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# El Niño Strengthens in the Pacific: Preparing for the Impacts of Drought

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SUMMARY A drought is moving through the Pacific Islands, brought by one of the strongest El Niño events since record keeping began 60 years ago. It started in the southwest Pacific, where it has brought famine to Papua New Guinea and Vanuatu. It is expected to reach the South Pacific, tropical West Pacific, and Hawaiian Islands between December 2015 and May 2016, potentially affecting 4.7 million people. While the effect of El Niño in the Pacific Islands receives little global attention, it has already proved severe, particularly among vulnerable island populations. Prolonged drought can compromise not only freshwater supplies and food security, but can also have cascading impacts on public health, economies, food distribution, and even trigger civil unrest. Past experiences with regional drought, current actions being taken, and the most current predictions for El Niño's anticipated effects on the Pacific Islands, suggest strategies that governments and aid groups can take to prepare for this powerful climate event.

## Introduction: El Niño and Drought in the Pacific Islands

An extended drought has hit the Southwest Pacific Islands and is moving east to the greater Pacific Islands region, with an expected arrival of late 2015 and extending into the first half of 2016. In Papua New Guinea, more than 2.4 million people are already affected, roughly one-fifth of them "severely," according to the Red Cross, which expects the drought to impact 4.7 million people throughout the region. While the Pacific Islands experience normal dry and wet seasons each year, the drought is the result of a climate phenomenon that can lead to weather extremes. It is the El Niño Southern Oscillation (ENSO), comprising a warm phase (El Niño), a cold phase (La Niña), and a neutral phase. Fortunately, scientists can predict—and communities can plan for—this phenomenon. ENSO is an ocean-atmosphere climate phenomena in the equatorial Pacific Ocean that naturally recurs approximately every three to seven years. As of December 2015, the world has been experiencing one of the three strongest El Niño events in 60 years of record keeping. (See Box 1 for more information on ENSO and El Niño.)

*In Papua New Guinea, 2.4 million people are affected, one-fifth of them 'severely'*

While media attention in the US mainland tends to concentrate on how El Niño could bring much-needed rainfall to drought-stricken California, the global consequences are varied and generally less optimistic. The impacts of El Niño in the Pacific Islands receive little global attention, despite these islands' geographic proximity to El Niño and their already vulnerable populations and smaller natural resource stores. The 1997–1998 record El Niño caused violent flooding in California, wildfires in Indonesia, disruptions to crucial fisheries off Peru and Ecuador, infrastructure damage in the United States, and major crop losses in Australia and Brazil.[1] A strong El Niño event causes reduced rainfall starting in the Northern Hemisphere's winter (December–February) and affects

Box 1. **Defining El Niño Southern Oscillation (ENSO) and Its Effects on Rainfall and Sea Level in the Pacific Islands**

The Pacific Ocean is the largest of the Earth's oceans, and is the origin of the largest year-to-year variation in global climate. On a repeating basis, the tropical Pacific Ocean basin undergoes large increases or decreases in sea surface temperature, sea level pressure, and sea surface height in the equatorial region, collectively called the ENSO cycle, comprising El Niño and La Niña phases. An El Niño is defined by anomalously warm sea surface temperatures in regions of the tropical Pacific Ocean, while a La Niña occurs when temperatures are anomalously cool. Periods in which conditions are normal are called neutral events. The El Niño or La Niña phase of ENSO recurs approximately every three to seven years, while most years are considered to be neutral. Sustained observations and research have led to a better understanding of El Niño, and therefore the ability to predict its occurrence and intensity up to a season or two in advance.

Physical indicators such as deviations in rainfall, winds, ocean temperatures, and sea surface heights make it possible to monitor the development of an El Niño or La Niña event in a given year. During an El Niño event, from December to the following May, rainfall is typically lower than average in the South Pacific, tropical West Pacific, and Hawaiian Islands. In addition to the island rainfall records, researchers measure sea level fluctuations recorded by a network of tide gauge stations in the Pacific. These measurements detect tsunamis, changes in tides, and slowly varying changes in water levels caused by wind, salinity, and temperature shifts. Temperature observations along traditional shipping routes, measurements from ocean-moored buoys, and more recently, satellite-derived products indicate that during a typical El Niño event, ocean surface temperatures can rise by as much as 4°C (7.2°F) above average across eastern-central parts of the tropical Pacific region. During the past six decades of reliable observational records, two exceptionally strong El Niño events and Pacific Islands regional droughts occurred: first in 1982–1983 and again in 1997–1998.

Pacific Island ecosystems and communities are highly susceptible to seasonal climate extremes such as droughts, floods, coastal inundation from waves and storms, coral bleaching, or drops in local sea level, which can sometimes happen on an extended timescale during climate phenomena such as ENSO. Due to the persistence for 12–16 months of the above average sea surface temperatures that define El Niño, and the extensive range of the climate event, its impacts are far reaching.

Box 2. **Predicting El Niño for 2015–2016: First Wetter, then Drier**

Figure 1a uses data from seven past El Niño events to show the average rainfall pattern in the Pacific during typical El Niño winters. Increased rainfall (blue-purple) in the central-eastern equatorial Pacific was accompanied by a horseshoe pattern of reduced rainfall (orange-red) covering the South Pacific, tropical West Pacific, and Hawaiian Islands. This pattern persisted into the subsequent Northern Hemisphere spring season, Figure 1b. In other words, past records show that about six months of drought-like conditions prevailed over most of the Pacific Islands during El Niño years. The predicted 2015–2016 El Niño event (shown in Figures 2a–b) should bring greater and more extensive rainfall than average (blue-purple), followed by more severe and more extensive drought-like conditions (orange-red) than average.

Figure 1. **Historical rainfall and drought conditions during past El Niño events.**

(a) Winter (Dec–Feb) (b) Spring (Mar–May)

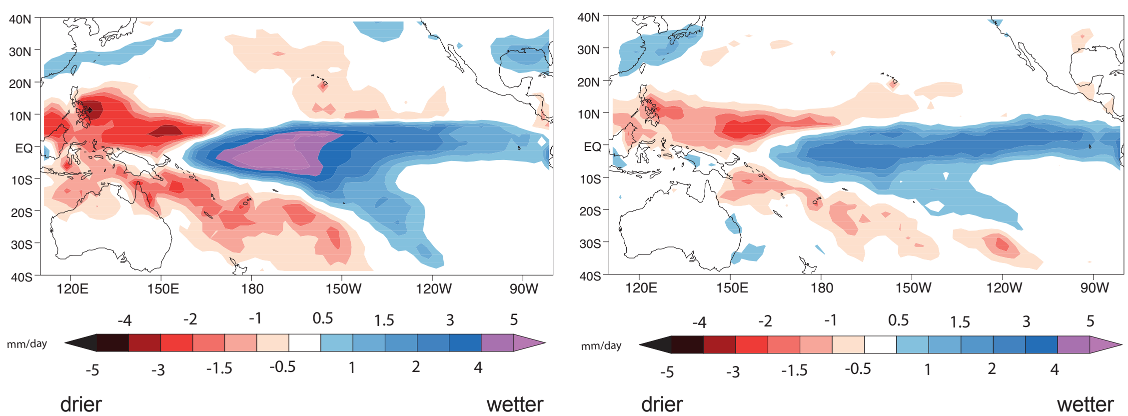
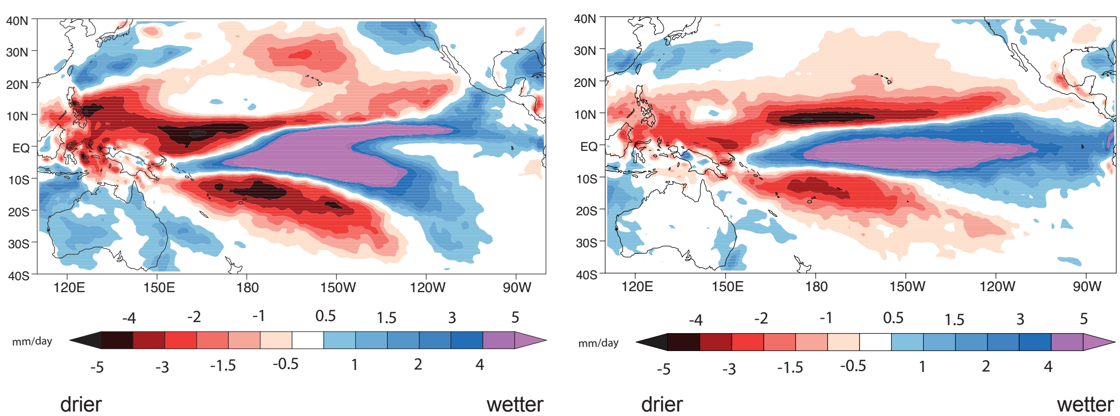



Figure 2. **Predicted rainfall and drought conditions for El Niño 2015–2016.**

(a) Winter (Dec 2015–Feb 2016) (b) Spring (Mar–May 2016)




the South Pacific, tropical West Pacific, and Hawaiian Islands. This pattern persists into the Northern Hemisphere's spring season of the following year, resulting in about six months of drought conditions in most of the Pacific Islands. Owing to the predictability of El Niño, governments, agencies, international aid groups, planners, and communities in which the drought has not yet occurred have the opportunity to prepare for its wide-ranging impacts. In countries in the tropical West Pacific where drought has already started to affect the population, local governments, meteorological services, and aid agencies such as the Red Cross are coordinating their responses and distributing food and water. Several countries including Papua New Guinea have designated drought relief funds, and national disaster agencies in Sāmoa have started allocating additional water tanks to vulnerable areas. On islands with affected crops, such as Vanuatu, agricultural research groups have identified drought tolerant varieties of sweet potato to distribute when it is again planting season. Islands expecting dry conditions through May of 2016 have the opportunity to learn from the successes and barriers encountered by states hit earlier, as well from the broad regional lessons from past El Niño drought responses.

### Regional Environmental and Sociopolitical Impacts of El Niño

An El Niño event has a significant influence on weather systems around the world, which in turn affects precipitation and temperature norms, as well as food and water security. Attention tends to focus on the El Niño—rather than the La Niña—phenomenon because its negative consequences are more severe and far reaching. El Niño functions as an additional variable in a complex landscape of environmental and sociopolitical factors, and can have cascading impacts on public health and well-being of communities, global economies, food distribution, and even civil unrest.[2]

***The effects of severe drought can be classified as a national security issue because the well-being of large populations is endangered***

**Endangered freshwater supply.** The potentially severe drought associated with El Niño in much of the Pacific Islands affects freshwater quantity and quality. The consequences are more severe on atoll communities, where freshwater resources are already strained. On islands with surface water supplies in rivers, streams, or reservoirs, an increased reliance on pumping from groundwater wells during times of drought requires the additional use of electrical power for pumping, limits hydropower production, and increases the need for oil and gas imports. Collectively, this issue is part of the "water-energy nexus," with consequences affecting supply chains and local and regional economies. The water-energy nexus describes the relationship between how much water is needed to create energy and how much energy is needed to transport, store, and clean water. During times of drought, when pumping groundwater or importing freshwater becomes necessary, the potential water-energy use footprint of the Pacific Islands grows higher because of cargo transport distances and the financial costs of fuel and supplies.

From the perspective of groundwater supply on both low- and high-elevation islands, increased pumping puts additional stress on freshwater wells and distribution systems, and heightens the possibility of overdrawing from a given aquifer and pumping brackish, non-potable water. The most severe droughts in the Pacific Islands have prompted international aid efforts in the past, with military and aid organizations bringing food, water, medical supplies, and mobile reverse osmosis units for desalinating ocean water. Drought and humanitarian crises should be classified as national security issues, because of the danger to the well-being of large populations, the role that militaries play in providing aid, and because of the potential movement of large numbers of people in response to scarce resources. The compounding stresses from previous droughts could make preparations for the oncoming drought both more difficult and more essential. (See Box 3 for a case study about recent drought response and national security in the Marshall Islands.)

**Insecure food supply.** Islands contending with drought conditions also face food security issues, especially on more remote islands or atolls, which often depend on subsistence agriculture and fishing. Warm ocean temperatures disrupt normal fisheries and fishing locations, which tend to move eastward in search of cooler waters. In addition, agriculture is affected as both irrigated and nonirrigated crops and trees become less productive or destroyed. Papua New Guinea, has been among the first islands in the Pacific to be severely impacted by drought from the 2015 El Niño event, resulting in crop failure, famine, and other diverse public health problems. Particularly affected have been the highlands, where 80 percent of food consumed is grown.[3] In addition to crop failures, the Ok Tedi gold and copper mine, which has experienced declining revenues and management problems for months, closed because of drought conditions. The

Box 3. **Case Study: Drought and Security in the Republic of the Marshall Islands**

Drought response is an international human and environmental security issue in the Pacific Islands, as impacts on one island state cause chain reactions in aid funding and missions, the movement of people, and supply distribution throughout other countries in the region. Among the Pacific Island populations most vulnerable to prolonged drought conditions are those in low-lying atoll nations. With a 2011 census population of 53,158 people living across 29 atolls, and with an average elevation of only seven feet above sea level, the Republic of the Marshall Islands (RMI) is highly dependent upon rainfall collection and catchment storage of water for drinking, bathing, and other household needs. The area last experienced a severe drought coupled with high wave events beginning in mid-2012 and continuing into mid-2013. By October of 2012, the water level in the main reservoir in Majuro was below half-full, which usually triggers additional rationing policies.[4] The northern atolls were hardest hit by the drought, with individuals in some areas surviving on less than one liter of water a day. In addition, these atolls suffered widespread crop failure, including breadfruit trees; poor water quality (salt and contaminants); and public health concerns from diseases, such as pink eye, diarrhea, and influenza.

Although drought impacts were widespread, the Weather Forecast Office in Guam, with input from the local RMI Weather Station Office, began issuing drought statements in February 2013. Soon afterwards, a state of emergency was issued, and disaster was declared for the northern atolls in May 2013. RMI President Christopher Loeak requested a federal disaster declaration on June 5, 2013, and President Obama signed it on June 14, permitting the use of federal funds for emergency relief. Several international and US organizations provided food and water through the Pacific Partnership (see photo), which utilizes US military forces during crisis events. Other assisting organizations included the UN Central Emergency Response, the US Agency for International Development (USAID), the Red Cross, the Federal Emergency Management Agency (FEMA), and the US Department of Agriculture (USDA). While the drought was not caused by an El Niño event, the international community can draw upon the experience to look ahead and strategize how to mitigate impacts on vulnerable communities in the current El Niño season. Preparation is especially important given the fact that many islands are still recovering from previous drought conditions.


Navy sailors unload reverse osmosis systems in July 2013 to provide desalinated drinking water for more than 15,000 Ebeye Island residents suffering the effects of drought in the Republic of the Marshall Islands.

*Picture: Official US Navy Imagery. (US Navy photo by Mass Communication Specialist 2nd Class Tim D. Godbee/Released.)*

mining company cited the drying up of the nearby Fly River and lack of available hydropower as the final factors forcing its closure.[5] The El Niño–related drought and famine in Papua New Guinea is an example of compounding environmental stressors magnifying the resulting negative impacts. In this case, the dry El Niño conditions resulted in a severe frost at the highest elevations where most subsistence crops are grown, destroying many of them. The result was that communities already suffering from a compromised food supply became increasingly vulnerable to the country-wide drought. Dozens reportedly died from famine, with children and elderly populations most at risk.

***The 2015 storm season has seen 21 category 4 or 5 storms, including massive storms in Vanuatu and Micronesia***

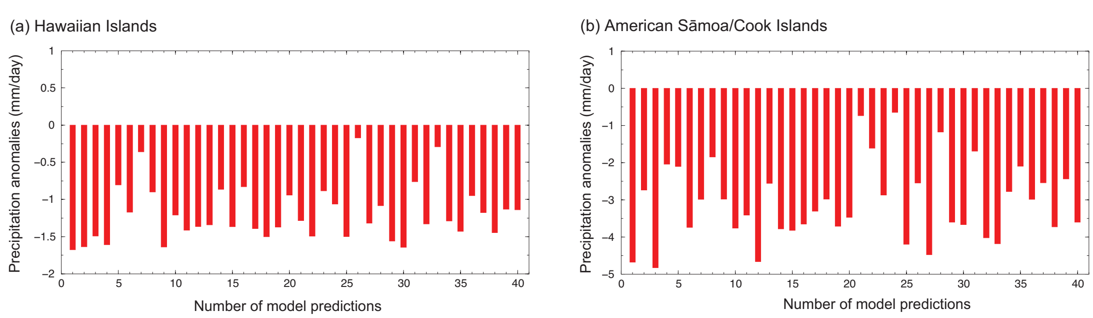
**Record-breaking storm activity.** There are usually more storms than normal in the Pacific basin throughout tropical cyclone season during an El Niño, partially fed by the abnormally warm sea surface temperatures. This trend is already evident in the 2015 season, which has had a record-breaking 21 category four or category five storms in the Northern Hemisphere as of late October 2015, and also massive storms in Vanuatu and Micronesia. The increased cyclone activity brings increased risk of damage to coastal infrastructure from waves and flooding, and negatively affects local agriculture, which may have to contend with the dual threats of decreased freshwater supplies and potential saltwater inundation. Either of these threats makes recovery more difficult and increases the need to import food. In addition to storm impacts, drops in sea level also commonly affect islands in the western and southern Pacific during strong El Niño events. The coupled stresses of lowered sea level and warm sea surface temperatures contribute to coral bleaching and coral mortality. As many countries rely on the health of their marine ecosystems to attract tourism, the negative impact on coral reefs contributes to the overall economic strain.

**Threats to human health.** Finally, extended drought conditions threaten human health. Contaminated drinking water increases the chance of waterborne diseases, including gastrointestinal illnesses such as typhoid and infections such as conjunctivitis. Negative health impacts often continue even when El Niño conditions end. When normal rainfall returns, standing water collects in informal catchments such as tires, and causes a second wave of health problems, including vector-borne disease, which often affect local populations. The ongoing stress from poor health can reduce the number of children attending school. Additional social impacts resulting from drought can include civil unrest and the movement of populations

Box 4. **Consistent Predictions of Below-Average Rainfall**

Figures 3a–b show predicted rainfall averaged over all Hawaiian Islands and a region surrounding American Sāmoa in the South Pacific, respectively. Each red bar represents a model prediction of El Niño winter rainfall. All 40 of the predictions are for below-normal rainfall, giving climate forecasters confidence in the model's prediction that dry conditions will occur in Hawai'i and around American Sāmoa.

Figure 3. **Predicted rainfall December 2015–February 2016**



into city centers or main islands due to food and water shortages. Economic impacts include families forced to spend more money on imported food. Researchers report that the global risk for violence doubles in El Niño years compared to La Niña years.[6] With the current knowledge of El Niño impacts and patterns, and with accurate forecast models that show predicted timelines across the region, governments can act to mitigate risks and prepare in advance, before problems become dire.

*The global risk for violence doubles in El Niño, as compared to La Niña, years*

### Strategies and Education for Responding to El Niño Impacts in the Pacific Islands

Regional, state, and local governments, planners, and resource managers on islands in which drought conditions have not yet started or peaked have an opportunity to prepare for the current large El Niño, whose effects are predicted to continue through May of 2016, and to learn from both past drought experiences and the effectiveness of current strategies used by islands already experiencing drought, such as Papua New Guinea, Vanuatu, and the Solomon Islands.

Impacts from El Niño are not new, and a regional framework addressing ENSO impacts and island-level decision support has been laid by aid groups such as the Red Cross, the Pacific Partnership, and research and outreach organizations like local meteorological offices and the NOAA Pacific ENSO Applications Climate Center (PEAC). The following recommendations are based on lessons learned addressing regional drought over the last 20 years. Policymakers and resource managers should plan for drought conditions and impacts based on the needs of their countries and the relative vulnerability of the communities and resources in question. Potential short- and long-term strategies for different groups preparing for impacts of El Niño are outlined below.

**Drought impact preparation (immediate actions).**

- Governments have the opportunity to reach out to communities not yet experiencing drought and inform them of the approaching dry conditions, as well as to provide guidelines for conserving water at the household and community level for populations currently in drought.
- Island coastal and agricultural extension agents are familiar with local conditions and communities, are often trusted suppliers of information, and are available to help educate different groups.
- The meteorological services are also an excellent educational resource for governments and resource managers, as they are aware of developing drought conditions and are connected to region-wide forecasts and groups reporting negative impacts. For Hawai‘i and the US-affiliated islands, excellent island-scale summaries of El Niño impacts on different sectors are available to download and distribute from Pacific RISA and the NOAA El Niño Tiger Team : http://www.pacificrisa.org/2015/11/12/pacific-island-fact-sheets-released-on-el-nino-and-sectoral-impacts/.
- Governments can assist in providing supplemental freshwater catchment tanks for community and household use, prior to the worst dry conditions. Check with local water utilities, aid organizations, and rainwater harvesting groups for information on increasing rainwater storage.
- Agricultural extension agents and aid groups can use El Niño as an opportunity to distribute information on local drought-tolerant food crops to plant ahead of time, provide drought-tolerant seedlings when available, and, post-drought, assist with replanting.
- Governments can contact aid organizations to map the most vulnerable areas and plan food and water distribution routes and strategies before the situation becomes dire.
- Public and private water suppliers can identify and fix leaks in freshwater distribution systems, especially in vulnerable or remote areas.
- Health departments can prepare to deliver fast medical and hygiene intervention (medicine, evacuation) in remote areas that lack robust backup supplies of freshwater.
- Both Pacific Island governments and the US federal government can expect declarations of drought and disaster, potentially in US-affiliated

Pacific Islands or US states that require federal assistance, and prepare to bring in mobile water desalination units via military and aid organizations.

- International aid organizations and state governments can assess the potential need for peacekeeping organizations to monitor areas with existing civil conflicts, where drought might aggravate conditions.

**Drought impact preparation (long-term planning and policies).** Working with a longer timeframe provides additional opportunities:

- Implement strategies that encourage diversification of the food supply, especially in rural areas in which subsistence farming is common. This can include local strategies, such as systematically gathering information from extension agents, or supporting international policies and trade agreements that make it less costly to import food staples.
- Add drought management to community disaster plans, identifying vulnerable populations and outlining coping strategies and actions.
- Collect data on public health impacts during and after drought events, which will help state governments and local health departments understand the health risks and get appropriate aid more quickly during future droughts.
- Increase access to global crop insurance to help Pacific Island states cope with impacts from severe drought or environmental disaster. While farmers in developed countries hold the majority of agricultural insurance policies, those in developing nations are more vulnerable to many risks, and many global insurers do not cover drought as a standard inclusion in developing countries. Strategies for increasing access to insurance in developing countries include combining government subsidies to help pay premiums, pooling policies, and looking to successful programs in other small, developing states, such as index policies.[7]
- Support policies that diversify the energy supply and reduce dependency on fuel imports (renewable energies), thus alleviating the financial strain on communities during drought conditions.
- At the state and local government levels, work with local planning and agriculture departments to address the need for better distribution routes for food and water from areas of surplus to areas impacted by drought, either from subsistence crop failures or from movement of populations to city centers.

Box 5. **Using Models to Forecast El Niño Rainfall and Sea Level in the Pacific Islands**

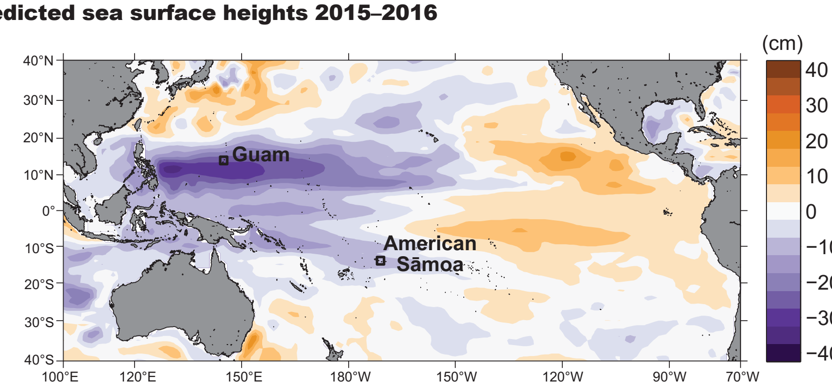
Climate scientists use sophisticated computer models to predict the future behavior of the climate. In a model, the land, atmosphere, and ocean systems of the Earth are divided into many equally spaced grids, with mathematical equations representing the dynamics and physics of the system solved in each grid cell. This is called a general circulation model (GCM), and requires supercomputer resources. Because El Niño arises due to strong ocean-atmosphere interactions, climate scientists employ coupled GCMs (CGCMs), a model configuration that passes two-way information from ocean models to atmospheric models. This method is essential to understanding and predicting El Niño. To validate the model's predictive ability, a commonly adopted approach is to ask the model to retrospectively forecast past events (called "hindcasting"), such as the 1982–1983 and 1997–1998 strong El Niño events. Assessing how well different variables in the model hindcast against observed data gives researchers an idea of the model's ability to predict real-time or future climate.

This article employs the prediction model developed by the US National Oceanic and Atmospheric Administration (NOAA). The authors have assessed the model's hindcast experiments for the period 1981–2012. For the Pacific Islands, the model was highly effective in hindcasting drought-like conditions that persisted from winter to the following spring during strong El Niño years, such as 1982–1983 and 1997–1998.[8] Encouraged by the overall model performance, the authors present real-time predictions of what to expect from the ongoing strong El Niño, as well as associated rainfall and sea level changes expected this winter and next spring (2015–2016).

Box 6. **Unusually Dramatic Sea Level Changes Predicted for El Niño 2015–2016**

One characteristic of an El Niño event is change in sea surface heights. Blue shading in this model (Figure 4) shows predicted sea surface heights that are below normal in the western Pacific, while orange shading shows sea surface heights that are above normal in the eastern Pacific (December to February 2015–2016). In the Northwest Pacific near Guam, a tide gauge has already recorded sea level drops exceeding 20 centimeters below recent average values. These levels are not expected to drop much further, and they should return to normal by February 2016. In the central South Pacific near American Sāmoa, sea levels are nearly normal and expected to remain so through December 2015. But beginning in early 2016, the model predicts sea levels in the western and central South Pacific basin will drop and remain below normal for most of the year, while sea levels return to normal in the western North Pacific. Such a large north-south swing in sea level between Guam and Sāmoa last occurred in 1998 after the strongest El Niño ever recorded.[9] Although the frequency of El Niño and La Niña events under climate change conditions in the future remains a highly uncertain area, new modeling evidence suggests that these types of sea level seesaws are likely to become more frequent in the future, driven by greenhouse warming and more extreme El Niño events. Reduced sea levels can cause bleaching and death of coral reefs and their ecosystems, affecting biodiversity, near-shore fisheries, coastal erosion, and local tourism.

Figure 4. **Predicted sea surface heights 2015–2016**




- At the national and international levels, encourage policies that make food distribution easier and more equitable, including increasing communication between agricultural departments and finance and economics departments, and maintaining larger food reserves as a buffer.

To assist local policymakers and planners in keeping informed about current El Niño conditions and predictions over the next several months, please see the following resources:

**Educational Resources.**

- Monitor global El Niño current and predicted seasonal conditions through the NOAA and University of Hawai‘i websites:
    - o http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml#current
    - o http://www.cpc.ncep.noaa.gov/products/NMME/iMMEindex.shtml
    - o http://apdrc.soest.hawaii.edu/projects/seasonal_prediction/
- Monitor specific impacts to Hawai‘i and the US-affiliated Pacific Islands through the Pacific ENSO Applications Climate (PEAC) Center: http://www.prh.noaa.gov/peac/
- Weather Service Office (WSO) Majuro: http://www.prh.noaa.gov/guam/
- NOAA Climate Prediction Center (CPC) : http://www.cpc.ncep.noaa.gov/
- Download island-specific El Niño impact fact sheets for Hawai‘i and the US-affiliated Pacific Islands: http://www.pacificrisa.org/2015/11/12/

pacific-island-fact-sheets-released-on-el-nino-and-sectoral-impacts/

- Information on implementing crop insurance in developing countries: ftp://ftp.fao.org/docrep/fao/008/y5996e/y5996e00.pdf

The potentially record-breaking El Niño occurring in the tropical Pacific will bring severe drought conditions to the Pacific Islands region that could affect millions of islanders. On islands where drought is already occurring, governments and aid groups are designating funds for food and water distribution, managing health impacts, and looking toward recovery and distribution of drought resistant crops in the next planting season. The Pacific Islands have a long history of co-ordinating regional responses to El Niño, and will draw on past experience to prepare for and mitigate drought impacts. They and other regional actors will also have the opportunity to document the current strategies used in preparation and recovery, and to examine more long-term policy and management decisions to increase the region's resiliency during future droughts.

## Notes

[1] *The Economist*, "The Season of El Niño," May 7, 1998.

[2] S.M. Hsiang and M. Burke, "Climate, conflict, and social stability: what does the evidence say?" *Climatic Change* 123(2014): 1, 39-55.

[3] Pacific Beat, "Papua New Guinea's Developing Food Crisis," ABC Radio Australia, October 2015, http://www.abc.net.au/news/2015-08-29/drought-frost-in-png-causing-food-crisis-photos/6732740.

[4] Pacific ENSO Applications Climate (PEAC) Center, *Pacific ENSO Update, 3rd Quarter* 19, no. 3 (August 1, 2013), http://www.weather.gov/media/peac/PEU/PEU_v19_n3.pdf.

[5] Pacific Beat, "Papua New Guinea's Developing Food Crisis," ABC Radio Australia, October 2015, http://www.abc.net.au/news/2015-08-29/drought-frost-in-png-causing-food-crisis-photos/6732740.

[6] S.M. Hsiang, K.C. Meng, and M.A. Cane, "Civil Conflicts Are Associated with the Global Climate," *Nature* 476 (2011): 438–441.

[7] R.A.J. Roberts, "*Insurance of crops in developing countries.*" (2005): FAO Agricultural Services Bulletin 159, Rome. ftp://ftp.fao.org/docrep/fao/008/y5996e/y5996e00.pdf

[8] H. Annamalai, J. Hafner, A. Kumar, and H. Wang, "A Framework for Dynamical Seasonal Prediction of Precipitation over the Pacific Islands," *Journal of Climate* 27, no. 9 (2014): 3,272–3,297.

[9] M.J. Widlansky, A. Timmermann, S. McGregor, M.F. Stuecker, and W. Cai, "An Interhemispheric Tropical Sea Level Seesaw Due to El Niño Taimasa," *Journal of Climate* 27, no. 3 (2014): 1,070–1,081.

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