The Sea Level Seesaw of El Niño *Taimasa*

During El Niño *Taimasa*, coral tops of Samoa's fringing reefs become exposed to air at low tide. Image courtesy of the National Park of American Samoa.

The huge swings in sea levels linked to the El Niño– Southern Oscillation (ENSO) threaten vulnerable island communities and coastal ecosystems in the tropical western Pacific. Sea level in that region can rise during La Niña and drop during El Niño by up to 20–30 cm. (See 'Klaus Wyrtki and El Niño' in *IPRC Climate*, vol. 6, no. 1, 2006, for a historical perspective of detecting these sea level seesaws.)

The most extreme sea level drops are in the southwestern Pacific, which by exposing the shallow reefs that circle and protect the islands, lead to catastrophic coral and fish die-offs. Samoans refer to very low sea level as '*taimasa*' (pronounced [kai' ma'sa]; translation from Samoan to English is "foul smelling tide" referring to the odor from decaying marine life). **Luafata Simanu-Klutz**, assistant professor of Samoan language and history at the University of Hawai'i, recalls times when the prevailing trade winds changed, sea level would drop, and "you could walk far out on the reefs. During the day, the stench was at times quite unbearable...fish died in the heat."

"Repeated exposure of shallow reefs to air at low tide causes the top portions of coral heads to die off, often creating what are known as micro-atolls on shallow reef flats," explained the managers at the National Marine Sanctuary of American Samoa to **Matthew Widlansky**, IPRC postdoctoral fellow.

"Hearing accounts of flat-top coral heads found throughout the western Pacific coastal reef ecosystem motivated me to further study the associated sea level drops," says Widlansky, who conducts research on tropical climate variability during his postdoctoral studies at the IPRC. "In spite of these ecological and societal impacts of El Niño-related sea level drops on Pacific islands, little is known about their causes, regional manifestations, and what will happen in the future with further climate change."

To explore why these sea level extremes occur and, hopefully, to improve prediction of future events, Widlansky

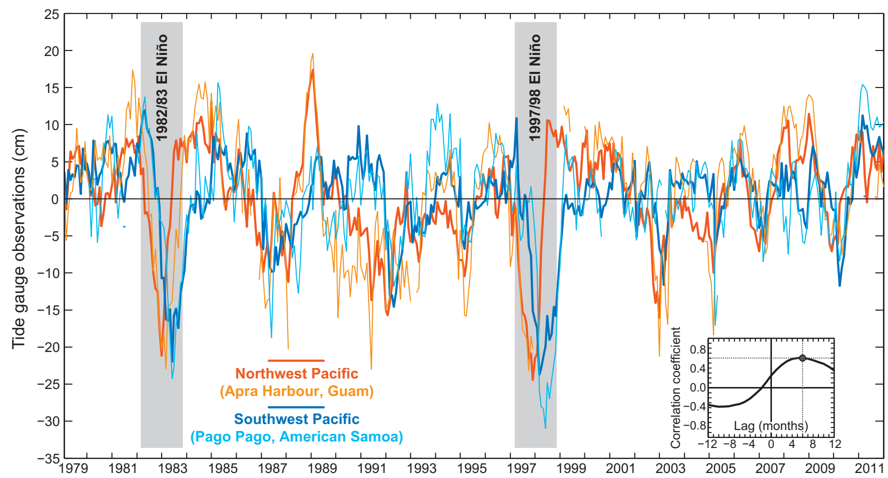

Figure 1. Tide gauge observations in the Northwest Pacific (orange) and Southwest Pacific (blue) with the linear trend in each region removed. Thick lines represent multi-station averages (see Fig. 2 for locations). Observations from Guam and American Samoa are highlighted. Insert shows the correlation coefficient between regions as a function of lag in months (Southwest Pacific lags Northwest Pacific; r = 0.60 at lag 6 months). Grey boxes highlight two strong El Niño events referred to throughout. Data from the University of Hawai'i Sea Level Center.

partnered with IPRC Faculty Member **Axel Timmermann**, and they began collaborations with an international team of climate scientists and oceanographers.

Using tide-gauge records throughout the tropical Pacific compiled by **Mark Merrifield**, director of the University of Hawai'i Sea Level Center, the scientists analyzed past sea level extremes.

"From the tide-gauge network, we saw that sea levels around Guam tend to recover quickly during the end of a very strong El Niño events, but in Samoa the below-normal sea levels persist up to six months longer," explains Timmermann.

The most severe sea level drops, the team noted, took place during the strong El Niño of 1982/83 and 1997/98 (see Figure 1). During both, tide gauge levels initially fell far below normal in the tropical northwestern Pacific but remained near normal around Samoa, creating a steep north-south sea level gradient across the equator (Figure 2a). Focusing on the sea level drops near Samoa, which occurred immediately after the peak of these two El Niño events, the scientists

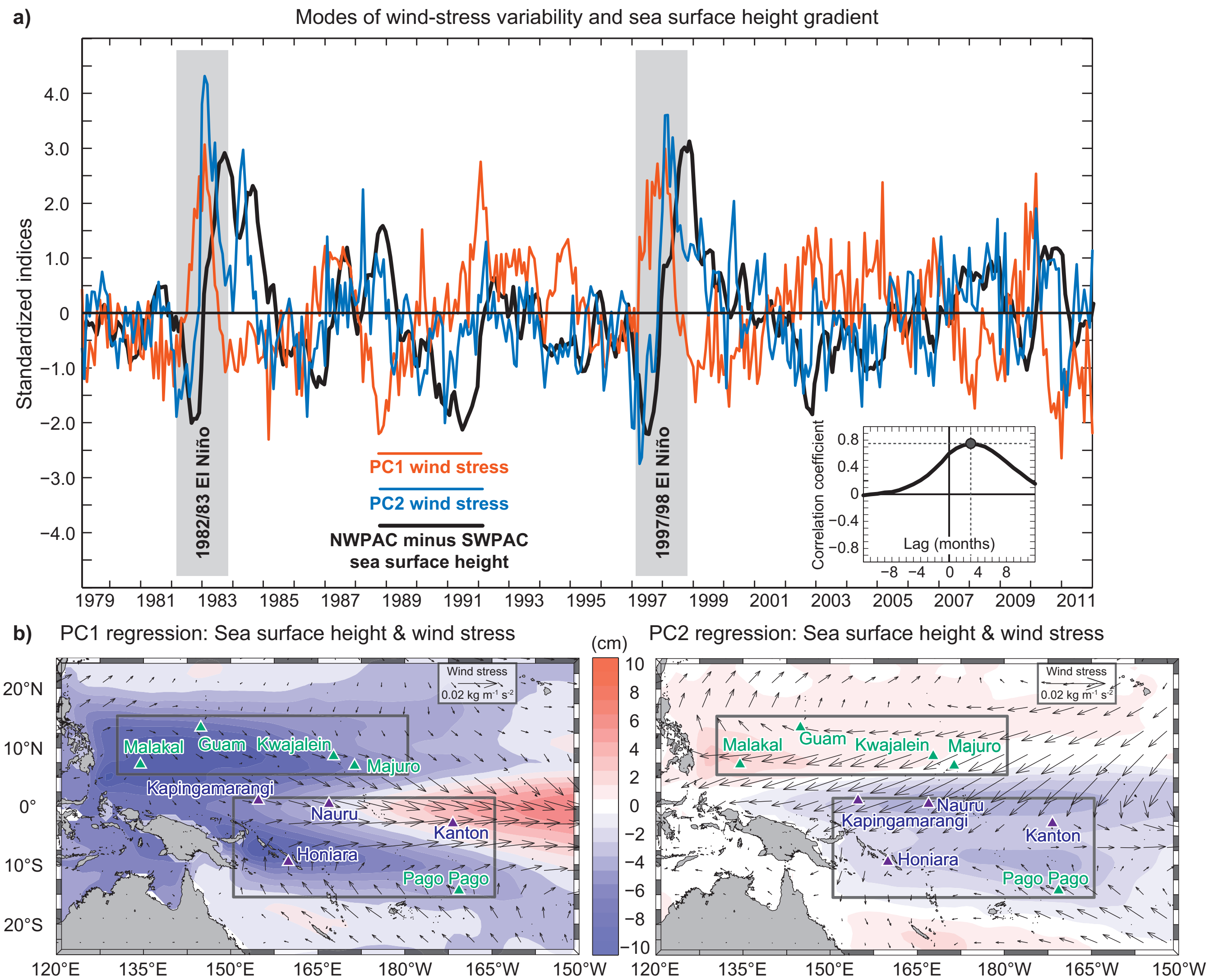

Figure 2. Two principal components (PC1 and PC2) of wind-stress and sea level variability in the tropical western Pacific based on empirical orthogonal function decomposition of the equatorial (10°S–10°N, 100°E–60°W) wind-stress anomaly. (a) PC1 (red) and PC2 (blue) respectively explain 26.3% and 14.9% of the equatorial wind-stress variance. Insert shows correlation between PC2 and Northwest Pacific minus Southwest Pacific sea surface heights (black) as a function of lag in months (sea level gradient lags PC2; r = 0.74 at lag 3 months). (b and c) Linear regressions of sea surface height (cm, shading) and wind stress (Kg m^{-1} s^{-2}, vectors) onto PC1 and PC2. Black boxes represent the Northwest Pacific (5°N–15°N, 130°E–180°W) and Southwest Pacific (15°S–2°N, 150°E–165°W). Triangles indicate tide gauge stations (U.S.-affiliated Pacific Islands green). Wind-stress and sea surface height observations (1979–2011) from respectively the ECMWF interim reanalysis and operational Ocean Reanalysis system 4.

discovered that these were periods when normal trade winds had returned in the North Pacific but remained weak south of the equator (compare Figure 2b-c).

Associated with these sea level and wind changes, is a northeastward shift of the South Pacific Convergence Zone, the largest rainband in the Southern Hemisphere (see *IPRC Climate*, vol. 12, no. 2). Such a shift in the rainband causes droughts south of Samoa and sometimes triggers more frequent tropical cyclones to the east. To describe this climate pattern, the scientists have coined the term El Niño *Taimasa*, a term that captures the damaging effects on shallow reefs around Samoa and nearby regions.

Widlansky collaborated with **Shayne McGregor**, a former IPRC postdoctoral fellow and now at the University of New South Wales, to study how the prolonged low sea level in the South Pacific is linked to the well-known southward shift of weak trade winds (see Figure 2c) that is collocated with the more zonal positioning of the SPCZ. They found this wind shift, associated with ENSO and the seasonal development of the SPCZ, causes the sea level seesaw between the North and South Pacific during the termination of very strong El Niños.

"This interaction—or combination—between ENSO and the annual cycle causes the prolonged sea level drops for Samoa and the abrupt recovery around Guam" explains **Malte Stuecker**, a meteorology doctoral student at the University of Hawai'i at Mānoa, who also participated in the study.

"As the SPCZ and wind response is greatest during the strongest El Niño events," McGregor notes, "we would not expect the extreme sea level drop during weaker El Niño events (including Modoki events) or La Niña."

The ENSO-dependent position of the SPCZ appears to explain the asymmetric sea level response during El Niño *Taimasa*. Timmermann, however, cautions, "A definitive association is limited by the small sample of zonal SPCZ events."

Given the well-established prediction of the seasonal evolution of climate and sea level once a strong El Niño is launched, the scientists think that the long duration of extreme sea level drops at the end of such an El Niño may be highly predictable. Such predictability could warn island communities several seasons in advance and give them the opportunity to adapt at least to some of the detrimental consequences of *taimasa* events.

Widlansky and Timmermann say further observational studies are planned, along with sophisticated hindcast experiments that are being conducted by IPRC Postdoctoral Fellow **Yoshimitsu Chikamoto**, to confirm predictability of future El Niño *Taimasa* impacts.

Though sea levels are likely to gradually rise with global warming, thereby perhaps offsetting somewhat the harm of extreme low sea level periods, recent modeling evidence presented by **Wenju Cai** (Commonwealth Scientific and Industrial Research Organisation, Australia) suggests that strong El Niño events are very likely to occur more often, and thus El Niño *Taimasa* events could also become more frequent.

Waves crash on the fringing reef in Uafato, Upolu, Samoa. Image credit Axel Timmermann.

This story is based on

Widlansky, M.J., A. Timmermann, S. McGregor, M.F. Stuecker, and W. Cai, 2014: An interhemispheric tropical sea level seesaw due to El Niño Taimasa. *J. Climate*, **27** (3), 1070–1081, doi:10.1175/JCLI-D-13-00276.1. IPRC-1018