White Paper #8b – The Tropical Pacific Observing System and the Pacific Islands

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1. Introduction

The daily lives of the ~10 million people living on the Pacific Islands are affected by weather and climate variability. Two examples are; low lying atolls usually have little natural water storage due to the their thin groundwater lenses, which means that agriculture and drinking water resources are vulnerable to low rainfall and wave overtopping from the ocean; and steep, high islands often experience high erosion during heavy tropical downpours and can suffer severe property damage and loss of life during resulting floods.

The Tropical Pacific Observing System (TPOS) provides immense value to the Pacific Islands. Most of this benefit comes via analysis products derived from the TPOS such as seasonal climate predictions which can enable Pacific Islands to plan for events such as drought, heavy rainfall and extreme sea level. Most benefit in the Pacific Islands from the TPOS comes from processed products, with only weather forecasters and researchers accessing raw data.

2. Benefits from the TPOS for Pacific Islands

Few of the Pacific Islands access raw data from the Tropical Pacific Observing System however all of the islands receive substantial benefit via products from the system. Examples are seasonal climate outlooks (of rainfall, temperature and sea level), weather forecasting (including wave conditions and aviation forecasting), cyclone warnings, fisheries management, tsunami warnings, and monitoring and prediction of climate change in the region. The products developed from the TPOS and the components they use are discussed below, and summarized in Table 2.1.

Table 2.1 – Seasonal climate outlooks produced for the Pacific Islands.

Product	Audience	Method	Outlooks of
United States NOAA ENSO Update	US Affiliated Pacific Islands		Rainfall, SST?, Sea Level
Australian BoM SCOPIC	Independent Pacific Islands,	ENSO indices	Rainfall, SST
New Zealand NIWA Island Climate Update	Independent Pacific Islands,	TPOS observations and dynamical models	Rainfall, SST

2.1 Seasonal climate outlooks

The Pacific Ocean is a key driver of global climate, predominantly through the processes of El Niño and La Niña, also known as ENSO (Collins et al., 2010). The Pacific Islands are situated at the core of this climate engine, and are particularly affected by ENSO. For example, records extending over the past 73 years show that during the dry season, rainfall on Tarawa Atoll, the capital of Kiribati, is correlated to the Niño 3.4 Index and Southern Oscillation Index with coefficients of 0.81 and -0.74 respectively (Australian Bureau of Meteorology et al., 2011).

Predictions of rainfall, temperature and sea level are produced by Pacific Island climate services in collaboration with development partners. These seasonal predictions are founded on the TPOS, particularly using data from the TAO/TRITON array, satellites (TRMM, SST) and met stations. The three main development partners are the U.S. National Oceanic and Atmospheric Administration (NOAA), the New Zealand National Institute of Water and Atmospheric Research (NIWA) and the Australian Bureau of Meteorology (BoM) as outlined in Table 2.1. Of the three seasonal prediction tools, the NIWA *Island Climate Update* (www.niwa.co.nz/climate/icu) goes into the most detail of data from the TPOS. Monthly teleconferences between NIWA, Pacific Island (PI) NMS, NOAA and BoM discuss the state of the tropical Pacific based on surface and subsurface data from the TAO/TRITON array, satellite data, and model output. Three month outlooks for rainfall and temperature within specific country areas are produced.

The BoM Seasonal Climate Outlooks in Pacific Island Countries (SCOPIC) programme holds a monthly Online Climate Outlook Forum (OCOF) with good attendance by PI NMS. Each of the participating Pacific Island countries runs a statistical comparison of past rainfall (and other parameters) against the relevant oceanic Niño index and uses recent SST analyses to provide 3 month rainfall outlooks for their particular regions within country. BoM is also providing experimental seasonal climate outlooks for the Pacific from the POAMA dynamical seasonal prediction model. The NOAA Pacific ENSO Applications Centre (PEAC) ENSO Update provides a comprehensive overview of current and projected ENSO conditions (http://www.prh.noaa.gov/peac/update.php). Forecasts of sea surface temperature, rainfall and sea level are then produced for each of the US Affiliated Pacific Islands (USAPI).

Current activities in the Pacific aim to link climate forecasts from the National Meteorological Services to sectoral responses. For example, water management for electricity and town supply in Samoa, and seasonal agricultural planning in Vanuatu. Seasonal climate outlooks in the Pacific region also have health applications, such as predicting the risk of vector-borne disease outbreaks. Dynamical seasonal prediction model output is also used to inform these seasonal climate outlooks in the Pacific. The skill of these models is dependent on the accuracy of initializing ocean analyses, requiring surface and sub-surface temperature and salinity. However, at present model error dominates over analysis uncertainty; this will change as models improve. The forecasts from the dynamical models can only be applied to local-scale sites through statistical downscaling that requires individual station data. For all numerical models (used for seasonal prediction, weather forecasting and climate change projections), the TPOS data is essential for forecast verification, calibration of satellite data included in analyses, model development and improving model parametrization.

2.2 Weather forecasting

Given the proximity of the observing array to the islands themselves, the real time data return is invaluable for providing boundary conditions for numerical weather predictions (NWP). The primary data sources for this are the surface wind conditions gathered from meteorological stations in the Pacific Islands along with data from TAO-TRITON array and satellite remote sensing. However, subsurface ocean data from the Argo array also contributes significantly to the long term accuracy of the NWPs (Andersson and Sato, 2012; Balmaseda et al., 2007; Dunstone and Smith, 2010). Tropical Cyclone (TC) forecasting is a special case of NWP, and provides obvious benefits to the Pacific Islands in predicting the timing and intensity of possible landfall. NWP skill in predicting TC tracks and intensities is strongly dependent on the accuracy of initialized winds, which across the Pacific are provided from scatterometer data. NWP is moving towards coupled modeling, so in future ocean initialization (particularly SST) will become important, with expected improvements in TC prediction.

2.3 Sea level monitoring and prediction

Sea level is of particular concern to all Pacific Islands. Low lying atolls are obviously very vulnerable, but the high islands also usually have most of their critical infrastructure located at the coast. The Pacific ENSO Applications for Climate (PEAC) centre provides sea level forecasts for the USAPI with a three month lead time, using statistical models. Experimental products have been developed by the Pacific Australia Climate Change Science and Adaptation Planning Program (at BoM) using the POAMA seasonal prediction model to give sea level outlooks up to 7 months ahead (Miles et al., 2013; Cottrill et al., 2013). The New Zealand National Institute of Water and Atmospheric research (NIWA) is also developing statistical products for sea level forecasting.

Sea level varies noticeably with ENSO; sea level generally rises (falls) in the western (central/eastern) Pacific during La Niña and falls (rises) in the western (central/eastern) Pacific during El Niño with considerable consequences (Australian Bureau of Meteorology et al., 2011). For example, the two main population centers of the Republic of Marshall Islands, Majuro and Ebeye, regularly suffer coastal inundation during king tides that coincide with La Niña conditions. Over the past couple of years, high sea swell has occurred with these extreme water levels, leading to severe inundation, property damage and contamination of aquifers. Monitoring of sea level is of particular concern to Pacific Island states, and is undertaken primarily by tide gauge networks operated by the UH Sea Level Centre and the Australian Bureau of Meteorology along with satellite altimetry. However to gain a deeper understanding of sea level, subsurface temperature and salinity data is vital. The TAO-TRITON array provides a slice of this information across the equator, and the Argo array extends these observations to the majority of the Pacific Islands that are beyond the ± 8° latitudinal extent of TAO-TRITON.

2.4 Fisheries

A substantial proportion of both formal income and subsistence food for Pacific Island communities comes from fisheries. Data from the TPOS underlies the Ocean Global Circulation

Models that are used by the region to model tuna populations, and extremely warm water or low tides can damage shallow coral reefs that are the foundation for many coastal fisheries.

The TAO-TRITON buoys also act as de-facto Fish Aggregating Devices (FADs) which has positive and negative implications. The increased concentration of tuna around the buoys means that researchers can tag fish much more efficiently; however, this also attracts fishing activity which can damage the buoys. Working with fisheries management agencies in the Pacific may help to alleviate this problem.

Many components of the TPOS feed in to the ocean models used for tuna modelling, and warning products for coral bleaching are based on satellite SST data (Liu et al., 2013) and forecasts from seasonal prediction models (Cottril et al., 2013). As noted in the sea level section, products for extreme water levels are currently being developed. High resolution data for monitoring around Pacific islands, for example to monitor coral bleach risk, is provided by the BoM and CSIRO Bluelink project, a high resolution analysis and short term ocean forecast that uses data from satellite altimetry, the Argo array and satellite SST.

2.5 Tsunami monitoring

The majority of destructive tsunamis in the Pacific are generated by earthquakes. Landslides are an additional generation mechanism that may cause localized damage; however these often occur with no method of detection (Dominey-Howes and Goff, 2012). The magnitude and depth of the generating earthquake are used to provide an initial model of tsunami propagation and threat across the Pacific, along with existing knowledge of the orientation of the fault line. These forecasts are theoretical until they have been validated against data collected from tide gauges and the DART buoy system (IOC-UNESCO, 2011).

2.6 Climate change

Communities in the Pacific Islands are among the most vulnerable to climate change (Duncan, 2012) being particularly sensitive to changes in sea level, rainfall patterns and temperature. Planning for adaptation to climate change is dependent on insights into how climate works and is expected to change. Identifying optimum adaptation strategies that ensure the best protection for communities relies on long term observations from land based stations, ocean observation arrays and upper air networks. Often external donor funding focuses on mitigation and adaptation to climate change at the policy and planning level without investing in the observation networks and their accompanying data needed to ensure these are effective. Enhanced understanding of current and past climate is critical to informing policy makers about future climate scenarios; however this is frequently not adequately considered (Australian Bureau of Meteorology et al., 2011). Climate records in the Pacific (ocean and atmosphere) are also vital for evaluating climate model performance, to drive model improvement and to understand model biases and the limitations of climate change projections (Brown et al., 2012).

Sustained, long term data series are required to distinguish between slow climate trends and climate variability. Several platforms are now building the long time series needed, such as TAO-TRITON, the tide gauge network and satellites. More recent innovations such as Argo have enabled monitoring of critical subsurface changes in the ocean that were not possible a decade ago and will greatly enhance our understanding over time.

2.7 Wave monitoring and prediction

Waves play a significant role on the Pacific Islands. Day to day activities such as subsistence and commercial fishing are affected by sea state, and reliable forecasts are needed to help communities plan their activities. In addition to the inundation events described in the Marshall Islands above, similar events have taken place recently in the Cook Islands, Fiji and Tonga.

Winds from global atmospheric models, assimilating data from the TPOS are used to drive basin scale wave models such as NOAA's WaveWatch III. However, the lack of observations in the region between New Zealand and Hawai'i means that there is little verification of the model. Anecdotal evidence has noted that there are discrepancies with the amplitude and timing of wave trains arriving in the Pacific.

2.8 Upper atmosphere observations and forecasting

Global models depend on availability of upper air data in the Pacific Ocean region for accuracy. All models used for day to day weather prediction display diminished skill when this data is not included in the model initialization. The limited accuracy of models can literally mean the difference between life and death when decisions are made in hazardous weather events such as tropical cyclones. In the same vein, the aviation industry is critical to the social and economic well being of the region and upper air data is vital for safe and dependable air services. Aviation is the main mode of international passenger transport in the Pacific, and carries a substantial amount of cargo both to and from the islands. The Pacific Islands play a key role providing information to the GCOS Upper Air Network (GUAN), however many of these stations are no longer active due to financial costs.

3. Summary and future needs

It is important to note that Pacific Island communities are reliant on the services founded on data from the TPOS. The use of these services in the Pacific save lives through warnings of extreme weather events, aid planning for seasonal extremes like drought, extreme sea level and health risk, and inform longer term adaptation planning to climate change impacts. Continued maintenance and development of the TPOS system is needed to support these services and to implement new products. Much of this is built on the research discussed in other white papers.

There are emerging needs and technologies that should be taken into account when considering the future of the TPOS. Examples of these are;

- Ocean Acidification is expected to have drastic consequences for coral reefs, pelagic fisheries and the Pacific Island communities that depend on them by the middle of this century. However, there are few sustained observations of marine carbonate chemistry and ecosystem response to the changes already being experienced. This baseline information is vital if management options are to be considered to mitigate this threat.

- The inclusion of biological monitoring components that can be interfaced into the existing physical systems. An example is the acoustic monitoring of fish abundance from TAO-TRITON moorings to investigate tuna behavior in response to ENSO.
- Higher sea levels are already causing issues on Pacific Islands, particularly when they coincide with a significant sea-swell. Nevertheless, models lack observations of wave conditions to calibrate against.
- The development of new technologies, such as wave powered gliders and sensors on submarine cables, open opportunities for new observations in the Pacific, and more cost effective methods of continuing existing observations.

Table 3.1 – Products used by the Pacific Islands and the components of the TPOS that contribute to them.

	TAO/ TRITON	Argo	XBT	Satellite	Tide gauge	Wave buoy	DART
Seasonal Predictions	X	X		X			
Weather forecasting	X	X		X		X	
Sea Level		X	X	X	X		
Fisheries	X	X		X		X	
Cyclone Forecasting				X	X	X	
Waves				X		X	
Tsunami warning					X		X
Climate Change	X	X	X	X	X	X	

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