PACIFIC ENSO UPDATE

A Quarterly Bulletin of the Pacific El Niño-Southern Oscillation Applications Climate (PEAC) Center

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Providing Information on Climate Variability in the U.S.-Affiliated Pacific Islands for the Past 20 Years.

http://www.weather.gov/peac

CURRENT CONDITIONS

During the first half of 2016, the climate state fell from strong El Niño into ENSO-neutral by mid-year. Then in the second half of the year, weak La Niña conditions developed (Fig. 1). The CPC's Oceanic Niño Index (ONI) began the year with a value well over the +1.5 threshold for "strong" EL Niño, and then underwent a dramatic decline all the way to the -0.5 threshold of La Niña. In the first two months of 2017, the ONI drifted back into ENSO-neutral, resulting in the CPC canceling its recent La Niña advisory (see the latest CPC ENSO statement below).

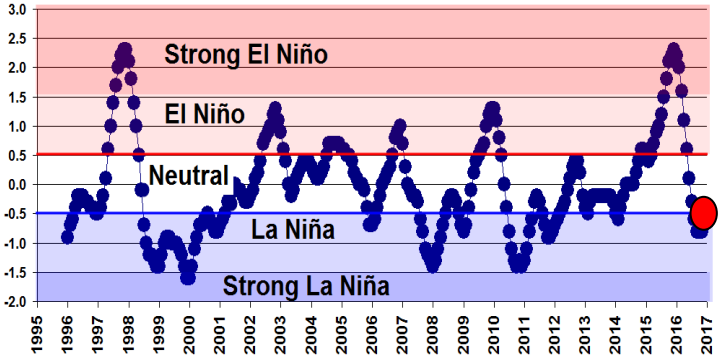

Figure 1. A composite of the Oceanic Niño Index (ONI) for the past two decades. The behavior of 2015-16 El Niño event is similar to that of the strong El Niño of 1997-98, with the notable exception that the 2015-16 event did not progress as strongly into La Niña territory in its post-Peak Phase. By early 2017 (big red dot), the climate state had re-entered ENSO-neutral, after the brief foray into weak La Niña territory at the end of 2016.

The first half of 2016 was very dry throughout most of Micronesia, with some of the multi-month accumulated totals spanning the latter half of 2015 through the first half of 2016 at-or-near record low values. This dryness was anticipated several months in advance since it is usually dry during the post-Peak phase of El Niño, and the PEAC was able to make some very good long-lead (3 to 6 months) forecasts of very low rainfall amounts for many US-API locations. Rainfall amounts recovered in the 2nd half of 2016. A very active monsoon trough during August brought the year's first widespread abundant rainfall throughout much of the region. Fall rainfall amounts were mostly near average. The year finished with a wet December, but the surplus was unable to overcome earlier dryness; and thus, the 2016 annual total rainfall was below average at most locations (Figs. 2 and 3).

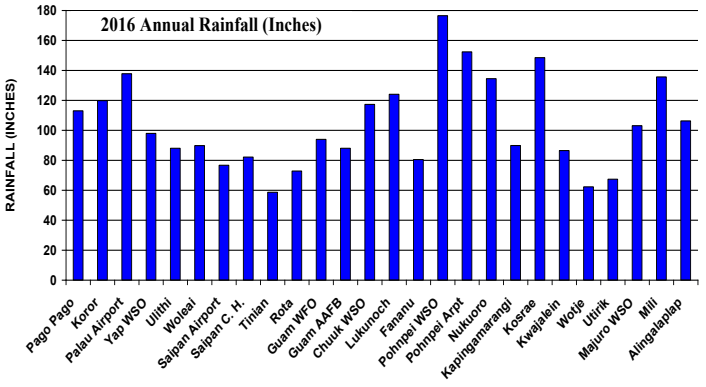

Figure 2. 2016 annual rainfall amounts in inches at the indicated locations.

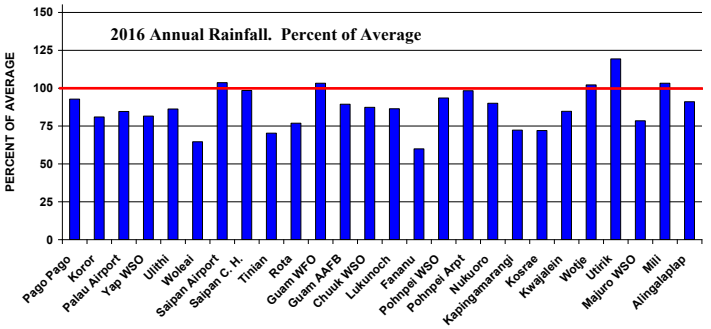

Figure 3. 2016 annual rainfall as a percent of average at the indicated locations. Note that most locations in Micronesia were below average, with the notable exceptions of Saipan, Guam, and the northern RMI atolls of Utirik and Wotje, and the southern RMI atoll of Mili..

Sea Level

During the 1st half of 2016, the sea level rebounded sharply from its low stands at the peak of El Niño in late 2015/early 2016 (Fig. 4). A sharp rise of sea level typically occurs in the first few months of the post-Peak year of an El Niño event. As anticipated by the PEAC, the sea level across Micronesia returned to above average values during the 3rd Quarter of 2016. During the 4th Quarter of 2016, the sea level was above average across all of Micronesia and also at American Samoa. Note that the rise and fall of sea level closely tracks the strength of the low-latitude trade winds, and hence the very strong connection of regional sea level with ENSO. See the sea level discussion for more details and specific forecasts.

CURRENT CONDITIONS

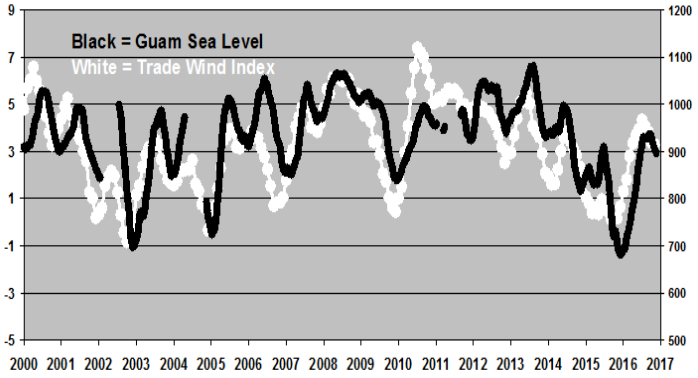

Figure 4. Time series of sea level at Guam (NOAA Sumay Cove tide gauge) from January 2000 through December 2016. Note the steady decline that reaches a low point at the end of 2015, and the subsequent sharp rise during 2016. Black line is a 12-month moving average of Guam's sea level, and the white line is a 12-month running sum of NOAA's trade wind index (5°S-5°N ; 135°E to 180°). The sea level at Guam and throughout the tropical western Pacific closely tracks the trade winds, with a small (1-2 month) lag that is perceivable in the diagram.

Breaking news:

Although the rainfall at most locations recovered to near average values in late 2016 and into early 2017, some of the atolls of the northern RMI experienced very dry conditions leading to shortages of drinking water. Emergency shipments of bottled water and reverse-osmosis equipment were made to some atolls. A drought information statement released by WFO Guam on 09 March 2017 states, in part:

"THE LAST EXPERIMENTAL DROUGHT ASSESSMENT OF THE U.S. DROUGHT MONITOR SHOWED THAT WOTJE AND UTIRIK OF THE NORTHERN MARSHALL ISLANDS WERE IN SHORT-TERM SEVERE DROUGHT (DROUGHT LEVEL 2 OF 4). BASED ON SATELLITE IMAGERY OVER THE LAST 10 DAYS...CONDITIONS LIKELY REMAIN SEVERE OR HAVE WORSENED TO EXTREME."

"THE ATMOSPHERE NORTHWARD FROM THE MARSHALL ISLANDS TO WAKE ISLAND CONTINUES TO BE VERY DRY...AND SEVERE OR EXTREME DROUGHT IS ALREADY AFFECTING WOTJE AND UTIRIK AND LIKELY OTHER NORTHERN AND THE WESTERN ATOLLS."

"THE MARSHALL ISLANDS GOVERNMENT INDICATES THAT UTIRIK AND ENEWETAK HAVE OPERATING REVERSE OSMOSIS (RO) SYSTEMS AND THAT SYSTEMS ARE BEING PREPARED FOR AILUK...WOTJE AND MEJIT. EVEN WITH RO UNITS... LOCAL VEGETATION AND FOOD SOURCES WILL SUFFER FROM THE DROUGHT.

LOCAL WELLS WILL BECOME MORE AND MORE SALTY. THE MARSHALL ISLANDS GOVERNMENT HAS ISSUED GUIDANCE FOR WATER CONSERVATION AND GOOD HYGIENE."

CURRENT STATE OF ENSO

ENSO Alert System Status: Not Active

ENSO-neutral conditions are favored to continue through at least the Northern Hemisphere spring 2017, with increasing chances for El Niño development into the fall.

ENSO-neutral conditions continued during February, with near-average sea surface temperatures (SSTs) across the central equatorial Pacific and above-average SSTs in the eastern Pacific. The latest weekly Niño index values were near zero in the Niño-4 and Niño-3.4 regions, and +0.4 and +2.2°C farther east in the Niño-3 and Niño-1+2 regions, respectively. The upper-ocean heat content anomaly increased during February and was slightly positive when averaged across the central and eastern Pacific, a reflection of generally above-average temperatures at depth. Atmospheric convection remained suppressed over the central tropical Pacific and enhanced over the Maritime Continent. The low-level easterly winds were slightly enhanced over the western tropical Pacific and were weaker than average over the eastern Pacific. Also, upper-level westerly winds were anomalously easterly over portions of the western and eastern Pacific. Overall, the ocean and atmosphere system is consistent with ENSO-neutral conditions.

Most models predict the continuation of ENSO-neutral (3-month average Niño-3.4 index between -0.5°C and 0.5°C) through the early Northern Hemisphere summer (May-July). However, some dynamical model forecasts, including the NCEP CFSv2, anticipate an onset of El Niño as soon as the late Northern Hemisphere spring (March-May 2017). Because of typically lower skill in forecasts made at this time of the year, and the lingering La Niña-like tropical convection patterns, the forecaster consensus favors ENSO-neutral during the spring (March-May) with a ~75% chance. Thereafter, there are increasing odds for El Niño toward the second half of 2017 (50-55% chance from approximately July-December). In summary, ENSO-neutral conditions are favored to continue through at least the Northern Hemisphere spring 2017, with increasing chances for El Niño development into the fall (click CPC/IRI consensus forecast for the chance of each outcome for each 3-month period:

(http://iri.columbia.edu/our-expertise/climate/forecasts/enso/current/?enso_tab=enso-cpc_plume)."

[1] Climate Prediction Center National Centers for Environmental Prediction. NOAA/National Weather Service. College Park, MD 20740

TROPICAL CYCLONE ACTIVITY

The PEAC archives western North Pacific tropical cyclone (TC) numbers, track coordinates, and 1-minute average maximum sustained wind taken from operational warnings issued by the Joint Typhoon Warning Center (JTWC) of the U. S. Air Force and Navy, located at Pearl Harbor, Hawaii. Western North Pacific tropical cyclone names are obtained from warnings issued by the Japan Meteorological Agency (JMA), which is the World Meteorological Organization's Regional Specialized Meteorological Center (RSMC) for the western North Pacific basin. The PEAC archives South Pacific TC names, track coordinates, central pressures, and 10-minute average maximum sustained wind estimates from advisories issued by the Tropical Cyclone Warning Centers at Brisbane, Nadi, and Wellington. The numbering scheme and the 1-minute average maximum sustained wind estimates are taken from warnings issued by the JTWC. There are sometimes differences in the statistics (e.g., storm maximum intensity) for a given cyclone among the agencies that are noted in this summary.

TROPICAL CYCLONE ACTIVITY

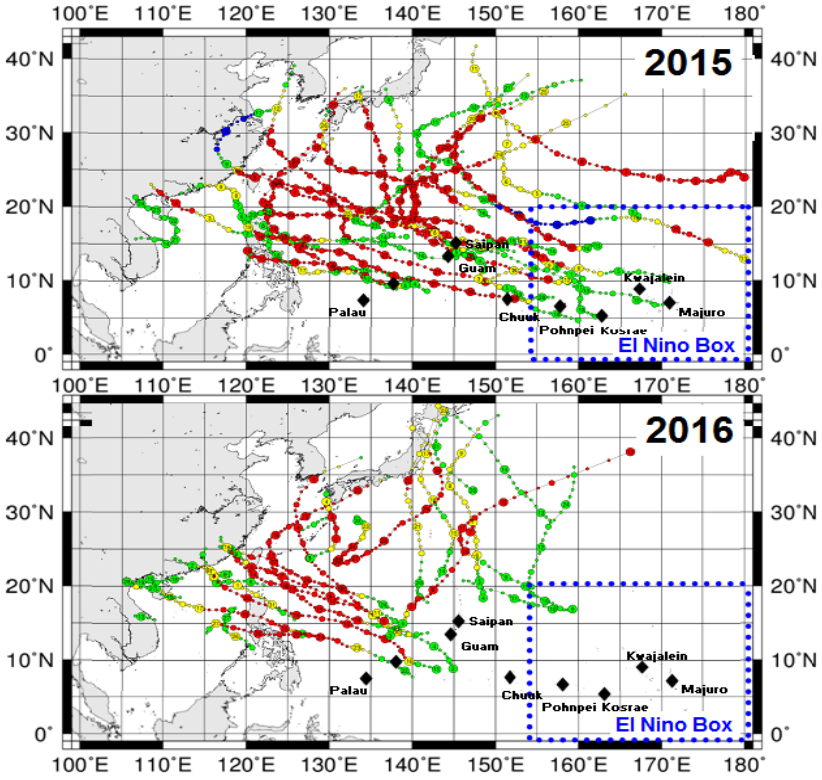

Figure TY1. Tropical cyclone tracks of 2015 and 2016 in the western North Pacific. A cluster of TCs in the subtropics to the north of Guam and Saipan formed during a strong far northward displaced monsoon trough during August. During September and October, a persistent focus of TC development was seen to the west of Guam. Clustering of TC activity and persistence of general track behavior are noted in most typhoon seasons, with each year possessing its own unique suite of characteristics. The blue "El Niño Box" is a region in which tropical cyclone occurrences are very strongly affected by ENSO.

Western North Pacific

The 2016 annual total of 30 TCs numbered by the JTWC during 2016 was near average. This belies some low-end statistics such as the late start and a below average number of typhoons (14 versus an average of 18). The number of tropical storms (10) was near average, but there was an abundance of tropical depressions (6) that helped to inflate the annual total. The number of named tropical cyclones passing through the bounds of Micronesia was greatly reduced from the high number of such TCs during 2015 (see Fig. TY1). The only common statistic of TC activity that was above average during 2016 was the high number of super typhoons: 6 versus the average of 4.

As anticipated by the PEAC, the 2016 typhoon season of the western North Pacific had a very late start, with the first named storm (Super Typhoon Nepartak) reaching tropical storm intensity on the 3rd of July. Through the remainder of July, the basin was quiet.

EastPac (Hawaii)

During October heavy rainfall occurred over the Big Island and Maui when remnant moisture from former tropical cyclone Ulika moved across both islands as an upper level low pressure system passed overhead. The resultant unstable conditions produced significant rainfall over the windward slopes that started on October 1 and continued through October 5.

Southern Hemisphere

The 2016-17 Southern Hemisphere (SH) TC season has so-far been remarkably quiet! Through 20 February, only six TCs have were numbered by the JTWC in the Southern Hemisphere. Of these, five were named by the responsible TC warning center. To-date, no TCs have been named in the South Pacific! Note: Cyclone Alfred (TC 06P) occurred in the Gulf of Carpentaria, which is considered by the JTWC to be part of the South Pacific for numbering protocol (i.e. "P" for the South Pacific versus "S" for the South Indian Ocean). Although the Australian Northwest Monsoon has had active penetrations into the South Pacific (indeed, across Samoa and into French Polynesia), there have been no disturbances in the monsoon trough to reach TC status. One recent disturbance in French Polynesia came close, but it moved south and acquired sub-tropical characteristics (as per the warning agencies: JTWC and MeteoFrance).

PEAC Tropical Cyclone Assessment

Western North Pacific and American Samoa

No official forecasts are yet available for 2017 seasonal typhoon projections. Using the current status of ENSO as a guide, the PEAC anticipates that TC activity will be near average in the western North Pacific basin through the first half of 2017. In general, any movement of the state of the climate system in the direction of El Niño (whether from La Niña to ENSO-neutral, or La Niña to El Niño) is correlated with average to above-average typhoon activity. The stronger the move toward El Niño, the more serious is the risk for an early season typhoon. For now, the basin TC activity should continue to exhibit a westward shift, with a near average basin count of 3 or 4 named cyclones during March through June 2017. One or two of these TCs may pass near Guam, the CNMI, Yap or Palau, but likely move away to the west before becoming named. If the climate system makes a stronger push toward El Niño, the early season (March-June) TC threat could be higher.

The new 2016-17 South Pacific cyclone season officially began 01 July 2016. No TC activity has occurred so-far (20 February) near American Samoa! Indeed, the whole Southern Hemisphere is experiencing unprecedented below average TC activity, with a quantity known as the Accumulated Cyclone Energy[1] (ACE) standing at a season-to-date total of 19.715, which is only 17% of the average year-to-date ACE of 112 (see: http://models.weatherbell.com/tropical.php). The Australian Bureau of Meteorology called for near average TC activity in the eastern region of the South Pacific, which, for the BoM, extends from New Caledonia eastward into French Polynesia (see: water http://www.bom.gov.au/cyclone/outlooks/seasonal/qld.shtml). In its last ENSO newsletter, the PEAC called for reduced activity in the South Pacific eastward of the International Date Line. However, the northwest monsoon has been active in the South Pacific, albeit with other atmospheric dynamics exhibiting some unfavorable values (H. Diamond, personal communication). It would be prudent to expect at least a near-average finish to the 2016-17 South Pacific TC season, which should see two or three named cyclones in waters stretching from Fiji in the west and eastward through Samoa, Tonga and Niue.

[1] ACE is an approximation of the wind energy used by a tropical system over its lifetime and is calculated every six-hour period.

SEASONAL SEA LEVEL OUTLOOK FOR THE US-AFFILIATED PACFIC ISLANDS

After nearly a decade of very high values, the sea level has dramatically fallen across Micronesia over the past two years, which typically occurs during El Niño year, with the lowest value of sea level occurring in December. A sharp rise occurs in the first few months of the post-peak year of the El Niño event, which is primarily due to rapid backflow of a bulk quantity of water to the western Pacific. Therefore, we have observed a sharp rise of sea level during the second half of 2016. In addition, the developing phase of ENSO-neutral or weak La Niña in the end of 2016 caused sea level to rise or stay elevated for some time. However, as it is ENSO-neutral now, so the sea level is likely to come back to normal soon.

The following sections describe: (i) the Canonical Correlation Analysis (CCA) forecasts for seasonal (mean and maxima) sea level anomalies (seasonal cycle removed) for the forthcoming seasons January-February-March (JFM), February-March-April (FMA), and March-April-May (MAM) of 2017 , (ii) JFM return values at 20 and 100-yr period, (iii) the observed monthly mean and maximum sea-level anomalies for the previous season October-November-December (OND) of 2016, and (iv) synopsis of last 2-years Sea Level variability and forecasts. *Note that, seasonal cycles have been removed for the data anomalies that are defined as 'deviations or departures from the normal' using the 1983 through 2001 mean sea level value computed at each station. Also note that CCA-forecasting technique adopted here does not account for sea level deviations created by other atmospheric or geological factors.*

Seasonal Sea Level Forecast (anomalies with respect to climatology) for JFM, FMA, and MAM of 2017

Forecasts of the sea-level anomalies in the USAPI (see http://www.weather.gov/peac/sealevel) are presented using CCA statistical model. Based on the independent SST and zonal wind (U) (SST-U) values in OND of 2016, the resulting CCA model has been used to forecast the sea level of three consecutive seasons: JFM, FMA, and MAM (see Table 1: left panel shows values for seasonal mean while the right panel shows the seasonal maxima). All the tide gauge stations (at 0 to 2-months lead time) provided skillful forecasts for these three consecutive seasons.

Table 1: Forecasts of sea level anomalies in inches (JFM, FMA, and MAM)

	Seasonal Mean Deviations [1]				Seasonal Max Deviations [2]				
Tide Gauge Station	**JFM**	**FMA**	**MAM**	**Seasonal Outlook[3]**	**JFM**	**FMA**	**MAM**	**JFM: Return Period[4]**	
Lead Time [5]	**0-M**	**1M**	**2M**	**Seasonal Outlook[3]**	**0-M**	**1M**	**2M**	**20- YR**	**100-YR**
Marianas, Guam	+5	+4	+4	**Above**	+22	+21	+21	5.6	6.7
Malakal, Palau	+3	+3	+3	**Above**	+40	+41	+40	9.6	14.3
Yap, FSM	+4	+4	+4	**Above**	+32	+34	+34	16.7	33.0
Chuuk, FSM**	+4	+4	+4	**Above**	+32	+32	+32	n/a	n/a
Pohnpei, FSM	+4	+4	+3	**Above**	+35	+34	+34	5.8	7.1
Majuro, RMI	+3	+3	+3	**Above**	+45	+44	+44	4.1	5.1
Kwajalein, RMI	+4	+4	+3	**Above**	+44	+42	+42	4.5	5.9
Pago Pago, Am. Samoa***	+5 (0)	+4 (-1)	+4 (-1)	**Normal**	+32 (+27)	+32 (+27)	+31 (+26)	3.9	5.4
Honolulu, Hawaii	+1	+1	+1	**Normal**	+21	+20	+20	4.1	5.9
Hilo, Hawaii	+2	+2	+2	**Normal**	+25	+24	+24	7.9	11.4

Table 1 and Supporting Statistics: : (-) indicate negative anomalies (fall of sea level from the mean), and (+) indicate positive anomalies (rise of sea level from the mean), n/a: data not available. Anomalies from -1 to +1 inches are considered negligible and anomalies from -2 to +2 inches are unlikely to cause any adverse climatic impact. Forecasts for Chuuk (**) are estimated subjectively based on information from WSO Chuuk and observations from neighboring stations of Pohnpei and Yap. *** There was a level shift (approximately 2-4 inches) in American Samoa at the time of September 2009 earthquake. So, -2 inches needs to adjust to the current tide-gauge values of Pago Pago. See PEAC website for the explanations of footnote (1 to 5). Also note that all information is based upon the 1983-2001 epoch.

The current sea level forecasts indicate that most of north and south Pacific stations are likely to be above-normal (normal and average are synonymously used throughout the sea level section) in the forthcoming JFM, FMA, and MAM seasons. In Hawaii, both Honolulu and Hilo are likely to be slightly elevated, but still close to normal. Despite some rise during the later half of 2016, current observations revealed that all the stations are stable now. This rise is somewhat expected and the stable condition also corresponds very well with the current developing phase of ENSO-neutral or weak La Niña condition. However, even as the tropical Pacific Ocean returns to ENSO-neutral conditions, the atmospheric impacts from La Niña could persist during the upcoming months JFM. So, sea level will still remain slightly elevated, but no further rise is anticipated, for the next couple of months.

SEASONAL SEA LEVEL OUTLOOK FOR THE US-AFFILIATED PACFIC ISLANDS

Observed Monthly Mean Sea Level Anomalies (with respect to climatology) for May-Jun-Jul (MJJ) of 2016

The monthly time series (January to March) for sea level anomalies have been taken from the UH Sea Level Center. The full time series (in mm) for monthly mean is available at: ftp://ilikai.soest.hawaii.edu/islp/slpp.anomaliess. Locations of all these stations can be found at http://www.prn.noaa.gov/peac/map.php.

Current Conditions/Impacts: After significant rise in September-October, the sea level recorded marginal fall in November and December of 2016. Only Pago Pago recorded further rise in December. As of December 2016, all stations are steady but stays well above normal. Other than Majuro, there were no inundation recorded, so far. Majuro suffered severe inundations in October, which was due to strong south winds across the lagoon placing the inundation on the south facing islet on the north side of the lagoon. It has been noted that when the sea state increases, possibility of inundation increases regardless of tide or sea level. However, high tide makes inundation worse.

Table 2: Monthly observed mean/maximum sea-level anomalies (in inches)

Tide Gauge Station	Monthly Mean Deviations[1]				Monthly Max Deviations[2]			
	Oct	Nov	Dec	Standard Deviations	Oct	Nov	Dec	Sea level Trend
Marianas, Guam	+4	+5	+4	**4.1**	+21(3)	+21(3)	+19 (0)	Above-Stable
Malakal, Palau	**+8**	**+5**	**+5**	**4.3**	+47(7)	+43(3)	+43(3)	Above-Stable
Yap, FSM	**+5**	**+6**	**+7**	**4.6**	+36(6)	+32(2)	+33(3)	Above-Stable
Chuuk, FSM*	**+9**	**+9**	+7	**	**	**	**	**
Pohnpei, FSM	+**10**	**+10**	**	**4.7**	37(7)	+40(10)	+35(5)	Above-Stable
Majuro, RMI	**10**	**+5**	**	**3.5**	+51(9)	+47(5)	+48	Above-Stable
Kwajalein, RMI	+6	+4	+2	**3.6**	+46(10)	+44(8)	+44(8)	Above-Stable
Pago Pago, American Samoa* **	**+12** (+7)	+11 (+6)	+13 (+8)	**3.1**	+38(8) (33)	+37(7) (32)	+39(9) (34)	Above-Stable
Honolulu, Hawaii	+5	+3	+4	**1.7**	+23(3)	+23(3)	+25(5)	Above-Stable
Hilo, Hawaii	+4	+4	+7	**1.8**	+25(2)	26(3)	+32(9)	Above-Stable

Table 2. +/- indicate positive anomaly (rise) and negative anomaly (fall) respectively. Note that any changes between (0~ ±1) inch is considered to be negligible. Also note that changes within the range of (+/-) 2 inches are unlikely to cause any adverse climatic impact. *** Guesstimated values, ** Data currently unavailable; Figures in parenthesis are year-to-year seasonal anomaly. 1: Difference between the mean sea level for the given month and the 1983 through 2001 mean sea level value at each station (seasonal cycle removed); 2: Same as 1 except for maxima; SD stands for standard deviations. * In Pago Pago, there was a level shift (approximately 2-4 inches) at the time of September 2009 earthquake. Values in parenthesis () in Max Deviations indicates anomaly from its long-term monthly average.

Synopsis of 2-years Sea Level Variability and Forecasts

Starting from OND of 2014, a comparative perspective of two years of seasonal sea level variations is given below (Fig. 5). The sea lever in the western Pacific started to fall from JFM of 2015. This falling trend continued up to JAS of 2015. Again it started to rise from OND of 2015 and, starting from JFM of 2016, sea level recorded an abrupt rise and remained high until JAS of 2016. The month of October also remained high. It started to fall from November 2016. However, it is likely to stay moderately elevated during the beginning (JFM) of 2017.

See page 15 for sea level observations from Jason-2 satellite picture (Fig. 6).

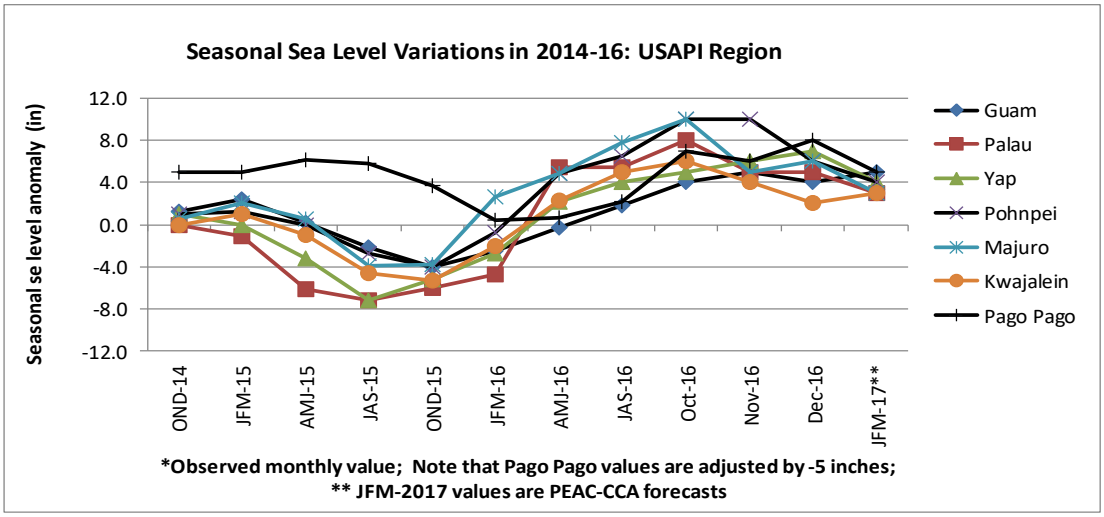

Figure 5. A comparative perspective of Island-wise seasonal sea level variations (OND 2014 to OND 2016) (*Note that Pago Pago data needs correction because of level shift after 2009 earthquake. ,There was a level shift (approximately 2-4 inches) at that time which has not been adjusted).

LOCAL SUMMARY AND FORECAST

American Samoa: At American Samoa during 2016, only one month (April) had above average rainfall (Fig. AS-1). In fact, there was an enormous amount of rainfall During April 2016 when 30.34 inches was experienced at the WSO Pago Pago, which was, by far, the highest April rainfall, and was also the 2nd highest rainfall total of any month in the historical record. If April were to have had its average value of rainfall (~12 inches), then the 2016 annual rainfall would have fallen substantially below average (77%). Even with April's full amount included, the 2016 annual rainfall total at the Pago Pago WSO was still below average (93%). After the Big Wet April, American Samoa passed through its dry season with no major impacts from a lack of precipitation, even though every month from June to October had below average rainfall. During the November and December onset of the 2016/17 rainy season, rainfall amounts were near average.

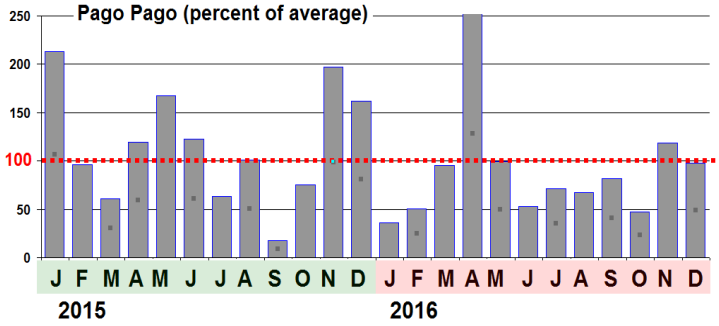

Figure AS-1. A time series of the monthly rainfall recorded at the Pago Pago WSO during 2015 through October 2016.

During the course of the 2016-17 rainy season (and cyclone season) so far (NOV + DEC 2016 and JAN + FEB 2017) one of the most noteworthy climatic anomalies has been a dramatic lack of TCs (see the TC description in the Current Conditions Section). The lack of TCs in the Southern Hemisphere has been profound, and has already set some new historical records for inactivity (e.g., latest first hurricane in the South Pacific, lowest accumulated cyclone energy to-date, etc.). The dearth of TCs has been widespread, with low-end statistics found from the South Indian Ocean all the way across into central South Pacific. Australia has had a few cyclones attempt to form over land (which, had they occurred over water or passed from land to water, would likely have developed to a named cyclone). During mid-February, a tropical low with east-side gales formed in French Polynesia, but was considered tropical-sub-tropical hybrid by the local TC warning agencies. Late in February, two other similar hybrid TCs formed in the SPCZ, this time a bit closer to American Samoa, but they moved rapidly to the SE away from Samoa, did not significantly intensity, and did not last long

The lack of TCs in the region of American Samoa (and elsewhere across the Southern Hemisphere) has correlated with some large-scale factors normally considered detrimental to TCs, and these include less than average vorticity (cyclonic spin) in the SPCZ/monsoon trough, higher than average sea level pressure and slightly lower mid-atmospheric humidity (Dr. H. Diamond, personal communication). Conditions have not been profoundly unfavorable, as the Australian Northwest Monsoon has, at times, worked its way across the International Date Line and into the Samoa region. Disturbances attempt to consolidate along the SPCZ/monsoon trough, but something is certainly keeping them in check.

The mean sea level in American Samoa fell during the first half of 2016 to a low level that has not been recorded since the

LOCAL SUMMARY AND FORECAST

first half of 2010 (see Fig. AS-2). Lowered sea level is a typical response to El Niño in American Samoa. The lowest value tends to occur in March or April and then rises thereafter. A rise of sea level has commenced (Fig. AS-2), and by the end of 2016, the sea level had risen to new historic highs at the Pago Pago tide gauge (***Fig. AS-3***) (see the sea level section for more details).

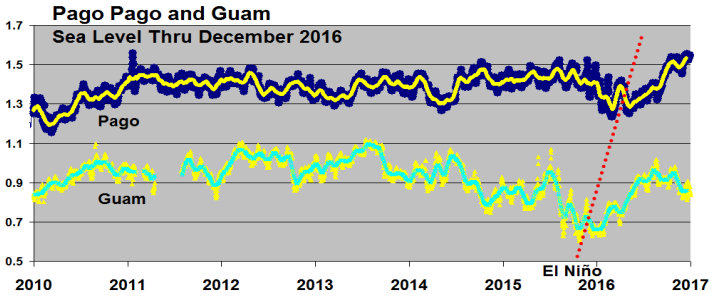

Figure AS-2. A time series of the monthly sea level recorded at the Pago Pago tide gauge and at the Apra Harbor, Guam tide gauge during January 2010 through December 2016. Note the substantial lowering of the sea level at both stations in response to the epic 2015-16 El Niño event. Note also the several month time lag (dotted line) in the response at American Samoa versus Guam. Sea level units are in meters above gauge benchmark.

American Samoa Rainfall Summary: OND 2016, 4th Quarter and 2016 Annual

Station		Oct	Nov	Dec	4thQtr	Annual
Pago Pago WSO	Rain (in)	5.12	12.86	14.24	32.22	113.02
	% Avg.	47%	119%	98%	89%	93%
Siufaga Ridge*	Rain (in)	.	.	.	.	.
	% Avg.	%	%	%	%	%

* Station temporarily out of service, data resuming in Feb 2017.

Climate Outlook:

Computer model forecasts are now indicating average to slightly above average rainfall over the next three months at Pago Pago, and the PEAC concurs with these projections. Weak La Niña recently transitioned to ENSO-neutral, where the state of the climate is anticipated to remain through the summer. Rainfall in American Samoa is only weakly related to the state of ENSO, with dryness immediately following strong El Niño the most consistent relationship. With La Niña having recently fallen back to ENSO-neutral, there are no compelling reasons at this time to manually intervene in the computer forecasts of rainfall for the region.

For now, the basin TC activity should continue to exhibit a westward shift, with a near average basin count of 3 or 4 named cyclones during March through June 2017. One or two of these TCs may pass near Palau as they develop and make their way westward toward the Philippines. If the climate system makes a stronger push toward El Niño, the early season (March-June) TC threat of gales and hazardous surf could be higher.

Tropical cyclone activity during the ongoing 2016-17 cyclone season was anticipated to be shifted westward, with highest TC activity in Australian waters eastward into the Coral Sea. The Australian Bureau of Meteorology called for above average TC activity in the Australian region (see: water http://www.bom.gov.au/cyclone/outlooks/seasonal/qld.shtml). In the South Pacific, eastward of the International Date Line, TC activity was forecast to be reduced, with American Samoa seeing a slight reduction to its risk of damaging effects from cyclones. Now that the TC season is into its final months, and with an ongoing widespread substantial reduction of activity, it would seem a natural choice to forecast a persistence of below average activity across Samo-

LOCAL SUMMARY AND FORECAST

an waters. The PEAC, however, will continue with a prudent forecast for a near average risk of a TC near American Samoa in the final few months of the cyclone season. This means that there is still a chance (through June), for one or two TCs to pass close enough to American Samoa to bring gales, high seas and surf, and an extreme daily rainfall (at-or-above 4-6 inches in 24 hours).

The sea level at American Samoa is now at a historically high level (that may be partly an artifact of a datum shift after a large nearby earthquake in 2009). In any case, the sea level is likely to remain at higher than average levels for the next few months (see the sea level section for more details).

Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]
January - March 2017 (Heart of Rainy Season)	110%
April - June 2017 (Onset of Next Dry Season)	100%
Jul - Sep 2017 (Heart of Next Dry Season)	100%
Oct - Dec 2017 (Onset of Next Rainy Season)	110%

[1] Forecast rainfall quantities represent BEST ESTIMATES given the probabilistic forecast for each particular season and station.

Guam/CNMI: The first half of 2016 was very dry throughout Guam and the islands of the CNMI (Figure G1). This dryness was anticipated several months in advance since it is usually dry during the post-Peak phase of El Niño. The dryness was not anywhere near a record, and the total rainfall of 77.01 inches during the 12-month period July 2015 to August 2016 was the 16th driest such period in the 63-year climate record at AAFB. Rainfall amounts recovered in the 2nd half of 2016. A very active monsoon trough brought abundant rainfall throughout the region during August. The year ended with a wet

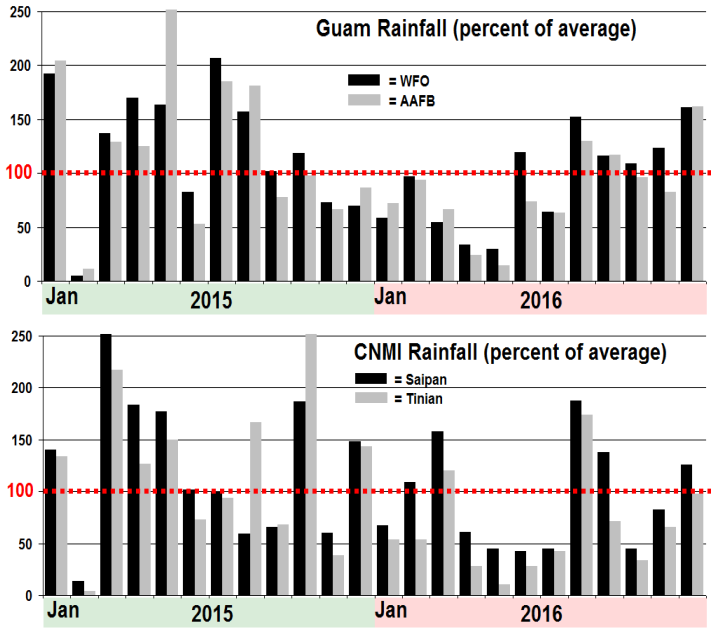

Figure G1. Top: A time series of monthly rainfall percentages at the Guam WFO and at AAFB. A wild 2015 settles into persistent dryness through the middle of 2016, with a recovery of rainfall in the final half of the year. Bottom: Same as the top panel, but for monthly rainfall percentages at Saipan and at Tinian.

LOCAL SUMMARY AND FORECAST

December, but it was not enough to overcome earlier dryness so that the 2016 annual total rainfall was below average.

Saipan experienced a very high extreme rainfall of 9.34 inches over a 24-hour period spanning the 3rd and 4th of August. This unusually heavy rainfall was focused over Saipan while the other islands of the CNMI received far less. The rainfall from this extreme event (and other heavy rainfall during August) pushed the 2016 annual rainfall total to above average on the island of Saipan (104%). At other islands of the CNMI, where August was nowhere near as wet as at Saipan, the 2016 annual rainfall totals were below average.

Several of the western North Pacific TCs of 2016 developed in a focused region just to the west-northwest of Guam and the CNMI, resulting in an unusual cluster of TC tracks originating in this region. But apart from making contributions to regional rainfall, the TCs of 2016 had little other impact on Guam and in the CNMI.

Guam and CNMI Rainfall Summary: OND 2016, 4th Qtr. & 2016 Annual

Station		Oct	Nov	Dec	4th Qtr	Annual
GUAM						
GIA (WFO)	Inches	13.14	10.13	8.68	31.95	93.94
	% Avg	109%	124%	161%	125%	103%
AAFB	Inches	12.35	7.52	9.68	29.55	88.01
	% Avg	96%	83%	162%	106%	89%
Southern Mountain	Inches	14.09	11.10	8.40	33.59	91.98
	% Avg	109%	122%	141%	120%	93%
CNMI						
Saipan Intl. Airport	Inches	5.07	4.97	5.04	15.08	76.69
	% Avg	47%	86%	131%	74%	104%
Capitol Hill	Inches	7.44	5.18	6.06	18.68	82.11
	% Avg	62%	71%	126%	78%	98%
Tinian Airport	Inches	4.07	4.81	4.70	13.58	58.64
	% Avg	34%	66%	98%	56%	70%
Rota Airport	Inches	7.38	6.57	7.72	21.67	72.81
	% Avg	58%	76%	136%	80%	77%

Climate Outlook:

Computer model forecasts are now indicating average to above average rainfall over the next three months, and the PEAC concurs with these projections. Weak La Niña recently transitioned to ENSO-neutral, where the state of the climate is anticipated to remain through the summer. Thereafter the odds of El Niño developing begin to rise. In general, any movement of the state of the climate system in the direction of El Niño (whether from La Niña to ENSO-neutral, or La Niña to El Niño) correlates well with average to above-average rainfall in our region. The stronger the move toward El Niño, the wetter and also the more serious the risk of an early season typhoon.

For now, the basin TC activity should continue to exhibit a westward shift, with a near average basin count of 3 or 4 named cyclones during March through June 2017. One or two of these TCs may develop near Guam and the CNMI, but likely move

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away to the west before becoming named. If the climate system makes a stronger push toward El Niño, the early season (March-June) TC threat could be higher

Predicted rainfall for the Mariana Islands from January through December 2017:

Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]	
	Guam/Rota	Saipan/Tinian
Jan-Mar 2017 (1st half of next dry season)	110%	100%
Apr-Jun 2017 (2nd half of next dry season)	110%	100%
Jul-Sep 2017 (Onset of next rainy season)	100%	95%
Oct-Nov 2017 (End of next rainy season)	100%	100%

Forecast rainfall quantities represent BEST ESTIMATES given the probabilistic forecast for each particular season and station.

Federated States of Micronesia

Yap State: For nearly a year (mid-2015 through mid-2016) Yap State was very dry (Fig. Y1). The continuous dryness at the end of 2015 into JFM of 2016 set a new historical record for low rainfall at the Yap Island WSO. The 6 months of OND (2015) + JFM (2016) were particularly dry with only 39% of average rainfall. Effects of low rainfall included a nearly complete drawdown of the municipal reservoir and wildfires that scorched roughly 4% of the land area of the island. Despite the depletion of the reservoir, other sources of water (e.g., wells), and water in storage precluded both mandatory conservation measures and water rationing. Uninterrupted 24-hour water service was largely maintained across most of the island. High rainfall during May 2016 averted any further deterioration in water resources.

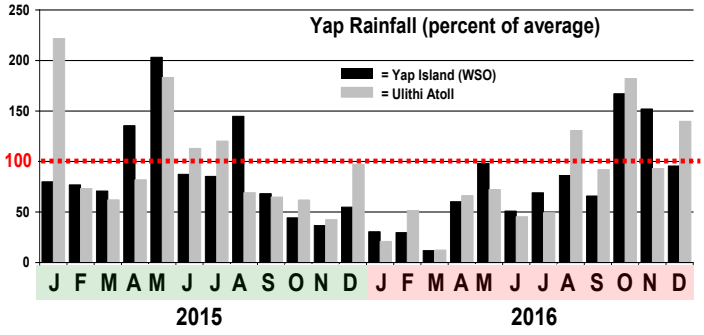

Figure Y1. Time series of monthly rainfall at the Yap Island WSO (black bars) and Ulithi Atoll (gray bars) for all of 2015 through December 2016. The continuous dryness at the end of 2015 into the spring of 2016 set a new historical record for low rainfall! Below average rainfall continued through September, but October 2016 was very wet! .

Rainfall was below average across Yap Island during the summer months, but amounts were sufficient to eventually refill the reservoir. Rainfall at the outer islands and atolls of Yap State also continued to be mostly below average, but then in October well-above-average rainfall was observed throughout most of Yap State as Typhoon Haima and some other tropical disturbances passed through the region. Abundant rainfall continued in Yap State for the remainder of 2016, and was above average in January of 2017 as well.

Two named tropical cyclones passed through Yap State in the final months of 2016: Haima (TC 25W) in October, and Nock-ten (TC 30W) in December. The northeastern atolls of Yap State (Ulithi and Fais) were most affected by both of these tropical cyclones. On the night of 15 October, Haima passed over Fais, and later on the morning of 16 October, passed nearby Ulithi Atoll. Haima was a tropical storm when it passed over Fais and became a Category 1 typhoon when it made its closest point of approach to Ulithi Atoll. There were no deaths or injuries on Fais or Ulithi, but food sources were partially destroyed. Residents of Ulithi were still recovering from Typhoon Maysak (May 2015), and recovery efforts were hampered by Haima. After exiting Yap State, Haima became a very intense typhoon that produced severe effects in the Philippines and Hong Kong.

During the daylight hours of 22 December, Nock-ten (as an intensifying tropical storm) passed near both Fais island and Ulithi Atoll. On microwave satellite imagery, the "eye" of the intensifying Nock-ten passed directly over Ulithi Atoll. The Atoll is quite large, with its ring of islets stretching nearly 25 miles, both north-south and east-west. The islet of Falalop (on the northeastern side of the atoll) is the most accessible, with an air strip, a small resort hotel, gas dealership, store, and a public high school. On the afternoon of December 22, as Nock-ten was passing through, residents of Falalop reported the occurrence of a "tornado". Eyewitnesses described a sudden roar -- like a jet engine – as a surge of high wind blasted across the islet filling the air with lofted debris that appeared to be rotating. A video and photos of the post-event damages were posted by Jon Rulmal Jr. on Youtube (https://www.youtube.com/watch?v=-muVOyWh0w4) and Facebook (https://www.facebook.com/media/set/?set=a.10209393480807985.1073741909.1053274685&type=3), respectively. A write-up of the event appeared in the 23 January 2017 issue of the Kasalehlie Press:

Standing with Ulithi- Tornado rips through island

Published: Monday, 23 January 2017 09:09

Written by Katlyn Murray

…

"On December 22, 2016, a water spout turned tornado ripped through the island, tearing apart over 20 newly repaired homes and cook houses along its path. "It sounded like a jet was flying low over the island. Luckily, we had been warned that Typhoon Nock-ten could be headed in our direction so we were prepared for a potential disaster. If we hadn't received warning about Nock-ten, this tornado would have claimed lives on Falalop," said local resident Jon Rumal Jr." …

The photos and the Youtube video are all taken shortly after the event, and show widespread "moderate" wind damage. Analysis of the wind damage is hampered by the fact that there is still evident damage to structures and trees that occurred during the passage during the May 2015 passage of Super Typhoon Maysak over the atoll. In any case, the new damage is "moderate": banana trees blown down, other tree branches broken, some pieces of sheet metal wrapped into trees and power lines, and several newly constructed wooden homes blown apart. PEAC scientist Dr. Mark Lander and WFO Guam WCM, Chip Guard estimate that wind gusts of at least 100 mph are needed to cause the observed damage as seen in the video and photos. We are not certain that this was a tornado. The event occurred just as the "eye" of Nock-ten (this TC then estimated to possess 55 kt sustained wind) was passing across the atoll. A plausible scenario could be the sudden arrival of the intense south or southwest wind on the eastern side of the eye. Both Lander and Guard have witnessed wind increases from less than 30 mph to over 100 mph in roughly one minute during typhoon eye passages over Guam. A massive wall of flying debris fills the air and green waste, garbage cans and other jumbles and bits of yard,

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porch and tool-shed flotsam skitter along the roadways at the onset of such sudden wind increases. In any case, it is not officially verified that this event was a tornado, but we cannot rule it out without further investigation, which lander and Guard plan, to some extent

Yap State Rainfall Summary: OND 2016, 4th Qtr & 2016 Annual						
Station		Oct	Nov	Dec	4thQ	Annual
Yap State						
Yap WSO	Inches	20.00	13.78	8.59	42.37	97.92
	% Norm	167%	152%	96%	141%	82%
Ulithi	Inches	18.51	7.17	10.67	36.35	88.01
	% Norm	182%	93%	140%	142%	86%
Woleai	Inches	18.39	6.31	10.09	34.79	89.76
	% Norm	135%	58%	88%	97%	65%

Climate Outlook:

Computer model forecasts are now indicating average to above average rainfall over the next three months, and the PEAC concurs with these projections. A weak La Niña recently transitioned to ENSO-neutral, where the state of the climate is anticipated to remain through the summer. Thereafter the odds of El Niño developing begin to rise. In general, any movement of the state of the climate system in the direction of El Niño (whether from La Niña to ENSO-neutral, or La Niña to El Niño) correlates well with average to above-average rainfall throughout Yap State. The stronger the move toward El Niño, the wetter and also the more serious the risk of an early season typhoon.

For now, the basin TC activity should continue to exhibit a westward shift, with a near average basin count of 3 or 4 named cyclones during March through June 2017. One or two of these TCs may become a tropical storm or low-end typhoon while passing through Yap State. If the climate system makes a stronger push toward El Niño, the early season (March-June) TC threat could be higher. The PEAC assesses the risk of some damaging effects, such as high waves, gales or very heavy rainfall at 10-15% (a 1-in-10 to 1-in-7 chance).

Predicted rainfall for Yap State from January through December 2017 is:

Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]	
	Woleai	Yap & Ulithi
January-March 2017 (Heart of next Dry Season)	100%	120%
April-June 2017 (End of Dry Season)	120%	120%
July-September 2017 (Heart of next Dry Season)	110%	100%
October-December 2017 (End of next Dry Season)	100%	100%

Chuuk State: The temporal distribution of rainfall at most locations in Chuuk State through 2015 and 2016 evolved in the same way as it did at most Micronesia locations: a wet 2015 with very high month-to-month variability, followed by persistent dryness that began in October 2015 and continued almost uninterrupted until November 2016 (Fig. CH-1). In fact, at the Chuuk WSO on Weno Island, all months from October 2015 to

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October 2016 had below average rainfall. By adjusting the start and end months, one can find noteworthy extremes of dryness, such as: The 7th driest October to July, and the 3rd driest October to October (Fig. CH-2). The dryness at the Chuuk WSO during the 13-month period October 2015 through October 2016 was exceeded only by the October-to-October periods of 82-83 and 97-98. Surprising levels of dryness continued at some locations in Chuuk State through the 3rd Quarter of 2016.

The period October 2015 through March 2016 was particularly dry throughout Chuuk State, which caused some problems with potable water supplies. Then, during the months of April through July of 2016, higher (but still slightly below average) rainfall amounts returned to central and southern islands and atolls. By May 2016, the perceptible impacts of dry weather had ended at all but the atolls in the far north and west of Chuuk State (e.g., Fananu, Onoun and Polowat) where dry conditions were more pronounced. Heavy above-average rainfall occurred at many locations in November and/or December, but it was not heavy enough to lift the 2016 annual rainfall total to above average at any location.

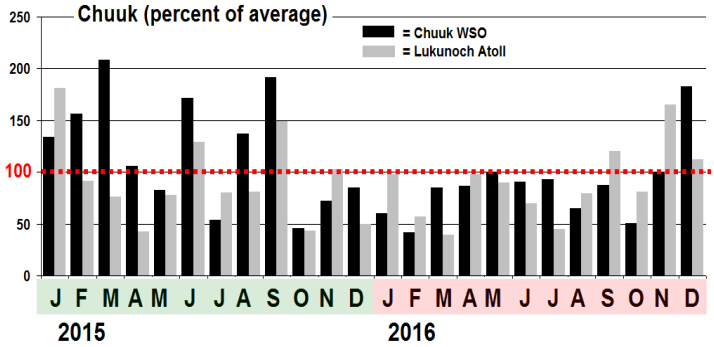

Figure CH-1. A time series of the monthly rainfall at the WSO Chuuk (black bars) and at Lukunoch (gray bars) during 2015 and 2016. Note the wild variability in 2015 followed by the long continual dry period lasting 13 months from OCT 2015 to OCT 2016.

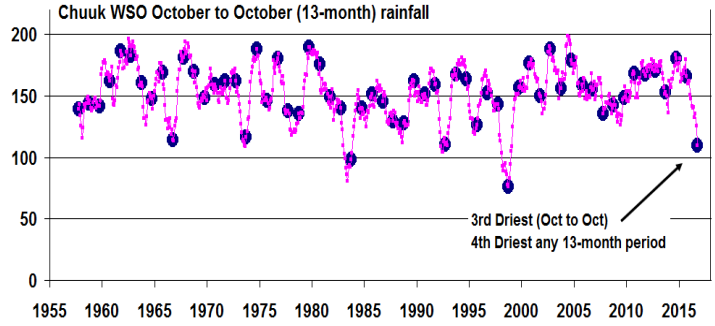

Figure CH-2. A time series of the accumulation of rainfall over 13-month intervals at the Chuuk WSO. Large dots are discrete October-to-October 13 month periods. Small pink dots connected by a thin pink line show moving 13-month sums (of which the blue dots are a subset). The last blue dot shows the recent 2015-16 dry spell and its status in the historical record.

Climate Outlook: Computer model forecasts are now indicating average to above average rainfall over the next 3 months at the Chuuk WSO. The PEAC concurs with the above-average projections for WSO Chuuk, and anticipates that the same projections are also valid at most of the other islands and atolls of Chuuk State. In the spring months, abundant convection should be found in an accentuated trade-wind trough, bringing abundant rainfall to most of the central and southern portions of the state. A 20-inch month is possible anytime between March and June.

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A weak La Niña recently transitioned to ENSO-neutral, where the state of the climate is anticipated to remain through the summer. Thereafter the odds of El Niño developing begin to rise. In general, at this time of year, any movement of the state of the climate system in the direction of El Niño (whether from La Niña to ENSO-neutral, La Niña to El Niño or ENSO-neutral to El Niño) correlates well with average to above-average rainfall across most of Chuuk State. The stronger the move toward El Niño, the wetter it tends to be, and also there are higher odds for an early-season tropical storm

For now, the basin TC activity should continue to exhibit a westward shift, with a near average basin count of 3 or 4 named cyclones during March through June 2017. One or two tropical disturbances may become a tropical depression or a tropical storm while passing through Chuuk State. If the climate system makes a stronger push toward El Niño, the early season (March-June) TC threat could be higher. The PEAC assesses the risk of some damaging effects, such as high waves, gales or very heavy rainfall at 10% (a 1-in-10).

Lastly, the sea level increased rapidly in the second half of 2016, and now stands above average (see the sea level section for details).

Chuuk State Rainfall Summary: OND 2016, 4th Quarter and 2016 Annual

Station		Oct	Nov	Dec	4thQ	Annual
Chuuk Lagoon						
Chuuk WSO	Inches	6.73	10.39	19.83	36.95	117.28
	% Avg	50%	101%	183%	107%	87%
Southern Mortlocks						
Lukunoch	Inches	8.41	18.02	14.42	40.85	124.05
	% Avg	45%	79%	120%	81%	76%
Northern Mortlocks						
Losap	Inches	10.81	13.33	19.93	44.07	108.19
	% Avg	81%	129%	184%	127%	81%
Northern Atolls						
Fananu	Inches	5.39	8.94	11.57	25.90	80.47
	% Avg	40%	87%	107%	75%	60%
Western Atolls						
Polowat	Inches	4.45*	3.41*	5.70*	13.56*	48.58*
	% Avg	37%	37%	62%	45%	40%

* It is possible that dryness at Polowat is caused by an exposure problem with the rain gauge.

Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]			
	Chuuk Lagoon, Losap, & Nama	Polowat	Northern Atolls	Mortlocks
Jan – Mar 2017	110%	90%	95%	110%
Apr-Jun 2017	120%	95%	110%	120%
Jul - Sep 2017	110%	95%	110%	110%
Oct - Dec 2017	100%	90%	100%	100%

[1] Forecast rainfall quantities represent BEST ESTIMATES given the probabilistic forecast for each particular season and station.

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Pohnpei State: Over the course of 2015 and 2016, there were enormous variations of rainfall throughout Pohnpei State (Fig. PN-1). On Pohnpei Island, persistent dryness began in the 2nd half of 2015 and continued through May of 2016. The 12-month period June 2015 through May 2016 was the 9th driest such period in the 63-year post-WWII historical record at the WSO Pohnpei. Despite the dry conditions, there were no serious impacts to municipal water quantity and quality. During a visit to Pohnpei Island in October 2016 by UOG PEAC scientists, it was learned that a temporary interruption of municipal water supply occurred early in 2016 when the Nanpil Reservoir (a primary water source for the municipal water treatment plant) was drawn down in a test of hydro-power generators downstream. Water volume was drawn below the diversion to the treatment plant, and low rainfall in late January and February 2016 caused a short delay in the refill of the reservoir to the level of the diversion channel. During April, May and June, rainfall amounts slowly recovered to near average. Rainfall during each of the months of SOND was above average. Abundant rainfall continued into the new year of 2017 with a wet January.

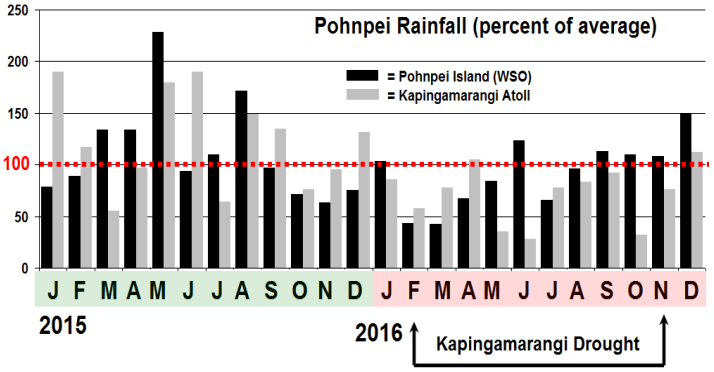


Figure PN-1. A time series of the monthly rainfall at WSO Pohnpei Island (black bars) and at Kapingamarangi Atoll (gray bars) during the two-year period JAN 2015 through DEC 2016. The period of prolonged dryness at Kapingamarangi is highlighted.

On the atolls of Pohnpei State at lower latitude (Nukuoro and Kapingamarangi) rainfall amounts were mostly below average from the late spring through summer of 2016. Eight of the nine months form January through August 2016 had below average rainfall at Kapingamarangi. When it turned very dry there in October and November, the atoll quickly began to experience serious problems with drinking water availability. Emergency supplies of drinking water had to be brought by ship. A Drought Information Statement was issued by the WFO Guam on 21 November 2016 to highlight emerging drought conditions at Kapingamarangi Atoll, and to focus attention on the possible later emergence of drought conditions at Nukuoro and at Kosrae. Abundant and above average rainfall returned to Kapingamarangi in December 2016 and also January 2017. Rain catchment tanks quickly filled, and serious damage to staple food crops and other plants was averted.

Large variations of rainfall are observed at Kapingamarangi (Fig. PN-2). 12-month rainfall totals there vary by a factor of 4 (50 inches to almost 200 inches!). Some of this variability, such as the dramatic swing from record dry to record wet in two years from 2011 to 2013 is not an obvious artifact of ENSO. By the end of 2016, the dryness at Kapingamarangi was the 3rd lowest in that location's short 17-year complete climate record

Sidebar 1

Rainfall at the WSO on Pohnpei Island has been declining over the 63 years of its post WWII climate record (Fig. PN-3).

LOCAL SUMMARY AND FORECAST

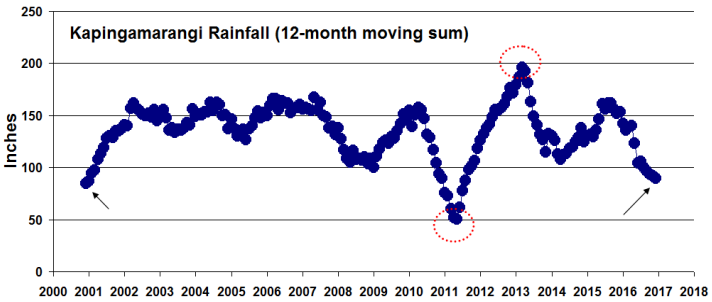


Figure PN-2. A 17-year time series of rainfall at Kapingamarangi. Values plotted are a moving 12-month sum (looking backward from the plotted position). Rainfall extremes are highlighted. Rainfall data is available prior to the year 2000, but it has many missing months, so it has been excluded here.

From the mid-1950s to the mid-2010s, there has been over a 10% loss of accumulated annual and 5-year rainfall. The magnitude of the loss during the whole period of record can be determined by the trend line on Fig. PN-3, and it has a value of -2.0597 inches per year per 5-year summation. In other words: starting at 1000 inches per 5-year summation period in the mid-1950s, the current rate is now less than 900 inches per 5-year period, for a loss of over 100 inches per 5-year period. Looked at on an annual basis, this is a loss of over 20 inches per year of annual rainfall from the 1950s to now. All the islands of Micronesia to the east of Pohnpei Island with a sufficient record (e.g., Kosrae, Kwajalein and Majuro) show this historical decline.

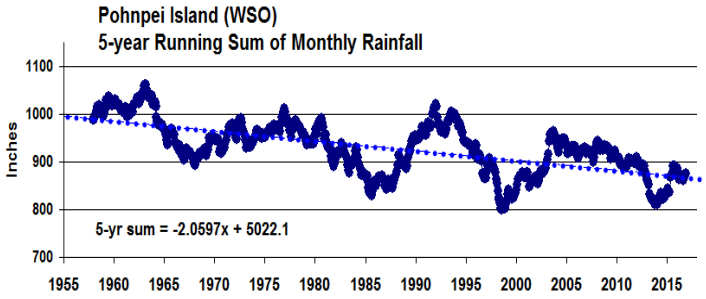


Figure PN-3. A time series of a moving 5-year summation (looking backwards at each plotted point) of the rainfall at the WSO Pohnpei. The dotted line is the applied linear trend. The equation is that of the trend line with the variable "x" representing the year.

Sidebar 2

A large Magnitude 8.0 earthquake occurred in the Solomon Island group on 22 January 2017. The Pacific Tsunami Warning Center issued a tsunami threat message indicating the possible occurrence of hazardous tsunami waves along some coasts of:

"PAPUA NEW GUINEA... SOLOMON ISLANDS... NAURU... POHNPEI… KOSRAE... VANUATU... CHUUK AND INDONESIA."

No damaging tsunami waves occurred in Micronesia, but the island of Pingelap reported some minor inundation, and at Kapingamarangi, people reported that they felt the shaking of the earthquake.

Climate Outlook: Computer model forecasts are now indicating above average rainfall over the next 3 months on Pohnpei Island (and likely also at Pingelap and other atolls near the latitude of Pohnpei Island). The PEAC concurs with the above-average projections for these two atolls, and anticipates that the same projections are valid for all atolls north of 10° N. At atolls farther to the south (e.g., Nukuoro and Kapingamarangi), where it has recently been very dry (and now wet), the outlook is not as clear, and therefore the forecast will be for near-average rainfall for the next few months, but the odds for above-, near-, and below-average are probably about equal.

A weak La Niña recently transitioned to ENSO-neutral, where the state of the climate is anticipated to remain through the summer. Thereafter the odds of El Niño developing begin to rise. In general, at this time of year, any movement of the state of the climate system in the direction of El Niño (whether from La Niña to ENSO-neutral, La Niña to El Niño or ENSO-neutral to El Niño) correlates well with average to above-average rainfall across most of Pohnpei State. The stronger the move toward El Niño, the wetter it tends to be, and also there are higher odds for an early-season tropical storm.

For the remainder of 2016, the threat of a damaging TC anywhere within Pohnpei State is very low (less than a 1-in-10 chance), with the caveat that any stronger-than-anticipated advance of the climate system toward El Niño carries with it a higher risk for an early-season tropical storm or typhoon.

Lastly, the sea level was very low in Pohnpei during the latter half of 2015 and early 2016, but has risen rapidly to now stand above average (see the sea level section for details).

LOCAL SUMMARY AND FORECAST

Pohnpei State Rainfall Summary OND 2016, 4th Quarter and 2016 Annual

Station		Oct	Nov	Dec	4thQ	Annual
Pohnpei WSO	Rain (Inches)	18.39	17.00	22.83	58.22	176.52
	% of Average	110%	108%	150%	122%	94%
PNI Airport	Rain (Inches)	15.33	14.02	21.67	51.02	152.38
	% of Average	112%	108%	173%	130%	98%
Atolls of Phonpei State						
Station		**Oct**	**Nov**	**Dec**	**4thQ**	**Annual**
Nukuoro	Rain (Inches)	7.61	5.80	19.08	32.49	134.45
	% of Average	71%	48%	159%	93%	90%
Pingelap	Rain (Inches)	5.98	15.99	18.68	40.65	88.14*
	% of Average	40%	112%	140%	96%	50%
Kapinga	Rain (Inches)	2.14	6.58	11.22	19.94	89.87
	% of Average	32%	76%	112%	78%	72%

* For most of 2016, the rain gauge at Pingelap had a known shortfall of rainfall from the shadowing effect of close-by structures and trees. High rainfall values during November and December indicate that the gauge may have been relocated.

Inclusive Period	% of long-term average	
	Pohnpei Island/ atolls	Kapingamarangi
Jan – Mar 2017	110%	95%
Apr – Jun 2017	120%	90%
Jul – Sep 2017	110%	90%*
Oct – Sep 2017	110%	95%*

* Located near the equator, the rainfall pattern at Kapingamarangi is much different than at islands and atolls farther to the north.

LOCAL SUMMARY AND FORECAST

Kosrae State: During the 24-month period from January 2015 through December 2016, Kosrae was very dry. Twenty of 24 months had below average rainfall (Fig. KS-1). Tabulations of rainfall over a variety of multi-month time periods reveal rainfall amounts in the lowest 10% of historical values. For example, 2016 was the 6th driest calendar year in the 52-year time series of rainfall at Kosrae, but the period from November 2015 through October 2016 Supplemental Aviation Weather Reporting Station (SAWRS) at the Kosrae Airport was the 3rd-driest for any 12-month period (Fig. KS-2). It should be noted that the location of the observing site is not the same for each segment of the record: Japanese data and the 1954-77 segments of the data were recorded at Lelu on the east side of the island, and the 1986 -to present data are recorded at the airport on the north side of the island. Despite the low rainfall totals, the PEAC received no reports of any serious problems related to dry conditions on Kosrae. This may be an artifact of the observed sequence of drier and wetter months, Kosrae's small population, and the fact that even with near-record dryness, several of the months had over 10 inches of rainfall. Only two months during 2016 fell below the PEAC/NCEI1 threshold of 8-inches per month for drought impacts to begin affecting drinking water quantity. In October, rain across the small mountainous island was highly variable with the airport in the north getting 9.87 inches, Utwe in the south getting 16.07 inches, and Tofol and Nautilus in the east getting 20.57 and 21.65 inches respectively. A big monthly rain was experienced across most of the island in December 2016. The total of 26.99 inches at SAWRS was the highest monthly total since 28.11 inches was recorded there during December 2011.

[1] The National Center for Environmental Information (NCEI). Contact person: Mr. R. Heim, author experimental U.S. Affiliated Pacifica Island Section of the U.S. National Drought Monitor.

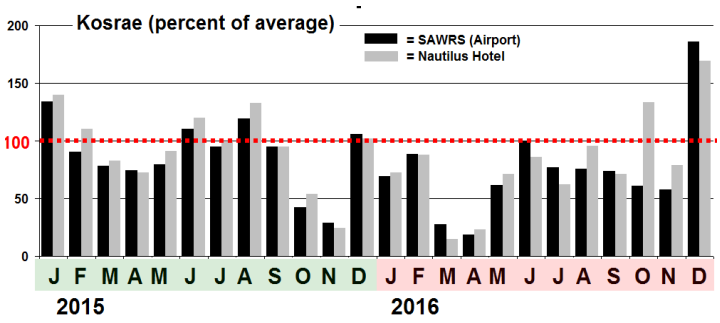


Figure KS-1. A time series of the monthly rainfall at the Kosrae Airport(black bars) and the Nautilus Hotel (gray bars) for the period January 2015 through December 2016.

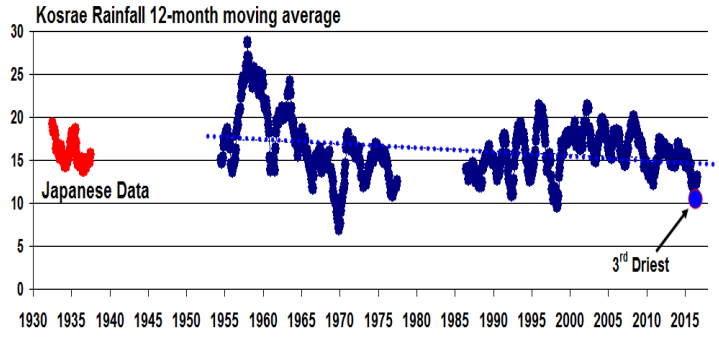


Figure KS-2. A time series of monthly rainfall at Kosrae Airport for the historical period of record. Rainfall data obtained by the Japanese from 1932-1938 is included. The long-term trend of rainfall (dotted line) appears to be downward, but the fragmentation of the time series and relocations of the observing site add uncertainty.

LOCAL SUMMARY AND FORECAST

Kosrae State Rainfall Summary: OND 2016, 4th Quarter and 2016 Annual.

Station		Oct	Nov	Dec	4thQ	Annual
Airport (SAWRS)	Rain (Inches)	9.87	9.21	26.99	46.07	148.48
	% of Average	61%	58%	186%	99%	72%
Nautilus Hotel	Rain (Inches)	21.65	12.57	24.52	58.74	159.71
	% of Average	134%	79%	169%	126%	77%

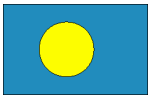
Climate Outlook: Computer model forecasts are now indicating above average rainfall over the next 3 months on Kosrae. The PEAC concurs with the above-average projections for this site; however, in consultation with Kosrae partners, the forecast of rainfall on Kosrae over the next few months was adjusted slightly to be near average to slightly above average. Very wet conditions are not expected unless the climate system moves more quickly toward El Niño.

A weak La Niña recently transitioned to ENSO-neutral, where the state of the climate is anticipated to remain through the summer. Thereafter the odds of El Niño developing begin to rise. In general, at this time of year, any movement of the state of the climate system in the direction of El Niño (whether from La Niña to ENSO-neutral, La Niña to El Niño or ENSO-neutral to El Niño) correlates well with average to above-average rainfall in Kosrae. The stronger the move toward El Niño, the wetter it tends to be, and also there are higher odds for an early-season (and late-season) tropical storm. The risk of a tropical storm or typhoon in Kosrae is typically very low, except during El Niño. The TCs affecting Kosrae during 2015 are a good recent example of the TC distribution in an El Niño year. At this time, the threat of any damaging impacts from a TC in Kosrae is considered to be very low (a 1-in-20 chance) through June.

Lastly, the observed sea level was very low at Kosrae during 2015, but increased rapidly during the 2nd half of 2016 to now stand above its average height (see the sea level section for details).

Inclusive Period (Kosrae)	% of long-term average / Forecast rainfall (inches) [1]
Jan – Mar 2017	110%
Apr – Jun 2017	120%
Jul – Sep 2017	100%
Oct – Dec 2017	100%

[1] Forecast rainfall quantities represent BEST ESTIMATES given the probabilistic forecast for each particular season and station.



Republic of Palau: During the second half of 2016, the Republic of Palau began a slow recovery from the record dry conditions that persisted continually over the previous 18 months (Fig. PL1). Thanks to abundant rainfall during October and November, the 4th Quarter total rainfall at the WSO Koror was above average. Because of substantial precipitation shortfalls early in the year, the 2016 annual rainfall total was below average at most locations. The accrued deficit of rainfall at the Koror observing site (starting the tabulation in January 2015) reached its lowest point of -85.73 inches in August 2016 (Fig.

LOCAL SUMMARY AND FORECAST

PL2). Wet weather during September, October and November helped to ease the long-term deficit by a small amount (~ 7 inches), but many months of above-average rainfall will be needed to fully erase the long-term rainfall accumulated deficit of the El Niño drought of 2015-2016.

As reported in the last newsletter, the substantial prolonged reduction of Palau's rainfall caused major disruptions to the municipal water supply and ecological impacts such as brush fires, reduced stream flow, yellowing of vegetation, and the death of millions of jellyfish in Palau's world-famous Jellyfish Lake. After the return of near average rainfall in April and May 2016, 24-hour municipal water service was fully restored in Koror (and other local Palau communities), and most ecological impacts were erased or reversed, except for the ongoing long-

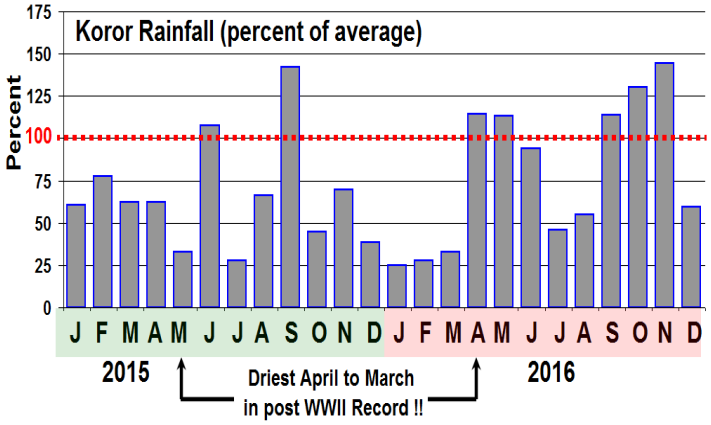


Figure PL-1. A bar chart of observed rainfall (percent of average) at the Koror WSO for 2015 and 2016.

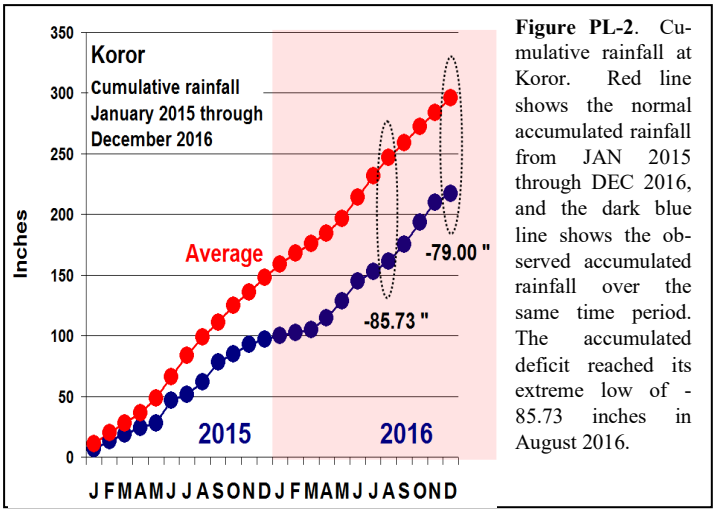


Figure PL-2. Cumulative rainfall at Koror. Red line shows the normal accumulated rainfall from JAN 2015 through DEC 2016, and the dark blue line shows the observed accumulated rainfall over the same time period. The accumulated deficit reached its extreme low of -85.73 inches in August 2016.

term recovery of Jellyfish Lake. We will report in the next newsletter on the status of the recovery of Jellyfish Lake.

Climate Outlook: Computer model forecasts are now indicating average to above average rainfall over the next 3 months, and the PEAC concurs with these projections. A weak La Niña recently transitioned to ENSO-neutral, where the state of the climate is anticipated to remain through the summer. Thereafter the odds of El Niño developing begin to rise. In general, at this time of year, any movement of the state of the climate system in the direction of El Niño (whether from La Niña to ENSO-neutral, La Niña to El Niño or ENSO-neutral to El Niño) correlates well with average to above-average rainfall across the Republic of Palau. The stronger the move toward El Niño, the wetter and also the more serious the risk of an early season typhoon.

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Republic of Palau Rainfall summary OND 2016, 4th Quarter and 2016 Annual.

Station		Oct	Nov	Dec	4thQ	Annual
Koror WSO	Rain (Inches)	18.06	16.38	7.13	41.57	119.79
	% of avg.	130%	145%	60%	112%	81%
Intl. Airport	Rain (Inches)	19.77	14.32	10.94	45.03	137.75
	% of avg.	130%	115%	83%	110%	85%
Nekken	Rain (Inches)	17.55	10.68	8.97	37.20	146.08
	% of avg.	127%	94%	75%	100%	99%
Intl. Airport	Rain (Inches)	9.72	8.17	7.91	25.80	89.23
	% of avg.	70%	72%	66%	69%	60%

Through June of 2017, rainfall amounts should be average to slightly above average throughout most of Palau. The occurrence and near passage of a TC could produce a much wetter than normal month.

For now, the basin TC activity should continue to exhibit a westward shift, with a near average basin count of 3 or 4 named cyclones during March through June 2017. One or two of these TCs may pass near Palau as they develop and make their way westward toward the Philippines. If the climate system makes a stronger push toward El Niño, the early season (March-June) TC threat of gales and hazardous surf could be higher.

Lastly, the sea level was very low in Palau during 2015, but increased rapidly during the 2nd half of 2016 to now stands above its average height (see the sea level section for details).

Palau Inclusive Period	% of long-term average / Forecast rainfall (inches) [1]
Jan-Mar 2017	110%
Apr-Jun 2017	110%
Jul-Sep 2017	100%
Oct-Nov 2017	100%

[1] Forecast rainfall quantities represent BEST ESTIMATES given the probabilistic forecast for each particular season and station.

Republic of the Marshall Islands (RMI): The RMI experienced an extraordinary variability of rainfall during 2015 through 2016, with extremes of both high and low rainfall observed. It was very wet in the spring of 2015, followed by a long period of very dry weather that began during September 2015 and lasting through the summer of 2016 (Fig. RMI-1). At Majuro, the heavy rainfall during January through September 2015 was the 6th wettest such period in that location's 62-year climate record, and the lack of precipitation during the 9-month period October 2015 through July 2016 was the lowest for that period. During the fall of 2016, abundant rainfall returned to the RMI, and 4th Quarter 2016 rainfall totals were above average at all RMI recording locations.

Most of the atolls of the RMI from Kwajalein and southward experienced a similar distribution of rainfall, with the prolonged El Niño-related dry spell finally broken by heavy rainfall in September and/or October. October 2016 rainfall was particularly heavy in the northern RMI, with both Kwajalein and Utirik re-

LOCAL SUMMARY AND FORECAST

ceiving over 18 inches! During October, Kwajalein atoll experienced three days with over 2 inches of rain, with an extreme event of 4.30 inches on 28 October that was its wettest day of 2016, and the wettest day since 17 November 2015 when 4.70 inches was recorded. During December 2016, there was an abrupt decline of rainfall over the northernmost atolls of the RMI (e.g., Wotje, Utirik, Mejit, and Ailuk). This dryness continued through January 2017. Potable water supplies were quickly impacted, with household rain catchment tanks depleted. Emergency short-term assistance was provided by the RMI government to the drought-impacted northern islands.

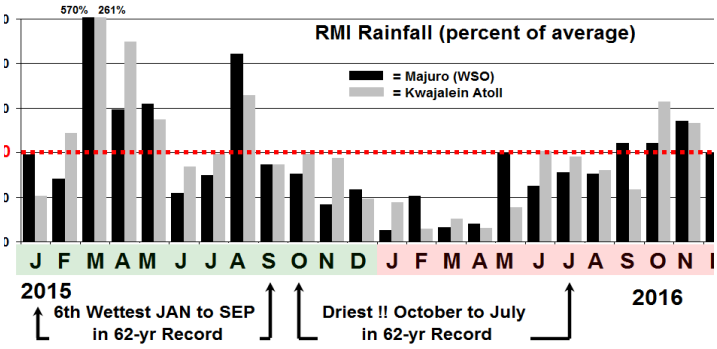


Figure RMI-1. A time series of rainfall at the WSO Majuro (black bars) and at Kwajalein Atoll (gray bars) during 2015 and 2016. Note the evolution from extremely wet to extremely dry during the course of the 2015-16 El Niño event, and the return of abundant rainfall in the fall of 2016 (at least at these two atolls).

RMI Rainfall Summary: OND 2016, 4th Quarter and 2016 Annual

Station		Oct	Nov	Dec	4thQ	Annual
RMI Central and Southern Atolls						
Majuro WSO	Inches	15.28	17.36	11.77	44.41	103.06
	% Avg	110%	136%	99%	115%	78%
Ailing	Inches	13.28	21.10	18.92	53.30	106.26
	% Avg	103%	180%	190%	154%	91%
Jaluit	Inches	14.50	12.29	17.23	44.02	95.68
	% Avg	105%	96%	145%	114%	73%
Arno	Inches	14.11	15.17	29.88	59.16	135.61
	% Avg	102%	119%	252%	154%	103%
RMI Northern Atolls						
Kwajalein	Inches	18.73	14.16	10.36	43.25	86.50
	% Avg	157%	133%	128%	141%	85%
Wotje	Inches	13.83	8.07	1.50	23.40	62.24
	% Avg	167%	118%	34%	120%	102%
Utirik	Inches	18.47	9.46	1.99	29.92	67.34
	% Avg	240%	149%	49%	165%	119%

Climate Outlook: Computer model forecasts are now indicating average to above average rainfall over the next three months at Majuro and at Kwajalein. The PEAC concurs with these projections for these two atolls, and anticipates that the same projections are valid for all atolls south of 10° N. Atolls north of 10° N (including: Wotje, Utirik and Mejit atolls), where it has been very dry over the past two months (December 2016 and January 2017), may see a persistence of below average rainfall for at least another month or two.

LOCAL SUMMARY AND FORECAST

Weak La Niña recently transitioned to ENSO-neutral, where the state of the climate is anticipated to remain through the summer. Thereafter the odds of El Niño developing begin to rise. In general, at this time of year, any movement of the state of the climate system in the direction of El Niño (whether from La Niña to ENSO-neutral, La Niña to El Niño or ENSO-neutral to El Niño) correlates well with average to above-average rainfall across the RMI. The stronger the move toward El Niño, the wetter it tends to be, and also there are higher odds for an early-season tropical storm.

The risk of a tropical storm or typhoon at any of the atolls of the RMI is typically very low, except during El Niño. The TCs affecting the RMI during 2015 are a good recent example of the TC distribution in an El Niño year. At this time, the threat of any damaging impacts from a TC in the RMI is considered to be very low (a 1-in-20 chance) through June.

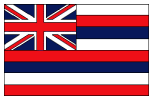
At this time of year (winter/spring), the atolls of the RMI are always at some risk of inundation by the arrival of large swell generated far to the north by the winter storms of the mid-latitudes. The risk of this source of damaging inundation is highest from December through March, with a 15-20% chance.

Lastly, the observed sea level was very low throughout the RMI during 2015, but increased rapidly during the 2nd half of 2016 to now stand above its average height (see the sea level section for details)

Inclusive Period	% of long-term average		
	South of 6ºN	6ºN to 8ºN	North of 8ºN*
Jan—Mar 2017	100%	110%	100%
Apr –Jun 2017	120%	110%	110%
Jul –Sep 2017	100%	100%	100%
Oct—Dec 2017	95%	100%	100%

* Dry conditions may persist through April at atolls north of 10° N. At these northern-most atolls, the Jan-Mar rainfall forecast is 60% and the Apr-Jun forecast is 75%.

[1] Forecast rainfall quantities represent BEST ESTIMATES given the probabilistic forecast for each particular season and station.



Hawaii: The following information was summarized from the NWS Honolulu Office Monthly Hydrology Precipitation Summaries and Drought Information Statements found at http://www.prh.noaa.gov/hnl/pages/hydrology.php. The start of the 2016 – 2017 Hawaiian Islands wet season (October through April) featured trade winds during all of October, which were unseasonably persistent for this time of year. On average, trade winds occur on roughly two-thirds of the days in October across the island chain. Generally speaking, windward areas received frequent rainfall while leeward areas were abnormally dry. During November there were no heavy rain events that caused significant flooding during the entire month. This is significant considering that historically November has the highest frequency of flash flood events during the year. Persistent trade winds and the slow start to the wet season has resulted in a worsening of existing drought conditions over the leeward areas of the state. By the end of November, drought had re-emerged in all four counties across the state and even reached extreme levels in

LOCAL SUMMARY AND FORECAST

small sections of leeward Kauai and Maui. Relatively dry conditions during November yielded to a wet weather pattern that affected the main Hawaiian Islands from December 1 through December 11. This pattern included several upper level low pressure systems that produced heavy rainfall and flash flooding in all four counties across the state. Most of the impacts occurred on December 2 with flash floods reported on Kauai, Oahu, and the Big Island. A wet weather pattern during the month of December brought much needed rainfall to leeward areas of the state and helped reverse the increasing drought trend from October and November. Extreme drought, or the d3 category on the U.S. drought monitor map, improved to the d1 category, or moderate drought, by the end of December on the leeward slopes of Kauai and Maui. Severe drought...or the d2 category...along the leeward Kohala slopes of the big island, improved to a drought free state following a month of above average rainfall.

Large rainfall fluctuations in the 2016-2017 Hawaiian Islands wet season (October through April) continued in February. Following a very dry January, many areas of the main Hawaiian Islands fell under wet conditions and near to above average rainfall.

Hawaii Rainfall Summary: AMJ 2016 2nd Qtr & 1st Half					
Station		**Oct**	**Nov**	**Dec**	**4thQ**
Lihue Airport	**Inches**	**0.45**	**0.40**	**1.17**	**2.02**
	%Norm	**14%**	**11%**	**37%**	**20%**
Honolulu Airport	**Inches**	**0.12**	**0.73**	**0.87**	**1.72**
	%Norm	**10%**	**54%**	**66%**	**44%**
Kahului Airport	**Inches**	**0.65**	**0.56**	**6.59**	**7.80**
	%Norm	**118%**	**30%**	**248%**	**154%**
Hilo Airport	**Inches**	**19.13**	**10.04**	**20.40**	**49.57**
	%Norm	**222%**	**88%**	**199%**	**164%**

Predicted rainfall for Hawaii State from December 2016 through August 2017 is:

	Station			
Inclusive Period	**Hilo**	**Honolulu**	**Kahului**	**Lihue**
Mar – May 2017	40% chance of below average rainfall	60% chance of rainfall near or below average	40% chance of below average rainfall	60% chance of rainfall near or below average
Jun – Aug 2017	Equal probabilities of below, average or above average rainfall	Equal probabilities of below, average or above average rainfall	Equal probabilities of below, average or above average rainfall	Equal probabilities of below, average or above average rainfall
Jun – Aug 2017	Equal probabilities of below, average or above average rainfall	Equal probabilities of below, average or above average rainfall	Equal probabilities of below, average or above average rainfall	Equal probabilities of below, average or above average rainfall

LOCAL SUMMARY AND FORECAST

Climate Outlook: From CPC Long-Lead Hawaii Outlooks. The NCEP constructed analog (CA) tool favors below media rainfall for Hawaii from NDJ 2017 to JFM 2018. Some dynamical models predict a warm event (El Niño) by the northern summer and fall, continuing into winter 2017-18. If correct, historical El Niño composites favor increased odds for dry conditions for Hawaii in winter, which is consistent with the forecast from the CA tool.

Seasonal Drought Outlook for Hawaii:

The CPC U.S. Seasonal Drought Outlook released on Feb 16, 2017 (available at http://www.cpc.ncep.noaa.gov/products/expert_assessment/sdo_summary.php) notes that Climatology favors removal of the small drought areas along the leeward sides of Kauai, Maui, and the Big Island of Hawaii.

SEASONAL SEA LEVEL OUTLOOK Cont.

Sea Level Observation from the Global Satellite Picture:

Observations from the recent global satellite picture (Fig. 6, below) revealed that the sea levels is slightly high over the western part of the Pacific Basin. ***The tropical Pacific atmosphere and ocean are still currently affected by the lingering impact of La Niña.*** *This satellite data are supportive to tide-gauge observations, and revealed that some of the stations located in Micronesia and Marshalls Islands is still elevated. This is a turning point when sea level transitions to normal from its year-long above normal stage.*

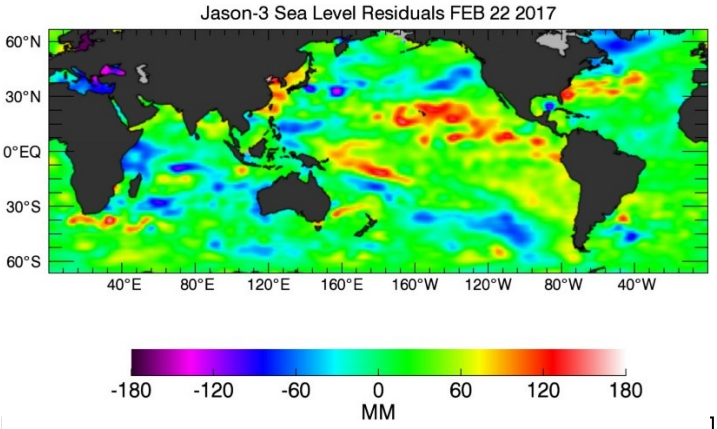


Figure 6. Jason-2 sea level residuals (Feb 22, 2017). (Source:https://sealevel.jpl.nasa.gov/images/latestdata/jason/2016/20160721G.jpg)

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SEASONAL RAINFALL OUTLOOK FOR THE US-AFFILIATED PACFIC ISLANDS

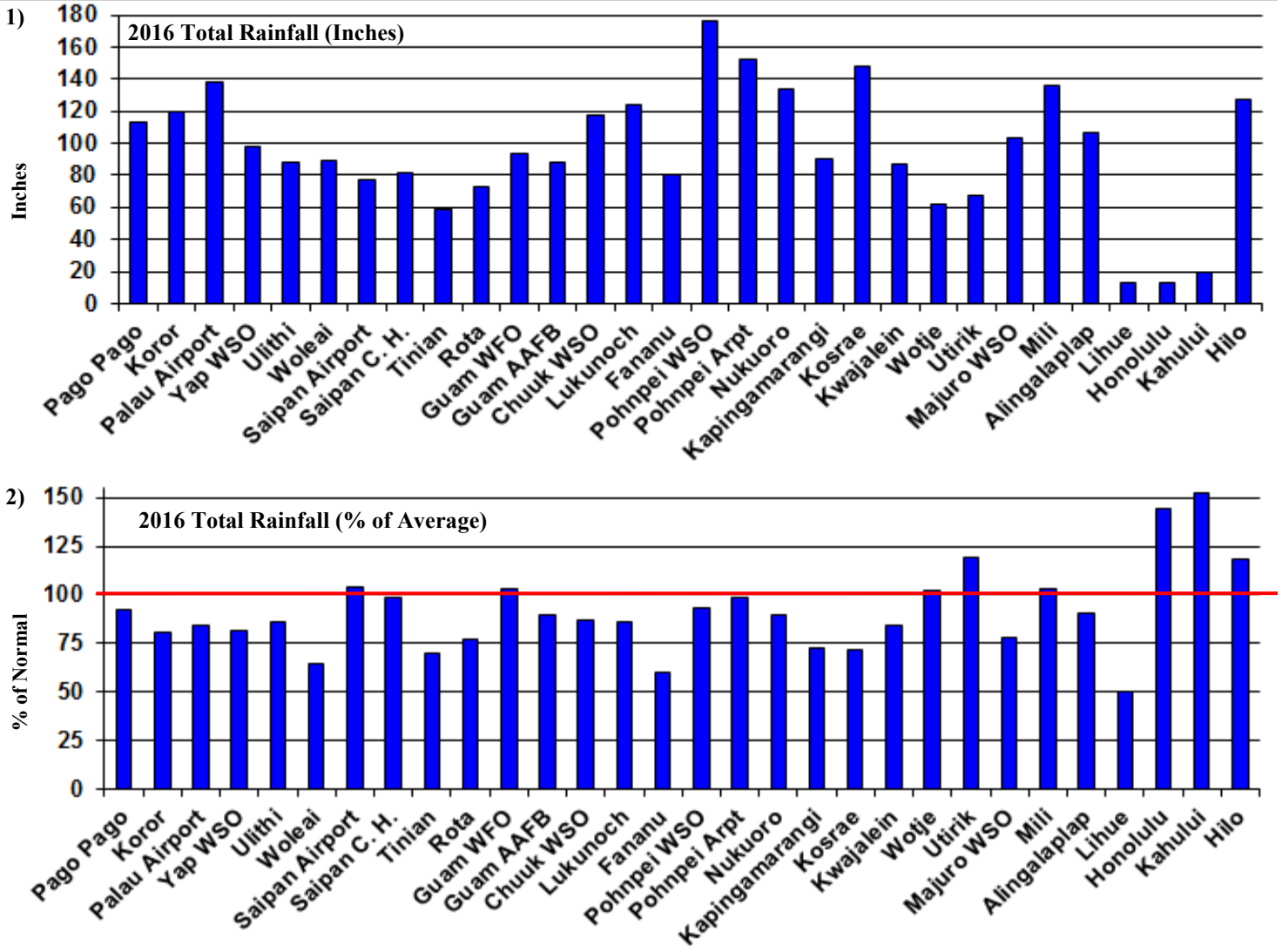

Figure 23 and 24, 2016 Total rainfall amounts in inches at the indicated locations and rainfall departure from average (in percent) at the indicated locations.

ACKNOWLEDGEMENTS AND FURTHER INFORMATION

Pacific ENSO Applications Climate (PEAC) Center:
HIG #340, 2525 Correa Road, Honolulu, Hawai'i 96822
Contact at 808-956-2324: for information on PEAC, the Pacific ENSO Update and ENSO-related climate data for the Pacific Islands.

Dr. Rashed Chowdhury,
Principal Research Scientist, at 808-956-2324: for information on ENSO and sea level variability in the USAPI.
Alejandro Ludert, Graduate Research Assistant and Webmaster, at 808-956-2324 for: information related to the PEAC website.

University of Hawai'i - Joint Institute of Marine and Atmospheric Research (JIMAR), School of Ocean and Earth Science and Technology (SOEST), Department of Oceanography:
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Dr. Mark Merrifield, PEAC Principal Investigator at 808-956-6161: for more information on sea level and climate in Hawai'i.

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Tom Evans, PEAC Director, at 808-973-5270: for information related to NWS.

NOAA National Weather Service—Weather Forecast Office (WFO) Guam:
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Chip Guard, Warning Coordination Meteorologist, at 671-472-0900: for information on tropical cyclones and climate in the USAPI.

University of Guam - Water and Environmental Research Institute (WERI):
UOG Station, Mangilao, Guam 96913
Dr. Mark Lander, PEAC Meteorologist, at 671-735-2685 for: information on tropical cyclones and climate in the USAPI.

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The Pacific ENSO Update is a bulletin of the Pacific El Niño-Southern Oscillation (ENSO) Applications Climate (PEAC) Center. PEAC conducts research & produces information products on climate variability related to the ENSO climate cycle in the U.S. Affiliated Pacific Islands (USAPI). This bulletin is intended to supply information for the benefit of those involved in such climate-sensitive sectors as civil defense, resource management, and developmental planning in the various jurisdictions of the USAPI.

The Pacific ENSO Update is produced quarterly both online and in hard copy, with additional special reports on important changes in ENSO conditions as needed. For more information about this issue please contact the PEAC Center at peac@noaa.gov or at the address listed below.

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