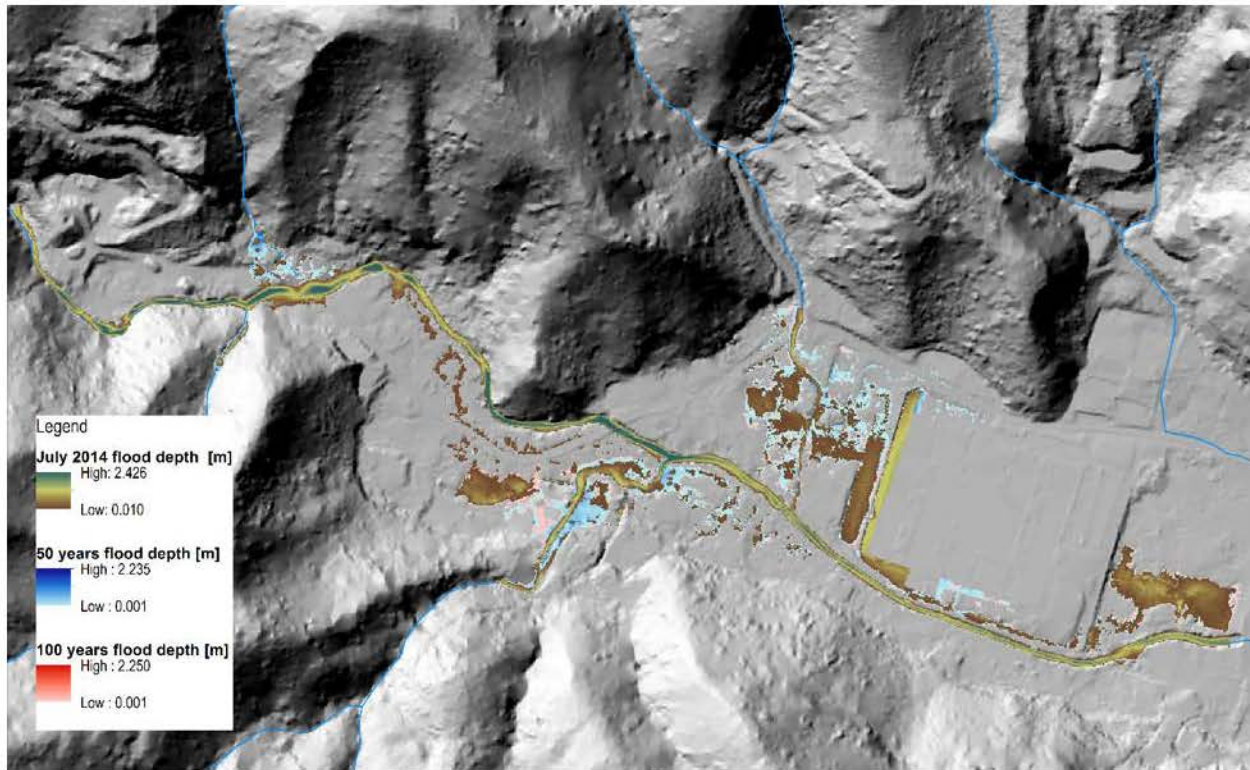
### *Republic of the Marshall Islands*

- ◆ Dr. Laura Brewington has conducted preliminary analysis of survey data collected in the Marshall Islands with 199 households, and in Hawai'i with 40 households. Analysis has focused on the health drivers of migration and findings were summarized for the Marshall Islands Ministry of Health and Human Services at the 2019 Association of State and Territorial Health Officials (ASTHO) in Honolulu, Hawai'i.

### *American Sāmoa*

- ◆ Communication with American Sāmoa EPA chief engineer David Engelstad suggests that AS-EPA may be considering groundwater recharge information from the product, "Groundwater Recharge for Tutuila, American Sāmoa Under Current and Projected Climate as Estimated with SWB2, a Soil Water Balance Model", to identify areas of interest for developing new regulatory frameworks for managing water resources availability. Communication with ASPA engineers (Katrina Mariner and Fidel Aguila) also suggests that the American Sāmoa Power Authority (ASPA) will be able to use this information in a land-dispute case regarding use of an important area for water resources development.
- ◆ Pacific RISA team member Dr. Chris Shuler lead a workshop on collaborative, integrated, groundwater modeling framework with ASPA and the Water Department's engineers and hydrologic technician. Workshop goals were: (1) Familiarize participants with the structure, limitations, and benefits of the ASPA-UHWRRRC integrated modeling framework; (2) Provide participants with an introduction to groundwater modeling and FloPy; and (3) Give UHWRRRC team a clear understanding of future water management plans, and goals for ASPA's groundwater modeling program.
- ◆ Pacific RISA PI Aly El-Kadi and collaborators calibrated and validated SWAT model of the Fagaalu watershed, American Sāmoa, and this was leveraged to assess the impact of climate change on the watershed's water budget components and extreme streamflow values (peak and low flows). El-Kadi and his team used dynamically downscaled hourly rainfall, temperature, wind speed, solar radiation, and relative humidity obtained from previous Pacific RISA output ([Zhang et al, 2016](#)). The future climate data refer to the period 2080 to 2099 that were projected based on baseline (historical) data of the period 1990 to 2009. Wind speed, solar radiation, and relative humidity data that are required inputs for SWAT model were not directly available from the dynamical model outputs. Therefore, these variables were computed based on the other available outputs of climate model (e.g., wind speed from zonal (V10) and Meridional (U10) of wind components and rescaled to 2 m, and relative humidity from specific humidity, temperature, air pressure) and appropriate equations. Finally, all the dynamically downscaled hourly climate data were converted to daily values as the developed SWAT model Fagaalu runs at daily time-scale. Based on their findings, the team selected and developed a Hydrologic Engineering Center River Analysis System (HEC-RAS) coupled with the HEC Hydrologic Modeling System (HEC-HMS) for flood modeling of the lower part of Fagaalu watershed. The models were calibrated based on historical data and then used for NOAA 50- and 100-year synthetic storm events flood modeling and inundation mapping purposes.





**Figure 3.** Flood inundation areas (for maximum depth) of 7/29/2014, 50-and 100-year storm events for the lower part of Fagaalu watershed in American Sāmoa.

### *Pacific Islands Region*

- ◆ Dr. Finucane provided an in-person presentation and led discussion with the larger Pacific RISA team of partners and collaborators on the topic of “When Facts Don’t Matter” at the East-West Center in March 2018. This discussion was requested by climate scientists across our region who were struggling with how to effectively communicate scientific findings in the larger national context, and how to convey a message of hope through adaptation and mitigation despite the severity of the scientific findings.
- ◆ Pacific RISA PI Brewington provided a literature summary of climate change and invasive species impacts, interactions, and future risks in Pacific Islands to the members present at the Pacific Invasives Partnership (PIP) meeting in June 2018. This informed a Global Climate Fund proposal developed by the Secretariat of the Pacific Regional Environment Programme (SPREP) targeting invasive species removal in Niue and Tonga. The resources gathered as part of the literature summary will be used for future regional proposal development and will be featured during the Hawai’i Conservation Conference in July 2019.

## **Outreach**

### *4th National Climate Assessment*

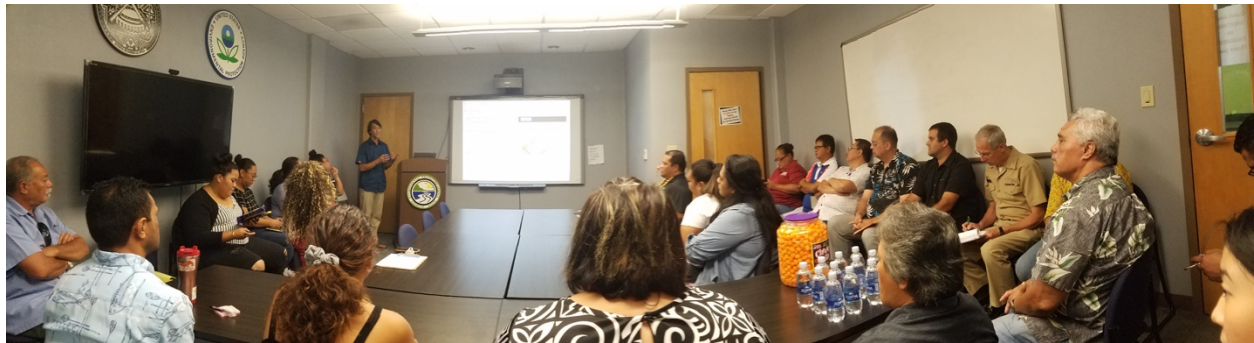
Outreach and dissemination of the NCA4 chapter and findings, thus far, has involved presenting to diverse scientific communities, communities, and decision makers at major conferences (Union Session at the AGU 2018 Fall Meeting), media outreach (Honolulu Public Radio, Honolulu Star Advertiser Editorial), briefings and presentations for stakeholder groups, and the authors’ individual interactions with decision makers. Additionally, PI Keener presented findings on a webinar for the Georgetown Climate Center State Policy Forum on March 21, 2019.

### *Collaborative and Integrative Groundwater Modeling in American Sāmoa*

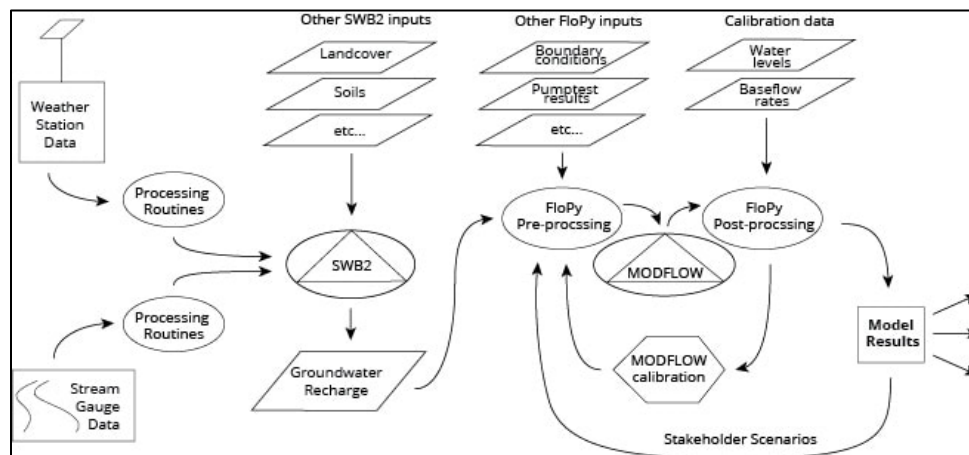
Pacific RISA doctoral researcher Chris Shuler gave a seminar at the American Sāmoa EPA Office on June 7<sup>th</sup> 2019, with 28 individual stakeholders in attendance from eight separate territorial agencies, summarizing five separate research products developed between 2017 and the present. Research products summarized included: 1) Conceptual Hydrogeologic Model and Exploratory Drilling Plan, 2) Hydrologic Monitoring Network, 3) Provisional Groundwater Sustainability Plan, 4) Groundwater Recharge Modeling, and 5) Integrated Collaborative Modeling Framework. All reports were subsequently emailed to all stakeholders in attendance. Shuler also shared this research through his dissertation defense on April 8, 2019 to a wide audience at the University of Hawai'i. This research was also featured as part of the IRC Science Seminar series at the NOAA Ford Island IRC Auditorium on May 16, 2019, where Dr. Shuler presented, "From Recharge to Reef: Assessing the Sources, Quantity, and Transport of Groundwater on Tutuila, American Sāmoa". Dr. Shuler has also developed two online, interactive outreach products:

(1) a website to promote to promote understanding of the integrated groundwater modeling framework: <https://integratedmodelingframework.weebly.com/> and

(2) a Github repository: This repository is open-source and makes all data, code, and results publicly available. The repository can be viewed or downloaded at: [https://github.com/cshuler/ASPA-UH\\_Integrated\\_Modeling\\_Framework](https://github.com/cshuler/ASPA-UH_Integrated_Modeling_Framework)



**Figure 4.** Dr. Chris Shuler gives an invited seminar to multi-sector stakeholders at AS-EPA, covering groundwater work partially funded by pacific RISA over the last 3-4 years.



**Figure 5.** Shown above is the data and modeling framework for the integrated groundwater, climate, and landcover collaborative modeling project in American Sāmoa. (Source: Chris Shuler, 2019)

### *Climate, Health, and Migration in the Pacific Islands*

Discussing the newly-funded IRAP project, Pacific RISA PI Dr. Laura Brewington was interviewed by Hawai'i Public Radio on December 10, 2018 to discuss migration, climate change, and health in Pacific Islands, audio available [here](#). Pacific RISA also contributed to the "Climate, Migration, and Health Workshop" held May 17-18, 2019. The two-day workshop brought together approximately 10 researchers and policy communicators to discuss, and move forward, research on this important intersection. It identified knowledge gaps and beginning papers/proposals designed to fill those gaps. Contributors included members of IUSSP's Special Emphasis Panel on Climate, Migration and Health, and the East-West Center's Project Specialist on migration and health, Dr. Daniel Ervin.

### *Climate-induced Migration: Analyzing Causes and Impacts of Climate-induced Migration in the U.S.-Affiliated Pacific Islands*

Preliminary findings from PI Maxine Burkett and team's research has been shared both in the region and internationally. Results from field work have been disseminated and ground-truthed with local partners at the "RMI Information Sharing Workshop" in Majuro (Jul 17, 2018), Republic of the Marshall Islands, and shared through a "Honolulu Information Sharing Workshop" at the Pacific Island Health Officers Association (PIHOA) Board Meeting in Hawai'i (Jul 22, 2018). The team briefed the Marshall Islands' Chief Secretary Ben Graham on the results of the field work on July 16, 2018. Internationally, the research has been presented by its team members at the "Adaptation Futures" meeting (Jun 18-21, 2018 in Cape Town, South Africa), the TransRe Conference (July 5-7, 2018 in Bonn, Germany), the International Student Festival (Feb 10, 2019 in Trondheim, Norway), and the Jornada Desplazados Climaticos (Apr 26, 2019 at Red Cross, Granada, Spain).

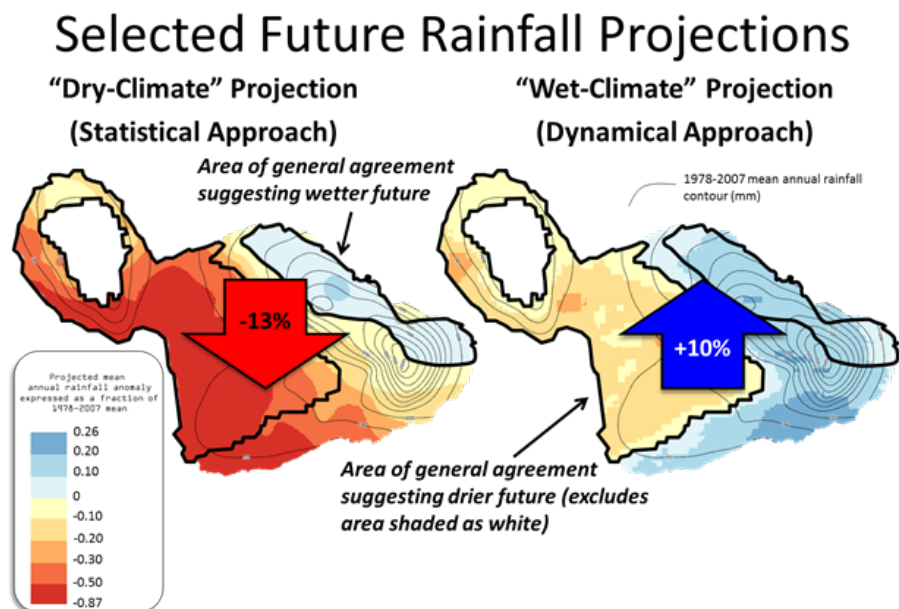
### *Pacific Islands Biosecurity Initiatives*

Pacific RISA PI Laura Brewington joined the Western Governors' Association Winter meeting was held in Kailua-Kona, Hawai'i, December 8-11, 2019. Dr. Brewington attended Hawai'i Governor David Ige's Biosecurity and Invasive Species Initiative workshop and presented recent Pacific Islands work linking the amplification of invasive species impacts by climate change and models of future species distributions under climate projections. The final Initiative report can be found [here](#). Dr. Brewington also represented Pacific RISA at the Pacific Invasives Partnership annual meeting (March 10-14, 2019) in Brisbane, Australia, joining others in the region to coordinate policy recommendations around invasive species and climate change in the Pacific Islands region. Ecosystem resilience and adaptation to climate change were highlighted as a key thematic framework for island and territorial officials to pursue, with examples from Hawai'i and Palau, and a Global Climate Fund proposal is being developed based on this framework. Meeting attendees included high-level representatives from Australia Department of Foreign Affairs and Trade, New Zealand Ministry of Foreign Affairs and Trade, CSIRO, and the US Department of Agriculture. Regional entities included the Secretariat for the Pacific Regional Environment Programme (SPREP), the Secretariat of the Pacific Community, the Nature Conservancy, BirdLife International, Conservation International, and various universities and other regional research programs.

### *The Maui Groundwater Project: Estimating changes in groundwater recharge under future climate and land-cover conditions*

For the last century, the island of Maui in Hawai'i has been the center of environmental, agricultural, and legal conflict with respect to both surface and groundwater allocation. Planning for sustainable future freshwater supply in Hawai'i requires adaptive policies and decision-making that emphasizes private and public partnerships and knowledge transfer between scientists and non-scientists. The Pacific RISA created both downscaled dynamical and statistical future climate projections for Maui and integrated them with a participatory scenario building process to quantify future changes in island-scale climate and groundwater recharge under different land uses. Although these projections are uncertain, stakeholder input was used to choose a set of projections that brackets both wet and dry futures. Participatory scenario planning began in 2012 to bring together a diverse group of ~100 decision-makers in government, watershed restoration, agriculture, and conservation to 1) determine the type of information (climate variables, land use and development, agriculture) they would find helpful in planning for climate change, and 2) develop a set of nested scenarios that represent alternative climate and management futures. This integration of knowledge is an iterative process, resulting in flexible and transparent narratives of complex futures comprised of

information at multiple scales. In this project period, the water budget modeling for the base and alternative land use scenarios was completed, and results were presented to a variety of different stakeholders. Outreach included speaking events at the Pacific Water Conference (Feb 20, 2019 in Honolulu), a presentation to the County of Maui Department of Water Supply (Mar 25, 2019 in Wailuku), a presentation to the Maui City Council (Apr 25, 2019 in Wailuku), a seminar at the University of Hawai'i Water Resources Research Center (Apr 23, 2019 in Honolulu), and a webinar for Maui stakeholders at the East-West Center planned for June 20, 2019 in Honolulu.



**Figure 6.** To bracket the variation in projected rainfall on Maui from both dynamical and statistical models, scenarios representing the driest (RCP8.5) and wettest (A1b) available end of century projections were chosen to be used in the water budget model. While the models had a large range of rainfall, ranging from a 13% decrease to a 10% increase in mean annual rainfall, there were regions that were consistent between the projections. The northern coast of east Maui was projected to become wetter in each model, while central and west Maui, the focus of future agriculture and development, was projected to become overall drier.

### *Ecological-economic modeling of ecosystem services in Maui*

Dr. Kirsten Oleson and post-doc Dr. Carlo Fezzi met with the Board of Water Supply and Department of Planning officials of Maui County to present findings from the ecological-economic modeling of different ecosystem services of interest that were identified in previous reporting periods through an online survey. They held three meetings each with 3-7 people joining from relevant agencies. Dr. Fezzi presented the findings at an event at Maui College. Audiences and decision-makers have been very interested in the concept of economic valuation of traditionally non-monetary resources, and liked the approach of using brown water days as a means of determining costs of impacts. Using this approach, Oleson and Fezzi estimated that the “welfare loss” of a relatively common two-week brown water event in West Maui represented an estimated loss of \$678,000 for local residents. Oleson and Fezzi also examined the “welfare benefits” of reef restoration activities in economic terms, with potential gains estimated at upwards to \$40 million/year. Those involved in the informational sessions found this information to be important for justifying efforts to manage watersheds, control erosion from new development, and other initiatives to reduce coastal pollution.

### *Evaluating Similarities and Differences Between Statistical & Dynamical Downscaling Projections*

Pacific RISA PI Thomas Giambelluca gave a presentation to the Honolulu Board of Water Supply Stakeholder Advisory Group and served on a panel at the group’s workshop in April 2019. Dr. Giambelluca presented the available projections of future precipitation for the island of Oahu, and discussed how to reconcile the differences in projections in freshwater supply planning processes.



## Next Steps

### *Evaluating Similarities and Differences between Statistical & Dynamical Downscaling Projections*

Dr. Thomas Giambelluca is conducting a comparison of old linear statistical downscaling results with the non-linear GAM method. In the coming year his team will be working to find the best combination of large-scale climate predictors by cross-validation of the regression model. Research results will be presented at conference(s) by the project's Graduate Assistant, and PI or co-PI. The Graduate Assistant will also be downloading additional CMIP5 multi-model ensemble data (for any new predictor variables) and applying the SD model to future scenarios. Planned activities for the coming year include,

- Producing new rainfall change scenario maps (GA student and co-PI)
- Manuscript writing and submission for peer-review (GA student, PI, and co-PI)
- Making data products publicly available, incl. metadata (GA student, PI, co-PI)
- Sharing the code online (GitHub or other public repository) (Co-PI, GA student)

In addition, PIs Giambelluca, Annamalai, Keener, and Brewington are co-authoring a journal article intended to provide specific guidance on best-practices for applying the available downscaled projections to decisions that resource managers in Hawai'i are facing.

### *Climate, Health, and Migration in Pacific Islands*

In 2019-2020, the NOAA IRAP-funded project will proceed with the development of workshops in 1) the Marshall Islands for climate services delivery to the health sector and 2) Hawai'i with community organizations and the Department of Health offices working with Micronesian migrants. At least one workshop in each location will be held by the end of the next year of reporting. Pacific RISA PI Brewington and Project Specialist Ervin plan to produce a white paper and associated publications on the nexus of climate, health, and migration in Pacific Islands, using the Marshall Islands as a case study. These publications will also be associated with a broader set of products from the Pacific RISA migration and climate change project, such as legal briefings, fact sheets on the Marshallese migration experience, and considerations for the Compact of Free Association (COFA) that is set to expire in 2023, all of which have implications for human health. Spatial data products based on survey responses from the Marshall Islands and indicator variables for human health will be produced to provide graphical information on the environmental risk factors to health and how they may be linked to migration decisions now and into the future.

### *Pacific Islands Regional Climate Assessment (PIRCA)*

The main focus of Pacific RISA's efforts to support the National Climate Assessment in 2019-2020 will be presenting the NCA4 chapter results to jurisdictional decision makers and gathering stakeholder feedback to inform future report and product development. Dedicated additional funding from the USGCRP (\$15,000) will allow us to visit each of the Pacific Island jurisdictions covered in the chapter and hold engagement workshops, which are essential for increasing equitable representation of the USAPI in future products and growing the network of regional stakeholders that trust and participate in future NCA activities. Specifically, funds will cover travel for two non-federal personnel (Ch. 27 Author and Sustained Assessment Specialist Zena Grecni, plus one subject-matter expert) to convene engagement workshops and meet with decision-maker groups in the Territory of Guam, the Commonwealth of the Northern Mariana Islands, the Republic of Palau, and the Federated States of Micronesia over two trips in 2019.

## Evaluation

Pacific RISA's evaluation work has two primary goals: (1) assess the value of the Pacific RISA program as a regional leader supporting real-world decision makers with climate information and services that are unique yet coordinated with other regional programs; and (2) support and adaptively improve the ongoing climate information and services developed by Pacific RISA. We utilize both external and internal evaluation to assess Pacific RISA's unique value in the region, and identify ways to improve upon the climate information and services we provide. To strengthen Pacific

RISA's internal evaluation capacity, in late 2018 we advertised for a new Program Manager position with expertise in evaluative research, hiring Dr. Wendy Miles in early 2019.

Pacific RISA's external evaluator, Susanne Moser, presented her findings from the 2017-2018 Pacific RISA evaluation to Pacific RISA team members and partners on March 13, 2019. Building on the momentum of Dr. Moser's presentation, on March 29, 2019, Dr. Keener and Dr. Miles facilitated an internal Pacific RISA Cross-Collaboration Planning Session. Activities included a self-assessment of individual and collective progress towards Pacific RISA's 2015-2020 core objectives, and both small-group and full-group cross-project collaboration brainstorming exercises. During the workshop, PIs and team members: (1) reviewed the Pacific RISA Theory of Impact Model and 2015-2020 "Road Map", (2) discussed our vision for Pacific RISA between now and the end of Phase 3 (Aug 2020), and how our individual projects each contribute to this vision; (3) explored common objectives for the next 1.5 years and identified opportunities to collaborate towards shared goals; and (4) provided advice on ways to improve the evaluative reporting process to best meet the needs and goals of Pacific RISA.

The Pacific RISA evaluation team – which consists of Finucane, Keener, and Miles (internal evaluation) and Moser (external evaluation) – are presently drafting an article to share several key findings of team's evaluation research to-date. This paper will focus on the evolution of Pacific RISA's evaluation activities and its role as a "boundary organization", with planned submission to *Nature Climate Change*.



**Figure 7.** Participants in the Pacific RISA Cross-Collaboration Planning Session, PIs and partners explored common objectives and ways to collaborate towards shared goals. (Photo courtesy of Shane Hasegawa, East-West Center)

## Evidence of Societal Impact

### *Hawai'i Climate Conference*

Pacific RISA organized and co-hosted the 1st Hawai'i State Climate Conference on January 14, 2019 with the Hawai'i Department of Land and Natural Resources (DLNR) in partnership with the Ulupono Initiative. The meeting was held at the East-West Center Imin Conference Center in Honolulu, Hawai'i, and featured opening remarks by Hawai'i Governor Ige, and Susanne Case, the Chair of DLNR. The full-day conference opened with a summary of the most up-to-date climate research and knowledge on all sectors across the state by Pacific RISA PI Dr. Victoria Keener, and featured discussion panels meant to highlight state climate initiatives and planned and possible adaptation and mitigation actions in three areas: (1) Hawai'i's emissions from the transportation sector, (2) how to accelerate adaptation to sea level rise, and (3) innovations in financing and implementation of adaptation. The cross-cutting theme of the entire conference was equity in climate adaptation planning, with a keynote speech by Dr. Beverly Scott, a transportation equity advocate. The meeting was open to the public, and was attended by over 350 people representing communities, academia, government, advocacy, industry, and students. The conference was held two days before the opening of the Hawai'i State Legislative session, and was meant to give legislators an opportunity to engage more meaningfully with ideas for meaningful climate adaptation measures. During the following several

months, eight climate bills were introduced and heard in committee, and over 15 more were not heard. Bills that passed included a study on a statewide carbon tax and updated appliance efficiency standards, while measures such as disclosure of properties in the sea level rise future inundation zone and a ban on permits for new coal burning facilities were not heard. The partnership was successful, and the Pacific RISA is collaborating with the DLNR to host the 2nd Annual State Climate Conference in January 2020, with a cross-cutting theme of “communication”.



**Figure 8.** Chair of the Hawai‘i Department of Land and Natural Resources (DLNR), Susanne Case, speaks to a packed audience at the 1<sup>st</sup> annual Hawai‘i Climate Change Conference. The full day meeting was open to the public and featured expert panels, real time audience polling, and a focus on equity in climate planning at the State level. As a successful new partnership, the Pacific RISA co-sponsored and helped contribute content to the conference. (photo: Shayne Hasegawa, East-West Center)

### *Collaborative and Integrative Groundwater Modeling in American Sāmoa*

In 2008, the USGS removed its final stream gauging site in American Sāmoa, effectively terminating a decades-long hydrologic monitoring program. This USGS monitoring program pullout from American Sāmoa was in response to a lack of funding and a change in leadership at the American Sāmoa Power Authority (ASPA). From 2008 to 2015, there was a hydrologic data gap, but in August of 2015 Pacific RISA PI Aly El-Kadi and his graduate researcher Chris Shuler collaborated with ASPA to break ground on installation of four inexpensive weather stations. By leveraging spare money from existing grants for equipment, salary funding from Pacific RISA, and travel costs, the ASPA-UHWRRRC hydrologic monitoring network was created. Since 2015, additional equipment funds from the AS-EPA were leveraged to expand the network to eight stream gauges, seven weather stations, and several groundwater monitoring well instruments.

ASPA has dedicated a full-time hydrologic technician position to upkeep and maintenance of the network, and is initially hosting weather station data on the company website. By working collaboratively with ASPA we are able to fill the need for production of publicly available hydrologic data at a fraction of the previous cost. For context, the cost proposed by USGS to install and operate five stream gauges and four rain gauges for a period of one year was \$153,600, of which ASPA would pay \$110,200. In contrast, this project has worked with ASPA to build their capacity to service monitoring instruments in-house, costing significantly less than what ASPA would have paid with the USGS. The cost savings for ASPA have allowed them to hire a full-time hydrologic technician to maintain the monitoring network and add other value to ASPA.





**Figures 8 and 9.** Pacific RISA team member Chris Shuler and ASPA technician Matt Erickson installing weather stations with ASPAs summer interns. (Image courtesy of Chris Shuler)

More recently WRRC and Pacific RISA have expanded the cyber infrastructure capacity to meet growing needs of data storage and data processing workflow capture and have developed an innovative cloud-based, open-source framework to archive raw data, to facilitate collaboration with stakeholders, and to distribute modeling or data products to the public and stakeholders. This raw hydrologic data is not only been used by our researchers for modeling, and by ASPA for general engineering needs, but has also been directly applied by other stakeholders such as the American Sāmoa Renewable Energy Committee who used the weather station solar radiation data to assess photovoltaic resource availability at sites across Tutuila, or by the American Sāmoa EPA who used streamflow data to calculate nutrient loads for assessing how population and land use is affecting as coral reefs.



**Figure 10.** Marine Sanctuaries staff being trained in taking streamflow measurements in American Sāmoa. (Image courtesy of Chris Shuler)



For our research group, the monitoring network data directly supplied needed information to numerical models that we collaboratively develop with ASPA and use to inform water resources needs. Specifically, this included development of a water budget model used to calculate groundwater recharge, which is now being used to parameterize an open-source python based numerical groundwater model.

The implementation of the water budget model was only recently completed, and that of the groundwater model is ongoing, but conversations with stakeholders suggests potential future impacts from this work, including helping water managers quantify the recharge and value of the Malaeimi Valley, an area that currently feeds some of the most productive well fields on the island, and has been proposed as a designated special-management area. However, ASPA is currently dealing with a land dispute occurring in the valley where a single land owner has blocked all access to the valley and is presently involved in a court case about previously negotiated use of water resources in the area. By applying the water budget model and quantifying the amount of recharge in the valley will assist policy makers and resource managers in working through this issue.

### *Pacific Islands Biosecurity Initiatives*

The New Zealand Ministry of Foreign Affairs and Trade (MFAT) and Department of Conservation incorporated the joint threat of invasive species and climate change in the Pacific region as part of the Pacific Reset and Pacific Pathway Plan. This was a direct outcome of the June 2018 Pacific Invasives Partnership meeting with representation from the Pacific RISA, during which Laura Brewington presented the case that invasive species need to be addressed in the context of climate change and environmental resilience. A summary of MFAT recommendations can be found [here](#), with Environment and Climate Change on page 25. In September 2018, the [Boe Declaration](#) established an expanded definition of Pacific Island security that explicitly calls out climate change and environmental security as the highest priority issues in the region, and to further develop international strategy on these issues Dr. Brewington will be attending the 3<sup>rd</sup> annual trilateral Track 1.5 Pacific Security Dialog in Canberra, Australia in late June 2019. In the United States, the Western Governors' Association (WGA) has released the [Special Report](#) from Hawai'i Governor David Ige's 2018 Biosecurity and Invasive Species Initiative. The report summarizes input from PIP members at the December 2018 WGA meeting in Kona, Hawai'i, including US Department of Agriculture, Hawai'i Department of Agriculture, Guam Department of Agriculture, the Pacific RISA, the US Geological Survey, and the Hawai'i Invasive Species Committees.

### *The Maui Groundwater Project: Estimating changes in groundwater recharge under future climate and land-cover conditions*

The Pacific RISA has worked on this project closely with the Hawai'i Commission on Water Resources Management (CWRM) since 2012. As a result of pioneering this experimental process and findings for the island of Maui from the integrated and collaborative nature of this project, although the process was slow and not always the easiest to get traction on with different agencies and groups, as of March 2019, the CWRM is now funding climate and groundwater recharge projections and modeling for all of the main Hawaiian islands. The RISA networks are partially designed to test new experimental climate services research and identify valuable new collaborations and ideas or methods that, if deemed of value by the stakeholders, will gain traction and get their own life. The fact that CWRM is pursuing this work for the rest of the islands is evidence of the effectiveness of the method and value of the results.

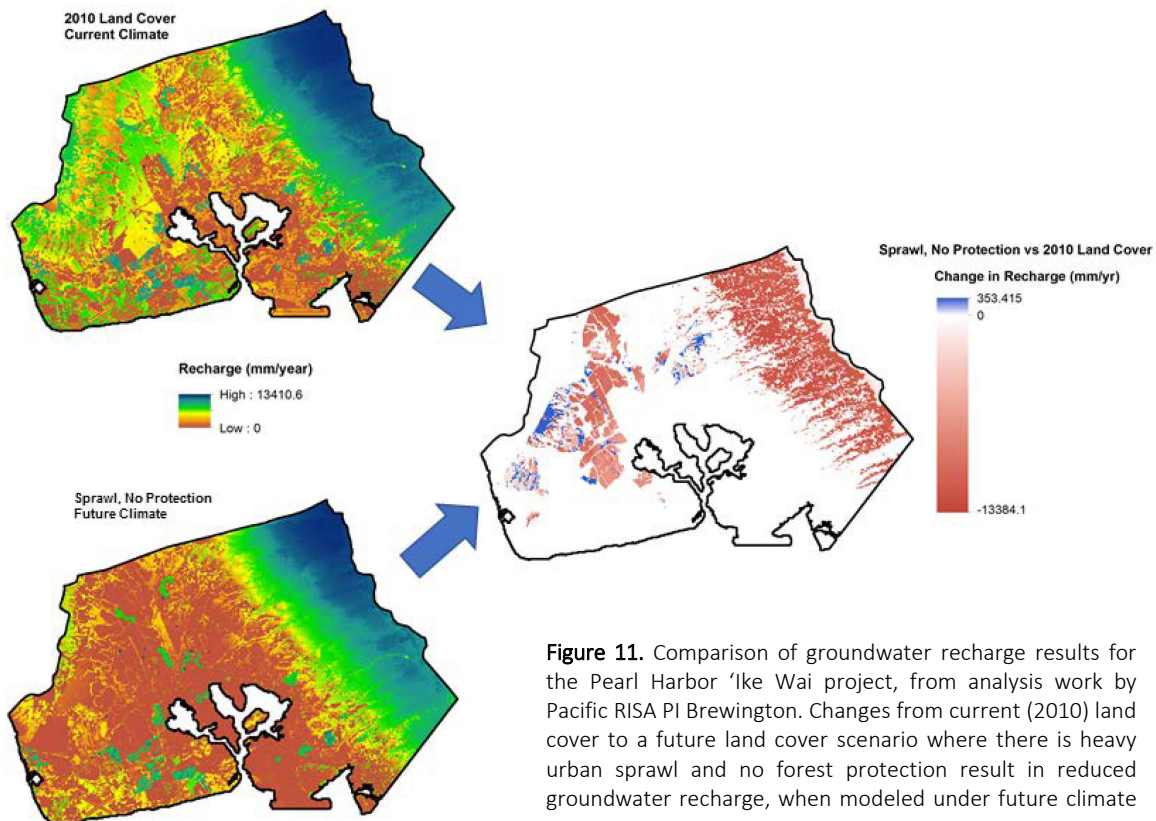
### *Fourth National Climate Assessment*

Evidence suggests the National Climate Assessment is building the confidence of Honolulu policy makers to propose policy measures and infrastructure projects that aim to achieve environmental, health, social, and economic benefits, in the context of climate change. A Honolulu City Council Resolution (18-221) in 2018 urges the City administration to accelerate implementation of the 2018 Global Climate Action Summit Policies and establish goals for 100 percent renewable energy. Lawmakers had introduced the measure prior to NCA4's release, and they later added specific reference to the chapter for Hawai'i and Pacific Islands as justification for the measure, which ultimately passed. Additionally, the Honolulu Mayor appears to be emboldened to propose adaptation strategies. He held a press conference on Nov. 26, 2018 with NCA4 chapter authors including Dr. Keener, calling attention to the findings and

stating that Honolulu will need to develop tailored adaptation strategies for various parts of the city, suggesting some areas would need to relocate infrastructure and others would require protection from increasing sea levels and coastal erosion. He discussed specific needs from the City budget to support these actions. He reiterated many of the points in the State of the City address in May 2019, making specific budgetary requests to the City Council.

#### *Further evidence of societal impact from the Pacific RISA team in Hawai'i*

- ◆ Preliminary results of local economic modeling of brown water events in Maui by Pacific RISA PI Oleson and post-doc Fezzi were well received by Maui county planners, who explained that efforts to place dollar figures on the damages from brown water events caused by extreme events could help them advocate for adequate budgets for resource management or stricter zoning.
- ◆ Members of Kailapa Community Association on Hawai'i Island reported using prior Pacific RISA work products (Keener et al. 2018, Keener et al. 2012, USGCRP 2018, Wallsgrove and Penn 2012, Zhang et al. 2016) to better understand the general scope of anticipated climate impacts on freshwater resources in their community, and how existing laws and policies might enable enhanced community stewardship of freshwater resources.
- ◆ [Sumida Farm in Aiea](#) is using information from the 'Ike Wai scenarios analysis work by Dr. Brewington and colleagues to inform future water use for watercress farming under climate change.



## Case Studies

### *Economic Returns to Stakeholders of Groundwater Modeling in American Sāmoa*

The assessment of aquifer properties as published in Shuler et al. (2019) provided information to the American Sāmoa Power Authority (ASPA), which assisted in their decision to filter water from existing contaminated wells, instead of drilling new wells in the same aquifer. ASPA estimated that the cost for drilling 7-9 new wells was ~\$250,000. The integrated collaborative groundwater modeling framework we are developing with ASPA utilizes open-source software. In contrast, proprietary modeling software that ASPA had previously purchased, but not used, due to lack of time and experience, initially cost the agency over \$10,000 in startup costs. The software had an annual fee of \$3,000/year and while the startup cost was not able to be saved, by assisting ASPA with developing modeling capacity using an open-source platform, they are able to now save \$3,000/year on the modeling software subscription. Additionally, the collaborative arrangement allows ASPA to benefit from modeling performed by Pacific RISA experts in a way that approximates having an in-house modeler. Therefore, the staff time saved for ASPA in not hiring a dedicated groundwater modeling position could be up to \$72,000/year.



**Figure 12.** Pacific RISA team member Dr. Chris Shuler conducting a workshop at ASPA to introduce engineers from their water department to our collaborative, open-source, cloud-based, integrated, groundwater modeling framework.

### *City of Honolulu Climate Change Commission and Adaptation Planning*

Pacific RISA Lead PI Victoria Keener serves on the five-person Climate Change Commission for the City and County of Honolulu. During the past year, Dr. Keener participated in a press conference with Honolulu Mayor Kirk Caldwell, CCSR Chief Resilience Officer Josh Stanbro, and Commission Vice-Chair Dr. Chip Fletcher about the release of the Hawai'i and Pacific Islands National Climate Assessment Chapter and the need for the city to adapt (Honolulu Harbor, Nov 26, 2018). Keener also authored an [op-ed](#) in the Honolulu Star Advertiser (Dec 2, 2018) about needed policy changes. In January 2019, Dr. Keener and Dr. Fletcher were invited by the City and County of Honolulu to a Honolulu Public Safety Sub-cabinet Meeting, where they spoke to representatives from the Police Department, Fire Department, Emergency Medical Services, and Lifeguards about projected climate impacts on public safety and vulnerable infrastructure (Honolulu City Hall, Jan 31, 2019). The Climate Change Commission authored two influential policy documents in 2018-2019:

- ◆ The [Climate Change Brief](#) written by the five-member Climate Change Commission describes the local, regional, and global impacts of climate change as documented by the peer-reviewed scientific literature and credible empirical data sources, including the National Climate Assessment and Pacific RISA research. The publication

provides a benchmark for the commission, attesting to the Climate Change Commission's concerns, underpinning the Commission's decisions and recommendations, and serving to inform those the Commission serves.

- ◆ The [Sea Level Rise Guidance](#) document provides nine succinct and specific policy and planning recommendations on how the Mayor and City of Honolulu could best respond to rising sea levels. The document advises the city to plan for two levels of SLR based on risk tolerance (3.2 and 6.0 feet), by two timelines – mid and late this century, and provides management suggestions include designation of exposure areas as special management districts, mandatory disclosure of public and private lands in these zones, and use of the SLR exposure zones as hazard overlays for all city planning. On July 16, 2018, a few weeks after releasing the SLR Guidance, the Mayor issued a directive on climate change indicating that all city departments should use the recommendations in planning. As a result of this publication, the state-level Climate Commission adopted our recommendations at the state level in September 2018 (<https://dlnr.hawaii.gov/blog/2018/09/05/nr18-181/>). This short document was able to move SLR planning forward at both the City and State scales in a matter of months.

## Most Significant Publications of the Year

**Publication 1** – Chapter 27 of the National Climate Assessment provides an authoritative examination of the risks and impacts of climate change and variability in Hawai'i and the U.S.-Affiliated Pacific Islands. The findings are based on an assessment of peer-reviewed scientific literature and other sources, and they have undergone extensive review by experts and the general public, as well as the Federal Government. The chapter was published in the Fourth National Climate Assessment, released by the United States Global Change Research Program in November 2018.

Keener, V., D. Helweg, S. Asam, S. Balwani, M. Burkett, C. Fletcher, T. Giambelluca, Z. Grecni, M. Nobrega-Olivera, J. Polovina, and G. Tribble. 2018. Hawai'i and U.S.-Affiliated Pacific Islands. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* [Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 1242–1308. doi: 10.7930/NCA4.2018.CH27 url: <https://nca2018.globalchange.gov/chapter/hawaii-pacific/>

**Publication 2** – A water budget approach using SWB2, a soil water-balance model was applied to Tutuila with the primary objective of calculating spatially and temporally distributed net-infiltration, which directly controls groundwater recharge rate. The potential effects of future climate change on water resources availability were simulated by integrating dynamically downscaled climate predictions for 2080 to 2099 derived from externally supplied global climate model results<sup>1</sup>. Climate scenarios suggested an increase in net-infiltration of 17 to 27% might be expected by the end of the century depending on the emissions scenario used.

Groundwater Recharge for Tutuila, American Sāmoa Under Current and Projected Climate as Estimated with SWB2, a Soil Water Balance Model.” Published as a WRRC Project Completion Report (Shuler and El-Kadi 2018) as well as a dissertation chapter (Shuler 2019).

**Publication 3** – Detailed diagnostics with the "best" CMIP5 models that simulated well the tropical Pacific climate, it was determined that with a projected warming climate, the number of tropical cyclones is likely to decrease for Guam and Kwajalein but remain about the same for Oahu; however, the maximum intensity of the strongest storms may increase in most regions. The likelihood of few but strong storms will necessitate new localized assessments of the risk and vulnerabilities to tropical cyclones in the North Pacific.

Widlansky, M.J., H. Annamalai, S.B. Gingerich, C.D. Storlazzi, J.J. Marra, K.I. Hodges, B. Choy, and A. Kitoh, 2018: Tropical cyclone projections: Changing climate threats for Pacific Island defense installations. *Weather, Climate, and Society*, 11 (1), 3-15, doi:10.1175/WCAS-D-17-0112.1.

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<sup>1</sup> Wang, Y. and Zhang, C. 2016. Project Final Report - 21st Century High-Resolution Climate Projections for Guam and American Samoa. Retrieved from: <https://www.sciencebase.gov/catalog/item/583331f6e4b046f05f211ae6>



## Publication List

\* Most significant Pacific RISA publications of past year have an asterisk and an accompanying abstract on prior page.

- Brewington, L. 2018. Stakeholder perceptions of invasive species and participatory remote sensing in the Galapagos Islands. In M. Lourdes Torres and C. Mena (Eds), *Understanding Invasive Species in the Galapagos Islands: from the Molecular to the Landscape*. Heidelberg: Springer, pp 175-192.
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