A Research Strategy for the Pacific Climate Information System

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Abstract

Based on a selective review of the outcomes of previous meetings, conferences, workshops, and papers highlighting climate variability and change research needs in the Pacific region, this paper presents a research strategy for increasing understanding of climate-society linkages in Pacific Island settings. The strategy provides a synopsis of emerging research goals and illustrative activities that users can rank according to their priorities. Grounded in the framework of the Pacific Climate Information System, the strategy is comprised of three key research elements: (1) research to enhance understanding of regional climate risks and consequences; (2) research to improve decision support and risk communication; and (3) research to improve climate adaptation capacity. We envision the strategy will contribute to enhanced understanding of scientific and societal knowledge of climate processes and their impacts and stakeholder capacity for building sustainable island communities for future generations.

A Research Strategy for the Pacific Climate Information System

Objective

The objective of this paper is to present a research strategy for increasing understanding of climate-society linkages in Pacific Island Countries and Territories (PICTs). Based on a selective review of the outcomes of previous meetings, conferences, workshops, and papers highlighting research needs in the Pacific region, the strategy provides a synopsis of emerging research goals and illustrative activities that users (e.g., policymakers, resource managers, researchers, planners) can rank according to their priorities. The strategy provides a systematic approach to developing relevant Pacific Island climate information, products, and services in the context of uncertainty posed by climate variability and change in the Pacific region. As such, the strategy supports the vision of the Pacific Climate Information System (PaCIS), a programmatic framework aiming to build resilient and sustainable Pacific communities using climate information, products, and services, to manage risks and support practical decision-making.

Pacific Context

Climate variability and change pose unique challenges for PICTs. Island vulnerability stems from limited size, proneness to natural hazards (drought, flooding, tropical cyclones, tropical cyclones, inundation, tsunami, and wildfires), physical isolation, low adaptive capacity for some, and high adaptation costs relative to gross domestic product. Fresh water is critical for all islands; when climatic events affect water supplies, then food security, livelihoods, and public health are threatened. In addition, climate-related disasters can have a domino effect causing one vulnerable sector to influence others. The effects of less dramatic climatic events may accumulate over time and set in motion a chain of negative events.[1-3]

Most regional climate change information to date has been based on the use of Coupled Atmosphere-Ocean General Circulation models (AOGCMs).[4] AOGCMs have proved to be most valuable tools in understanding the processes that determine the response of the climate system to anthropogenic forcings, such as increases in greenhouse gas (GHG) concentrations and changes in land use and atmospheric aerosol loadings.[4] They have also provided valuable information on climate change at the global to sub-continental scale.[5] Although we have seen significant improvements in these models, especially in the past decade, due to better representation of atmospheric and earth surface processes and enhanced computational capabilities, the horizontal resolution of most present day AOGCMs is still of the order of hundreds of kilometers. This prevents them from capturing the effects of local forcings (e.g. complex topography and land surface characteristics) which modulate the climate signal at fine scales. Coarse resolution also precludes global models from providing an accurate description of extreme events which are fundamental importance to users of climate information with respect to the regional and local impacts of climate variability and change.

Current AOGCM models show a vast array of possible outcomes for the tropical Pacific region in global warming scenarios (e.g., Fig. 10.16 of AR4).[6] A substantial number of models forecast an increase in variability about a mean El Niño-like warming. The strong 1997-98 El Niño—and to a lesser extent the 2009-2010 El Niño—had significant impacts on Pacific Island communities

such as water rationing, crop losses, job losses, wildfires, dry stream beds, and coral bleaching. These impacts were managed by advanced seasonal-to-inter-annual forecast information provided by the Pacific El Niño Southern Oscillation (ENSO) Applications Climate (PEAC) Center and other Centers coupled with a sustained program of outreach.[7] The events reinforce the need for an integrated, interdisciplinary approach to climate-risk management in the Pacific Islands.

Following the 2004 review of the PEAC Center, the Pacific RISA team, the National Weather Service (NWS) Pacific Region, and partners of PEAC including NWS Climate Predictions Center, NOAA IDEA Center, University of Hawai'i (UH), and the University of Guam, began joint planning for the emergence of the Pacific Climate Information System (PaCIS). The PaCIS mission is implemented via three working groups, including (I) Education, Outreach, and User Information Needs; (II) Operational Climate Observations, Products and Services, and (III) Research and Assessment. To translate research and assessment results into useful and usable climate information, services, and products, key priorities of Working Group III are to: implement an effective program of regional downscaling and local applications; expand understanding of the nature and consequences of climate extreme events in the Pacific region; and enhance resilience through an understanding of regional vulnerability and support for climate adaptation. To address these priorities, a research strategy and concomitant research activities are needed to balance and coordinate scientific responses.

Approach

Our approach is grounded in the PaCIS framework. PaCIS facilitates the development and implementation of research in the Pacific region because it provides a structure and coordination mechanism that leverages individual agency efforts through increased cooperation, collaboration, and the joint development of research priorities. Specifically, we address key priorities of PaCIS Working Group III (Research and Assessment); we do not address needs related to observations or monitoring because these are addressed via Working Group II (Operational Climate Observations, Products, and Services).

In accord with the goals and objectives of PaCIS and of the US Climate Change Science Program,[8] the strategy we present balances research across a range of science, risk and resource management, and science delivery actions aimed at developing ways of sustaining healthy island ecosystems for future generations. Three research elements serve as the organizing framework:

1. Research to Enhance Understanding of Regional Climate Risks and Consequences. This first element focuses on the analysis of extreme climate events, advancing downscaled models, developing databases on extreme climate events, understanding socio-economic, political, and cultural impacts and responses, and understanding local and traditional knowledge.

2. Research to Improve Decision Support and Risk Communication. The second element integrates information generated in the first research element by developing decision-support and risk-communication tools for policymakers, planners, and resource managers

at all levels wanting to better understand and convey climate impacts. This includes reducing uncertainties of future risks from diverse information sources.

3. Research to Improve Climate Adaptation Capacity. The third element focuses on developing and evaluating, along multiple physical and social dimensions, alternative risk and resource management approaches for adapting to a changing climate.

Although we present the three research elements separately, we acknowledge that they are in fact interrelated and overlapping. Despite the fuzzy boundaries, distinguishing the three elements provides a convenient way to describe emerging research goals. For each research element, we provide a series of specific examples of research activities. The illustrative examples are not intended to provide an exhaustive list of every possible research project, but rather to indicate the breadth and depth of needed activities.

Key Research Elements

Element 1: Research to Enhance Understanding of Regional Climate Risks and Consequences

Representative regional model guidance is needed to enhance understanding of regional climate risks and consequences. Currently, most long-term, global climate-change scenarios have been performed with atmospheric component models with effective horizontal grid spacings of ~200-300 km, a resolution too coarse to be directly applicable to most PICTs.[2] Some state-of-the-art global coupled models predict a wide range of basin-scale responses in the low latitude Pacific, varying from "El Nino-like" weakening of the east-west sea-surface temperature gradient to strengthening. The lack of resolution and wide-ranging responses can have profound effects on the patterns of projected rainfall changes.[9] Future research on the most likely climate-change scenarios should aim to make current global models of climate change more useful for regional adaptation planning through dynamical and statistical downscaling. Such research will help to provide new capacity for projecting climate impacts on land, ocean, and coastal areas linked to adaptation capabilities at PICT level. In addition to understanding the climatic processes and their environmental impacts, we need to analyze future health, economic, social, and cultural impacts, so that comprehensive adaptation programs can be developed. Although constantly changing and hard to quantify, nonphysical systems such as social, cultural, and economic factors strongly influence how individuals and societies cope with hazardous events.[10] Characterizations of the social dynamics of risk clarify for policymakers the factors that motivate societies in the face of environmental challenges such as climate variability and change. More precise, multi-dimensional information will help to improve evaluation of tradeoffs when examining alternative adaptive management options.

Element 1 Research Activities

Research activities to enhance understanding of regional climate risks and consequences need to focus on past risk events, analyzing trends and return levels of risks, elucidating the physical processes that drive local climate change and variability, downscaling to assess future local changes, and climate-society linkages.

a. Research is needed on the coupled atmosphere-ocean system to enhance our understanding of the impacts of long-term climate variability and change on Pacific Island populations, communities, and ecosystems at multiple spatial and temporal scales. Example activities include:

- Developing a database of extreme climate events for the Pacific island communities using data from various sources. For some sources, data may be only available in paper copies so considerable efforts shall be spent to digitize them. Development of innovative quality control procedures is needed to insure data homogeneity.

- Delineating climate risk assessment maps using different ways such as the percentile method or the expected event intensity for a given return period (using the generalized extreme value distribution).[11] Estimating event intensity changes as a function of time to accommodate for a non-stationary climate.

- Determining the trends of climate change indices using nonparametric tests because the underlying distributions of these indices are probably not Gaussian. Time-dependent changes in these indices will be investigated to understand whether, and to what extent, the long-term trends are stable or changing through time.

- Identifying possible abrupt shifts in the climate indices as changes may have occurred in a non-stationary background. This would lead to a better understanding concerning regime shifts at the decadal or longer time scales.

- Assessing, improving, and applying atmospheric regional and global models with a focus on issues of particular relevance to the Pacific region, including the representation of the atmospheric boundary layer and clouds over oceans in the tropics and subtropics.[12]

- Assessing, improving, and applying explicit high-resolution dynamical models and other partially statistical approaches to project changes in tropical cyclone climatology (frequency, location, and intensity) in an altered climate.[13]

- Assessing, improving, and applying global and regional coupled ocean-atmosphere-cryosphere models with a focus on representing and understanding the processes that lead to robust regional patterns of climate change in the Pacific region.[14]

- Developing models at multiple geographic and temporal scales, including the downscaling (dynamical and statistical) of global AOGOM models, that integrate data from multiple inventories, remote sensing, and observation sites to define the range of variability at local sites.[15]

- Characterizing the processes governing global absolute sea-level rise including volume changes due to temperature and salinity changes, as well as changes to glaciers, ice caps, and terrestrial water reserves in a changing climate.[14]

- Characterizing the processes governing local relative sea-level rise including those related to land movement, as well long-term trends and probability of exceedance of extreme water levels in a manner that accounts for non-stationary processes.[14]

- Determining important thresholds, tipping points, and transitions of ocean, coastal, upland, and inland ecosystems under alternative climate scenarios so that resource managers can anticipate those changes and plan accordingly.[2,15,16]

- Using projections of climatic conditions togther with stochastic hydrologic models to analyze drought patterns and to assess the sustainability of ground water resources.[2,17,18]

- Delineating climate risk assessment maps using different approaches such as the percentile method or the expected event intensity for a given return period (using the generalized extreme value distribution).[11]

b. Research is needed to enhance understanding of climate-society linkages in terms of the health, socio-economic, and cultural impacts of a changing climate for Pacific communities. Example activities include:

- Examining how climate-sensitive sectors (e.g., water resources, agriculture, transportation, tourism, and coastal resources) will be impacted by rising air and ocean temperatures, changes in rainfall patterns, and changes in coastal inundation and erosion and ocean acidification.[17,19-21]

- Analyzing the impacts of the changing climate on Pacific Islanders' terrestrial and marine resource use, livelihoods, and cultural traditions.[22]

- Analyzing patterns of emerging infectious diseases and other health risks to vulnerable population groups (especially those exposed to multiple hazards) using disaggregated data, focusing particularly on exposure pathways.[17,23]

- For PICTs, examining potentially nonlinear interactions between multiple socio-economic stresses (e.g., rapid and unplanned movement of rural and outer-island residents to major population centers, political instability, rising poverty and external debt, deteriorating or hazard-prone infrastructure) and ecosystem stresses (land-based pollution, invasive species, migration, etc) under a changing climate.[2]

- Identifying diverse models of connections between atmospheric processes and people (e.g., through narratives reflecting traditional or local environmental knowledge) and how socio-cultural factors affect perceptions of climate risks and willingness to take protective action.[24]

Element 1 Research Products

Near-term products resulting from research designed to enhance understanding of regional climate risks and consequences might include the following:

a. A review of basic, physical, climate-change science issues in the Pacific Islands which could be included in the Intergovernmental Panel on Climate Change Assessment Report V (IPCC AR5)

b. Guidance on long-term climate changes expected in the region, based on high-resolution dynamical and statistical downscaling and model simulations.

c. Analysis of current trends and patterns of extreme events (weather and climate) and how these might be changing in a changing climate.

d. Analysis of climate risk maps to reveal the areas where risks are historically high and their expected return periods.

e. Integrated assessments of climate impacts on coupled natural-human ecosystems to determine vulnerabilities across various spatial and temporal scales.

f. A concise, approachable, and authoritative synthesis of what is known, uncertain, and unknown regarding potentially nonlinear interactions between multiple socio-ecological stresses on small-island developing states.

g. A survey of diverse community members to provide a characterization of alternative understandings of climate processes and their impacts and key socio-cultural factors affecting societal those understandings and likely responses.

Element 2: Research to Improve Decision Support and Risk Communication

Decision-support and risk-communication research is aimed at determining what information needs, products, and services to be provided when and what methods of information integration are most reliable and valid. Such research supports policy, planning, and resource management by promoting decision-making and communication strategies based on an integration of the best available science with a well-articulated understanding of community values and preferences. Products of this research should aim to translate available scientific information into useable adaptive management options. This research must be planned in response to specific decision-support and risk-communication needs expressed by the user communities in the Pacific region.

Element 2 Research Activities

Research activities to improve decision support and risk communication need to focus on developing models, evaluating tools, and examining the intersection of different types of knowledge.

a. Developing multi-system models (including environmental, economic, health, social, and cultural information) that integrate linkages among climate and other stressors for decision making in resource management (water, land use, wildlife, marine). Example activities might include:

- Analyzing past and current extreme climatic events (e.g., high seas, storms, heavy rain, drought) to provide information to support scenario development for coastal land-use planning and resource management, for establishing infrastructure (e.g., roads, water, and sewer) design criteria and validating physical and hydrological models.[14,20]

- Developing various climate-change scenarios based on downscaled dynamical or statistical climate models as input for decision-support systems at a local level to examine how to increase and maintain the sustainability of island ecosystem services (water supplies, wildlife and fish populations, endangered species, etc.) under a changing climate.[15,22]

- Examining Bayesian analysis as a framework for distilling uncertainties by incorporating diverse information sources such as historical observations, model simulations, and subjective beliefs to come up with the best estimate of the parameter of interest.[25,26]

- Improving and expanding the application of existing and future decision-support tools for identifying and prioritizing risks, for example by using environmental, socio-economic, and cultural information to enhance early alerts for health threats.[16,23]

b. Improving understanding of the strengths and limitations of decision-support and risk-communication tools, for example by:

- Quantifying the uncertainty in estimates of future change in resources to support risk analyses and build risk estimates into management strategies.[2,15]

- Enhancing understanding of the differences among (and challenges of) various approaches and techniques for modeling storm inundation for Pacific Islands to improve risk managers' decision making about how to increase resilience to storm surge and high surf.[27]

- Developing case studies of specific weather and climate events (e.g., Typhoons Chataan and Isa, 1997-1998 drought, and Hurricanes Ofa and Val) to examine how meteorological services operated during these events and determine the strengths and weaknesses of their early warning decision processes under conditions of uncertainty, especially across political jurisdictions.[16]

- Analyzing the information supply that supports the regional climate information system and meets the stakeholder demand for the information.[16,21]

- Developing and evaluating metrics of the effectiveness and acceptability of alternative science delivery mechanisms and modes of communication (e.g., video conferencing, webinars, face-to-face) among scientists and diverse stakeholders (e.g., resource managers, private landowners, policy makers, community groups) attempting to develop and implement adaptation strategies collaboratively.

c. Examining the intersections of scientific, traditional, and local knowledge, identifying points of convergence and divergence that facilitate or impede decision making and risk communication. Example activities might include:

- Examining how the use of several indicators from climate science and traditional and local knowledge can be used together to increase confidence in forecasts of climatic conditions, particularly in places where there is limited scientific or instrumental data.[28]

- Evaluating the value of scientific, traditional, and local approaches to predicting weather and climate, as measured by improvements in health or more efficient use of resources.[20,23]

- Developing interdisciplinary methods to examine how traditional or local knowledge can be used to improve resource management (e.g., for examining how the Ahupua‘a Resource Management System combines science with traditional Hawaiian knowledge and practices to optimize use and conservation of resources).[2,20]

- Analyzing the kinds of information, dissemination methods, and participatory approaches that are most effective in engaging diverse decision makers in a regional climate information system.[17]

Element 2 Research Products

Near-term products resulting from research designed to improve decision support and risk communication might include the following:

a. Quantitative and qualitative tools to assist in the analysis of the environmental, economic, health, social, and cultural impacts of climate variability and change on Pacific Islands' socio-ecological systems.

b. Data sets that can be used by multiple government agencies and other organizations as input into local models or to generate information (e.g., for newsletters).

c. Educational tools (courses, workshops, manuals, models) for resource managers and policymakers, teaching the principles of climate science in a Pacific Island context and its applications to planning and managing sustainable island ecosystems under a changing climate.

d. New tools for integrating scientific information with traditional and local knowledge about climate processes and impacts and optimal responses.

Element 3: Research to Improve Climate-Adaptation Capacity

The efficacy of current risk- and resource-management practices in the Pacific Islands under a changing climate will depend on the nature of climatic changes, the resilience and vulnerability of social and ecological systems to those changes, and the adaptive capacity of the systems.

Developing effective adaptation capacity requires research that elucidates the strengths, weaknesses, and unintended consequences of alternative programs in the context of sustainable island development.

Element 3 Research Activities

Research activities to improve climate-adaptation capacity need to focus on developing assessment techniques and conducting integrated evaluations.

a. Developing robust methods and tools for assessing distinct quantitative and qualitative components of diverse adaptation strategies. Example activities might include:

   - Determining standardized methods for representing uncertainty, the relative value of future benefits (e.g., discounting) of adaptation programs, and the achievement of equity. These methods could be used to assess the costs and benefits of investing in various adaptation strategies at the regional or local level.

   - Developing tools for analyzing the cost-effectiveness and social acceptability of alternative management and adaptation options at a local scale, taking into account the uncertainty and extended timeframes associated with climate change.[2,17]

   - Identifying best practices for assessing environmental, economic, health, social, and cultural impacts from adaptation policies (such as increasing use of wastewater in the agriculture and water sectors).[23]

b. Conducting multi-dimensional, integrated evaluations of alternative adaptation programs, using the methods and tools described above. Example activities might include:

   - Improving estimations of the contribution of climate change to the burden of mortality and morbidity, with greater attention to mechanisms such as the effects of population displacement or food and water insecurity and the degradation of other ecosystem services.[23]

   - Analyzing the capacity and availability of resources for responding to climate-related events (e.g., inundation, drought) at a local level to minimize impacts and the subsequent need for external post-disaster assistance.[17,27]

   - Identifying the unintended consequences of policies and management strategies (e.g., the impacts of armoring shorelines with sea walls and levees) embedded in adaptation plans.[27]

   - Evaluating climate adaptation law and policy implications using place-based legal and decision analyses that accommodate the continual, unpredictable, and nonlinear transformation of complex ecosystems.[20,29]

Element 3 Research Products

Near-term products resulting from research designed to improve Pacific Island climate adaptation strategies might include the following:

a. Enhanced quantitative and qualitative methods and tools for assessing environmental, economic, health, social, and cultural impacts of alternative climate adaptation strategies on Pacific Islands' socio-ecological systems.

b. An integrated strategic evaluation of local, regional, and national policies and management and adaption actions for Pacific Islands, including a concise, approachable, and authoritative synthesis of what is known, uncertain, and unknown regarding Pacific Island climate adaptation plans.

c. A systematic evaluation of the effectiveness of environmental and health interventions and risk communication strategies for dealing with climate-sensitive health risks, over a range of contexts, and whether they will be compromised by a changing climate.

Infrastructure, Scientific Collaboration, Science Delivery

A coordinated partnership is required to support the infrastructure, scientific collaboration, funding requests, and science delivery needs of a regional research strategy in the Pacific. While there is already considerable collaboration and communication among scientists and stakeholders in the Pacific region, high priority needs must still be met to facilitate and improve collaborative studies. Determining how to effectively coordinate data collection, consolidation, and formatting for analysis and modeling is key because good data are the basis for developing a comprehensive understanding of climate processes and impacts. Also critical is a virtual forum that highlights opportunities for research funding and training and for collaboration on research projects, with a focus on developing island states that are most vulnerable to climate impacts and have the weakest research capacity. The research activities and products described above will help to determine what types of partnerships work best for whom, when, and why. In-depth analysis of what has worked in the past and iterative pilot testing of new approaches for the future are key elements for determining how to build, maintain, and grow a research strategy for the geographically and culturally diverse region of the Pacific. PaCIS is well positioned to coordinate research activities in the Pacific given its diverse domestic and international partners representing state and federal government agencies, non-governmental organizations, and community groups. Place-based, collaborative, stakeholder-driven activities are the cornerstone of PaCIS and form the context in which a research strategy for Pacific Islands needs to be developed and refined.

A successful research strategy will need to follow certain guiding principles that accommodate the diverse people, cultures, and histories and the significant environmental, health, and socio-economic challenges faced in the Pacific context. First, research activities require early and continuous partnership and collaboration with climate-information providers and service users. Trust and credibility needs to be built over the long-term, with sustained face-to-face contact and using existing institutions and trusted information brokers. Project topics must reflect historical

events, patterns, and trends, traditional knowledge and practice (projects translated into local dialects and languages), and provide useful and usable information appropriate to the intended decision makers. Finally, constraints such as political and institutional boundaries and challenges such as communication in remote locations need to be addressed.

Conclusion

The significant and increasing challenges from climate variability and change, in concert with population, socio-economic, and environmental pressures, mean that now more than ever before Pacific Island communities need to enhance and build climate variability and change adaptive capacity. This synthesis and summary presents a research strategy that directly addresses the needs of Pacific Island resource managers, researchers, and policymakers at all levels. As such, we envision the strategy will contribute to stakeholder capacity for building sustainable island communities for future generations. In this paper we provide a "categorized menu" of emerging research goals and illustrative activities. The next step requires researchers, policymakers, and community groups to rank the goals and activities according to their priorities, bearing in mind there is no 'silver bullet' to addressing in full the research needs of Pacific communities. Systematic research programs to manage climate hazards involve a range of inter-related research activities. Managing climate risks is a journey, not a destination, Building local adaptive capacity is a critical component in this journey.

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