The Pacific ENSO Applications Center and the 1997-98 ENSO Warm Event in the US-Affiliated Micronesian Islands: Minimizing Impacts through Rainfall Forecasts and Hazard Mitigation

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The Pacific ENSO Applications Center

In August 1994, the Pacific ENSO Applications Center (PEAC) was established as a pilot project to provide ENSO (El Niño-Southern Oscillation) forecasts and information products to the US affiliated Pacific Islands. The University of Guam, the University of Hawaii, the Pacific Regional Office of the US National Weather Service, the US Office of Global Programs (NOAA), and the Pacific Basin Development Council developed PEAC as a joint venture to serve American Samoa, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, Guam, Hawaii, the Republic of the Marshall Islands, and the Republic of Palau.

PEAC has consisted of two clusters of coordinated research and applications activities. The research effort has been aimed primarily at developing statistical rainfall models and synoptic climatologies for the jurisdictions PEAC serves. The Office of Global Programs had originally assumed that experimental forecasts based on coupled ocean-atmosphere models developed at Scripps, Columbia University, Florida State, and other academic institutions could be translated into simple information products to communicate and explain the model forecasts and to educate information users. However, the spatial resolution of large-scale models used widely by climate researchers and modelers did not meet the needs of the people the Center was intended to serve.

PEAC directed its research effort at the development of canonical correlation analysis (CCA) models. These would allow the Center to forecast rainfall on specific islands using historical rainfall data. Two CCA models were developed in close collaboration, one by Tony Barnston and Yuxiang (Luke) He at the Climate Prediction Center (CPC) within the National Weather Service, and the other by Chip Yu at the University of Hawaii at Manoa. Chip Yu worked closely with Tony and Luke at CPC, Alan Hilton, PEAC's public information and education officer, and Tom Schroeder, now the Director of the Joint Institute for Marine and Atmospheric Research.

During the first stages of the pilot project, Chip Guard and his colleagues at the Water and Environmental Research Institute (WERI) at University of Guam began developing synoptic climatologies for the Micronesian Islands. They spent the first year (1996-97) of their effort focusing on Guam and the Northern Marianas. In the second and third years, the emphasis shifted to the Federated States of Micronesia, the Republic of the Marshall Islands, and the Republic of Palau. Chip Guard, Mark Lander, and Leroy Heitz, of WERI, published simple guides that describe rainfall and tropical cyclone activities expected under "normal," El Niño, and La Niña conditions. Chip Guard wrote the meteorological portion of the newsletter, which was developed as part of PEAC's public information and education program.

Development of the public information and education program involved extensive collaboration and work throughout the Pacific. Alan Hilton and Mike Hamnett, at the University of Hawaii and the Pacific Basin Development Council developed the public information and education program in collaboration with Chip Guard and Leroy Heitz at WERI. They conducted workshops, focus group meetings, and local briefings about ENSO in all of the client jurisdictions during 1995 and 1996. PEAC staff also made presentations at regional meetings organized by a wide-range of organizations: the Pacific Basin Development Council; Pacific Regional Office of the US National Weather Service; the South Pacific Regional Environment Programme; the South Pacific Programme Office of what is now the UN Office of the Coordinator of Humanitarian Affairs; the Pacific Caucus of Emergency Managers; the Pacific Basin Coastal Zone Conference; the World Meteorological Organization Regional Area V; and, other organizations and conferences. The information included a background discussion of the formation and history of ENSO cycles and overview of PEAC, which had been envisioned as a means to provide end-to-end climate forecasts.

From these briefings, PEAC identified the concerns of participants on potential impacts of El Niño and La Niña events, and elicited information about the specific kinds of ENSO forecast information needed. The clients also identified the type of forecast information that they could use. PEAC compiled a mailing and contact list of agencies, individuals, private sector interests, and organizations that would find forecast information useful.

Alan Hilton developed the *Pacific ENSO Update* newsletter and corresponding website. The newsletter, which has been published and distributed in hard copy and on the website four times a year beginning in August 1996, became PEAC's primary information dissemination vehicle.

In addition, PEAC assisted Tony Barnston and Luke He at the Climate Prediction Center in developing a rainfall atlas, *A Precipitation Climatology for Stations in the Tropical Pacific Basin: Effects of ENSO*, which was published in February 1998. The atlas provides analyses of rainfall for sixty-six stations throughout the Pacific Islands region using data for the period 1955-1996. For each station rainfall histories are graphed, and mean monthly rainfall amounts for "normal," El Niño, and La Niña years are presented in a variety of forms. Significant support for the publication of the atlas was provided by the US Department of the Interior through the National Weather Service Pacific Region.

Initial financial support for PEAC came from the Office of Global Programs (OGP) at the National Oceanic and Atmospheric Administration, because of their interest in the feasibility of providing end-to-end climate information. One grant was made to the Joint Institute for Marine and Atmospheric Research (JIMAR) at the University of Hawaii to support the Canonical Correlation Analysis model development and to involve Tom Schroeder and other researchers at the UH School of Ocean Earth Sciences and Technology.

OGP provided a separate grant to the Pacific Basin Development Council. This grant supported the applications work conducted by Alan Hilton and Mike Hamnett for PEAC and development of synoptic climatologies at the Water and Environmental Research Institute (WERI) at the University of Guam. There were also substantial in-kind contributions made by the participating institutions, including the US National Weather Service. Year three and year four funding was provided by OGP for the applications division. The US Department of the Interior (DOI), through Office of the US National Weather Service Pacific Region, has covered funding for Ray Tanabe from the School of Ocean and Earth Sciences and Technology to maintain the website and edit the newsletter. DOI has also provided funding for Cheryl Anderson of the JIMAR and the Social Science Research Institute (SSRI) to work on the ENSO impact assessments.

DOI and the National Weather Service have supported Climate Prediction Center participation. The applications division also received assistance from Dr. Mark Morrissey of the Environmental Verification and Analysis Center (EVAC) at the University of Oklahoma, who temporarily took over editorial responsibilities for three issues of the *Pacific ENSO Update* when Alan Hilton returned to sea duty in April 1998.

PEAC and the 1997-1998 El Niño

In February 1996, PEAC began discussions with the Office of Global Programs about continued funding for PEAC. OGP requested that PEAC attempt an assessment of the value of the information provided to the islands we served. PEAC staff said jokingly that if OGP were willing to fund an El Niño, the staff could probably conduct the analysis. Otherwise, it would only be possible to ask hypothetical questions about the value of our forecast information in a survey of those who received the newsletter.

In February and March 1997, several of the coupled atmosphere-ocean models that we consulted on a regular basis indicated the development of an El Niño warm event. By

May, it was clear that an ENSO event was developing very quickly. PEAC began alerting our clients through the *Pacific ENSO Update*. As PEAC staff tracked the model analysis, they informed government officials that drier than normal conditions could be expected beginning in late 1997 and running through May or June 1998.

Getting the Word Out: ENSO Briefings and Forecasts

Officials on Guam requested more specific information. They wanted to know how much rain they could expect. Chip Guard from Water and Energy Research Institute (WERI) at the University of Guam produced rainfall forecasts in terms of percent of normal rainfall for three-monthly seasons and provided those to the Guam and the Commonwealth of the Northern Mariana Islands governments. WERI subsequently produced rainfall forecasts and provided these quantitative rainfall forecasts for the Republic of the Federates States of Micronesia (FSM) and the Republic of Palau at their request. By October 1997, PEAC issued the first quantitative rainfall forecasts in the *Pacific ENSO Update*.

Determining the rainfall forecasts for the Republic of the Marshall Islands (RMI) presented a problem for PEAC. Previous studies and analyses indicated that the risk of typhoons increased for the eastern islands of FSM and RMI during an El Niño as the area of ocean cyclonogenesis shifted to the east and expanded the area of "warm water" over which the typhoons could travel gaining strength and momentum. But, historically, during some ENSO warm events, Majuro and Kwajalein were wetter than normal, and during other El Niños they were drier than normal. Chip Guard and Mike Hamnett decided to go with a qualified drought forecast because of the strength of this event and because past strong ENSO warm events shifted the area of the Pacific that gets wetter than normal during an El Niño to the east of the Marshalls.

In September 1997, Chip Guard and Sharam Koshrapanan of WERI began government briefings on the impending drought. In October, Chip went to Palau, and, in November, he went to the Federated States and Marshall Islands. Briefing sessions were organized, and Chip reviewed the forecasts PEAC had developed and suggested that governments begin preparing to respond immediately. The personal briefings were later identified as a key component of issuing the forecasts, gaining and understanding of the situation, and motivating people to action.

Chip encountered some difficulties in conveying the severity of the expected drought impacts. It rained during the briefings in several jurisdictions, which minimized the impact of the seriousness of the drought threat. There were skeptics about PEAC's ability to forecast rainfall six to twelve months in advance. Some people even told Chip that it was for "God to know if a drought was coming, not for man to know." Nevertheless, El Niño, or drought, task forces were established in all jurisdictions served by PEAC.

Public InformationCampaigns

In Yap, Federated States of Micronesia, a drought task force was in place before the PEAC onsite briefings. It had been organized in response to the forecast in the *Pacific ENSO Update,* and Chip was able to reinforce the message being conveyed by the public information program that the task force had developed. The other jurisdictions, the Republic of the Marshall Islands, the state and national levels in the Federated States of Micronesia, the Republic of Palau, and Guam developed similar task forces and mitigation plans, which included water conservation plans and extensive outreach and educational programs into all of the communities and villages on the islands. The task forces maintained weekly contact by using PEACESAT satellite teleconferencing, where Chip could regularly inform them of updates and provide technical information through WERI, such as specific catchment design requirements and estimates of water needed per person to withstand the drought.

The drought task forces mounted public information campaigns to inform the public about what to expect from this El Niño. They shared information on measures that could be taken to conserve water and prevent outbreaks of water-related diseases. They explained the increased wildfire risk and what could be done to reduce it, and informed the people about new regulations resulting in fines for trash burning and any other unnecessary fire.

In Pohnpei State, a video was produced and aired on the public television station four times a day from early January through May. Agencies represented on the task force established a hotline, developed brochures, aired public service announcements on local radio and television stations, and made presentations on El Niño and the drought in schools. On Pohnpei, a US Geological Survey staff person composed a song about El Niño for the video. The song became a local hit and was played frequently on the local radio station. Residents of Pohnpei jammed the hotlines with requests about where to purchase the "hit single," and responded to operators that they already knew about El Niño. Pohnpei State even created a sign in three languages saying, "El Niño is Here," to provide a continuous visual alert.

Water Conservation

Water management agencies in Majuro, Pohnpei, Yap, Palau, Guam, and Saipan developed conservation plans, and, in some areas, developed and updated schedules for water hour schedules as the droughts progressed, based on the PEAC forecast. In Palau, the Department of Public Works surveyed the water distribution system in Koror and completed repairs on about 80 percent of the system before the onset of the drought. Throughout the FSM, people repaired water catchment systems. In Yap, local vendors were able to supply new household catchment tanks to meet the demand that developed in response to the public information campaign. In the Marshalls, local hardware and building supply companies ordered new catchment tanks, but, unfortunately, they did not arrive until after the drought was underway.

Call for Help: Financing Costly Relief Efforts

In November 1997, Chip Guard wrote a report to the US Department of the Interior (DOI), the Federal Emergency Management Agency (FEMA), and the Commander in Chief Pacific (CINCPAC) on the results of his island briefings. He recommended drought mitigation measures that could be implemented before the on-set of the impending droughts. He also advised that new well development be accelerated in Yap and reverse osmosis units be pre-positioned in other parts of the FSM and Republic of the Marshall Islands. PEAC staff in Hawaii actively consulted and discussed these recommendations with federal officials, trying to impress on them the fact that the cost of providing disaster assistance could be reduced significantly should plans be implemented before water needs became critical. Unfortunately, response to these opportunities required a US presidential disaster declaration before the agencies could take action against the impending disaster.

In November 1997, the Congress of the Federated States of Micronesia appropriated $5 million to address potential impacts of anticipated droughts. Late in 1997, the US Ambassador to the Republic of the Marshall Islands requested assistance from the US Commander in Chief (CINCPAC) Pacific to secure equipment and replacement parts to refurbish pumps for wells on Laura islet on Majuro Atoll. Assistance was also requested to increase water storage capacity was expanded in anticipation of the drought.

Cumulative ENSO Impacts: Tropical Cyclones followed by Drought

Increased storm activity heightened the effects of the drought. CNMI experienced three typhoons in two months, and Supertyphoon Paka, in December 1997, severely debilitated the islands of Guam, CNMI, and the Marshall Islands. Typhoon Paka struck the Marshall Islands, seriously affecting three atolls. Paka also did widespread destruction on Guam. Even though it provided Guam the last month of near-normal monthly rainfall, it resulted in a presidential disaster declaration. These storms brought the last significant rainfall.

By January 1998, the rainfall declined significantly in the Micronesian Islands. Early in 1998, the Republic of the Marshall Islands requested assistance from the Government of Japan for reverse osmosis units. Disasters were declared by national governments in the Republic of the Marshall Islands and Federated States of Micronesia, and President Clinton made formal declarations in March 1998 that allowed FEMA to provide assistance to both countries.

The drought in Samoa was delayed until April because of its location in the Southern Hemisphere. For the Samoas, PEAC anticipated an increase in the risk of tropical cyclones and drought as a result of the El Niño. In April, May and June of 1997, rainfall in Pago Pago was only 64 percent of normal. In July 1997, it was only 59 percent of normal. Their summer was closer to normal, but PEAC forecast that rainfall for the period April through August 1998 would be well below normal and this has been borne out. The American Samoa government organized a drought response and has continued to rely on the PEAC and National Weather Service forecasts for their response.

Water Supply During the Drought

All of the islands experienced rainfall deficits, and they all imposed water hours for conservation. At the worst, during April and May 1998, the Marshall Islands water utility operated once every fourteen days for seven hours to supply water until the pumps for wells on Laura were repaired. Other islands maintained a conservative, but daily supply of water, especially to critical facilities such as the hospitals.

Throughout the height of the drought in the North Pacific, Chip Guard provided weekly PEACESAT satellite teleconference briefings on rainfall measurements and our forecast. Municipal water system managers on Majuro, Pohnpei, Guam, Saipan, Koror, and Yap relied on PEAC's rainfall forecast and these briefings to manage the water rationing programs. In Palau and Pohnpei, municipal water was available every day but only for a couple of hours at the height of the drought. In the outer islands of Pohnpei State water was supplied by ship and tanker trucks supplied at schools in rural areas on the main island. Water supplied to the Koror-Airai area in Palau was reduced from 111 million gallons per month to 9.3 million gallons per month during the height of the drought.

The Japanese government provided two 20,000 gallon per day (gpd) and one 16,0000 gpd reverse osmosis (RO) units for the Marshall Islands in February. Following the US presidential disaster declaration in March, six larger RO units were provided with funding from the US Federal Emergency Management Agency in April. RO units were also supplied by FEMA to Yap State.

The drought resulted in new innovations to cope with decreased water supply. To maintain the equipment in the hospital, the CNMI hospital engineers developed water catchment systems to collect condensation from air conditioners. Although the water could not be consumed because it contained trace amounts of copper and other minerals, it was perfect for use in X-ray film development and machine maintenance and cleaning inside the hospital.

Wildfires

Pohnpei, Chuuk, Yap, Guam, and Palau experienced severe wildfires, often in the interior areas, which were not accessible with conventional firefighting equipment. The islands realized substantial agricultural and financial losses from the combination of drought and fires.

Rainfall forecasts from PEAC allowed agencies responsible for fire suppression to prepare to respond. The Government of Guam decided that fresh water from their main reservoir should be conserved, and used brackish water to fight fires. In Yap, firefighters worried about the long-term result of increasing the salt content in the garden areas, so they used water pumped from an old quarry. The forestry division on Yap prepared by ordering backpacks to hold water, which enabled firefighters to attack the fires in the interior sections of the island. On Pohnpei, the State Division of Forestry conducted a fire response workshop.

Unfortunately, Pohnpei had only one fire truck and many of the fires were inaccessible by road. On Yap, they had 89 fires officially recorded, and government firefighters and

volunteers battled fires almost 24 hours a day from March through May. In Palau, about 136 acres burned, including two mahogany farms. On Guam, the Division of Forestry's fire prevention and response efforts relied heavily on the PEAC rainfall forecast. Despite their efforts, Guam had a total of 1,400 fires between January and April and the cost of fighting fires for March, the worst month, was over $600,000.

Agriculture

Agriculture suffered everywhere from the droughts, except on Guam. There, farmers used public water for irrigation, and the delay of heavy rains toward the end of the drought resulted in one of the most productive harvests in recent history. In CNMI, citrus and garden crops were most affected by the drought, and the hospital had to buy imported fruits and vegetables rather than rely on local suppliers. A limited damage assessment was done on Pohnpei and serious losses of both food and cash crops were sustained. Over half the banana trees evaluated had died or were considered seriously stressed. Sakau (kava) was probably the most serious economic loss because it has become a major cash crop. On Yap, taro losses were estimated at 50-65 percent, and betel nut prices increased more than 500%, although only 15-20 percent of the trees were lost. In Palau, imported food shipments increased from twice a month to once a week.

Relief food was supplied beginning in January to islands in the Marshalls hit by Typhoon Paka and beginning in May for those affected by the drought. Food relief was supplied to the outer islands of Pohnpei, Chuuk, and Yap. The Pohnpei Agriculture and Trade School, the US Natural Resources Conservation Service and Pohnpei State Agriculture Department provided assistance to the farmers as the drought began to subside. The disaster management offices used PEAC and National Weather Service forecasts to plan food relief and replanting programs for the droughts in RMI and FSM.

Health

In November 1997, PEAC became concerned about the increased risk of water-borne diseases from the impending drought. Initially, PEAC sought assistance from the US Center for Disease Control, FEMA, and the US Department of the Interior to deal with this risk.

In FSM, the public education and awareness campaigns developed by the state governments put a heavy emphasis on the increased risk of illness from dwindling surface water supplies and urged people to boil their water. Videos showed ways to treat water. Health care professionals visited villages in Yap and Palau and trained the islanders in treating the water. The incidence of diarrhea among children at the Pohnpei state hospital actually declined as a result of the public information campaign. None of the jurisdictions reported an outbreak of water-borne illnesses. However, in the FSM and the Marshalls, the incidence of skin disease increased significantly.

Air quality problems posed a serious problem in several jurisdictions, and resulted in increased cases of respiratory illness. Wildfires on Guam, Pohnpei, Yap, and in Palau

caused local air quality problems. People in Yap and Palau said they thought the fires in Indonesia were having an effect on local air quality as well. There were cases reported of respiratory illnesses and allergy symptoms, such as eye irritation. Most of these cases occurred in people with a predisposition to such illnesses. There were no severe cases reported as a direct result of the fires.

Ecology and Impacts on Local Ecosystems

The droughts also had an impact on the ecology of the islands. On Pohnpei, populations of fresh water shrimp, eels, and fish suffered losses as rivers and streams dried. In Yap, the erosion risk has probably also increased, as indicated by sediment flows onto the reef. The landslide and soil erosion risks have also probably increased significantly as a result of the fires.

Extreme tides in Yap and Palau resulted in saltwater intrusion into low-lying areas and damage to crops. Episodes of coral bleaching were reported initially with the warm event in 1998, but occurred also during exposure and low tides as the water level changed with the change in ocean temperature. Reef fish in the outer islands were lost because of extreme tides and higher water temperatures on reef flats. Reefs on Guam were reportedly impacted from soil erosion once the rains returned.

Impact of ENSO Cycles of Fisheries

Fisheries were also affected by the El Niño in all jurisdictions served by PEAC. In January 1998, the Social Science Research Institute (SSRI) began an assessment of impact of ENSO cycles on Pacific tuna fisheries. In February 1998, SSRI staff interviewed vessel captains, fleet managers, and management staff at the two tuna canneries in American Samoa. They also gathered catch data from the National Marine Fisheries Service for the US purse seine fleet based in Pago Pago from July 1988 through December 1997.

From the interviews and catch data, it is clear that during recent El Niño events there was a general shift of the catch to the east followed by a general shift to the west. During the 1997-1998 El Niño, beginning about April 1997, there was a significant decline in the catch in FSM, Papua New Guinea, and Solomons and an increase in catch in the Line and Phoenix Islands and areas east of Samoa. There was, however, an overall decline in the catch and the species mix was very unusual. US purse seiners landed a much higher proportion of yellow fin, and, late in 1997, vessels landed skipjack weighing up to 35 pounds.

SSRI staff also interviewed fleet managers and fisheries officials in the Marshalls, FSM, Guam, and Palau in August 1998. The general shift of tuna stocks to the east was observed throughout the western Pacific. The Marshall Islands reportedly experienced a decline in access agreement income during 1997 and anticipates a doubling of tuna access license income from $1.5 million to $3 million in 1998. In Yap and Palau, there

were almost no tuna caught by either purse seiners or longliners for months. In Yap, the transshipment operation laid off fifty-seven of their sixty employees. In Guam, port calls were well below normal, and some species of nearshore pelagics, that seasonally come close to the island during the winter and spring stayed off shore.

Some tuna fleet managers and vessel captains in American Samoa received ENSO forecasts from a range of sources, but they were generally unaware of PEAC and had not obtained forecast information from us. They were, however, very keen to work with PEAC to develop a better understanding of the impact of ENSO cycles on fisheries and asked to be put on our distribution list for forecast information.

The first phase of research on the impacts of climate variability to pelagic fisheries in the Pacific region was completed in September 1999. The Social Science Research Institute (SSRI) finalized the report and submitted it to the Office of Global Programs. The document was distributed at the Drought Mitigation Workshop in Fiji in 1999. In addition, the Pelagic Fisheries Research Program at the University of Hawaii offered to publish and distribute the document to fisheries management experts throughout the Pacific region.

Extension of PEAC's Approach to the South Pacific

In the last quarter of 1998, SSRI and WERI began work with the South Pacific Disaster Reduction Program at the South Pacific Geoscience Commission (SOPAC) and the Fiji Government to design an ENSO impact analysis for Fiji. SOPAC and Fiji Government completed an assessment of drought impacts based on the template provided by PEAC staff. PEAC staff also helped plan an ENSO Impact Assessment Workshop for Fiji Government. Materials for the workshop were developed from a preliminary analysis of rainfall patterns in Fiji, 1997-1998 forecast information, and the work of PEAC and SOPAC.

PEAC staff facilitated the ENSO Impact Assessment Workshop for SOPAC and Fiji Government in June 1999. The workshop included presentations of the climate analysis conducted by the Fiji Met Service with assistance from PEAC staff and presentations of the results of the PEAC ENSO Impact Analysis conducted in the US Affiliated Pacific Islands. PEAC staff also presented a history of the Pacific ENSO Applications Center and its role in the response to the 1997-1998 ENSO warm event and associated droughts and typhoons in the North Pacific. A series of worksheets were designed by PEAC staff to identify response and mitigation options for future ENSO events based on the climate analysis, availability of ENSO forecasts, and impact analysis conducted by SOPAC and Fiji Government.

In early 1999, the UH Social Science Research Institute (SSRI) submitted a proposal to the Center of Excellence for Disaster Management and Humanitarian Affairs (COE) to develop a manual for using climate analysis, ENSO forecast capability, and ENSO Impact Analysis for disaster response and mitigation. SSRI tested the methods to be

incorporated in the manual at a workshop for disaster managers, water system managers, and meteorologists from the Pacific Islands region held in Fiji in October 1999.

The workshop introduced disaster managers, water system, managers, and meteorology service directors to the use of climate information and forecasting in developing drought response and mitigation plans. PEAC staff and the South Pacific Geoscience Commission (SOPAC) organized the workshop and funding support was provided by the British High Commission in Fiji, the Office of Global Programs at NOAA, and the UN Environment Programme. The Water and Energy Research Institute of the University of Guam, assisted by the Fiji Met Service, conducted climate analyses for the workshop. The workshop consisted of a series of presentation on seasonal to interannual climate modeling, the experience of PEAC in the US affiliated Pacific Islands, and a Fiji case study based on the impact analysis conducted by SOPAC and Fiji Government.

The workshop also included a climate forecasting and disaster response simulation exercise designed by PEAC staff. Chip Guard developed three-year hypothetical climate scenarios and generated data sets on a range of climate and ocean conditions at six month intervals over a total of three years. These data were provided to five country groups (Fiji, Cook Islands, Federated States of Micronesia, Vanuatu, and Kiribati), who were representative of five sub-regional areas in the Pacific. These groups consisted of met service officials, disaster managers, and water system managers for each of the countries and sub-regions. The climatologists provided six monthly climate and ocean condition data sets to the met service officials. The met service officials worked in the five country groups to generate storm and rainfall forecasts that were issued to disaster managers and water system managers who develop response plans based on the forecasts.

During the first part of the exercise, while the meteorologists met to develop their forecasts for the simulation, the water managers and disaster managers broke into working groups facilitated by UH and SOPAC staff. They considered the types of information that they needed and the ways in which they could improve communication with the meteorologists and other managers in their countries. On the second day of the simulation, the UH team provided the country groups with disaster response worksheets to guide participants through the activity. Each group developed and updated response plans based on the climate forecasts.

The simulation exercise was successful, although, because of time constraints, only three iterations were possible. Only one of the five groups completely misinterpreted the data on climate and ocean conditions, and therefore, failed to forecast a strong ENSO warm event. Feedback on the simulation exercise was very positive and it clearly demonstrated that local meteorological services can develop the kinds of climate forecasts issued by PEAC. In addition, disaster and water system managers can develop response plans based on those forecasts.

Workshop participants identified climate information and forecast needs over and above those currently available. They also developed a series of recommendations to the South Pacific Applied Geoscience Commission, the South Pacific Regional Environment

Programme, and the Pacific ENSO Applications Center to assist with the development of seasonal to interannual climate forecasting capacity for the South Pacific. Participants also discussed the feasibility of conducting sub-regional workshops to develop more detailed response and mitigation plans using the manual.

PEAC staff are currently completing the manual proposed to the Center of Excellence based on PEAC's experience during the 1997-1998 El Niño, materials developed for both the Fiji workshop held in June 1999 and the regional workshop held in October 1999. The manual will provide island governments with methods to (a) assess the impact of ENSO events for use in disaster response and mitigation planning; (b) use climate analysis and information on climate forecasting capability to anticipate the impacts of future ENSO associated climate events; and (c) use impact assessments and climate analyses for planning response and mitigation strategies to deal with future ENSO events. The manual will include case studies from the US affiliated Pacific Islands and response and mitigation planning in Fiji. The case studies will illustrate approaches to impact assessment and disaster response and mitigation strategy development that can be replicated in other island jurisdictions of the Pacific Islands region.

The Future of PEAC and Lessons Learned

In 1992 and 1993, PEAC began as a pilot project to test the feasibility of providing "end-to-end climate variability research, forecast and application services." Eileen Shea, then Deputy Director of NOAA's Office of Global Programs, can be credited with securing the initial grant support for PEAC, and providing support for developing the pilot project while she worked with OGP. No institutional model for providing seasonal to inter-annual climate applications on an operational basis existed. PEAC has proven that the "end-to-end" concept is not only feasible, but can actually be used to reduce the suffering and the cost of extreme climate events associated with the ENSO cycle.

The Pacific Regional Office of the US National Weather Service is committed to securing financial support for PEAC as an operational program. Permanent funding support would enable the continuation of the PEAC under the aegis of the Pacific Region of the US National Weather Service. They have discussed the feasibility of continuing a networked organizational structure for PEAC similar to the one that now exists.

Through its work with the South Pacific Applied Geoscience Commission, PEAC staff began the process of building capacity to provide seasonal to interannual climate forecasts and applications information to the independent and freely associated states of the South Pacific. PEAC staff held extensive discussions with the South Pacific Regional Environment Programme about development of a newsletter similar to the *Pacific ENSO Update* for the entire region.

The regional workshop convened by SOPAC in October 1999 reinforced the fact that there is a demand for seasonal to interannual climate forecasting and applications in the Pacific region. It also demonstrated that meteorological services in the South Pacific

have some capacity to do their own forecasting and that governments can apply those forecasts to disaster response and mitigation planning. However, in order to provide the kinds of climate services to the countries and territories outside of PEAC's area of operation, some additional training and technical assistance will be required. Moreover, to extend the use of climate forecasting to health, fisheries, and other sectors, additional research will be required.