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CONSEQUENCES OF CLIMATE VARIABILITY AND CHANGE FOR PACIFIC ISLAND WATER RESOURCES: CHALLENGES AND OPPORTUNITIES

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1. INTRODUCTION

"For Pacific Island states, climate change and its associated effects are our main security concern."

Leo A. Falcam, President of the Federated States of Micronesia,
HONOLULU ADVERTISER, August 12, 2001.

President Falcam's words highlight the importance that Pacific Island governments, businesses and communities place on dealing with changes in climate. In this context, they are as concerned with reducing vulnerability to today's patterns of climate variability as they are with planning for a future that is being shaped, in part, by long-term climate change associated with greenhouse gas emissions. Changes in climate matter in the Pacific:

- Year-to-year variability in the climate system – most notably the El Niño-Southern Oscillation (ENSO) cycle – has significant consequences;
- Climate processes in the Pacific Ocean are key to year-to-year variability and will play a central role in determining the nature and consequences of long-term climate change;
- Pacific Islands and coastal communities are considered among the most vulnerable in assessments of climate change;
- Economic plans for Pacific Island nations are dependent on climate-sensitive sectors and resources; and
- The Pacific Region is rich in biodiversity and unique ecosystems.

This paper provides an overview of a recent effort to assess the consequences of climate variability and change for a number of Pacific Island jurisdictions conducted as a regional contribution to the first U.S. National Assessment of the Consequences of Climate Variability and Change (National Assessment). The National Assessment was organized by the agencies contributing to the U.S. Global Change Research Program and the White House Office of Science and Technology Policy. The Pacific Assessment was funded through a grant from the National Science Foundation (NSF Grant OCE-9907547) with support from NSF, the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA) and the U.S. Department of the Interior.

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2. PACIFIC ISLANDS REGIONAL ASSESSMENT

The Pacific Islands Regional Assessment of the Consequences of Climate Variability and Change (Pacific Assessment) was designed to explore how and why changes in climate matter to the peoples of the American Flag and U.S. Affiliated Pacific Islands (the State of Hawaii, American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, the Republic of the Marshall Islands and the Republic of Palau). The final report of the Pacific Assessment entitled "Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change for Pacific Islands" is available on-line at http://www2.EastWestCenter.org/climate/assessment

The Pacific Assessment was an exciting and highly interactive process involving over 200 participants engaged in research, focused discussions and two major workshops designed to support two, mutually supportive objectives:

- Develop a more complete understanding of the regional consequences of climate variability and change for Pacific Island jurisdictions in light of existing social, economic and environmental stresses; and

- Support a dialogue among scientists, governments and communities in the Pacific region that promotes the use of climate information to support decision-making.

The Pacific Assessment process responded to the findings and recommendations of a March 1998 Workshop on the Consequences of Climate Variability and Change for the Hawaii-Pacific Region conducted at the East-West Center in Honolulu, HI. Participants in the Pacific Assessment then re-convened in November 2000 for a Workshop on Climate and Island Coastal Communities which reviewed the results of the two-year research effort and provided an opportunity for representatives of Pacific and Caribbean Island communities, businesses, governments and NGO's to review the findings of the Pacific Assessment analytical studies and further explore options for responding to the challenges and opportunities presented by climate variability and change.

3. FOCUS ON VULNERABILITY

The Pacific Assessment focused on an exploration of climate "*vulnerability*" with an emphasis on enhancing resilience or adaptive capacity. In this context, the Pacific Assessment used a definition of "vulnerability" developed by Clark et al (2000) which focuses on vulnerability as a "multidimensional concept involving at least

- *exposure* – the degree to which a human group or ecosystem comes into contact with particular stresses;
- *sensitivity* – the degree to which an exposure unit is affected by exposure to any set of stresses; and
- *resilience* – the ability of an exposure unit to resist or recover from the damage associated with the convergence of multiple stresses.

By focusing on the identification of appropriate response options, the Pacific Assessment process was able to engage experts from all walks of life in a process of shared learning and joint problem solving.

Pacific Assessment research, modeling and dialogue activities addressed climate-related challenges and opportunities in six key areas: providing access to fresh water; protecting public health; ensuring public safety and protecting community infrastructure; sustaining tourism; sustaining agriculture; and promoting wise use of coastal and marine resources. In all of these areas, the Pacific Assessment highlighted the need to understand and address the consequences of both long-term trends – such as changes in sea level – and shorter timescale patterns of natural climate variability with particular attention to climate-related extreme events such as tropical cyclones, droughts and floods. Model-based climate projections used in the Pacific Assessment highlighted the following changes:

- A *general warming trend* (1.3°C by 2034; 2.6°C by 2099 in the fastest warming areas);
- *Changes in precipitation* with some areas drier despite a general trend toward enhanced rainfall in the region;
- *Changes in natural variability*, including the possible emergence of "persistent El Niño-like conditions" with significant regional implications;
- *Increased ocean temperatures* with implications for sensitive ecosystems (e.g., coral reefs) and marine resources such as fisheries;
- *Potential changes in tropical storm patterns* (due to increased sea surface temperature and changes in the El Niño-Southern Oscillation (ENSO) cycle); and
- *Changes in sea level* including both long-term trends and periodic changes associated with ENSO.

Consistent with the guidelines for the National Assessment, these projections of climate change over the next 100 years were based on the results of two coupled ocean-atmosphere models: the first generation coupled general circulation model of the Canadian Center for Climate Modeling and Analysis (CGCM1) and a similar general circulation model used by the United Kingdom's Hadley Centre for Climate Prediction and Research (HADCM2). Both runs used the core scenario for the National Assessment which is a 1% rate of annual increase in carbon dioxide and sulfur aerosols (the GHG+A scenario.

4. PROVIDING ACCESS TO FRESHWATER RESOURCES

As one participant in the March 1998 Workshop noted, "Water is gold." Water's value is even greater in island settings where surface water is limited if it exists at all, aquifers are small and fragile and potable water may be available only from rooftop catchment. Given the precarious state of island hydrological systems, climate change or protracted anomalous conditions can have extreme effects on water supply. For example, during the 1982-83 ENSO warm event, Majuro's reservoir held 6 million gallons (Mgal) on January 1. By January 17, the water dropped to 4.8 Mgal. By May 1983 total storage had dwindled to 0.8 Mgal, most of which was being reserved for the hospital (Republic of the Marshall Islands, 1999). Similarly, during the 1997-98 ENSO warm events, all islands in the North Pacific experienced a rainfall deficit and water managers were forced to ration municipal water supplies. The Marshall Islands again suffered the most extreme water shortages. At the height of the drought, municipal water on Majuro was only available for seven hours every fourteen days.

The problems of limited water supply are intensified by increasing demand for water. Population growth rates in some Pacific Islands are quite high. The Northern Marianas, for example have an estimated annual population growth rate of 5.6%. The Marshall Islands are estimated to grow at a rate of 4.2% per year and American Samoa at 3.7% (Secretariat for the Pacific Community, 2000). Further, domestic and international migration has contributed to the rapid growth of urban centers throughout the region. If the habitability of small islands and atolls is threatened by environmental change, migration to urban centers and high islands is likely to increase even more.

In addition to population pressure, economic development throughout the region also presents new demands on water resources. Tuna processing plants in American Samoa, for instance, require tremendous amounts of fresh water daily. Tourism, the premier industry in many island economies, is also water intensive. The island of Guam, for instance, had 8,119 hotel rooms in 1997. The hotel occupancy rate for that year was 82% (Osman, 1999). This suggests that on any given day, Guam's water supply supported 6,650

visitors, roughly 4.4% of Guam's population in 1997. The maintenance of golf courses, a popular tourist attraction, places additional pressure on precious local water resources. On several islands, disputes over access to limited water supplies have divided communities and entangled state agencies, private industries and local communities in lengthy legal battles. On some islands, water availability is the major problem, while on other islands distribution is the focus of disputes.

Long-standing institutional arrangements for managing water are challenged to adapt to the combined pressures of dwindling supplies and increasing demands. The search for alternative water supplies continues in earnest with research and development into desalinization projects (such as reverse osmosis systems). After the 1997-1998 ENSO warm event, the islands of Saipan, Majuro, Yap and Palau all made significant improvements in water storage and delivery systems. These initiatives have been complemented by efforts to reduce demand and promote efficient water use; new legislation in CNMI, for instance, imposes fines for wasting water. Water management institutions, whether based on traditional arrangements or administered by municipal, territorial or state agencies have already benefited from climate information in their efforts to predict water supply and demand and allocate water supplies.

4.1 *Enhancing Resilience to Climate Variability and Change*

Pacific Assessment discussions reinforced the importance of addressing the adequacy and long-term stability of on-island water resources. They highlighted the importance of effects on freshwater resources as an underlying factor in determining the consequences of climate variability and change for most of the activities addressed in the Assessment. During the November 2000 workshop, for example, the importance of understanding climate-related changes in freshwater resources was seen as particularly central to: agriculture (including subsistence farming and fishing as well as commercial activities such as cash crops and the use of water in fish processing and transshipment facilities); personal consumption/domestic use of water; tourism and other commercial uses of water; public health, and the maintenance of natural ecosystems. Exploring issues related to the competition for this limited resource among these various uses can be as important as understanding the effects of climate variability and change for any of them individually.

There are a number of Pacific Island characteristics that will influence the effects of climate on freshwater resources, including:

- Island type, most notably the differences between high islands with greater groundwater and surface water assets and low islands with limited freshwater lenses and very little (if any) groundwater sources;
- Demographics, including population growth, overseas immigration and emigration and internal migration out of smaller communities in more remote, low-lying islands and atolls and into urban centers;
- Remoteness, which is related to the population issues described above and to distance from potential sources of freshwater during emergencies;
- Access to technology, including issues related to acquiring new technology and the capabilities to maintain existing or new facilities;
- Economic activity, including the reliance on water-intensive industries like tourism, agriculture and fisheries as dominant sources of national income; and
- Social and cultural characteristics, including issues related to land tenure and resource management.

Despite these differences, Pacific Islands also share a number of common characteristics that affect their ability to respond to the effects of climate variability and change on freshwater resources. Pacific Islands, for example, share a general reliance on rain-fed sources of freshwater (whether groundwater, surface water or rainfall catchment systems). This reliance on rainfall makes Pacific Islands particularly sensitive to climate extremes like prolonged droughts. A reliance on a combination of freshwater sources imposes a variety of requirements related to water quality and treatment. Pacific Islands are experiencing increasing development and population pressures that are reflected in land use changes, which affect water quality and overall quantity. Storage capacity and water distribution systems in Pacific Islands are already stressed; while some improvements (like fixing leaks in distribution pipelines) may be relatively easy to do, major improvements to water resource infrastructure in some Pacific Islands may require substantial economic investments. On many Pacific Islands, much of the water distribution infrastructure is old and needs to be replaced. It is estimated, for example, that water and wastewater improvements on Guam could exceed $250 million. As is the case in all of the activities discussed during the Pacific Regional Assessment, addressing these basic infrastructure concerns is an important first step in responding to the consequences of climate variability and change (as well as other stresses on Pacific Island water resources).

Discussions of options for enhancing the resilience of Pacific Islands to climate-related stresses on freshwater resources focused on responding in three categories:

natural systems (surface and ground water, watersheds, wetlands, near-shore waters); human and institutional systems (including urban centers, rural communities, government agencies and regulatory regimes) and specific economic activities (e.g., agriculture, tourism, fish processing, domestic use/personal consumption). Table 1 summarizes key recommendations in each of these areas.

5. RESPONDING TO THE CHALLENGES OF CLIMATE VARIABILITY AND CHANGE

Whether their primary interest was in coastal management, water resources, public health and safety or any of the other sectors addressed in the Pacific Assessment, the participants highlighted a number of shared principles designed to enhance the resilience of Pacific Islands to climate variability and change. These principles are described briefly below.

First, the Pacific Assessment points to the **importance of being proactive** in climate adaptation and mitigation efforts. Some of our colleagues from the Federated States of Micronesia encouraged the adoption of the local concept of "meninkairoir" or taking the long view and thinking several generations ahead when evaluating today's decisions.

Secondly, the Pacific Assessment points to the value **of using climate information to meet today's needs as well as to support planning for the future**. A related recommendation encourages Pacific Island governments and communities to place a high priority on **addressing current constraints on critical infrastructure** such as water, sanitation, transportation and public health systems.

The Pacific Assessment, like other recent climate assessment efforts, points to the importance of **planning for extreme events** as an important aspect of enhancing resilience in the face of climate variability and change. Participants in the Pacific Assessment pointed to the importance of pursuing comprehensive emergency management programs as a way to improve current capabilities to respond and reduce long-term vulnerability to climate-related extreme events such as hurricanes, droughts and floods.

The Pacific Assessment points to the value of a strong **program of education, outreach and dialogue** designed to enhance public awareness and support a sustained, participatory process to understand and respond to the challenges and opportunities presented by climate variability and change.

Finally, the Pacific Assessment calls for the **adoption of flexible management approaches** that **integrate climate information into decision making** in a regular and sustained manner. Meeting this challenge requires the development and application of useful and usable climate forecast, assessment and information products specifically designed to meet information needs identified by user communities. It also will require strong and sustained partnerships in climate observations, modeling, research, forecasting, assessment and information management that combine the unique capabilities and special responsibilities of individuals and institutions at international, regional, national and local levels. Together, these partnerships will help create a new climate information system that more effectively links climate science with decision-making and policy formulation. Figure 1 represents the Pacific Assessment's conceptual view of such a regional climate information system designed to incorporate science and broad-based collaboration in public decision-making.

6. REFERENCES

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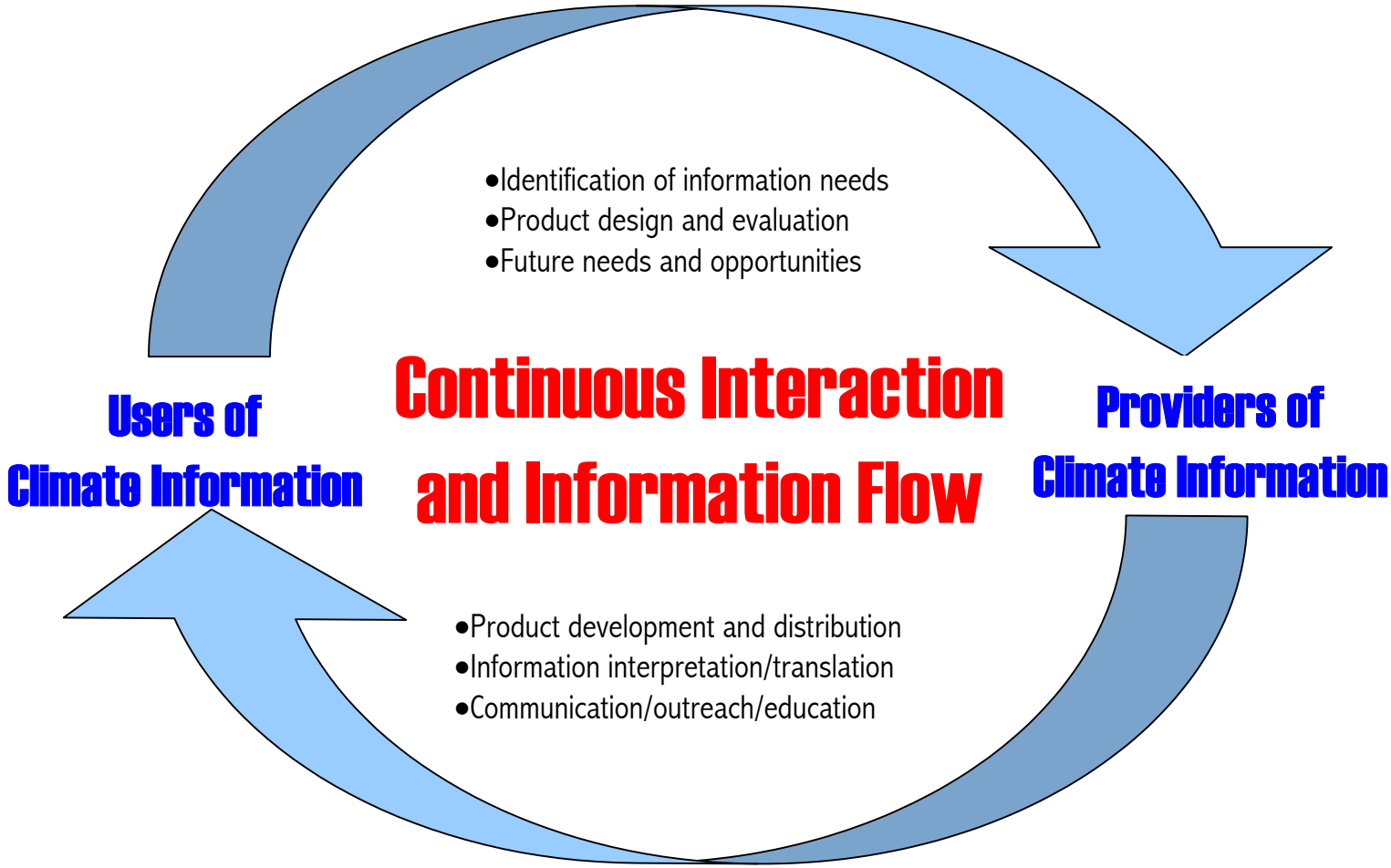
Table 1 Enhancing Resilience of Pacific Islands to Climate-Related Stresses on Freshwater Resources	
Natural Systems	Watershed Protection and Restoration
	Water Conservation, Recovery and Re-use
	Integrated Water and Land Use Management
	Evaluation of Existing Assets (from all systems)
	Developing Unused/Alternative Sources
Human and Institutional Systems	Improve Infrastructure and Increase Capacity
	Explore Traditional and Customary Practices for water resource management
	Long-term Planning Emphasizing Self-Sufficiency
	Wastewater Recovery, Treatment and Re-use
	Promote Water Conservation
	Review Permit and Regulatory Regime
	Use Climate Forecasts and Information in Decision- Making—Establish Targeted Climate Information System (building on examples like PEAC)
	Improve Climate and Water Resource Monitoring (including socio-economic data)
	Address Population and Demographic Issues
	Promote Education and Awareness
Economic Activities	Provide Economic Incentives for Water Conservation, Recovery and Re-use
	Plan for Extremes (particularly droughts)
	Develop Public-Private Partnerships especially among Large-scale Users (including the Military)
	Develop Businesses Targeted at Water Resource Management Systems
	Use Climate Forecasts and Information in Decision- Making
	Promote Public Awareness and Conservation (e.g., in hotels and restaurants)
	Promote Information Exchange and Dialogue

Conceptual Model of a Pacific Climate Information Service



Assessment as Continuing Process of Shared Learning and Joint Problem Solving (Shea, 2001)